ANNUAL REPORT

2019-2020

G.B. Pant National Institute of Himalayan Environment

(An Autonomous Institute of Ministry of Environment, Forest & Climate Change Govt. of India)

Kosi-Katarmal, Almora 263 643, Uttarakhand, India

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Former Chief Secretary
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Member Secretary
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GBPNIHE, Kosi-Katarmal, Almora

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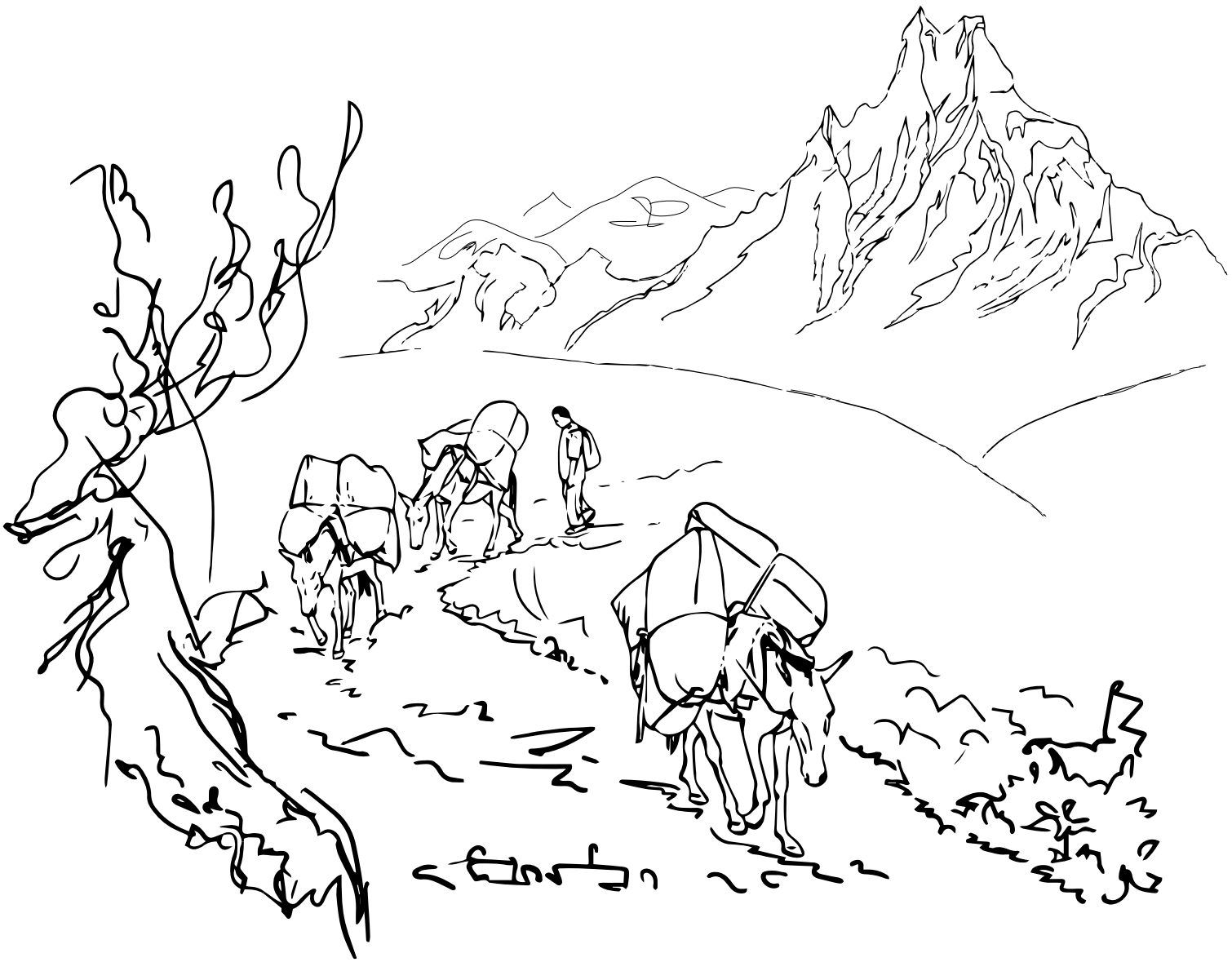

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FOREWORD

The Institute, along with its partners, continue to provide research based solutions on diverse aspects of Himalayan Environment & Development. The R&D interventions in four sectors of Institute's core competence, i.e., Land & Water Resource Management (LWRM), Socio Economic Development (SED), Biodiversity Conservation & Management (BCM), and Environmental Assessment & Climate Change (EA&CC), are increasingly being recognized by diverse stakeholder groups. Also, the decentralized set-up, with the Regional Centres and their dedicated multidisciplinary faculty distributed across the Indian Himalayan Region (IHR), has made Institute's presence felt across the region. In this context, the year 2019-20 has further added value.

Setting-up of Ladakh Regional Centre at Leh, which took lead in joining hands with Ladkh Union Territory Administration for organization of 'Carbon Neutral Ladakh - a New Beginning' summit, remained one of the major highlights for 2019-20. The event has helped in drawing actions and responsibilities for Ladakh UT administration to take forward the agenda of 'Carbon Neutral Ladakh'. Among others, establishment of a Genetic Resource Centre for selected medicinal plants at Himachal Regional Centre, and making functional the Rural Technology Centre (RTC) and the East Himalayan Plant Biodiversity & Forest Resources Monitoring Centre at Sikkim Regional Centre are other major highlights for the year.

Under the 100 days programme of Ministry of Environment, Forest & Climate Change, the Institute, succeeded in launching Jal Abhyaranya (i.e., Water Sanctuary) programme to address water scarcity issues on a pan-Himalayan scale to cover all 11 Himalayan States of India. Towards scaling-up the pilot successes, cluster approach adopted for promotion of medicinal plant cultivation in 14 remote villages of Chaudans Valley in Uttarakhand, has yielded encouraging results. The Rural Technology Centres (RTC's) at HQs and Regional Centres have proved extremely beneficial in reaching-out the people. For example, the pine needle processing unit at RTC-HQs has gained popularity for eco-friendly pine needle based products such as file covers, meeting folders, carry bags, envelops, etc. Also, the conversion of pine needles into smokeless bio-briquettes is receiving appreciation of rural masses. This venture, while addressing the issue of forest fire has contributed equally for rural livelihoods promotion by effectively engaging with rural women groups.

This year also witnessed successful completion of 9 in-house projects. The findings have been reviewed by the Scientific Advisory Committee (SAC), which accorded it's approval to the project completion reports. I am confident, readers will find the summaries of these reports, as included in this Annual Report, informative and beneficial.

Realizing the geographical extent of IHR and diversity of issues, the Institute is following a path of partnership and collaboration. Towards building such partnership, the Institute joined hands with 14 other Institutions/agencies to organize a workshop on ''Himalaya Matters in Changing World". The event partners and other participating organizations resolved to establish a functional knowledge network for the Himalaya. The network has been envisaged to enhance collaboration and networking among all relevant institutions engaged with Himalaya specific R&D that lead to environmental conservation and sustainable development.

The Institute continues to receive guidance and encouragement of its Apex Bodies (i.e., the Society, the Governing Body, and the SAC). I place on record our deep gratitude to all members of these bodies. Institute's researchers and faculty deserve appreciation for remaining motivated and enthusiastic to deliver the best. I thank them all. The help rendered by various partner agencies and stakeholder groups is gratefully acknowledged. The Institute remains committed for the cause of Environment & Sustainable Development in the Indian Himalaya and beyond.

Dr. R. S. Rawal,
Director

MAJOR ACHIEVEMENTS (2019-2020)

1. A new Regional Centre of the Institute was established and made functional in Leh (Ladakh) to cater to the need of Trans Himalayan region of Indian Himalaya. As a new beginning, Ladakh Regional Centre joined hands with Ladakh UT administration to organize a 4 days summit (2-5 March 2020), which made recommendations and action agenda for incorporating the science of sustainability in laying foundation of the UT.

2. A Genetic Resource Centre (GRC) has been established for germplasm conservation of the target medicinal plant species, *Picrorhiza kurroa, Swertia chirayita, Rubia cordifolia,* and *Nardostachys grandiflora,* at Himachal Regional Centre of the Institute. Also, an inventory of 2095 shrub species (140 Families and 747 Genera) of IHR was prepared and web portal developed (www.ihrplantresources.org).

3. Institute succeeded in preparing People's Biodiversity Registers (PBRs) of 24 Biodiversity Management Committee (BMCs) in Kullu district (H.P.); two PBRs of Nainital district (Uttarakhand); and 5 new BMCs in Arunachal Pradesh along with training to build capacity 20 BMCs.

4. The "Jal Abhyaranya (*Water Sanctuary*)" programme was launched as 100 days programme of MoEF&CC to address water scarcity issue on pan-Himalayan scale wherein at least one drying spring in 11 identified districts (including 9 Aspirational Districts) of the 11 IHR states were selected for field augmentation as spring rejuvenation models.

5. Under NMHS sponsored project, institute developed a cluster of 14 villages of Chaudans valley (Distt. Pithoragarh, Uttarakhand) for promotion of medicinal and aromatic plants in around 3 ha land involving 175 farmers. Also, buy-back mechanism was facilitated for selected species towards ensuring conservation and livelihood improvement.

6. The Pine needle processing unit at the Rural Technology Complex (HQs), succeeded in developing various products, i.e. file covers, folders, note pads, wedding cards, carry bags, bio-briquettes, etc., using chir pine needles fallen on the forest floor. Women groups of nearby 08 villages were successfully engaged in collection of needles. The intervention yielded benefits of (i) reducing fire intensity in surrounding Pine forests, and (ii) improving livelihoods of local communities.

7. Under NMSHE TF-05 on Traditional Knowledge System (TKS) 19 districts of 6 Himalayan states, covering 26 communities, were investigated for TKS on soil and water management, bio-resources and bio-processing. An inventory of 4036 species was prepared as part of TKS in Arunachal Pradesh, Nagaland, Sikkim, W.B. Hills, Uttarakhand and Himachal Pradesh.

8. At Sikkim Regional Centre, Pangthang one Rural Technology Centre (RTC) and Eastern Himalayan Plant Biodiversity & Forest Resource Monitoring Centre was made functional.

9. Successfully organized various green skill building programmes at Institute HQs and four Regional Centres covering aspects of forest resource management, climate adaptation/mitigation, home stays, agro-production system, bio-prospecting, tourism product development, dee keeping, ornithology and bird watching, preparation of people's biodiversity register, and livelihood enhancement. A total of 198 trainees benefitted from five Himalayan states.

10. A total of nine in house projects successfully concluded, draft project completion reports (PCRs) reviewed by the Scientific Advisory Committee (SAC), and approved.

Publications

1.	Peer Reviewed Scientific Journals National & International	-	**78**
2.	Chapters in Books / Proceedings	-	**21**
3.	Authored/ Edited / Books / Booklets / Bulletins / Monographs	-	**12**
4.	Popular Articles	-	**15**
5.	Policy Papers	-	**02**

EXECUTIVE SUMMARY

The G.B. Pant National Institute of Himalayan Environment (GBPNIHE), mandated for environmental conservation and sustainable development of the Indian Himalayan Region (IHR), addresses front-running environmental issues of physical, biological and socio-economic nature in an integrated manner. The R&D mandate of the Institute is broad and covers all the facets of environment and development. Towards achieving this 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 and development and demonstration of best practices, technology packages and delivery systems for improved livelihood of the people remains at the core of 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 Institute programmes through different initiatives. 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 thematic Centres and five regional Centres. Thematic Centres include, (i) Centre for Land and Water Resource Management (CLWRM); (ii) Centre for Socio-Economic Development (CSED); (iii) Centre for Biodiversity Conservation and Management (CBCM); and (iv) Centre for Environmental Assessment and Climate Change (CEA&CC). The regional Centres of the Institute are: (i) Himachal Regional Centre; (ii) Garhwal Regional Centre; (iii) Sikkim Regional Centre; (iv) North-East Regional Centre; and (v) Mountain Division Regional Centre housed in MoEF&CC, New Delhi. Recently, the Institute has setup Ladakh Regional Centre at Leh for addressing the ecological and environmental problems of Trans Himalayan region. A brief summary of R&D activities and achievements of different Centres of the Institute during the reporting year 2019–20 is as follows:

1. Thematic Centres

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

During the year 2019-20, the activities of the Centre were implemented in the form of one In-house and eight externally funded projects which covered the major land and water resource themes. The year also saw the completion of In-house Project - 'Water Sustainability Mapping in Himalaya - Issues, Trends and Options' which was implemented in Kali and Kosi river basins of Kumaun Himalaya. This prepared grounds for the basin level hydrological studies through large

scale instrumentation along the Kali river basin. The development of water scarcity mapping, hydro-geological and Digital Elevation Modelling (DEM) maps of Kali basin and scenario simulations for Pancheshwar dam were the major highlights of the project. The limited time frame of 3 years was a major constraint in achieving the ambitious targets of the project, but the network of instrumentation created will help in continuing and supporting the hydro-meteorological monitoring through other projects. Another project on investigation of alternative boundary layer scaling properties over the complex terrains of Himalaya completed during the year, studied the energy exchange properties within the convective boundary layer and successfully tested the Chaotic Dynamic Systems approach over two sites (on-ridge and on-slope) of Kumaun Himalayan terrain and a flat terrain site near Varanasi (UP); the outcome could be useful for convective boundary layer parameterization for weather forecasting models.

The Kosi watershed has remained the major focus of the Centre's R&D activities; and projects - 'Rejuvenation of Kosi river through field interventions & people's participation', 'Use of system dynamic modeling for water resource management', and 'Enhancement of quality of livelihood and resilience in urban-rural ecosystems' were envisaged and carried out for evolving strategies for integrated-holistic development of the area. In the first project monitoring of 23 springs catchments of Devalikhan recharge zone, and a few 3rd order minor streams was initiated for discharge rates and water quality, and base maps were prepared; in the second project the forest cover area of Kosi watershed was analyzed for estimation of fragmentation and the cellular automata model was developed to understand and simulate future projections of forest cover till year 2030, 15% increase in the forest cover of the Kosi watershed from 2017 situation was predicted. In the Livelihood Project standard DEFID framework was used for status assessment with respect to - human capital, natural capital, physical capital, social capital and financial capital sets. The survey of households in 32 villages revealed that all the villages lacked severely in terms of these capitals, therefore the strategies for resilient and sustainable rural urban system should focus on strengthening of these capital sets. Also preliminary SWOT analyses for identification of strategies for different sectors in terms of 'ease of implementation' and 'anticipated benefits' was carried out in some villages through group consultations. Also the schematics of livelihood strategies were developed for further refinement.

In a newly initiated project on 'Rainfall structure and rainfall erosivity', the monsoon heavy rainfall observations at the Kosi-Katarmal were analyzed, and the performances of weather prediction model physics were evaluated. In 'Spring-shed management - a strategy for climate change adaptation' project the inventory of springs of Seraj and Barot valleys of Himachal Pradesh was compiled. The project on Himalayan Cryosphere that aims to understand the glacier dynamics and mass balance in the Himalayan region through the study of Chipa Glacier (Dhauliganga basin, Uttarakhand) and Khangri Glacier (Tawang Basin, Arunachal Pradesh), the GDPS results based on observations during 2017-19, revealed recession rate of 7.9 m/yr for Chipa Glacier and 6.5 m/yr for the Khangri glacier.

The alternative uses of pine needles which are major cause of forest fire were explored for purification of wastewater by synthesis of activated and bacterial activated carbon; a pilot plant was developed and activated carbon samples prepared. Uses of pine needles for removing pharmaceutical and personal care products from contaminated water were also explored. Also phyto-remediation experiments to study the effect of contaminants on soil enzymes were tested; in the project on 'Nutritional status of traditional crops', documentation of cuisines of scheduled community and their nutritional analyses was carried out.

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

In the diverse bio-physical and socio-economic setting of the IHR sustainable development of rural ecosystems poses a challenging task. Given the physical inaccessibility, marginality of communities and ecological fragility of the ecosystems there is broad gap between sustainable developmental plans and ground actions, also referred to as "Development Dilemma". One of the major lacuna in such efforts is the non-availability of appropriate cost-effective and environment-friendly mountain-specific technologies and capacity of rural people to implement them. Thus, unplanned development, degradation of natural resources, alteration in land use, unsustainable livelihood and outmigration has been in the centre of development debate always in the IHR. The Centre for Socio-economic Development (CSED) has been engaged in upscaling, popularizing and building capacity

of stakeholders on diverse range of livelihood and natural resource management practices brought out by the R&D of our Institute as well as similar Institutes working for the IHR. The R&D focus of this year has been largely geared towards (i) capacity building of village communities and officials of line department engaged in extension of various departmental schemes of rural development relating to agriculture, horticulture, animal husbandry etc. (ii) strengthening sustainable livelihood through promotion of on-farm and off-farm activities; (iii) demonstrating and disseminating specifically designed models and knowledge products; and (iv) strengthening entrepreneurial skills and self-employment opportunities through capacity building in rural areas and community-driven participatory planning approach. Interventions in horticulture, agriculture, forestry, animal husbandry etc. were made by distributing elite seed and root stocks of promising varieties and R&D based demonstrations were also maintained among the rural areas and substantial income was generated by the people through the sale of farm produce. R&D activities were also carried out on documentation of traditional knowledge on various aspects of NRM, community livelihood practices, socio-economic database, and use of forest produce for making various eco-friendly products such as Pine tree needles for bio-briquettes, file covers, folders, note pads, wedding cards and carry bags etc. that helped in employment and income generation of rural people, particularly women, and reducing the risk of forest fire. In the reporting year CSED has undertaken four projects with the focus to address priority socio-economic problems and management of natural resources. In a project on 'Livelihood improvement by integrated natural resource management' 8 villages were targeted for introducing innovative approaches and practical models on natural resource management. Under the Network Programme on convergence of Traditional Knowledge System (TKS) for sustainable development' documentation of TKS was carried out in communities residing in six Himalayan states. As an integrated farming approach three villages have been targeted for designing and demonstrating polythene lined fish farming ponds, a low cost poultry shed, and vegetable cultivation. In addition, through three fellowships socio-economic database was built and demonstrations on NRM practices were upscaled in the region. CSED is extending training and capacity building support for establishment of rural bio-resource complex for economic empowerment of Himalayan communities, extending technical support to state agencies, line departments, and district administration. In the reporting year 36 training courses / meetings were conducted both at the Rural Technology Complex (RTC) of the Institute and in the villages of project areas and thus capacity of 750 people of 52 villages of four districts of Uttarakhand was built on various NRM technologies (protected cultivation, cash crop cultivation, fish farming, poultry farming, vermi-composting, bio-briquette, bee keeping and other livelihood generating and yield increasing technologies). Also, live demonstrations of these NRM technologies were maintained / demonstrated at RTC and in the project villages. Thus, through various R&D efforts we tried to accomplish the mandate of CSED.

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

During the reporting year, CBCM succeeded in establishing long-term ecological monitoring (LTEM) sites in four dominant forest types of the west Himalaya 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 were also studied. It was found that the tree species of timberline in west Himalaya are responsive with respect to earlier initiation of growth by even a mild increase in mean annual temperature (MAT) and growing season mean temperature. However, effect of slight change in the MAT was not registered by other phenological attributes of leaf and shoot growth parameters. 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 through plantations in the community wastelands were also undertaken seeking participatory approaches of rural people at several locations. To monitor the extent of distribution of high value plants in the alpine zone hyperspectral imaging technique was applied to capture the inaccessible areas. 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. One of the main aim of CBCM is to demonstrate and disseminate biodiversity conservation approaches among various stakeholders through organization of training and capacity building programmes for school children and teachers, University students and researchers, farmers and local people. Therefore, several such programmes were carried out at the Nature Interpreation and Learning Centre of CBCM at the Institute HQs. Thus, centre's R&D efforts covered a wide span of activities: strengthening data-base through inventorization and prioritization of biodiversity (flora and fauna), assessment of floristic diversity among diverse ecological conditions such as cold deserts, wetlands and aquatic systems, arboreal habitats, etc., population status of RET category of species, threat assessment (due to biotic interference, invasion of weeds, etc.), use pattern of bio-resources (NTFPs) based on pilot studies, digital data base development, documentation of case studies and indigenous knowledge on conservation and sustainable management of biodiversity and suggest methods for reducing pressure on biodiversity and promoting sustainable use.

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

The Himalayan ecosystem, topographically fragile and ecologically delicate, is under the anthropogenic pressure due to developmental activities at different magnitudes across the IHR. These developmental interventions in many forms have a certain degree of negative impacts which need to be understood and identified in view of mitigation measures. As a result, appropriate R&D based strategies are required to address the adverse impacts so as to find suitable solutions to them. Moreover, in recent times, climate change (CC) is causing a critical situation in many aspects in the fragile mountain ecosystem. It has been projected that even with global warming of 1-2 °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 implication of these impacts can be seen on the livelihoods of local communities who depend on a variety of local natural resources. Thus, it is important to assess the likely impacts of projected CC on the IHR and develop adaptation strategies for both conservation and management of natural resources and safeguard the livelihoods of people. The Centre for Environmental Assessment and Climate Change (CEA&CC) successfully achieved its targets during 2019-20. The ongoing activities during reporting period were mainly focused on 11 projects out of which 2 belong to in-house activities and 9 externally funded projects. Two externally funded projects- ISRO Aerosol Radiative Forcing over India (ARFI) and ISRO Environmental Observatory, Atmospheric Chemistry Transport and Modelling (EO AT-CTM) are mainly supported from ISRO-GBP. While the three projects (i.e. one medium, one small grant and one fellowship) are implemented with the support of National Mission on Himalayan Studies (NMHS), MoEF&CC, New Delhi and the National Mission for Sustaining the Himalayan Ecosystem, Task Force-3 (NMSHE T3) is supported by DST, New Delhi. Impacts and habitat degradation due to biotic pressure in sub-alpine and alpine grassland ecosystems is being carried out under UNDP project. While the other two projects aim at studying microbial endophytes and soil enzymes as indicators of climate resilience with respect to Himalayan Birch, and bio-prospecting of ethnomedicinal plants having anti-cancerous properties. Forest fire project indicates that sub-tropical sal *(Shorea robusta)* forests in the foothills are equally prone to fire in addition to pine *(Pinus roxburghii)* forests, which results in black carbon (2572 ± 187.1 ng m^{-3}) emissions. Conservation and sustainable use of biodiversity regarding microbial diversity of endophytic microorganisms project investigated *Taxus wallichiana* endophytes for taxol production. The project eco-physiological assessment took into account two medicinal plants such as *Valeriana jatamansi* and *Hedychium spicatum* and subjected to high temperature and drought stress conditions to understand their physiological and biochemical mechanism in view of adaptation to climate change.

2. Regional Centres

(i) Himachal Regional Centre (HRC)

The baseline data for solid waste status, its management and related issues were generated with the primary and secondary data for 6 districts of Himachal Pradesh. The impact of solid waste on soil and water health and status of heavy matels was investigated and native suitable plant species were planted on these sites for reclamanation. A community driven model for solid waste management has been developed with people's participation, capacity building workshops, development of solid waste demonstration parks, etc. A Genetic Resource Centre (GRC) was established for germplam conservation of the target species, *Picrorhiza kurroa, Swertia chirayita, Rubia cordifolia,* and *Nardostachys grandiflora* at the

HRC. Ecological Niche Model of *Taxus contorta* in Kullu district of Himachal Pradesh was developed by using Maximum Entropy Modelling (Maxent version 3.3.3k). Standardization of post-harvest technology and its protocol has been developed for Wild Rose Hips and disseminated among the 24 Women Saving and Credit Groups (WSCGs) with 203 women who were involved in various stages of Rosehip collection and processing in Kullu Valley. People Biodiversity Register (PBR) of 24 Biodiversity Management Committee was prepared and submitted to Himachal Pradesh State Biodiversity Board, Shimla. Population assessment of 3 RET species *(Arnebia euchroma, Carum carvi* and *Angelica glauca)* at 25 locations with 17 sites for *Arnebia euchroma*, 2 for *Carum carvi* and 6 for *Angelica glauca* were done at cold desert area of Spiti in Lahaul and Spiti district, Himachal Pradesh. Base line information on Water Quality Monitoring in Parbati Basin was generated. The overall water quality index falls under good water quality index. List of 2095 shrub species (140 Families and 747 Genera) of IHR was prepared and developed a web portal with domain name www.ihrplantresources.org. Long-term data base on meteorological parameters was generated to assess climate change scenario and its impact on apple orchards. Also, long-term data base was generated on 'ozone and its precursors' and 'aerosols climatology, radiative forcing and temperature rise' in the Kullu valley of Himachal Pradesh. To conserve the sensitive biodiversity elements, the Himachal Regional Centre of the Institute developed an herbal garden, medicinal plant nurseries and Arboretum spreading over 2 ha land, located at 1155m amsl in the Mohal Khad watershed, Kullu. Arboretum comprises around 50 species of trees and shrubs. Majority of the species are native to the Himalaya and used for various purposes. The HRC has a Rural Technology Centre wherein various rural technologies/models are functional for demonstration purpose such as Entrepreneurship Cell, Poly Tunnel Technique, Water Harvesting Tank, Vermi Composting, Weed Composting, Apiculture, Nursery, Green/ Poly House, Shed House / Medicinal Plants Shed Net, Solid Waste Demonstration Park, Automatic Bio Composter, Amphi theater, etc. A policy brief on "Guidelines for Assessing Carrying Capacity of Hill Stations and Eco-Sensitive Zones in the Country" has been developed in response to the directives of National Green Tribunal's (NGT) Principal Bench, New Delhi. A monograph entitled "Status of Solid Waste Management in Himachal Pradesh" and a technical manual entitled "Waste Management: Collection, Segregation Strategy and Efficient Disposal by Various Techniques" has been published by the HRC.

(ii) Garhwal Regional Centre (GRC)

The Garhwal Regional Centre (GRC) is working on biotechnology, water resources sustainability, tourism, regional assessment of climate change impacts and actively engaged in training and demonstration through several skill development programmes. The Centre also contributes towards demonstration and sensitization of local stakeholders towards Swatch Bharat Abhiyan. The GRC has several field demonstration sites located in different districts of Garhwal Region. The Centre is not only working on demonstration models for water conservation in water scarce region of Garhwal Himalaya but also leading research on conservation of a few high value plant species such as *Malaxis muscifera, Myrica esculenta* and *Hippophae salicifolia* as well as genomic resource conservation of local landraces of Rajmash. Database on different accessions of Rajmash from Uttarakhand is prepared in the Centre following the standard pattern of NBPGR, and demonstration of different accession is prepared for RTC Triyuginarayan along with planning for their accessioning.

Outcome of the In-house research project on ecotourism study in the Kedar valley highlighted environmental factors to have significant impact on the local tourism and can potentially shape the future of tourism in the Kedar Valley. The yearly, monthly and daily tourist influx data collected from tourism department of district Rudraprayag shows, a yearly growth rate of almost 50% in the valley. In the post-disaster years beyond 2015, the two main tourist influx months constitute more than 75% of total tourist influx between opening and closing of Kapat of the Kedarnath temple. The month of May between 2015-2018 recorded the highest number of tourist and constitutes 65 to 84 % of total tourist influx, whereas in 2019 the month of June was the highest tourist influx month with more than sixty lakh people visited the district. Some regulatory norms should be exercised to control the peak monthly influx during the Yatra season. Five training programmes each of two-days on "Capacity Building and Skill Development of the target population in the field of Ecotourism, Management of Bioresources through Eco-friendly Technologies, Livelihood Enhancement and Entrepreneurship Development and Biodiversity Conservation" were organized during April 2019 to March 2020 for a total of 333 participants. Under Spring Sanctuary concept based project, baseline data in terms of spring-flow and peizometric head measurement for pre-and-post implementation years was generated for 2017,

2018 and 2019 for Domat Khal intervention site. Intervention site at Domat Khal 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 and drought year of 2019 compared to the 2017 monsoon rainfall. The reason could also be attributed to the fast preferential flows through the stratified meta-sedimentary rocks in the study area. Deep recharge well in Domat Khal indicates 4 to 19% recharge during the monsoon period of 2018. The Centre also carried out plantation of appropriate species through participatory approach involving village institutions, and educational institutes.

(iii) Sikkim Regional Centre (SRC)

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 dependent opon natural resources for their livelihood. However over-extraction and utilization of the natural resources demands immediate measures 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 Centre 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 Centre 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.

(iv) North East Regional Centre (NERC)

The North-East Regional Centre of the Institute was set up in the year 1989 and started functioning from Chuchuyimlang, Mokokchung in Nagaland. In 1997, the Regional Centre was shifted to Itanagar, Arunachal Pradesh and since then, the Unit has been contributing to the cause of conservation and development of the entire NE region, which is known for its rich diversity of flora, fauna, socio-cultural, linguistic and ethnic communities. Unfortunately, the rich biodiversity of the region is currently facing various threats including degradation, deforestation, settlement expansion, indiscreet hunting, therefore, warrants developing viable, replicable and effective community based resource management initiatives to conserve it. The NERC, through wider networking with strategic partner institutions, credible NGOs, line departments of north-eastern states and others, and fruitful collaboration with international organizations (UNDP, UNESCO, Mac-Arthur, ICIMOD, IUCN, etc.) and national (MoEF, DST, DBT, IIRS, NRSA, NATP, NEC, etc.), has been able to make an impact on the conservation of the biological resources and development of the culturally rich and unique ethnic communities of the entire region by implementing more than 35 R&D projects across the NE region. In the process, some of the critical issues like biodiversity conservation through CBNRM, shifting agriculture focusing on fallow management, technology development, dissemination and backstopping, documentation and validation of TEK, role of culture in biodiversity conservation and development, landscape development, etc. are being addressed. The NERC disseminated its research contribution in the Eastern Himalayan region through publications in national and international journals. Under the In-house project, the NERC has formulated 6 new SHGs in Lower Subansiri district and 5 new BMCs in East Siang district. Additionally, demonstration Centres on vermicomposting and weed composting were set up at 6 villages of Lower Subansiri and East Siang districts of Arunachal Pradesh. These Centres were handed over to the SHGs of the concerned villages for their use and training of other interested local farmers. The important events organized during the year were: (i) Green Skill Building Programme (GSBP): Certificate course on 'Rural Technologies and Livelihood' ; (ii) Meeting with 7 member European Union (EU) delegation for knowledge exchange on ongoing R&D activities of the institute and possible future collaborations; (iii) Annual Day and 6th Popular lecture of NERC on "People, policies and practices in conservation: Grassroots priorities and potentials in environmental conservation and development in Northeast India" by Dr. V.T. Darlong, VC, Martin

Luther Christian University on Annual Day of the Institute; and (iv) Stakeholder's consultation on carrying capacity of hill stations in IHR. In addition, a number of trainings and awareness workshops on various subjects such as rural technologies, beekeeping, mushroom cultivation, photography, research tools and techniques and BMC and PBR guidelines were organized for local stakeholders including farmers, women SHGs, students and research scholars of different educational and research institutes.

(v) Ladakh Regional Centre (LRC)

The Trans Himalayan landscape with most of its area lying above 3,000 masl is characterized by extreme cold climate, minimal annual rainfall (9-10 cm, more than 300 sunny days) and with very sparse vegetation. This landscape, most often, is also termed as cold desert. The region is endowed with rich diversity of culture, unique biodiversity elements and significantly large wetlands/water bodies (lakes). Although, the communities inhabiting these areas have adapted for extremely harsh climate and resource poor living conditions, they face numerous challenges. Especially under changing climate scenario, when impacts are expected to be more intense in higher altitudes, the Trans Himalayan landscapes and people are likely to face more severe challenges. This calls for better understanding of its landscape components and developing strategies and implementation plans for addressing issues of environmental conservation, people's livelihoods and sustainable development under changing scenario. Realizing the above, and recognizing the need, the Governing Body of GBPNIHE in its 41st meeting (September 16, 2019) at Sikkim Regional Centre of the Institute, Pangthang (Sikkim) after due deliberations approved the proposal of setting-up of a Regional Centre of the Institute in Ladakh. Setting-up of this centre would ensure Institute's R&D outreach in entire Trans Himalayan zone of Indian Himalaya by way of targeting following objectives such as (i) to promote alternative and innovative livelihoods for climate change vulnerable cold-desert communities, (ii) to facilitate conservation of critical/important cold desert habitats and biodiversity, (iii) to strengthen and establish approaches for addressing issues of water scarcity, and (iv) to foster climate smart communities in the trans-Himalayan landscape. Towards bringing changes and achieving the targets, this centre of the Institute will focus on following cardinal principles: (a) science for society, (b) networks and collaborations, (c) success model promotion, (d) private sector engagement, (e) harness energies of bright energetic young professionals, and (f) use of technology.

(vi) Mountain Division Regional Centre (MDRC)

The MoEF&CC has established a dedicated unit as 'Mountain Division' within the MoEF&CC as one of the Centre of GBPNIHE 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 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. The Centre 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 trade-offs 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 2019-20, 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 regional centers, viz., Himachal Regional Center (Kullu), Garhwal Regional Center (Srinagar-Garhwal), Sikkim Regional Center (Pangthang), NE Regional Center (Itanagar), Ladakh Regional Centre (Leh) 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 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 on Himalayan Studies (NMHS). The Scientific 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 Centre (HRC), (ii) Garhwal Regional Centre (GRC), (iii) Sikkim Regional Centre (SRC), (iv) North-East Regional Centre (NERC), (v) Ladakh Regional Centre (Leh), and (vi) Mountain Division Regional Centre housed at MoEF&CC, New Delhi.

During the reporting period, R&D work pursued on various projects across the IHR. Summary 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 2019–2020 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

Meeting with European Union (EU)

NERC of the Institute organized a meeting with 7 member official delegation from European Union for knowledge exchange on ongoing R&D activities of the Institute and possible future collaborations at Itanagar, Arunachal Pradesh (5 April, 2019). The EU delegation visited the NERC along with other organizations as well working in Arunachal Pradesh to explore the potential areas of research collaboration between India and the EU. Ms. Tania Friederichs, head of the delegation explained about 'Horizon 2020', which is a seven year programme of the EU Research & Innovation Framework, started in 2014 and is open to the world in diverse research areas. The delegation commended the research activities undertaken by the Institute and assured to facilitate future collaboration with global scientists working in similar research areas. All the scientists and researchers working at NERC attended the meeting.

International Biodiversity Day (22 May 2019)

The Institute celebrated the International Day for Biological Diversity (IDB) under the theme, "Our Biodiversity, Our Food, Our Health" at various localities across the IHR through its HQs at Kosi-Katarmal, Almora and the four regional Centers (GRC, HRC, SRC and NERC). In addition the Institute also participated and showcased the R&D accomplishments in biodiversity conservation through posters and videos based on the R&D work highlighting the importance of mountain biodiversity in the national level event organized by National Biodiversity Authority (NBA) and MoEFCC at Kalaivanar Arangam, Chepauk, Chennai. Shri. M. Venkaiah Naidu, Hon'ble Vice President of India inaugurated the function. In his address Hon'ble Vice President said that biodiversity is fundamental to the survival of the human race and human being must re-establish the link with nature like our ancestors. The GBPNIHE stall organized at this event was visited by over 400 delegates.

At the Institute HQs one day programme at Nature Interpretation and Learning Centre (NILC) was organized wherein 32 students (12 boys and 20 girls) and 6 teachers from six different schools of Almora district, Uttarakhand participated. Field based demonstrations and presentations of modules related to biodiversity value i.e. importance of traditional food, nutritional composition of traditional and modern (fast) food, wild edibles and livelihood, herbal spices, role of traditional agro-diversity, importance of medicinal plants, organic farming were made. An exhibition by students was also made on this occasion. IDB was also celebrated at R&D field sites of the Institute such as Sri Narayan Ashram, Chaudas (Pithoragarh) and at the Institute of Biotechnology, G.B. Pant University of Agriculture & Technology, Patwadangar (Distt. Nainital). At the Sri Narayan Ashram 60 local farmers, 41 students and 2 teachers of Chaudas valley participated in the event. The main focus was given on the wild edibles and medicinal and aromatic herbs diversity of the area and their cultivation practices. At Patwadangar (Distt. Nainital) two day (22-23 May 2019) event was organized for 25 employees of Research Wing of the State Forest Deptt., Uttarakhand and reserchers of the regional Universities with a focus on Long- Term Ecological Monitoring (LTEM) of forest bio-diversity.

At the HRC, Kullu, IDB was jointly celebrated with Himachal Pradesh State Biodiversity Board (HPSBB), Shimla. At this occasion a brain storming session was organized to discuss on the mountain biodiversity and its role in livelihood and health in which 135 participants representing various stakeholder groups

participated. At the SRC, Pangthang (Sikkim) the IDB was celebrated in the form of an exposure visit and biodiversity knowledge interpretation competition for students and plantation drive. The day was linked with the three days nature camp (May 22-24, 2019) where students were introduced to diverse aspects of biodiversity. At the GRC, Srinagar an awareness program and brain storming session for 30 students and 15 teachers of local schools was organized in which biodiversity conservation and food security was focused to sensitize the students. At the NERC, Itanagar events were organized for the students of Donyi Polo Vidya Bhawan School, Itanagar at the Rural Technology Centre (RTC) of the Institute. In this event Institute scientists shared valuable information with the participants on forest biodiversity, agricultural diversity; its importance and conservation practices. After technical discussions, a drawing competition was organized among the school students on the theme biodiversity of Arunachal Pradesh.

National Seminar in collaboration with NERIST

A two-days National Seminar on 'Tribal empowerment through entrepreneurship of indigenous produced products' was organized by NERC in collaboration with North East Regional Institute of Science and Technology (NERIST), Nirjuli (29-30 May 2019). The objective of the Seminar was to provide a forum for discussions and a platform for the exchange of experiences as well as observations on "Tribal Empowerment through Entrepreneurship of Indigenous Produced Products". About 30 farmer beneficiaries were

trained and 10 resource persons were selected from the different villages to coordinate effectively and efficiently to implement these techniques and use of skills over the three years period of the project. The themes of seminar include (i) Changing development paradigm and its implications for the sustainability in entrepreneurship development, (ii) Eradicating issues related to implementation of modern practices of entrepreneurial activities, and (iii) Emerging issues of environment and development in IHR and future concerns of these communities.

Celebration of World Environment Day 2019

World Environment Day 2019 was celebrated by the Institute at its HQs Kosi-Katarmal, Almora and regional centers (HRC Kullu; GRC Srnagar; NERC Itanagar; and SRC Pangthang, Sikkim). The day was celebrated on the theme "Beat Air Pollution". At HQs, the day was celebrated with the 135 school students of different schools of Almora. Various competitions on the theme of the WED were organized. At HRC, the day was celebrated with 44 students & 9 teachers of 9 schools of the Kullu district. At SRC, the day was celebrated by organizing one-day brain-storming workshop on "Air pollution and Environmental Risks in Sikkim Himalaya: Causes, Impacts and Mitigation Measures" at Pangthang. Among others, Prof. G. K. Niroula Chhetry, Vice Chancellor of Sikkim State University, Dr. Gopal Pradhan, Member Secretary of Sikkim State Pollution Board, researchers GBPNIHE-SRC, Sikkim University, Sikkim State University, other organizations, etc., discussed and deliberated on the air pollution

risk and its solution in Sikkim Himalaya. A total of 55 participants from various government organizations and NGOs such as Sikkim Central University, Sikkim State University, DST-Sikkim, Sikkim State Disaster Management, Sikkim State Pollution Control Board, WWF, ECOSS, TMI, etc., participated in the workshop.

Scientific Advisory Committee Meeting (SAC)

The 25th Meeting of the SAC was held on 16-17 July, 2019 at the Institute's HQs, Kosi-Katarmal, Almora. The SAC meeting was chaired by Prof. V.P. Dimri, FNA. Among the SAC members, Dr. Kishor Kumar (Member), Prof. A.R. Nautiyal (Member), Dr. A.A. Mao (Member), Prof. S.C. Rai (Member), Dr. N. Bala (Representative of Director, FRI), Dr. R.S. Rawal, Director, GBPNIHE (Convener) and Institute members Dr. R.C. Sundriyal (GBPNIHE nominee), Er. M.S. Lodhi (GBPNIHE nominee) and Ms. Sarla Shashani (GBPNIHE 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.

Consultation Workshop on Carrying Capacity of Hill Stations

A consultation workshop on "Guidelines for Assessing Carrying Capacity of Hill Stations" was organized on August 2, 2019 at HRC of the Institute at Mohal-Kullu (H.P.). Total 28 participants from various line departments of District Kullu participated in this meeting. Various topics such as definition of carrying capacity, its types, dimensions and necessity of assessing carrying capacity were addressed during the workshop. The major recommendations came out from the workshop was to involve stakeholders and local people in making policies for developmental activities. Similary, SRC (Sikkim) organized a consultation workshop to finalize and validate draft guidelines for assessing the carrying capacity of Hill Stations of IHR (August 2, 2019). The objectives of the consultation workshop were: (i) Identify predominant issues and options of hill stations in Sikkim Himalaya, (ii) Prioritizing activities having impacts on hill stations, and (iii) Validation on guidelines for assessment of carrying capacity of hill stations of IHR. Total 40 participants including officials from different Central

Government organizations, State Government departments/ line agencies, academicians from Universities, and other stakeholders from various NGOs and representatives of travel agencies and hotel associations in Gangtok, Sikkim participated in the workshop.

Launch Event of "Jal Abhyaranya Campign" in Chamba district of Himachal Pradesh

Himachal Regional Centre, Mohal - Kullu organized a launch event of 'Water Sanctuary Programme' at District Rural Developmental Agency (DRDA) office Chamba on 13th August, 2019. Hon'ble Deputy Commissioner of Chamba Shri Vivek Bhatia, IAS was the Chief Guest of the programme. The event was attended by total 30 participants from various government departments including IIT Mandi, Forest, Irrigation and Public Health, Block Development Office, District Tourism Development Office, Hydropower, District Rural Developmental Agency, Town and Country Planning, Public Work Department, Agriculture Department, President and Members of Chamba Municipal Council, Pradhan and Ward Members, local NGOs and staff of GBPNIHE. It was unanimously agreed that shared responsibility and involvement of all stakeholders will make this Jal Abhyaranya campaign successful in Chamba disrict.

Training Programme for Livelihood Enhancement

A two-days training and capacity building programme on natural resource management through simple technological interventions for livelihood enhancement in disaster affected village of Kedar valley was organized by GRC (Srinagar) at Tilwara, district Rudraprayag, Uttarakhand (19-20 August 2019). The objective of the programme was to avail a common platform for sharing experiences and ideas among different stakeholders including scientists, officials of state government line departments, villagers, NGOs, and students to identify potential livelihood options of the disaster affected people of the region through implementation of potential hill specific technologies. Scientist In-charge, GRC addressed the participants and delivered a presentation on the potential of natural resource, strategies for sustainable utilization and management of these resources to enhance livelihood through adopting the rural technologies demonstrated by GRC. A total of 155 stakeholders of different background such as farmers, students, NGOs, members of line departments of the region participated in the programme. Various issues related to sustainable utilization and management of bioresources and linking them with livelihood of the stakeholders were shared among the stakeholders during the programme. The training addressed the issues covering different sectors of livelihood useful for natural disaster affected Kedar valley and revival of livelihood of the local people by wise utilization of natural resources and their management through introduction of simple technologies.

Voluntary Certification Scheme for Medicinal Plant Produce (VCSMPP)

Towards certifying the medicinal plants produce, a training programme was jointly organized with Quality Council of India, New Delhi on Voluntary Certification Scheme for Medicinal Plant Produce (VCSMPP) at GBPNIHE, Almora (22 August, 2019). The aim of the workshop was to include farmers of the Chaudas valley (KSL region, of Pithoragarh district) under VCSMPP so that they get benefit while selling their produce. The following major points were discussed during the training: (i) certification of progressive farmers and authorizing their cultivated quality plant materials; (ii) promotion of medicinal plants sector in the Chaudas area to connect them with Central/ State schemes; (iii) development of market linkages for selling of cultivated produce; (iv) combating the challenges regarding the quality, safety and efficacy of medicinal plants produce; and (v) sensitization of the diverse stakeholder groups through exposure visits and conducting training programs.

Brainstorming Workshop to Strengthen R&D in Sikkim Himalaya

A brainstorming workshop was organised by SRC of the Institute on 9 September, 2019 at Pangthang, Sikkim for development of roadmap for regional level collaboration between Botanical Survey of India (BSI), Zoological Survey of India (ZSI) and GBPNIHE for strengthening research and development activities in Sikkim Himalayan region. The workshop was organized as a follow-up of the meeting of the Directors of ZSI, BSI & GBPNIHE held on May 2, 2019 at ZSI, HQs Kolkata wherein it was agreed that the regional stations/centres of three organizations located/ working in the Himalayan region will establish a mechanism of regular interaction (quarterly) and joint project/programme development. The main aim of the brainstorming workshop was to explore possible opportunities of collaboration among three organizations especially for promotion/ strengthening of R&D activities and their outputs in the IHR, and share information amongst each others to avoid repetitions and build synergy for combined development of knowledge products. During the workshop, strategy for joint research activities including field expeditions, development of new projects, data base for Sikkim Himalaya, and field manuals, organization of training and capacity building programmes, seminars, conferences, workshop was devised and approach and roadmaps for regional collaboration for various R&D activities was framed.

Brainstorming-cum-Workshop on MAPs of High Altitude Landscapes

A brainstorming-cum-workshop was organized under UNDP sponsored SECURE Himalaya Project (8-9 Sept 2019) as a pre-event of Annual Day of the Institute with an objective to provide platform to diverse stakeholders for holistic deliberation on the MAP sector in Uttarakhand with a focus on medicinal and aromatic plants (MAPs) of high altitude landscapes. This included: (i) to critically review the status of MAP sector development in the state especially w.r.t. high altitude MAPs, (ii) to identify most important challenges and issues related to MAP sector development and suggest remedial measures, and (iii) to provide inputs for policy interventions and strategy for development of the MAP sector. During the workshop, it was recommended that there is huge scope to strengthen MAP based livelihood in the Uttarakhand and efforts to promote MAPs conservation and cultivation. Govt. of Uttarakhand is already implementing programs and schemes related to cultivation and conservation of medicinal and aromatic plants. Needful awareness and support be extended to local communities for cultivation of MAPs in their own fields.Training programme for farmers/ cultivators/collectors should be organized. At the end of the two day meet, Dr. R.S. Rawal, Director expressed his satisfaction on the

outcome of the meet. In his concluding remarks Dr. G.S. Rawat emphasized that prioritization of economically important MAPs for cultivation will bring better income options to locals. About 50 experts from 30 organizations including people from academic/research organizations, line agencies and government agencies (i.e., forest department, horticulture department, bhesaj sangh, state biodiversity board, etc.), NGOs, pharmaceutical industries, traders, and other organizations working on the MAPs in the region participated.

Annual Day Celebration

Annual Day Celebration of the Institute and 25th G.B. Pant memorial lecture was organized at Institute HQs Kosi-Katarmal, Almora on September 10, 2019. Mr. Ajay Tamata, State Minister of Textile Ministry presided over the function. Prof. Raman Sukumar, Centre for Ecological Sciences, Indian Institute of Science (IISc) Bangalore, delivered the G.B. Pant memorial lecture. In his lecture, Prof. Sukumar talked about the human-wildlife conflicts and stressed on the need for developing framework for wildlife protection. Guest of honour, Prof. S.P. Singh, former Vice Chancellor of HNB Garhwal University, Srinagar-Garhwal, talked about the issue of climate change and its impact on Himalayan ecosystem. Dr. Rajendra Dobhal, DG, UCOST, Dehradun, talked on the implementation of lab research outputs in rural areas. Dr. G.S. Rawat, Director, Wildlife Institute of India, Dehradun spoke on the impact of disturbance on flora and fauna of Himalaya. Dr. R.S. Rawal, Director of the Institute, presented the achievements and future vision of the Institute. Mr. Ajay Tamata, Hon'ble MP Almora, in his presidential address highlighted about the mission and vision of Bharat Ratna late Pt. Govind Ballabh Pant ji. He emphasized upon potection of natural wealth of Himalaya for the sustenance of the regional inhabitants. About 350 people participated in the function including researchers from various research organizations, scientists, research staff and employees of the Institute.

At Himachal Regional Centre, 6th Himalayan Popular lecture entitled "The Mighty Himalayas: Need and Proposed Planning Strategies for its Conservation" was delivered by Dr. Kulraj Singh Kapoor, Former Director, Scientist-G & Group Research Coordinator, Himalayan Forest Resarch Institute, Shimla. Sikkim Regional Centre of the Institute celebrated the Annual Day at Forest Secteriate, Department of Forest, Enviornment and Wildlife Management, Deorali, Sikkim. Prof. G.K. Niroula Chhetry, Vice Chancellor, Sikkim State University, Sikkim delivered 6th Pt. G. B. Pant Popular Lecture on "Himalayan Agro-Ecological Farming & Prospects for Biodiversity Conservation: an Eastern Himalayan Perspective". This function was presided over by Shri Indra Hang Subba, Hon'ble Member of Parliament, Sikkim. At Northeast Regional Center, Annual Day was

organized and 6th Popular lecture was delivered by Dr. V.T. Darlong, Vice Chancellor, Martin Luther Christian University on "People, policies and practices in Conservation: Grassroots priorities and potentials in environmental conservation and development in Northeast India". At Garhwal Regional Centre the Annual Day was celebrated by organising 6th Himalayan Popular Lecture on "Uttarakhand Himalaya: A State Meant Disaster" delivered by Prof. Annpurna Nautiyal, Vice Chancellor, H.N.B. Garhwal University, Srinagar-Garhwal, Uttarakhand.

Training on Scientific Paper Writing and Statistical Analysis using R

A six day skill building hands-on training on "Scientific Paper Writing and Statistical Analysis using R" was organized by the Institute HQs at Kosi-Katarmal (Almora) from September 10-15, 2019. The aim of this training was to enhance capacity of young researchers in scientific communication, paper writing and statistical data analysis. A total of 32 participants from four regional centres of the Institute participated. The training was inaugurated with key note lecture on 'Scientific Paper Writing' delivered by Prof. S.P. Singh, Former V.C. HNB Garhwal University, Srinagar on 10th September 2019. Dr. R.S. Rawal, Dirctor said that there is need to translate the research into the field application so that communities get benefitted. During this training a detailed training module was prepared and given to all the participants including basic introduction on statistical analysis of ecological, survey and spatial data intended to provide young researchers a brief idea about the software. All the participants were satisfied to have the basic information regarding applications of statistics in their future scientific endeavours.

MAPs Sensitization Workshop for High Altitude Communities

A workshop for medicinal and aromatic plants (MAPs) sensitization and discussion on the government initiatives and project aim for promotion of cultivation was carried out at Gangotri-Govind and Darma-Byans landscape of Uttarakashi and Pithoragarh districts under UNDP-SECURE Himalaya project. In Gangotri landscape, a total of 257 people from 14 villages (viz., Mukhua, Dharali, Harsil, Jalha, Purali, Jaspur, Hurri, Bhangeli, Bhuki, Tihar, Salang, Bharsu and Sukki) showed their concern over

MAPs cultivation. In the Govind landscape this programme was organized in which a total of 256 (207 male and 49 female) participated. The number of farmers engaged in the cultivation of MAPs ranged between 1-3 in six villages (Sankari, Taluka, Dhatmeer, Gangad and Osla) and in two villages cultivation was not inititated by the villagers (Doni and Satta). In Darma-Byans landscape a total of 148 individuals targeting 6 villages namely Dantu, Sippu, Marcha, Tidang, Bon and Dugtu participated in the sensitization programme.

Memorandum of Understanding (MoU)

Need for close linkages among national research organizations/ Institutes and the Universities has been recognized by different scientific Ministries, Departments and other agencies, including the MoEF&CC and the University Grants Commission (UGC). In compliance to this felt need, the GBPNIHE and the Sikkim University, Gangtok, Sikkim (A Central University established under an Act of Parliament of India, 2007 and accredited by NAAC in 2015) entered into a MoU on 13 September 2019 at Gangtok, Sikkim for providing collaborative research opportunity to

the scientists, students and researchers of either institution in increasing the effectiveness of teaching and research, jointly organise seminars, conferences and academic workshops on topics of mutual interests, publish books, monographs, seminar and workshop volumes etc., and knowledge dissemination. The MoU between the two organizations was signed by Dr. R.S. Rawal, Director, GBPNIHE and Mr. T.K. Kaul, Registrar, Sikkim University. Furthermore, the MoU was also signed between GBPNIHE and the Sikkim State University, Sikkim on 17 September 2019 at Gangtok, Sikkim.

India- ICIMOD Partners Day

Continuing the long standing India-ICIMOD partnership, the 50th ICIMOD Board of Governors meeting was hosted by the MoEF&CC and the Government of Sikkim in Gangtok. High-level government officials from the eight ICIMOD regional member countries who are members of the Programme Advisory Committee and ICIMOD Support Group (Development Partners) attended the meetings. Around 60 participants from more than 20 countries participated in the meetings in Gangtok. One of the hallmark events of the Board Meeting the India–ICIMOD partners' day was held on 14 September 2019 at Chintan Bhawan, Gangtok, and was attended by high-level government officials of the Government of India (specifically the Government of Sikkim) and GBPNIHE and other ICIMOD partner organizations from the country's north-east region. The main objectives of the India–ICIMOD partners' day event were to strengthen partnerships in India by aligning its Medium-Term Action Plan and to showcase ongoing or recently completed projects and activities.

Institute Governing Body Meeting

The 41th Governing Body meeting of GBPNIHE was held on September 16, 2019 at the Sikkim Regional Centre, Pangthang, Sikkim. This meeting was chaired by Shri C.K. Mishra, Secretary, MoEF&CC (Chairman) and attended by Shri Praveen Garg, AS & FA, MoEF&CC (Member), Shri Ravi Agrawal, AS, MoEF&CC (Member), Shri Arvind Nautiyal, JS, MoEF&CC (Member), Prof. R.K. Kohli, Vice-Chancellor, Central University of Punjab (Member), Shri Ramesh Singh Negi, Chairperson,

DCPCR Delhi (Member), Shri Brijendra Swaroop, Dy. CEO CAMPA, Representative of DG&SS, MoEF&CC (Member), Shri Lalit Kapur, Senior Consultant, MoEF&CC (Special Invitee), Shri Surya Kant, Finance Officer, GBPNIHE (Special Invitee), Dr. R.S. Rawal, Director, GBPNIHE (Member Secretary). Among others, the GB took a decision to open a new regional center of the Institute in Ladakh to cater to the need of Trans Himalayan region of Indian Himalaya.

World Tourism Day 2019

A workshop was organized on 'Promotion of Community Based Ecotourism as a Potential Livelihood Option in Khangchendzonga Landscape-India' by SRC to celebrate the World Tourism Day (September 27, 2019). The workshop was organized with an aim to underline the issues, challenges and opportunities for community based tourism promotion in the Khangchendzonga Landscape-India in Barsey-Singalila Pilot site (Ribdi-Bharang Village). A total of 86 participants participated in the programme. The event provided a platform for stakeholders from all the three pilot sites of Khangchendzonga Landscape (Dzongu, Barsey-Singalila and Bandapani) to work with a common vision to promote sustainable community-based tourism in the landscape. Further, to mark the celebration of the event as part of the World Tourism Day one training programme on bird watching and homestay management was conducted and Ecotourism Committee was formed for better functioning of ecotourism group.

Workshop in Collaboration with WWF and PSI

A one-day workshop in collaboration with WWF-India and People's Science Institute (PSI), Dehradun on 'Identifying scope of springshed development works in collaboration with Government of Arunachal Pradesh' was organized at GBPNIHE-NERC on 1st October, 2019. A total of 18 participants attended the meeting. The major recommendations include: (i) Water conservation and biodiversity conservation need to go hand in hand, (ii) Springshed development needs an integrated and multifaceted approach involving stakeholders from government institutions, civil society organizations and community, (iii) A joint proposal by PSI, WWF-Inida, GBPNIHE can be developed and submitted to Planning Department, Government of Arunachal Pradesh to support training and capacity building of concerned

departments related to springshed development, and (iv) The funds allocated under CAMPA may be utilized for springshed management in the state(s).

Training on Strengthening Livelihood Based on Pilgrimage Tourism in Kedar Valley

A two-days training programme on stakeholders consultation workshop on strengthening livelihood of local people based on pilgrimage tourism in Kedar valley was organized by GRC of GBPNIHE at Rural Technology Center, Triyuginarayan (Distt. Rudraprayag), Uttrakhand between 9-10 October 2019. A total of 70 stakeholders belonging to diverse backgrounds i.e. farmers, youth, NGOs, SHGs, hoteliers, workers at dhabas, mandir samiti, and politicians participated in the workshop. Padma Bhushan Shri Chandi Prasad Bhatt was the chief guest of the programme. The programme identified the need for capacity building of farming communities with respect to enhance the quality of agro-products by integrating these products with organic farming so as to fetch premium price at national and international market. Value chain to reduce the risk in price controlling of the products and timely selling as identified one of the critical step to be taken to bridge the gap between producers and buyers.

Brainstorming-cum-Workshop on MAPS

Two days Brainstorming-cum-Workshop entitled

"Promoting Medicinal and Aromatic Plant (MAP) Sector for conservation of Snow Leopard Habitats in Himalaya" was organized at Defense Institute of High Altitude Research (DIHAR), Leh-Ladakh on October 14-15, 2019. A total of 62 participants of 20 organizations (GBPNIHE, LAHDC, NCF, DIHAR, Hort. Dept, MAP cultivator, Dabur, LEDG, WWF, NRISR, Forest Department, LEHO, UNDP, SKUAST, Amchi, CIBS, EJM Ladakh Organic Farming) participated in the workshop. After the discussion and experts' opinion, ten species i.e., *Saussurea lappa, Inula racemosa, Hippophae rhamnoides, Carum carvi, Meconopsis aculeata, Dactylorhiza hatagirea, Picrorhiza kurroa, Juniperus spp. and Sinopodophyllum hexandrum, and Rhodiola*

imbricata were prioritized for detailed study. The experts were of the opinion to conserve and promote the MAP in the area so that habitat of endangered spcies such as Snow Leopard could be conserved.

Himalaya Matters in a Changing World

Towards celebrating International Mountain Day (IMD), a three day conference (9-11 December 2019) was organized at GBPNIHE HQs Kosi-Katarmal on the occasion of International Mountain Day. The focus was to effectively articulate on 'Himalaya Matters in a Changing World". There were three parallel sessions conducted everyday on prominent issues such as water, agriculture, biodiversity (flora and fauna), livelihood and ecosystem services. In addition a dozen side events on specific issues such as conservation of high altitude wildlife, habitats, trans-boundary conservation, forest resources, timbre line, climate change etc. were held during

this conference. These sessions were organized by leading organizations such as Botanical Survey of India, Zoological Survey of India, Indian Council of Agriculture Research, Wildlife Institute of India, National Institute of Ecology, IUCN, Tata Trusts, Himmothan, National Mission on Himalayan Studies, NMSHE, Task Force 3 (DST), ICIMOD (Kathmandu), WWF, CHEA etc. This conference was expected to build partnership and networking with the Institutes working for the sustainable development and environmental conservation of the Himalaya. As a way forward, following major outcomes emerged: (i) Establish Consortium of Himalayan Knowledge Partners; (ii) Promote water sanctuary "Jal Avayaranya" for water security; (iii) Maintain uniqueness of biodiversity under changing climate; (iv) Incentivize on-farm conservation and foster climate smart communitie; (v) Harness traditional knowledge system for innovative livelihoods, and (v) Enhance appreciation for ecosystem services flowing from the Himalaya. This conference was attended by over 250 delegates, representing 33 organizations working for the Himalayan ecosystem. At the SRC (Sikkim) the IMD was celebrated by organizing a two-day Workshop-cum-Training Programme on mountain biodiversity and livelihood opportunities. At HRC (Kullu) the IMD was celebrated with Members of Mahila Mandal, Yuvak Mandal, Pradhan of various Panchayats of Kullu district, etc.

Institute Society Meeting

The 21st meeting of the G.B. Pant Society of Himalayan Environment and Development (GBPSHED) was held under the Chairmanship of Shri Prakash Javadekar, Hon'ble Union Minister of MoEF&CC, Government of India, and the President of GBPSHED, on 30th December 2019 at MoEF&CC, New Delhi. Among the dignitaries those attended the meeting were Shri Ravi Agrawal, Additional Secretary, MoEF&CC, Shri Siddhanta Das, DG (Forest) and Special Secretary, MoEF&CC; Dr. R.B.S. Rawat, Ex-PCCF, Dehradun; Padmabhusan Shri Chandi Prasad Bhatt; Prof. V.K. Gaur, FNA, Banglore; Dr. A.A. Mao, Director BSI; representatives from Sikkim University Gangtok; Govt. of Sikkim; ICFRE; Agriculture Research & Education; Ministry of Jal Shakti; Department of Urban Development; Ministry of Rural Development; Department of Agricultre, Cooperation & Farmers Welfare; Environment Ministry, Himachal Pradesh. Shri Arvind Nautiyal, Joint Secretary, MoEF&CC, and Dr. Subrata Bose, Director, MoEF&CC, were the special Invitee. Dr. R.S. Rawal, Director, the Member Secretary, GBPNIHE convened the meeting. Among others, the Society adopted the Annual Report of the Institute and changed Institutes name as G.B. Pant National Institute of Himalayan Environment (NIHE)

Training on Low Cost Technologies and Alternate Livelihood to Farmers

A two day (14-15 January, 2020) training for farmers on 'low cost technologies and alternate livelihood options' viz. low-cost agricultural technologies, beekeeping, mushroom cultivation etc. were organized under In-house project on 14-15 January, 2020 at RTC, DNGC campus Itanagar. The main objective of the training programme was to provide the basic information and hands-on-knowledge to the selected farmers from different villages of Arunachal Pradesh on rural technologies and alternative livelihoods options so as to enhance their livelihood. Additionally, participants were informed about the importance and sustainable use of bio-resources. A total of 25 trainees (mostly women) attended the training programme. The trainees included farmers, SHG members (mostly women candidates) and students.

Monitoring & Evaluation (M&E) Workshop 2020

The 3rd Monitoring and Evaluation (M&E) Workshop was organized during 28-29 January 2020 at Indian National Science Academy (INSA), New Delhi to review the work progress and provide the guidance for achieving quantifiable outputs and target deliverables of the projects under National Mission on Himalayan Studies (NMHS). The workshop was chaired by Shri Ravi Agrawal, Additional Secretary, MoEF&CC and co-chaired by Shri Arvind Nautiyal, Joint Secretary, MoEF&CC, New Delhi in the presence of other eminent members, subject experts and the NMHS Monitoring, Learning and Evaluation (MLE) Panels. Under four distinct Technical Sessions, the M&E Workshop Panel mentored the evaluation process of all 32 NMHS Projects completing their project term by March, 2020. On this occasion, a new book "Proceedings of the 1st Himalayan Researchers Consortium, Volume II – Assessment of Faunal Diversity of the Indian Himalaya" was also released by the Chief Guest.

Special Session on Conservation of Migratory Species of Wild Animals

The Institute organized a special session under the theme Community Participation and Livelihood during the 13th Session of the Conference of Parties to the Convention on the Conservation of Migratory Species of Wild Animals at Gandhi Nagar, Gujarat, India (15-22 February 2020). The general theme for the conference was migratory species connect the planet and together we welcome them home. The session by GBPNIHE was conducted on 21st February 2020 on the specific theme "Migratory Birds in the Himalaya: Participatory Conservation and Improved Livelihoods". Various key note lectures during the session were delivered. These included (i) Migratory birds and livelihood opportunities in the Himalaya with particular emphasis on the trans-Himalayan region of Ladakh by Dr. Suresh Rana, Scientist, GBPNIHE, (ii) Conservation of migratory birds and promotion of livelihoods in Ladakh, India by Dr. Pankaj Chandan, Team Leader, WWF-India Western Himalayas Landscape Office, and (iii) International significance of migratory bird conservation as an alternate source of livelihood for local communities in the Himalaya by Dr.Tsewang Namgail, Director, Snow Leopard Conservancy Trust India. In addition, Mr. Intesar Suhail, Wildlife Warden, Department of Wildlife Protection, Jammu & Kashmir presented on the avifaunal richness and uniqueness of Kashmir valley and Ms. Usha Lachungpa, Department of Wildlife Protection, Sikkim shared nature tourism and bird watching experience from eastern Himalayan state of Sikkim. Finally in the discussions it was unanimously agreed by the experts and participants that bird watching could be one of the potential tourism activity in the Himalaya, which is one of the option for livelihood for the Himalayan people, and therefore, eco-friendly home stays need to be developed and promoted in remote corners of the Himalaya. The session was attended by over 40 experts and participants from different countries.

Carbon Neutral Ladakh - A New Beginning

The Institute in collaboration with UT administration

of Ladakh organized a 4 day summit at Leh during 2-5 March 2020 on the theme "Carbon Neutral Ladakh- A New Beginning" focusing on sustainable development and achieving carbon neutrality in Ladakh. It was a pioneering action to develop a road map and strategic plan for the sustainable development and for achieving carbon neutrality in Ladakh. The summit was inaugurated by Shri R.K. Mathur, Hon'ble LG of Ladakh. During this four day summit, a dialogue with rigorous and scientific discussions was conducted between the scientific experts of relevant fields, local and national government officials and policy makers. Institutes, departments and ministries which took active interest included MoEF&CC, International Centre for Integrated Mountain Development (ICIMOD), UN Environment Programme (UNEP), NITI Aayog, Indian Institute of Remote Sensing (IIRS), Wildlife Institute of India (WII), Jawaharlal Nehru University (JNU), Kumaun University, Ladakh University, GBPNIHE HQs and various regional centres, Indian Army, Ladakh Wildlife Departments, Indian National Science Academy (INSA), Zoological Survey of India (ZSI), Botanical Survey of India (BSI), Himalayan Forest Research Institute (HFRI), Indian Institute of Technology (IIT), National Institute of Hydrology (NIH), Central Arid Zone Research Institute (CAZARI), CSIR Institute of Himalayan Bioresource Technology, Sher-e-Kashmir University of Agricultural Sciences & Technology, Central Water Commission, HP Science and Technology Council, J&K Science and Technology Council, NARPA Fellowship, and NGOs like Central Himalayan Environment Association (CHEA), Nainital, Central Institute of Buddhist Studies (CIBS), Integrated Mountain Initiative (IMI), etc. The summit specifically made recommendations and developed action agenda for (i) sustainable tourism, (ii) disaster management, (iii) ecology and culture heritage, and (iv) road map for carbon neutral Ladakh.

Training Workshop

One-week Training workshop on "Statistical Application in Ecological Research" was organized during 2-6 March, 2020 at SRC of the Institute at Pangthang, Sikkim. The specific objectives of this training workshop were to: (i) get familiar with design of experiment for planning and implementation of the research, (ii) illustrate sampling methods for improved data collection, which can provide the desired precision of estimates and possess a higher degree of accuracy, (iii) explain methods of field data collection and statistical analyses, and (iv) provide hands-on

training on appropriate application of statistical methods for data analysis and interpretation of results. A total of 27 participants from 7 different organizations and 5 IHR States participated in the training. The training modules included lectures, hands-on training and field exercise on broad topics of statistical application to ecological studies, viz., (i) Basic concepts of design of experiment, sampling theory & classification of data, (ii) Vegetation sampling & data collection, (iii) Systematic botany & herbarium cataloguing, (iv) Statistical methods for vegetation analysis, (v) Testing of hypothesis (comparative & relational analysis), and (vi) Multivariate analysis and ordination methods.

Swachh Bharat Mission

Under the Swach Bharat Mission, cleanliness drive was conducted at HQs Kosi-Katarmal, Almora and all the regional centers (SRC Pangthang; HRC Kullu; NERC Itanagar; GRC Srinagar). A one-day training programme and stakeholders consultative meeting on Swachh Bharat Mission was organised by GRC of GBPNIHE on 12th March 2020 at village Kimana, Guptakashi, Rudraprayag. A total of 92 participants including local people, students, homstay owners, NGOs, SHGs and Mahila Mangal Dal participated in the programme. At HRC various activities like cleaning of office premises (01/06/2019), Cleanness Drive in Public Parks (03/06/2019), World Environment Day-2019 (Pre-event on 04/06/2019), Swachhta Rally (08/06/2019), Cleaning of Mohal Khad (28/04/2019) and Nukkad Nataks in Nature Park, Mohal (15/06/2019) during Swachhta Pakhwada (01 – 15 June, 2019) were organized. NERC, Itanagar organized various activities viz. Cleaning drive at office premises, public parks (energy park), tourist places (Ganga Lake); awareness rally in the market area (Vivek Vihar) on ODF, sanitization practices, health and hygiene; painting competition on 'Swachh Bharat

Mission at Vivekananda Central School (VCS) Itanagar; etc.

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. These include: (i) Training on Soil, Water and Plant Quality Assessment, (ii) Ecotourism & Livelihood Enhancement, (iii) Sustainable Solid Waste Management: Turning Waste into Resources, (iv) Natural Resource Management through Technological Interventions for Livelihood Improvement of Tribal Communities of High Himalayan Region, (v) Rural Technology and Livelihood, and (vi) Forest Resources and Plant Biodiversity. Skills of 198 stakeholders were built through 10 GSBP programme, which span across 4 states of the Himalaya (Table 1).

Table 1: Summary of GSBP organized by GBPNIHE (2019-20)

S.No.	Skill Building Event(s)	Duration (Days)	Place (State)	No of Beneficiaries
Green Skill Building Events at HQs				
1.	Wild Bee Keeping & Processing	5-27 November 2019	GBPNIHE, State Apairy Board, Jeolikote & GBPUAT, Pantnagar	15
2.	Bird Identification& Basic Ornithology	11-26 January 2020	GBPNIHE, Corbett National Park Landscape, Nainital	17
3.	Training on soil, water and plant quality assessment	17-28 February 2020	Kosi-Katarmal, Almora (Uttarakhand)	15
4.	Beekeeping: A major livelihood option	12 February - 2 March 2020	Kosi-Katarmal, Almora (Uttarakhand)	20
5.	Preparation of People's Biodiversity Register	13 February - 2 March 2020	GBPNIHE & Uttarapath Sewa Samiti, Thal, Pithoragarh	13
6	Vegetation Assessment, Herbarium Techniques and Statistical Analysis for Long-Term Ecological Monitoring	24 Feburary - 6 March 2020	Kosi-Katarmal, Almora (Uttarakhand)	33
Green Skill Building Events at Regional Centres				
7.	Ecotourism & Livelihood Enhancement	3 -12 February 2020	Pangthang, Sikkim	18
8.	Sustainable Solid Waste Management: Turning Waste into Resources	3 -17 February 2020	Mohal Kullu (Himachal Pradesh)	22
9.	Natural Resource Management through Technological Interventions for Livelihood Improvement of Tribal Communities of High Himalayan Region	12-18 March 2020	Srinagar (Garhwal)	30
10.	Certificate Course on Rural Technology and Livelihood	3-25 March 2020	Itanagar (Arunachal Pradesh)	15

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 'Centre 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. The objectives of the center are to (i) conduct studies on land and 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 land and water resource management policies.

Summary of completed project

Water Sustainability Mapping in Himalaya - Status, Trends and Options (In House, 2017-2020)

The water sustainability mapping of IHR involves diverse set of issues pertaining to glacier dynamics and hydrology, water availability and management for household supplies and irrigation, hydropower planning through cumulative impact assessment, and harnessing of tourism potential associated with sacredness value of Himalayan rivers. The present study was envisaged to understand the water availability i.e. water demand and supplies for three critical uses namely household and irrigation, hydropower development, and water-borne sacredness / recreational use at the river basin level thru the study of mountain hydrology, hydropower impacts, and economic value of river based pilgrimage/ recreational tourism. The broad objectives of the study were: (i) assessment of mountain hydrodynamics through hydrological instrumentation and by using field observations data for water status mapping; (ii) long term mapping of water flow and stock for hydropower development and its impacts, and (iii) estimation of sacredness and recreational value of water as river based pilgrimage and tourism and its multipliers and contributions to local economy. The study was carried out over Kali watershed divided into five sub-watersheds as: (i) Sarayu (2252 km^2), (ii) Dhauliganga (1364 km^2), (iii) Goriganga (2141 km^2), (iv) Ramganga (1930 km^2) and (v) Kali (2154 km^2). The hydrodynamics study of the experimental watershed includes (i) establishment of river gauging stations over two major rivers of the study area, (ii) comparison of flow properties and water chemistry of major river systems within the study area, and (iii) assessment of water demand and availability through survey for a selected sub-watershed within the Kali watershed. The long-term discharge data comparison between Saryu and Goriganga river of the watershed indicated that the seasonal stream flow variability of Goriganga is higher than Saryu, wherein a gradually increasing base flow was noted for Goriganga unlike a sudden enhancement of base flow in Saryu indicating a smoother response of the Goriganga glaciated system to environmental change than Saryu. Similarly, streamflow and base flow data between Kali and Saryu rivers indicated the baseflow index (BFI) of Saryu river was marginally higher (0.68) than Kali (0.67), indicating Saryu has higher 'baseflow contribution of groundwater to river flow'. The water chemistry analysis between Kali and Saryu indicated that generally, both the rivers are having 'Good' water quality deteriorating mostly during monsoon season due to excessive turbidity through soil erosion. The integrated index based approach for estimating Water Scarcity, wherein hydrological, environmental and demographic factors are coalesced, was carried out for the first time for any watershed in the Indian Himalaya, i.e. Saryu watershed within the Kali basin. It was noted that albeit significantly high density of glacier fed rivers in the Saryu watershed, around 232 villages in the Saryu watershed were severely water scarce. The GIS based numerical modeling of the Pancheswar dam indicated that although the entire Kali watershed has high potential for hydro power projects, the socio-physical impact of the Pancheswar Dam at 680 m full reservoir level can cause substantial loss of villages through submergence. The sacredness related and recreational use of river water is mainly availed in the form river based pilgrimage/ ritualistic and adventure/recreational tourism. The review of tourist inflow to IHR reveals that Uttarakhand receives nearly 55-60% of total tourist inflow of IHR, and around 50% of total tourist inflow, of which related to inflow to Haridwar and Rishikesh, is related to water based pilgrimage and recreational use of water mainly associated with the existence value of the river Ganges. A survey based case study of Champawat and Lohaghat area within the Kali watershed reveals that 4-months tourism in the area contributes to more than 42.5% of annual earnings of the local business communities. The annual fairs alongside the rivers and their confluence places help in ensuring circulation of money in local economy and provide market for promoting growth of local handicrafts products, metal products, cereals and traditional crops, and small scale trans-boundary trade opportunities, and thereby sustain the local industries and economic activities. However, observations reveal that drying of rivers, streams, and springs etc., on permanent basis or as a seasonal feature, adversely affect the availability of water for different uses including that for meeting tourism demands and its competing uses for host population and other developmental needs. This also adversely affects the recreational use of the river for rafting, kayaking, etc. activities.

Investigation of Rainfall Vertical Structure and Rainfall Induced Erosivity Over a Garhwal Himalayan Station Using In-situ Observation and Modeling (SERB, DST, 2019-2022)

The Indian summer monsoon rainfall process is significantly modulated over the complex terrains of Himalaya often leading to extreme precipitation events or cloud bursts. Although the proposed mechanism for such extreme rainfall events indicates orographically induced formation of deep convection within a land locked valley due to moist thermal instability, in-situ observations of rainfall vertical structure (VSR) and integral rainfall parameters (IRP) at a very high frequency during such extreme precipitation events over the western Himalayan region is seldom investigated. In fact, investigation of VSR and IRP of normal (< 20 mm/day) and light monsoon seasonal rainfall (<10 mm/day) events of western Himalaya are inadequately investigated. Therefore, this research proposal aims to assess monsoon period IRP and VSR over the western Himalaya using in-situ observations and dynamical modeling. The dynamical modeling of accumulated rainfall at hourly, 3-hourly and 6-hourly time scale during the extreme precipitation events is anticipated to establish the physical mechanism of extreme precipitation events along with identification of suitable cloud micro-physical and convective parameterization schemes for enhancement of forecast accuracy.

Objectives:

- To investigate vertical profiles of rainfall and integral rainfall parameters during monsoon seasons using an *in situ* Micro Rain Radar and Disdrometer measurement.
- To establish relationship between the rainfall intensity and kinetic energy for deduction of erosivity.
- To assess performance of WRF-ARW cloud microphysical schemes with respect to *in situ* observations on simulating vertical profiles of integral rainfall parameter/s during selected rainfall events of monsoon season.

Achievements:

1. The monsoon seasonal 1 min precipitation observations at the Kosi-Katarmal, Uttarakhand, were categorized as per the World Meteorological Organisation specified rainfall type, i. e. heavy drizzle with rain (Hdr) and heavy rain (Hr). The rainfall intensity (R), reflectivity (Z), and particle number (N) were analyzed for a total of 8640 no. of 1 min precipitation observations during 16-21 July, 2014. It was noted that heavy rain (Hr) accounted for ~12% of total rainfall having maximum R of 39.4 mm/hour with average Z of 35.1 dBz. However, maxima of Z = 53.4 dBz could be rarely observed, and are expected to linked with sever meso-scale convective systems often associated with multi-cell storms during monsoon.
2. The 3-dimensional Z—R—N plots for Hdr category of precipitation indicates a clear two regime structure of precipitation distribution where R and Z are related to each other through an exponential law. The two regimes of precipitation could be distinguished at Z ~ 22.5 dBz. The average Z, R, and N at Z $\times$ 22.5 dBz were found to be 17.7 (1.9) dBz, 1.9 (1.1) mm/hour, and 50.1 (23.6). Similarly, the average Z, R, and N at Z $\times$ 22.5 dBz were found to be 28.4 (2.7) dBz, 4.3 (3.0) mm/hour, and 90.1 (26.8). No such two regime structure was observed for the Hr category.
3. The WRF model sensitivity was tested through multiple experiments over three nested domains. Irrespective of

experiments, the best model performance was observed over domain 1 for hourly prediction (probability of detection = 0.21). Similarly, irrespective of domain and rainfall interval, the best experiment was a combination of new simplified Arakawa-Schubert cumulus and WRF single moment microphysics class 5 schemes (probability of detection = 0.21). Better performance of the new simplified Arakawa-Schubert cumulus scheme corroborates well with the reported observations during high convection over homogeneous regions of India.

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, MOEF&CC, 2018-2021)

Notable changes in terms of the quantity and space-time characteristics of rainfall and snow-melt over Himalayan region have been reported in recent decades. In addition, shift in the cropping systems, urbanization and population growth added additional stress on the available freshwater. These changes significantly disrupt the balance of the regional hydrological cycle through negative feedbacks. Therefore, 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 Himalayan region at short-term through intervention strategies and long-term through adaptive measures is proposed to be developed. Therefore, Kosi watershed of Uttarakhand is being selected for study. The Kosi River is drying up with time with diminishing spring discharge, reduced summer flows and the rising water demands, subsequently, the river ecosystem have put the region under severe water stress. Accordingly the basin is selected for first 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.

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 stake holder for enhanced decision making on water management.

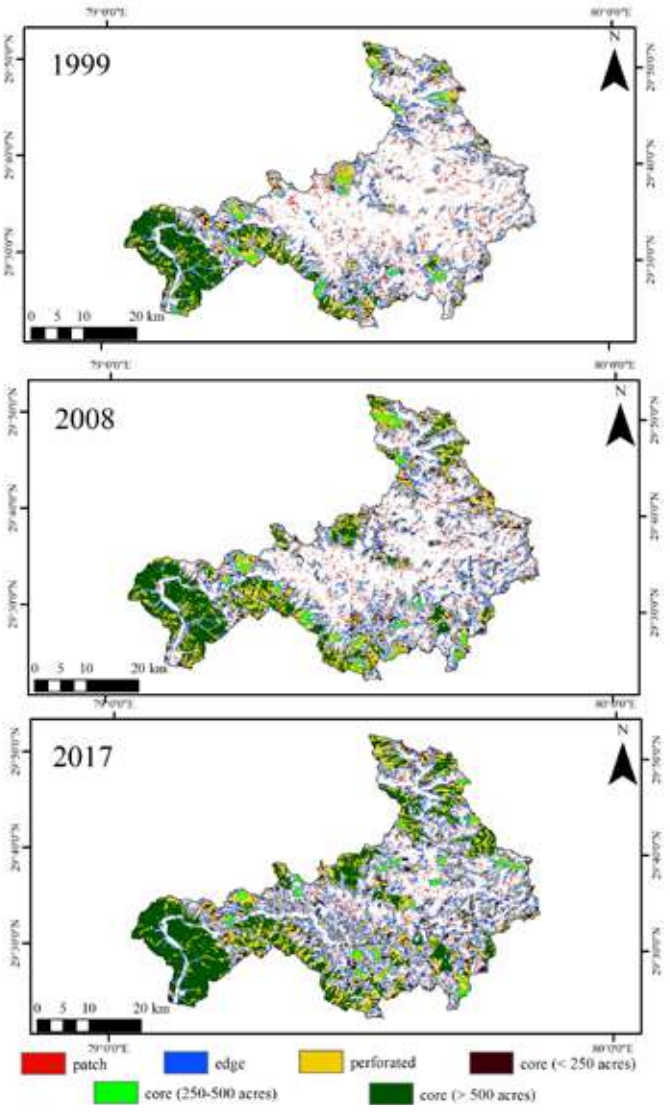


Fig. 1: Land fragmentation status of forests in Kosi-watershed during 1999, 2008 and 2017

Achievements:

1. The general forest cover enhancement was noted to be 15.4% between 1999 and 2017 over the watershed. The core forest area having size > 500 acre was found to be 368.2 km^2 in 2017 with respect to 201.7 km^2 area of 1999. Subsequently, patchy forests had decreased from 125.8 km^2 to 74.2 km^2 between 1999 and 2017 (Fig. 1).
2. The forest cover and built-up area of the watershed had changed from 835.1 km^2 to 1123.4 km^2, and 40.1 km^2 to 251.4 km^2 during 1999-2017. The CA model performance was evaluated for 2017 and standard error for predicted forest cover area was noted to be 5%, within an acceptable level of prediction accuracy. The CA model predicted a notable increase in the forest area (~15% increase) from 2017 to 2030 over the Kosi watershed within the protected forest areas under the generalized hypothesis that no statistically significant change in hydro-climatological parameters would take place to perturb the current environmental state.

Springshed Management: A Strategy for Climate Change Adaptation through Inventory and Revival of Springs (DEST, Govt. of Himachal Pradesh, 2019-2021)

The springs dry-up or discharges decline, the resulting water shortage becomes a major environmental and social threat. There is increasing evidence that springs are drying or their discharges are reducing throughout the IHR. Numerous factors including population growth, agricultural intensification, land use change, ecological degradation and climate change are responsible for drying of springs. Hence, spring management is becoming a subject of national debate. Recently, there has been increasing studies for rejuvenation of springs in parts of Himalaya, but most of the studies were blindfolded while rejuvenating the springs. Investigator does not find any pertinent study on spring rejuvenation in the Himachal Pradesh and, therefore, this study of springshed management was undertaken where detail inventory of springs is being prepared for developing standard geo-database of the springs. Further, springs will be rejuvenated using hydro-geological research based structural interventions in the area, and strategy for climate change adaptation will be attempted. A replication plan will also be proposed to replicate the study of springshed management in other parts of the State with area specific modification.

Objectives:

- To understand social, cultural and environmental aspect of the springs.
- To develop better understanding of geo-hydrology of the springshed.
- To develop climate change adaptation strategy through revival of springs by Spring Sanctuary Concept (SSC).
- To develop and suggest the replication plan for springshed management.

Achievements:

1. Inventory of springs (i.e location, latitude, longitude, elevation, accuracy and local name of the place) are being prepared through extensive field surveys in the study area; inventory of 16 spring locations in Barot valley and 23 locations in Saraj valley completed.
2. Physical parameters of springs like pH, electrical conductivity, total dissolved solid, discharge and temperature are duly noted; and water quality analysis of all spring sources in Barot & Seraj valley was done and compared with BIS and WHO standards. Except for the pH in some of the spring water samples of Barot valley, all spring water was found fit for domestic and irrigation use. The wide range of EC values indicates the multiple sources of ions such as atmospheric, geogenic and anthropogenic contamination.
3. Initial inferences drawn based on water quality status which shows acidic characteristics in both valleys the pH value was found closer to that for the rain water (pH = 5.6). EC and TDS values further corroborate that the values are on the freshwater domain inferring less residence time in host medium of these ground water-fed springs, implying that the sources are recharged by rain water during the monsoon season.

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)

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 thru contemplation of suitable strategies and policies through harnessing of resource potential and by risk minimization. This collaborative project of CSIR-4PI Bangaluru, University of Kashmir and the GB Pant National Institute of Himalayan Environment (GBP-NIHE) 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 part of the project 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 stake holder 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. For development of livelihood enhancement strategies, the assessment of the livelihood scenario in the rural areas was carried out by using the standard DFID framework comprising of five types of capitals; namely - the Human Capital, Natural Capital, Physical Capital, Social Capital, and the Financial Capital. Each of such capital type was assessed in relation to a set of 5 indicators where each indicator was valued in relation to a maximum score of 1, and thereby the total performance of the capital was assessed with respect to a total score of 5 points. The results of the capital sets were obtained through a survey of 328 households of 32 villages. The capital indicators, categories used for score assignment, and the scores in respect of the five capitals are compiled in Table 3. The scores indicated in the table display the composite picture of rural areas which reveal that these areas lack in terms of all the five capital sets; therefore, the strategies to be developed and tested through use of System Dynamic Modeling should integrate strengthening of these capital sets in light of the average score of the indicator categories.
2. The PRA surveys of selected villages - where agriculture/ horticultural/ livestock farming/ homestay & ecotourism etc. is practiced as a major/ dominant economic activity, were carried out for identification of sector specific problems and their prioritization by using problem matrix and pair-wise ranking tools. This was followed by SWOT analyses to obtain inputs towards development of better human-natural resource management strategies. The strategies envisaged through these exercises were evaluated with respect to 'Anticipated Benefits' and 'Ease of Implementation' in 0-5 point scale through community consultations by engaging 10 or more participants at one time. The outcome of 4 such consultations for villages in dominant agricultural belt depicting average score of such surveys against the above two choice sets, is shown in Fig. 5. The results suggest that SO1, SO3, WO1, and WO2 are the best set of strategies for the domain (Table 2).

Table 2. Rural households livelihood capital measurement indicators and scores

Types of Capital	Measurement Indicators	No. of Categories used for score assignment	Category score out of 1	Capital score out of 5
Human Capital (5)	Dependency Ratio- ratio of age person in group 16-64 to total population	3 categories	0.42	2.20
	Education of HH head	5 categories	0.44	
	More than one occupation	4 categories	0.34	
	Health of HH head	3 categories	0.58	
	Card Holder	2 categories	0.42	
Natural Capital (5)	Farm Land	5 categories	0.38	1.42
	Type of Land	2 categories	0.15	
	Forest Area Type	3 categories	0.56	
	Source of Water used for Irrigation	4 categories	0.15	
	Fruit crops for sale	2 categories	0.18	
Physical Capital (5)	Type of House	2 categories	0.9	2.60
	Use of Micro. Irrigation, Poly house	2 categories	0	
	Livestock (ACU)	4 categories	0.39	
	Communication/ Transport/ Machinery/ Tools	2 categories	0.31	
	Electricity	2 categories	1	
Social Capital (5)	Number of Migrants	2 categories	0.56	0.82
	Association with NGO/SHGs	2 categories	0.2	
	Cold Storage/ Seed facility/ Warehouse	2 categories	0	
	Marketing organizations	2 categories	0.06	
	Active Participation in GPDP	2 categories	0	
Financial Capital (5)	Income	4 categories	0.54	2.22
	Saving Acc.	2 categories	0.99	
	Migrant remittance	4 categories	0.4	
	Health Insurance	2 categories	0.21	
	Crop Insurance	2 categories	0.08	

Pine Needle-based Wastewater Treatment Method for Recycling of Domestic Waste Effluents (NMHS, MOEF&CC, 2019-2022)

Grey water is the wastewater without any input from toilets, which means it consists of wastewater produced in bathrooms (e.g. bathtubs, showers, hand basins), washing areas (e.g. laundry machines), kitchen (e.g. kitchen sinks) in households, office buildings, schools etc. In India, as per IS 1172-1957, the total domestic water consumption is about 135 liters/capital/day under normal condition of which 70-90 liters is generated as grey water. There are various technologies available for the treatment of grey water such as physico-chemical treatment, wetland treatment and advance treatment e.g. ultra-filtration. For the first time, in 1970s grey water treatment system was used by NASA through diatomaceous earth filter followed by activated carbon. Pine needles and litters are believed to be an environmental problem due to enhancement of forest fires. The fire enhancing property is due to its unique composition consisting of lignocellulosic composition along with volatile matter. The possibility of pine needle for using as a source for designing grey water treatment material are being explored in this project both at lab as well as at a pilot scale. Along with adsorptive treatment of grey water, phytoremediation mode is also being tested. Two plants have been selected for this study.

Objectives:

- To synthesize the activated and bacterial activated carbon in bulk and their characterization.
- To standardize combined water purification system having phytoremediation, bioremediation and fixed bed activated carbon-based process.
- To demonstrate the standardized purification system with model contaminants mixture and actual contaminated water.

Achievements:

1. A pilot plant based on lab based fixed bed experiment was designed, and various activated carbon samples were prepared. These were tested for their adsorption and desorption capacities for grey water contaminants at different conditions of bed height, feed concentration, and feed flow rate. The breakthrough times were found increasing with increase in bed height.
2. Activated carbon GBPI-H1212 has shown higher adsorption capacity and lower desorption rate for bacteria, so it is suitable for the preparation of biological activated carbon in bulk; 1 g/L carbon dosage was found suitable for attachment of selected bacterial strain for preparation of bacterial activated carbon.
3. In the phyto-remediation experiment, the effect of contaminants on the soil enzymes were tested in different time intervals (Fig. 2), the urease activity found higher at the start of the experiment, which decreased afterwards. This may be due to the consumption of ammonia and nitrate by the plant. The dehydrogenase enzyme found decreasing with the time may be due to organic matter decomposition by rhizospheric microorganisms.

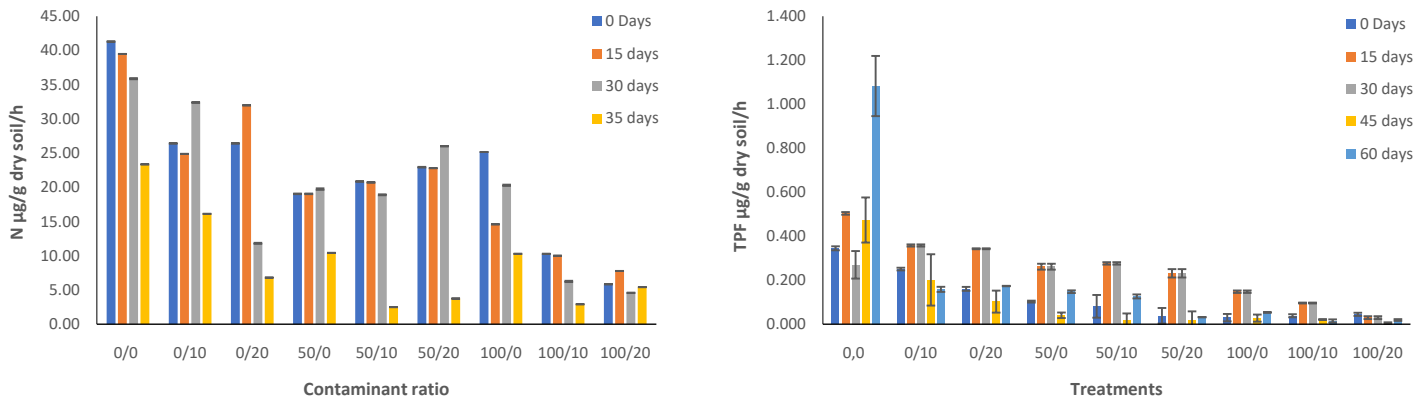


Fig. 2: Effect of contaminants on (a) urease, (b) dehydrogenase enzyme at 15 days interval

Nutritional Status of Traditional Crops of Uttarakhand Utilized by Scheduled Community (DST-NRDMS, 2016-2020)

Uttarakhand is a hill state, situated in central Himalaya and can be differentiated from other areas based on topography, geographic features, flora and fauna, land use system and socioeconomic conditions. Therefore, lifestyle of the people residing here also differs from plain areas of the country. There are different types of traditional crops, like cereals, millets, pulses, oilseeds, vegetables, grown in the region, but the people are taking less interest in their cultivation. Subsequently, food insecurity exists in the region. Diversification of food recipes is a major specialty of the region. There are many recipes used as substitute of items, which are meagerly produced in the region. The nutritional information of processing steps starting from raw materials to final recipes following different processing steps is not yet available. The present study will develop proper documentation of traditional food consumed by Scheduled communities residing in the selected areas of study along with their nutritional content, which will give importance to the nutritious food consumed by the community. Carrying out the proposed scientific evaluation would help in objectively promoting the traditional recipes not only for better health but also for economic advancement of the large farming community in the state. These foods can also become a part of food consumed in other regions of the country.

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. Complete nutritional analysis (proximate, antioxidants, phenolics, flavonoids, minerals and antinutrients) of the traditional cuisines prepared from horse gram, black soybean, rice bean and barnyard millet has been completed.
2. Among all the cuisines Bhatt ki Chutkani contains highest amount of protein (28.35%). Total phenolic content was found to be higher in all the recipes of black soybean and barnyard millet in comparison to raw seeds whereas decreasing in the recipes of rice bean. Total flavonoid content was found higher in rice bean recipes than its raw material whereas in all other recipes it was lower than the raw grains.
3. Antinutrient content was seen decreasing in all the cuisines compared to the raw grains; this might be due to heating effect and soaking of grains during preparations. All the recipes were rich in phosphorus followed by sodium and potassium.

Rejuvenation of the Kosi River of Kumaun Himalayas Through Field Intervention and People's Participation (NMHS, MOEF&CC, 2019-2022)

Kosi watershed of Kumaon Himalaya falls within Almora and Nainital districts of Uttarakhand. The Kosi river originates from its north at Pinath (north-west of Kausani, district: Almora), which flows down towards the discharge point at Kosi Barrage (Ramnagar, Nainital). Geographically, the catchment covers about 1868.64 km2 area. The absolute relief of the catchment ranges between 349 m to 2758 m from the mean sea level. Over the year, the flow of water in the river is decreasing drastically due to the climate change, anthropogenic activities, infrastructural changes etc. In view of this, various initiatives and campaigns for the rejuvenation of Kosi River have been started by the government and other organization such as Uttarakhand Forest Department, Eco Task Force of the Army, and GBPNIHE. This project is part of this initiative and aims to monitor Devalikhan and Simtola recharge zone for assessing water availability and water quality and for analyzing the possibilities for making water conservation structures for recharging of springs within the area.

Objectives:

- To supplement and support water conservation activities for rejuvenation of the Kosi river.
- To monitor the water availability in the Kosi river and its tributaries through flow and discharge measurements along with quality measurements.
- To develop the conservation models in selected villages and schools in 2 recharge zones of Kosi watershed.
- Creation of an institution for monitoring Kosi river system.
- Skill capacity building of the local youth (SC/ST/WOMEN) as a tourist and other activities in the upper Kosi-watersheds.

Achievements:

1. Topographic map of the study sites was prepared, and

geophysical resistivity survey for aquifer mapping by obtaining geophysical information for selected recharge zones was completed (Fig. 3).

2. 23 springs of different orders, have been identified in three catchments of Devalikhan recharge zone. Out of those, 9 springs have regular water flow since November 2019. Water level recorders are established on third order stream of Devalikhan recharge zone and data have been collected since January 2020 (Fig. 4).
3. Major rock type of the recharge zones has been identified eg. Deolikhan Recharge Zone has various types of metamorphic rocks such as Garnetiferous Mica Schist, Quartzite and Quartz veins which is highly fractured. The water quality was found affected by high iron content as its concentration is higher than the acceptable or desirable limit which might be due to the weathering of Almandine Garnet which is found imbedded in Garnetiferous Mica Schist.

Fig. 3: Geophysical resistivity survey in Devalikhan recharge zone

Fig. 4: Installation of water level recorder in Devalikhan recharge zine

Removal of Pharmaceuticals and Personal Care Products (PPCPs) from Contaminated Water Using Pine Needle-based Activated Carbon/Biological Activated Carbon (DST-WTI, 2016-2020)

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, bisphenol-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. Surface area of synthesized activated carbons from biomass was found comparable with the commercial one.
2. Adsorption capacity was found increasing with the increase in bed height while performing adsorption experiment with the mixture of ibuprofen, bisphenol A and caffeine as PPCP compounds. At 7.5 cm bed height the adsorption capacity was 1819.78 kg/m^3 at adsorbate flow rate of 0.0002 m^3/h while the length of unused bed height (LUB) was 6.75 cm. So, there was still a lot of potential for further use (Fig. 5).
3. Bacteria showing degradation capacity for the selected compounds were impregnated on activated carbon samples directly as well as in the form of hydrogel.

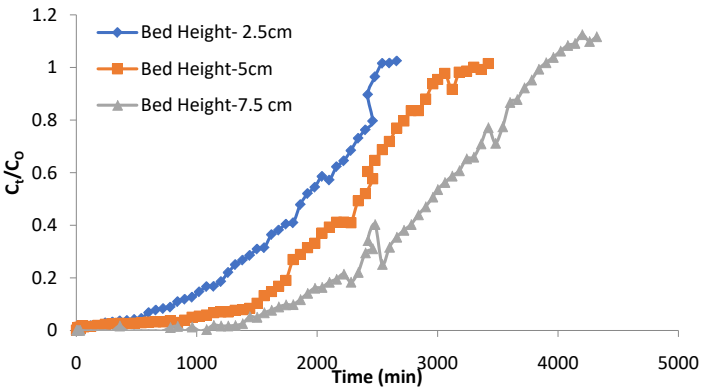


Fig. 5: Breakthrough curve for caffeine with different activated carbon bed heights

Beds at heights of 2, 5, and 7.5 cm at influent concentration and flow rate of 1 ml/min indicate that breakthrough times were increasing with increase in bed height. This is due to the increase in surface area of adsorbent which provided more binding site for the adsorption of bacterial cells.

Summary of Completed Project / Activity

Investigation of Alternative Boundary Layer Scaling Properties Over the Complex Terrains of Himalaya (MOES, GOI, 2016-2019)

Exchange properties of energy within the convective boundary layer have been traditionally addressed with the statistical fluid mechanical (SFM) approach of Reynold's averaged Navier Stokes Equation. Following this framework, the dimensional analyses of Monin-Obukhov (MO) and Deardroff similarity theory have provided the conceptual and practical foundations for almost all modeling of the convective boundary layer (CBL) during the last few decades. However, with extensive and thorough experiments of CBL energy exchange processes, it has been realized that neither MO theory nor the Deardroff similarity theory is conclusive and dynamically efficient in explaining the CBL energy exchanges. As an alternative to this framework, a chaotic dynamical system (CDS) approach has been put forward by McNaughton et al. (2004, 2006) where the fundamental energy exchange processes in a CBL are assumed to be due to interaction of different types of eddies. This new CDS approach, unlike the SFM approach, describes the turbulence processes with few nonlocal parameters. These newly developed nonlocal scaling parameters of the CDS approach are found to be satisfactorily collapse the energy, momentum and tracer spectra in a wavenumber axis when turbulence is measured over a flat terrain. However, the model was never tested over a complex terrain and over the flat terrains of India before its ubiquitous acceptance. This project has successfully extended this CDS approach for spectral analysis of CBL turbulence over two sites (on ridge-top and on-slope) of the Central Himalayan region and a flat terrain site near Varanasi, India, where few new scaling properties are found to collapse the wind velocity and temperature spectra successfully, unlike the traditionally accepted MO model. Moreover, sets of numerical relationships between aerodynamic drag coefficients and horizontal wind speeds are developed as a function of aerodynamic roughness length, representing distribution of surface elements, for complex terrain of Himalaya during monsoon and winter period. The outcome of this project potentially could lead to development of a new convective boundary layer parameterization for weather forecasting models.

Integrated Studies of Himalayan Cryosphere in Uttarakhand and Arunachal Pradesh (SAC-ISRO, 2016-2020)

Two benchmark glaciers were selected for the study, namely Chipa Glacier in Dhauliganga Basin, Pithoragarh (Uttarakhand) at the elevation of 3500 m above msl and other one is Khangri Glacier in Tawang Basin, Tawang (Arunachal Pradesh) at the elevation of 4900 m above msl. The major objectives of the study were: (i) GPS measurement of elevation on glacier for mass balance estimation using geodetic method, (ii) measurement of glacier ice thickness using GPR, (iii) velocity of ice derived from optical and SAR data and its validation on ground, (iv) monitoring of snow line at the end of ablation season on ground of selected glaciers, (v) water discharge measurement of selected glaciers, and (vi) mapping and change detection using high resolution data of selected glaciers. The study was conducted through field expeditions during the ablation seasons for DGPS/GPS survey of snout location, stakes installation for velocity estimation, water discharge of glacier-fed stream, ground validation of remote sensing based results. Moreover, the space based inputs were also utilized for continuous monitoring of glacier parameters such as snow, snout, velocity, mass balance, snow cover area (SCA), snow line and velocity. It was noted that the Chipa glacier clearly demonstrates the retreating pattern through its snout and mass balance dynamics. Through the comparative analysis of DGPS and field monitoring derived results during the period of 2017-2019, result shows that glacier is receding with an average rate of 7.9 ± 0.14 m. The velocity of the glacier was calculated to be ~0.035 m/day using the geodetic and remote sensing data. The net loss in mass balance of the Chipa glacier from year 1961 to 2008 was found to be (0.275 ± 0.017) km^3 and between 2000 to 2008 was calculated to be (0.1461 ± 0.06) km^3. It can be concluded that the mass of the glacier is declining at an average rate of 5.27 x 109 kg/year. The discharge observation shows that average discharge in 2018 was higher (5.9 cu.m/sec) as compared to the years 2017 (5.63 cu.m/sec) and 2019 (5.82 cu.m/sec). The snow line of the glacier lies at 3990 masl. The average SCA of Chipa glacier for the year 2017, 2018 and 2019 were estimated to be 8.89 km^2, 13.03 km2 and 11.7 km^2 respectively. The SCA for the Chipa glacier throughout the study period was found to be in the range of 4.36 km^2 to 14.01 km^2. For the Khangri glacier, it has been found that glacier is receding with an average rate of 6.5 ± 3 m using the GPS/DGPS in 2017, 2018 and 2019. The glacier velocity was observed to be varying from 0.032 to 0.62 m/day for year 2018 and from 0.0037 m/day to 1.29 m/day with an average velocity of 0.099 m/day as evident from the SAR remote sensing data. The mass balance change in Khangri glacier was calculated to be (0.21613 ± 0.08 km^3) between 2000 and 2008 using SRTM and ALOS Palsar DEM. The average discharge of the glacier stream was observed as 3.39 m3/sec (Monsoon season - August 2018) and 1.6 m^3/sec (post monsoon season - November 2019). It was also observed that highest discharge of the Khangri glacier of outlet stream was found on 4 Aug 2018 is 6.55 m^3/sec due to heavy rainfall. The snow line of the glacier lies at 5160 masl. The average SCA of Khangri glacier for the year 2017, 2018, and 2019 were estimated to be 78.22 km^2, 122.84 km^2, and 100.41 km^2 respectively. The SCA for the Khangri glacier throughout the study period was found to be in the range of 24.37 – 174.22 km^2

Launch of Jal Abhyaranya Abhiyaan (Water Sanctuary Campaign) in 11 states in IHR (MoEFCC, 2019-2020)

Over the years, mountain springs are increasingly drying up, or becoming seasonal, inducing irrefutable misery to both rural and urban inhabitants of the Indian Himalayan Region (IHR). In spite of many spring rejuvenation programs undertaken by different agencies using springshed concept in place of watershed approach for selected catchment area, limited success was noted due to deficiencies in policy, planning and field implementation. Therefore, there is an urgent need for implementing spring rejuvenation programme, developed based on the sound scientific principles and experiences gained from successful good practices and implementation models, across all the Himalayan States in a campaign made. The "Jal Abhyaranya (Water Sanctuary)" programme of GBPNIHE, Almora, was launched as 100 days programme of MoEF&CC, GoI to address this issue on pan-Himalayan scale wherein at least one drying spring in 11 identified districts (including 9 Aspirational Districts) of the 11 IHR states will be field augmented for rejuvenation model. As immediate specific intervention strategies, targeted within 100 days period after the initiation of the project are: (i) source wise distributions of water supply schemes in each block of 12 Himalayan states are compiled and it was noted that the supply of fresh water in the hilly districts largely depends on first order streams, i.e. rivulets and springs, for example in Uttarakhand around 48.0% and 14.0% of total water supply schemes are found to be dependent on Rivulets and Springs, indicating these fresh water resources like springs and rivulets are most vulnerable under changing climate and socio-economical scenario requiring immediate intervention; (ii) administrative block wise fresh water scarcity assessment is carried out for 11 states using an integrated index based approach of estimating Water Scarcity Index (WSI). The WSI included hydrological factors such as rainfall and river discharge; environmental factors such as agriculture and forest cover; demographic factors such as human and cattle population with respective water demand; and Himalayan topographic factors such as vertical proximity and digital elevation model. Out of total 594 blocks were mapped, 285 blocks were identified to be water scarce (Arunachal Pradesh: 31; Assam: 15; Himachal Pradesh: 54; Manipur: 18; Meghalaya: 3; Mizoram: 2; Nagaland: 39; Sikkim: 20; Tripura: 19; Uttarakhand: 78; West Bengal: 6); (iii) Inventorization of springs in selected district in each of the 11 IHR states (i.e. Uttarakhand, Himachal Pradesh, Arunachal Pradesh, Assam, Sikkim,

Manipur, Mozoram, West Bengal, Tripura. Nagaland & Meghalaya) are initiated through collaboration work completed in selected districts of 4 states (Uttarakhand, Arunachal Pradesh, Sikkim and Himachal Pradesh) and 2900 springs have been mapped. Geo-tagged spring distribution maps in these 4 states have been prepared; (iv) mass awareness campaigns on Jal Abhyaranya among different stakeholders are launched in Himachal Pradesh (Chamba district), Uttarakhand (Champawat), Sikkim (West Sikkim district), Arunachal Pradesh (Namshai district) and Nagaland (Kiphri district). New web page has been developed on "Jal Abyaranya" and linked with the website of the GBPNIHE for uploading available information from secondary sources; (v) total 11 water scarce villages in 11 IHR states (Sikkim, Manipur, Arunachal Pradesh, Mizoram, Nagaland, HP, West Bengal, Tripura, Assam, Meghalaya and Uttara-khand) have been selected for developing pilot models of water sanctuary. Field level interventions have been started in 10 sites with baseline mapping of springshed area.

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 Centre 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. Over the years the CBCM has expanded its scope of R&D activities from devising both in-siitu and ex-situ pacakage of practices on biodiversity conservation approaches and scaling up these approaches among a wide range of stakeholders spanning from rural landscapes, school children and reserach community, forest department and policy makers and practitioners. The participatory models of biodiversity conservation and management are being promoted particularly among the

rural communities by taking up pilots on medicinal and aromatic plants cultivation and wasteland restoration on community lands. In this process the capacity and skills of stakeholders is built and opportunities of replication of such models is ensured to achieve the mandate of CBCM. Thus CBCM has set in the following objectives for executing its R&D activities: (i) mainstreaming of Himalaya biodiversity knowledge in conservation decision making at local/state/national level, (ii) establishing representative long-term ecological monitoring sites/plots so that LTEM data becomes part of regional synthesis and long-term predictions, (iii) promoting partnership and collaboration for knowledge networking and capacity improvement to address issues of biodiversity conservation at local to sub-national level, and (iv) standardizing protocols/approaches for sustainable utilization of bioresoures (i.e., harvesting, nutritional and therapeutic potential assessment, propagation and cultivation packages, etc.)

Summary of Completed Project

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

Himalayan forests are highly complex and diverse systems and sensitive towards natural (e.g., climate change) and human induced perturbations. The magnitude and consequences of the impacts of climate change and loss of biodiversity are poorly understood that has likely many impacts on the livelihood of local communities and downstream people as well. Therefore, to understand intensity and direction of on-going and potential changes on structure and functioning of forests, and its associated biodiversity attributes, four Long-term Ecological Monitoring Site(s) of 1 ha each were established along an altitudinal gradient (679–1861 m asl) encompassing four major forest types in River Gaula catchment (Distt. Nainital; west Himalaya) viz., Sal *(Shorea robusta)*, Chir Pine *(Pinus roxburghii)*, Mixed Broadleaf *(Quercus glauca - Pinus roxburghii)* and Banj Oak *(Q. leucotrichophora)* for periodical monitoring on meteorology, soil physico-chemical parameters, seasonality of flora and weed species, vegetation structure and functional aspects (density, regeneration pattern, biomass and productivity, periodicity of major phenophases) and eco-physiological and biochemical responses of selected species in these forests. The overall aim of this research was to understand the response patterns of the floral diversity of these forests due to changes in climatic parameters for planning and decision-making for management of the forest ecosystems and biodiversity conservation in the region.

Through this project the long-felt need of establishment of LTEM sites was fulfilled that will serve as a training and demonstration site for various stakeholders and generation of data-sets useful for Forest Deptt. and other agencies. Collection of meteorological data along the altitudinal transect will add to the climate data base of the region which has been referred to as “Data Deficient” by IPCC (2007). Across these LTEM sites the mean annual temperature declined with increasing altitude while the relative humidity and rainfall showed a reverse trend. The warmer year 2019 had a telling effect on the phenological earliness of all the phenophases (leafing, flowering, fruiting and leaf drop) by 1-2 weeks as compared to 2018. We recorded 168 plant species in the four LTEMs, belonging to 131 genera and 71 families. The herb life-form dominated in all the sites. While comparing the plant diversity among the forest types, Chir-Pine forest dominated with 66 species (54 genera and 33 families) followed by Mixed broad-leaf forest with 59 species (49 genera and 40 families), Oak forest with 55 species (50 genera and 33 families) and lowest in Sal forest with 44 species (42 genera and 25 families). Further, five invasive species: *Ageratina adenophora, Ageratum conyzoides, Bidens pilosa, Oxalis corniculata* and *Physalis peruviana* were recorded in these LTEMs (three species in Chir-Pine forest and one species in Sal forest). The 8 important species studied for various eco-physiological parameters at seasonal interval revealed that they behave differently at different altitudes. A higher photosynthetic rate was recorded for species of high altitude than those of the lower altitude. Baseline data on soil physico-chemical properties up to 30 cm depth revealed that the soil nutrient capital varies with forest types, season and depth. As a withdrawal strategy we collaborated with Research Wing, Forest Department, Govt. of Uttarakhand to monitor these LTEM sites for continued data-set generation in future to understand the impact of climate and anthropogenic drivers of change on biodiversity and forest ecosystems of the region.

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), GBPNIHE, 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 act as technical advisory agency. The GBPNIHE 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. A total of 9 hectare degraded land of Chandak-Unlaghat watershed (i.e., Digtoli 2.5 ha; Naikina 2 ha), Hat-Kalika watershed (Jajoot 2 ha; Chitgal 1.5 ha) and Upper & Lower Gori watershed (Lumti 1 ha) was identified for restoration activities.
2. Soil properties (i.e., bulk density, moisture, NPK, etc.) of each study sites were analyzed.
3. A total of 550 sapling of various plant species *(Cinnamomum tamala, Quercus leucotricophora, Q. glauca, Morus alba, Pittosporum eriocarpum, Zanthoxylum armatum)* were planted through participatory approaches at Naikina village (1 ha), and 700 saplings at Digtoli village (2.5 ha) during the reporting period (Fig. 6).

Fig. 6: Participatory approach for restoration of degraded land at Digtoli and Naikina villages

Assessing Climate Change Impacts on Floristic Diversity of Alpine Regions in West Himalaya (NMHS, MoEF&CC, 2019-2022)

Mountain ecosystems are regarded as important biodiversity hotspots as well as one of the most ecologically fragile zones. The varying topography, micro and macro-climatic conditions cause variations in habitats as well as among the life-forms, which are highly sensitive towards natural and human perturbations. As elsewhere in the mountain environments, the high-altitude alpine life zones are considered to be particularly sensitive to climate warming because they are determined by low temperature conditions. Model projections of climate change impacts on floral diversity suggest that suitable habitats of plants could reduce drastically by the end of 21st century, particularly where climate warming is combined with decreasing precipitation. Even if alpine plants do not disappear rapidly, a growing extinction debt will have to be paid later on, if they are unable to adapt or cope with changing conditions. The severity of such extinction scenarios can only be documented by long term in situ monitoring. However, in absence of long-term monitoring sites in alpine region, data sets or evidences are not available for Himalayan alpines to assess the trends of vegetation changes due to changing climate. Furthermore, The Intergovernmental Panel on Climate Change (IPCC) described the Himalayan Region as data-deficient in terms of climate monitoring (IPCC, 2007). The paucity of long-term climate data in the region, and uncertainty of data quality has also been underlined on account of compatibility mismatch of instrumentation and methodology. Towards addressing these data gaps in the IHR, especially in alpine areas, the project targets to establish Long Term Ecological Monitoring sites in the alpine region of Uttarakhand, West Himalaya for continuous monitoring following the Global Observation Research Initiative in Alpine Environments (GLORIA) procedure to understand floristic diversity patterns in alpine regions under the influence of climate change as well as to provide conservation implication and awareness on floristic studies.

Objectives:

- To analyse the floristic diversity and its composition patterns along representative altitude zone in different alpine landscapes of West Himalaya.
- To establish and strengthen Long-Term Ecological Monitoring site(s) following the Global Observation Research Initiative in Alpine Environments (GLORIA) protocol for continuous monitoring of floristic diversity patterns in alpine environment.
- To investigate the change in plant diversity patterns under the influence of climate change in different alpine sites.
- To build plant assessment and taxonomic identification capacity of master's students and researchers.

Achievements:

1. Revisit of the Chaudas valley (district Pithoragarh) Target site in 2019 revealed a total of 107 vascular plants of 72 genera and 35 families in 64 plots, ranging from 10 to 22 species per plot (Table 3; Fig. 7). The most represented families were Asteraceae and Scrophulariaceae with 14 and 12 species in the total species pool. The most abundant species overall in terms of cover were *Kobresia nepalensis* (9.53%), *Geum elatum* (7.27%) and *Bistorta vaccinifolia* (5.08%) with varying abundance between summits. The dominant species were *Danthonia cachemyriana* and *Geranium wallichianum* (8.31% and 6.00%, respectively) in Bhairavghati (BHT), *G. elatum* and *Bistorta affinis* (10.00% and 7.74%, respectively) in Kharangdang (KHA), *Carex setosa* and *K. nepalensis* (14.71% and 9.71%, respectively) in Ganglakhan (GAN) and *K. nepalensis* and *B. vaccinifolia* (17.59% and 13.96%, respectively) in Sekuakhan (SKN). The most abundant species in each aspect were: in the north, *B. vaccinifolia* and *K. nepalensis* (13.34% and 8.63%, respectively); in the south, *K. nepalensis* and *C. setosa* (17.97% and 9.94%, respectively); while in east and west were *D. cachemyriana* (8.88% and 6.55%, respectively) and *G. elatum* (8.21% and 10.59%, respectively).
2. Revisit of these summits reveals temporal patterns in community changes represented by significant increase in plant cover (%) in all sites while species richness increased in KHA, GAN and SKN summits (Table 3). Aspect wise analysis exhibited highest species richness in North and West aspect.
3. Soil temperature averaged across the 15 data loggers did not show a significant trend over the five years ($r^2 < 0.1$; August 2015 to July 2019). The highest soil temperature was recorded in 2016-2017 (5.92°C) and lowest in 2018-19 (4.83°C). Difference between the last (2018-19) and the first (2015-16) minimum temperature recorded for four-year series was negative for BHT and KHA (-1.40°0C and -0.05°C, respectively) and positive for GAN and SKN (0.27°C and 5.22°C, respectively). Apart from this, minimum, maximum and mean temperature was also calculated across aspects as well as summits (Table 3).

Table 3. Floristic data for plant species recorded in Survey-2015 and Survey-2019 across four summits in Chaudas Target Region. Summit temperature is the monthly average temperature at the four aspects across the four summits (mean ± standard deviation) obtained from data loggers below the soil surface for the 2015-2019 period.

Summit code	Number of species at plot scale		Plant cover (%) at plot scale		Species turnover	Temperature (°C)		
	Survey-2015	Survey-2019	Survey-2015	Survey-2019		Min	Mean	Max
BHT	78	75	87.5	92.4	11.11	0.59±4.30	7.41±4.30	13.40±5.99
KHA	50	51	94.7	100.0	19.64	-0.85±4.82	5.54±4.82	12.82±7.28
GAN	33	38	90.2	95.2	22.50	-0.29±4.85	5.93±4.85	13.63±7.70
SKN	27	32	60.7	68.5	15.63	-6.09±5.31	2.52±5.31	12.02±9.50
N	72	66	87.1	92.6	23.08	-3.28±5.43	4.42±5.43	13.09±5.43
S	59	65	83.9	92.5	22.86	0.21±4.01	6.31±4.01	12.56±4.01
E	59	59	89.4	95.1	18.46	0.88±4.31	7.43±4.31	13.35±4.31
W	72	65	72.7	75.9	29.17	-3.18±5.22	4.46±5.22	12.97±5.22

BHT= Bhairavghati, **KHA=**Kharangdang, **GAN=**Ganglakhan, **SKN=**Sekuakhan; **N=**North, **S=**South, **E=**East, **W=**West.

Fig. 7: Activities undertaken during resurvey of Chaudans valley GLORIA Target Region 2019.

Investigation on Source Dependent Variation Phytochemical Nutritional Quality Underutilized Wild Edibles of Indian Himalayan Region (IHR) (CSIR, GoI, 2019-2020)

Recent upsurge in the use of wild edible plants (WEP) for health promoting and anti-ageing bioactive contents has become a choice of researchers. The WEPs are reported rich source of nutritional and nutraceutical compounds including flavonols, flavones, anthocyanins, hydroxycinnamic acids, etc., and their possible beneficial effects on human health

and preventive properties against various diseases are well known. A number of WEPs have been screened for their health promoting and radical scavenging activities; however, many are yet to be screened. Therefore, systematic investigation on the Himalayan WEPs is essential for identification of new and novel source of health promoting bioactive contents. This project has targeted three wild edibles of IHR, namely *Rubus ellipticus, Pyracantha crenulata* and *Prinsepia utilis*. All these are abundantly found between 1000-3000 m asl and the fruits are traditionally been consumed raw and also used in different medicines.

Objectives:

- To investigate the effect of edaphic and climatic factors on the phenology and fruit yield of selected species.
- To understand the responses of nutritional and phytochemical content of selected species in different locations.
- To optimize the suitable solvent system and extraction conditions for nutritional and phytochemical contents.
- To evaluate the antioxidant and anti-mutagenic properties of extracts of selected species.
- To develop strategies for conservation and domestication based on the objectives 1-4 above.

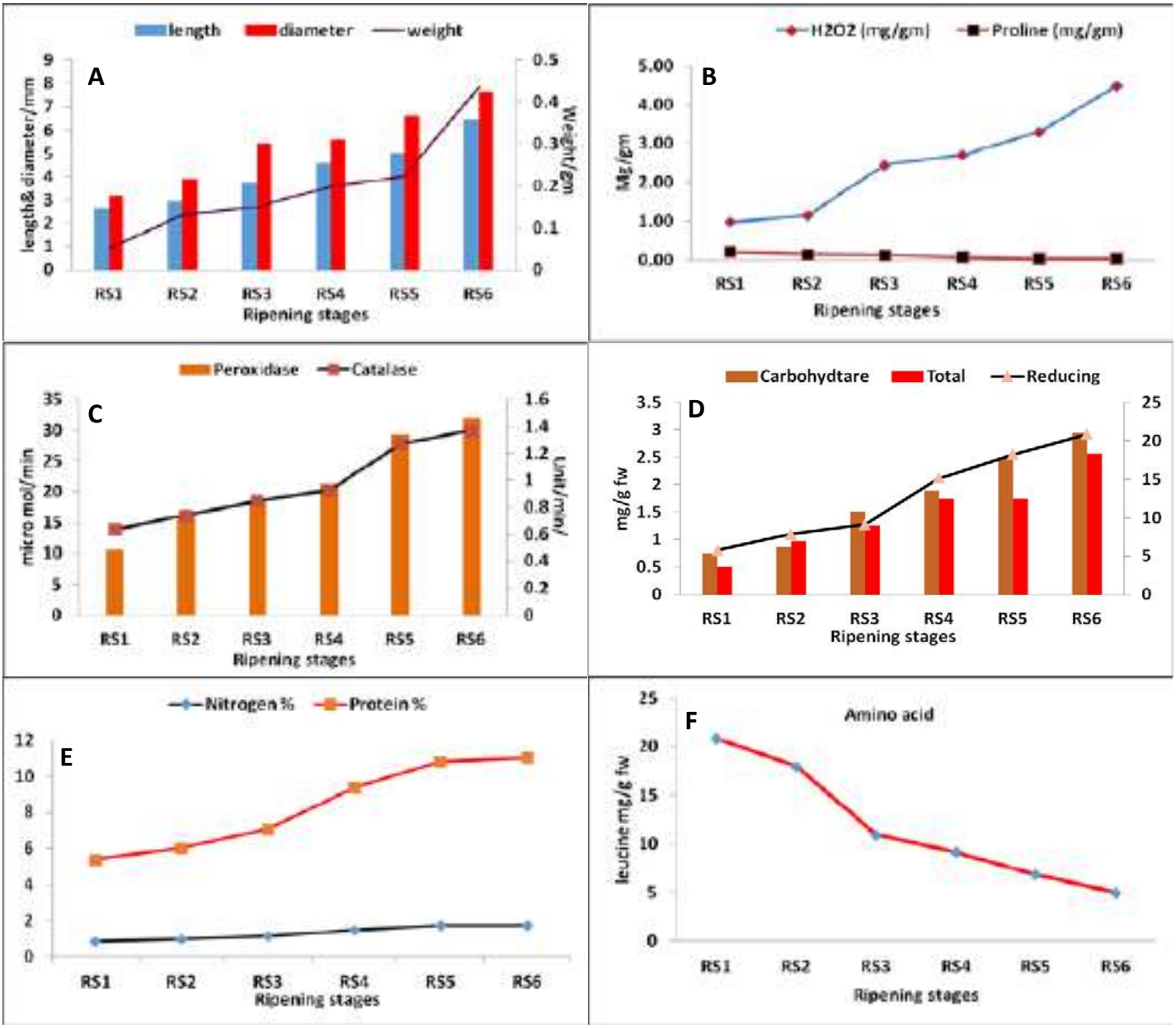


Figure 8: Trends of biochmical and nutrional parameters at different ripening stages (A) morphological (B) H_2O_2 and proline (C) peoxidase and catalase (D) carbohydrate, reducing and total sugar (E) nitrogen and protein content and (F) amino acid

Achievements:

1. Phytochemicals (total phenols, flavanoids, tannins, anthocyanins, catechin, vanillic acid, ferulic acid and t-cinnamic acid), and antioxidant activity (ABTS, DPPH, FRAP) varied among the fruits of target species collected from different localities. Similarly, polyphenolics compound varied across the locations/altitude. For instance, maximum total phenols (12.3±1.50 mg GAE/g FW) was found in the *Rubus* collected from Chitgal at 1550 m asl whereas minimum was recorded from Haat Kalika at 1720 m asl (7.40±0.25 mg GAE/g FW). Similarly, total flavonoids (1.85±0.20 mg QE/g FW) was higher in the fruits collected from Jajoot at 1450 m asl, as compared to Chodiyar at 1900 m asl (1.07±0.01 mg QE/g FW).
2. Developmental stages of the fruits influence the morphological and phytochemical attributes of the target species (Fig. 8A-F). For instance, the morphological attributes of *Pyracantha crenulata* fruits such as fruit shape, size and biomass were found to be changed during fruit maturation. Increasing trend of enzymatic antioxidant activity were also observed. Carbohydrate, total soluble sugar and protein in different ripening stages show increasing trend whereas amino acid showed decreasing trend.
3. Optimization of extraction condition for polyphenolics content in *Rubus ellipticus* suggest that ultra sonic assisted extraction is good for obtaining higher yield of polyphenols and can be applied in other target species as it required low solvent concentration and lesser time.

Detailed Assessment of Medicinal and Aromatic Plant (MAP) Species Including Their Collection, Usage, Demand, Markets, Price Trends and Life Cycle, Focusing on Landscapes in Uttarakhand Under SECURE Himalaya Project (UNDP, 2019-2020)

Indian Himalayan Region (IHR) is known to harbor over 1700 plant species of medicinal importance. These medicinal plants are the source for the health care as well as livelihood support to the people residing near villages and involved in the trade of these plants. Therefore, documentation of indigenous knowledge along with the assessment of availability and threat to different medicinal plants is urgently needed for protection and effective utilization. As such, cultivation of medicinal plants is globally recognized as a viable option for meeting current and future demands for mass production of plant based drugs and relieving pressure on the wild harvest. The present project, therefore, initiated in the selected sites of Uttarakhand i.e., Govind Gangotri landscape (District Uttarkashi) and Darma Byans landscape (District Pithoragarh) in the upper catchments of river Ganges and Yamuna. This project has been incepted with the detailed investigation on the socio-economic-ecological value of biodiversity and ecosystem services, generation of baseline information on medicinal and aromatic plants (MAPs), development of sustainable collection and cultivation practices of MAPs, assessment of impact of mass tourism on the biodiversity and livelihood and awareness generation on the diverse aspects of biodiversity. The combined outputs of the above mentioned studies would be helpful in the conservation of the MAPs and raising awareness among the inhabitants.

Objectives:

- To conduct a detailed assessment of Medicinal and Aromatic Plant (MAP) species in the project landscapes.
- To ensure sustainable cultivation and harvesting by identifying usage patterns and studying existing value chains.

Achievements:

1. Data on distribution, usage, demand, price trends, threats, collection practices and conservation status of the target species were documented using both primary as well as secondary information (Fig. 9 a&b). Review of existing high value MAP species was carried out, and a total of 54 plant species were documented from Darma-Byans landscape, and 33 species from Govind-Gangotri landscape.
2. Price trends (last 5 years) in the target species at landscape level as well as their role in the rural livelihood was assessed. A total 18 native plant species were identified from both the landscapes having high market price with significant economic end usage. Based on commercial and conservational value, 5 species in each category have been selected.
3. Based on the secondary data, MAP rich sites were assessed and information was validated with primary data. Total 4 sites in Darma-Byans (Sangosti bugyal,

Tedang Gubbey bugyal and Panchchuli), and 2 in Gangotri-Govind (Har-ki-dun and Dayara Bugyal) landscape have been identified as potential Medicinal Plants Conservation and Development Areas (MPCDAs).

Fig. 9: Different activities in field (a) Interaction meeting with villagers, and (b) field survey of MAP species

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 R&D agenda after realizing the fact that it can serve the basic needs of human beings, 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 are 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 stakeholder groups towards promoting conservation of threatened medicinal plants.

Achievements:

1. Species-specific protocols for medicinal plants i.e. *Allium stracheyi, Hedychium spicatum, Saussurea costus* and *Picrorrhiza kurroa* have been developed. Over, 5,000 plants of *Saussurea costus* have been produced through seed germination.
2. Three field orientation workshops were conducted in Chaudas valley for promotion of high value threatened medicinal plants. A total of 50 farmers from 6 villages (Niyang, Sosa, Palankari, Pasti, Jaykot, Himkhola) have initiated the cultivation (0.8 ha land) of *Allium stracheyi, Saussurea costus, Hedychium spicatum* and *Valeriana jatamansi*.
3. Awareness programme and field oriented training programme conducted in the Chaudas valley and a total of 600 stakeholders (farmers, students) have been sensitized towards promoting conservation of threatened medicinal plants. High altitude nuresery developed at Sri Narayan Ashram (SNA) is being maintained for conservation and production of threatened medicinal plants (Fig. 10).
4. Memorandum of Understanding (MoU) is signed with two agencies viz. Human India, Srinagar and Surkunda Jadi-Buti Samuh, Bageshwar for marketing of raw produce of farmers under Buy-back system.

Fig. 10: Maintenance of MAP nursery at Sri Narayan Ashram and seed germination of *Saussurea costus* in polyhouse

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

In recent decades satellite based investigations using advanced RS and GIS tools and techniques have become very popular among scientific communities. In the field of plant science, these techniques are very useful to locate the distribution and assess the population dynamics of plant species. Under the current climate change scenario, that has affected and threatened many high value plant species, it is necessary to know the exact status of each species. In Himalayan region, most of the high valued medicinal plants are facing threat due to various drivers of change. Some of the species have gone extinct; some are critically endangered, endangered and vulnerable. Most of these plant species grow in the alpine and subalpine regions of Himalaya. The alpine terrains and landscapes of Himalaya are very difficult to approach physically; hence working with sophisticated equipments is not feasible. Besides this, due to lack of proper routes and conveyance and harsh climatic conditions it becomes difficult to carry heavy and expensive equipments to those regions. In this regard the role of RS and GIS technology becomes very crucial. Commencement of modern RS and GIS technologies has made it possible to detect and quantify the biophysical and biochemical parameters of different vegetation types for assessment of population using hyperspectral imaging technologies. Hyperspectral acquisition 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 spectro-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. Beside this, the forward and inverse modelling approach of hyperspectral remote sensing can be further used for the estimation of phenolic contents in different plant species.

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. Field exploration in Pindari region (District Bageshwar) was conducted in August, 2019 and the remote areas, viz. Kharkiya, Jaikuni, Dwali and Furkiya, were explored. The spectral images of 66 plant species under 52 genera and 40 families were recorded, as per standard protocol. Besides, Leaf Area Index (LAI), soil moisture and temperature data were also recorded.
2. The spectral images for high value taxa, i.e. *Berberis jaeschkeana, Cedrus deodara, Taxus wallichiana* were collected in different populations in Bageshwar and Almora districts of Uttarakhand.
3. Field exploration in Almora region were conducted in March, 2020 and spectral images of 47 species under 43 genera and 35 families were collected from Jageshwar, Kausani, Kosi and Ranikhet region.

Promoting Restoration Programmes on Degraded Lands Through Medicinally Important Species- A Participatory Approach (NMBP, 2019-2022)

Rehabilitation of degraded lands in the IHR is important from local as well as national/regional/ global standpoint towards sustainable development approach. To address the rehabilitation of degraded land, the interplay of various aspects such as ecology, sociology, economics, anthropology and culture needs to be considered together in a landscape approach. Setting rehabilitation targets in these "multifunctional landscapes" requires addressing trade-offs among a variety of ecosystem services and stakeholders. Given that conservation and avoiding deforestation is no longer a viable option the loss of biodiversity and ecosystem services, forest restoration activities should be considered as an important component in national strategies and action plan for degraded land rehabilitation programme. Therefore, the present project addressed rehabilitation of degraded community land using selected medicinal/ multipurpose tree, shrubs and herbs species with people's participation approach and incorporating livelihood enhancement strategies.

Objectives:

- To establish convergence with community institution for restoration through livelihood promotion and biodiversity conservation.
- To develop value chain of the medicinally important produce and value addition in each site.
- To make cost – benefit analysis of each prototype developed.
- To promote restoration through plantation of medicinally important species.
- To enhance capacity of the diverse group of stakeholders on restoration of degraded land.

Achievements:

1. Under the awareness programme on restoration of degraded land, a total of 6 meetings were organized across selected pilot sites (Chandak-Unlaghat watershed, Bin Block, Pithoragarh), Hat-Kalika watershed (Gangolihat Block, Pithoragarh), and Upper & Lower Gori watershed (Munsiyari Block, Pithoragarh) in which 174 village people (male: 106; female: 68) from 6 different villages participated.
2. A total of 6 hectares land has been identified for the restoration intervention in four different villages (Chitgal, Digtoli, Nakina, and Lumti) in these watersheds.
3. Training on preparation of land for restoration programme was organised, in which 20 village's resource persons from Digtoli and Naikina village (Chandak-Unlaghat watershed) participated.

Creating a Genomics Platform for Apple Research in India (DBT, Govt of India, 2018-2021)

Biotechnological tools (various DNA markers) have proven immensely useful in genetic analysis of many crops including the problematic 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 expected 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 Chaubattia 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:

1. A total of 140 individuals of clonal mapping populations received from Kashmir University were planted at Govt. Horticulture Garden, Chaubatia (Distt. Almora) and only 94 individuals survived. Initial morphological data of all the survived individuals were collected.
2. The data on growth and morphological characters of survived plants revealed that maximum (61.1%) plant height were between 60-80 cm, while minimum (1.2%) tree height were between 80-100 cm, and not much increase in plant height was observed when compared to 2018. Similarly, maximum (45.3%) plants were having leaf area between 8-15 cm^2, while minimum (0.8%) plants having 1-2 cm^2 leaf area. Maximum (54%) trees having 10-20 leaves while the minimum (3.4%) plants having 30-40 leaves.
3. A total of 131 apple genotypes collected from different locations (44 local, 32 HP & 55 J&K) are growing in Surya-Kunj (Kosi, Almora) and Govt. Horticulture Garden Chaubatia.

Timberline and Altitudinal Gradient Ecology of Himalayas, and Human Use Sustenance in a Warming Climate (NMHS, MoEF&CC, 2016-2021)

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. Documentation of 474 vascular plants species (trees-44, shrubs-57, herbs 321, grasses-32 and 14 sedges) from high altitude region of Tungnath, Uttrakhand was carried out.
2. Plant diversity and distribution patterns along altitude gradient covering temperate to treeline ecotone forested zone reveal that (i) maximum parallel distribution of tree species recorded at lower altitude zone, (ii) influence of the anthropogenic disturbances apparent on the regeneration performance of the tree species, especially for high altitude zone, (iii) higher accumulation of *Rhododendron arboreum* seedlings and saplings at 3200-3300 m asl (SW aspect), (iv) *Abies pindrow, Taxus wallichiana, Abies spectabilis* and *Rhododendron barbatum* showed poor regeneration.
3. Phenological events and leaf and shoot growth dynamics studied in the five treeline species (viz., *A. spectabilis, B. utilis, Q. semecarpifolia, R. arboreum* and *R. campanulatum*) in timberline of Tungnath (Uttarakhand) showed annual variations both in initiation and culmination of the various phenophases which was found significantly correlated ($p < 0.001$) with mean annual temperature.
4. Inter annual variations in timing of vegetative bud-break and leafing was also observed. In the slightly warmer spring in 2017 bud-break and flowering occurred earlier by about two weeks in all the species (mean temperature= 7.4°C in 2017).
5. The annual TLR increased from moist to dry sites, lowest being in Sikkim (-0.50°C/100 m), followed by Uttarakhand (-0.52°C/100 m) and Jammu & Kashmir (-0.66°C/100 m).
6. Along the Yuksam-Dzongri transect (Sikkim), a total of 248 plant species (74 tree, 51 shrub and 123 herb species) were recorded. The overall plant species richness for three life forms (i.e., herbs, shrubs and tree species) has shown a significant monotonic decline towards the higher elevation.
7. Along the elevation gradient (1700-4000m), 128 species of lichen were recorded, this include fourteen new record of lichen species for lichen flora of Sikkim Himalaya and one new record for the country. Lichen diversity along the altitudinal gradient has also showed a monotonic decline in diversity towards the higher elevation (Fig. 11).

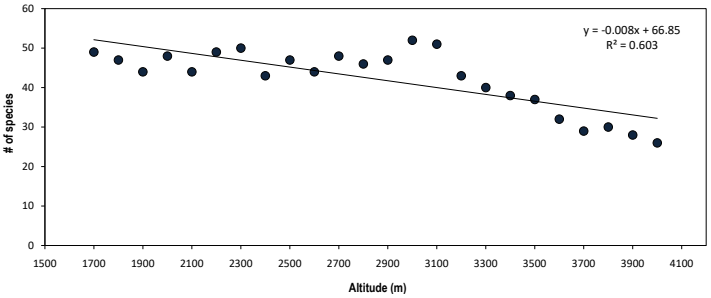


Fig. 11. Trends of Lichen species richness along elevation gradient (1700-4000m) in Yuksam-Dzongri transect, West Sikkim.

Summary of Completed Project / Activity

Multidisciplinary Studies in Floristic Assessment, Ecological Analysis, Ecosystem Services, Conservation and Sustainable Management of Selected National Parks in Western Himalaya (NMHS, MoEFCC, 2016-2020)

- A total of 614 taxa (609 species, 03 subspecies and 02 variety) belonging to 277 genera and 70 families have been recorded and 72 plant species addition to valley of flowers national park (VoFNP). A total of 966 taxa (907 species, 02 subspecies and 06 variety) belonging to 476 genera and 103 families have been recorded from great Himalayan national park (GHNP). A total of 72 plant species as additions to VoFNP and more than 100 plants were addition to GHNP. The Asteraceae represented as dominant family in both the National Parks. A total of 14 endemic species were found from GHNP and 13 species from VoFNP. Five species were recorded from both the National Parks namely, *Aquilegia nivalis, Corydalis vaginans, Saussurea atkinsonii, Thalictrum reniforme* and *T. saniculiforme.* A total of 64 threatened plants from VoFNP and 74 from GHNP as per the categories provided by IUCN, CAMP and RDB. Out of which, 18 species namely, *Abies pindrow, Arisaema jacquemontii, Barbarea vulgaris, Betula alnoides, Betula utilis, Calamagrostis pseudophragmites, Caltha palustris, Chamerion latifolium, Myosotis sylvatica, Parochetus communis, Phleumalpinum, Prunella vulgaris, Silene vulgaris, Trigonella emodi, Urtica dioica, Verbascum thapsus, Juniperus communis, Pinus wallichiana* were found Least Concern from both the NPs.

- The plant density of VoFNP and GHNP ranges from the 3.70 ind/m^2 to 12.30 ind/m^2 and 5 ind/m^2 to 14 ind/m^2, respectively. The highest density was recorded at 3200 m elevation; while lowest density was recorded at 4500 m asl. for both the sites and the trend is decreasing towards the higher altitude.

- In VoFNP and GHNP, total number of tourists recorded in 2016 was 9819 and 979 in VoFNP and GHNP, respectively. In VoFNP, most of the tourists visited in the month of August and in GHNP the peak of visitors recorded in June. In 2016, the revenue of Government from tourism was Rs. 17,64,300 (Indians Rs. 13,75,500 & foreigner Rs. 3,88,800).

Quality Plant Production and Promotion of Cultivation of Selected Himalayan Medicinal Plants for Livelihood Enhancement (Uttarakhand Council of Biotechnology, 2016-2020)

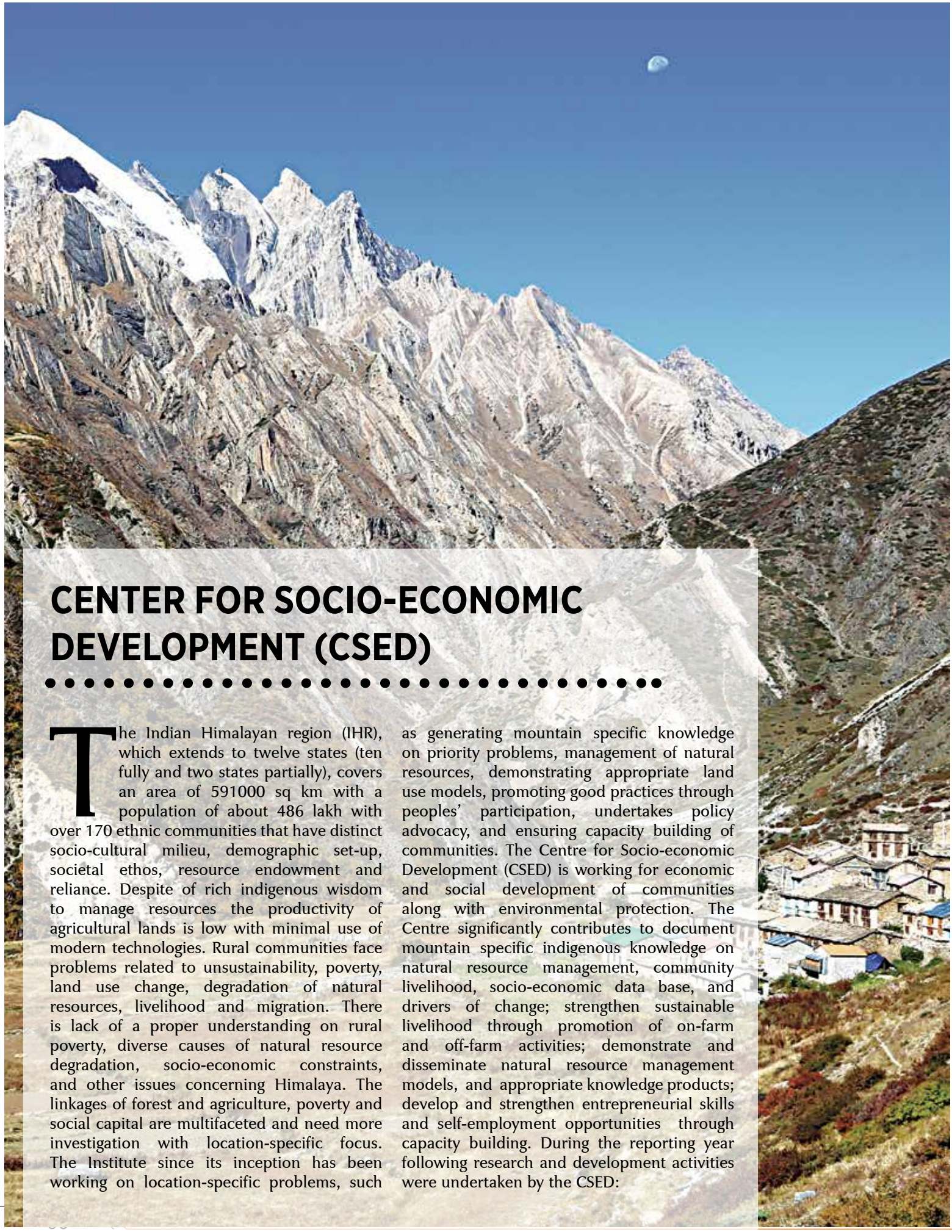
The IHR is one of the major repositories of biodiversity and a home of large number of medicinally useful species. However, the increasing demand of medicinal plants coupled with harsh climatic conditions, slow growth rate and limited natural regeneration, a large number of species are declining. Moreover, 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 selected species under this project are valued for their medicinal properties. Through this project, following have been achieved:

- In vitro propagation protocol of *Valeriana jatamansi* has been developed. Similarly, propagation protocol of *Hedychium spicatum* using seed germination and rhizome cutting was developed for mass multiplication of the species. Plants produced through the methods have been planted in different field conditions for evaluation of physiological and phytochemicals properties. Through various means over 50,000 plants have been produced and the same have been planted in different field conditions.

- 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*. Low irradiance (shade condition) is suggested for large scale cultivation of *V. jatamansi* for improving plant growth and harnessing higher bioactive compounds. The leaf contained highest amount of bioactive compounds and antioxidant activity, especially in the summer season, indicating that the aerial plant part can be utilized and this might reduce the destructive harvesting of the species. Summer season could be considered as the optimum harvest time for harnessing higher bioactive compound like velerenic acid. Stress related antioxidant and biochemical were found higher in plants under full sunlight. For the assessment of eco-physiological responses, two demonstration plots

on different altitude were selected on the basis of completing one year of life cycle. One year population of *V. jatamansi* showed maximum eco-physiological response as compared to Suryakunj population. Results of morphological assessment showed that plant height, leaf number, leaf length, leaf width, root number and root length were approximately similar at different cultivated land. Below ground biomass of *H. spicatum* as well as *V. jatamansi* were higher in demonstration plot at Sri Narayan Ashram (SNA) as compared to Suryakunj- GBPNIHE campus. Valerenic acid content was also higher in demonstration plot at SNA.

- Training on different aspects of medicinal plants cultivation was imparted to different villages of Chaudas valley to over 500 villagers. As a follow-up, a total of 134 farmers of 9 villages were agreed for cultivation of medicinal plants. Propagated plants of *V. jatamansi* and *H. spicatum* were distributed to some of the farmers for initiating cultivation. At the initial stage, 19,700 plants of *H. spicatum* and 10,300 plants of *V. jatamansi* were distributed.



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 set-up, 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 resources, demonstrating appropriate land use models, promoting good practices through peoples' participation, undertakes policy advocacy, and ensuring capacity building of communities. The Centre 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 data base, 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:

Summary of completed project

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

The Indian Himalayan region shows great heterogeneity in land use pattern in tune with the natural and cultural diversity of the region. Therefore, a generalized and uniform developmental plan cannot be of much use in such a diverse area. The age old survival skills and livelihood options of the mountain people have evolved, and the indigenous knowledge of communities indicate that continued adjustments have been made in view of the prevailing conditions. Thus, in view of the vast diversity, in respect of topography, natural and cultural landscape, climate, water availability, etc., only the location specific management plans can be useful. At a juncture when development is constrained by resource depletion and environmental degradation, the role of appropriate technologies and practices which promote ecologically sustainable development becomes indispensable. Use of locally available resources, both material and manpower, is thus pivotal for the success of such endeavors. In view of the above, three villages (Bhetuli, Jyoli and Malera; Distt. Almora) representing the typical ecological and socio-economic conditions of the west Himalaya were selected to prepare "Model Village Action Plan" through participation of village people and also involving officials of line departments of the state Govt (Table 4). In these villages 79 to 97% farmers were marginal having land holding less than 0.5 ha. The approach of community mobilization, sensitization, capacity building and linkage with development were taken into consideration and tools of PRA and SWOT analysis were applied for outcomes. During the project tenure 34 trainings were conducted for community sensitization, mobilization and capacity building on various low-cost, environment-friendly rural technologies. Total 48 technological packages i.e., protected cultivation; poultry farming and horticulture and agro-forestry species plantation were disseminated and demonstrated among the village people. Fruit trees (9500 nos. of plum, walnut, peach, guava, citrus) and 2060 plants of agro-forestry species (oak, falyat, bamboo, amla etc.) were provided to village people covering 13 ha land. Also, 700 kg ginger seed (160 HH) and 2330 Chicks birds (120 HH) were distributed in studied villages. The beneficiary farmers earned of Rs. 125100 (Malera village), Rs. 337400 (Bhetuli) and 339450 (Jyoli) by selling chicken and eggs. Through various R&D activities in the project, 48 field demonstrations (43 Poly houses, 3 Poly tank, 1 Compost Pit, 1 Fish tank) were maintained among 209 beneficiaries of these villages and supported protected cultivation, cash crop cultivation, fish farming, poultry farming, vermi-composting, bio-briquette making. One of the main outcome of this project has been preparation of 'Model Village Development and Action Plan' for the three target villages through active participation of people and capacity building of Govt. officials to prepare similar plans for 11 "Adarsh Grams" selected in Distt. Almora under the 'Veer Shiromani Madho Singh Bhandari Integrated Village Development Program' of Govt. of Uttarakhand. It is expected that the approach of participatory planning with the village people will allow learning many new lessons for rural area development in the west Himalayan region, and such efforts may lead villages towards achieving sustainable development.

Table 4: Socio-economic profile of the project villages (M= Male; F= Female; T= Total; P= Primary; S= Secondary; and T= Tertiary) (Source: Primary survey 2018).

Village	Block	Altitude (m asl)	Total area (ha)	Total Households (population)	Total population		Gender composition (%)		SC population	Literacy rate (%)			Working population (%)		
					M	F	M	F		T	M	F	P	S	T
Bhetuli	Takula	1840	202.5	151 (713)	379	334	47	53	286	85	89	80	54	10	36
Jyoli	Hawal bagh	1422	212.8	103 (630)	330	300	44	56	237	80	81	79	53	5	42
Malera	Hawal bagh	1166	86.0	19 (93)	41	52	47	53	-	90	89	90	52	11	37

A Sustainable Approach for Livelihood Improvement by Integrated Natural Resource Management in the Central Himalaya (NMHS, MOEFCC, 2016-2020)

The Himalayan mountain communities have been living in harmony of nature and utilizing the natural resource sustainably through generations using indigenous wisdom. However, in the recent decades the productivity of agricultural lands is on decline, fodder resources for livestock are dwindling, forests are degrading and water is becoming scarce that has weaken the agri-sylvi-pastoral mode of living of rural people. One of the major constraints in adopting modern agriculture is small and rain-fed land holdings scattered over undulating terrain making the input cost much higher than the output in terms of crop yield. Therefore, people are poor and economically marginalized. There is a need to look for possible solutions to improve livelihood and increase income of rural poor, and protect the environment in an integrated way. This project attempts to strengthen integrated natural resource management and demonstrate a few promising rural technologies in 8 selected villages (viz. Gwalakot, Jyula, Tiloura, Saknia Kot, Pitharar, Bhelgar, Darim Khola and Sakar) of Hawalbagh Development Block, Almora District (Uttarakhand) having 470 households with a population of 1977 people. It aims to enhance the productive capacity of natural resources and reduce the vulnerability of the farming sector. Special emphasis was placed on economic use of Chir Pine needles fallen in the forests that causes forest fire and damage to the regional ecology considerably. People's participation in the entire project cycle has been a very strong component of this project.

Objectives:

- Manage natural resource sustainability in target villages by introducing innovative approaches and practical models by participatory management.
- To extend technical help and packages for demonstrating 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 sections, 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. Various low-cost, eco-friendly and replicable on-farm and off-farm technology packages for sustainable income generation were transferred to the farmer's field e.g., polyhouse, integrated fish farming (2 beneficiaries), cultivation of vegetables (5 beneficiaries), cash crop cultivation (motivated 305 farmers for vegetable cultivation), backyard poultry farming (250 beneficiaries), horticulture, vermi-composting, vegetable cultivation, bio-briquetting of pine needles, etc. About 2.5 ha abandoned land of 21 HH was put under ginger cultivation that yield 83 Q/ha and sold for Rs. five lakhs.
2. 2000 multipurpose fodder species such as Bhimal (*Grewia optiva*), Falyat (*Quercus glauca*), Quiral (*Bauhinia variegata*) etc. were distributed among 200 households for development of about 2 ha waste land. About 4 ha waste land of 36 families was taken up for Kiwi plantation. Waste land (0.5 ha) was put under plantation of tejpatta (*Cinnamomum tamala*), and various citrus species registering a survival rate of 73% after three years.
3. A Pine processing unit established under the project is functioning well (Fig. 12). Various products i.e. file covers / folders (1800), note pads (100), carry bags (100) and wedding cards etc. were made using 2500 kg chir pine needles as a raw material and supplied to various government departments earning Rs. 28892.00 during the reporting period.
4. In order to develop farmers' skill and knowledge for sustainable income generation through NRM, 120 farmers (52% women and 29% SC) were trained on various technology packages i.e. bee keeping, bio-briquetting, making decorative items from chir pine needle and cones etc. Also, a group of 30 selected farmers from the study area was taken to Liti, Shama and Danda villages (Bageshwar District) well known for Kiwi production, floriculture, organic vegetable cultivation and rural tourism.

Fig. 12: Director of the Institute explaining the functioning of Pine Unit to the Addl. Secretary, MoEF&CC.

Network Programme on Convergence of Traditional Knowledge System for Sustainable Development of IHR (NMSHE TF-5, DST, 2015-2020)

The Indian Himalayan region (IHR) occupies a special place in the mountain ecosystems of the world in view of its role in provisioning for water, biodiversity, food, energy, etc. 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 in the fragile mountain landscape and more liking towards modern developmental practices, the traditional knowledge systems are eroding at a faster pace. It is now increasingly being felt that the TK regarding resource management can play a key role in the conservation of natural resources and sustainable livelihood options thus need to be documented. Therefore, the present Network Program was undertaken as a component of NMSHE Task Force 5 being coordinated by JNU, New Delhi.

Objectives:

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

Achievements:

1. The study covered 19 districts and 26 communities of 6 Himalayan states (Arunachal Pradesh-7 Districts, 4 communities); Nagaland (3 Districts, 2 communities); Sikkim (4 Districts, 5 communities); W.B. Hills (1 District, 2 communities); Uttarakhand (1 District, 1 community); and Himachal Pradesh (3 Districts, 12 communities). We documented IKS on 16, 11, 24 and 15 good land & soil management practices (related to agriculture) for Northeast, Sikkim, Uttarakhand and Himachal Pradesh, respectively.
2. Similarly, a total of 10, 11, 5 and 22 traditional water conservation, management and indigenous irrigation systems was documented for northeast, Sikkim, Uttarakhand and Himachal Pradesh, respectively. Some community specific good practices are Sugang, Hirong, Hirong Laanhiko, Zabo, Guhl, Kuhl, Naula, Dhara, Khatri, Jairu or Baudi, Nawn, Kuhls, Khatris, Churudus, Tithe, Chal-Khal, Chhrudu etc. in different states.
3. An inventory of 704, 381, 456, 452, 1620, 323 species used for medicine, food, spices and condiment fuel, fodder, fibre, paper and pulp, timber, thatch, dye and colour, oil, gum, resin, tannin, agricultural tools, furniture and handicraft, house construction, pesticides, incense and aroma, and ornamental plants (1021 species) was submitted to JNU for creation of a digital library on TKS.
4. A total of 56, 14, 18 and 38 local fermented foods, beverages, local recipes and delicacies were recorded for Arunachal Pradesh, Sikkim, Uttarakhand, and Himachal Pradesh, respectively (Fig. 13). Some commonly used fermented foods are Ekung, Eup, Namsing, Churpi, Chkchoro, Nanding, Apong, Raksi etc. in northeast, Sinki, Gundruk, Kinema, Sel roti in Sikkim, Arsa, Singal, Changa in Uttarakhand, and Lwad, Babru, Siddu in Himachal Pradesh.

Fig. 13: Traditionally prepared fermented food and beverages products by tribes of Sikkim and W.B. Hills.

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

The well-being of human beliefs is integrally linked with biodiversity and ecosystem services. It is now recognized that if the current rate of loss of biological diversity is continued the next generation will face problems in livelihood opportunities. Globally majority of the forests are undergoing increasing pressure from change drivers such as land use change, habitat loss, degradation, over-exploitation and unsustainable use of resource and invasive alien species. The biggest challenge 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 ecosystems that will ultimately affect quality of ecosystem services. Therefore maintaining species richness in forest communities is critical for sustaining ecosystem services. Present study investigates species richness and diversity, certain structural and functional aspects and selected ecosystem services of selected forest stands (Sal, Pine and Oak forests) in the west Himalaya that are 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

Table 5: Nutrient concentration (N, P, K) of leaf litter in the selected forest stands

Forest type	Leaf Litter species	Nutrient (%)	Rainy	Winter	Summer	Average
Sal	*S. robusta*	N	1.74±0.17	1.48±0.30	1.08±0.30	1.43±0.19
		P	0.16±0.017	0.13±0.0023	0.14±0.0029	0.14±0.008
		K	0.85±0.12	0.73±0.020	0.59±0.021	0.72±0.075
Chir-Pine	*P. roxburghii*	N	1.01±0.06	0.68±0.11	0.57±0.14	0.75±0.13
		P	0.121±0.009	0.134±0.023	0.144±0.029	0.13±0.006
		K	0.66±0.012	0.59±0.09	0.56±0.007	0.60±0.029
Banj-Oak	*Q. leucotrichophora*	N	1.88±0.30	1.78±0.36	1.47±0.31	1.71±0.31
		P	0.105±0.003	0.075±0.009	0.051±0.005	0.077±0.015
		K	0.57±0.56	0.56±0.0124	0.54±0.0074	0.55±0.008
Mixed-Oak	*Q. lanuginosa*	N	1.91±0.09	1.74±0.18	1.51±0.09	1.72±0.11
		P	0.086±0.012	0.054±0.032	0.062±0.0056	0.067±0.009
		K	0.44±0.012	0.41±0.006	0.40±0.0016	0.41±0.012
	Q. floribunda	N	2.01±0.18	1.20±0.15	1.18±0.17	1.13±0.22
		P	0.16±0.0094	0.09±0.0076	0.025±0.004	0.062±0.039
		K	0.48±0.036	0.32±0.03	0.35±0.007	0.38±0.042

N= Nitrogen, P= Phosphorus, K= Potassium

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 state 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. The Sal forest recorded highest biomass ranging from 567 t/ha in 2017 to 587 t/ha in 2019. While the mixed-oak forest recorded minimum biomass ranging from 217 t/ha in 2017 to 236.10 t/ha in 2019. The total annual litter fall ranged from 12 to 775 g m^{-2} among the four sites. The highest litter fall was recorded for chir-pine (1167 gm^{-2}), followed by banj oak (1050 gm^{-2}), mixed oak (1014 gm^{-2}) and lowest for sal forest (775 gm^{-2}). Temporal changes in litter fall data of 1980-83 gathered by earlier workers revealed an increase from 17% (Sal) followed by mixed oak stand (30%), chir-pine (54%) to 81% (Banj-oak) during 1980-83 to 2017-19 in these forest stands.
2. Out of a total of 50 species recorded in tree layer (tree, sapling and seedling) in all four studied forest stands only 28 species were regenerating (5, 4, 9, and 10 species at Sal, Chir-pine, oak and mixed oak stand, respectively). In the Sal and Chir-pine stand satisfactory number of seedling were present but they did not accomplish sapling stage in satisfactory ratio. The numbers of seedlings were maximum 3086 to 1696 ind/ha at Sal and Pine stand, respectively. However, in the Banj-oak and mixed oak stand number of tree (>30) were maximum. The contribution of seedling in was higher in Sal (75%), followed by Chir pine (67%) and Banj oak and mixed oak forest (17%) (Fig. 14).
3. Concentration of various nutrients (nitrogen, phosphorus and potassium) in the leaf, wood and reproductive parts litter across the four forest types and summer, rainy and winter seasons (Table 5) revealed that Oak forests were rich in N, Sal forest rich in P and K, and Pine forests were poor in all these nutrients.

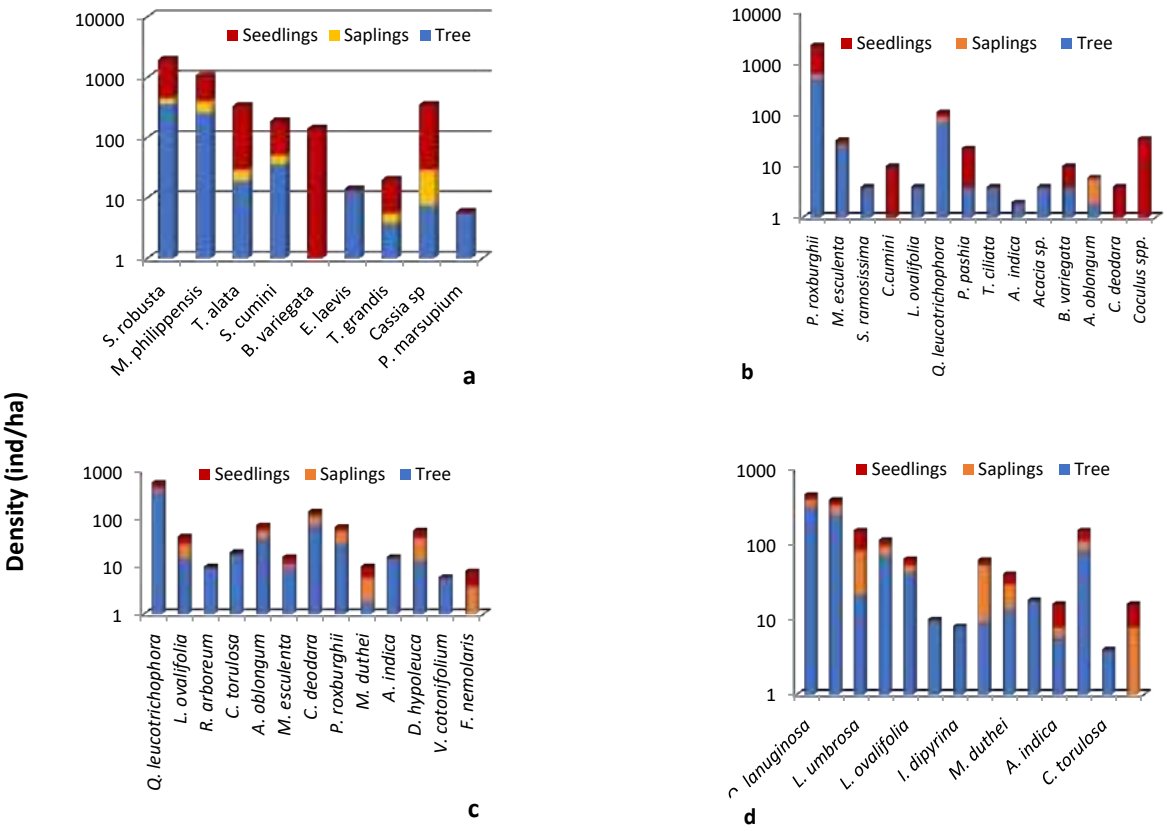


Fig. 14: Regeneration status of species across the study sites a, b, c, d

Livelihood Enhancement of Small Farmers of Uttarakhand Hills Through Integration of Simple, Cost-effective, Eco-friendly Rural Technologies (DST WOS; 2017-2020)

A large number of natural resource based hill specific, low cost, eco-friendly technologies are available for adoption by poor hill farmers to enhance their livelihood and income. However, such technologies reach to a few, leaving sometime the real needy farmers to benefit them in terms of employment and income generation. Under this activity natural resource based technology-centric village development model(s), integrating interventions such as Integrated Fish Farming (IFF), off-season vegetables and mushroom cultivation, green fodder production; bio-composting/ vermicomposting and bio-briquetting were introduced in three selected villages in Almora district, Uttarakhand. In this system different components were 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 ensured effective recycling of wastes, utilization of farm and forest biomass, energy saving and eventually helped in wise use of natural resources and protection of environment apart from income and employment generation.

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 labor 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. In three IFF sites developed in earlier years (Matela, Kaneli and Kalon villages in Almora district) fingerlings of exotic carp species viz., silver carp *(Hypophthalmicthys molitrix)*, grass carp *(Ctenopharyngodon idella)* and

Table 6. Stocking and harvesting of fish at Kalon and Kaneli village

Fish species	Stocking of fingerlings			Harvesting of fish		
	Length (cm)	Number	Survival (%)	Weight (g)	Number	Total Weight (kg)
Village Kalon						
Silver carp	5.0-7.2	105	80	160-390	84	13.5
Grass carp	7.0-8.5	120	85	220-650	102	28.5
Common carp	7.0-8.0	75	84	150-315	63	11.5
Village Kaneli						
Silver carp	5.0-7.2	90	70	165-325	63	8.5
Grass carp	7.0-8.5	100	75	210-525	75	14.5
Common carp	7.0-8.0	60	78	165-275	47	7.0

common carp *(Cyprinus carpio)* at a density of 3/m^2 were stocked into the ponds during April, 2019. Total earnings by selling fish+ vegetables+chicken+ milk was recorded Rs. 102850.00. Altogether, 8 trainings were imparted to 222 beneficiaries, including 84 women farmers belonging to various parts of District Almora.

2. Survival rate of fingerlings of different species across two IFF (Kalon and Kaneli villages) was recorded between 70 and 85% and the fingerlings attained average size of 150-650 gm and 165-525 gm within eight months, respectively (Table 6). Highest growth rate was recorded in grass carp, followed by silver and common carp at both the sites. Composite carp culture yielded 53.5 kg and 30.0 kg fish at Kalon (100 m^2) and Kaneli (80 m^2), respectively, which corresponded to 5350 kg/ha and 3750 kg/ha.
3. To reduce the production cost, and to ensure availability of food and manure for fish production, zero day old chick birds (@3000 birds/ha) hybrid species (Kuroiler) were integrated with fish farming at all the three sites. In total 450 chick birds were distributed among 30 farmers. High survival (95-100%) and substantially high growth rate was recorded in chick birds, which grew to 0.950-3.25 kg within 4 months and started laying eggs after 24 weeks. Total earnings by selling the chicken and eggs was Rs. 3,90,000. Besides regular earning, farmers' family got fish, eggs, chicken and a fresh vegetable for consumption and thus nutritional security was also achieved.

Summary of Completed Projects / Activity

Study and Quantification of Non-timber Forest Products (NTFPs) and Related Value Chain from the Western Himalaya (NMHS-RA Fellowship; 2016-2020)

Still today, about 60% of the world's forests - approximately 2.4 billion ha are primarily or partially used for the production of wood and non-wood forest products. Food and Agriculture Organization (FAO) estimates that 80% of the population in the developing countries rely on NTFPs for nutritional and health needs and over 1.2 billion of rural population generally depend on common resources for NTFPs that supplement their basic needs. In India, more than 95% of the total medicinal plants are used in preparing medicines by various industries are harvested from wild. The role of NTFPs is particularly important in the Himalayan region, where a large proportion of rural population depend on these resources for food, nutrition, fodder, fiber, medicine, condiment, dye and other useful materials and have commercial value that generate substantial revenue. Livelihood security of rural mountain people depends greatly on the status and condition of these resources. It has been estimated that many village communities derive as much as 10-50% of their household income from the sale of the forest products. The aim of the present study was to provide a comprehensive database that provides baseline information for developing management plans for the conservation of NTFPs and enhancing livelihood of forest dwellers in Himachal Pradesh. The objectives of the study were: (i) Inventorization of diversity and management practices of NTFP species; (ii) Status on marketing, value addition and enterprise development; and (iii) Governance, policies and regulations related to NTFPs and their impact. Thus, through review of various documents of forest department, forest working plans, libraries and published work in journals, articles, books, reports electronic sources from the Internet a comprehensive database that provides baseline information for developing management plans for the conservation of NTFPs and enhancing livelihood of forest dwellers was prepared. Valuation of NTFPs was based on market rates and conducting value chain analyses. Quantitative techniques were used to evaluate the relative usefulness of different types of NTFPs on account of cultural, practical, economic, and total values. The present study found that up to 61% flora of H.P. has medicinal value. Family use value was highest for Asteraceae (FUV= 76.75). NTFPs were listed under 18 categories as per their use. The main uses of NTFPs, in terms of numbers of species, were for medicine, edible, and forage. Different parts of these species, such as whole plants, roots (including rhizomes and tubers), leaves, flowers, fruits, seeds, stems, barks, etc. are used for curing different diseases. The richness of medicinal plants decreased with increasing altitude but the percentage of high value plants steadily increased with increasing altitude. Maximum numbers of NTFPs are used from sub-alpine zone followed by the alpine, warm temperate, temperate and sub-tropical zones. A total of 811 NTFPs were documented and evaluated in Himachal Pradesh. As many as 137 NTFPs fall under diverse level of threat as per the threat categories of IUCN (2019), while 105 species are under threat as per stakeholders perception due to excessive exploitation. Analysis of quantum of NTFPs harvested in the past six decades exhibited a declining trend supposedly due to depletion of resource base in their natural habitats. On an average there was more than 85% decline in harvests from past 43 years. Average collection period of NTFPs in different districts ranged from 34 to 82 days annually. Due to lack of systematic marketing, the rate of NTFPs is driven mostly by market demand, mediator and bargaining power. With the decrease in quantity and very high demand of NTFPs, forest dwellers are mostly collecting NTFPs for business purpose. Net income of secondary collectors was more than 75%. Average collection period of NTFPs in different districts

ranged from 34 to 82 days annually while average annual income of household was highest for district Chamba. High dependence was found on divine NTFPs that help poorly marginal people to fulfill their domestic needs. Continuous extraction of NTFPs e.g., *Aconitum heterophyllum, Angelica glauca, Gentiana kurroo, Nardostachys jatamansi, Saussurea costus, Lilium polyphyllum, Trillidium govanianum* etc. from these areas has put the species in the threatened category. Such species can be multiplied and popularized in traditional agroforestry systems. There is also a need to give more emphasis on NTFPs conservation in the forest working plans.

Weakening of Traditional Livelihood in the Mountains: NMHS Fellowship Programme (2016-2020)

Uttarakhand is a mountainous state with 92.6% area covered by the mountains, and the rest 7.4% is tarai plains. The mainstay of the rural people is agriculture, supported by animal husbandry, horticulture, and forest products. Most of the agriculture in the state is rain fed, which accounts for about 85% (excluding the Tarai area which falls in the district Haridwar, Dehradun and Nainital and Udham Singh Nagar) of the total agricultural land. The occupational structure today is very much different from the past few decades. The percentage of cultivators is decreasing and they are pursuing other opportunities outside the state to support their livelihood. Main reasons for these changes are scarcity of resources for the traditional practices, decreasing size of landholdings and significant increase in population that is forcing people to move out for other options for earnings. The success and failure of the farming system depends upon quantity and distribution of rainfall and other climatic conditions. The increasing demographic pressure in the rural areas, urban expansion and declining farmlands has placed intense pressure on agriculture. This situation has changed the survival strategies of the rural people that is reflected in the weakening of traditional livelihood practices in the region. To understand the dynamics of change this study was carried out in 12 villages of six hill districts of Uttarakhand with the objectives: (i) To identify the causes of weakening traditional livelihood, (ii) To study the relationship between land abandonment and out migration, and (iii) To identify the supplementary livelihood options in the rural areas in the changing scenario.

To identify the causes of weakening traditional livelihood, a total of 674 households were surveyed in the 12 study villages using key-person interviews and household surveys. Most of the holdings were marginal and small across the study villages. Villager's perception on 13 various aspects/issues leading to weakening traditional livelihood were recorded and man-wildlife conflict was the major cause of weakening of traditional agriculture, followed by outmigration and erratic rainfall (Table 7). Gwalakote and Thapliyal gaon people having permanent migration more but in Byasi and Jakhand seasonal migration is dominant. In the Gwalakote and Thapliyal gaon have more population migrated before 2007 but in the Byasi and Jakhand after 2007 migration increased. Also the villages differ in terms of seasonal and permanent migration which is significantly influenced by availability of irrigation facilities and man-wildlife conflict. As per the stakeholders perceptions it was found that in different altitudinal zones people are interested in different kind of livelihood activities, but they lack technological inputs and appropriate knowledge. Most people were interested in protective cultivation, vegetation cultivation, cash crop cultivation, bee-keeping and integrated fish farming (fisheries, vegetables, cash crops, poultry etc.). If agro-based entrepreneurial ventures are to be promoted in the region there is an urgent need for timely introduction of radical policy, institutional and land reforms.

Table 7: Depiction of causes for weakening traditional livelihood

S. No.	Causes of weakening traditional livelihood	Respondents (%)
1.	Man- wild life conflict	62.0
2.	Unemployment leads to out migration	37.4
3.	Erratic rainfall & crop damage due to extreme events	35.8
4.	Population pressure	25.8
5	Scarcity of nearby good medical facilities	22.5
6.	Scarce drinking water and irrigation sources	21.9
7.	Increasing natural hazards (cloud-burst, forest-fire etc.)	21.4

8.	Poor education system	20.0
9.	Increasing land degradation, fragmentation and small landholdings	15.2
10.	High risk low production	14.4
11.	Poor infrastructure	13.5
12.	Poverty	12.3
13.	Changing psychology and interests of young generation	7.0

Documentation of the Post Project Status of Land Rehabilitation Models Developed by the Institute in Uttarakhand (In-house, 2019-2020)

Land degradation is a consequence of either natural hazards or direct anthropogenic and underlying causes. Ecological restoration of wastelands is essential for sustaining the diversity of life on the Earth and establishing an ecologically healthy relationship between man and nature. It is also important for provisioning a range of ecosystem services such as provisioning of fuel wood and fodder, NTFPs, biodiversity conservation, soil formation and soil fertility maintenance, watershed protection, carbon sequestration, etc. Plantations are a useful tool for wasteland restoration. Fast growing, native pioneer species with high productivity are recommended for the initial stages of restoration of degraded lands. In the IHR wastelands accounts for about 34% of the total geographical area (i.e., 180533 sq. km), which is about two times as compared to India (i.e., 19.4%). This is mainly because about 22% land in the IHR is either under snow or barren and does not support any biological growth. In Uttarakhand 24% area is under wasteland of the total geographical area of the state. Wastelands of this region have challenges of slope, stoniness, soil depth, soil moisture and poor soil fertility etc. and they are in the process of further degradation due to overgrazing, deforestation, and natural erosion caused by high intensity rains. Such lands have poor production capacity and need to put under other forms of land management models. The GBP-NIHE since its inception in 1988-89 took this issue on priority basis and implemented a number of R&D based approaches and technologies for the rehabilitation of wastelands in Uttarakhand as well as in other parts of the IHR.

The objectives of the present study were to investigate present status of selected land rehabilitation models created by the Institute in Uttarakhand and to analyse the positive and negative aspects and suggest future strategy for upscaling these technologies to rehabilitate wastelands in the IHR. In this investigation three districts of Uttarakhand were assessed namely Almora, Bageshwar and Champawat where our Institute had implemented land rehabilitation models in the past through field work and consultation of the documents available on these models with the Institute (Table 8). To take a view of the people in these sites about the success/failure of these models a questionnaire was prepared in Hindi and the perception of the people were recorded. Also, group discussions were carried out with beneficiaries and non beneficiaries. Syntheses of the data/information on these sites revealed that in terms of tree growth these sites can be categorized as successful but for benefits accruing from plantation of multipurpose tree species were not accrued judiciously due to poor management by the stakeholder communities and project withdrawal strategies. Using the criteria of planted area maintained and ecological parameters including tree growth the most successful site was Surya Kunj (Kosi-Katarmal, Almora) followed by Bantoli, Anna (Distt. Bageshwar) and Kolidhek (Distt. Champawat). It was least successful in Nanda Van (Almora). The study suggests that there is still large inequity in the ownership, management and flow of benefits from both the use and conservation of biological resources. Partnership for sustainability of rehabilitation projects is must be with a government agency or NGO of repute for stronger ownership. Accordingly we need to redesign the exit strategy. Linking biophysical aspects of ecosystem with human benefits through the notion of ecosystem services is essential to assess the trade-offs (ecological, socio-cultural, economic and monetary) involved in the loss of ecosystem services and biodiversity in a clear and consistent manner. Creating economic value for our forests and natural ecosystems is one of the most powerful incentives for sustaining them. Most villages are witnessing drastic development and hence it is time to enforce strict environmental laws to forbid cutting of trees and removal of vegetation for infrastructure development. Strengthening the VPs with more power and fund is required to protect and propagate forests. There is also a need to take some of these rehabilitation sites for long-term monitoring and research.

Table 8: Geographical coordinates, altitude and area of rehabilitated sites

Name of sites / Distt.	Area rehabilitated (ha)	Altitude (m asl)	Latitude (N)	Longitude (E)
Suryakunj (Institute campus)	28.7	1150-1250	29.6	79.6
Nanda Van, Almora	1.2	1,638	29.5	79.6
Bantoli, Bageshwar	5	1,684	30.2	79.3
Anna, Bageshwar	9	1, 414	29.8	79.6
Kolidhek, Champawat	5.6	1,745	29.4	80.1

A Compendium of Relevant and Environment Friendly Rural Technologies for IHR (In-house, 2019-2020)

Technological interventions can hardly be suggested as a panacea for solving all social and environmental problems in the IHR. However, they help to reduce the prevalence and severity of many problems, be it environmental or the social-economic in nature. Low-cost technological interventions can help in improvement of the quality of life, especially for the poor and disadvantaged groups of people. In the rural landscape of the Himalayan region, livelihoods of the people depend heavily on agriculture, animal husbandry and forestry sectors and they are intricately connected with each other. The role of forest goods and services in sustaining the productivity of agriculture and animal husbandry is immense. Livelihoods of majority of the poor/marginal and traditional societies are heavily dependent on natural resources, particularly in the hilly region. To address livelihood, income and employment generation issues a range of technological applications are being developed and implemented by various R&D institutions working in Himalayan region that include different sectors such as energy, agriculture, water, micro and small scale, agro-based manufacturing, sanitation, health, transportation, communication, environmental conservation, and employment. In this context, capacity building of rural people, particularly women is urgently required for sustainable utilization of natural resources to provide alternatives for livelihoods and employment and help reducing drudgery and out migration.

Our Institute right from its inception in 1988-89 had a strong focus on R&D based solutions to livelihood enhancement, employment and income generation by the rural people and created a Rural Technology Complex (RTC) in 2001-02 at Kosi-Katarmal, Almora where some technology packages were demonstrated at pilot scale for training and capacity building of farmers and other stakeholders. Participation of the stakeholders in technology adoption and feedback based improvement in these technologies were also the important elements of this endeavour. These packages were location-specific and based on topography, climate, soil fertility, crop production and need of the local people. Some of the prominent technologies adopted by rural people along with the number of technologies (829 nos.) those were adopted by 1854 farmers and rural people of the region (Table 9). However, many other technologies such as vermi-wash, B.D. heap, NADEP compost, green manuring, vegetable and cash crop cultivation, mushroom cultivation, fruit and vegetable processing, traditional food items, traditional art, nursery development, zero energy cool chamber, drip irrigation/handi (pitcher) irrigation etc. have been demonstrated by us at the RTC and so far we have trained 20200 people (~15% SC/ST) on these various livelihood supporting and income generating technologies. The RTC earned Rs. 69,58,345 so far through training and capacity building programmes sponsored by various State Govt. Departments, NGOs and other funding agencies Through adoption of these technologies on average income generated by the stakeholders was found ranging from Rs. 15,000 - 3,00,000.00 per year.

Continuous monitoring and technical backstopping of these interventions in the rural areas is a regular activity of RTC. Data / information is also recorded on yield of various farm produce and income generated through sale of this produce by the farmers. Some of the common issues reported by farmers are insect infestation of crops in poly-houses, damage by wild animals, failure of crop due to climatic factors, scattered holdings, and marketing support which suggests strong technical backstopping. Overall, the RTC has been a significant platform for the Institute for science-practice-policy interface and has demonstrated that this has a self-sustaining potential through various sponsored training programmes of State Govt.

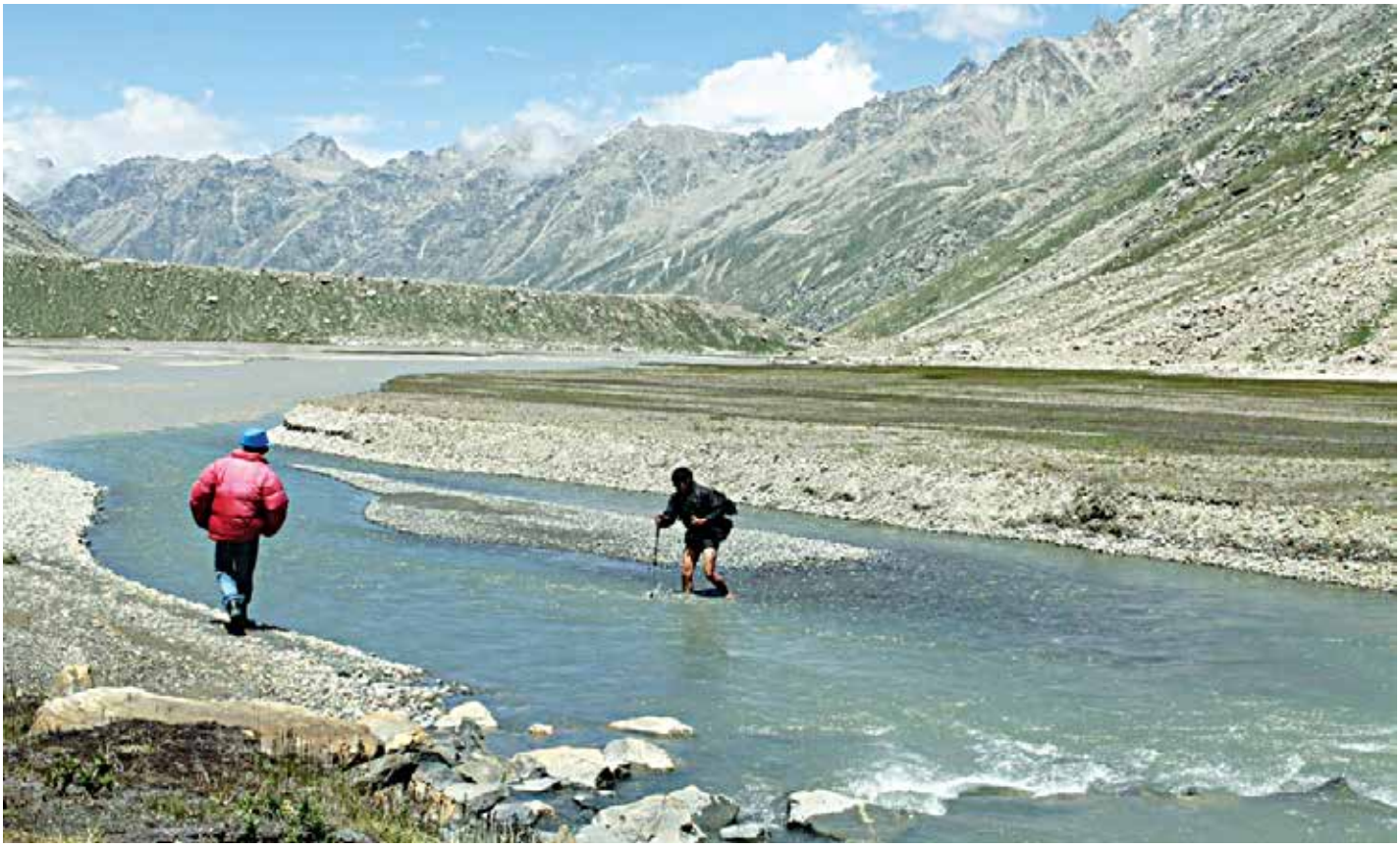
Table 9: Year wise capacity building of various stakeholders at RTC and income generated by rural people through adoption of various environment-friendly rural technologies

Year	Total participants				Income generated by RTC (Rs.)	No of people who adopted the technologies	Visitors (other than farmers) to RTC
	Male	Female	SC/ST	Total			
2001-02	838	886	224	1724	115000	10	89
2002-03	1203	938	236	2141	247600	177	43
2003-04	798	758	178	1556	194000	132	19
2004-05	706	683	136	1389	559500	120	70
2005-06	421	1035	205	1456	389815	127	112
2006-07	570	1010	305	1580	1106630	111	119
2007-08	384	587	194	971	677100	108	71
2008-09	583	506	203	1089	377800	119	71
2009-10	334	594	173	928	402070	97	32
2010-11	491	769	206	1260	252085	115	20
2011-12	155	459	94	614	258265	87	30
2012-13	166	315	81	481	533500	83	44
2013-14	309	432	111	741	106410	92	18
2014-15	259	207	61	466	568710	72	22
2015-16	299	565	134	864	410160	89	13
2016-17	515	481	208	996	366800	85	28
2017-18	362	409	114	771	160900	71	61
2018-19	445	282	132	727	150000	89	32
2019-20	219	227	72	446	82000	70	18
Total	9057	11143	3067	20200	69,58,345	1854	912

CENTER FOR ENVIRONMENTAL ASSESSMENT AND CLIMATE CHANGE (CEA&CC)

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 publications 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 where natural resources' dependency of societies is very high. The Centre for Environmental Assessment & Climate Change (CEA&CC) caters the Himalayan needs on these issues in tune with MoEF& CC and SDG (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 resources generation, (ii) development of indicators of climate change in the Himalaya in identified sectors, and (iii) inclusion of Citizen Science Approach in research, and adaptation and mitigation strategies. Practice-Science-Policy connect through integration of community level experiences (acclimatization / adaptation / coping mechanism) in policy framework, and (iv) collaboration with other organization / Universities on climate change projects.

The objectives of the centre are to assess and monitor the physical, biological and socio-economic environmental parameters for the development of the IHR and designing 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 (Uttarakhand): Environmental Impacts and Prevention Strategies (In-house, 2018-2020)

Fire strongly influences carbon cycling and storage in forests. In 2016, about 3774.14 km^2 (representing 15.28% of the total forest area of Uttarakhand) was burnt. The forest fire activities were spread all across the state, and most of the events occurred in the zone of Pine *(Pinus roxburghii)* dominated areas. However, sub-tropical sal *(Shorea robusta)* forests along foothills are equally prone to such fires in changing environment. Forest fire in Uttarakhand is not a simple issue of fire fighting. It involves various components of abiotic, biotic and management factors of our biosphere, and their cascading effects on ecosystem, humans and management system. The focus of the present fire fighting approach lies in the symptom treatment, however, topography, and poor infrastructure of the concerned department (primarily state forest) are important bottlenecks. However, committees are in place (District to Village Level) and mechanism for flow of information for coordination among agencies is in place, the system remains inefficient on quick responses to fire incidences which sometimes turn into a disastrous event. Preparedness is the basic need and involvement of the responsible citizens through awareness and technological means (use of mobile App) are few pre-requisites in preparedness. Prevention is the key element in fighting with forest fire in Uttarakhand. The release and transport of aerosol, change the optical properties of the atmosphere, resulting in the reduction of visibility and changes in regional and global climate (Table 10).

Table 10: Status of atmospheric pollutants

Parameters	Forest fire months (March-June)			Post-forest fire months (July-October)		
	Min.	Max.	Avg.	Min.	Max.	Avg.
TSP (μg/m^3)	81.37±9.9	198.85 ±10.29	115.94±8.5	80.04±10.4	98.91±0.96	89.94±5.1
PM_{10} (μg/m^3)	32.66±5.5	145.15±6.50	66.68±7.4	44.11±5.3	59.91±0.81	53.67±6.5
$PM_{2.5}$ (μg/m^3)	17.16±3.2	98.12 ± 5.34	48.06±4.1	6.68±2.1	39.72±1.30	25.63±5.4
BC (ng/m^3)	508.8±57.1	78818±140.0	2572± 187.1	69.7±1.5	1446.6±24.8	491±19.35
NH_3 (μg/m^3)	7.0±2.1	17.8±2.7	10.5±1.9	7.0±1.5	14.7±3.1	10.2±2.2
NO_2 (μg/m^3)	1.7±0.5	10.2±1.6	4.4±2.5	0.9±0.2	6.8±2.5	4.2±1.5
SO_2 (μg/m^3)	0.6±0.1	5.6±1.4	2.7±0.4	0.3±0.1	4.3±1.2	2.2±0.9

These pollutants play an important role in atmospheric dynamic processes. These pollutants when cross their certain permissible limits, impact adversely human beings, plants, and climate. Forest fires have reasonably deteriorated ambient air quality level in terms of gaseous pollutants and particulate matter. Black carbon, being heat absorbing aerosol, have also shown increasing pattern due to forest fires in the region (Fig. 15). This may lead further to ill-health impacts and/or would increase local temperature.

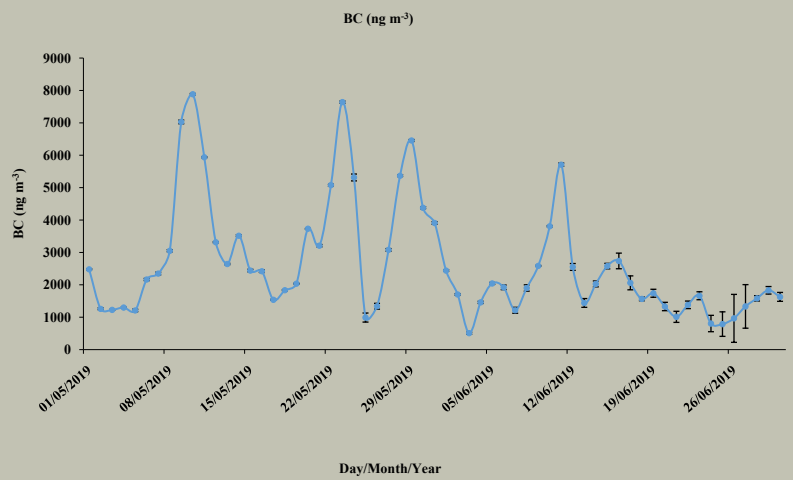


Fig. 15. Concentration of Black Carbon during forest fire months (May-June 2019)

Gaseous Air Pollution in the Background Sites of Sprawling Urban Environment in the North-Western Indian Himalaya (ISRO, EO-AT-CTM, PRL, Ahmedabad; 2008-09 & Onwards as Long-term Study)

Ambient air is one of the most important components of our environment. Deterioration in air quality in the form of particulate matter, gases, and chemicals in the atmosphere create harmful effects and discomfort to human and another living organisms. Several atmospheric trace gases such as surface ozone (O_3), sulfur dioxide (SO_2) and nitrogen oxides (NOx) are released into the atmosphere mainly from anthropogenic sources which chemically are reactive to influence atmospheric process at a regional level. The relation between O_3 and its precursors (NO+ NO_2, CO, VOCs) represent one of the major scientific challenges associated with gaseous pollutants. An analysis of the influence of meteorological parameters on O_3 and its precursors at a specific site can contribute to better understanding of local and regional level pollution. Considering the importance of gaseous air pollution, two monitoring sites were established at: (i) Mohal-Kullu (Himachal Pradesh) and (ii) Katarmal-Almora (Uttarakhand).

Objectives:

- To measure concentration of important gaseous pollutants such as surface ozone (O_3), nitrogen dioxide (NO_2) and sulphur dioxide (SO_2) to establish background values in the Himalayan region.
- To observe local meteorological parameters and relate these with gaseous pollutants, and analyze in the background of long range transport sources.
- To suggest some feasible mitigating measures for implementing at policy level.

Achievements:

1. Surface O_3 at Mohal- Kullu was 24.29± 12.64 ppb in June 2019 and minimum 10.76± 8.3 ppb in December 2019. While NOx concentration was maximum 4.48±1.89 ppb in May 2019 and minimum 2.35 ± 0.7 ppb in August 2019 (Fig. 16a).
2. Daytime concentration of O_3 was found to be directly linked to the night-time NOx. The concentration of daytime O_3 is positively correlated with that of night-time NOx.
3. Total columnar ozone at Katarmal-Almora was found increasing from March 7, 2019 to April 15, 2020 (r = 0.00325). Also, the average aerosol optical thickness (AOT) at 500 nm within 30 minutes sample was 0.47 (r = 0.003) (Fig. 16b).
4. During forest fire months, maximum mean concentration of particulate matter stood to be 66.68±6.50×g m^{-3} for PM_{10}, 48.06±5.34×g m^{-3} for $PM_{2.5}$ and 2572±187.1 ng m^{-3} for black carbon. While concentration of gaseous pollutants - NO_2, SO_2 and NH_3 were 4.9±2.7×g m^{-3}, 2.2±1.6×g m^{-3} and 10.9±1.4 ×g m^{-3}, respectively (Table 11).

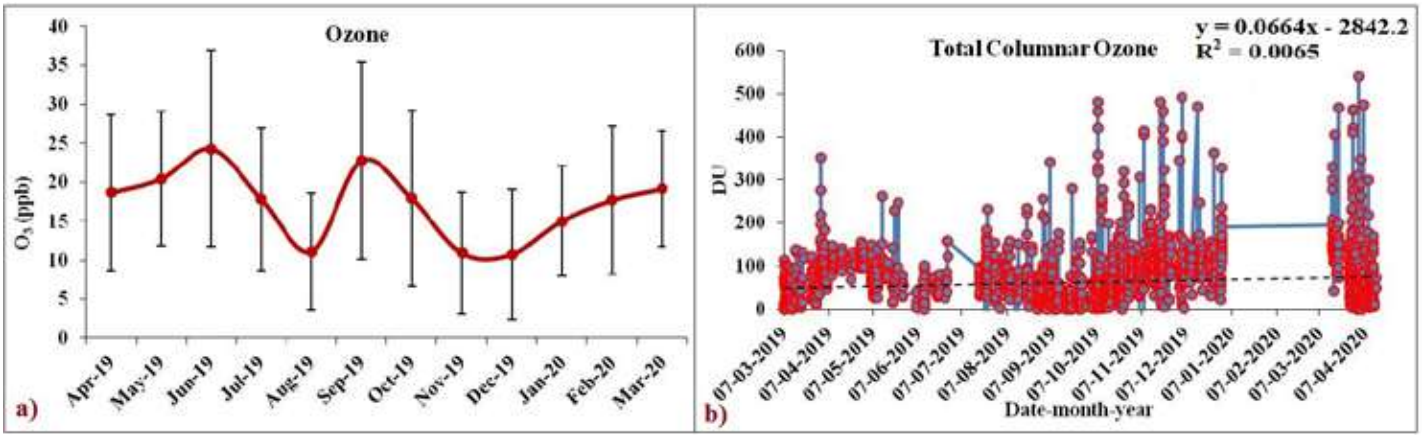


Fig. 16. (a) Monthly concentration of surface O^3 at Mohal-Kullu, Himachal Pradesh, and (b) Total columnar ozone at Kosi-Katarmal, Almora, Uttarakhand

Table 11: Concentration of ambient particulate and gaseous pollutants during forest-fire days based on 24 h and 8 h sampling at Katarmal-Almora, Uttarakhand

Date	Sampling hrs (IST)	TSP (μg m^{-3})	PM_{10} (μg m^{-3})	$PM_{2.5}$ (μg m^{-3})	BC (μg m^{-3})	NO_2 (μg m^{-3})	SO_2 (μg m^{-3})	NH_3 (μg m^{-3})
6/5/2019	0900-0900	157	86	66	2165	3.3	1.4	6.2
7/5/2019		151	88	69	2348	2.6	1.0	8.1
8/5/2019		176	91	74	3051	2.7	0.4	5.2
9/5/2019		198	108	84	7028	4.1	1.4	9.6
10/5/2019		185	113	88	7882	3.3	0.2	8.3
23/5/2019		175	115	94	3732	8.3	1.4	18.2
20/6/2019		269	145	98	1331	7.9	2.8	11.4
25/5/2019	0600-1400	189	114	93	1340	-	-	16.1
	1400-2300	227	144	96		8.2	3.9	12.2
	2300-0600	213	137	93		8.1	2.2	28.7
22/6/2019	0600-1400	259	143	120	1664	7.4	1.4	37.1
	1400-2300	298	166	157		8.9	2.0	42.7
	2300-0600	256	119	153		6.6	2.4	62.9

Aerosols Climatology Over the Northwestern Indian Himalayan Region: Himachal Pradesh & Uttarakhand (ISRO, SPL, Thiruvanthapuram; 2005-06 & Onwards as Long Term Study)

Climate change is one of the most important issues all over the planet where aerosols play an important role in influencing it. The two important sites; one Mohal-Kullu in Himachal Pradesh (in-opeartion since 2005) and other Katarmal-Almora in Uttarakhand (in-opeartion since 2019) sites in the northwestern Indian Himalaya were taken into account. These regions are suffering due to tourists' influx and ever-increasing number of native populations together with forest fires. Some of the aerosols such as sulphate reflects back shortwave radiation into the atmosphere and cools the earth's surface. Black carbon, produced from incomplete combustion of fossil fuel, biofuel and biomass burning, absorbs shortwave solar radiations, and warms the atmosphere thereby contributing to global warming. Also, black carbon aerosol if deposits on snow and ice, it darkens its surface and reduces albedo. This process affects the melting process of snow by increasing it. Aerosols not only affect the ecosystem and its climate but also the human health. The present study unfolds the status of aerosols in these topographically fragile and ecologically delicate regions of the Himalaya.

Objectives:

- To obtain variations in aerosol optical depths (AODs) at ultra-violet, visible and near infrared spectrums (380-1025 nm) using Multi-Wavelength Radiometer (MWR) at Mohal and by using Microtops II Sunphotometer at Katarmal.
- To obtain Black Carbon Aerosol concentrations at Mohal and Katarmal.

Achievements:

1. AODs are wavelength dependent; higher at shorter wavelengths and lower at larger wavelengths indicating dominance of anthropogenic interferences in the surrounding environment. AOD 500nm at Mohal in 2019 stood to be 0.31± 0.12 (Fig. 17a) ranging from 0.10 to 0.61. AOD 500nm at Mohal showing 14.4% increase from 2006 to 2019.
2. Diurnal variation of BC in 2019 (April – December) showed bimodal peaks at Mohal with its highest concentration in the morning and evening hours (Fig. 17b). Here, monthly average BC varied from 1360.3±654.9 to 3069.9±2765.4 ng m-3.
3. AOD 500nm at Katarmal in 2019 stood to be 0.74 ± 0.08 which is mainly influenced by forest fire and other impacts (Fig. 17 c & d). This indicates that finer particles are dominating over the coarse particles showing anthropogenic impacts in the surrounding region.

4. Diurnal variation of BC in 2019-20 (April- March) showed unimodal peak at Kosi with its highest concentration from 1030 ± 354.8 ng m^{-3} at 0500 hr IST (1541 ± 540.8 ng m^{-3} at 0900 hr IST. This is mainly because of two reasons; first shallowness of the boundary layer in the morning and evening, and second biomass burning (fuel wood burning for cooking and heating in the morning, and forest fires either noon or afternoon).

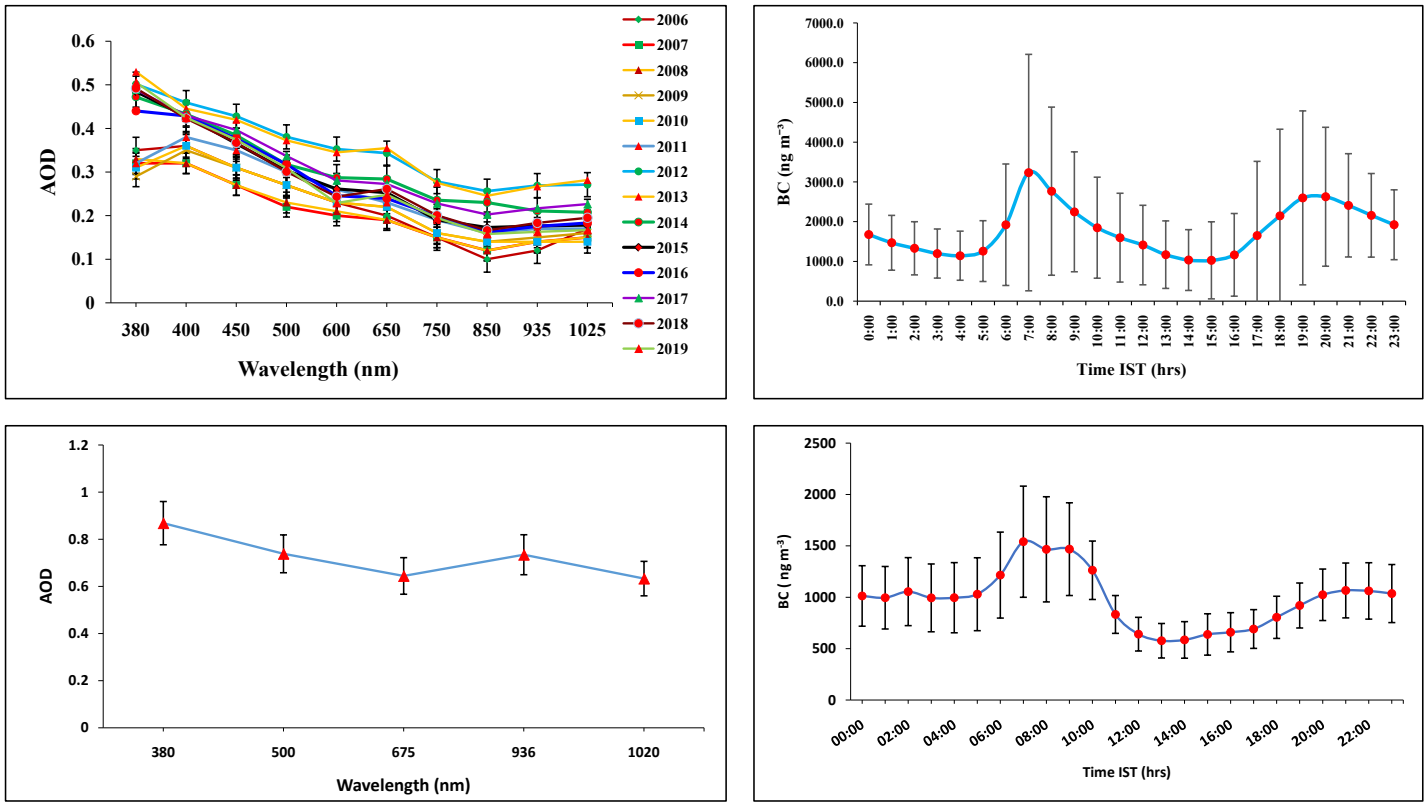


Fig. 17. (a&b) AOD and BC at Mohal in Himachal Pradesh, and (c&d) AOD and BC at Katarmal in Uttarakhand

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

The Himalayan ecosystem is under transformation in terms of its current environmental scenario. These changes from mountain top to its base are melting of glacier/snow, erratic seasonal surface run-off, and its effect in down slope regions mainly on existing developmental interventions. As a result, the two different parts of ecosystems such as snow and/or headwater region on the top of mountains and riverine basins in down slope regions are going to be adversely affected from the northwestern to the northeastern Indian Himalayan Region (IHR). As a result, monitoring of the major impacts due to anthropogenic pressure within these ecosystems in the IHR for a long duration is must in view of mitigation, management and sustainable development.

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, and
- To suggest mitigating measures and management options due to anthropogenic impacts and to

provide policy guidelines for strengthening existing polices, if any.

Achievements:

1. Daily Climate Forecast System Reanalysis (CFSR; globalweather.tamu.edu) data for 36 years (1979-2014) reveals that the seasonal average temperatures have shown increasing trend with different rates in different basins except the precipitation in winter season (Table 12).
2. In Dhauliganga basin, using automatic water level recorder (AWLR) and manual gauging data, the maximum, minimum and average discharge obtained at Dugtu and Sobla which were found to be 12.64, 2.96 and 7.06 cumecs, respectively. While at Sobla, the values obtained were 122.5, 21.35 and 68.74 cumecs in 2019. The total silt load was found 90,510 tons (2018) and 68,967 tons (2019) at Dugtu which were 5,94,964 tons (2018) and 7,10,426 tons (2019) at Dugtu and Sobla in Dhauliganga Basin, respectively (Fig. 18).
3. The isotopic variability of glacier and snow water samples in the Parbati basin in 2019 was much more pronounced than the isotopic content of snow water. Glacier, snow and stream water δ18O values ranged from -12.4 ‰ to -10.4 ‰ with an average of -11.4‰. Whereas, dD values ranged from -84.6 ‰ to -63.5 ‰ with an average value of -74.1 ‰.
4. The land use and land cover (LULC) maps for 2005 and 2017 for the Dhauliganga basin showed 1366 km^2 area. Due to climatic or seasonal variation, the area under snow and glacier decreased from 37.8% in 2005 to 25.8% in 2017 with a change of (-12.1%). However, forest land increased from 9.5% in 2005 to 13.3% in 2017.
5. Green Skill Development Programme (GSDP) at Katarmal (12 Feb. to 02 March, 2020) for 200 hours for 20 participants, in Imphal Basin, was organized for women on 'wild vegetation' in view of their potential for income generation. In this context, lemon grass cultivation, essential oil and banana fibre extraction were introduced to local people during 10-23 February 2020. Here, total 138 participants participated; out of which 100 were women.

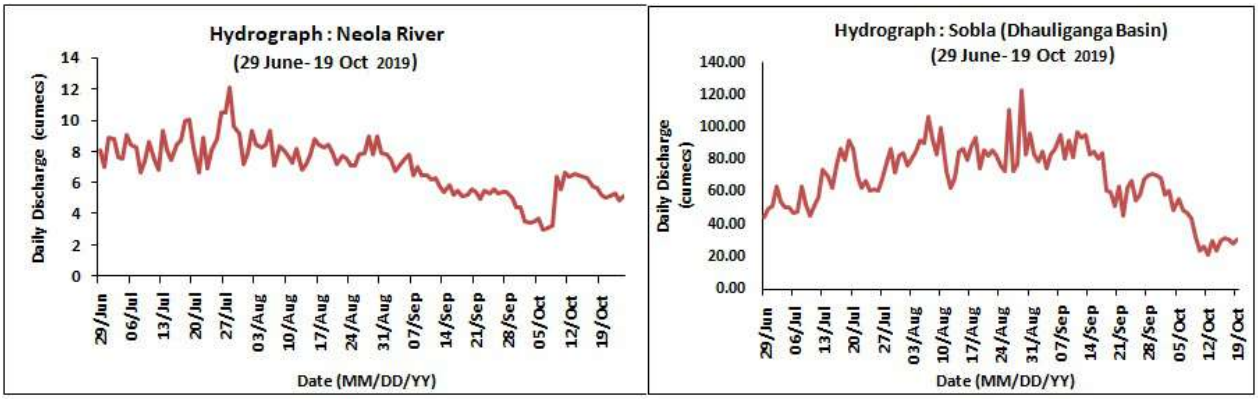


Fig. 18. Daily river discharge in upland and lowland of the Dhauliganga Basin. (a) River Neola, and (b) River Sobla.

Table 12: Rate of increase / decrease of the seasonal average maximum, minimum temperatures (°C) and precipitation (mm) in glacier-fed and non-glacier fed region computed by linear regression slope (b)

Season	Basin	Sindh Basin	Parbati Basin	Dhauliganga Basin	Ranganadi Basin	Imphal Basin
Summer (April-June)	Temperature Maximum	0.011	0.15*	0.064*	0.005	0.011
	Temperature Minimum	0.01	0.141*	0.08*	0.038*	0.014
	Precipitation	4.632*	-2.233	0.45	7.29	0.789
Winter (November-February)	Temperature Maximum	0.227*	0.166*	0.047*	0.172*	0.065*
	Temperature Minimum	0.117*	0.158*	0.033	0.115*	0.017
	Precipitation	-0.635	-1.17	-1.491	-2.775	-0.312

*Indicates a trend statistical significance at 95% confidence level (+ increasing and − for decreasing)

Characterizing Patterns and Processes of Alpine Ecosystem in Indian Himalaya (Space Application Centre, ISRO, Ahemdabad; 2019-2022)

Due to the compression of thermal zones and isolation caused by low temperature, the alpine landscape has highest level of sensitivity to changes in temperature as they are thriving at the threshold of their climatic limits. Least influenced by anthropogenic activities the alpine ecosystems can be considered as "natural laboratories" for observing changes due to climate. In the alpine ecosystems the transition zones (ecotones) are most sensitive spots and changes can be observed there in minimum turnaround time. This study will use the primary data from HIMADRI site to further build the change scenarios and additional science components in order to enhance the understanding of alpine ecosystems in the Indian Himalaya and its response to climatic variabilities.

Objectives:

- Understanding the alpine ecotone structure and function through space based and in-situ observations in Kumaon, Uttarakhand.
- Monitoring biodiversity as per HIMADRI protocol.
- Assessment of nutrient dynamics, physiognomy and physiology in ecotonal zone across elevational gradients around alpine treeline.

Achievements:

1. Transect study has been completed at two HIMADRI summits– (1) Nan-Pakhwa (30°07´22.1´´N, 79°58´33.0´´E; 3365m amsl) and (ii) Pakhwa (30°07´35.7´´N, E79°58´44.4´´E; 3465m amsl).
2. At each summit four transects were laid on North, West, East, South directions from the summit point. Treeline positions were determined on each transects line (zero elevation was considered at the highest treeline point on transect line). Location and altitudinal details of treeline occurrence for each aspect are given.
3. A total of 59 species (9 trees, 11 shrubs and 39 herbs) of plants were recorded in both of the study sites. Number of species reduced from lower summit to upper summit i.e. 55 and 50, respectively.
4. Total tree species number at transects of both the summits was 7, however species composition differs making total number of tree species 9 at the summit region.
5. Total shrub species number at transects of lower and higher summits was 10 and 11, respectively, however species composition differs at summits thus reaching total number of shrub species 11 at the summit region.
6. Total herb species number at transects of lower and higher summits was 38 and 32, respectively. However, species composition differs at summits thus reaching total number of herb species 39 at the summit region. At treeline height (zero elevation), herb species number increased from lower summit to higher summit (Fig. 19).

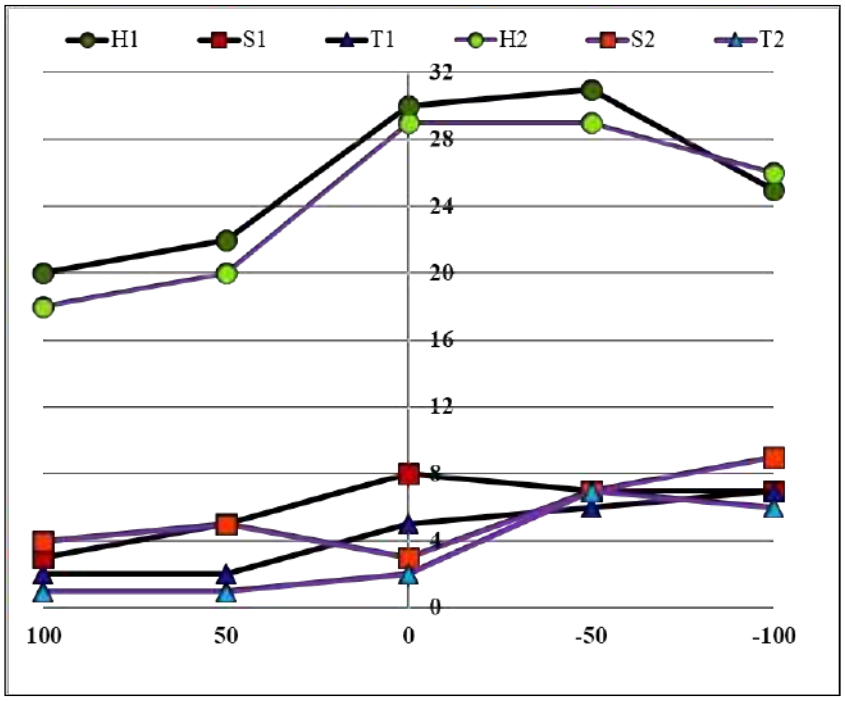


Fig. 19. Total species number along the four transects of both of the Summits (H1= Herbs of Nan Pakhwa, S1=Shrubs of Nan Pakhwa, T1=Trees of Nan Pakhwa, H2= Herbs of Pakhwa, S2= Shrubs of Pakhwa, T2= Trees of Pakhwa).

Undertaking a Study to Define the Extent and Intensity of Habitat Degradation, to Identify the Drivers of Degradation and Prepare a Study Proposal for Developing Model Mitigation Plan in Alpine and Sub-alpine Areas in SECURE Himalaya Project Landscapes of Uttarakhand (UNDP-GEF; 2018-2020)

The rich habitat/biological diversity, current status of habitat degradation and fast depletion of natural resources in the sub-alpine and alpine areas, necessitates the vital need to assess the health of these areas, identify the factors leading to the degradation, identify area where habitat improvement is required and evolve models for effective eco-restoration/mitigation plans. The present project is being implemented in the two vital landscapes of Uttarakhand, i.e., the Gangotri-Govind landscape (31°27'5.25"N- 79°24'44.44"E) in Uttarkashi (Garhwal region), and the Darma-Byans landscape (30°33'36.74"N - 81° 2'27.21"E) in Pithoragarh (Kumaun region).

Objectives:

- To develop an understanding of the issues related to pastureland specifically in the context of degradation.
- To identify the areas of intensive degradation which have the potential of impacting the habitat characteristics of the landscapes.
- To prescribe interventions for eco-restoration/mitigation.

Achievements:

1. In the Gangotri-Govind landscape total forest cover is 679.26 km^2, which has been classified into three classes, viz., dense forest (6.74 %), moderately dense forest (3.85 %), and open forest (3.62%) (Fig. 20). In Darma-Byans landscape, total forest cover 100.59 km^2 has been classified in dense forest (4.4%), moderately dense forest (52.3 %) and Open Forest (43.4 %).
2. Total alpine pasture land of 330.98 km^2 in the Darma-Byans landscape and 107.21 km^2 in the Gangotri-Govind landscape were identified and mapped. In the Gangotri-Govind landscape, major trekking routes, Gangotri to Tapovan in the Gangotri and Taluka to Har Ki Dun in the Govind landscape were mapped with buffering zone of 50 m. In the the Darma-Byans landscape, trekking routes starting from Nazang up to Jolingkong and Kalapani was mapped.
3. Mapping of landslide vulnerable zones were completed in both landscapes by considering 11 thematic layers namely slope angle, elevation, rainfall, proximity to lineaments, geomorphology, lithology, vegetation cover, land use/land cover, proximity to road, proximity to drainage, soil erosion and current landslide points.

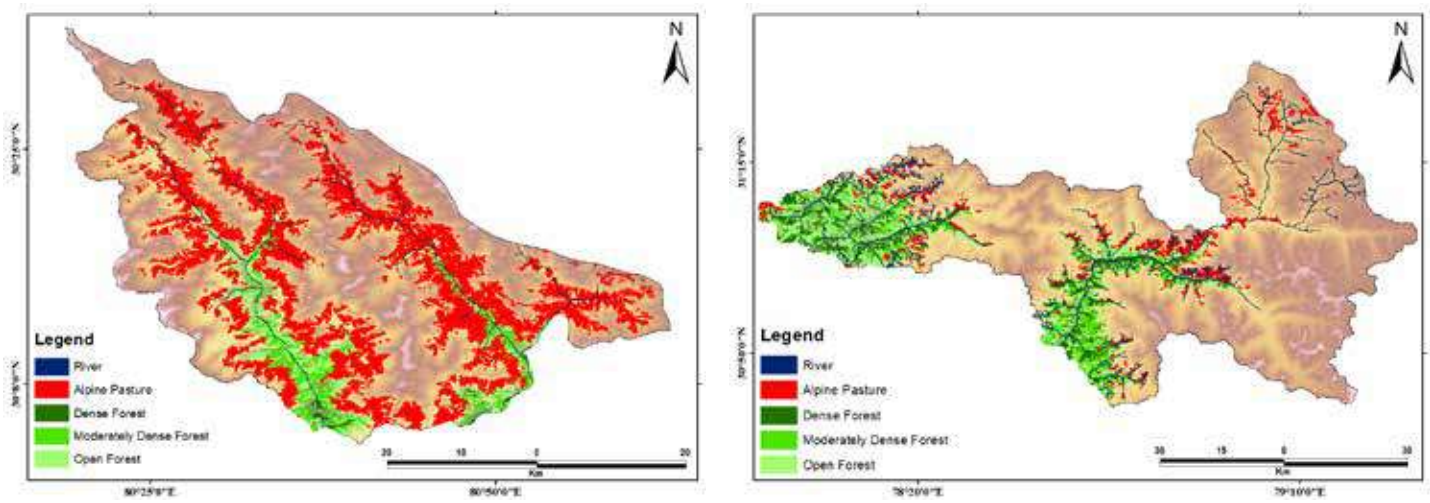


Fig. 20. Forest and alpine pasture cover of: (a) the Darma-Byans landscape (left), and (b) the Gangotri-Govind landscape (right)

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

Betula utilis D. Don (common name: Himalayan birch, Hindi name: Bhojpatra; Family: Betulaceae) 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 - 4,500 m amsl and forms tree line all across the Himalaya. In mountain ecosystem, change in climate is observed along with the change in altitude. 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. Due to natural calamities, changing environmental conditions and over exploitation, the species (*B. utilis*) has become vulnerable and habitat alterations have started taking place. Microbial associations will also change with habitat alterations and climate change. Such changes may affect the mutual benefits of these species.

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 of *B. utilis* populations.

Achievements:

1. Population assessment of *B. utilis* was carried out in two districts (Kullu and Kinnaur) of Himachal Pradesh. Six soil enzymes viz. acid and alkaline phosphates, urease, ß-glucosiadse, aryl sulfatase, and dehydrogenase were selected based on importance in soil nutrient cycle and their activity were assessed in two seasons (growing and dormant season). Alkaline phosphatase, ß-glucosidase and dehydrogenase activity in soil were higher in dormant season, while the physico-chemical content in the rhizosphere soil of *B. utilis* was higher in active season as comparable to dormant season.
2. Suppressive rhizosphere effect was exerted by roots on the rhizosphere microbial community. Total 14 (9 bacterial and 5 fungal) endophytes were isolated from *B. utilis* roots. The isolated microbial endophytes were assessed for qualitative and quantitative plant growth promoting (PGP) activities like ammonia production, Hydrogen cyanide (HCN) production, Indole acetic acid (IAA) production, Phosphate solubilization, Siderophore production and bio-control activities.
3. In Kullu district, the population assessment was done at Fozal valley (04 sites) and Hamta Pass (16 sites) area and in Kinnaur district at Chitkul area. Maximum sites were represented by Shady moist habitat in Kullu district (09 sites) and Kinnaur district (03). Four tree communities namely, *Acer acuminatum, Abies pindrow, Betula utilis, Betula utilis-Abies pindrow* mixed and *Quercus semecarpifolia* from Hamta Pass and three tree communities namely *Abies pindrow – Quercus semecarpifoli*a mixed, *Acer caesium – Abies pindrow* mixed and *Abies pindrow - Acer caesium* mixed from Fozal sites were identified.
4. Two Capacity building cum Awareness Programmes on Himalayan Birch: A critically endangered timber line species were conducted at Dhara and Himbri village of Kullu district.

NMSHE Task Force-3: Forest Resources and Plant Biodiversity (DST Govt. of India, 2014-2020)

The National Action Plan on Climate Change (NAPCC) 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. Accordingly, NAPCC sets out National Mission for Sustaining the Himalayan Ecosystem (NMSHE) as one and the only area-specific mission among the eight National Missions, which envisages to take appropriate measures for sustaining and safeguarding the glaciers and mountain ecosystems. The mission anchored by the Department of Science and Technology (DST), GoI, New Delhi, encompasses six thematic study groups or Task Forces, and GBNIHE has been assigned with responsibilities as Nodal Institute for Task Force 3: 'Forest Resources and Plant Biodiversity'. Task Force 3 has been proposed to undertake the initiative for developing coherent database for forest resources and plant diversity, establishing effective monitoring system for forest resources and plant diversity, validating climate change model projections with reference to forest resources and plant diversity and sensitizing and capacity building of inhabitants towards climate change adaptation and mitigation.

Objectives:

- Development of coherent database for forest resources and plant diversity of the 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 the Indian Himalayan Region.
- Sensitization and capacity building of inhabitants towards climate change adaptation and mitigation.

Achievements:

1. Inventory of wild edibles species of IHR is prepared. A total of 1490 species of wild edibles belonging to 172 families and 748 genera have been documented from different IHR states (Fig. 21). The state-wise distribution of wild edible species revealed an extremely unequal pattern. Uttarakhand had the highest number (636) of wild edible species followed by Sikkim (335), Assam (329), Manipur (310), Arunachal Pradesh (293), Meghalaya (282), Jammu & Kashmir (265), Mizoram (263), part of West Bengal Darjeeling (231), Himachal Pradesh (209), Tripura (199), Nagaland (176) and Ladakh (78).
2. Rapid vegetation sampling in campaign mode was completed in the Eastern Himalaya (Teesta valley of Sikkim) along altitudinal gradient (1000-4000 m amsl) to identify the forest structure, composition and regeneration status of different forest types. The altitude transect assessment has provided quantitative detail on availability, distribution and abundance of 75 tree species (31 families) in the Eastern Himalaya.
3. On the basis of literature review and available secondary data, a total of 476 sacred forest sites were recorded of which, 254 sites showed complete information and 222 sites have partial information. Out of these 476 sacred sites, 318 are sacred groves and 158 are sacred forests. Maximum numbers of sacred forests were found in Pithoragarh district followed by Bageshwar and Champawat.
4. Tree ring width chronology of selected indicator species have been developed. Statistical assessment of selected tree species exhibited high dendroclimatological potentially of these species. At lower altitude sites, a 412-year-long (AD1609–2015) tree ring chronology for *Cedrus deodara*, and 309 year (1707-2015) for *Pinus roxburghii* have been developed.

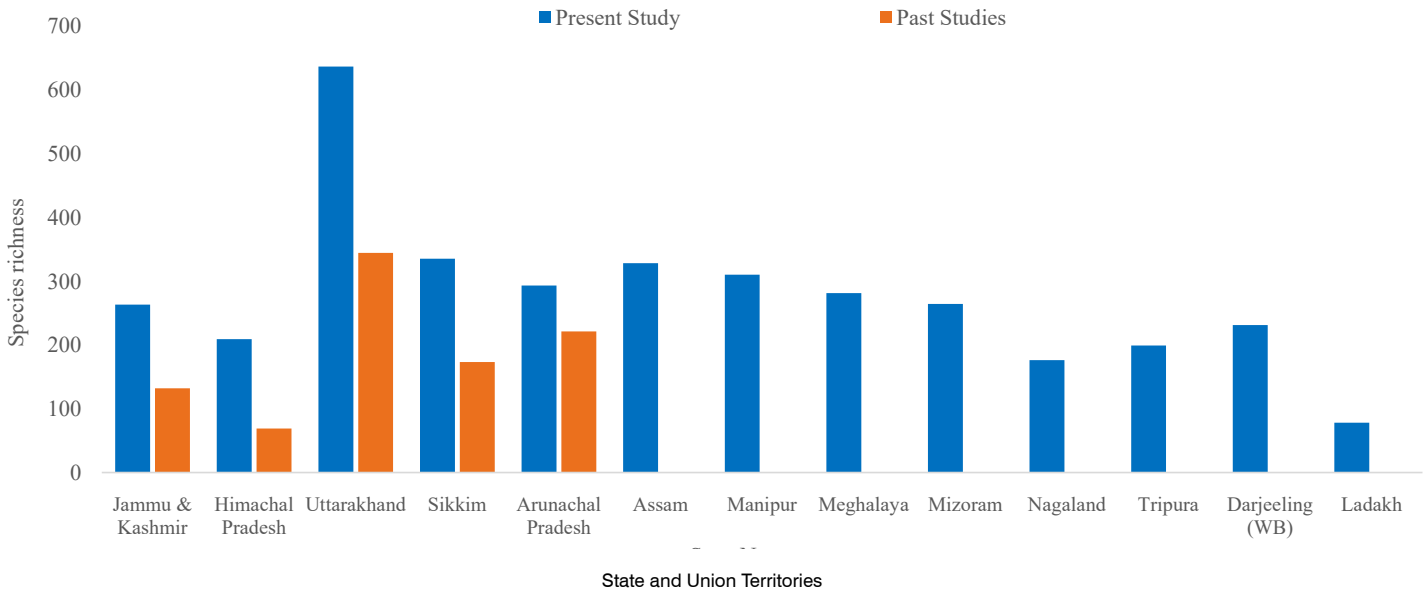


Fig. 21. State wise distribution of wild edible in Indian Himalayan State and Union Territories

Summary of Completed Projects

Conservation and Sustainable use of Biodiversity with Particular Reference to Microbial Diversity (NMHS Fellowship, 2016 to 2020)

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 present study is, therefore, based on the plant microbe-interactions with respect to *Taxus wallichiana.* The extracts of *Taxus* plant parts (needles, stems and bark) have also been investigated for their antimicrobial potential against bacteria, actinobacteria and fungi. The objectives were mainly to: (i) understand diversity of endophytic microorganisms associated with *Taxus wallichiana* roots and their biotechnological applications, and (ii) to evaluate bioactive compounds of *T. wallichiana* with particular reference to antimicrobial activity (bacteria, actinobacteria and fungi).

Two bacteria and five fungi were isolated from the roots of *T. wallichiana*. The Taxus endophytic bacteria, identified as Burkholderia contaminans and Enterobacter asburiae, could grow at wide range of temperature (5-40 °C, opt= 25 °C) and pH (1.5-11.0, opt= 25 °C) and tolerate salt concentration up to 12 %. Burkholderia contaminans and Enterobacter asburiae were found to be potential phosphate solubilizers at wide temperature range (5-35 °C), by utilizing tricalcium, iron, and aluminium phosphate as substrate. Bioformulation of these endophytic bacteria enhanced growth of *Oryza sativa* and *Glycine max* under net house experiments. 5 endophytic fungi of *T. wallichiana* were tested for the taxol production by biochemical and molecular methods. Out of 5 endophytic fungi, two fungi viz. GBPI_TWR F1 (*Penicillium* sp.) and GBPI_TWR F5 (*Aspergillus* sp.) found to be taxol producing with 31.23±0.83 and 60.56±1.07 mg pt/L taxol, respectively. To further improve taxol production, different parameter like temperature, pH, incubation time and medium constituents i.e., salt concentration, carbon and nitrogen source were optimized. 10 compounds (palmitic acid, stearic acid, arachidic acid, behenic acid, myoinositol, hexadecane cinchonine, procainamide, nicotinamide and timolol) having antimicrobial potential were identified from needles of *T. wallichiana.*

GARHWAL REGIONAL CENTER (GRC)

The major R&D activities of Garhwal Regional Centre 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 on 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 objectives of the center include (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.

Summary of Completed Project

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

Stakeholder's attitude/perception on tourism development in Kedar valley was assessed using five factors i.e. environmental, involvement, schemes, development and opportunities. Statistical analysis using Principle Component Analysis (PCA) followed by regression analysis revealed that environmental factors significantly (ß= 0.19, $p < 0.02$) affect the attitude of the local resident in Kedar Valley. Furthermore, it was found that involvement of the local people with tourism related activity was strongly correlated to attitude. Data on yearly, monthly and daily tourist influx were recorded from tourism department of district Rudraprayag that show that after the 2013 Kedarnath tragedy, the year 2014 witnessed relatively lower tourist influx. Nevertheless, beyond 2016, a yearly growth rate of almost 50% was observed in the valley. In the post-disaster years beyond 2015, the two main tourist influx months constitute more than 75% percent of total tourist influx between opening and closing of Kapat of Kedarnath temple. The month of May between 2015-2018 records the highest number of tourist and constitute 65 to 84% of total tourist influx whereas in 2019 the month of June was having the highest tourist influx with more than sixty lakh people visited the district. Solid waste along the route of Kedarnath was quantified, and average solid waste generation during tourist season per day was estimated to be around 49.8, 27.8, 97.4, 99.6, 98.1, 299 and 196.2 Kg/day for Guptakashi, Phata, Rampur, Sitapur, Sonprayag, Gaurikund & Kedarnath, respectively. Annual fuel wood consumption in lodges in the different towns of the valley was estimated, and noted that maximum 208 tons/year fuel wood is consumed by a lodge at Phata while minimum 58.8 tons/year is utilized by a lodge located at Kedarnath. The monetary benefit by each hotel located in different towns along the Kedarnath route was estimated. During peak season (May & June), minimum and maximum net profit earned by a single hotel/lodge was estimated to be Rs. 1.71 lakhs in Gaurikund and Rs. 3.8 lakh in Sitapur, respectively. The minimum profit earned per hotel was Rs. 2.56 lakhs in Phata and maximum Rs. 4.56 lakhs in Guptakashi during the four months of July, August, September and October. Total maximum and minimum income earned per season per lodge was Rs. 9.945 lacks at Sitapur and Rs. 3.22 lakhs at Rampur, respectively. It was also noted that a total of 682 persons are getting employment during peak season through hotels/lodges in the Upper Kedar valley, and average earning per person ranges between Rs.9500-12000. In the upper Kedar valley, one of the livelihoods options of the women folk is fodder collection for the pack animals. There are 6200 pack animals in the valley and about 192 women were engaged in this venture, and on an average, a women earned about Rs.37000 during the period of four months. During the tourist season, thousands of horses and mules migrate to Garhwal Himalaya from Najibabad, Dhampur and Saharanpur of Uttar Pradesh state. In the upper Kedar Valley, approximately 6200 pack animals were used as mode of transportation and more than 4200 persons were engaged in this venture. The average net profit earned by per pack animal owner per tourist season was estimated to Rs. 1.45 lakhs. A total of 09 training programmes (i.e. 03 numbers of two-day programme under pilgrimage tourism and 06 numbers of one-day programme under Swachh Bharat Mission) were organized through which a total of 556 participants (246 women and 310 men) from different villages of district Rudraprayag were made aware about the motives of training programmes. Aims of the programmes were to aware participants about the Swachh Bharat Abhiyan, to encourage pilgrimage and other forms of tourism, and to promote nature conservation. The participants were also provided training on protected cultivation, bio-prospecting of agro and wild bio-resources including medicinal plants (MAPs), home stay, arts and crafts as a source of income. The stakeholder's consultative meetings and workshops played a key role in discussing various issues related to environment, religious belief and employment and emphasized on appropriate action plan and strategies that can address the present issues and can help in opening avenues for livelihood and lead environmental conservation in the valley. The assessment of socio-economic impact of tourism/pilgrimage in the Kedarnath valley manifests that tourism has both positive and negative impacts on the local/ host communities. Its positive socio-cultural impacts include: the improvement of various local services such as health, telecommunications, banking, entertainment and income generation and employment opportunities for local people in diverse areas. However, on the other hand, it also has negative socio-cultural impacts, which threaten the traditional institutions of local environmental governance, and thereby their effectiveness of sustainable natural resource management, and overall quality of life of local people.


NBA

Characterization of Kidney Beans (Rajmash) Rhizosphere Microbiome From Higher Altitude of Indian Central Himalaya and Its Field Application (NMHS, MOEFCC, 2019-2021)

Kidney bean or Rajmash (*Phaseolus vulgaris* L.) is a high value cash crop in Indian central Himalayan region. It is a kharif crop cultivated in Uttarakhand with acreage of about 7350 hectare with production of 7358 thousand ton. The average productivity is 874 kg/hectare as compared to 1217-1430 kg/hectare in plains of India. Although Rajmash is cultivated in plains of India, local cultivars growing in hills are known for their premium quality, unique taste and nutritional values. Presently, the farmers are unable to commercialize the crop due to low productivity. Nevertheless, Department of Microbiology has carried out in depth genomics and proteomics studies of kidney bean rhizosphere microbiome from higher altitudes during the last decades. Moreover, several psychrophilic and psychrotolerant bioinoculants have been characterized in relation to low temperature N_2 fixation and P-solubilization. Based on the past experience, it is being proposed to select commercial Rajmash land races that are highly adapted to local climatic conditions.

Objectives:

- Selection of highly adapted kidney bean cultivation sites.
- Field demonstration of elite cold adapted bioinoculants.
- Monitoring, yield assessment and documentation.
- Determination of rajmash rhizosphere microbiome at selected sites.

Achievements:

1. Database on different accessions of Rajmash from Uttarakhand is prepared following the standard pattern of NBPGR and accessioning. Sites were identified and 32 accessions of Rajmash were collected and assessed for morphological characteristics following standard pattern of NBPGR. Different parameters like weight, length, and width of kidney beans accessions were evaluated (Fig. 22)
2. Local landraces/ germplasm of Rajmash were also collected from Uttarakhand following NBPGR pattern including geographical information, landrace, variety, name of collector and date of collection.
3. The impact of bioinoculant was assessed in a total of 7 farmer's field sites located in Tiryuginaryan, Rudarpryag district, Uttrakhand using psychrophillic and psychrotroph bioinoculant. Local landrace from Triyuginarayan was treated by bioinoculant and growth parameters were assessed.

Fig. 22: Collected specimens of *Phaseolus vulgaris* from Uttarakhand

Standardization of Propagation Protocols For Mass Multiplication, Biochemical Assessment and Elite Identification of *Malaxis muscifera* and *Malaxis acuminata* In Western Himalaya (NMPB, New Delhi, 2019-2022)

In the present project qualitative and quantitative morphological analysis of the *M. mucifera* and *M. acuminata* are proposed for germplasm characterization. The standardization of the propagation protocols, mass multiplication, and reintroduction of the *M. mucifera* and *M. acuminata* in nature will be helpful to meet out the gap of demand and supply, availability of the quality material and continuous supply of the target species along with ensuring the conservation and ecological sustainability of the target species. Identification of elite chemotype will help to identify potential material for future cultivation, development of pharmaceutical and neutraceutical products, bioprospecting and protecting the intellectual property rights along with the long term conservation of these species.

Objectives:

- Exploration, population status assessment and germplasm collection of *M. mucifera* and *M. acuminata* in western Himalaya.
- Identification of elite germplasm of *M. mucifera* and *M. acuminata* using qualitative and quantative morphological and phytochemical variations.
- Standardization of micro-propagation techniques for elite germplasm of *M. mucifera* and *M. acuminata.*
- Development of domestication protocols for target species and community mobilization through participatory approaches.

Achievements:

1. Gap area in the propagation, multiplication and accessioning of the *Malaxis* species has been evaluated by reviewing the information.
2. Sites have been identified for detail morphological and ecological analysis.
3. Morphological assessment of four population of *Malaxis muscifera* has been conducted. Ecological assessment of these populations is also initiated.

Summary of Completed Project/Activity

Rejuvenation of Springs and Spring-Fed Streams in Mid-Himalayan Basins Using Spring Sanctuary Concept (NMHS, MoEFCC, 2016-2020)

Water being a fundamental constituent of environment and vital for the living beings, sensitivity of water recourses has 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 attempted 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.
- Dissemination 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, 2018 and 2019 for Domat Khal intervention site.
2. Intervention site at Domat Khal 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 and drought year of 2019 compared to the 2017 monsoon rainfall. The reason could also be attributed to the fast preferential flows through the stratified meta-sedimentary rocks in the study area (Fig. 23).
3. Deep recharge well in Domat khal indicates 4 to 19% recharge during the monsoon period of 2018. Plantation of appropriate species was carried out through participatory approach involving village institutions, and educational institutes.
4. More than 250 samples of rainfall and springs were collected and analyzed from four different elevation ranging between 1400 m to 1850 m to generate the local meteoric water line as well as to decipher the recharge elevation of Ayal village spring located within the study area.
5. Developed a technical manual on "Inventory and mapping of distribution of springs in headwaters of Paschimi Nayar River, Pauri district" reporting village-wise spring inventory, and creation of Geo-database in GIS domain for Ir-gad watershed.

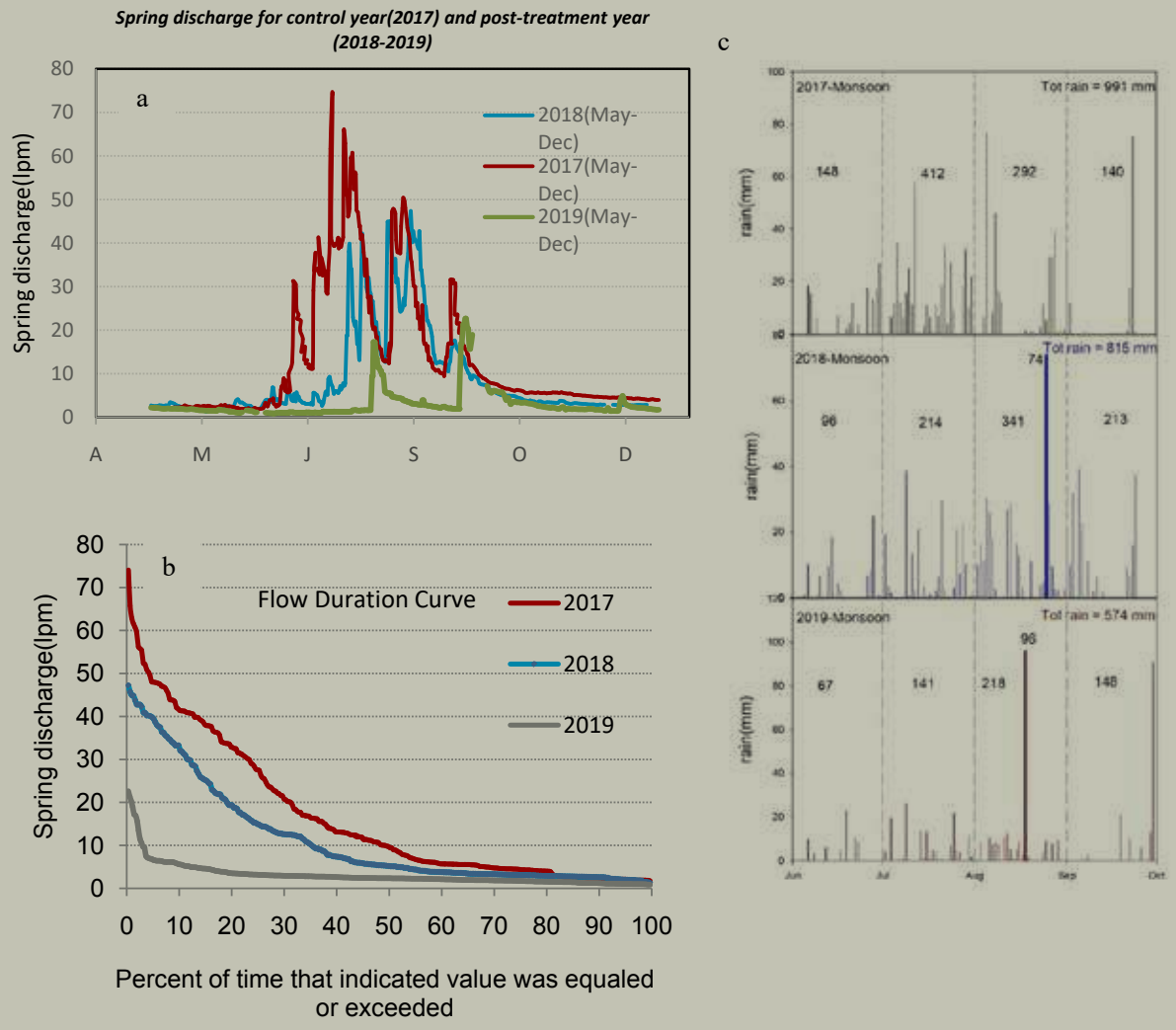


Fig. 23: Spring hydrograph of Mandir dhara spring (a) and flow duration curve (b) during 2017 and post implementation period of 2018 and 2019 do not indicate an increase in the base flow during the post-monsoon period. The variable rainfall pattern for 2017, 2018, and 2019 years (c) is depicted with recent drought year of 2019

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

Indian Himalayan region (IHR) is a global biodiversity hotspot that comprises unique biodiversity of angiosperms, gymnosperms, petridophytes, and bryophytes. However, due to urbanization, anthropogenic pressure and climate change, severally reduced diversity and density of these species ultimately affected 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. Actinorhizal plants are a group of angiosperms and have symbiotic association with di-nitrogen fixing actinobacteria known as *Frankia*. Actinorhizal species are distributed in Asia, Africa, Europe, Australia, North America and South America and grow in a variety of ecosystems like coastal dune, arctic tundra, forest, glacial sediment and alpine region. Thus these species play an important role in regeneration of nutrient deficient soil and also help in reducing the use of fertilizer in horticultural crops and waste land rehabilitation. The proposed project was, therefore, planned to take up the following studies taking two of the important actinorhizal species, namely *Hippophae salisifolia* and *Myrica esculenta* from different forest types of Uttarakhand, mainly with respect to: (a) estimation of rate of nitrogen fixation through standard laboratory techniques, and (b) regeneration pattern assessment using phytosociological parameters. The objectives of the project included (i) 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, (ii) 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, (iii) 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, and (iv) Field plantation and establishment of demonstration plots at different Himalayan locations. The project on completion achieved the following:

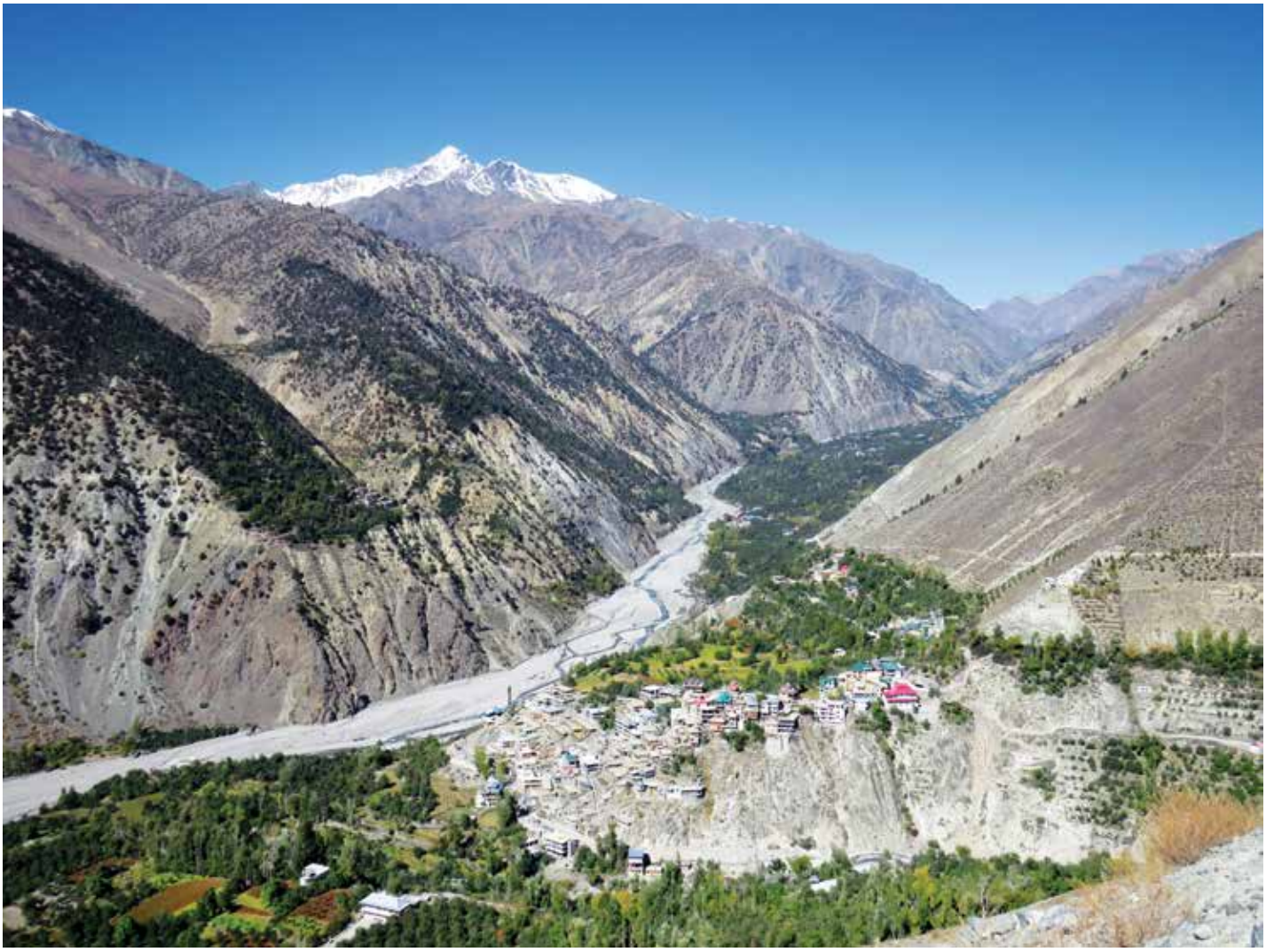
1. Vegetation and regeneration potential of M. esculenta and H. salicifolia was evaluated using standard methods. A total of 17 sites from Uttrakhand (Tehri, Pauri, Chamoli and Uttarkashi) were selected for detailed study of M. esculenta (10 Nos.) and H. salicifolia (7 Nos.). Average nitrogen (10 ± 0.07 gm/kg), phosphorus (0.23± 0.002% gm/kg), potassium (0.670± 0.16 gm/kg), pH (7.08 ± 0.16), water holding capacity (67 ± 5.30%), organic carbon (100.3 gm/kg ± 0.45%), and moisture content (0.74 ± 0.29%) were recorded for M. esculenta. While in case of H. salicifolia average value for nitrogen (0.48g ± 0.04 gm/kg), phosphorus (0.21 ± 0.001 gm/kg), potassium (0.477 ± 0.11gm/kg), pH (7.17 ± 0.24), water holding capacity (59.07 ± 6.65%), organic carbon (89.9 ± 0.55gm/kg), and moisture content (0.50 ± 0.14%) were also determined. Among 10 studied sites of M. esculenta recorded maximum values of N content (Kirshu 10.31 ± 0.06gm/kg) and P content (Ghat 0.03 ± 0.007 gm/kg). Potassium content (Paun 0.808 ± 0.19gm/kg) show varying trend in studied populations. Likewise, maximum pH (Pauri 7.6), water holding capacity (Kirshu 74.9 ± 5.8%), moisture content (Kirshu 1.210 ± 0.141%), maximum organic carbon (Ranichauri 118.22 ± 0.170gm/kg) in different sites were recorded.

2. Several experiments on seed germination of *M. esculenta* and *H. salicifolia* were performed through seeds or cutting to improve seed germination. Different seed treatments (i.e. hot water scarification, H_2SO_4 scarification, and cold scarification) were used for breaking seed dormancy of *M. esculenta*. Non-treated seeds exhibited poor rate of seed germination. Only 1.8% of seed germination was observed among 1000 seeds of *M. esculenta*. Seed germination rate of *H. salicifolia* is good in natural condition due to production of viable seed for longer period. Our seed germination study revealed 70.4% germination of *H.salicifolia* out of total 500 seed sown. However, further experimentation is required to draw clear cut conclusions.

3. Root colonization of *M. esculenta* observed by preparing the slides of roots for microscopic examinations. Total 100 slides of roots were prepared and observed. Total percent of bacteria (55%), fungal mycelium (63%), vesicles (15%), hype (40%), dark septate (43%), arbscules (32%), and spores (65%) were recorded in *M. esculenta* root slide. However, no nodules were recorded during winter season in *M. esculenta* roots. Root colonization of *H. salicifolia* showed total percent of bacteria (41%), fungal mycelium (51%), vesicles (69%), hype (79%), dark septate (28%), arbscules (36%), and spores (79%). Nodules of *H. salicifolia* showed total percent of bacteria (22%), fungal mycelium (80%), vesicles (54), hype (78%), dark septate (23%), arbscules (52%), and spores (69%). These observations were based on microscopy visualization. Moreover, further confirmation of bacterial strains or *Frankia* isolates is required.

HIMACHAL REGIONAL CENTRE (HRC)

The focus of the HRC 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, (iv) development of strategies for monitoring and management of water resources under climate change scenario, (v) assessment and sustainable management of eco-tourism through entrepreneurship development, (vi) assessment, monitoring and analysis of the anthropogenic and natural environmental impacts for developing management strategies, and (vii) development and strengthening of institutional mechanism for information sharing and capacity building of the stakeholders for environmental management.



Summary of Completed Project/Activity

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

The Himalayan ecosystems exhibit a great dynamism, and are recognized for its ecological and economic values manifested by ecosystem integrity, adaptability and ecosystem services. Among the anthropogenic activities, solid waste management has become one of the major problems in the Indian Himalayan region. The unplanned disposal of solid waste by the inhabitants has increased the air, water and soil pollution leading to deterioration of ecosystem health. The baseline data for the solid waste and its management status for the 6 districts of Himachal Pradesh were generated with the primary and secondary sources. The household surveys were performed and the average per capita waste generated for these 6 districts was found to be 0.241 Kg/day. This household waste mainly comprised of Kitchen waste (69-79%), Paper/cardboard (5-14%), and plastic to be 4-9% of the total waste generated. A meeting with rag pickers and scrap dealers was conducted to find out the challenges and suggestion about the better waste management in these cities. It was found that there lies a business potential in this sector if the management practices such as segregation and optimum prices for the scrap are provided. To check the contamination due to leaching and seeping of grey water from open waste dumping sites due to rain was tested and it was found that the water in the streams did not indicate any presence of contaminants above permissible limits. Also, none of the samples showed any sign of heavy metal contamination apart from Iron (Fe) and Zinc (Zn), which were present in very small concentration below harmful level. The results for soil samples taken from control and dumping sites showed that there were increased values of NPK for the soil samples in comparison to control sites. Heavy metal analysis for the soil samples shows that most of the dumping sites do not have any heavy metal contamination above the required limits except the Bilaspur site having Cadmium (Cd) contamination above permissible limits according to FAO/WHO guidelines. These results indicate that at present, the contamination due to dumping site on the water and soil health is not substantial but in near future if the piling of non-segregated waste in dumping sites continues, this can harm soil and water sources. These dumping sites were examined for native floral species which have soil reclamation properties and accordingly suitable species were planted on such sites to extract trace metals and for aesthetic purpose including foul smell. It will help in rejuvenation of the dumping sites and further pollution into soil and water sources will be controlled. Also, for the proper waste management, support from people and administration is required to resolve the waste mis-management in the state. The dumping sites should be made in scientificlly with proper segregation and management techniques to convert waste into resources such as RDF material, cement products etc. The waste generated should be looked as a resource as its reuse can give livelihood to a rag and scrap dealing community.

Identification of Elite Planting Material of Selected Temperate Medicinal Plants, Mass Multiplication, Field Demonstration and Post- Harvest Processing (DBT, New Delhi, 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 led 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. 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 st*udy, high value medicinal plants such as Picrorhiza kurroa*, *Nardostachys grandiflora*, *Rubia cordifolia* and *Swertia chirayita* have been selected for cultivation and conservation.

Objectives:

- Identification of elite planting material of *Rubia cordifolia* and *Nardostachys jatamansi grandiflora* as per API standards of Ayurvedic industries and contents of desired chemical constituents in herbal extracts from different locations of H.P. and Uttarakhand.
- Establish Genetic Resource Center of elite material for target species, *Swertia chirayita, Rubia cordifolia, Picrorhiza kurroa* and *Nardostachys jatamansi* at research stations of HRC or Kullu, H.P.
- Mass multiplication of already identified elite planting material of *Swertia chirayita* and *Picrorhiza kurroa.*
- Optimizing post-harvest primary processing of herbal raw material of *Swertia chirayita* and *Picrorhiza kurroa.*
- Training farmers for proper harvesting, drying, storage, and packaging of herbal plant material as per industry requirements.
- Arranging buy-back mechanism and capacity building of primary growers to set up Marketing Federation.
- Exposure visits of selected farmers to user industries and major markets.

Achievements:

1. A Genetic Resource Center (GRC) was established for germplam conservation of the target species, *Picrorhiza kurroa, Swertia chirayita, Rubia cordifolia,* and *Nardostachys jatamansi* at Dhoranala nursery site of the HRC. Presently, 06 populations of *P. kurroa* of Himachal Pradesh, 03 Population of *R. cordifolia* of Himachal Pradesh and 02 populations of *S. chirayita* from Nepal and Solan, Himachal Pradesh are being maintained at the GRC.
2. Mass multiplication protocols of *S. chirayita* and *P. kurroa* were standardized. *P. kurroa* cultivation is being promoted in around 4 acre land of farmers in Kullu & Chamba districts of HP. Around 20,000 seedlings of *P. kurroa* were also distributed to medicinal plant cultivators of the state. An elite medicinal plants nursery was established at HRC for providing planting material to *S. chirayita* and *P. kurroa* to farmers (Fig. 24).
3. API analysis was carried out of three populations collected from *P. kurroa* from Sainj valley, Parvati valley & Tirthan valley. Picroside content (Picroside I & Picroside II) was recorded highest at Sainj valley (3.75% w/w) followed by Trithan valley (3.65% w/w) and Parvati valley (3.16% w/w). Total bitters was observed maximum at Trithan valley (9.70 %w/w) followed by Parvati valley (8.23% w/w) and Sainj valley (8.22% w/w). Total ash content was recorded between 3.26-4.70 (% w/w) in all three populations.
4. Project review meeting was conducted at HRC, Kullu on 29-11-2019. Project progress of Uttarakhand and Himachal Pradesh were discussed and road map for future project activities was also prepared during the meeting.

Fig. 24. Genetic resource centre of elite medicinal plants established at HRC, Kullu

Returning *Taxus* to the Forests and the People: a Study in Shimla and Kullu Districts of the Indian Himalayan Region (NMHS, MOEF & CC, 2019 – 2022)

The West Himalayan Yew (*Taxus contorta* Griff.) has suffered a severe range wide population decline of up to 90% in the Indian Himalayan Region (IHR), mainly because of overexploitation for its medicinal properties, especially for the commercial extraction of the anti-cancer drug Taxol. Earlier workers have reported a very poor situation of regeneration of this species and have predicted the extirpation of this species from the sanctuary. Hence, there is an urgent requirement of understanding the causes of decline in regeneration and to try to decipher the factors that have resulted in the successful regeneration, in a few habitats where *Taxus* has been able to establish itself. Hence this project would focus on trying to establish those conditions, be it nurse shrubs, shrubs or trees to which the birds responsible for the dispersal of *Taxus* seeds are attracted, or inoculating the soil with mycorrhizae that help in the early establishment of the seedlings, litter thickness that provides the appropriate temperature, soil fauna that aid in creation of the ideal soil environment and help to prevent seed predation, and the soil compaction, pH level, temperature and litter C:N ratio that ultimately help to establish *Taxus* seedlings in the habitat for in situ conservation.

Objectives:

- Assessment and mapping of populations of *Taxus* in Shimla and Kullu district.
- Investigation of the physicochemical and biotic factors associated with regeneration of *Taxus*.
- Development and standardization of protocols for mass multiplication of *Taxus* and comparison of its phytochemistry relative to natural individuals.
- Establishment of plantlets of *Taxus* involving the forest department and the local communities.

Achievements:

1. Ecological niche model of *T. contorta* in Kullu district of Himachal Pradesh was developed by using Maximum Entropy Modeling (Maxent version 3.3.3k). Thirty-one (31) point distribution data (28 secondary and 3 primary occurrence data) of *T. contorta* and 22 bioclimatic variables in high resolution (i.e., ~1 km) (http//www.Worldclim.org) were used to predict the suitable habitat model. Based on Area Under Curve (AUC) value, the quality of model was evaluated and graded as poor (AUC<0.8), fair (0.8<0.9), good (0.9<0.95) and very good (0.95<1.0). MaxEnt developed the potential distribution models of *T. contorta* (Fig. 25). The AUC test was 0.860 ± 0.138 and quality of model falls in the fair category.
2. Contribution of the environmental variables indicated that precipitation of wettest month (bio_13) was the most influential variable out of 22 variables used in determining habitat suitability model and contributed 19.4%. Temperature annual range (bio-7) had the maximum influence on the habitat model considering the permutation importance and contributed to 68.5%.
3. On the basis of habitat suitability for *Taxus contorta*, the map shows that the area with very high probability was 419 km^2 (7.60%) and area with high probability was 429 km^2 (7.79%).
4. Mass multiplication of *Taxus* was carried out through branch cutting. The germplasm was collected from different location of the Kullu district. A total of 6000 saplings of *Taxus contorta* were raised through mass multiplication at the Dhoranala nursery of the institute.

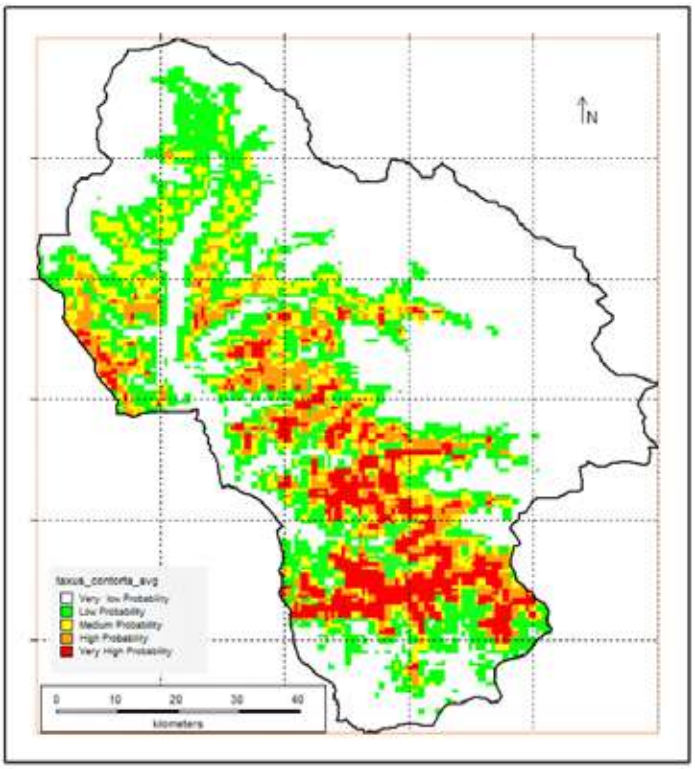


Fig. 25. Map showing species distribution model of *Taxus contorta* in Kullu district of Himachal Pradesh

Development of Peoples' Biodiversity Register (PBR) of Selected Panchayats in Kullu District, Himachal Pradesh – Phase II (Himachal Pradesh State Biodiversity Board, Shimla, 2019 –2020)

The concept of biodiversity has been known to man ever since he began to minutely observe the living being around him. In the simplest sense, biodiversity may be defined as the sum total of species richness, i.e. the number of species of plants, animals and microorganisms occurring in a given region, country, continent of the entire globe. To conserve and protect biodiversity, National Biodiversity Authority (NBA) has initiated to develop Peoples' Biodiversity Register (PBR). Following the initiatives of NBA, Himachal Pradesh State Biodiversity Board (HPSBB) has initiated to document PBR at village, panchayat, block, district and municipality level in selected districts of Himachal Pradesh through Biodiversity Management Committees (BMC) and Technical Support Groups (TSG). This is mainly the second phase of the PBR preparation involving 18 BMCs of the district Kullu and Mandi. 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 BMCs.
- 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 document 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 or 18 village Panchayats namely Manali, Malana, Gojra, Nasogi, Gahar, Neoli, Karjan, Bada Gran, Palchaan, Bhalyani, Bajaura, Haat, Kothisari, Garsa, Danogi of Kullu District and Nau, Chhamyar, Lower Riwalsar of Mandi district were selected for PBR preparation. MoU for the same was signed as TSG with the BMCs and HPSBB, Shimla for the preparation of PBRs.
2. A 2 days meeting-cum-interactive session with the BMC members of 18 panchayats was conducted for PBR preparation and further data collection processes.
3. Extensive field survey and data collection on the various parameters including 36 formats has been collected from the 18 BMCs of the Kullu and Mandi district. Draft preparation of all the BMCs for submission to HPSBB, Shimla is under process.

National Development of Sustainable Rural Livelihood Options Utilizing Locally Available Bio-Resources Through Transformative Rural Technologies in the Indian Himalayan Region of Himachal Pradesh and Sikkim (NMHS, 2018 – 2021)

The Sea buckthorn 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. Sea buckthorn berries (locally known as 'Drilbu 'and 'Chharma' in Himachal) also have the unique characteristics of shrubs throughout the winter months despite of the subzero temperature. As such, many bird's 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. Sea buckthorn can act as a prominent afforestation species of cold desert due to its property of having physiological mechanisms to grow under environmental stress. The inhabitants of this entire cold desert region develop various kinds of good food products like jam, tea, pulp and wine from this wonder berry by using their indigenous techniques.

Objectives:

- Development of 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 region.
- Development of appropriate scientific and technological interventions for processing and value addition of these local

bio-resources into high value products.
- Establishment of 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. Technology Incubation Center (TIC) has been established in Kirting Village, Lahual and Spiti district, Himachal Pradesh for processing of sea buckthorn. MoU done for the TIC and field implementation agency for the day to day work at the unit.
2. Organized 2 workshop/seminar on value chain management of Sea buckthorn in which 191 local inhabitants participated. Problems were identified in the value chain management of sea buckthorn and possible mitigation measures were also done. Awareness on the good harvesting and post harvesting method of Sea buckthorn was spread among the farmers group.
3. Assessed the traditional techniques of harvesting and post harvesting techniques of Sea buckthorn leaves and berries. Seed oil analysis has also been done. Post-harvest method for the Sea buckthorn leaves drying and tea of the leaves has been developed and available on sale under RTC of the institute.

Ex situ Conservation and Development of Gene Bank of Commercially Important Threatened Medicinal Plants in the High-Altitude Areas, Himachal Pradesh (NMHS, MoEFCC, 2019 – 2022)

Biodiversity is most valuable for the human beings directly, indirectly, aesthetically and ethically. The ecological and economical importance of biodiversity for maintaining the environmental balance and socio-economic development of inhabitants has been realized throughout the globe. Sixteen species from Himachal Pradesh and fourteen species from Jammu & Kashmir have been categorized as Critically Endangered and Vulnerable Categories. In view of the above, it is essential to initiate studies on identification of potential natural habitat of RET population and their morphological studies of the selected sensitive high value biodiversity elements; development of convention propagation protocols and evaluation of responses in different propagation systems; ensuring - ex situ conservation. The present study was conducted on above lines in Himachal Pradesh, North West Himalaya with a particular focus on conservation of three selected species *Arnebia euchroma, Carum carvi* and *Angelica glauca.*

Objectives:

- Morphological studies of the selected wild populations and collection of different accessions of selected commercially important threatened medicinal plants.
- Establishment of a gene bank, field observation, chemical and molecular characterisation of target species.
- Selection of elite accessions from the cultivated species, their multiplication (by conventional and tissue culture technique).

Achievements:

1. Field visits for identification and ecological study were carried out on the selected species *(Arnebia euchroma, Angelica glauca, Carum carvi)* in the different high-altitude location of the project site. A total of 25 locations were selected for population assessment of the species (17 for *Arnebia euchroma,* 2 for *Carum carvi* and 6 for *Angelica glauca*).
2. Roots and seeds of selected species from different habitats of the high-altitude area of Himachal Pradesh have been planted in the CSIR-IHBT centre, Ribling, Lahaul Spiti. Also, roots of *Angelica glauca* have been planted in the Dohranala Nursey of our institute at Mohal-Kullu.
3. Seeds of *Arnebia euchroma, Angelica glauca, Carum carvi* has been processed for the further chemical profiling of the species in CSIR-IHBT lab.

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 can be seen as faster melting of glacie, and erratic river flow patterns that impacts hydropower projects, biodiversity, riverine aquatic life and above all livelihood options and well-being of human inhabiting the region. The faster melting of the glaciers and snow causes erratic distribution pattern of surface run-off over the

seasons in the river basins wherein some pockets a 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. So understanding changes in either of the ecosystem due to anthropogenic impacts including climate change and its inhabiting human populations and its mitigation and management options in these sensitive parts of the IHR would be an important 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 100 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. Eight Land use/ Land cover (LULC) categories have been identified and used in current study using different temporal high satellite datasets of Indian Remote Sensing (IRS), LISS-IV Resource-sat 2 MX from 28, October 2013 and LISS-IV Resource-sat 2 MX from 07, October 2017.
2. Parbati River flow was recorded 2.32m/s, minimum velocity 1.63m/s and average velocity 2.10m/s. The observations were recorded thrice during the whole day; morning (8:00 a.m.) afternoon (02:00 p.m.) and evening (07:00 p.m.). Glacier, snow and stream water samples of snout point of Parbati River and surrounding area were collected to check the physico-chemical properties. The concentrations of all chemical parameters were in normal range.
3. To know the 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, etc. questionnaire survey was conducted in Parbati basin (covered 8 villages, 613 households) with the sample size of about 30% of the total village population and number of surveyed households (N=172).
4. A capacity building training was organized in Parbati Basin (25 July 2019) to aware the people including women about 'Bee-Keeping' and its economic benefits. In total, 80 participants, 59 women and 21 male were trained.

Summary of Completed Project / Activity

Standardization of Post-Harvest Technology for Wild Rose Hips and Promotion as Sustainable Livelihood Option Among Poor Self-Help Women Groups in Kullu Valley, Himachal Pradesh (DST, New Delhi, 2015–2019)

As envisaged under the project, 24 Women Saving and Credit Groups (WSCGs) with 203 women were involved in various stages of Rosehip collection and processing. Over 6 workshops cum training programmes (659 women members) were organized for awareness on Rosehip species and its sustainable harvesting techniques (harvesting, cleaning, drying, product development and packaging). Protocol was developed for sustainable harvesting and post harvesting techniques and disseminated among the women member and pictorial handouts for its better understanding. With introduction of post-harvest technology like the Seed Shredder machine, the time and drudgery involved in processing Rosehip pods reduced considerably i.e decoding and separation of the seeds from pods with 200 kg per day capacity as compared to manual 3.4 kg a day. Developed two variants of Rosehip based tea, (Rosehip and Rosehip Mint) and Rosehip seed oil. These products were tested for various parameters by established testing labs such as SGS India Pvt. Ltd, CSIR-IHBT, Palampur, IIT, New Delhi, GBPNIHE, etc. Also, necessary FSSAI certification was obtained for the products. Further, the developed products are marketed through Mountain Bounties and retail stores at regional/state/national level agencies.

Development of Peoples' Biodiversity Register of Selected Panchayats in Kullu District, Himachal Pradesh – Phase I (Himachal Pradesh State Biodiversity Board, Shimla, 2017- 2019)

To conserve and protect unique biological diversity of the different regions of the country, National Biodiversity Authority (NBA) has initiated to develop Peoples' Biodiversity Register (PBR) throughout the country under the 36 different formats. Following the initiatives of NBA, Himachal Pradesh State Biodiversity Board (HPSBB) has initiated to document PBR at village, panchayat, block, district and municipality level in selected districts of Himachal Pradesh by Biodiversity Management Committees (BMC) through the help of Technical Supporting Groups (TSGs). The GBPNIHE was identified as a TSG to develop a PBR in the Kullu district. Under the Phase 1, 24 Panchayats were selected for PBR preparation 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 and final PBR of all the 24 panchayats have been submitted to Himachal Pradesh State Biodiversity Board, Shimla.

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, 2014 – 2020)

The IHR with its unique topography, diverse habitats and varied altitudinal range (200-8000 m, amsl) supports representative, natural, unique and socio-economically important floristic diversity. The high anthropogenic pressure coupled with changing environmental conditions has resulted in rapid depletion of economically important species in the region. Along with this large number of hydro-electric projects (HEP) have come up on the rivers originating from the Himalaya. The adjacent areas towards the GHNP of the Sainj HEP are very rich in flora and fauna including threatened species. The present study has been carried out for conservation of some selected species namely *Desmodium gangeticum, Delphinium denudatum, Polygonatum verticillatum* by doing population assessment, standardization of propagation protocols, promoting mass multiplication, hardening and establishment of seedlings and plantlets of these species.

Total 19 sites sampled for the population assessment of selected species in surrounding areas of Sainj Hydro-Electric Project in the Sainj valley of Himachal Pradesh. Out of total 19 sites sampled for the population assessment, 13 sites containing populations of *P. verticillatum* and 3 sites containing populations of *D. denudatum* were studied and 3 sites were common for both species. Seeds of *P. verticillatum* and *D. denudatum* were collected from the surrounding area of Sainj valley. Seeds of *P. verticillatum* were also collected from Inderkila National Park and Khokhan Wildlife in the last week of October. Seeds and tuber of *P. verticillatum* were sown in the nurseries and herbal gardens at GBPNIHE, HRC-Mohal. 300 plantlets of *D. denudatum* and 350 plantlets of *P. verticillatum* were shifted from old polybags to new nursery and 250 new plants of *D. denudatum* and 200 section cuttings of *P. verticillatum* were shifted from culture room to new nursery.

Status Assessment and Policy Dimension Pertaining to Indian Honey Bee *(Apis cerana)* in Himachal Pradesh (In house Short Term, 2019 – 2020)

Honeybee (Hymenoptera: Apidae) is a social insect known as the most economically valuable insect because of its honey production and pollinating activities. Himalayan region harbors five different species of honey bees. Among these, *Apis cerana, Apis dorsata, Apis florea* and *Apis laboriosa* are native, whereas the European honey bee, *Apis mellifera* is exotic species and introduced to the India. The present study was carried out to know the status of Indian honey bee *(Apis cerana)* colonies maintained by the beekeepers/farmers of the Himachal Pradesh. The study was conducted in four districts i.e., Kullu, Kinnaur, Mandi, and Kangra in upper, mid and lower hills of Himachal Pradesh. Structured questionnaire was prepared and data was collected through questionnaire survey objectives from randomly selected beekeepers of the selected study sites. Among the 04 districts, a total of 1560 household (farmers/beekeepers) representing to 158 villages, 77 Panchayats of 12 blocks were surveyed to gather information on various aspects of Indian honey bee. Majority of the respondents have the knowledge about the Indian Honey bee in all the study sites and most of them knew about the Indian honey bee since last 10-20 years. Most of the respondents agreed that the Indian honey bee is the most suitable and well adapted for beekeeping in cold climatic conditions. As per the survey conducted, due to excessive use to pesticides, heavy use of agro- chemical, modern cement houses, shortage of bee flora and climate change, the population of honey bee is declining over the period of time at all the study sites. The farmers strongly agreed that implementation of following measures may be helpful to increase the declining population of Indian honey bee i.e., conservation of remaining wall hives, controlled use of chemical and pesticides in hill agriculture, massive training on bee disease identification and their management, wide publicity of Govt. projects and schemes related to beekeeping development, providing training on the use of modern beekeeping equipment's and motivating the rural youth for adoption of the beekeeping as a sustainable livelihood option.

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 Fellowship, 2016 – 2020)

The mountain ecosystem is one of the most vulnerable ecosystems to the climate change and so are the mountain communities, especially those which mainly depend on animal husbandry, marginal agriculture and horticulture. The present study was carried out at Mohal (1154 m), Kothi (2500 m), Raison (1359m) and Beasar (2181m) in Kullu valley. Beasar was seleted as a control site. Air Quality was monitored throughout the project period. Respirable Dust Sampler (RDS; Envirotech NL-460) was used to monitor PM_{10} under ambient air quality monitoring based on filtration-gravimetric method. Fine Particulate Sampler (APM-550 make Envirotech) was used for $PM_{2.5}$. The Whatman Glass Micro Fibre Filter paper (GF/A (47 mm) was used to expose $PM_{2.5}$. The samples were exposed on 24 hourly bases. The monthly mean concentration (January 2017 to December 2017) of TSP at Mohal was observed 76.5± 3.14 and for Kothi it was 47.4 ± 4.19 $\mu g\ m^{-3}$ (for three months), respectively. The maximum concentration was 187.2 $\mu g\ m^{-3}$ at Mohal and 93.3 $\mu g\ m^{-3}$ at Kothi on 31st December and 11th April 2017, respectively. While the minimum concentration at Mohal and Kothi were 7.2 μg m-3 on 31st August 2017 and 24.7 $\mu g\ m^{-3}$ on 17th May 2017, respectively. A study of air quality in terms of gaseous pollutants throughout the year from January 2017 to December 2019 showed that all the parameters such as NO_2, SO_2 and NH_3 were well within the permissible limit. During winter season the $PM_{2.5}$ concentration ranged between 10.4 μg m-3 to 53.3 $\mu g\ m^{-3}$ with the mean value of 22.7±1.8 $\mu g\ m^{-3}$. During spring season the highest concentration of $PM_{2.5}$ (51.3 $\mu g\ m^{-3}$) was observed on April 24, 2019. The value of $PM_{2.5}$ was recorded minimum 5.6 $\mu g\ m^3$ on April 14, 2019. The average concentration of $PM_{2.5}$ was observed 23±3.4 $\mu g\ m^{-3}$. While the status of $PM_{2.5}$ during summer season was observed 42.1 $\mu g\ m^{-3}$ as maximum on May 04, 2019 and 18.4 $\mu g\ m^{-3}$ minimum on June 03, 2019. The $PM_{2.5}$ concentration ranged between 10.3 $\mu g\ m^{-3}$ to 40.6 $\mu g\ m^{-3}$ with the mean value of 21.6±1.9 $\mu g\ m^{-3}$ at Raison. Highest concentration of PM_{25} (40.6 $\mu g\ m^{-3}$) was observed on June 20, 2019. On the other hand, at the Beasar (Control) site PM_{10} concentration ranged between 3.1 $\mu g\ m^{-3}$ to 17.2 $\mu g\ m^{-3}$ with the mean value of 10±0.9 $\mu g\ m^{-3}$. The AQI study reveals that air quality of Mohal falls under good to moderate category. The seven days back trajectories were drawn using Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) from National Oceanographic and Atmospheric Administration to indicate long range transport source during pollution episodes. Most of the air masses reach Kullu valley from western regions and some are from Indo-Gangetic regions. Temperature data of 35 years was analyzed from 1985-2019. Temperature is continuously increasing in the study area. The maximum temperature was recorded 29.5°C during 2019. On the basis of temperature data analysis, the temperature has been increasing at the rate of 0.07° C per year. Chilling hour's data were calculated during 2009-10 to 2019-20. Chilling hours is decreasing at the rate of 22.7 hours / year which is directly impacting the apple production in the region and is also leading to an increase in the occurrence of diseases in apple orchards.

SIKKIM REGIONAL CENTRE (SRC)

Sikkim state supports rich floral and faunal diversity varying in different eco-climatic ranges (300m to 8685m). The high endemic and threatened species covering diverse ecosystems and habitats represent the unique biodiversity of the state. Local people are largely dependent on natural resources for their livelihood. However, over-extraction and utilization of the natural resources demands immediate measures 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. Considering the abovementioned priorities of the region, Sikkim Regional Centre (SRC) of the Institute has been working on environmental and developmental issues of the Sikkim Himalaya which includes entire Sikkim state and West Bengal Hills (Darjeeling & Kalimpong districts). Main thrust areas of Sikkim Regional Centre are (i) Biodiversity safeguarding at ecosystem, species and genetic level, including ecosystem services, (ii) Natural resource use, management, and sustainability, (iii) Geo-environmental assessment of land hazards and mitigation strategies, (iv) Assessment of climate change impacts and vulnerability on critical ecosystems, and (v) Enhance implementation of strategies through participatory planning and policy analyses.

Summary of the Completed Project

Gridded Biodiversity Database for Conservation and Development in Sikkim Himalaya (focus: woody taxa) (In house Project, 2017-2020)

Biological resources are viewed as 'resource capital' of a nation. Cataloging, mapping and geographical distribution of these natural resources are the most important information needed for conservation and management of biological resources. There is need for cataloging and mapping of natural plant resources, including Endemic, Rare, Endangered and Threatened plant species for drawing suitable management plan to conserve these species under the climate change scenario. Sikkim, the state of north-eastern region of India, is very rich in floral and faunal diversity. The varied ecological conditions such as rainfall, temperature, altitude as well as soil allow abundant growth of tropical to alpine flora in the State. This project was aimed at a fine-scale quantitative assessment and grid based spatial datasets of the woody taxa diversity, floristic composition, population structure, socio-economic dimension and mapping threats on natural 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. A total of 58,434 individual stem size ≥10 cm girth at breast hight (gbh) were recorded in 63 transects under seven major forest types. The phytosociological analysis yielded 431 species from 306 genera and 116 identified families (Table 13).
2. Tropical semi-evergreen, subtropical mixed broad leaved, subtropical oak-dominated, rhododendron mixed and Himalayan wet temperate forests represents a highly heterogeneous and diversified community coupled with low Simpson's dominance index and high evenness index and also shared mixed dominance of a number of species in top canopy, sub-canopy and under-storey.
3. Mapping of villages in and around the Khangchendzonga Biosphere Reserve (KBR) in Dzongu, North Sikkim was carried out and socio-economic survey was carried out in three fringe villages of KBR-: (i) Sakkyong (1556 m asl) (ii) Lingdem (1218 m asl) and (iii) Lingthem (1026 m asl).
4. Based on the survey, total 20 medicinal plants, 19 wild edible plants, 7 species for handicrafts, and 20 plant species for other purposes, used by the Lepcha tribes of the region, were documented. Fruits and the seeds are most used parts of the plants in comparison to the other parts.
5. Further, distribution records of species (14,439 individuals of 2,114 species, including herbs, shrubs and trees) from secondary information incorporated in different sampling grids for further strengthening the spatial database. By using primary and secondary information on distribution of natural plant resources, database for 84 sampling grids was prepared for Sikkim Himalayan region.
6. A template on information for each sampled grid was prepared for generation of grid based spatial database. Complete information of each transects viz., number of species, girth classes, fauna, major vegetation types, disturbance, hazards, etc., was incorporated and hyperlinked with the designed template.
7. A Herbarium was established at Sikkim Regional Centre of GBPNIHE wherein 2,789 herbarium specimens of flowering plant species and 1,245 specimens of lichen were prepared and preserved. A total of 738 species of flowering plants (trees, shrubs and herbs) and 127 species of lichens were identified. This includes fourteen new records for the state and one new record for the country.
8. Documentation of Sacred Groves (SGs) as model for community based conservation of biodiversity (Gumpa forest-worshipped and protected by the Buddhists community and Devithans- worshipped by the people of Hindu faith) in Sikkim was carried out through field survey. A total of 23 SGs were documented out of which 4 were in South district, 8 in East district, 7 in West district and 4 in North district of Sikkim. It also included information on dominant floral species, threats and conservation measures of the sacred grove of Sikkim Himalaya.
9. A document on woody taxa of Sikkim Himalayan region, emphasizing their spatial distribution, taxonomic description and current status was developed. A monograph of woody taxa (endemic, threatened and medicinal and economically important, including rhododendron species) of this region was prepared.

10. A first of its kind grid based spatial database of natural plant resources developed for Sikkim Himalaya would help in long-term conservation and management planning for Sikkim Himalaya. The data generated will also help in developing the thematic maps for the region which could be useful for the forest managers to draw up suitable working plans and conservation strategies at a regional level. The same could be replicated in other states of IHR and in neighbouring countries.

Table 13: Phyto-sociological attributes, floristic composition and species diversity of woody taxa for the seven forest types of Sikkim Himalayan region.

Parameters	Forest types						
	TSDF	TMDF	TSEF	SMBF	SODF	RMF	HWTF
Transect sampled (nos.)	11	8	11	13	7	6	7
Area (ha)	5.5	4	5.5	6.5	3.5	3	3.5
Number of individuals	11,732	8,243	9,638	9,705	7,775	6,854	4,487
Number of species	94	102	154	196	204	124	84
Number of Genus	74	78	104	158	144	82	68
Number of Family	31	38	48	69	64	51	39
Density (ha^{-1})	693.71	598.4	607.27	862	904.1	304	209
Basal area (m^2 ha^{-1})	15.0	16.56	20.73	17.52	14.31	15.64	19.02
Mean basal area (cm^2 $individuals^{-1}$)	216.34	276.82	341.44	203.29	158.28	141.5	149.2
Shannon's diversity index	0.792	1.665	1.955	1.93	1.9	1.34	1.29
Evenness index	0.401	0.842	0.874	0.815	0.808	0.784	0.792
Dominance index	0.464	0.036	0.017	0.024	0.022	0.031	0.042
Species richness index	22.884	29.607	50.76	61.519	57.573	44.27	40.28

Tropical sal-dominated forest (TSDF), tropical moist-deciduous forest (TMDF), tropical semi-evergreen forest (TSEF), subtropical mixed-broadleaved forest (SMBF), subtropical oak-dominated forest (SODF), rhododendron mixed forest (RMF) and Himalayan wet temperate forest (HWTF)

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

The Khangchendzonga Landscape (KL), one of the six transboundary landscapes identified in the Hindu Kush Himalayan region is home to diverse ethnic communities and rich in biodiversity. It 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. The KLCDI programme offers a common platform to the three countries for sharing the transboundary issues (e.g. human-wildlife conflict, limited livelihood options, natural resources management, and climate change) and collective efforts to resolve them and undertake a sustainable approach for management of the natural resources and better livelihood to the marginalized communities. In India, the KL spreads from 26°29'13.56" to 28°7'51.6" latitudes and 87°59'1.32" to 89°53'42.96" longitudes with elevation ranging from 40-8586 masl covering an area of 14061.7 km^2 which include Sikkim and northern part of West Bengal (districts Alipurduar, Darjeeling, Jalpaiguri, and Kalimpong). The aim of the KLCDI include management and conservation of ecosystem services for improved livelihoods and enhanced ecological integrity, economic development, and sociocultural resilience to environmental changes. The defined activities have been concentrated in three pilot sites in India (i.e. Bandapani- a foothill range of West Bengal; Barsey-Singalila -lies within the political boundary of Darjeeling, West Bengal and West Sikkim; and Dzongu-part of Khangchendzonga National Park in North Sikkim).

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.
- To strengthen regional cooperation for transboundary landscape management in the Khangchendzonga Landscape.

Achievements:

1. Provided technical supports to more than 163 beneficiaries for polyhouse (06 Nos.), vermicomposting (04 Nos.) and resource recovery/waste segregation centre (01 No.).
2. Promoted traditional knowledge systesm (TKS) of Lepcha tribe (12 households) on use of nettle plant (*Girardinia diversifolia*) as alternative livelihood option and conservation of TKS.
3. Developed participatory integrated landscape-level management strategy/ plan by defining and evaluating the extent of landscapes (alpine and subalpine) in selected districts of Sikkim.
4. Situation analysis of water security in Bandapani pilot site of KLCDI-India was conducted using GIS-based interventions, with special emphasis on Garochira pilot village.
5. Generated baseline information on Yak subsistence livelihood and challenges from highland areas of KL-India through community consultation.
6. Established one long-term monitoring site in Neora Valley National Park, Kalimpong for systematic monitoring of maling bamboo (*Yushania maling*), and collected data to study species richness in tree, sapling and seedling layers (Fig. 26).
7. Built skill and capacity of community groups through synchronizing community-level activities e.g., Songbing culture tourism festival in Dzongu, Sikkim livelihood promotions (ecotourism, organic farming, solid waste management, etc.) in Gorkhey-Samanden village of Darjeeling.
8. Developed knowledge products such as technical manual on low-cost organic farming techniques; a policy brief "Converting conflicts to consensus: A road map for mitigating human-wildlife conflict in the Khangchendzonga Landscape", a issue brief "Protecting a Himalayan icon: The need for transboundary cooperation to secure the future of yak in the Khangchendzonga Landscape", and working paper "Transboundary ecotourism in the Kangchenjunga Landscape: Opportunities for sustainable development through regional cooperation".

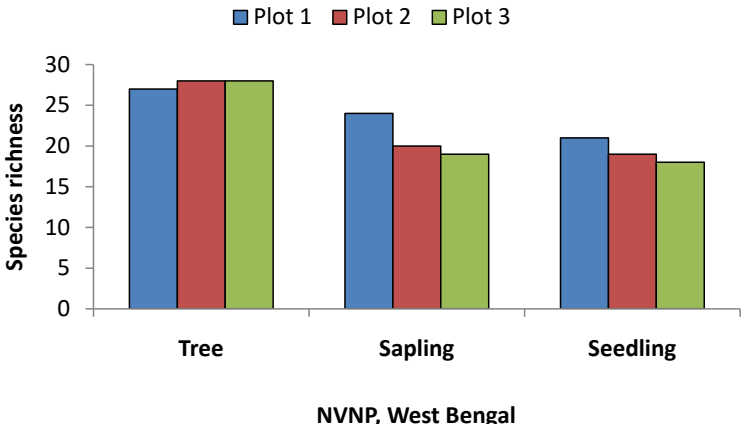


Fig. 26: Status of species richness of tree, sapling and seedling in three long-term monitoring maling (bamboo) experimental plots (1 ha) in NVNP.

Promotion of Sustainable Community Based Tourism in the Khangchendzonga Landscape: Linking Livelihoods with Nature Conservation (NMHS, MoEFCC, New Delhi, 2018-2021)

Tourism development in the Indian Himalayan Region (IHR) has experienced continuous growth. Thus, tourism promotion and development in IHR can diversify local economy through employment opportunities and by engaging locals in income generation activities. However, large scale tourism promotion and development in IHR poses threat to the natural and cultural heritage. Therefore, to bring tourism into the main stream of development agenda, it needs to consider 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. This discourse was brought into the Khangchendzonga Landscape (KL) of IHR by implementation of this project. The Indian part of KL harbors 17 protected areas, including recently inscribed the Khangchendzonga National Park a UNESCO World Heritage Site, rangelands and alpine-pastures, rich biodiversity and ethnic diversity. Hence, it sets a suitable platform to introduce community-based tourism in the landscape to generate employment, income and conserve local cultural and natural heritage.

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. Field surveys were conducted at three pilot sites, namely Barsey-Singalila (Okhrey, Ribdhi, Hillay, Gorkehey and Samanden villages), Dzongu (Lingthem, Lindem and Tingvong villages) and Bandapani to collect baseline data. A total of 38 Homesatys were inventorized in two pilot sites (11 in Dzongu and 27 in Barsey-Singhalila).
2. Six training programmes were organized at Dzongu and Barsey-Singhalila pilot sites of KL for strengthening the community-based ecotourism, and developing Homestay model.
3. For implementation and monitoring of Community Based Ecotourism (CBET) at Barsey-Singhalila Pilot Site, Ribdi Bharang Eco-tourism Committee (RBETC) was formed in consultation with panchayat president, SHGs, and local community and stakeholders.
4. A total of 2,345 plant species were recorded from three pilot sites to develop complete inventory of floral resources for study sites of KL.
5. A manual on monitoring protocol of key species was drafted wherein 14 species (3 angiosperms, 2 lichens, 3 mammals, 2 birds, 2 butterfly and 2 herpeto-fauna) included and their conservation status, distribution map, description and monitoring protocol was depicted.

Establishment of Nature Learning Centre, Sikkim (NMHS, MoEFCC, 2019-2022)

Sikkim state is rich in floristic biodiversity. The diversity of plants as well as other life forms in the state is yet to be enumerated. Lack of awareness on the rich biodiversity causes problems in its management. Hence, there is a need to make efforts to utilize the available natural resources of the State to educate and create awareness among diverse stakeholders for protection and conservation of nature. In Sikkim, there have been few scanty initiatives and interventions taken by various departments and councils towards creating awareness and sensitizing people on nature conservation; these are often isolated efforts and thus need a concentrated and focused approach through a dedicated Nature Learning Centre (NLC) which may work towards increasing understanding of the nature, natural ecosystems, biological resources, their importance and conservation. Keeping this in view, a project is intitited to establish NLC at Sikkim Regional Centre, Pangthang in collaboration with Forest, Environment and Wildlife Management Department of Government of Sikkim and supported by National Mission on Himalayan Studies (NMHS), Ministry of Environment, Forest & Climate Change, government of India. The main aim of the NLC are: awareness and dissemination of knowledge on nature conservation through various models; development of conservation and demonstration site for different representative taxa of the region; develop learning

module and knowledge products; capacity building of different stakeholders for conservation and livelihood generation; promotion of citizen science approach for conservation education and create a cadre of nature enthusiasts in the state.

Objectives:

- To develop a learning and interpretation centre for biodiversity conservation through various interactive models.
- To develop and demonstrate best practices on sustainable models such as forest management practices, waste management, composting, water harvesting, etc.
- To promote participatory conservation action and efficient utilization and management of natural resource base for livelihood generation.
- To promote eco-tourism for biodiversity conservation and livelihood generation.
- To build capacity of diverse stakeholders on conservation of resource base and development of knowledge products for dissemination and awareness generation.

Achievements:

1. Inventorization and documentation of plant species of the arboretum (including herbs, shrubs, trees and seedlings) of Sikkim Regional Centre has been completed. Subsequently, preparation of herbarium of herb and shrub species for proper identification and authentication has been done along with the tree tags preparation.
2. Complete check-list of tree species within the arboretum and outside, with vernacular names and families has been prepared.
3. One Orchidarium is under construction, and sites for one Rhododendron trail and fern trail have been identified within the arboretum.
4. Development of nature trails (2 No.) and water conservation model (1 No.) has been initiated.

Developing Disaster Resilience Action Plan through GIS and Prioritizing Actions for Natural Disaster Risk Reduction in Urban Agglomerations of Shillong and Gangtok (NMHS, MoEFCC, 2017-2020)

Urbanization exerts environmental stress (including air and water pollution, deforestation, construction activities) and increases the risk of frequency of natural disasters like food, landslides, water scarcity, etc., thereby enhances the risk of hazards as well as vulnerability of the urban population. 60% of the country's landmass and various geological settings are prone to earthquakes of various seismic zones, 40 million hectares of land is prone to floods, 8% prone to cyclones and 68% face drought of some form which directly impact agriculture, water, environment and health. The north-eastern region of the country primarily faces three main disasters: earthquake, landslide and flood and more vulnerable to natural and man-made disasters owing to its location, fragile geo-environmental setting and economic underdevelopment. A high degree of vulnerability to these disasters may lead to environmentally insecure region in the future unless pragmatic interventions are made. 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. Sikkim, which falls under the seismic Zone IV is presently undergoing through disproportionate urbanization because of the fast-growing population and tourist influx. This collaborative project between IRAde, New Delhi, GBPNIHE Sikkim, and NESAC Shillong focuses on study of two cities (Shillong and Gangtok) with a view to develop disaster resilience plans using Geographical Information System (GIS). Under this project, GBPNIHE, 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 priorities 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. Focus group discussion were carried out in Gangtok and Shillong municipal area wherein a total of 1175

respondents from both the cities participated. In Gangtok Municipal Corporation (GMC), earthquake was identified as the main hazard (37%) followed by hailstorm (24%), erosion (15%), landslide (15%) and thunderstorm (8%) during last two decades.

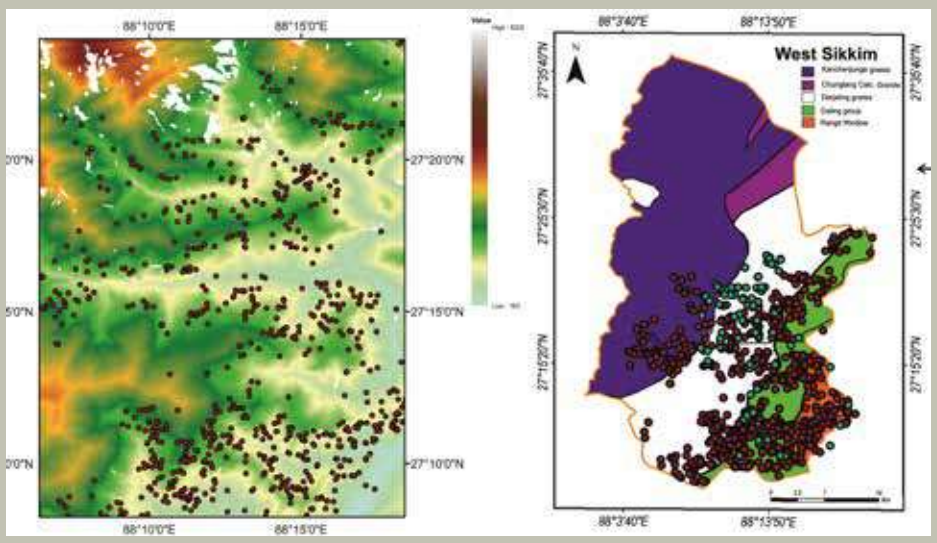
2. In Shillong Municipal Corporation (SMC) area earthquake was considered as the main hazards (48%) followed by landslide (16%), fire (18%), flashflood (13%) and hailstorm (3%) during the past 20 years.
3. 80% of people have experienced climate change during last 2 decades in GMC including increase in summer temperature (60% respondents), increase in the winter temperature (48% respondents), insignificant change in monsoon rainfall (55% respondents) and winter rainfall (82% respondents) patterns.
4. In SMC, deforestation was considered as the main reason for climate change (48% respondents), followed by urbanization (18%), natural reasons (8%). An increase in both winter temperature (63% respondents) and summer temperature (82% respondents) was also preceived. According to 56% respondents, monsoon rain in Shillong has decreased and high variability in its pattern and seasonality was felt during last two decades.

Summary of Completed Project / Activity

Inventorization and Mapping of Springs in West Sikkim District of Sikkim (NMHS, MoEFCC, 2019-2020)

In mountains springs are the main sources of fresh water which serve nearly 40 million people across the Himalayas. Over the years, these precious resources are drying up or becoming seasonal. In Sikkim, acute water shortage is also felt in many villages due to drying of the springs. Nearly 80% of the state's rural households are dependent on springs for drinking water and irrigation purpose. In Sikkim, water scarcity is more pronounced in South Sikkim and West Sikkim districts. Under the National Mission on Himalayan Studies (NMHS) programme, SRC started "Jal Abhyaranya" programme for inventorization and rejuvenation of natural springs in West Sikkim district, one of the aspirational districts in 12 IHR states. The main aim of the programme was to develop and demonstrate models of Jal Abhyaranya to help in policy planning for further rejuvenation of drying springs. The inventorisation of the springs was done through the secondary information and primary field surveys. Physical parameters of the springs including discharge, water quality and location were collected using the hand held instruments. The following were achieved from the project:

1. Total 900 springs were inventorized through secondary information and primary field surveys. Out of the 110 springs mapped during field survey, 60 were seasonal whereas remaining 50 springs were identified as pereinnial (Fig. 27a & b).
2. The discharge of the springs vary from 0.25 lpm (in Hee Martan block) to 250 lpm (Chakung block). The highest number of people (495) depend on one spring in Chongrang block.
3. A detailed geological mapping was performed in the parts of West Sikkim district which showed that lithology (rock type) plays major role for recharge of springs in the region.
4. Two workshops were conducted in West Sikkim district on awareness generation and spring rejuvenation and to monitor physico-chemical parameters of spring water.



(a) (b)

Fig. 27a. Location of the springs along elevation marked with dots,
b. Distribution map of springs in West Sikkim district.

National Mission on Himalayan Studies Fellowship Programme (NMHS, MoEF&CC, GoI, 2016 -2020)

The IHR harbours 50% of the total medicinal plants (MPs) available in the country varying across the eco-climatic zones, which are largely associated with rich biological and cultural linkages. In Sikkim, the indigenous community like, Lepcha, Bhutia, Limboo and Nepali depend on traditional medicinal practices. Due to the indiscriminate exploitation, obliteration of natural habitats, invasion of alien plant species, and global climate change, a number of plant species are under threat. Therefore, it is essential to have proper documentation of MPs and its bio-cultural linkages to initiate proper conservation and management priorities and plans. In view of the above, documentation of endemic, threatened and high value medicinal plant species of Sikkim was carreid out under the Himalayan Research Fellowship Programme supported by National Mission on Himalayan Studies (NMHS). Key achievements of the fellowship programme were :

1. Total 209 medicinal plant families in Sikkim Himalaya were recorded; highest number of medicinal plants (148) were represented by Asteraceae Family.
2. The medicinal plants were found distributed within the elevation range 400-4000 m. Some of the species are in endangered category while some of the varieties are at low risk category.
3. These medicinal plants, having high market demand, are being exploited in unplanned manner and supplied in the local market (Fig. 28). Therefore, urgent mechanisms are required for their proper conservation.

Fig. 28. Different processed products being sold in the local market in Singhtam, Sikkim.

NORTHEAST 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 focusing. The Regional Centre 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 and 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 and promotion of mono-cropping, lack of marketing network, depletion of traditional knowledge base and implementation deficiency in promotion of alternative and innovative livelihoods are the biggest constraints for the North East region. To contribute to these major issues inventorization of biodiversity, sacred groves, community conserved areas, village forests, hotspots and keystone species needs to be addressed, particularly for biodiversity conservation and augmentation of bio-resources. Also, alternative employment opportunities based on biodiversity based tourism needs to be explored.

Summary of Completed Project

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

The project explored 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 were made. The significant achievement of the project are as follows:

1. Detailed survey of all the BMCs in the targeted districts was conducted and a total of 16 BMCs of Ziro, Lower Subansiri district and 4 BMCs of East Siang District were identified. All these BMC's are registered under the State Biodiversity Board, Govt. of Arunachal Pradesh. A total of 5 new BMCs were formed in East Siang District and necessary documents have been submitted to the State Biodiversity Board (A.P.) for registration of the BMCs.
2. Interventions on biodiversity conservation and sustainable development in the project sites suggested that policy and programme level recommendations such as (i) need to protect the indigenous crops and other technologies such as Kiwi fruit, Kiwi wine, Finger millet Apong, and paddy cum fish cultivation through GI, and (ii) organic certification of agri-horticultural crops and value-added products are important. These policy interventions can enhance the livelihood of the local people.
3. During the project period, a total of 11 consultation workshops/meetings and 12 training programmes were organized for the capacity building of the stakeholders' of the project. Under the 11 stakeholders' consultation workshops a total of 187 local community representatives including SHG members were consulted/ involved on issues like biodiversity conservation, alternate livelihoods, natural resources management, role of community in conservation etc.
4. A total of 431 individuals/representatives were trained on various low cost rural technologies like weed-composting, vermi-composting, trellis, beekeeping, mushroom cultivation etc. Trainings were also organized for BMC members of Ziro and Lower Subansiri districts on basic operation guidelines of BMCs, process of PBR preparation and herbarium collection.
5. Under the project, a total of 15 activities were organized uunder 'Swacch Bharat Mission'. These programmes have involved and inspired more than 546 individuals from different walks of life including students, officials, village people, farmers etc. Message of SBM was spread to even larger population through these events at places such as schools/colleges, towns, villages, etc.

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

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 based 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. Also, a Letter of Agreement (LoA) was signed between GBPNIHESD, 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.

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. Construction of 5 fully furnished home-stays in the selected project site was completed and run by the families associated with these homestays.
2. A 5 days long residential training-cum-exposure programme was organized for the 14 selected candidates of the study area on homestay operations and eco-tourism development.
3. Trainings on rural agriculture technologies (weed compost, vermi-compost etc.) with field models were also provided to local farmers.
4. Socio-economic status (livelihoods, agriculture, vegetables cultivated, NTFPs, market chain, etc.) of study area (i.e. in and around Namdapha National Park, NNP), extensive questionnaire survey (households and personal interviews) was carried out.
5. Field survey was carried out inside NNP forest for the collection of primary data on endangered and highly threatened floral (10 tree spp.) and faunal species (mammals = 29 spp.; birds= 13 spp.; reptiles= 5 spp.) found in NNP. Perception study (through meetings and interactions) were also conducted with the help of local community members (Chakmas, Lamas, Singphos, & Tangsas) to explore the opportunities of possible alternative livelihood options including home-stays and eco-tourism.
6. Baseline data on human-animal conflict was also collected from the field. To create awareness forest conservation; awareness campaign followed by plantation drive of economic, medicinal and ecologically important tree saplings was carried out in 3 villages.

Summary of Completed Project / Activity

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 products continued to play a 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. In this activity fruit samples 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. Phytochemical analysis of targeted species (Fig. 29) viz. *C. caesia, Zingiber zerumbet, Curcuma* sp. have shown that total phenolic (TP; mg GAE/100g dw) content was highest in methanol for all the three species viz. *C. caesia* (721.83±1.80), *Z. zerumbet* (752.25±2.67) and *Curcuma* sp. (732.75±4.30), respectively. The total flavonoid (TF; mg QE/100g dw) content was also found highest in methanol for both the species: *C. caesia* (271.57±2.55) and *Z. zerumbet* (419.30±3.79) while for *Curcuma* sp. it was highest in ethyl acetate extract (401.10±6.75). The total tannin (TT; mg TAE/100g dw) content was also found highest in methanol for all the three species viz. *C. caesia* (242.86±5.76), *Z. zerumbet* (323.39±11.68) and *Curcuma* sp. (453.79±17.16), respectively.
2. Antioxidant analysis of different solvent extracts of *I. griffithii* in different assays found that Methanol and Acetone (mM AAE/100g dw) was the highest activity in FRAP (4.926±0.130) and ABTS (4.145±0.035), respectively. While in the case of *C. caesia,* ethanol and methanol exhibited highest activity in ABTS assay (0.798±0.002) and FRAP assay (0.672±0.003), respectively.

3. The antimicrobial analysis of the *C. caesia* have shown that highest activity was recorded in ethanol and methanol extracts against, *Pseudomonas chlororaphis* (11.00 ± 0.06) and *Serretia marcescens* (11.00 ± 0.12), respectively. While *Pythium afertile* and *Trematis hirsuta* were found resistant to all the extracts and didn't show any antifungal activity, only *Fusarium oxysporum* and *Aspergilus niger* show antifungal activity in methanolic and ethanolic extracts. The MIC values of ethanol, methanol, ethyl acetate and acetone ranged between 300-700 µg/mL for bacteria, 400-600 µg/mL for actinobacteria and 700-900 µg/mL for fungus. The ethanolic extract and acetone extract showed the lowest minimal inhibitory concentration against *Pseudomonas chlororaphis* and *Bacillus megaterium*, respectively.
4. The antibacterial analysis of *I. griffithii* revealed highest activity in Ethanol and Acetone extracts against, *S. marcescens* (14.67±0.86) and *E. coli* (13.33±0.03), respectively. The Acetone extract exhibited activity (20±0.06) against *B. subtilis,* while other solvent extracts didn't show any activity against it. For *Curcuma* sp. the ethyl acetate extract have shown highest activity against *E. coli* (28.3±5.58) and *S. marcescens* (24.7±0.27), followed by other solvents extract. The *Bacillus subtilis* was resistant to all the solvent extracts and didn't show any activity under all the solvent extracts. The MIC values were ranged between 300-500 µg/ml in *E. coli* and 300-800 µg/ml in *S. marcescens* for all the solvent extracts. For *Z. zerumbet,* the antibacterial analysis revealed that ethyl acetate and methanol have highest activity against *E. coli* (16.7±0.98), and *S. marcescens* (23.3±0.72), followed by ethanol against *E. coli* (16.3±0.27) and methanol against *S. marcescens* (20.0±0.47). Methanol and ethanol extract also exhibited higher activity against *B. subtilis.* Ethanol, methanol and ethyl acetate extracts exhibited antifugal activity only against *A. niger.* The MIC values ranged between 400-700 µg/ml for all the bacteria while for fungus the value varies b/w 450-700 µg/ml.
5. The cultivation of the four selected species viz. *I. griffithii, C. caesia, Z. zerumbet* and *Curcuma* sp. in different environmental conditions at NERC-RTC, DNGC campus Itanagar, and RTC Ziro shown a healthy growth except *I. griffithii.* This also indicates that *I. griffithii* require the specific climatic conditions particularly a low temperature and less humid conditions while other species can grow in other places with varying environmental conditions. Almost all the species have medicinal, industrial and other significant values and can play a major role in livelihood enhancement of the rural communities and farmers.

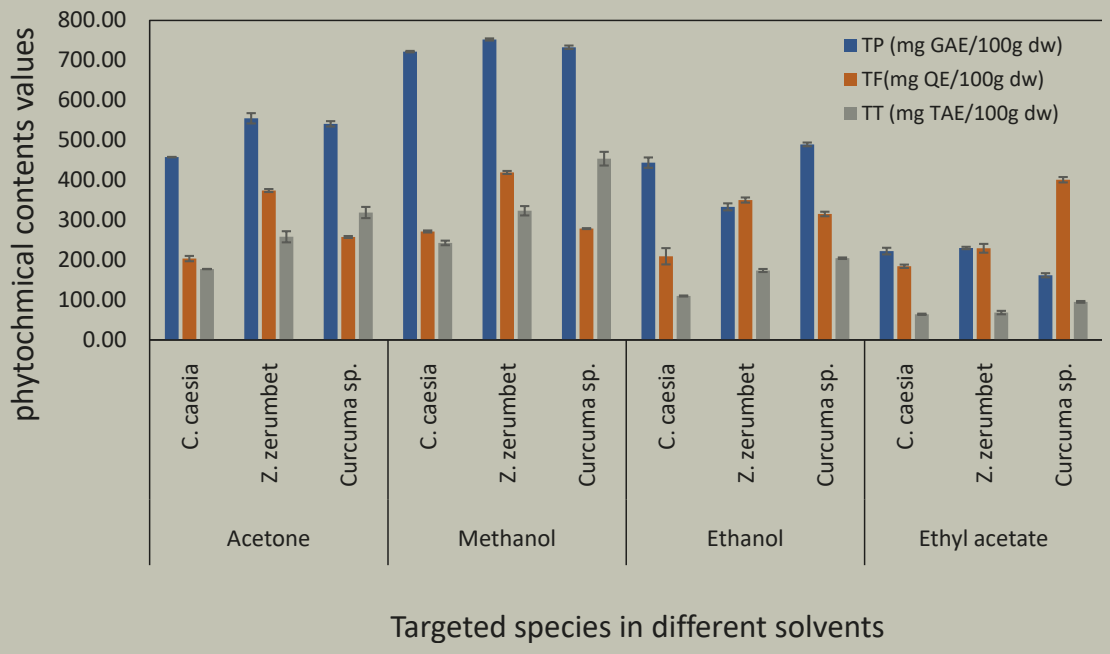


Fig. 29. Phytochemical contents in different solvent extracts of the targeted species

MOUNTAIN DIVISION REGIONAL CENTRE (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 GBPNIHE 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; and 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.

A GIS Based Approach to Delineate Spring Ecosystem Boundary in Middle Himalayan Region (Mountain Division, 2019-2022)

Spring is an outlet of water from aquifer on the surface. Spring is one of the most important sources of fresh water. The Indian Himalayan region is home to millions of springs which are also source to many big and small rivers in this region. People here, highly depend on the springs for household water supply, livestock and irrigation work. In various studies conducted in the last few decades it has been reported that the discharge of the springs in general has declined and the quality of water has also degraded due to the changing pattern of rainfall and human interferences. The perennial springs have now turned into seasonal and many of them have dried up. This is not only a matter of concern for recharge of the spring but is also important in terms of the Springs's ecosystem. With the changing and declining pattern of water discharge, the ecosystem dependent on spring is also degrading. Springs has been scientifically understudied and overlooked. Groundwater springs contributes to a very small portion of fresh water sources but are eminent parts of larger and greater watersheds. For the past few decades, many agencies have been doing much for the rejuvenation of springs in different areas but holistic studies on the ecological importance of springs still remains absent. Springs have the potential to support groundwater ecosystem but till date the springs have been studied keeping in view the anthropocentric approach. A healthy spring possesses great potential of providing ecosystem services within its boundaries. This study is therefore focused on the delineation of boundaries of spring dependent ecosystem and its dynamics.

Objectives:

- To develop a protocol to delineate the spring ecosystem boundaries based on the ecosystem functions and services provided by them.
- To analyze impact of spring ecosystem productivity on its socio-cultural services.
- To recommend policies and practices that help in enhancing the productivity of a spring ecosystem with regard to socio-cultural services.

Achievements:

1. The site visits conducted at Mann Dhunga village of Lohaghat block was primarily focused on learning and understanding the patterns of spring discharge and quality (Fig. 30) for bringing up a model for a water scarce village in Himalayan region to form a water sanctuary through technology and community based approaches.
2. The community interaction programme at the site helped in knowing the spring discharge variations from the residents and the problem of water scarcity (Fig. 31). The gradual decrease in the discharge of water from springs has resulted in unrest amongst the people of the village specifically the women and also promotes rural out migration.
3. The spring inventory of district Champawat shows that the population here highly depends on spring water for drinking and domestic work. This inventory has helped in understanding the need and requirements of the areas that requires quick action. These sites would be observed for time to time discharge to determine the pattern of flow.

Figure 30: Sample collection from the site

Figure 31: Community interaction at Mann Dhunga Village, Lohaghat

GIS Based Land use Modeling for Deriving the Trends of Urban Sprawl in the Cities of Indian Himalayan Region (Mountain Division, 2019-2022)

The urbanization scenario in the mountainous region of India is taking a dynamic turn as it is deteriorating the ecological balance of the mountainous ecosystem. The Indian Himalayan Region which is tectonically dynamic and having a fragile ecosystem is a home to 75% rural population and 25% urban population is exerting pressure on the mountainous biodiversity. Urban sprawl which is the increase in population size in relation to both magnitude and direction can be considered as a negative outcome of urban growth. One of the negative characterization of urban sprawl is its considerable contribution in climate change, and the most adverse ones are felt upon agriculture land, water bodies thereby changing the whole hydrological system. The uncontrolled and irregular urbanization in the Himalayan region is responsible for many problems, which our Himalayan cities experience today, leading to low standard of living environment and acute problems of drinking water, garbage mounting, soil and air pollution, traffic congestion etc. and also depletion of natural recourses and man-made disasters like landslides. It therefore becomes crucial to have a thorough understanding of past, and present land use 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. GIS based land use modeling can be used to support planning, policy and aiding in the decision making process. Two sites have been selected for the study viz. Almora city, 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 and GIS and stochastic (statistics) model.
- Assessment of impact of increasing urban sprawl using multi-criteria analysis.
- Suggestions and guidelines for sustainable urban development.

Achievements:

1. The landuse and land cover classification of very high resolution 4 band (Red, Green, Blue, and Infra Red) Pleiades satellite imagery at 0.5 m is completed for both Almora and Gangtok for the year 2018 using object based classification method.
2. The accuracy of the classification is measured to be more than 85% which fulfils the general criteria for further assessment. For Almora, the classes were resolved for their area calculation using standard UTM projection.
3. The classified datasets of 2005, 2013 & 2018 for Almora are utilized to calculate the Shannon's entropy to understand the type of Urban Sprawl for Almora city dividing the city in nine concentric zones taking the city centre as the centre of all zones (Fig. 32).

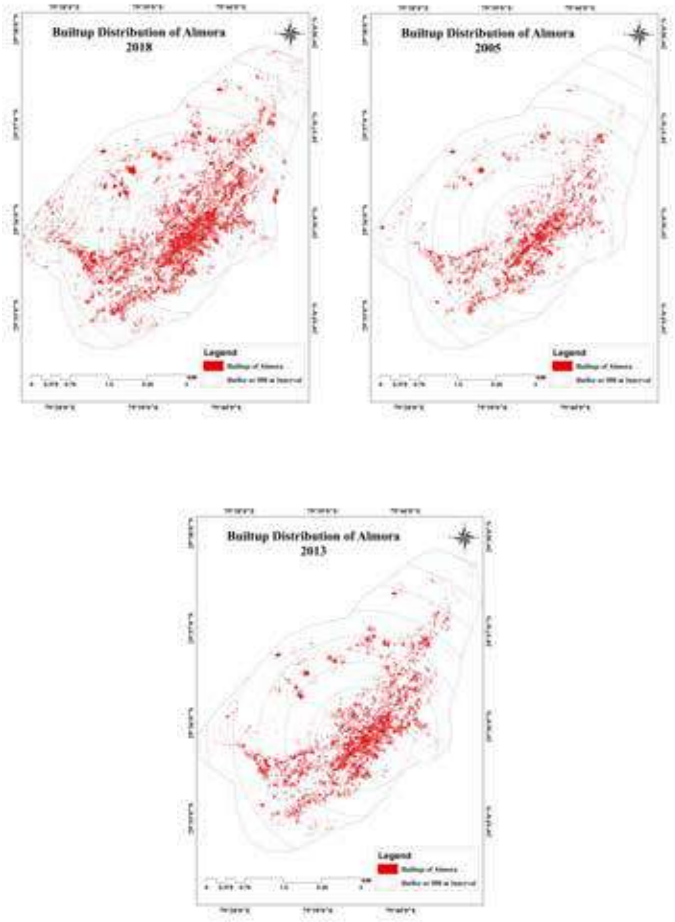


Fig. 32: Zonation for Shannon Entropy estimation over built-up distribution.

Assessment of Organic Farming and its Status, Problems and Constraints in Hilly Region of Uttarakhand (Mountain Division, 2019-2022)

A large section of the Central Himalayan mountain population depends upon agricultural based activities for their livelihood. This region serve as a reservoir for a large number of traditional mountain crop species like grains, millets, pseudo-cereals, pulses, tubers and oil seeds etc. With passage of time these traditional crops were gradually superseded by wheat, rice, maize and potato. However, the production and consumption of these crops still occupy an important place in the rural settlements of this region where they are used for cooking, baking, brewing, medicines and many other purposes. These crops are generally considered inferior food grains as compared to common food crops, whereas their nutritional and nutraceutical quality has been found to be as good as even better than the latter in several aspects. The demand of organic food emerged during the 1970s when ill-effects of agrochemicals on environmental and human health were realized in the developed world. Therefore, organic farming drew attention for its potential to produce healthy food together with environmental conservation in the developed world and as a new opportunity of income in food-surplus developing countries like India. There is a need of developing an objective decision making tool: where and how long to practice organic farming and conventional agrochemical based farming. In the absence of such tools, farmers will operate in a state of confusion.

Objectives:

- To assess the status and present scenario of organic farming with particular reference to hilly districts of Uttarakhand.
- To evaluate the relevance of organic farming and identify the key problems causes and scope of solutions based on the perceptions of farmers participating in the organic farming training and development.
- To analyse and evaluate the impact as well as strength and weakness of organic farming policy of Uttarakhand particularly in hilly region.

Achievements:

1. A survey has been made in ten villages in Rudraprayag district falling in Kedarnath forest division, located in high altitude where ringal-based products are made by the community and to assess the potential of widely available natural resource in sustainable development of the locals through product development (Fig. 33).
2. The input cost and the market value of the ringal-based handicrafts were assessed to the potential as an option for promoting the rural livelihood. The traditional community was also imparted technical knowledge to improve the quality of the products through technical advancement.
3. The traditional community was also imparted technical knowledge to improve the quality of the products through technical advancement.

Fig 33: Promoting Ringal artisan and crafts

Understanding the Process of Change in Far-Eastern Indian Landscape Linking with Conservation and Management (Mountain Division, 2019-2022)

The Far-Eastern landscape, while rich in its natural resources, is also equally known for its extreme vulnerability to changing faces of development and global climate. There are numerous conservation and developmental challenges. Agriculture expansion and illegal trade of wild life are on rise mainly manifested by acute poverty. Other challenges include limited conservation and development investments and inadequate capacity and skills of communities and climate change. There is a need of collaborative efforts to support conservation of complex biodiversity and address the poverty through conservation linked developmental strategies. The proposed study will help in understanding the various drivers of change (land use, climate, social etc.) and also in formulating comprehensive planning for sustainable development of the landscape and ensuring adaptation to climate change and well-being of people. The study will also help in formulating plans/policies for sustainable livelihood development and climate change adaptations. The study would enhance multi disciplinary research (including traditional ecological knowledge) and knowledge base on socio-economic status, ecosystems and cultural diversity of the landscape including understanding on drivers of change. It also envisages addressing poverty and climate change threats through designing good practices and technology transfer among the local communities and strengthen policy environment through state and national policy analysis.

Objectives:

- To develop baseline database on socio-economic status, ecosystems and cultural diversity of the landscape including drivers of change.
- To study the land use /land cover change, climate change and other dynamic systems of the landscape.

Achievements:

1. Questionnaire survey was carried out in 6 villages namely M'Pen II (7th Mile), M'Pen II (8th Mile), M'Pen II (9th Mile), Budhisatta, Budhisatta II and Lama village for collection of information on socio-economic aspects and problems associated with different sector.
2. Survey analysis revealed that the average family size in these villages is 5.5, literacy rate is 57%, the average landholding (agriculture) is around 1.5 ha only. All the families in the study villages are involved in livestock rearing (cattle, poultry, pig, and goat). The main livelihood is agriculture in the all the study villages. There are mainly 3 agriculture crops namely Paddy, Wheat *(Oryza sativa)* and Fafar *(Fagopyrum esculentum)* which are grown by almost all the families in the study area.
3. Horticulture crops, ginger, turmeric and vegetables are grown by villagers for their own consumption and source of income. A very few families (only in Lama village) are involved in jhum (shifting) agriculture.

Mapping and Promoting Conservation of Medicinal Plants of Sikkim Himalaya (Mountain Division, New Delhi, 2019-2022)

Sikkim is a very small hilly state in Eastern Himalayas with a total geographical area of 7096 sq. km blessed with abundant natural resources. Sikkim covering just 0.2% of the geographical area of the country, harbours over 26% flowering plants and has rich biodiversity and has been included in the Eastern Himalayan Biodiversity hotspot. Forest is one of the richest natural resources of Sikkim with luxuriant forest abounding in all parts of the State. A large section of the rural people still rely on native system of medicine for healthcare management. Globally, 80% of people in developing countries are dependent on herbal drugs for their primary healthcare, whereas over 25 % of prescribed medicines in developed countries are derived from wild plant species. Currently, a total of 15,000 plants species are threatened with extinction due to over-harvesting and habitat destruction and 20% of their wild resources have nearly exhausted with the increasing human population and plant product consumption. Many of the species in Sikkim Himalaya and their habitats are threatened by over-exploitation, over-grazing and climatic uncertainties. Identification and monitoring of biodiversity, paying particular attention to those species and varieties offering the greatest potential for sustainable use and requiring urgent conservation measures is the important initiative by Convention on Biological Diversity (CBD). Mapping of spatial distribution of natural resources can contribute significantly for the improved understanding and monitoring of biodiversity. Considering, the above facts, in mind, this fellowship programme attempts to map and promote conservation of high value medicinal plants of Sikkim Himalaya.

Objectives:

- Inventorization and documentation of medicinal plants species of Sikkim Himalaya.
- Quantification of population distribution of selected medicinal plants of West District of Sikkim.
- *Ex situ* conservation and capacity building on conservation of selected medicinal plants of the study region.

Achievements:

1. A complete list of 643 medicinal plants species belonging to 169 families of Sikkim Himalayas is documented. Among the documented medicinal plants species dominant families are Asteraceae followed by Ranunculaceae, Zingiberaceae, Euphorbiaceae and Poaceae (Fig. 34).
2. On the basis of medicinal uses the most of the plants are used against fever, cough & cold, asthma, piles, jaundice etc.
3. A total of 67 medicinal plants species are found under different threat categories.

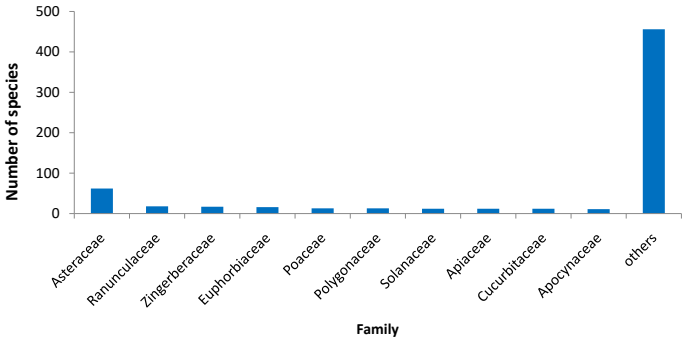


Fig. 34. Dominant families of medicinal plants documented in Sikkim.

4. Most of the parts used for medicinal purpose are leaves followed by roots, whole plants, barks, seeds, flowers/ inflorescence and rhizomes.

Plant-Animal Interaction Database Development for Biodiversity Conservation in Himalayan Forest Ecosystem (Mountain Division, 2019-2022)

Interactions between plants and animals embrace many of the processes fundamental to ecosystem structure and function. As a field of ecology, the subject has received increasing attention over the last few decades. Despite the tendency of many authors to treat the subject as one fundamentally concerned with herbivory, it is an extremely diverse and complex field. The interactions between plants and animals may be tight, such as in the classic concept of coevolution between plants and their pollinators and insect herbivores, but may equally be loose and diffuse, such as in the provision of habitat by plants or in the acceleration of nutrient cycling by soil invertebrates. Given the diversity and complexity of this field combined with the paucity of relevant data it is not possible to provide a comprehensive overview of the structure and function of plant-animal interactions in the Himalayan region. In the Himalaya, the exploration and taxonomic classification of the organisms started about two centuries ago. The biodiversity research started with reporting and naming new species (taxonomy) but later evolved into various other disciplines like ethnobiology, community ecology, molecular and genetic studies etc. This unique biogeographic location of Himalaya at the confluence of four zoogeographic regions, viz. the Palearctic, Saharo-Arabian, Sino-Japanese and Oriental, provides a wide range of ecosystems, habitats and dispersal corridors for the colonization of a multitude of species assemblages. Eastern Himalaya being closer to tropics supports richest diversity of flora and fauna hence, considered as a biodiversity hotspot. On the other hand, western parts of the Himalaya are situated more towards north and harbours comparatively lesser biodiversity. For example, plant species richness in east is three-fold higher as compared to northwest and the richness decreases both along elevational and latitudinal-longitudinal gradients of the Himalaya. However, in comparison to many other fields of research in ecology, number of studies on ecological interactions between different taxonomic groups are relatively less. In this study we have compiled all the literature published in the field of ecology and specifically reviewed and synthesized the research patterns on the plant-animal interactions from the Himalayan region.

Objectives:

- To evaluate the temporal trends in the research on plant-animal interaction in the Himalaya based on an exhaustive literature review.
- To classify the literature across various Indian Himalayan states, Nepal and Bhutan.
- To evaluate the taxonomic coverage for the studies on plant-animal interaction in the Himalaya.

Achievements:

1. A total of 15,166 research papers in the field of ecology and 362 papers in the sub-field of ecological interaction were found in the literature review. In the discipline of ecology, highest number of articles were published in

the field of diversity & distribution (47%) followed by taxonomy (17.9%), disease ecology (8.8%), community ecology (8.3%), forest ecology (4.4%), etc. Temporal trends again show a continuous increase in the number of journal articles in all sub-disciplines of ecology with a considerable momentum during 1970's and an abrupt increase during the first decade of 21st Century after 2000 in most of the research disciplines (Fig. 35).

2. Among the taxonomic groups highest number of journal articles were published on angiosperms followed by vertebrates, invertebrates, fungi and bacteria. Number of studies on the lower organisms like viruses, bacteria, algae, fungi, bryophytes, pteridophytes are comparatively very less across all the geographic regions.
3. Kingdom animalia is the most extensively studied taxonomic group and highest number of studies was published on Arthropoda, mammals, fishes and birds. The amount of literature published on various taxonomic groups is proportional to species richness of the group, but lower organisms might be under-explored.

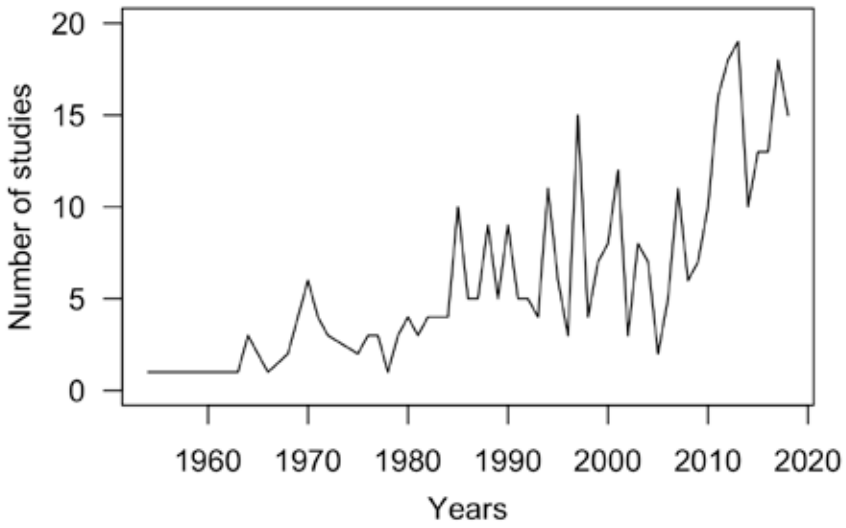


Fig. 35: Temporal trends on the growth of literature in the field of ecological interaction from the IHR, Nepal and Bhutan during 1950-2018.

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

Water is considered as one of the quintessential natural resource on which life depends, which comprises the river system, glaciers, ground water and wetlands. The increasing demand of water and its depleting sources have pulled worldwide attention to preserve it for economic, social and sustainable development. Fresh and clean water is one of the major challenges of 21st century and as a result water reuse and reclamation have become the main components of water resource management all over the world. 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. Sustainable management of water resources requires the long- term future, as well as present needs are considered in a balanced way. Sustainable water resources systems are those designed and managed to fully contribute to the objectives of society, now and in future. So, there is a need to analyze the water quality of fresh river water system and the other sources which will help in the management of environmental flow in the River Parbati basin.

Objectives:

- Assessment of status of water sources like river, streams, springs, hand pumps, etc.
- Assessment of topographic, anthropogenic and climatic impacts on water resources.
- Assessment of changing water quantity and quality (physico-chemical, biological) of existing water resources.
- To delineate the palaeo-channels of Parbati sub basin and existing drainage system of the study area with the help of remotely sensed data.

Achievements:

1. After collection of water samples from the Parbati basin and its analysis, the minimum values were 6.7 for pH at

Nhyarathach, the uppermost remote part of the Parbati basin and maximum 8.6 in Charod, whereas Bhunter has maximum value of 600 mg l^{-1} and Rudranag has minimum value of 300 mg l^{-1} for total alkalinity in the month of June. All the other parameters were well within the permissible limit.

2. The overall water quality index in the month of June, September and December was 50.92, 44.82, 40.36, respectively and falls under good water quality index (Table 13). Most of the samples from 18 sites fall under good to excellent quality Index.
3. 22 spring water samples and 8 stream water samples were analyzed in the month of September. All the parameters of spring water were within the permissible limits except for total alkalinity from Tosh (1125 mg l^{-1}), Barshaini (875 mg l^{-1}), Tulga (800 mg l^{-1}), and Manikaran (700 mg l^{-1}) and Jari (725 mg l^{-1}) spring waters. The stream samples from Tulga-Pulga nalla (1076 mg l^{-1}) and Shat nalla (970 mg l^{-1}) have exceeding values of alkalinity and Bicarbonates.

Table 13: Average water quality parameters in River Parbati basin

	June 2019				September 2019				December 2019			
Parameters	**Mean**	**Max**	**Min**	**SD**	**Mean**	**Max**	**Min**	**SD**	**Mean**	**Max**	**Min**	**SD**
pH	7.66	8.6	6.7	0.58	6.84	7.32	6.5	0.23	7.48	8.05	6.72	0.32
EC (µs cm^{-1})	99.63	138	68	19.1	53.78	95.5	34	19.1	69.15	185	34.7	31.41
TDS (ppm)	64.76	89.7	44	12.4	37.31	68	24	13.4	55.01	125	28.4	23.32
TH (mg l^{-1})	40.22	56	22	9.33	103.44	150	76	22.91	88.00	152	56	22.07
Alkalinity (mg l^{-1})	443.06	600	300	85.7	491.67	875	325	132	468.06	825	150	207.2
DO (ppm)	6.27	7.56	5	0.71	6.68	8.2	5.8	0.58	6.66	7.6	5.4	0.63
Ca (mg l^{-1})	10.09	15.1	6.7	2.5	11.26	16	5.9	3.19	13.22	27.8	5.05	4.86
Cl (mg l^{-1})	1.10	1.42	0.6	0.25	0.99	1.56	0.4	0.34	0.95	1.42	0.43	0.26
Mg (mg l^{-1})	3.62	7.48	0.6	1.82	18.30	32.4	9.3	6.40	13.36	30.3	3.91	5.94
HCO3 (mg l^{-1})	540.53	732	366	105	599.83	1067	397	161.1	571.00	1006	183	252.01

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 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 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.

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. During the reporting period, total 7 sites near Kheerganaga, Parvati valley were surveyed with altitude ranging between 2934m– 3624m amsl. Habitat conditions varied from Shady moist (3), followed by Dry (2), Bouldery (1), and Open grassland (1) habitats. 3 sites were having Northeast aspect, 4 in North aspect and slope varied from 20°-65°.Two plant communities *Abies pindrow* and *Betula utilis* were identified in the sub-alpine landscape, whereas, sampling was also conducted in two alpine sites of study area.
2. Total Basal Area (TBA) was recorded between 1.67-8147.45 m^2ha^{-1} in the tree layer. Maximum TBA was recorded in *Abies pindrow* community and minimum TBA was recorded in *Betula utilis* community. Tree density was ranged between 40- 390 Ind/ha^{-1}. Species Diversity (H') ranged from 0-1.04. Maximum Species Diversity (H') was recorded in *Betula utilis* community. Concentration of Dominance (Cd) ranged from 0.37- 1.00. Maximum Concentration of Dominance (Cd) was recorded in *Betula utilis* community (at site 6) and minimum was recorded in *Betula utilis* mixed community (at site 3). Species richness ranged from 5-11 species. Species richness was maximum in *Abies pindrow* community (11) at site 1 and minimum at *Betula utilis* (5) community at site 6.
3. For herb layer, density ranged from 3.50-64.75. Maximum density was recorded in *Abies pindrow* community (at site 1) and minimum density was recorded in *Betula utilis* community (at site 3). The species diversity (H') of herbs ranged from (0.00-2.67). Concentration of dominance (Cd) of herbs ranged from (0.00-1.00). Concentration of dominance was highest in *Betula utilis* community at site 3 and minimum was recorded for *Betula utilis* community at site 4 (Table 14).

Table 14: Structure and composition of trees, shrubs and herbs layers in the study area

Sites	Community types	Trees					Shrubs			Herbs		
		SR	TBA (m^2ha^{-1})	Density (Ind/ha^{-1})	Cd	H'	Density (Ind/ha^{-1})	Cd	H'	Density (Ind/ha^{-1})	Cd	H'
1	AP	11	954.7	390	0.51	0.8	16.10	0.23	1.76	64.75	0.10	2.67
2	AP	7	8147.45	340	0.54	0.8	5.60	0.48	0.94	5.10	0.01	0.00
3	BU	7	81.81	150	0.37	1.04	5.2	0.51	0.95	3.50	1.00	0.00
4	BU	6	10.38	150	0.88	0.24	3.90	0.36	1.15	6.80	0.00	1.52
5	-	-	-	-	-	-	-	-	-	31.525	0.07	1.45
6	BU	5	1.67	40	1.00	0.0	3.00	0.27	1.34	4.25	0.71	0.47
7	-	-	-	-	-	-	-	-	0.00	24.10	0.28	1.40

Abbreviations used: TBA = Total Basal Area; SR = Species Richness; H' = Species Diversity; Cd = Concentration of Dominance; AP = *Abies pindrow* community; BU = *Betula utilis* community

Summary of Completed Project / Activity

Tradeoffs Between Conservation and Livelihood Outcomes in Protected Area Management: An Assessment Based on Stakeholder Analysis (Mountain Division; 2016-2019)

The present study clearly shows that the PA interventions in the western Himalayan region have resulted into substantial tradeoffs particularly in the form of human-wildlife conflicts as well as win-win outcomes in the form of increased employment opportunities and livelihood sustainability through ecosystem goods and services. However, both the negative and positive impacts of PA interventions depend on the size, geographical location, flagship species and management objectives. Following are some recommendations that could help minimize the tradeoffs around PAs in the western Himalayan region:

- Increased wildlife population: The wildlife population has increased many folds in both Binsar Wildlife Sanctuary (BWLS) and Corbett Tiger Reserve (CTR) over the years. While this growth in wildlife population is an indicator of successful conservation outcomes, this exponential growth of wildlife in limited piece of land has raised several issues. For example in addition to

increased human-wildlife conflicts, the rise in the number of tiger and leopard has also resulted into coexistence problems in CTR. Similarly, the increase in the number of ungulates has also caused a substantial rise in the cases of crop raiding in the villages around CTR and BWLS. Thus the population of wild animals needs to be controlled within a protected area purposively by shifting wildlife to another PAs of the region or country.

- Timely compensation for villagers loss: The issue of timely compensation of loss borne by local people in the form of human wildlife conflicts need to be addressed urgently since it is creating resentment among the rural communities about PA management. Furthermore, a perceived delay in the mitigation of crises or taking management action will create higher public pressure. Although there is a provision of compensation for villagers' loss, it generally takes huge time for the villagers to get this compensation in their hand. A delay in this process ultimately provokes rural communities and makes PA management far more difficult for the managers. For example, the administration of BWLS has faced the problem of road block many times by the villagers due to their resentment about the delay in compensation process.
- Protection of agricultural land: The magnitude and intensity of crop raiding by increased number of wildlife can also be reduced significantly by a number of precautionary measures. For example, the boundary wall constructed around the agricultural fields in the Dalar village of the BWLS has resulted into substantial decrease in the crop raiding incidences by wild animals. This agricultural land in the Dalar village was left unused by villagers a decade ago due to heavy crop raiding by wild animals. But with the construction of boundary wall around this agricultural land in the year 2010, villagers again started to cultivate this land. Barbed wire and electric fencing is another way that needs to be promoted in the villages near PAs to reduce the threat of crop raiding by wild animals.
- Employment generation: Since the PA interventions severely affected subsistence based livelihoods in the nearby villages mainly due to increased human-wildlife interactions and restriction on forest produce use, creating alternative off-farm income generating opportunities in these villages may reduce the resentment among the villagers on the one hand and improve local livelihoods on the other. The villagers living around PAs sometimes called as 'conservation refugees' thus need to be provided with additional support from the government departments. A range of developmental interventions such as ecotourism, home stay etc. can lead to livelihood improvement of these conservation refugees.

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

The project entitled "Eco-physiological assessment of selected medicinal plants with changing environment for understanding adaptation mechanism" was carried out to study the response of selected Himalayan medicinal plants under different climatic variables like temperature, water deficit and light conditions for identifying best suitable conditions for growth and metabolite production. Studies were also carried out on the various morphological, physiological and biochemical mechanisms of adaptation of selected plants under stressful conditions for identification of tolerant individuals. Among the Himalayan medicinal plants, *Valeriana jatamansi* and *Hedychium spicatum* were selected based on their importance in different Ayurvedic and modern medicine. Also, both the species are in high demand by pharmaceutical companies; however the availability in nature is decreasing. The decrease in availability is largely due to anthropogenic pressure and changing environmental conditions, which is also reported to affect the quality and quantity of bioactive compounds of the medicinal plants including the selected species (*V. jatamansi* and *H. spicatum*). Thus, to improve conservation and sustainable utilization, promotion of cultivation is extremely important for the target species at farmer's field. The salient findings of the study are summarized below:

- Various growth parameters (plant height, leaf number, leaf area, relative water content, biomass) and principle bioactive compound (valerenic acid) of *V. jatamansi* were higher under 50% shade conditions, while most of the phenolic compounds and antioxidant activities were higher under full sunlight (open field). This indicates that for harnessing the better plant biomass and valerenic acid content, plant should be cultivated at shady places, while for harnessing the polyphenolic content, plant should be cultivated at open field condition.
- Among different plant portions, leaves of *V. jatamansi* were found to contain highest amount of phytochemicals and antioxidant activities suggesting great commercial implications of aboveground plant parts which can subsequently reduce the destructive harvesting of root and rhizomes.
- Summer season (August) is the optimum harvesting time for *V. jatamansi* since most phenolic compounds and bioactive compounds were higher during this season.

- Both plant species could survive water deficit conditions well up to soil moisture content of 12-26% under optimum temperature (25ºC) conditions, and up to 21-28% under high temperature (35ºC). Below this critical soil moisture levels, plant growth can be hampered due to inefficient adaptation mechanisms. Therefore, to obtain the better yield the moisture level of the soil should be maintained up to 26-28%.
- In *V. jatamansi,* most of the phenolic compounds and principle bioactive compound (valerenic acid) were higher when primed with optimum temperature of 25ºC as compared to heat stress of 35ºC. Highest phytochemical content including valerenic acid was obtained when plants were treated with 20-25 days of water deficit (21-25% soil moisture) under optimum temperature conditions. Therefore, to obtain higher phytochemical content, plants should not be irrigated for 20-25 days in the field conditions.
- In *H. spicatum,* most of the phenolic compounds were higher under severe stress conditions i.e. at 25-30 days of water deficit conditions (4-9% soil moisture) and heat stress (35ºC). Principle bioactive compound (linalool) was maximum at high temperature (35ºC) and high soil moisture (32%).
- Altitudinal studies suggest that good plant growth and high phytochemical content in *V. jatamansi* and *H. spicatum* were found at higher altitude. Physiological parameters like photosynthesis, transpiration rate, stomatal conductance and carboxylation efficiency were also high at higher altitude (2650 m asl). Therefore, to obtain higher phytochemical yield, the selected species can be cultivated at around 2650 m asl.

APPLICATION OF R & D OUTPUTS IN DEMONSTRATION AND DISSEMINATION

Integrated Eco-development Research Programme (IERP) in the Indian Himalayan region

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 369 R&D projects have been supported by IERP so far, to the Universities, Institutions, NGOs and other

Government Organizations, out of them 335 projects have been successfully completed.
2. The 22nd Project Evaluation Committee (PEC) meeting was organized on 16 March 2020 at NBRI, CSIR, Lucknow, and a total of 23 projects were evaluated, of which 3 were recommended for financial support during 2020-21.
3. At present 34 R&D projects are under various stages of implementation, covering 7 States (namely; Assam, Arunachal Pradesh, Meghalaya, Mizoram, Sikkim, Tripura and Uttarakhand) of the IHR.
4. Regular monitoring of project activities is carried out and feedback is being received from project implementing agencies

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

Environmental Information System (ENVIS) Centre on Himalayan Ecology was set up in the Institute in the financial year 1992-93 as a part of ENVIS network in India by the Ministry of Environment, Forest & Climate Change (MoEF&CC), Govt. of India; the nodal agency in the country for collecting and collating all available information from 62 ENVIS Centres nationwide to provide national scenarios to the international set up, INFOTERRA Programme, of the UNEP.

Objectives:

- To collect, collate, compile and build qualitative and quantitative database 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. The center compiled data on subject experts and important web links related to Himalayan Ecology.
2. ENVIS Centre also published ENVIS Bulletin on Himalayan Ecology (Vol. 27, 2019) on the theme of (i) Environment & Ecology, and (ii) Impact of Climate Change on Himalayan Ecology. In addition, four thematic ENVIS Newsletters Vol. 16 (1-4), 2019 were also published.
3. The centre conducted various programme (Fig. 36) such as three certificate courses on Green Skill Development Programme (GSDP) namely (a) Value Addition and Marketing of NTFPs (Animal Origin): Wild Bee Keeping and Processing (5-27 November 2019); (ii) Bird Identification and Basic Ornithology (11-26 January 2020) 15 experts from different organizations delivered various lectures and field-exercises; and (iii) Preparation of People's Biodiversity Register (13 February – 2 March 2020). During these programmes skills of 45 trainees

Fig 36: Secretary, MoEF&CC releasing ENVIS publication (Left); and participants of the GSDP programme (Right).

from almost all the districts of Uttarakhand were built involving 55 resource persons and master trainers from previous GSDP training courses conducted by ENVIS.

4. On the occasion of National Review Meet of ENVIS Centres at MoEF&CC, New Delhi (2nd April 2019) ENVIS centre exhibited/ demonstrated various knowledge products i.e., Posters, Fliers, e- banners, GSDP course modules etc. During this event State at a Glance -Assam Hills and West Bengal Hills was released by Secretary MoEF&CC, Govt. of India, New Delhi.

Central Laboratory Services

Institute has centralized facilities for physicochemical, biological, heavy metal analysis of fresh and wastewater, quantification of organic compounds (mainly volatiles) of water, soil and plant samples, elemental analysis (carbon, hydrogen, nitrogen, and sulphur) 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 (Varian AA280Z, equipped with graphite tube atomizer). Quantification of aromatic and volatile compounds are carried out using Gas chromatograph (Chemito, Ceres 800plus). For elemental analysis, CHNS (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 (shimadzu), flame photometer (Systronics), digestion systems (Pelican, India), extraction units (MAC, India) 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. In the financial year 2019-20, Institute had collected Rs. 107967/- as a Central laboratory service charge from different organizations including ten public organizations, two private organizations and three requests came from individuals. Apart from this, the Central Lab has also facilitated Institute research work (In-house and external funded projects) in the form of sample analysis using AAS, GC & CHNS. Figure 37 shows month wise income of central lab.

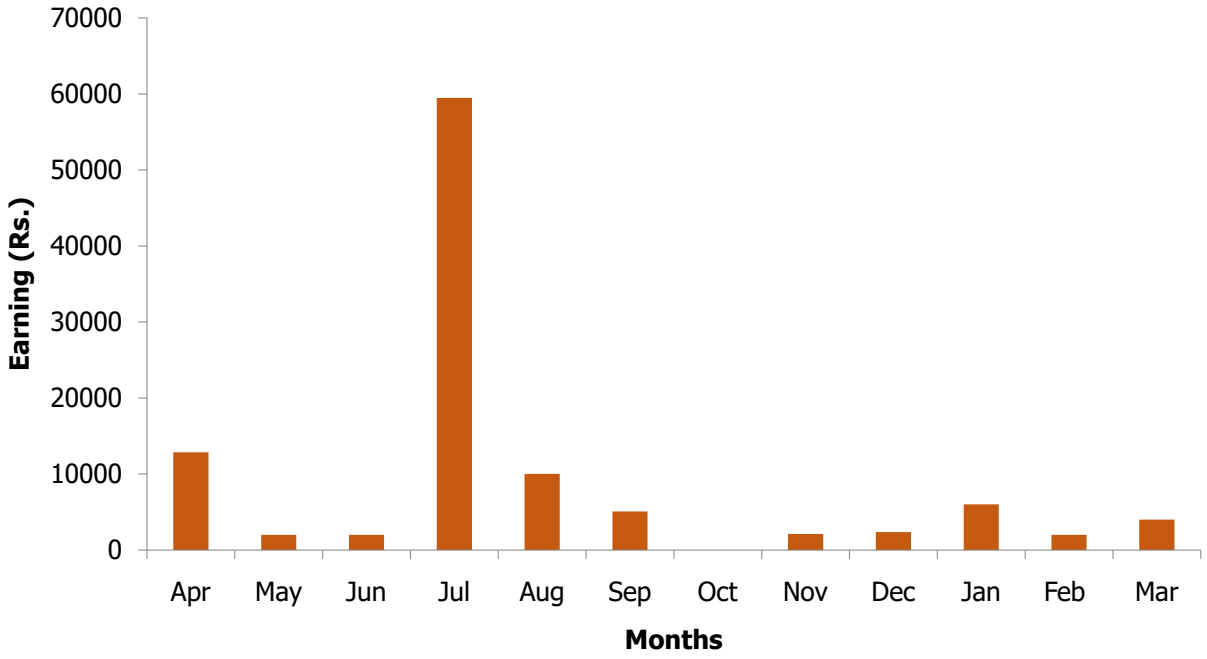


Fig. 37: Graphic representation showing total samples analysed under Central Laboratory Services in financial year 2019-20.

Strengthening and Maintenance of the Central Library at HQ

The Central Library of the Institute at its headquarters, at the end of financial year 2019-2020, had 17608 books. The library is subscribing a total of 57 periodicals (46 Foreign and 11 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 website (https://librarygbpnihesd.weebly.com/). During the reporting year, 221 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, Himprabha and Institute's 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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DAVER KARNATAK & ASSOCIATES
CHARTERED ACCOUNTANTS

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

Opinion

We have audited the financial statements of **G.B. PANT NATIONAL INSTITUTE OF HIMALAYAN ENVIRONMENT** (A Institute of Govind Ballabh Pant Himalaya Paryavaran Evam Vikas Society), which comprise the balance sheet as at March 31, 2020, 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 Society as at March 31st, 2020 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 forin the financial accounts.

Some Accounts generally in the nature of payable's are showing debit balances and appearing as receivable require careful review,

DAVER KARNATAK & ASSOCIATES * CHARTERED ACCOUNTANTS * NOIDA

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TDS on excess withdrawal of cash over and above the limit prescribed by Income Tax Act from bank account indicating cash transactions by the Institute.

Society has changed method of providing depreciation on fixed assets as per the rates prescribed for WDV method under Income Tax act 1961 from the straight line method as per the rate prescribed in schedule XIV to the Companies' act 1956 new method of providing depreciation is in compliance with the act applicable to the society please refer Schedule 8 read with point 4 of schedule 22 to the financial Statement.

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 Society 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: 16.09.2020

Place: Almora

For Daver Karnatak and Associate
(Chartered accountants)

DAVER KARNATAK & ASSOCIATES CHARTERED ACCOUNTANTS FRN 013196N NOIDA

CA. Sanjay Karnatak
FCA .DISA,DIRM (ICAI),LLB
M NO.501670
UDIN 20501670AAAABQ1787

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G.B.PANT NATIONAL INSTITUTE OF HIMALAYAN ENVIRONMENT
KATARMAL, KOSI (ALMORA) UTTARAKHAND
BALANCE SHEET AS ON 31ST MARCH 2020

PARTICULARS	SCHEDULE	CURRENT YEAR (₹)	PREVIOUS YEAR (₹)
LIABILITIES			
CORPUS / CAPITAL FUND	1	50169557.17	42456716.16
RESERVE AND SURPLUS	2	425378585.35	500857266.72
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	1602056433.80	1514044792.88
TOTAL		**2077604576.32**	**2057358775.76**
ASSETS			
FIXED ASSETS	8	425378585.35	500857266.72
INVEST. FROM EARMARKED/ENDOWMENT FUND	9	42589138.17	32060769.16
INVEST. OTHERS	10	0.00	0.00
CURRENT ASSETS , LOANS, ADVANCES ETC.	11	1609636852.80	1524440739.88
MISCELLANEOUS EXPENDITURE			
TOTAL		**2077604576.32**	**2057358775.76**
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

DATED : 16.09.2020
PLACE : KOSI- KATARMAL, ALMORA
UDIN: 20501670AAAABQ1787

(DR. R. S. RAWAL)
DIRECTOR

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

(SURYA KANT)
FINANCE OFFICER

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G.B.PANT NATIONAL INSTITUTE OF HIMALAYAN ENVIRONMENT
KATARMAL, KOSI (ALMORA) UTTARAKHAND
INCOME & EXPENDITURE A/C FOR THE YEAR ENDED 31ST MARCH 2020

PARTICULARS	SCHEDULE	CURRENT YEAR (₹)	PREVIOUS YEAR (₹)
INCOME			
Income from Sales/Services	12	250359.00	288976.00
Grants/Subsidies(net off exp)	13	735328023.61	463618444.16
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	429255.01	8121973.00
Other Income	18	7033227.00	5837065.00
Increase (decrease) in stock of Finished goods and work in progress)	19	0.00	0.00
TOTAL (A)		**743040864.62**	**477866458.16**
EXPENDITURE			
Establishment Expenses: a) Institute	20	116128616.00	124898597.00
b) Projects		47054947.00	44747200.00
c) F.C (Projects)		2998125.00	2861267.00
Administrative Expenses :a) Institute	21	75844469.61	62399276.01
b) Projects (As per Annexure)		476752795.52	211562330.15
c) F.C (Projects)(As per Annexure)		4276946.00	6378918.00
Expenditure on Grants, Subsidies etc.	22	12272124.48	10770856.00
Interest			
Depreciation (Net Total at the year-end-as per Sch. 8)		145036294.36	31404723.48
TOTAL (B)		**880364317.97**	**495023167.64**
Balance being excess of Income over Expenditure (A - B)		**137323453.35**	**17156709.48**
Transfer to special Reserve			
Transfer to/ from General Reserve			
BAL.BEING SURPLUS TRF.TO CORPUS FUND (Other Income)		**137455875.36**	**19941581.48**
BAL.BEING SURPLUS TRF.TO CORPUS FUND (Corpus Interest)		**132422.01**	**2784872.00**
Add: Transferred from General Reserve Fixed Asset Fund		**145036294.36**	**31404723.48**
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

DATED : 16.09.2020
PLACE : KOSI- KATARMAL, ALMORA
UDIN: 20501670AAAABQ1787

(DR. R. S. RAWAL)
DIRECTOR

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

(SURYA KANT)
FINANCE OFFICER

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G.B. PANT NATIONAL INSTITUTE OF HIMALAYAN ENVIRONMENT
KATARMAL, KOSI (ALMORA) UTTARAKHAND
RECEIPTS & PAYMENTS A/C FOR THE YEAR ENDED 31ST MARCH 2020

RECEIPTS	CURRENT YEAR	PREVIOUS YEAR	PAYMENTS	CURRENT YEAR	PREVIOUS YEAR
I. Opening Balances			**I. EXPENSES**		
a) Cash in hand	206511.64	91023.78	**a) Establishment Expenses**		
	0.00	0.00	**I) Institute**	115165535.36	125808394.00
b) Bank Balances	0.00	0.00	**b) Administrative expenses**		0.00
	0.00	0.00	a) Institute	50552452.79	38254167.01
i) In current accounts	0.00	0.00	b) R&D(Rev) expenses	14950879.79	25404982.00
ii) In deposit accounts (Corpus Fund)	2725298.17	5770666.96	c) Payments for current liabilities(gratuity/leave)	5856429.00	0.00
iii) Savings accounts	424889948.00	173503753.46	**C. Capital expenditure**	0.00	0.00
c) Advances & Others	1081344058.59	951290838.10	a) Purchase of Fixed Assets	24557720.00	19732896.00
(As per annexure Attached)	0.00	0.00	b)Expenditure on Capital Work in Progress	40887658.00	27453771.00
F.C. ACCOUNT	0.00	0.00	c) Acquirement of land (Lease money)	0.00	0.00
A) Cash in hand	4976.33	17846.33	**II Payments made against funds for various proj.**	0.00	0.00
b) Cash at bank	4625994.18	5809273.66	**Expenditure State govt. projects**	0.00	0.00
c) FC Advances	3386785.25	1058177.96	a) Capital	5255313.00	11492046.00
II. Grants Received	0.00	0.00	b) Revenue;	0.00	0.00
a) From Government of India	260000000.00	275000000.00	Establishment exp	49454411.00	39750217.00
i) Institute & IERP	0.00	0.00	Administration exp	479411603.88	211525952.69
Contribution corpus from CPF	3057179.00	0.00	**Expenditure FC projects**		0.00
b) From Other agencies	628459515.00	606797265.00	**a) Capital**	114957.00	1750270.00
c) From other sources [from FC]	7749850.22	11830934.81	**b) Revenue;**	0.00	0.00
III. Income on Investments from	0.00	0.00	Establishment exp	2998125.00	3102166.00
a) Corpus Fund(Received from Institute)	10395947.00	7749601.21	Administration exp	5124856.00	5846041.00
IV. Interest Received	0.00	0.00	**IERP grant released**	12272124.48	10770856.00
a) On Bank deposits savings a/c	4010274.00	17753069.00	**III Investments and deposits made**	0.00	0.00
b)On term deposits a/c	0.00	0.00	Pension trust (out of corpus fund)	3057179.00	15506465.00
c) Loans, Advances etc.	259182.00	490860.00	**IV Refund of Surplus money/Loans**	0.00	0.00
d) Interest income Corpus Fund	14712629.00	245446.00	a) To the Government of India	23099648.00	2684367.00
V. Other Income	0.00	0.00	b)To Others/ security/ caution money)	0.00	6000.00
Received in Corpus Fund	0.00	1067195.00	Refund to MoEF&CC (HBA/MCA)	0.00	0.00
(As per annexure Attached)	0.00	4958846.00	**V Other payments**	0.00	0.00
VI. Amount Borrowed	0.00	0.00	Other Payment to Instt. FC Proj.	0.00	0.00
VII. Any other receipts.	7279011.00	0.00	Unspent Balance [FC]	0.00	0.00
Interest Received in NMHS Payable to Government	19140894.00	0.00	Payment of Current Libilities	0.00	474400.00
	0.00	0.00	Refund of EMD	10395947.00	7641990.21
Other Receipt FC a/c	0.00	0.00	Fund transfar to Corpus fund	0.00	0.00
a)Performance Guarantee	0.00	34600.00	**VI Closing balances**	88374.34	206511.64
b) Receipts Current Liabilities	0.00	0.00	**a) Cash in hand**	0.00	0.00
c) IERP grants refunded by grantee Org.	0.00	411186.00	**b) Bank Balance**	0.00	0.00
d)Construction Fund	0.00	0.00	i) In Current account	42589138.17	2725298.17
e) Corpus Fund FDR'S	14755264.00	0.00	ii) In deposit accounts (Corpus Fund)	329604045.52	424889948.20
f) Caution Money	0.00	10500.00	iii) In savings accounts	0.00	0.00
g) Security Deposit	0.00	166470.00		1264664382.26	1081344058.59
h) EMD	199533.00	331000.00	**C) Advances and others**	0.00	0.00
i) Royalty	0.00	0.00	**FC Project**	4976.33	4976.33
j) Sales Tax / GST	0.00	0.00	a) Cash in hand	5781763.46	4625994.18
k)Service Tax/GST	0.00	0.00	b) Bank Balance	1315331.00	3386785.25
		0.00	c) Advances and others		0.00
		0.00	Adjustment of previous year closing Advances		
		0.00			
		0.00			
TOTAL	2487202850.38	2064388553.27	TOTAL	2487202850.38	2064388553.27

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 : 16.09.2020
PLACE : KOSI- KATARMAL, ALMORA
UDIN: 20501670AAAAB01787

DAVER KARNATAK & ASSOCIATES * CHARTERED ACCOUNTANTS * FRN 010196N NOIDA

(Dr. R. S. RAWAL)
DIRECTOR

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

(SURYA KANT)
FINANCE OFFICER

G.B.PANT NATIONAL INSTITUTE OF HIMALAYAN ENVIRONMENT
KOSI-KATARMAL, (ALMORA) UTTARAKHAND
ANNEXURE FORMING PART OF BALANCE SHEET AS ON 31 MARCH 2020

CURRENT ASSETS

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

PARTICULARS	CURRENT YEAR (₹)
C.B.I Kosi A/c No. 3173366206	98765661.07
S.B.I Almora A/C No. 10861359986	13049902.67
S.B.I Tandong A/c No. 11226047758	5939088.67
S.B.I Kullu A/c No. 10792147561	4774101.31
S.B.I Itanagar A/c No.10940060114	67361.47
S.B.I Srinagar A/c No. 10972182864	4996416.17
S.B.I Ladakh A/c No. 39128027055	75029.60
S.B.I Tandong A/c No. 37000934072 (NMHS IHTP DK	77711.10
C. B. I. Kosi A/c No. 3604013559 (Core Grant New Account)	36711679.46
S. B. I. Kosi A/c No. 36883992887 (NMSHE TF-03 New Account)	137541.00
S.B.I Srinagar A/c No. 3690636305 (NMHS ST KK)	1611063.45
S.B.I Almora A/c No.10861359975 (F.C)	5781763.46
C.B.I Kosi A/c No. 3561532026 (ENVIS New Account)	277429.00
C.B.I. Kosi A/C No. 3530505520 (NMHS-PMU)	152392586.75
S. B. I. Kosi A/c No. 36959540111 (NMHS ST KK)	4183703.00
S. B. I. Kosi A/c No. 36935490949 (NMHS Fellowship)	4046337.30
S. B. I. Kosi A/c No. 36935414822 (NMHS JCK)	308147.50
S. B. I. Kosi A/c No. 36935498701 (NMHS IHTP GCSN)	151081.00
S. B. I. Kosi A/c No. 36944701949 (NMHS IHTP S. Sharma)	321770.00
S. B. I. Kosi A/c No. 36944702502 (NMHS IHTP Rajesh Joshi)	100170.00
S. B. I. Kosi A/c No. 36944702987 (NMHS IHTP R. S. Rawal)	404598.00
S. B. I. Kosi A/c No. 36959556518 (NMHS D. S. Rawat)	632457.00
S. B. I. Kosi A/c No. 36959540698 (NMHS BSI K. C. Sekar)	7817.00
S. B. I. Mohal A/c No. 36998149642 (NMHS JCK H.P.)	296731.00
IDBI Itanagar A/c No. 0161104000055514 (NMHS JCK N. E. Unit)	275662.00
Cheque in transit: Regional Centre N.E.	0.00
Regional Centre H.P.	0.00
Regional Centre Sikkim	0.00
Regional Centre Garhwal	0.00
Fund Transfer to Core Grant Account	0.00
	335385808.98

DUE FROM STAFF — **ANNEXURE"E1"**

PARTICULARS	CURRENT YR. (₹)
Adv. a/c of Dr. G.C.S. Negi Sci. G (ENVIS)	0.00
Adv. a/c of Sh. Chandra Lal	0.00
Adv. a/c of S. Tarafdar (GRC Unit)	80000.00
Adv. a/c of Tribhuwan Rana (GRC Unit)	25000.00
Total:	**105000.00**

DUE FROM OTHERS — **ANNEXURE"E2"**

PARTICULARS	CURRENT YR. (₹)
Adv. a/c of TATA Motors Ltd. Core	2836.00
Adv. a/c of Meterological Department Core	8000.00
Adv. a/c of NRSC Hydrabad Proj. 04 Core	24000.00
Adv. a/c of M/s International Trade link Core	34328.00
Adv. a/c of VPKAS Almora Core	26560.00
Adv. a/c of STUP Consultant Haldwani Core	(7435.00)
Adv A/C E.E. RES Almora Core	1571000.00
Adv. a/c of E. E. CCU N. Delhi Core	0.00
Adv. a/c of NIH Roorkee Core	100000.00
Adv a/c NICSI New Delhi Core	35106.00
Employment news New Delhi Core	48287.00
Adv a/c M/S Sigma Aldrich Chemicals Core	10590.00
Adv A/C NRSA Hydrabad Core	35300.00
Adv a/c M/S R.K. Nanda & Sons Core	28517.00
Adv. a/c of Sh. Manoj Tiwari (Advocate) Core	20000.00
Adv. a/c of INSA New Delhi Core	30000.00
Recoverable from Unit Core	4772.00
Adv. a/c NRSA Hydrabad (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'**	1216831247.78
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)	48578.00
Adv. a/c of Sustainable Dev. Forum (NMHS-IDB)	175000.00
Adv. a/c Forest Vardhanik Uttaranchal (NMHS-IDB)	360000.00
Adv. A/c M/s Moets Catering Services, New Delhi(Mount. Divn.)	64574.00
Adv. a/c NRSC, Hydabad (Mount. Divn.)	0.00
Adv. a/c IMI New Delhi.(Mount. Divn.)	1000000.00
Adv. a/c Mizoram University (HERP)	300000.00
Adv. a/c of Finance Officer Mizoram University (Core)	92250.00
Adv. a/c IISF Expo 2018 New Delhi.	0.00
Adv. a/c of Mahila Haat New Delhi (NMHS-DSR)	418000.00
Adv. a/c of Manoj Kumar Patley (SAC Glacier Phase III)	0.00
Adv. a/c of H.N.B Gharwal University, Srinagar (ICSSR RKM G. Ur	970822.00
Adv. a/c of M/s Airport Handling (NMSHE TF-03)	230000.00
Adv. a/c of University of Kashmir (NMHS JCK)	2003512.00
Adv. a/c of NEIST, Manipur (NMHS JCK)	637354.00
Security Deposit CET Sikkim Core	11000.00
Adv. a/c of D S Bisht (NMHS-DSR)	(40.00)
Security Deposite N.E. Unit Core	1750.00
Adv. a/c of IIT Mandi (NMHS-S.Tarafdar)	994375.00
Adv. a/c of Rain Forest Research Institute (NMHS-S.Tarafdar)	124900.00
Adv. a/c of National Remote Sensing Centre, Hydrabad (UNDP-JCk	69738.00
Adv. a/c of Executive Engineer CE-IICCU(NMHS-NILC-IDB)	4311247.00
Adv. a/c of IIT-ROORKEE(NMHS-PINE OAK-SM)	4406760.00
Adv. a/c of NIT-ROURKELA(NMHS-PINE OAK-SM)	876760.00
Adv. a/c of JNU NEW DELHI(NMHS-PINE OAK-SM)	1351280.00
Adv. a/c of IIT MUMBAI (NMHS-PINE OAK-SM)	1291280.00
Adv. a/c of DIRECTOR U COST DEHRADUN (NMHS-HIMALAYA C	600000.00
Adv. a/c of National Remote Sensing Agency Core)	73544.00
Adv. a/c of Regional Science Centre (Core)	89936.00
Adv. a/c of Sikkim College (Core)	430000.00
Adv. A/c of NIRDPR (Mount .Div)	(123019.00)
Adv. A/c of D.K.Agarwal (Core)	0.00
Adv. a/c of Delhi Productivity Council (Core)	114932.00
Adv. a/c of Manipur Institute of Technology (core)	273125.00
Adv. a/c of Airport Handling Services (Core)	240000.00
Adv. a/c of Nagaland College (Core)	120000.00
Adv. a/c of NIT Assam (Core)	650000.00
Adv. a/c of National Performing Service Centre (Core)	104189.00
Adv. a/c of Tripura College (Core)	155000.00
Adv. a/c of Mountain Divisions (Core)	25000.00
	1245171981.78

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Institute Faculty

Head Quarter

S.N.	NAME	DESIGNATION	AREA OF SPECIALIZATION
1.	Dr. R.S. Rawal	Director	High Altitude Ecology; Conservation Biology
2.	Er. Kireet Kumar	Scientist-G	Environmental Engineering; Hydrology
3.	Dr. R.C. Sundriyal	Scientist-G	Plant Ecology; Rural Ecosystems
4.	Dr. G.C.S. Negi	Scientist-G	Forest Ecology; Watershed Management; EIA
5.	Dr. J.C. Kuniyal	Scientist-G	Development Geography; Waste Management
6.	Dr. I.D. Bhatt	Scientist-F	Plant Physiology; Phytochemistry
7.	Dr. Paromita Ghosh	Scientist-E	Plant Science; Soil Science
8.	Dr. K. Chandra Sekar	Scientist-E	Plant Taxonomy; Animal Taxonomy
9.	Mr. Ranjan Joshi	Scientist-E	Ecology Economics; Resource Valuation
10.	Dr. Vikram Singh Negi	Scientist- E (Adhoc)	Forest Ecology, Rural Ecosystems
11.	Dr. S.C. Arya	Scientist-D	High Altitude Ecology
12.	Dr. Vasudha Agnihotri	Scientist-D	Soil Science; Plant Analysis; Instrumentation
13.	Dr. Sandipan Mukherjee	Scientist-C	Climate Change; Ecosystem Services
14.	Dr. Mithilesh Singh	Scientist-D	Plant Tissue Culture; Bioprospecting
15.	Mr. Asutosh Tiwari	Scientist-C	Remote Sensing & GIS
16.	Dr. Sumit Rai	Scientist-C	Soil Science, Soil & Water Conservation
17.	Dr. V.E. Gosavi	Scientist-C	Hydrology; Watershed Management
18.	Dr. Harshit Pant	Scientist-C	Forest Ecology
19.	Dr. Shailaja Punetha	Scientist-C	Agriculture, Horticulture
20.	Dr. Kapil Kesarwani	Scientist-C	Cryospheric, Atmospheric and Environmental Sciences
21.	Dr. B.S. Majila	Tech. Gr. IV(4)	Forest Ecology; Restoration Ecology
22.	Dr. Subodh Airi	Tech. Gr. IV(3)	Forest Ecology; Biotechnology

Garhwal Regional Centre

23.	Dr. R.K. Maikhuri	Scientist-G & Head	Plant Ecology; Rural Ecosystems
24.	Mr. Soukhin Tarafdar	Scientist-E	Weather & Climate Change; Glaciology; Hydrology
25.	Mr. A.K. Sahani	Scientist-D	Social Science; Anthropology
26.	Dr. Arun Kumar Jugran	Scientist-C	Plant Biotechnology
27.	Dr. Lakhpat Singh Rawat	Technical Group IV (1)	Socio Economic Development (SED)

Himachal Regional Centre

28.	Er. Rakesh Kumar Singh	Scientist-E & Head	Information Technology
29.	Dr. K.S. Kanwal	Scientist-D	Strategic Environmental Assessment
30.	Mrs. Sarla Shashni	Scientist-D	Rural Entrepreneurship and Small Business
31.	Dr. Renu Lata	Scientist-C	Environmental Governance and Policy

32.	Dr. Kishore Kumar	Tech.-IV(2)	Pollination Biology; Conservation Education

Sikkim Regional Centre

33.	Dr. Rajesh Joshi	Scientist-E & Head	Mathematical Modeling
34.	Dr. Devendra Kumar	Scientist-C	Climate Change
35.	Dr. Sandeep Rawat	Scientist -C	Biodiversity conservation; Conservation genetics; Biochemical and nutritional analysis
36.	Dr. Mayank Joshi	Scientist -B	Tectonic Geomorphology; Active tectonics; Palaeoclimate ; Natural Hazards
37.	Dr. Y.K. Rai	Tech. Gr. IV(4)	Rural Ecosystem
38.	Dr. K.S. Gaira	Tech. Gr. IV(1)	Biodiversity Conservation

North-East Regional Centre

39.	Mr. M.S. Lodhi	Scientist-E & Head	Environmental Assessment
40.	Dr. Kesar Chand	Scientist -C	Climate Change and Environment Pollution
41.	Dr. Wishfully Mylliemngap	Scientist-B	Ecosystem Services
42.	Dr. Mriganka Shekhar Sarkar	Scientist- B	Ecology, Genetics
43.	Mr. Om Prakash Arya	Tech-IV(2)	Biotechnological Applications

Ladakh Regional Centre

44.	Dr. Subrat Sharma	Scientist-F & Head	Agro ecology; Remote Sensing/GIS
45.	Dr. Suresh Kumar Rana	Scientist- B	Biogeography, Evolutionary ecology, Biocuration

Institute Supporting Staff

S.N.	NAME	DESIGNATION
1.	Mr. Anil Kumar Yadav	Administrative Officer
2.	Mr. Surya Kant	Finance Officer
3.	Mr L.M.S. Negi	Accounts Officer
4.	Mr. S. Higgins	Tech. Gr. III(3)
5.	Mr. Mahesh Chandra Sati	Tech. Gr. IV(2), Lib
6.	Mrs. Sarita Bagdwal	Stenographer
7.	Mr Jagdish Kumar	Stenographer
8.	Mrs Mamta Higgins	O.S.
9.	Mr Heera Singh	O.S.
10.	Mr. K.K. Pant	U.D.C.
11.	Mrs. Hema Pandey	U.D.C.
12.	Mr. Atul Bisht	L.D.C.
13.	Mr. Nitish Mathpal	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	Technical II(1)
20.	Mr. Gopal Singh Bisht	Group 'C'

Garhwal Regional Centre

21.	Mr. D.P. Kumeri	UDC
22.	Mr. M.P. Nautiyal	Tech. Gr. II (2)
23.	Mr. J.M.S. Rawat	Tech. Gr. II (2)
24.	Mr. R.C. Nainwal	Technical Group I (4)
25.	Mr. R.P. Sati	Technical I(3)

Himachal Regional Centre

26.	Mr. Daulat Ram	Group 'C'
27.	Mr. Ajay Pawar	Group 'C'

Sikkim Regional Centre

28.	Mr. R.K. Das	LDC
29.	Mr. Jagnnath Dhakal	Technical Group I (4)
30.	Mr. P.K. Tamang	Technical Group I (4)

31.	Mr. Musafir Rai	Group 'C'
32.	Mr. Shya mbir	Group 'C'

North East Regional Centre		
33.	Mr. Sandip Kumar	L.D.C.

As on 31st March 2020 Institute has a total number of 47 Group 'A' and Group 'B' officers on its rolls as per the table below:-

Group	General	SC	ST	OBC	PH	Total
Group- A						
Scientific	26	5	3	3	-	37
Non Scientific	1	1	-	-	-	2
Group- B						
Scientific	-	-	-	-	-	0
Non Scientific	7	1	-	-	-	8
Total	**34**	**7**	**3**	**3**	**-**	**47**

As on 31st March 2020 Institute has a total number of 30Group C staff on its rolls as per the break-up given below:-

Group	General	SC	ST	OBC	PH	Total
Group- C						
Group C	19	8	1	2	-	
Total	**19**	**8**	**1**	**2**	**-**	**30**

Participation of Institute Faculty/Project Staff in Different Events:

Events	HQ	Regional Center				Total
		NE	Sikkim	Garhwal	HP	
National						
Symposia/Conference/Workshop	32	10	15	8	15	80
Training Courses	35	03	8		19	62
Meetings	23	01	20	15	36	95
Participation as a Resources Person	38	08	22	3	19	90
Any Other	3		10	-	11	24
International	7	03	10	1	-	21

SCIENTIFIC ADVISORY COMMITTEE

Chairman

Dr. V.P. Dimri, Padma Shri, FNA, FNASc ,FTWAS,
Former Director & CSIR Distinguished Scientist
CSIR-National Geophysical Research Institute &
INSA Senior Scientist, Hyderabad

Thematic Experts

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 Professor (Retd.)
Geotechnical Engineering Division
CSIR - Central Road Research Institute, Noida, U.P.

Prof. S.C. Rai
Professor & Head
Department of Geography
Delhi School of Economics; University of Delhi, New Delhi

Peer Institutions

Director/ or his representative
Director
Botanical Survey of India
Kolkata, West Bengal

Director/ or his representative
Director
Forest Research Institute
Dehradun, Uttarakhand

Institute Faculty

Er. M.S. Lodhi
Scientist - E
North East Regional Centre (NERC), GBPNIHE,Itanagar, Arunachal Pradesh

Dr. Sarla Sashni
Scientist - D
Himachal Regional Centre (HRC), GBPNIHE
Mohal, Kullu, Himachal Pradesh

Convener

Director, GBPNIHE,
Kosi-Katarmal, Almora

PROJECT EVALUATION COMMITTEE

Chairman

Prof. Saroj Kanta Barik
Director
CSIR-National Botanical Research Institute
PO Box No 436, Rana Pratap Marg
Lucknow - 226 001 India

Members

Prof. R.M. Pant
Director
National Institute of Rural Development (NIRD)
&Panchayati Raj, 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,Gangtok, Sikkim

Prof. Zafar A. Reshi
Department of Botany
University of Kashmir
Srinagar - 190 006, J&K

MoEF&CC Representative

Dr. Subrata Bose
Scientist-E
Ministry of Environment, Forest and Climate Change,
Mountain Division, New Delhi

Member Secretary (Nominee of the Director, GBPNIHE)

G.B. PANT NATIONAL INSTITUTE OF HIMALAYAN ENVIRONMENT

G.B. Pant National Institute of Himalayan Environment (GBPNIHE) was established in 1988-89, during the birth centenary year of Bharat Ratna Pt. Govind Ballabh Pant, as an autonomous Institute of Ministry of Environment, Forest and Climate Change (MoEF&CC), Govt. of India. The Institute has been identified as a focal agency to advance scientific knowledge, to evolve integrated 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 its Headquarters at Kosi-Katarmal, Almora (Uttarakhand) and six Regional Centres, namely, Ladakh Regional Centre (LRC) at Leh, Himachal Regional Centre (HRC) at Kullu (H.P.), Garhwal Regional Centre (GRC) at Srinagar Garhwal (Uttarakhand), Sikkim Regional Centre (SRC) at Pangthang (Sikkim), North-East Regional Centre (NERC) at Itanagar (Arunachal Pradesh), and Mountain Division Regional Centre (MDRC) at MoEF&CC(New Delhi).

For further information, please contact:

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