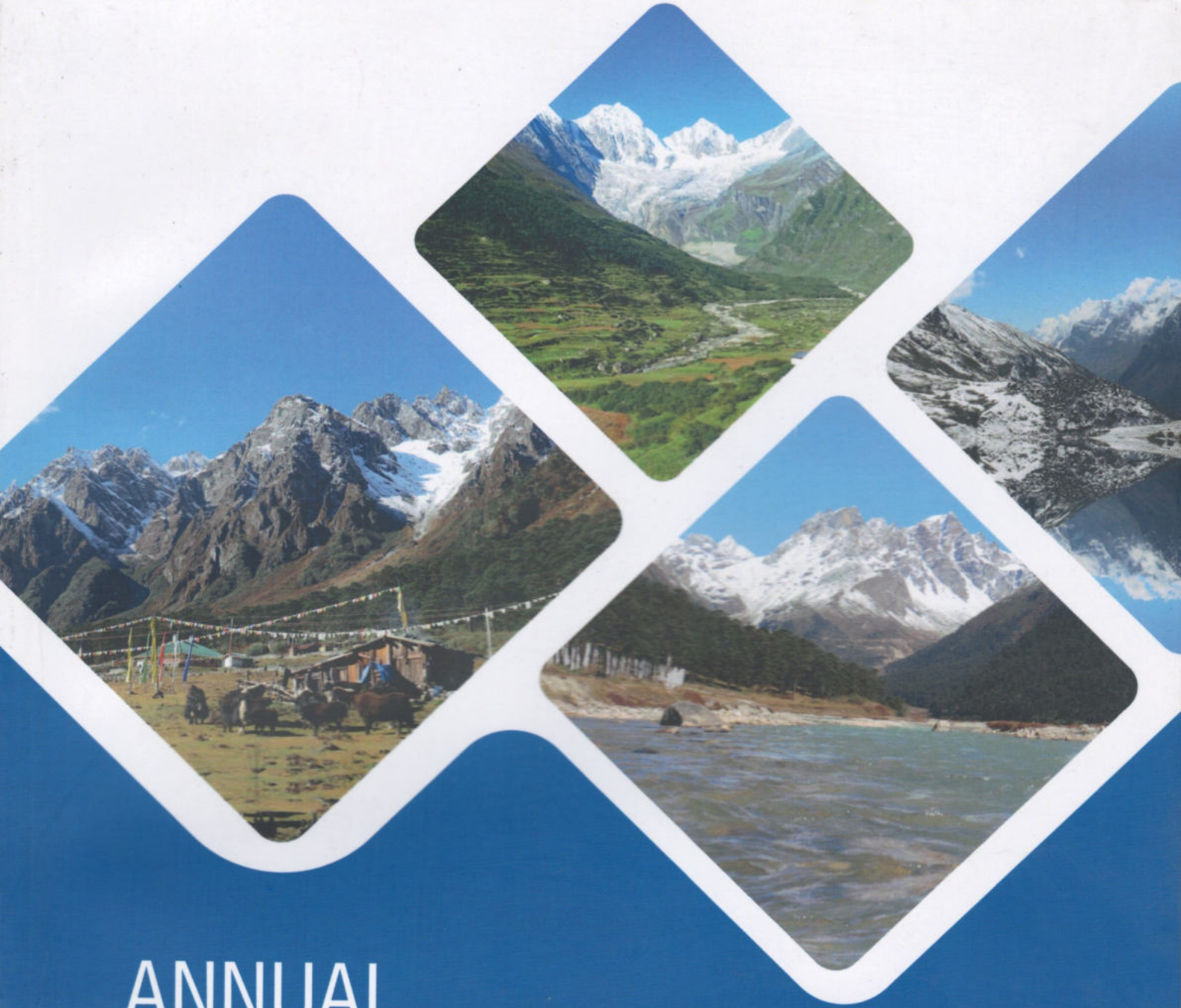

ANNUAL REPORT

2020-21

G.B. Pant National Institute of Himalayan Environment

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

Kosi-Katarmal, Almora 263 643, Uttarakhand, India

Website: www.gbpihed.gov.in

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Wildlife Insttute of India, Dehradun, Utarakhand

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Former Chief Secretary
Arunachal Pradesh

Member Secretary
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GBPNIHE, Kosi-Katarmal, Almora

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Contents

Foreword

The Institute in this year stepped into a new phase of **"**Transformative Work**"** for the next five years under the guidance of Ministry of Environment, Forest & Climate Change (MoEF&CC), Govt. of India. The major paradigm shift for this approach was driven by a need to upscale and out scale the various R&D based best practices brought out by the Institute in the past about three decades in diverse locations across the Indian Himalayan region (IHR). In this approach dovetailing, synergy building with other Govt. Line agencies, R&D organizations and participation by stakeholders was envisaged to bring about impact on the ground under Input, Output, Outcome and Impac (IOOA) framework. To implement the R&D based best practices on natural resources management (NRM) the Institute has selected 6 village clusters (over 30 villages) across H.P. (Mohal Khud watershed in Kullu, Uttarakhand (Jyoli village cluster in Almora and Jakholi village cluster in Rudraprayag), Sikkim (Mamlay watershed in South Sikkim) and A.P. (lower Subansiri Distt.) for developing them as eco-smart model villages through the Institute HQs and Regional Centres. Baseline data collection and resource use mapping and management plans of these selected villages is being carried out by capacity building of the village youth (Change Leaders). The Model Village development interventions by us have started producing outputs such as in the village cluster of Distt. Almora where the 178 beneficiary HH earned about Rs. 40,000 through vegetables cultivated in polyhouses, poultry farming, Pine needle biobriquettees, Rakhi and Aipan.

R&D activities this year although heavily constrained by COVID pandemic still it has been quite productive for us in the form of organization of 276 events through virtual mode (Webinars / Web meetings / Workshops / Conferences / Symposia 162; Training Courses - 114 etc.). Institute faculty participated in 558 such Regional/National/International events in virtual mode. Also, this year we could publish a good number of documents as time spent in field work and tours was substantially curtailed. However, we continued to provide research based solutions 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), to different stakeholders on diverse aspects of Himalayan Environment & Development. Also, the decentralized set-up, with the Regional Centres and their dedicated multidisciplinary faculty distributed across the IHR made Institute's presence felt across the region.

During the year 2020-21 among some of the notable achievements, the Institute, succeeded in collecting and geotagging 4346 springs across the IHR under Jal Abhayaranya Programme launched as 100 days programme for rejuvenation of Himalayan springs by MoEF&CC to address water scarcity issues on a pan-Himalayan scale. Towards restoration of community wastelands, 12 ha degraded habitats in parts of Distt. Pithoragarh (Uttarakhand) was put under plantations. The Rural Technology Centres (RTC's) at HQs and Regional Centres have proved extremely beneficial in reaching-out to the mountain rural people. For example, the RTC at HQs could reach out to 1513 individuals across 43 various stakeholder groups on various environment-friendly income generating activities and generated Rs. 1,16,591 through sale of Pine needle based products (e.g., file covers, file folders, carry bags, bio-briquettes, etc). This venture, while addressing the issue of forest fire has contributed equally for rural livelihoods promotion by effectively engaging rural women groups for income generation. This year 12 externally funded R&D projects were completed. Summaries of these project reports are included in this Annual Report.

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 the State Councils for Science & Technology in H.P. and A.P. and with the USAC for establishing State-Chapters under Himalaya Knowledge Network, a part of Centre for Data Management Agency initiated at the Institute HQs under the guidance of Niti Aayog. 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.

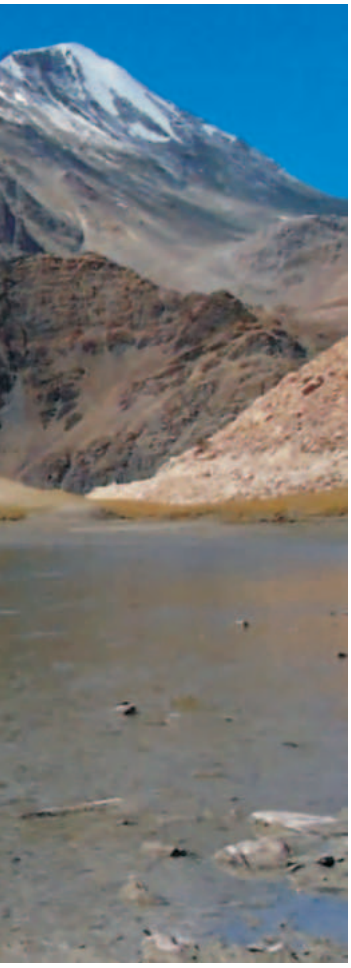
The Institute continues to receive guidance and encouragement of its Apex Bodies (i.e., the Society, the Governing Body, and the Scientific Advisory Committee). I place on record our deep gratitude to all members of these bodies. Institute's researchers and faculty deserve appreciation for staying motivated and enthusiastic to deliver their best in this testing time of Corona pandemic. 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

- Under *Jal Abhayaranya* Programme launched as 100 days programme for rejuvenation of Himalayan springs, data for 4346 springs in 10 IHR States has been collected and geo-tagged. Also, Long term (2005-06 & onwards) data recording on aerosols, black carbon and surface ozone was continued at Mohal-Kullu, Himachal Pradesh and Almora, Uttarakhand.

- Under the "Transformative Work" of Govt. of India 5 village clusters (30 villages) have been selected across H.P., Uttarakhand, Sikkim and A.P. for developing them as eco-smart model villages. In "Jyoli village cluster" Almora Distt. various environment-friendly technologies with people's participation and by developing a dozen Change Leaders, were implemented among 178 HH (705 people, including COVID returnees) those earned Rs. 32,175.00 through sale of poultry products, Pine needle based biobriquettees, *Rakhi* and *Aipan*, and cultiveted vegetables in polyhouses costing Rs. 16,100.00.



- Provided technical support to State Biodiversity Boards and Biodiversity Management Committees of Uttarakhand, Himachal Pradesh, Sikkim and Arunachal Pradesh in preparation for People's Biodiversity Registers to facilitate implementation of Biodiversity Act (2002) and access and benefit sharing. Prepared PBRs of 22 Panchayats and 5 blocks in Mandi and Kullu districts and submitted to H.P. State Biodiversity Board. Also, promoted cultivation of high value threatened and medicinal plants among farmers in Uttarkhand and developed market linkages.

- Developed grid based spatial datasets for natural plants for 63 grids in Sikkim in which a total of 58,434 individuals (431 species, 306 genus, and 116 families) were recorded. Also, inventorization and documentation of 638 medicinal plant species of Sikkim Himalaya was completed. Inventory of 1504 species of wild edibles (750 genera and 173 families) was prepared across all IHR states / UTs.

- Capacity building programmes on climate change and livelihood were conducted in Sindh, Parbati, Dhauliganga, Ranganadi and Imphal river basins of the IHR covering 523 local community people. In rural areas of Ladakh capacity building programmes on low-cost techniques for extended winter cultivation and off-farm employment were conducted.

- Letter of agreement (LoA) was signed between Institute HQs and Uttarakhand Space Application Agency, NERC and A.P. State Council for Science & Technology, HRC and H.P. Council for Science, Technology and Environment, Shimla for establishment of Himalaya Knowledge Network (HKN) State Chapters and organized several workshops, strategic meets, Youth Forums across the Regional Centres of the Institute to implement HKN activities. NERC developed a network of 25 government organizations and 120 NGOs working in A.P. for implementation of HKN project activities.

- Initiated establishment of Nature Learning Centre at Pangthang, Sikkim in collaboration with Dept. of Forest, Environment and Wildlife Management, Govt. of Sikkim in which one Orchid trail-cum-ex-situ conservation sites with 38 epiphytic and terrestrial orchid species and one herbal garden (with 26 RET medicinal plant species) were developed.

- At the Rural Technology Complex (RTC) 63 training programmes, workshops, etc. were organized (following COVID SoPs), and capacity of 1513 stakeholders (Male= 800, Female= 713, 11 Govt. line agencies / 9 NGOs) was built on various environment-friendly, income generating technologies. Popularized Pine needle based 7362 products (e.g., file covers, file folders, carry bags, bio-briquettes, etc.) among 43 organizations/NGOs/individuals, and earned Rs. 1,16,591 through sale to Governor House, Ladakh, G.B. Pant University of Agriculture & Technology, Pantnagar etc.

- The Institute continued its R&D outreach even during the COVID pandemic and organized 276 events (Webinars / Web meetings / Workshops / Conferences / Symposia / Training Courses etc.) through virtual mode across a range of stakeholders within and outside the IHR.

Publications:

1. Peer Reviewed National & International Journals	-	**76**
2. Chapters in Books / Proceedings	-	**36**
3. Authored/ Edited / Books / Booklets / Bulletins / Monographs	-	**15**
4. Popular Articles	-	**33**
5. Policy Papers	-	**2**

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 to cater to the need of a range of stakeholders including academia, policy makers and planners, Govt. line agencies engaged in field implementation, NGOs and CBOs etc. The R&D mandate of the Institute is broad and covers all the facets of mountain 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. 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 invited and 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 and socio-economic development of the people. Also, conscious efforts are made to mobilize a variety of stakeholders (students, researchers, academicians, farmers, citizens, NGOs, policy makers, National and International funding agencies and others) to participate in Institute programmes through different initiatives and mechanisms. 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 six 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; (v) Ladakh Regional Centre; and (vi) Mountain Division Regional Centre housed in MoEF&CC, New Delhi. These regional centres cater to the specific R&D need of the respective States / regions. During the reporting period 55 R&D projects are being implemented across the IHR and completed 12 projects. A brief summary of R&D activities and achievements of different Centres of the Institute during the reporting year 2020-21 is as follows:

1. Thematic Centres

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

During the year 2020-2021, an In-house umbrella project on a contemporary theme of popular interest under the domain of the CLWRM's activity, which is implementable across the IHR and replicable at larger scale was developed. After several rounds of brain-storming and review a novel theme on 'Spring Ecosystem Assessment and Management' was identified, the project focuses on spring inventory development, identification of spring ecosystem boundary and health indicators, implementation of interventions, and documentation on state of spring ecosystem and management practices and policies. A webinar on this subject chaired by Prof. VK Gaur (*FNA,* Distinguished Professor – CSIR 4PI, Bangaluru) was organized to discuss spring inventory protocols, and to develop concept on spring ecosystem boundary and role of collaborating institutions and scientists. To expedite the intervention part and to supplement and consolidate spring information across IHR, another project on 'Spring Rejuvenation for Water Security in Himalaya' under funding support from NMHS was initiated, this project to be implemented through institutional collaboration envisages establishment of one model spring sanctuary (*Jal Abhayaranya*) in the water scarce 'Aspirational Districts' of each of the 11 IHR states and 1 UT. Under the project, an introductory webinar was organized and spring sanctuary work initiated. Also, investigations on vertical rainfall structure and rainfall erosivity- the vertical structure of rainfall for winter period over Central Himalaya was studied using a micro rain radar. In the project 'Pine and Oak forest ecosystems-interactions with water, climate and plant bio-diversity' a relationship of net ecosystem exchange (NEE) and rainfall for *Pinus roxburghii* dominated vegetation was assessed, and a comparison of sap flow density of *P. roxburghii* and *Q. leucotrichophora* stands for winter revealed comparatively higher water demand by the Pine species. In the system dynamical modeling-based project on water resource management, 9 sub-watersheds in Kosi-watershed were identified by using GIS aided morphometric analyses; these watersheds were further prioritized on the basis of cumulative indexing for scale of interventions to be required for water resource augmentation. In NMHS funded livelihood project, the participatory Causal Loop Diagram (CLD) depicting livelihood system linkages for rural areas of Kosi-watershed was developed and a Fuzzy Cognitive Model for livelihood system and scenario building was run on the household data revealing outmigration, net sown area, livestock herd size, water availability as crucial factors affecting the rural livelihood sustainability. A DST funded project on the nutritional status of traditional foods of Uttarakhand utilized by scheduled community was successfully completed, wherein the nutritional composition of food prepared and consumed by the scheduled community using horse gram (Gahat), black soybean (Bhat), rice bean (Rains), and barnyard millet (Jhangora) were analyzed. It was noted that cuisines made up of black soybean has highest amount of protein among all the recipes.

(ii) Centre for Biodiversity Conservation & Management (CBCM)

The Center for Biodiversity Conservation and Management (CBCM) of the Institute has played an active role and contributed immensely to achieve the mandate of the Institute. The R&D activities of CBCM span across the north western Himalaya. The Center via various ongoing projects has significantly tried to address key biodiversity challenges in the region and has assisted technical support to various Biodiversity Management Committees (BMCs) in the preparation of People's Biodiversity Register (PBRs) so as to strengthen the Access and Benefits Sharing (ABS) mechanism. Through the project "Promoting conservation of threatened plant species in West Himalayan region – a participatory approach" cultivation of some highly threatened species was promoted in the region. Further, the beneficiary farmers were registered with Herbal Research and Development Institute (HRDI, Gopeshwar, Uttarakhand) for certification and Quality Council of India (QCI) for authorization of farmers produce. Also, the Center through the project developed a market linkage between Human India, Srinagar, and Surkunda Jadi-Buti Samuh, Bageshwar and imparted trainings for farmer's skill development. In line with the UN decade (2021-2030) of restoration, the ongoing projects, "Mainstreaming landscape approach for biodiversity conservation, improved livelihoods and ecosystem health in Kailash Sacred landscape part of India" and "Promoting restoration programme on degraded lands through medicinally important species", the Center over the years has strengthened community institutions and established convergence for restoration of degraded habitats and management of ecosystems in various parts of Distt. Pithoragarh (Uttarakhand). As of now a total of 12 ha degraded land has been covered under both the projects for restoration interventions.

Changes in climate over the last few decades in the Himalayas have already started affecting natural resources. Impacts of climate change and how species responds to these changes needs thorough assessments. The Center with the project "Assessing climate change impacts on floristic diversity of alpine regions in West Himalaya" has established several Long-Term Ecological Monitoring (LTEM) sites in the alpine region of Uttarakhand, West Himalaya for continuous monitoring following the Global Observation Research Initiative in Alpine Environments (GLORIA) procedure and recording data on regular intervals. Through another similar project, "Timberline and altitudinal gradient ecology of Himalayas and human use sustenance in a warming climate", we analyzed the patterns of forest vegetation along an altitudinal gradient till tree line, and prepared inventory of plants (lower and higher taxa) of Tungnath region, Uttarakhand. A total of 474 species of Angiosperms and Gymnosperms, 42 Pteridophytes, over 120 Bryophytes, 108 Lichens were listed. Similarly, under the project "Hyperspectral imaging for sharper definitions of Himalayan ecosystems and its high value plant species under climate uncertainties", spectral library of two important yet highly threatened species i.e., *Taxus wallichiana and Pittosporum eriocarpum* has been developed, and 42 species (including 12 lichen species) represented by 25 families (6 lichen families) and 36 genera (11 lichen genera) were sampled for further development of spectral library. Likewise, efforts are on to develop and upscale propagation protocols for mass multiplication of *Dactylorhiza hatagirea* and *Paris polyphylla* and study their eco-physiological aspects.

(iii) Centre for Socio-economic Development (CSED)

In the Himalayan region, over 70% population resides in the rural areas and needs greater attention for socio-economic development. The livelihood of rural people in the region is mostly dependent upon marginal agriculture, horticulture, animal husbandry, forests, pasture, water, and various wild resources. On a regional scale the farm produce meets only about half of the annual food demand of the people, triggering migration of youth to plains for better livelihood opportunities leaving women back to bear the brunt of carrying out almost all livelihood activities. At this juncture when socio-economic development is constrained by resource depletion and environmental degradation in the IHR, the role of appropriate technologies, which promote ecologically sustainable development becomes indispensable. A critical issue is also to up-scale and out-scale cost-effective and environment-friendly rural technologies. Use of locally available resources, both material and manpower, and networking is pivotal for the success of such endeavours. Therefore, CSED aims at to promote equitable, inclusive, and sustained growth by safeguarding economic and social interests of communities along with environmental protection in the IHR. CSED works as an effective conduit of dissemination and demonstration of best management practices emerged out of the Institute R&D among the rural mountain communities through a Rural Technology Complex (RTC).

The R&D focus of CSED this year has been geared towards (i) training and capacity building of faculty of Regional Centres, village communities and representatives of CBOs in developing bio-physical and socio-economic database of village clusters for development of resource use maps, village selection criteria and participatory developmental planning; (ii) strengthening sustainable livelihood through demonstration and promotion of on-farm and off-farm best practices; (iii) capacity building of a range of stakeholders on entrepreneurial skills and self-employment opportunities on various environment-friendly and income generating activities; and (iv) popularization and sale of environment-friendly products prepared at RTC to generate income of the Institute and maintenance of various R&D based package of practices at the RTC. Interventions in agriculture (protected cultivation), horticulture, bee keeping, forestry, animal husbandry (poultry), use of Pine needles in biobriquetting, green skilling (rakhi, alpna etc.) were made through participatory approach with beneficiaries mainly belonging to weaker sections (SC, BPL, Antyodaya and COVID returnees) that generated substantial nutritional supplements (vegetables, fruits, poultry products) and income through the sale of farm produce in the village cluster selected under "Transformative Work" of Govt. of India. Through the use of Pine needles eco-friendly products such as bio-briquettes, file covers, folders, note pads, carry bags, envelopes, etc. made at RTC were popularized across a range of stakeholders (rural people, Govt. Line agencies, entreprenures, NGOs and others) and sold to earn Rs.1,16,591.00. CSED is running four projects on front-running environmental issues of IHR to address priority socio-economic problems and management of natural resources focusing on (i) valuation of economic loss due to forest fire in Uttarakhand and M.P.; (ii) Himalayan knowledge network with a philosophy of science-policy-practice interface to increase outreach across a range of stakeholders; and (iii) climate change impact on tree line species. This year CSED organized 63 meetings/

workshops/training programmes thus increasing outreach to 1513 stakeholders (M= 800, F=713, 11 Govt. line agencies /9 NGOs). Also, live demonstrations of of natural resource management (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. Also, a few important projects were successfully completed dealing with livelihood improvement of farming communities by integrated NRM, NMSHE Task force-5 project on convergence of traditional knowledge for sustainable development of IHR, forest ecosystem services a comparison of past and present in selected forests of eastern and western Himalaya. Summary of the findings of these projects is presented in this report.

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

The Himalayan ecosystem, topographically fragile and ecologically sensitive is under the anthropogenic pressure due to developmental activities at different magnitudes across the IHR. The developmental interventions in many forms have a certain degree of negative impacts, which need to be identified and understood. Moreover, in recent times, climate change (CC) is causing a critical situation in many aspects in the fragile mountain ecosystems. It has been projected that even with global warming of 1-2 ^{0}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 the projected CC in 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 2020-21. The ongoing activities during reporting period were mainly focused on 10 projects (1 in-house and 9 externally funded projects). This year the transformative project under in-house activity was initiated. Two externally funded projects- ISRO Aerosol Radiative Forcing (AFRI) over India and ISRO Environmental Observatory, Atmospheric Chemistry Transport and Modelling (EO AT-CTM) and a consultancy project on 'Preparation of State/District Environment Plan for Uttarakhand' supported by 'Uttarakhand State Pollution Control Board' are being carried out by CEA&CC. The ISRO funded two projects pertain mainly to AFRI over India and EO AT-CTM are continuing wherein monitoring of aerosols and gaseous pollutants are being continuously monitored. The state/district environment plan for each district of Uttarakhand is under preparation under consultancy project. Impacts and habitat degradation due to biotic pressure in sub-alpine and alpine grassland ecosystems is being carried out under UNDP-GEF 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 medicinal plants of Sikkim Himalaya against breast cancer angiogenesis. DBT-RA fellowship is accounted for green synthesis of bioactive nano-pesticide against phytopathogens of *Picrorhiza kurroa.* Two projects-NMSHE TF-3 and NMHS were completed during this year. NMSHE TF-3 included development of database on plant diversity, establishment of long-term ecological monitoring sites, development of growth chronology in tree species and their relation with CC in the IHR, vulnerability assessment at community level, and training and capacity building of diverse stakeholders on forest resources and plant biodiversity, etc. Another completed project under NMHS added an additional knowledge in understanding the extent of anthropogenic impacts on the high altitude ecologically sensitive regions mainly in terms of water flow pattern and its quality, its impact on land use and land utilization (LULC), aquatic biodiversity, capacity building and alternate livelihood options of the local communities in headwater regions of the IHR.

2. Regional Centres

(i) Himachal Pradesh Regional Centre (HPRC)

During the reporting period the major highlights of research at HRC were: ethno-medicinal surveys in 16 villages of the Kullu district and documentation of 91 medicinal plant species belonging to 45 families. Also, school herbal gardens were established at Khalogi and Dohranala Govt. schools. An elite medicinal plants nursery was established at HPRC, Kullu for providing planting material of *Swertia chirayita* and *Picrorhiza kurroa* to farmers. Also, around 12,000 saplings of medicinal plants were raised and mass multiplication of *Taxus* was carried out. Genetic Resource Center at the HPRC was strengthened by cultivating other accession of target species. Alpine floral diversity of Himachal Pradesh was assessed, wherein maximum species richness was recorded for *Rhododendron anthopogon-Rosa macrophylla* community (42 species). A total of 95 medicinal and aromatic plants (Angiosperms - 93 and Gymnosperm -

02) belonging to 35 families and 71 genera were recorded from Changthang landscape. In the project on "community driven eco-smart model village development to improve livelihoods and fostering ecological security in the Himalaya", questionnaire survey for baseline data collection and resource use mapping for eco-smart model village development were filled with 213 households of the identified cluster villages. Also, documentation on climate resilient practices was done on night soil composting techniques of Lahaul & Spiti districts. Standardization of drying methods of leaves was done for sea buckthorn leaf tea development and training on value addition processes of Sea buckthorn was also done with the stakeholders at Technology Incubation Center at Kirting, Lahaul & Spiti. Rhizomes and seeds of *Angelica glauca* and seeds of *Carum carvi* collected from the Kullu and Lahul valley were planted in the field at Dhoranala nursery of the Institute for further multiplication. The HPRC team prepared People Biodiversity Registers (PBR) of 22 Panchayats in Mandi and Kullu districts and 5 blocks of Kullu District. Spring inventory of Barot and Seraj valleys of Mandi district was prepared. A total of 70 water samples were collected from Parbati river basin (18), springs (27) and streams (15) for physio-chemical analysis that doesn't indicate any deterioration in the surface water quality. Also, physico-chemical properties of soil was analyzed for different sites of Kullu (14) and Kinnaur District (3) of Himachal Pradesh. The stream ordering in the Parbati river basin has been generated using Strahler (1953) method in ArcGIS. Measurements on surface ozone were continued in Mohal-Kullu. Land Use Land Cover (LULC) map of the Beas basin for 2020 has been generated using LANDSAT-8 satellite data. Letter of agreement (LOA) was signed between HPRC and Himachal Pradesh Council for Science & Technology (Shimla) for establishment of HKN state chapter and implementation of various HKN activities in H.P. Demonstrations on R&D outputs was a strong activity area of HPRC. The herbal garden, medicinal plant nurseries and arboretum spread over 2 ha land of HPRC have been further strengthened through cultivation of new species. More than 120 floral species mostly native to the Himalaya are being conserved at arboretum & Dhoranala herbal garden. The HPRC 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, Waste Demonstration Park, Automatic Bio Composter, etc. Further, dissemination of R&D outcomes including policy briefs, manuals, technology packages, etc. was a strong activity of HPRC.

(ii) Garhwal Regional Centre (GRC)

The Garhwal Regional Centre (GRC) of the Institute was established in 1989 at Srinagar (Garhwal) in Pauri District (Uttarakhand). The GRC since its inception is devoted to undertake innovative R&D activities for holistic development of the region. The major R&D activities 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 park-people conflict resolution, eco-tourism, biodiversity conservation using modern biotechnological tools, skill development of stakeholders on environment-friendly simple technologies for National Resource Management and livelihood enhancement, etc. Some on-going major R&D thrust areas include climate change impact, adaptation and coping strategies, water security through spring ecosystem approach, bio-prospecting of wild resources, biodiversity conservation and genetics studies, promotion and cultivation of medicinal and aromatic plants, sustainable tourism, and conservation and management of protected areas and eco-sensitive zones.

Enough thrust is placed on demonstration and dissemination of R&D outputs and outcomes through (i) Empowering local communities in social, legal and local level governance on natural resource management; (ii) Promoting environmentally sustainable income generating activities for livelihood enhancement and socio-economic development; (iii) Model demonstration on innovative best practices and skill development for farming communities through on-site action research and training; (iv) Organizing open dialogue between diverse stakeholders (local people, NGOs, scientists, educationists and policy planners) for developing mountain specific policies. The Centre has generated immense R&D information, knowledge and policy briefs in the above mentioned areas and actively involved in developing connecting links between knowledge providers, knowledge seekers and users for sustainable development of the region. It has a strong R&D collaboration with national and regional R&D institutions, universities, national and multi-national companies, departments and line agencies of Central and state Governments, district administration, various regional and local NGOs, village institutions, etc. The GRC is working closely with local communities since its inception through participatory action research with focus area on NRM, agro-rural ecosystem development and sustainable livelihood.

(iii) Sikkim Regional Centre (SRC)

The Sikkim Regional Centre, since past 30 years, has been taking up R&D activities on environmental, ecological and social aspects in Sikkim Himalaya. During 2020-21, activities of the Center were focused towards spring rejuvenation, improving livelihood and ecological security, fostering climate smart communities, biodiversity conservation, landscape level conservation and development, strengthening regional cooperation for transboundary landscape management, establishment of Nature Learning Centre, mapping and promoting conservation of medicinal plants, documentation of traditional knowledge, mitigation of natural disasters by implementation of 4 In-house projects, 8 externally funded projects, 1 Trans-boundary landscape programme, and 1 fellowship programme. This year the four new In-house projects were initiated in Sikkim, which deals with spring-ecosystem assessment and rejuvenation, community driven eco-smart model village development, fostering climate smart communities and mainstreaming biodiversity for sustainable development. Under these projects, baseline data on springs, water demand and utilization pattern, demography, climate adaptations by the communities and biodiversity rich area were compiled through secondary information and primary field surveys. Under the Khangchendzonga Landscape Conservation and Development Initiative, one Resource Recovery Centre was developed in Gorkhey village for better management of solid waste. Also, stakeholder's network for sharing knowledge on post-harvest, value-chain management and morphological studies of large cardamom, and a Yak network in trans-boundary landscapes in the Himalaya for socio–ecological resilience of the highland communities was initiated. To promote the sustainable community based tourism, an inventory of 50 home stays at Dzongu and Barsey-Singhalila pilot sites was completed to link it with web-enable resources. Under the NMHS funding, a Nature Learning Centre (NLC) was started at SRC campus Pangthang wherein one orchid trail (with 38 epiphytic and terrestrial orchid species), 1 herbal garden (with 26 RET medicinal plant species), 1 bio-composting and vermi-composting model, and 2 polythene lined rain water harvesting ponds were developed. The centre also documented 638 species of medicinal plants belonging to 169 families from the Sikkim State under a fellowship programme on mapping and promoting conservation of medicinal plants. During 2020-21, the centre also completed four externally funded projects: Traditional knowledge on land and soil management, documentation of bioresource management and bio-processing practices of different ethnic groups under the NMSHE Task Force-5 and ecosystem services from two different forest types were studied for Eastern Himalaya. Furthermore, the annual and seasonal patterns of temperature lapse rates and vegetation patterns for tree line environment in Yuksam-Dzongri transect in Sikkim were studied. The centre contributed in developing disaster resilience action plan for natural disaster risk reduction in Shillong and Gangtok. The centre also organized various workshops, awareness, training, and capacity building programme (e.g. workshop on sharing best practices for Yak rearing, GSDP on large cardamom cultivation, nature camp, state level workshops for knowledge networking, post harvest and value chain management of large Cardamom, etc.) for dissemination of the knowledge and extension of its activities.

(iv) North-East Regional Centre (NERC)

The North-East Regional Centre of GBPNIHE was set up in the year 1989 and started functioning from Chuchuyimlang, Mokokchung in Nagaland. In 1997, it was shifted to Itanagar, Arunachal Pradesh and since then, the Centre has been contributing to the cause of conservation and development of the entire NE region. This region known for its rich diversity of flora, fauna, socio-cultural, linguistic and ethnic communities is currently facing various threats including degradation, deforestation, human settlement expansion, indiscrete hunting, therefore, warrants viable, replicable and effective community-based resource management initiatives for NRM. The NERC, through wider networking with strategic partner institutions, credible NGOs, line departments of north-eastern states and others, and fruitful collaboration with international (UNDP, UNESCO, Mac-Arthur, ICIMOD, IUCN, etc.) and national (MoEF&CC, DST, DBT, IIRS, NRSA, NATP, NEC, etc.) organizations 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 region by implementing more than 35 R&D projects across the NE region so far. 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. were addressed. During the reporting period some of the important events organized were: (i) Certificate course on 'Natural resources conservation' under the Green Skill Building Programme (GSBP); (ii) organizing popular lecture on “Agriculture in North-East: Transition and Strategies for future Development Under Changing Climate” delivered by Prof. A.

Bhattacharyya, Vice Chancellor of Assam Agricultural University, Jorhat; (iii) State level consultation workshop on identification of priority thematic areas of the States under Himalayan Knowledge Networking Project; (iv) State-level webinar on 'impacts of COVID-19 pandemic on rural livelihoods in North-East India and possible solutions; (v) Certificate courses on 'Para-hydrology with special reference to spring rejuvenation', PBR and PRA tools and techniques with special emphasis on village resource mapping'. In addition, a number of trainings and awareness workshops on various subjects such as rural technologies, beekeeping, mushroom cultivation, research tools and techniques and biodiversity management committees and PBR guidelines were organized for local stakeholders including farmers, women SHGs, students and researchers of different educational and research institutes. The NERC also organized specific events on occasions such as World Environment Day, International Day for Biological Diversity, International Mountain Day, etc.

(v) Ladakh Regional Centre (LRC)

The Trans Himalayan landscape with most of its area lying above 3,000 m asl is characterized by extreme cold climate, minimal rain (9-10 cm/yr., >300 sunny days) and 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 conditions, still they face numerous challenges especially under changing climate scenario, when impacts are expected to be more intense in higher altitudes. 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. Realizing the above, and recognizing the need, the Governing Body of GBPNIHE in its 41st meeting after due deliberations approved the proposal of setting-up of a Regional Centre of the Institute in Ladakh. Setting-up of this centre is expected to ensure Institute's R&D outreach in entire Trans Himalayan zone of the IHR by way of following objectives: (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 focuses 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 at New Delhi as one of the Centres 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 ecosystems 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 MoEF&CC 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. During the reporting period the following six project based studies were carried out through Himalayan Research Fellows and Associates that addresses various important research and policy issues across the IHR: (i) GIS based land use modeling for studying the future projection and dynamic impact on IHR; (ii) GIS based land use modeling for deriving the trends of urban sprawl in the cities of IHR; (iii) Understanding the process of change in Far-Eastern Indian landscape linking with conservation and management; (iv) Mapping and promoting conservation of medicinal plants of Sikkim Himalaya; (v) Water quality assessment of existing water sources in the lower Parbati Basin; and (vi) Assessment and valuation of alpine and sub-alpine ecosystems of Himachal Pradesh in relation to climate change.

1. INTRODUCTION

During the year 2020-21 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 Centres, 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 (MoEF&CC, New Delhi). In all the R&D activities a major thrust has been to deal with issues of environmental conservation and sustainable development in the IHR, 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 NRM, 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 annually and provides guidance to develop new R&D programmes. All these R&D projects are implemented through the four Centres 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 (iv) Center for Environmental Assessment and Climate Change (CEA&CC), and the region specific issues of the IHR are addressed by regional Centres 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 (LRC), and (vi) Mountain Division Regional Centre (MDRC) housed at MoEF&CC, New Delhi.

During the reporting period, R&D work pursued on various projects across the IHR. The summary of the major outputs / outcomes of these projects are given in this report along with the summary of completed projects. 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 2020-21 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 quality of outputs of various R&D activities.

2. MAJOR EVENTS

International Day for Biological Diversity

A webinar on "Himalayan Biodiversity and Future Solutions" was organized (22 May 2020) at the Institute HQs to mark the International Day for Biological Diversity (IDB-2020) on the theme 'Our Solutions are in Nature'. Panellists drawn from the Himalayan region deliberated upon: (i) ways to improve quality of life of local communities, (ii) develop local products, markets, and supply chains, and (iii) alternate options of livelihoods to unemployed rural youth. IBD at the SRC was celebrated through on-line discussions on the role of biodiversity and biotechnological approaches, agro-biodiversity, etc. which was attended by over 40 participants. At the HRC a Webinar-cum-Brainstorming on "Biodiversity of North-Western Himalaya" was organized in which the experts presented on flora, fauna and role of MAPs in biodiversity conservation and livelihood avenues in the IHR. At the NERC, on the occasion of IBD a Webinar on "Nature-based solutions for local communities of Eastern Himalaya" was organized in which experts delivered talks on biodiversity and traditional knowledge to 16 participants including NERIST, Spice Board Itanagar, Uttar Banga Krishi Vishwavidyalaya, West Bengal and others.

World Environment Day

World Environment Day (5 June 2020) was celebrated at GBP-NIHE HQs and across all the regional centres. On this occasion, a webinar on "Agrobiodiversity of IHR with Special Emphasis on Traditional Food" was organized at HQs. The HRC, Kullu organized a webinar on "Himalayan Biodiversity for Livelihood and Health Care in the Context of COVID-19 Pandemic" in which panellist/subject experts from academic/research organizations and representatives from NMPB, SBB, scientists, NGOs, pharmaceutical industries, farmers participated. At the GRC discussions on the role of natural ecosystems in the life of human beings and ways to maintain ecosystem and biodiversity were organized. At SRC a plantation programme was carried out at this occasion. The NERC organized a Webinar on the "Current Environmental Issues and Biodiversity Conservation". Resource persons like Dr. A. Kumar, Associate Prof., NERIST and Dr. U. Shilla, Union Christian Collage, Shillong delivered lectures.

Inauguration of Eco-Smart Model Village Development Programme

Hon'ble M.P. Almora Shri Ajay Tamta inaugurated the In-House Project-2 (Community driven eco-smart model village development to improve livelihoods and foster ecological security in the Himalaya) of GBPNIHE at RTC, GBPNIHE, Kosi, Almora (5 July 2020). Coordinator of the project, Centre Head CSED briefed about project objectives and expected outcomes and mentioned that under "Transformative Change" Govt. of India this project has selected 5 village clusters (25 villages) across the HQs (Jyoli village cluster, Hawalbagh block, Distt. Almora) and across four Regional Centers of the Institute. Director of the Institute and highlighted that the R&D based best practices will be implemented in these villages. This function was attended by 38 participants (25 M, 13 F), Gram Pradhans of Jyoli and Kaneli villages (Hawalbagh Block, Almora), institute faculty, researchers and invited guests.

Solid Waste Management in Matho Village (Leh)

This programme (3-7 August 2020) was initiated by the youth organization of Matho Village under the technical guidance of LRC- GBPNIHE in a participatory mode. During the campaign villagers were made aware about (i) types of waste and its impact, (ii) segregation of biodegradable and non-biodegradable waste, (iii) management of biodegradable waste to produce bio-compost manure, and (iv) recycling of non-biodegradable waste. In this event the youth organization played key role in promoting awareness on solid waste management through Awareness Campaign using Audio-Visual aids in five Halqas of villages. Mr. Stanzin Chosphel (Councillor, Martselang Constituency) provided required fund for Segregation Unit, and Village Council provided land for this unit. Mechanism is being developed to feed this accumulated waste to the recycling unit (Solid Resource Management Centre, Choglamsar).

Webinar on Spring Ecosystem

A Webinar on Spring Ecosystem was organized at GBPNIHE, Kosi-Katarmal (2 Sept. 2020) to discuss standard definition of spring ecosystem, it's boundary limits, and parameters for study of spring ecosystem variability. It was chaired online by Prof. V. K. Gaur,

Distinguished Scientist CSIR-4 PI Bangalore; Prof. S. K. Bartarya, Retd. Scientist, WIHG, delivered keynote address on 'Himalayan springs classification and characterization', and Prof. S. Sen, IIT Roorkee, on 'Spring ecosystem assessment'. In this event organized by Centre Head, CLWRM and Institute faculty flagged the issues and inputs were provided by Prof. A. P. Dimri, JNU, Prof. A. K. Saraf, IIT Roorkee, Prof. Krishnaswamy, ATREE, Bangalore and others.

Webinar on 'Environmental Conservation and Socio-economic Development of the IHR'

This online webinar was organized by the HRC, Kullu (3 Sept. 2020) to help in developing future strategy for natural resources conservation and socio-economic development of local communities of IHR. Prof. R.C. Sundriyal, H.N.B. Garhwal University, Prof. Varun Joshi, GGS Indraprastha Univ. New Delhi, Dr. Anil Kumar, Scientist, ZSI, Dehradun, & Dr. Randeep Singh, Amity University, Noida, were the speaker in the Webinar. Over 40 participants (faculty and researchers) across several organizations participated in this webinar.

Webinar on Climate Change, Adaptation & Resilience Building and Covid-19

The CEA&CC of GBPNIHE organized an International webinar on 'Adaptation & Resilience Building Challenges for the Himalayan Communities: Climate Change & Covid-19' (4 Sept. 2020) to discuss key issues: (i) climate vulnerability framework for identification of the vulnerable communities in the IHR, (ii) adaptation and resilience building mechanism for fostering climate smart communities under Covid-19 scenario, and (iii) formulating policy guidelines for the vulnerable communities in the IHR. Key messages of the deliberations were: (i) importance of vulnerability assessment in identifying current and potential hotspots, (ii) identification of the indicators that drive vulnerability and the factors contributing to the vulnerability, (iii) factors underlying a system's vulnerability that can serve as a starting point for identifying and prioritizing suitable adaptation interventions, (iv) ecosystem management at optimum level to local livelihoods, and (v) climate proofing for the vulnerable groups.

Annual Day Celebration

The Annual Day function of the Institute was celebrated across the regional centres and HQs of the Institute (10 Sept. 2020). At the Institute HQs, on this occasion, Chief Guest, Shri Ajay Tamta, Member of Parliament, Almora, appreciated the efforts made by the institute regarding sustainable development and conservation of natural resources. Prof. Tej Pratap, Vice Chancellor, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, delivered 26th Pt. G.B. Pant Memorial Lecture on "Future of Himalayan Farm Economy". Across the regional centres of the Institute, 7th Himalayan Popular Lectures were organized. At NERC, Popular Lecture was delivered by Dr. A. Bhattacharya, Vice Chancellor of Assam Agricultural University, Johrat, Assam, on the issues and options related to hill agriculture in NE India. At the SRC Popular Lecture on the management and conservation of natural resources for environmental sustainability in Sikkim was delivered by Prof. P.P. Dabral, Central Agricultural University, Imphal. At the GRC, Prof. A. K. Saraf, IIT Roorkee, delivered the Popular Lecture on the science and technology applications in Himalaya. Prof. Kuldeep Ch. Agnihotri delivered a Popular Lecture on the current challenges in Himalaya at the HRC, H.P. Institute celebrated the Annual Day by way of extended academic events during 25 August to 9 September, which included 8 events and received inputs of 72 Experts/Panellists representing 54 organizations and a total of over 250 attendees.

Workshop on Network Development & Synergy Building

This State-level Workshop was organized by HPRC (25 Sept. 2020) under the Himalaya Knowledge Network (HKN), which was attended on-line by 25 participants from different Scientific Institutes and Universities of H.P. Key points discussed were: identification of Network Partners & Synergy Building and identification and prioritization of thematic areas for H.P. Two thematic areas, Biodiversity Conservation and Management and Water Resource Conservation and Management were identified. Also, to fulfil the objectives of HKN project Youth Forum on "Himalayan Environment, Climate Change Adaption and Sustainable Development of the IHR" was organized (18 March 2021) in which over 100 participants representing scientists, research scholars and students from the different scientific Institutes and Universities of H.P. participated.

Swachh Bharat Abhiyan

On the occasion of Gandhi Jayanti (2 October 2020), several events were organized across the Institute HQs and Regional Centres. At the Institute HQs, two cleanliness campaigns were organized in Kantli village, Someshwar and Sun Temple, Katarmal village, Almora district. A programme was organized at Jyoli Inter College, Almora, in which 33 students, Gram Pradhan of Jyoli and Kujyari and other participants cleaned their school campus and the nearby Jyoli bazar. The NERC

organized (i) awareness workshop and a cleanliness drive in collaboration with Botanical Survey of India, A.P. (24 Sept. 2020); (ii) Awareness workshop and competition for school students (29 Sept. 2020); and (iii) Swachhta Awareness Campaign through electronic and print media (1 Oct. 2020). This Abhiyan was carried out by the GRC in Domathkhal and Bhimli Talli villages, Pauri Garhwal by plantation involving students, teachers and the local people.

National Wildlife Week – 2020

Towards celebrating National Wildlife Week 2020 (2-8 October 2020), drawing and painting, poem and popular article competitions were organized by inviting online entries by CBCM at GBPNIHE HQs. The themes for different competitions were: (i) 'Wildlife that attracts me' for Poem competition, (ii) 'Himalayan wildlife and its conservation' for Drawing and Painting competition, and (iii) 'Wildlife for Happy Future' for Popular article competition. The LRC of GBPNIHE organized this event in collaboration with 'Ladakh Science Foundation' where students were appraised by the experts of different disciplines and their understanding was evaluated through various competitions (debate, quiz, drawing, and painting). Also, "Ladakh Environmental Photographer of the Year competition (2020)" was organized on local ecology of the landscape.

Trainings Under Livelihood Support Project

Three hands-on-trainings on bio-briquette making and other environment-friendly rural technologies were organized at RTC, GBPNIHE (Almora) under Livelihood Support Project, Govt. of Uttarakhand (October 12-13, 15-16 and 20-21, 2020) for preparation

of Chir Pine leaf litter (*Pirul*) charcoal based smokeless bio-fuel (bio-briquette) for household use by the local people to reduce forest fire and to provide alternative livelihood options. This training was imparted to 126 farmers (6 M; 120 F), Mrs. Anju, and Mr. A. Bhatt of Training Centre, Hawalbagh, in which the technical aspects were demonstrated by CSED scientists and RTC staff.

Workshop on Preparation of District / State Environment Plan for Uttarakhand

Thirteen consultative workshops on 'Preparation of District/State Environment Plan for Uttarakhand' in all 13 districts of Uttarakhand were organized under the Chairmanship of respective District Magistrates with government officials of the districts during October-November, 2020. In the workshops, 15 thematic areas such as solid waste, bio-medical waste, construction & demolition, hazardous, electronic, plastic waste; pollution– land, air, water, noise; polluter stretches, illegal sand mining, ground water contamination, industrial clusters, STP/CETP/ETP and rejuvenation of water bodies were discussed as per the Hon'ble National Green Tribunal (NGT), vide order O.A. no. 360/2018, dated 26.09.2019.

Training Workshop on Bee Keeping and Green Skilling

A nine days (14-22 October 2020) training workshop on Bee Keeping organized for 22 farmers (15 M; 7 F) of Jyoli, Kaneli, Bisra, Kujyari and Dilkote villages of Hawalbagh block (Almora) was inaugurated by the Chief Guest of the function Hon'ble R.S. Chauhan, Deputy Speaker, Vidhan Sabha, Uttarakhand. This event was attended by Director, GBPNIHE, subject experts Er. Deep Bisht, Gram Pradhans of village Kujyari, Jyoli and Kaneli and 100 village people. After completion of this training Mr. Manuj Goyal, CDO, Almora distributed certificates and bee boxes to the trainees. Also, two hands-on-trainings on polyhouse construction were conducted (22 & 26 October 2020) at Dilkote and Kaneli villages in which 27 farmers (20 M; 7 F including Covid returnees) were trained. Based on this training 35 polyhouses were constructed by the village people in which about a dozen different vegetables are grown by them priced of Rs. 16,100.00. Also, a 7 days training workshop on Aipan (Kumaun folk art) making was conducted (7-13 November 2020), which was inaugurated by Mr. G.C. Pant, DDM, NABARD for skill/entrepreneurship development of 21 women of Jyoli village cluster.

Training Programmes on Organic Farming

A three days training program for capacity building of farmers on organic farming for livelihood enhancement through use of bio-inoculants was organized (30 October 2020) at Tolma (Chamoli) and 22-23 November 2020 at

Triyuginarayan (Rudraprayag) to provide hands-on exposure to the farmers about the use of bio-inoculants in cultivation of high altitude Rajmash (*Phaselous vulgaris*) for income generation. A total of 56 farmers belonging to different villages participated in the programme. Also, an awareness programme and training on environmental conservation and vermin-composting was organized in Ziro village of Lower Subansiri district (11th March 2021), which was attended by 19 participants (village people and female SHG).

Workshop-cum-Exhibition on Yak Rearing in the Himalaya

A regional "Workshop-cum-Exhibition on Yak Rearing in the Himalaya- Strengthening Yak Networks in Transboundary Landscapes for Social-Ecological Resilience of the Highland Communities" was organized (25-26 November 2020) for 40 participants from India, Nepal and Bhutan. A 'Yak based stakeholders' network was initiated to share best practices among Yak rearing communities. Subsequently, an exhibition-cum-meeting with Yak based stakeholders involving policy makers, line departments and Yak herders/owners (30 participants) was organized at Chungthang, North Sikkim.

ToT for Implementation of Biodiversity Act (2002) in Uttarakhand

To implement the Biological Diversity Act (2002) under the support National Biodivesrity Authority of India (NBA) a Training of Trainers (ToT) programme for 40 selected participants (Panchayat Raj Officers) from different districts of Uttarakhand was organized by the CBCM - GBPNIHE in collaboration with SBB, Uttarakhand and GIZ, Chennai from 26-28 November, 2020. This programme was inaugurated by Dr. V.B. Mathur, Chairman, NBA and attended by Director, GBPNIHE and Dr. Geetha, GIZ Chennai. Various biodiversity related laws, formation of BMCs and PBRs, Access and Benefit sharing etc. were deliberated by CSED & CBCM faculty in an interactive mode with participants.

Hands-on-Trainings on Bio-briquette Making

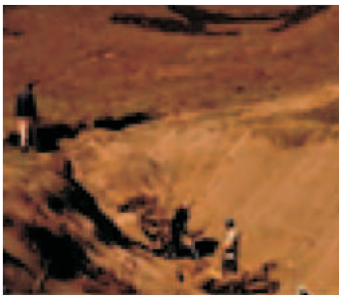
Three hands-on-trainings on bio-briquette making were organized at Kaneli, Bisra, Kujyari and Dilkote villages (Hawalbagh block, Almora) on November 25 & December 3, 2020 (32 farmers), on 2 February 2021 for Syama Devi Swayatt SHG, Raingal village, Hawalbagh (12 farmers at RTC), and on 2 March 2021 for the cooperative stakeholders and trainers (12 people) of Himalayan Trust Society, Garur (Distt. Bageshwar). The main objective of these trainings was to make charcoal based smokeless bio-fuel (bio-briquette) from chir pine

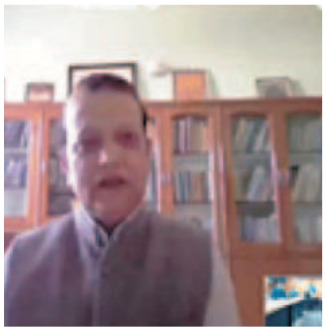
needles for use by the village people and to reduce forest fire and provide alternative livelihood options to the farmers. Women of the Katarmal and Jyoli village clusters have now started making the bio-briquettes and also earned Rs. 1000 by selling them apart from their own use for cooking and heating.

International Mountain Day

On the occasion of International Mountain Day (IMD) a webinar on "Renovate Himalaya" on the theme "Mountain Biodiversity" concerning the habitat degradation issues in Uttarakhand was organized (14 December, 2020). Several eco-restoration and technological interventions to tackle these issues were suggested to be linked with the National Environmental Plan. The IMD was celebrated HRC at Kullu by organizing a webinar on "Significance of Himalayan Biodiversity for Sustainable Development", in which experts talks were delivered. The SRC celebrated IMD at Yuksam, West Sikkim in collaboration with Khangchendzonga Conservation Committee, Yuksam and Dept. of Horticulture, Govt. of Sikkim in which 30 delegates and participants from Sikkim, Darjeeling and Kalimpong were present.







Green Skill Development Programme (GSDP) on Large Cardamom

A GSPD on Large Cardamom Farming & Livelihood Enhancement was organized (11–24 December 2020) at Yuksam, West Sikkim in synergy with Khangch-endzonga Conservation Committee to motivate rural youths towards rural entrepreneurship through skill building. Training and exposure on various aspects of large cardamom farming and its value-chain, schemes related to large Cardamom, cultivar identification, nursery establishment, curing and manuring, post-harvest, value-addition and market linkages, etc., were imparted through online interaction with international/ regional experts and onsite demonstrations.

Certificate Course on Peoples' Biodiversity Register Management

This Course on Peoples' Biodiversity Register (PBR) management was conducted to form a skilled work force to facilitate PBRs formation by the NERC during 21-24

December, 2020. Total selected 12 students participated from 7 different districts of Arunachal Pradesh and 1 district of Assam. These trainees will become helping hands to the State Biodiversity Board of A.P. and its TSGs in PBR preparation. Lectures and hands-on were imparted to the trainess on flora, fauna and agricultural biodiversity of A.P. by the Institute faculty and outside experts.

Stakeholders Consultation on Climate Change Impact, Resilience and Adaptation

A three days training and capacity building programme (24 December 2020 and 16-17 February 2021) for stakeholders was organized by GRC at village Kothiyara and Pangroli (Jakholi Block, Distt. Rudraprayag). About 106 stakeholders belonging to different background participated in the workshop. The workshop focused on enhancement of livelihood of stakeholders through rural technologies, improving the capacity of village community through informed decision making, mitigation of impacts of climate change, conservation of biodiversity, sustainable management of natural resources etc.

Workshop on Biodiversity Conservation and Sustainable Farming

The GRC organized three days training programmes (17 February 2021 and 25-26 March 2021) on promoting biodiversity conservation and sustainable farming at village Pangroli (Jakholi block, Rudraprayag) which was attended by 98 participants from different villages and school students. Training to the participants was given on preparation of smokeless biobriquettes from

Pine needles for use by them as fuel and also to reduce the forest fire. The GRC also conducted a two-day training-cum-consultative meeting on Participatory Springshed Management in collaboration with Dept. of Geography, H.N.B Garhwal University, Srinagar (19-20 February 2021) and imparted training to 61 participants representing the students and research scholars, NGOs and village people from Pauri and Tehri districts.

State Level Consultation Workshops under HKN

NERC organized 3 State-level consultation workshops in which representatives from Govt. organizations, researchers, academic institutes and NGOs participated. These workshops facilitated finalization of major thematic areas for R&D in Arunachal Pradesh. One 'State-level Consultation Workshop on Identifying Priority Thematic areas of the state under Himalayan Knowledge Networking (HKN) was conducted (24 February 2021), which was attended by 33 participants from 19 Govt. organizations working in Arunachal Pradesh. On the same theme, 2nd consultation workshop was organized (25 February 2021) in which representatives from NGOs participated.

Celebration of National Science Day

Two days webinar (28 February- 1 March 2021) entitled "Rejuvenation of Spring fed Rivers in IHR" was organized by CLWRM on the occasion of National Science Day. Mr. A. Mishra, IAS, Advisor, NITI Aayog

(water and land), Director, GBPNIHE, Dr. S.K. Bartarya, Scientist-G (Retd), Wadia Institute of Himalayan Geology Dehradun; Prof. S. Tambe, IIFM Bhopal; Prof. G. Jeelani, Univ. of Kashmir; Dr. V. Joshi, GGSIP, Univ. New Delhi; Dr. D. Sen, Director, People's Science Institute, New Delhi; Dr. H. Kulkarni, Director, ACWADAM; Dr. S. Sen, Dept. of Hydrology, IIT Roorkee; Dr. Indra Sen, IIT Kanpur; Mr. N. Bhadauria, DM, Almora; Mr. M. Goyal, DM Rudraprayag; Dr. S.K Upadhyay, UDWDP, Almora; Dr. N. Qazi, Forest Hydrologist; Shri B.S. Baneshi, Naula Foundation; Ms. Jaclyn, Germany shared their views.

International Women's Day

On the occasion of International Women's Day (8 March 2021) the CSED at HQs made door-to-door visits to 25 women entrepreneurs engaged in various environment-friendly activities in Jyoli village cluster (Hawalbagh block, Almora). CLWRM organized an interaction with women employees of the Institute with Ms. Apoorva Pandey, SDM Rankihet and discussed about various challenges and opportunities of the women's. Director, GBPNIHE briefed about various initiatives being taken by the Institute for women employees. On this day the LRC prioritized developmental issues with diverse stakeholders and in collaboration with women's groups organized a brainstorming workshop on "Environmental and Developmental Perspectives: Women in Ladakh". The SRC celebrated this day by organizing a one-day Workshop on "Enhancing Climate Adaptation among Rural Women for Livelihood Enhancing and Resilience Building" at Lower Jaubari, South Sikkim, which was attended by 30 ladies. The NERC celebrated this day with the women farmers of Den Azin Farmers' Club of Khemir village, Papumpare district (A.P.) during which they were given hands-on training on vermi-composting.

Training of Para-hydrologists

A one-day training programme on para-hydrologists was organized in Lower Jaubari village (10th March 2021) for 15 youth and bare-foot engineers. During the training, significance of springs, their mappings, measurement of physical parameters of water quality were demonstrated. A field-based training was

conducted for the participants at the nearby Pheni Khola spring that included identification of various types of springs, measuring its discharges and data collection on various physical parameters of water (pH, TDS, EC etc.) and handling of instruments.

World Water Day

The World Water Day (22 March 2021) was celebrated by four thematic centers of the Institute in collaboration with Namami Gange Programme of SSJ University, Almora. Along with students and teachers from G.I.C. Hawalbagh and officials from District Administration, Almora, around 100 NSS students accompanied by Dr. Mamta Aswal and Kosi river expert Prof. J.S. Rawat of Kumaun Univ. Campus, Almora. The Kosi river cleanliness campaign was organized and a Kosi pledge was taken by the participants at the bank of the river. Participants were motivated by the experts and teachers about the importance of water conservation and river rejuvenation. Kosi river water quality analysis demonstration was carried out for the students. The programme was concluded by the remarks of Director, GBPNIHE, to the participants at Suryakunj of the Instititute.

Training on Plant Taxonomy, Vegetation Assessment and Statistical Analysis

The CBCM conducted this three days (March 25-27, 2021) field-oriented training in collaboration with the Department of Botany, S.S.J. University (SSJU), Almora for 89 participants (M.Sc./Ph.D. scholars) from SSJU. Major aspects covered in the training included: (a) Plant taxonomy: Classification, identification and cataloguing; (b) Plant ecology: Methods of field surveys, data collection, analysis and interpretation in ecology and vegetation science; (c) Plant conservation approaches, nursery management and plantation techniques; and (d) Statistical application in the field of plant science and ecology. Classroom lectures and field exercises were conducted on above aspects during field work in Jageshwar, Almora.

Stakeholder Consultations on Valuation of Loss due to Forest Fire

A series of consultative meetings were held with local people and Forest Deptt. officials and field-level staff in the forest fire affected areas in Uttarakhand and Madhya Pradesh under the MoEF&CC (CAMPA) project to

estimate the monetary loss due to forest fire. Consultations / meetings were organized in Uttarakhand (35) and Madhya Pradesh (39) involving forest officers/field-level staff (323) and local people (511 Male/ 306 Female) around the sampled burnt forest sites. In these consultations the project team elaborated on the loss due to forest fire and in the ensuing discussions estimated the cost of various forest products.

Summary of Some Important Webinars / Web Meetings Organized by the Institute

S. No.	Date (s)	Title of the Event	Venue	Total participants
1.	May 22, 2020	Himalayan biodiversity and future solutions on the occasion of International Day for Biological Diversity-2020	HQs, GBPNIHE	32
2	22 May, 2020	Biodiversity for nature-based solutions to combat pandemics	SRC, Sikkim	41
3.	May 22, 2020	International Day for Biological Diversity 2020	NERC, A.P.	16
4.	Jun 03, 2020	Consultation meeting on 'Pine-Oak ecosystem - Interactions between climate, water and plant biodiversity'	HQs, GBPNIHE	14
5.	Jun 05, 2020	Agrobiodiversity of IHR with special emphasis on traditional food	HQs, GBPNIHE	40
6.	Jun 19, 2020	Webinar on village cluster selection criteria	HQs, GBPNIHE	04
7.	30 June 2020	Post-harvest and value chain management of large Cardamom in the Khangchendzonga landscape	SRC, Sikkim	26
8.	Jul 28, 2020	Webinar on village cluster selection criteria	HQs, GBPNIHE	40
9.	Aug 24-28, 2020	Tools and techniques used for impact assessment of climate change on different components of environment	HQs, GBPNIHE	50

S. No.	Date (s)	Title of the Event	Venue	Total participants
10.	Aug 28, 2020	Promoting medicinal and aromatic plants sector for sustainable development under post Covid - 19 scenario in the Western Himalaya'	HQs, GBPNIHE	50
11.	Sep 02, 2020	Spring-ecosystem: definition, scale, and assessment protocol	HQs, GBPNIHE	25
12.	Sept. 3, 2020.	Impacts of COVID-19 pandemic on livelihood in North-East India and possible solutions	NERC, Arunachal Pradesh	60
13.	Sep 4, 2020	Adaptation & Resilience building challenges for the Himalayan communities: Climate Change and Covid-19	HQs, GBPNIHE	35
14.	Sep 14 -17, 2020	'Statistical analysis of ecological parameters'	HQs, GBPNIHE	26
15.	Sep 16, 2020	World Ozone Day	HQs, GBPNIHE	50
16.	Nov 4-5, 2020	Webinar on village cluster selection criteria	HQs, GBPNIHE	11
17.	Nov 26-28, 2020	'Training of Trainers (ToT) on Biodiversity Management Committees'	HQs, GBPNIHE	40
18.	Dec 11, 2020	Awareness programme on climate change impact on high altitude medicinal plants of Himalaya: A step toward developing climate awakened future ayurveda medical practitioners	HQs, GBPNIHE	54
19.	Dec 14, 2020	Renovate Himalaya	HQs, GBPNIHE	50
20.	Dec 21-24, 2020	Certificate course on peoples' Biodiversity Register Management	NERC, GBPNIHE	12
21.	Dec 29, 2020	Webinar on "Trans-boundary forum on Biodiversity Management	HQs, GBPNIHE	24
22.	Jan 22, 2021	Identification of representative villages for community-led planning process for preparation of eco-smart model village plans across IHR.	HQs, GBPNIHE	08
23.	Feb 06, 2021	Cultural heritage of KSL-India with special focus on Rung community	HQs, GBPNIHE	20
24.	Feb 28 - Mar 01, 2021	Rejuvenation of Spring fed rivers in IHR (National Science Day)	HQs, GBPNIHE	25
25.	Mar 08, 2021	International Women Day	HQs, GBPNIHE	25
26.	Mar 23-25, 2021	Reorienting resource persons for promoting conservation education in IHR	HQs, GBPNIHE	38

3 RESEARCH AND DEVELOPMENT PROGRAMMES

CENTER FOR LAND AND WATER RESOURCE MANAGEMENT (CLWRM)

Land and water resource management has remained a major R&D activity of the Institute since its inception and pursued under various programs of the Institute. Widespread experience gained over the years in fields of mountain hydrology, water resource augmentation, glacier dynamics and hydrometeorology, geo-tectonics and landslide restoration, catchment area treatment, soil and water conservation technologies saw its culmination in the form of establishment of a dedicated Centre for Land and Water Management (CLWRM) in the Institute in the year 2017. In recent years, challenges posed by globalization and climate change, melting of glaciers, increasing incidents of drought and waterborne disasters, continued outmigration of Himalayan people for livelihoods, and improved understanding of existence value of Himalaya as a water tower, climate regulator, and ecosystem service provider to the entire North Indian plains, have further corroborated the need for more focused R&D for conservation and management of land and water resources of the Himalaya. Therefore, the activities of the Centre were contemplated to cover the concurrent themes of interest like spring ecosystem, water security, cryosphere, livelihood and water pollution keeping in view their societal relevance and conformity to the policy environment. 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.

Water Security in Himalaya through Spring-Ecosystem Assessment and Management (GBPNIHE In-House Project-1, 2020-2025)

Springs are ecosystems where groundwater is exposed, and typically flows from the Earth's surface. Springs vary greatly in flow, water chemistry, geomorphology, ecology, socio-cultural and economic importance. However, problem of drying of springs is being increasingly felt resulting into substantial alteration of springs ecosystem structure and functions. It has been observed that the interaction of dependent ecosystem services of springs is hardly documented or being studied over Himalaya, and no standardized spring-ecosystem management practices are available. This has set the stage for development of protocols to enhance systematic inventory and spring ecosystem research components. The objectives of the present study are two-fold; first to provide a better understanding of functioning of the spring-ecosystems and secondly to enhance water security through revival of spring through *Jal Abhayaranya* concept. This project being a transformative in nature in IHR, will be carried out in 4 IHR states through 4 regional centers of the Institute.

Objectives:

- Development of 'Spring-Ecosystem' inventory protocol and compilation of the baseline data/information of mountain springs.
- Selection and quantification of ecosystem health indicators, and designing of spring-ecosystem assessment protocol as a performance evaluation tool.
- Implementation of '*Jal Abhayaranya*' concept based on the scientific approaches integrating hydro-geology, spring-ecosystem environment, socio-economy and climate aspects.
- Development and dissemination of inter-disciplinary approaches for spring-ecosystem restoration and management in collaboration with different stakeholders.

Achievements:

HQs (Kosi-Katarmal, Almora)

1. The project was initiated with field visits across four Himalayan states (Fig. 1) for reconnaissance and baseline/household surveys. For spring inventory, visits to Jyoli and Mandunga village cluster in Almora and Champawat districts in Uttarakhand, villages in Parvati valley & Mohal khad watershed of Kullu in H.P., Jakholi block of Rudraprayag district in Garhwal region, Uttarakhand, Lower Subansiri district of A.P., and South Sikkim district of Sikkim were made. A total 160 springs were inventoried and geo-tagged for documenting and analyses of their geo-physical, qualitative and quantitative details. Representation of water chemistry of springs of Jyoli village cluster is shown in Table 1.

2. Total eleven awareness/capacity building programmes were organized at HQs and regional centers in different sites across the IHR. The participants were the stakeholders from villages, scientists, academicians, line-departments, NGOs, students and the research scholars. In all 64 participants were trained as "Para-hydrogeologists" through lectures

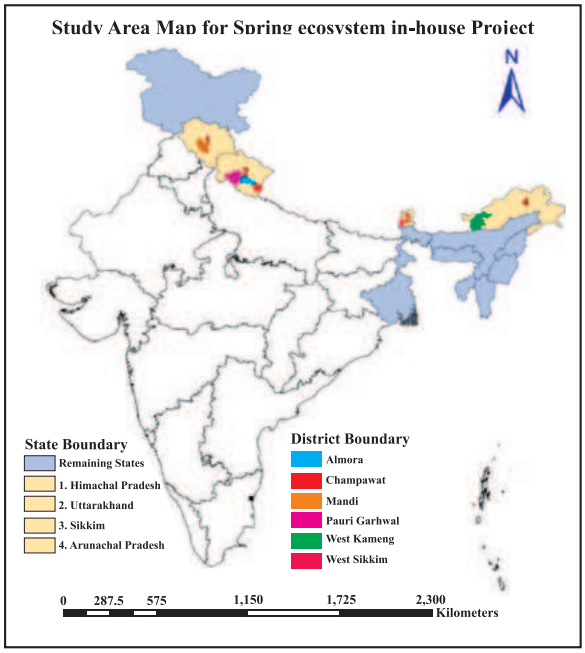


Fig. 1: Location of study area across IHR

Table 1: Water chemistry of springs of Jyoli village cluster in February 2021 (Hawalbagh block, Almora).

S. No.	Spring sites/name	pH	EC (µs/cm)	Turbidity (NTU)	TSS (g/l)	TH (mg/l)	CaH (mg/l)	Ca (mg/l)	Mg (mg/l)	NO_3^- (mg/l)	SO_4^{2-} (mg/l)
	Sisari Dhara	6.27	46.5	0.0	0	20	14.70	5.89	1.288	0.37	8.47
2.	Sisari Naula	6.30	70.3	0.0	0	38	27.30	10.93	2.60	0.84	11.76
3.	Baas Naula	6.20	61.2	0.84	0	36	23.10	9.25	3.135	0.61	10.54
4.	Budh khadak Naula	6.20	565	0.06	0	166	119.70	47.94	11.251	14.00	42.72
5.	Kuhadi Handpump	6.26	582	0.00	0	180	132.30	52.99	11.591	12.88	48.36

EC= Electric conductivity; TSS= Totala suspended soilds; TH= Total hardness; CaH= Calcium Hardness

and field demonstrations. One water conservation and spring augmentation model was developed at SRC.

3. GIS based thematic maps (DEM, slope, aspect, flow direction, flow accumulation, stream network, LULC, geomorphology, lithology, lineaments, land degradation map, soil, decadal population change etc.) were prepared for study sites for delineation of possible spring recharge zones and spring ecosystem boundary.

Himachal Pradesh Regional Centre

- Reconnaissance field visits to Parvati river valley and selection of common intervention village cluster (Pahnala, Muthal, Kareri, Buragran and Sharach in Khadihar and Balh Panchayats) for in-house projects were undertaken.
- Eighty one HH surveys in 5 villages were conducted and samples of spring water were collected. The physical analysis of water for pH, TDS, and EC was carried out and inventory and geodatabase prepared for water samples for 10 locations.

Garhwal Regional Centre

- Baseline survey was carried out in common transformative site of Jakholi block, Distt. Rudraprayag, Uttarakhand for assessment of water demand and supply gaps, and inventory of springs. Thematic mapping of land use /land cover, drainage, watershed demarcation and spring inventory, and assessment of socio-economic drivers for the 9 villages were carried out (Fig. 2).
- A training cum consultative meeting programme was organized on "Participatory springshed management" in collaboration with Dept. of Geography, H.N.B Garhwal University, Srinagar-Garhwal.

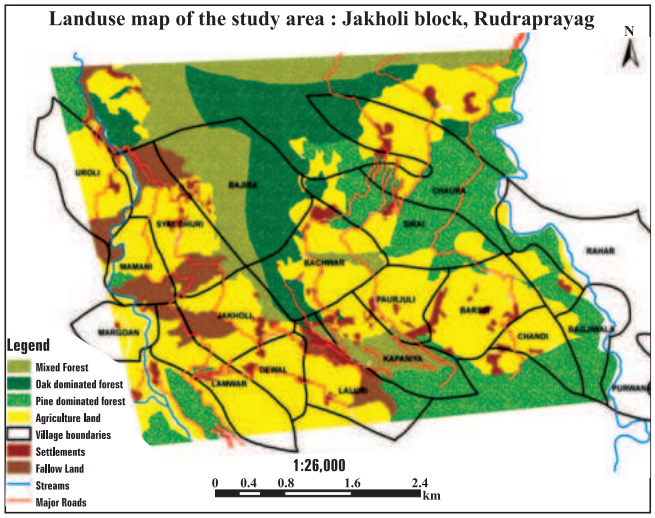


Fig. 2: Landuse and landcover for the common intervention site in Jakholi block.

Sikkim Regional Centre

- Compiled base line data on springs, water demand and utilization through secondary information and primary field surveys at the common intervention site in South Sikkim district. Developed questionnaire for data collection to document impact of climate change on water resources and adaptation measures by the community towards management of water resources due to climate change.
- Organized two consultation meetings in collaboration with the state government department with stakeholders at the common intervention site in South Sikkim district. Around 65 persons, including youth from community and college students, were trained as para-hydrogeologist.

North-east Regional Centre

- A short-term certificate course on 'Para-hydrologists with special reference to spring rejuvenation' was organized in which participants were trained on hydrological concepts and fundamentals of spring rejuvenation and conservation.
- Thematic maps of DEM, slope, aspect, geology/ lineaments, drainage, village location, forest, etc. were produced for lower Subansiri district of Arunachal Pradesh to study the springs and associated ecosystem characteristics. Water samples from 22 springs (including 2 open wells) were analyzed for physico-chemical parameters. The pH (range = 6-7.4) and EC (range = 12-30 µS/cm) were within the acceptable ranges for most of the springs except for two wells (pH < 5.78; EC = 184 and 302 µS/cm) (Fig. 3).

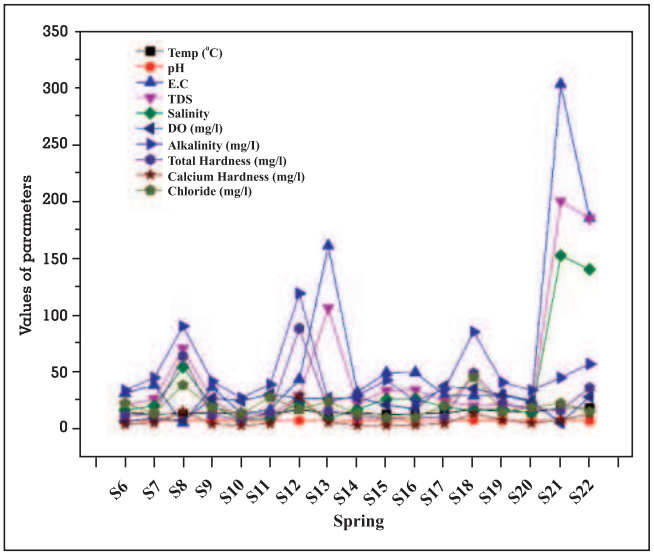


Fig. 3: Physicochemical parameters of water across the springs.

Spring Rejuvenation for Water Security in Himalaya (NMHS, GoI, 2020-2023)

Mountain natural springs are the main fresh water sources which serve to nearly 40 millions people across the Himalayas. Over the years, these precious resources are increasingly drying up, or becoming seasonal due to varying natural and anthropogenic reasons, inducing untold misery to both rural and urban inhabitants of the IHR. Subsequently, many programs were undertaken by different agencies to revive these drying springs using various concepts but resulted in limited success. Therefore, there is an urgent need for implementing spring rejuvenation programmes developed on the scientific basis of successful good practices/models, across IHR in a mission mode. GBPNIHE through its various partners is taking lead in developing demonstration models of *Jal Abhyaranya* (Water Sanctuary) ensuring at least one sustainable source of water within the village in one Aspirational Districts identified in each 12 IHR States by Niti Aayog.

Objectives:

- To develop at least one *Jal Abhyaranya* demonstration model in each Aspirational District of all 12 Himalayan States.
- To promote replication of field model for rejuvenation of drying springs in the Himalayan States through technology and community based approaches for providing water security to local communities in collaboration with state agencies.

Achievements:

1. Initiated 12 *Jal Abhayaranya* demonstration models in 11 states and 1 UT in IHR (including Aspirational Districts identified by NITI Aayog) – Uttarakhand, Himachal Pradesh, Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura, West Bengal and Jammu & Kashmir (Fig. 4).

2. The implementation of the *Jal Abhayaranya* model initiated with Inception Workshops organized in Webinar mode at GBPNIHE Kosi - Katarmal, Almora and important strategies were identified.

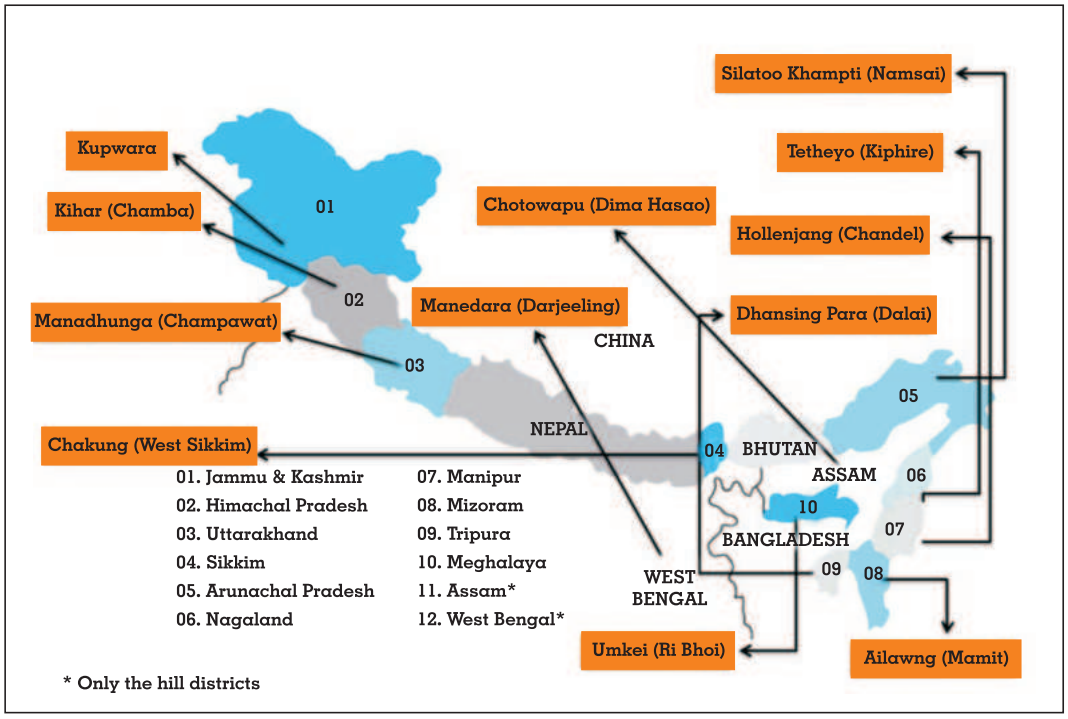


Fig. 4: Location map of the project

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

The 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, VSR and IRP over western Himalaya are inadequately investigated. Therefore, this research aims to assess 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 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.

Achievements:

1. The rainfall vertical structures of winter period (Nov. 2020 to Feb. 2021) were investigated using rainfall observations of a Ka-band (24.1 GHz) micro rain radar over Central Himalaya (Fig. 5). A total of six rainy days resulting 71.4 mm rainfall were investigated. The mean bright band signature of stratiform rainfall was identified at an average location of 2536.5 (±422.1) m above ground.

2. The average snow and rain layer heights during winter stratiform rainfall were identified at 3546.8 (±442.8), and 1461.2 (±433.4) m above ground, respectively. The average bright band thickness (1687.5 m) during winter stratiform rainfall was much higher than the same for central and peninsular India, and it could be attributed to enhanced rimming process of super cooled droplets.

3. A nearly linear relationship between the average radar reflectivity at snow and rain layer indicated linear conversion of a single snow particle to a rain drop wherein snow particle densities were greater than 0.1 g cm^{-3}.

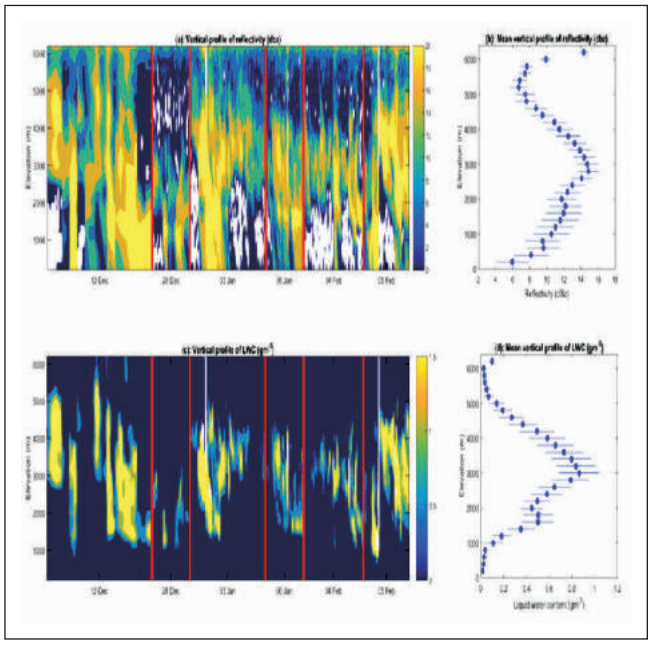


Fig. 5: Vertical profiles and mean values of (a, b) radar reflectivity and (b, c) liquid water contents, as observed using a micro rain radar, are provided for 12 Dec. 28 Dec. 2020, 3 Jan. 6 Jan. 4 Feb. and 5 Feb. 2021, respectively.

Pine and Oak System: Interactions of Water Climate and Plant Biodiversity (NMHS, GoI, 2019-2023)

There is an increasing common perception that Himalayan Pine (*Pinus roxburghii*) stands may systematically be replaced with Oak (*Quercus leucotrichophora*) forests, and subsequently the paradigm of water, climate and biodiversity is expected to change significantly from its current state. However, a thorough assessment of differences in hydro-meteorological properties, hydrological budgets and ecosystem exchanges of carbon and water over these forests including their anticipated changes in a warmer climate are seldom carried out. Moreover, a recent study based on long-term direct measurement of net ecosystem exchange (NEE) from Pine and Oak dominated forest patches indicate that Pine dominated forest ecosystem may have higher carbon sequestration rate than an Oak dominated forest ecosystem, indicating potential for a detailed study. Therefore, this proposal is framed such that it would address multiple research and policy issues pertaining to the hydrometeorology and ecosystem services of Pine-Oak systems of the IHR.

Objectives:

- Assessment of Pine and Oak forest distribution under a warmer climate over two watersheds of Central Himalaya.
- Assessment of hydrological budget of Pine-Oak dominated watersheds of Central Himalaya.
- Assessment of microclimate variability of Pine-Oak dominated forests and future changes under a warmer climate.
- Assessment of eco-hydro-climatological processes with information theory-based process network and understanding resilience under shock.

Achievements:

1. A 2 x 2 km grid based approach was adopted to assess current distribution of plant diversity over Kosi-watershed (Almora) having a total area of 1860 km^2. A total of 100 numbers of 2 x 2 km grids were noted to be dominated by *P. roxburghii*, whereas 21 grids of 2 x 2 km were found to be dominated by *Q. leucotrichophora forests.*

2. Impact of microclimatic variability on NEE of a *P. roxburghii* dominated vegetation of Kosi-watershed was assessed using wavelet spectral method, and daily rainfall and NEE data of 1445 days. The Pine dominated vegetation was a sink of CO_2 having average NEE of -3.35 $\mu mol.m^{-2}.s^{-1}$ implying an annual uptake of around 1270 $gC.m^{-2}$. Wavelet coherence analyses indicated a statistically significant correlation between daily average NEE and daily rainfall having band periods of 70-120, 35-64, 60-90, and 64-120 days of monsoon, respectively, where rainfall leading to NEE. Daily rainfall > 64.4 mm of monsoon period enhanced carbon sequestration with average band periods of 4 days; whereas, same for winter time heavy rainfall events resulted NEE band periods of 15 days with very high local correlation (Fig. 6).

3. Comparison of sap flux densities (Jp) during winter season (Nov-Feb) between *P. roxburghii* and *Q. leucotrichophora* stands indicated significantly higher water demand by *P. roxburghii* (J_p = 0 - 20 $mm.cm^{-2}.min^{-1}$) than the *Q. leucotrichophora* (J_p = 0 - 8 $mm.cm^{-2}.min^{-1}$).

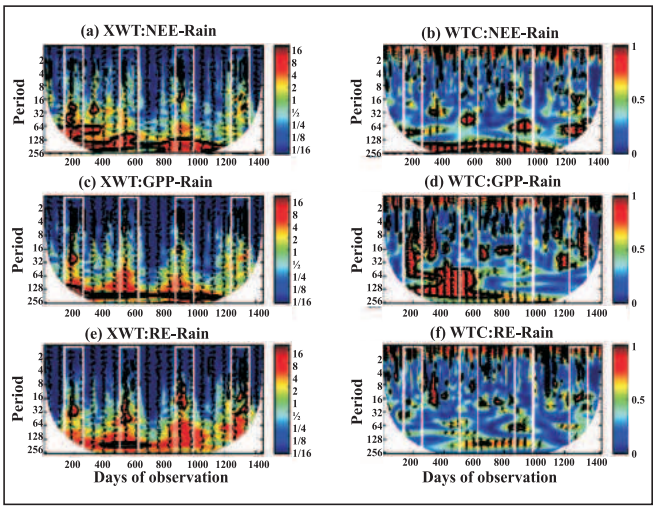


Fig. 6: Cross wavelet (subplots a, c, e) and squared wavelet coherence (subplots b, d, f) of daily average NEE, GPP and RE with daily total rainfall for 2014-2017.

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, GoI, 2018-2021)

Rainfall and snow-melt are the major sources of water in the Central Indian Himalayas. Notable changes of rainfall and snow-melt over this region have been reported in recent decades. In addition, shift in the cropping systems, urbanization and population growth adds additional stress on the availability of freshwater. These changes significantly modify runoff and the quality of available freshwater, in turn, disrupting the balance of 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 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 regions is proposed to be developed for the Kosi watershed of Uttarakhand. Subsequently, changes in the land and water resources are to be quantified.

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 stakeholders for enhanced decision making on water management.

Achievements:

1. In order to identify suitable sub-watersheds for ground water augmentation activities within the Kosi-watershed (total area ~ 1860 km^2), remote sensing and GIS aided morphometric analyses were carried out using ALOS palsar digital elevation model of 12.5m. A total of 9 sub-watersheds within the Kosi-watershed were identified based on 6^{th} order-stream classification.

2. The morphometric linear (bifurcation ratio, drainage density, drainage texture, stream frequency, length of overland flow) and shape (circularity ratio, form factor, elongation ratio, shape factor, compactness coefficient) parameters were computed for each sub-watershed. Subsequently, cumulative indices were computed for each sub-watershed using linear and shape parameters, which were direct and inversely proportional to erodibility. Finally, sub-watersheds were ranked based on cumulative indices where lowest cumulative index (0.228) was considered as rank 1 implying the sub-watershed needing highest water augmentation activities, and the sub-watershed having highest cumulative index (0.255) needing lowest water augmentation activities (Fig. 7).

3. A total of 3 sub-watersheds having a total area of 887.8 km^2 within the Kosi watershed were identified needing suitable groundwater augmentation and soil-water conservation activities.

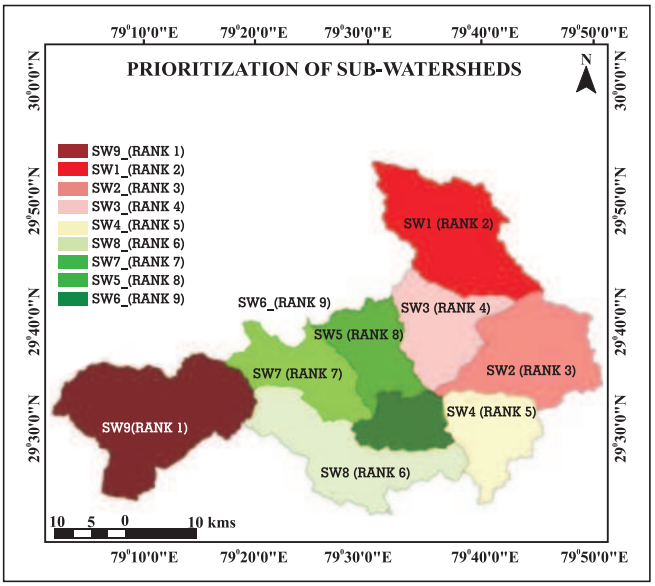


Fig. 7: Prioritized rank of sub-watersheds within the Kosi-watershed needing water augmentation activities.

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, GoI, 2018-2021)

The traditional urban-rural ecosystem of Uttarakhand and most of IHR states comprised of small townships surrounded by a number of villages forming a symbiotic system where rural areas catered to the urban demands of food items and labor, and urban areas provided the livelihood opportunities.

Later, this symbiosis was disrupted due to outmigration for jobs, poor agricultural productivity, urban sprawl in rural pockets, globalization, ingress of markets, socio-economic reasons and climate change - adversely affecting the system productivity, livelihood and economic contribution of rural sector. Urban areas suffered from problems of congested growth, waste, traffic jams, pollution further affecting the natural resources, their environmental amenity value, ecosystem-service flows, hence, the sustainability and resilience of the system with long-term implications for the tourism and economy of the region. The project seeks to explore ways to improve the livelihood scenario and urban-rural ecosystem sustainability in the Kosi-Suyal watershed of Almora town.

Objectives:

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

Achievements:

1. For assessment of livelihood vulnerability and enhancement strategies, PRA and household survey of DFID capital assets were continued, and primary data of 100 households was collected and responses of 404 households compiled after screening for further analyses.

2. Based on PRA, field surveys and community interactions a Causal Loop Diagram (CLD) showing the linkages, cause-effect relationship, balancing/reinforcing behaviour amongst different capital assets, their elements and components was developed to examine the livelihood scenario in the rural ecosystem (Fig. 8a). The CLD analysis shows the livelihood in the region depends on a combination of various socio-economic, technological, institutional factors affecting the system components, production efficiency and resilience.

3. With the help of CLD diagram 'Fuzzy Cognitive Model' of livelihood system was developed (Fig. 8b). The DFID data was used to run the model for livelihood system analyses and scenario building for river valley and upland (mountain) rural settlements. Three sets of model components i.e. Transmitter (forcing function), Receiver (utility function) and Ordinary component, and 20 factors and 34 connections were identified for scenario effects. The results of the analyses for 15 proxy indicators reveal that for valley and uplands - migration (centrality – 5.24 & 3, respectively), livestock herd size/ACU (3.52 & 2.33), type of forest area (2.52 & 1.18), water availability (1.99 & 0.64), and farm and/net sown area (1.75 & 1.17) are the important and limiting factors affecting the livelihood system in the region (Table 2). Therefore, these factors need to be considered for strategy development for livelihood improvement and system sustainability.

Table 2: Fuzzy Cognitive Model based assessment of livelihood components for Kosi watershed: valley & upland Areas.

S. No.	Livelihood proxy indicator/ assessment parameter	Centrality in river valley	Centrality in mountain settlement
1.	Dependency ratio-ratio of age group 16-64 yrs. to total members	0.67	0.75
2.	Education of HH head	1.96	0.88
3.	More than one occupation	1.87	1.13
4.	Farm land	1.75	1.17
5.	Forest area	2.52	1.18

S. No.	Livelihood proxy indicator/ assessment parameter	Centrality in river valley	Centrality in mountain settlement
6.	Source of water used for irrigation	1.99	0.64
7.	Livestock (ACU)	3.52	2.33
8.	Communication/ transport/ machinery/tools	1.4	0.62
9.	Number of migrants	5.24	3
10.	Association with NGO/SHGs	0.58	0.44
11.	Cold storage/ seed facility/ warehouse	0.2	0
12.	Organic market	0.36	0.12
13.	Income	0.54	0.69
14.	Migrant remittance	0.75	0.84
15.	Crop insurance	0.49	0.44

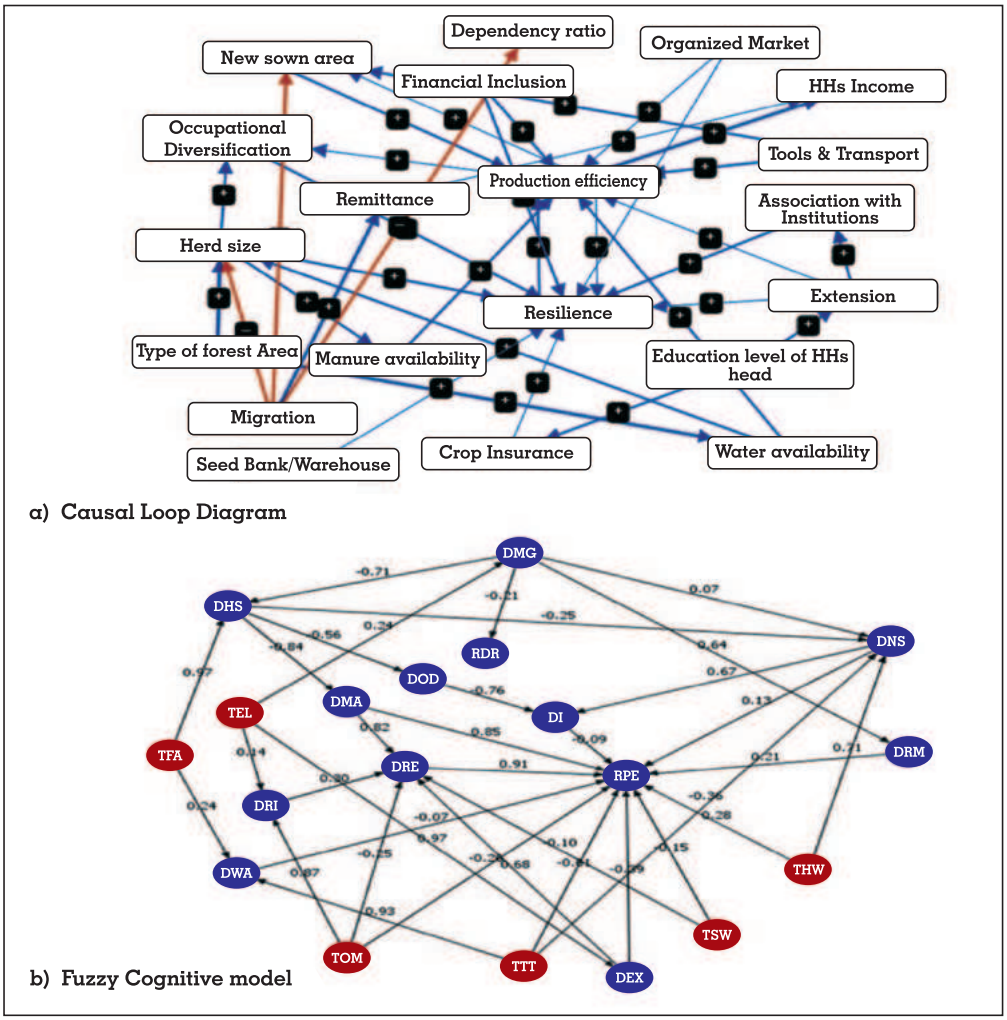


Fig. 8: Causal Loop Diagram (CLD) of livelihood and iteration results of Fuzzy Cognitive Model of rural ecosystem of Kosi watershed (RDR- Receiver dependency ratio, RPE- Receiver production efficiency, TEL- Transmitter education TFA- Transmitter forest area, TOM- Transmitter organized market, TTT- Transmitter tools and transport, TSW- Transmitter source of water, DHS- Livestock herd size, DMG- Migration, DNS- Net sown area, DRM- Remittance, DI- Income, DOD- Occupational diversification, DMA- Manure availability, DWA- Water availability, DEX- Extension, DFI- Financial inclusion, and DRE- Resilience).

Permafrost Mapping and Characterization of Western Himalayan Region (NMHS, GoI, 2018-2021)

Permafrost is unconsolidated sediment or bedrock that remains frozen for at least two consecutive years. Permafrost studies are sparse in the Hindu Kush Himalayan (HKH) region in general, and IHR in particular. Preliminary studies in Ladakh region indicate that the ground ice melt could be significant in the streams of this region. Permafrost (perennially frozen) soils store vast amounts of organic carbon (C) and nitrogen (N) that are vulnerable to mobilization as dissolved organic carbon (DOC) and dissolved organic and inorganic nitrogen (DON, DIN) upon thawing. Such releases will affect the biogeochemistry of permafrost regions. The DOC, DON, DIN and total dissolved nitrogen (TDN) broadly influence terrestrial and aquatic ecosystem functions and greenhouse gas emissions. So, it is critical to quantify sources that become newly available as permafrost thaws.

Objectives:

- Modeling of permafrost extent in Leh district of Ladakh region.
- Modeling active layer thickness of permafrost in selected study areas.
- Assessment of regional climate and fluxes over permafrost regions.
- Assessment of water quality and biogeochemistry of permafrost horizon with special emphasis to DOC, DOM, DON and DIN in active layer.
- Assessment of ground ice melts contributions to regional water resources and estimates the sources of local and transported moisture using isotope technique.

Achievements:

1. Water, permafrost leachate and soil sampling was carried out at different locations of Leh within an altitudinal range of 3405-5437 m. Areas covered during sampling were Upshi, Tso Kar / Tso Morari (Indus River), Warila, Tanglangla (Rumtse), Zingrel, North Pullu, South Pullu, Changla, and Ganglass (Fig. 9). Garmin Etrex 10 GPS was used to find the location of each sampling site for preparation of base map on GIS platform.
2. The onsite water quality assessment at three sites revealed that water was alkaline (pH > 8.5) in some of the sites e.g., Tsokar and Tso Morari, Zingrel, North Pullu, Ganglass and Punchh glacier area. Electrical conductivity and salinity of Puga hot water (EC= 2670 µS/cm, salinity = 1.23 psu) was highest, followed by Tsokar lake (EC= 1188 µS/cm, salinity= 1.03 psu), and Tso Moriri lake (EC= 1144 µS/cm, salinity= 0.91 psu), respectively.
3. Total nitrogen content in soil was highest in active layer collected from down Warila (0.86 gm/kg) followed by Tsokar, and Pucche glacier (0.83 gm/kg, and 0.43 gm/kg), respectively (Fig. 10).

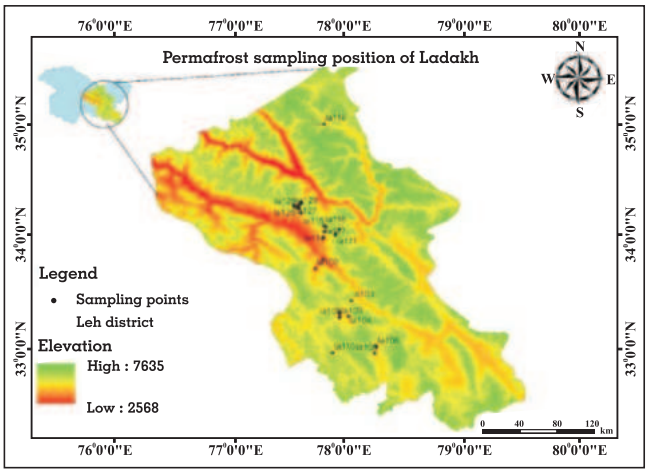


Fig. 9: Different sampling locations in Leh (Ladakh)

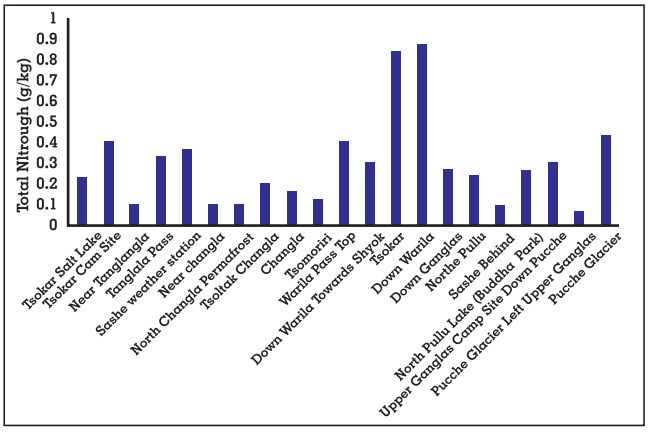


Fig. 10: Total nitrogen content in the active layer soil sampling sites in Leh, Ladakh.

Pine Needle Based Waste Water Treatment System for Recycling of Domestic Waste Effluents (NMHS, GoI, 2019-2022)

Greywater is the wastewater usually generated from the kitchen sink, shower, laundry or washing machine, etc., which is disposed-off in the surrounding environment as a waste. This water can be reused by a simple and cost-effective treatment technique. Grey water treatment methods, such as physical methods include coarse sand, soil and membrane filtration. Chemical treatments include coagulation, photo catalytic oxidation, ion exchange and granular activated carbon. Biological treatment includes chlorination and disinfection. Activated carbon is considered to be attractive for the treatment. Studies have reported the use of various organic wastes, like sugarcane bagasse, sawdust, rice hulls, and pine bark as filter media for grey waste water treatment, however, sand filtration, coagulation and pine needle based filter combination has not been used so far. Therefore, this project aims at utilizing the pine needles for the treatment of grey water in combination with other known wastewater treatment processes.

Objectives:

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

Achievements:

1. The maximum surface area shown by the carbon (GBP-C9), prepared in inert atmosphere, was >1000 m^2/g carbon. The Scanning Electron Microscopic image is attached as Fig. 11.

2. Salinity, electrical conductivity, chemical oxygen demand, ammonium ions, chloride ions, caffeine, bisphenol A, phenol content was reduced a lot in the effluent coming out from the lab scale setup (Fig. 12).

3. Impact of organic pollutants such as bisphenol A (observed pollutant of collected grey water) and ibuprofen was tested on *Brassica juncea* (L.) Czern. (locally known as Lahi) and *Mentha spicata* L. (locally called Pudina), and it was observed that these plants are able to remove the higher concentration of pollutants (100 ppm BPA and 21ppm IBU) through roots, shoot and stem parts and not getting concentrated in leaves, which are generally consumed in food items. This shows that the selected plants are degrading the compounds through rhizo-degradation process.

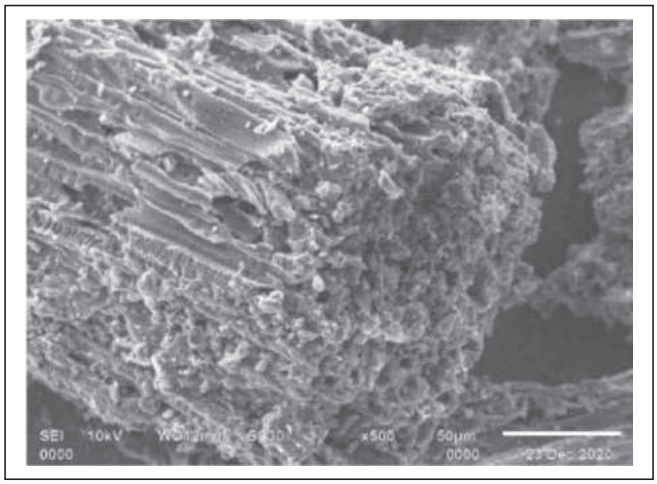


Fig. 11: SEM diagram of the carbon sample.

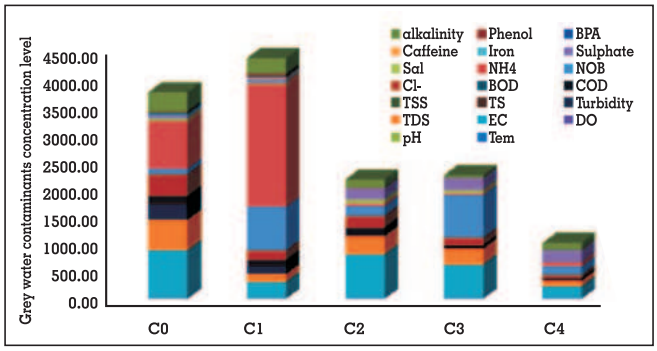


Fig. 12: Status of water quality during the treatment of greywater through different steps.

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

Food and nutrition security is a building block for achieving Sustainable Development Goal (SDG-2) along with SDG-3 & SDG-6. According to the Global hunger index, India ranks 94 among 107 countries with a score of 27.2. This shows the seriousness of nutritional deficiencies among the people of India. The problem becomes severe in case of marginalized communities mainly schedule caste and tribes, who are living in poor conditions. Although the Himalayan region is rich in agricultural diversity, due to diverse biophysical environment but due to limitations in the socio-economic development, nutritional security is a challenge for Himalayan schedule communities. 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 socio-economic conditions. As a consequence, lifestyle of the people residing here also differs from plains of India. Almora district falls under zone C among agro-climatic zones of Uttarakhand, where the hill-agriculture is practiced, soil is red to dark and rainfall distribution is 1200-2500 mm/year. There are different types of traditional crops like cereals, millets, pulses, oilseeds and vegetables cultivated in the region. Many of these crops are also identified as super foods, which were earlier known as neglected and underutilized species (NUS), but, farmers are taking less interest in their cultivation. Diverse food recipes are a major speciality of the region. There are many local recipes within the region that uses crops which are meagrely produced in the region. A total of 5 villages within Almora district, namely Katarmal, Hawalbagh, Shuona, Panchgav and Matela were selected for this study. Demographic and food habit questionnaire survey were conducted for behaviour of residents including schedule communities (SC). Demographic survey revealed that people are moving away from agriculture as only 31% SC people are engaged in this activity among the selected villages. During survey in 2017, it was found that 56% people from marginalized community used chulhas, while in the year 2020 its use decreased to 19%. The percentage of people using both chullha and gas stove increased to 64% from 11% in the year 2017. This shows the positive effect of Ujjwala Yojana of Govt. of India. The nutritional compositions of food prepared using horse gram (gahat), black soybean (bhat), rice bean (rains), and barnyard millet (jhangora) and consumed by the stakeholders were analysed following standard methods. Cuisines made up of black soybean have highest amount of protein among all the recipes. Very less reduction of protein was observed in case of recipes prepared using horsegram as raw ingredient. Ricebean recipes found to have highest amount of carbohydrate among all the cuisines. Total fat was highest in Gahat ke dubke, while recipes made up of black soybean have higher amount of total fat amongst all the recipes. Bhat ka jaula has highest amount of potassium. Iron content was highest in Gahat ki chatni. It was noted that all the selected cuisines were equally nutritious in terms of selected parameters. There was a significant variation among the cuisines in terms of ash content, total fat, potassium, tannin content, FRAP activity. Although the variation was not significant for most of the parameters among the recipes as shown in the heat map (Fig. 13). The stakeholders informed that the cause of less interest in eating traditional cuisine is easy availability of food grains from ration system and interest of younger generation towards fast food and other easily available food items. It was also suggested by the stakeholders that millets and pseudo cereal ingredients (known as super foods) based traditional food may be promoted through ICDS and PDS programs. It was observed that there is need to look towards the integrated approach for understanding relation among livelihood, tourism, and regional foods. Outcomes of this study can be summarized as (i) the traditional cuisines were found rich in vitamins. The fat-soluble vitamins such as vitamin D3 and vitamin E were observed in the range of 0.011-0.006 g/100 g dry sample weight and 0.027-0.6 g/100 g dry sample weight, respectively; (ii) cuisines made up of black soybean were having highest amount of protein and fat among all the recipes. Ricebean recipes were having highest amount of carbohydrate among all the cuisines; and (iii) traditional cuisine Bhat ka jaula had highest amount of potassium, where as iron content was highest in Gahat ki chatni.

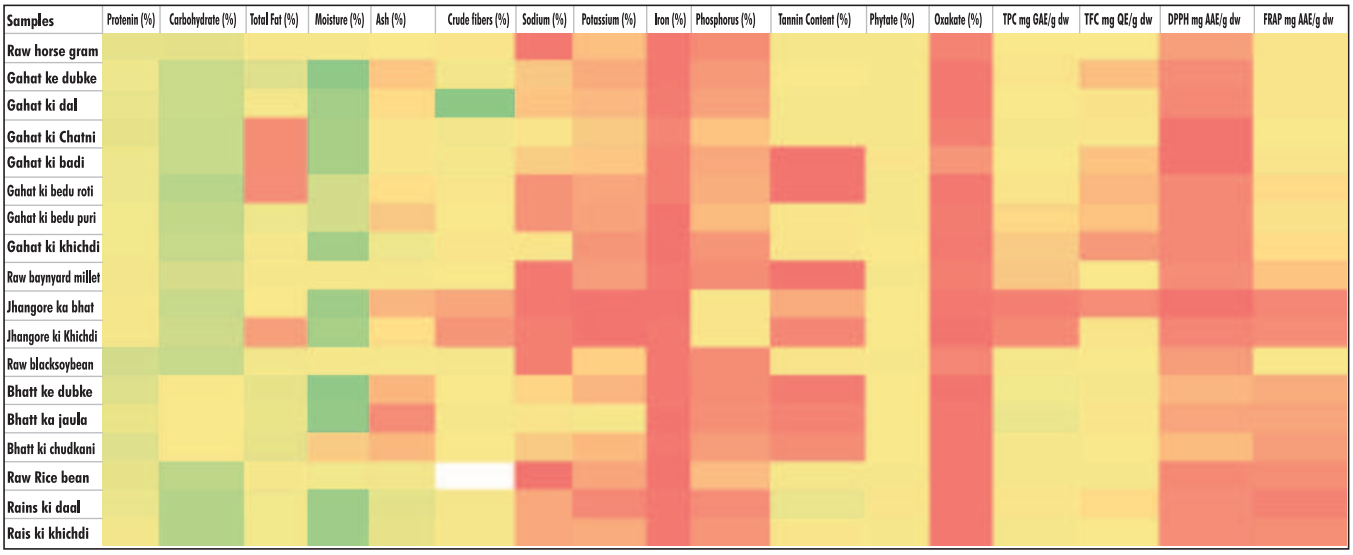


Fig. 13: Heat map showing the variation among the nutritional composition of traditional cuisines prepared in the way consumed by scheduled communities residing in the selected villages.

CENTER FOR BIODIVERSITY CONSERVATION AND MANAGEMENT (CBCM)

Recognizing that the Himalaya is: (i) one of the hotspots for biodiversity, and (ii) provider of ecosystem goods and services to large population in Indian subcontinent, biodiversity conservation and management deserve 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-situ and ex-situ package of practices on biodiversity conservation approaches and scaling up these approaches among a wide range of stakeholders spanning from rural landscapes, school children and research 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 (MAPs) 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 Himalayan 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.).

Mainstreaming Himalayan Biodiversity for Sustainable Development (GBPNIHE In-House Project-4, 2020-2025)

The Himalayan region is one among the 36 global biodiversity hotspots and supports peoples' livelihood directly and indirectly through a range of ecosystem goods and services, including the most desired carbon sink. With a broad goal of ensuring sustainable use of Himalayan biodiversity for human well-being and improved ecosystem health, the project intends to facilitate the process of formation of BMCs and PBRs so as to strengthen Access and Benefits Sharing (ABS) mechanism in IHR. Also, the project targets *ex situ* and *in situ* conservation of selected endemic and threatened plants. Further, establishment of market value chains for selected high value medicinal/wild edibles plants, as envisaged, will help the stakeholders in optimizing the benefits. The project finally attempts to create a cadre of green skilled, nature oriented, and conservation awakened youth and women for sustainable use and long-term maintenance of Himalayan biodiversity.

Objectives:

- To facilitate BMCs and PBR formation for implementation of Biodiversity Act (2002) in selected villages of IHR.
- To develop and demonstrate applicability of *ex situ* conservation of selected endemic and threatened plants in IHR.
- To identify and map selected biodiversity rich areas for promotion of *in situ* conservation in the IHR.
- To establish market value chains of selected high value medicinal plants and wild edibles in the IHR.
- To engage and inspire diverse stakeholders towards biodiversity conservation through conservation education and green skill building programme.

Achievements:

HQs (Kosi-Katarmal)

1. Documentation of Good Agricultural Practices (GAP) of 21 threatened and endemic plants. A total of 1195 endemic plant species (463 genus and 107 families) identified from IHR, 196 species geo-coded to identify the biodiversity hotspots in Western Himalaya.
2. Plantation of *Cinnamomum tamala in* village Kamad (Gangolihat), Kujyari (Almora) and Manan (Almora) and *Hydechium spicatum* in Bamdigad (Almora) was done for *ex situ* conservation.

Himachal Pradesh Regional Centre

- Technical support was provided to District Administration of Kullu district for preparation 140 PBRs in 6 blocks of Kullu. Also, four training programs were organized for young trainees recruited for the preparation of PBRs.
- Ethno-medicinal survey was conducted among 210 respondents about collection, usage and sale of MAPs in 16 villages of Kullu district, and a total of 91 MP species belonging to 45 families were documented (Fig. 14).
- Herbal gardens were established in Dohranala and Khalogi Govt. schools as part of *ex-situ* conservation of threatened MPs. Planted graft cuttings of *Rhododendron arboreum*, *Taxus wallichiana* and *Zanthoxylum armatum* using various treatments in the Institute nursery to develop optimal cultivation protocols.

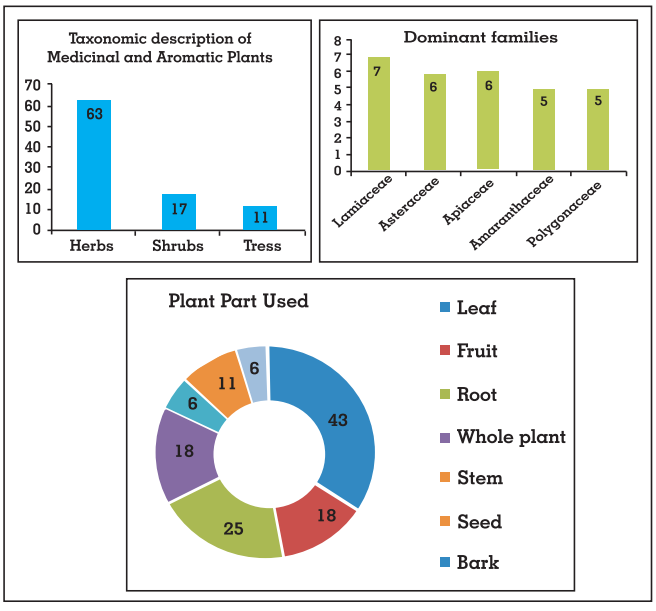


Fig. 14: Overall statistics from the ethno-medicinal surveys of various villages in H.P.

Garhwal Regional Centre

1. A workshop-cum-field scoping visit was organized to select a common intervention site for the project and 16 villages of Jakholi block (Distt. Rudraprayag) namely, Jakholi, Kapriya, Bachwar, Barsir, Khothiyada, Candi, Bajira, Dhankurali, Uroli, Gorti, Uchana, Budna, Lotiyag, Palakurali, Thuker and Mehr Gaon.

2. Domesticated plant (agricultural, horticultural, ornamental, medicinal and religious) and animal (mammals) diversity in 16 villages of Jakholi village cluster was listed with a total of 88 varieties/species of agricultural crops and other important species (Fig. 15).

3. To raise the quality planting material (seeds) of threatened medicinal plant *Sassurea costus, seeds* were collected and sown in the nursery for further *ex-situ* conservation at Jakholi village cluster intervention site, Pangroli and Triyuginaryan villages.

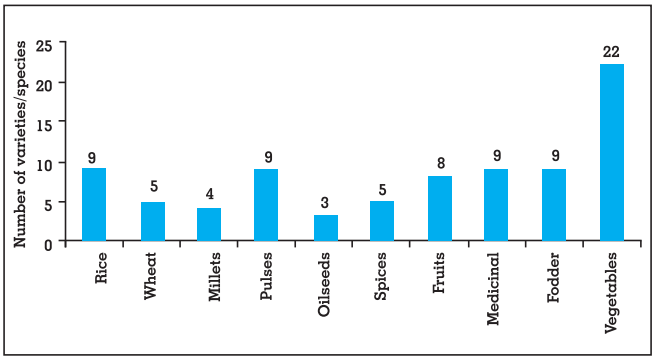


Fig. 15: Diversity of traditional crops and other important plant species in villages of Jakholi block.

Sikkim Regional Centre

- Provided technical support in facilitating 2 BMCs and 1 PBR for implementation of Biodiversity Act (2002) to Sikkim Biodiversity Board. Two consultation meetings with the stakeholders were organized for scoping of project activities at Mamlay watershed, South Sikkim.

- Lab and field work was carried out for developing and strengthening propagation protocols of 4 endemic plants of Sikkim Himalaya (i.e., *Rhododendron dalhousiae*, *R. niveum*, *R. wigthtii* and *R. madenii)*. Also, a germplasm repository of high value MPs of Sikkim Himalaya (*Swertia chirayita, Berginia ciliata, Paris polyphylla and Aconitum ferox*) are being maintained in herbal garden of SRC.
- Developed gridded maps for identifying and mapping of biodiversity rich area of IHR. A total of 368 distribution records of 17 threatened and endemic plant species of Sikkim Himalaya consulting regional herbariums, published literature and online database (i.e. GBIF) were compiled.

North-East Regional Centre

- Administrative map, DEM, topography, slope and aspect, proportion of forest cover, NDVI, Topographic Position Index, distance from rail and major road network and distance from water sources were digitized for Lower Subansiri district to prepare a weighted biodiversity rich area map (Fig. 16).

- Consultation meetings with the Forest department and BMC of Lower Subansiri District was conducted to identify biodiversity rich area, *in situ* and *ex situ* conservation and creating a market value chain of medicinal plants.

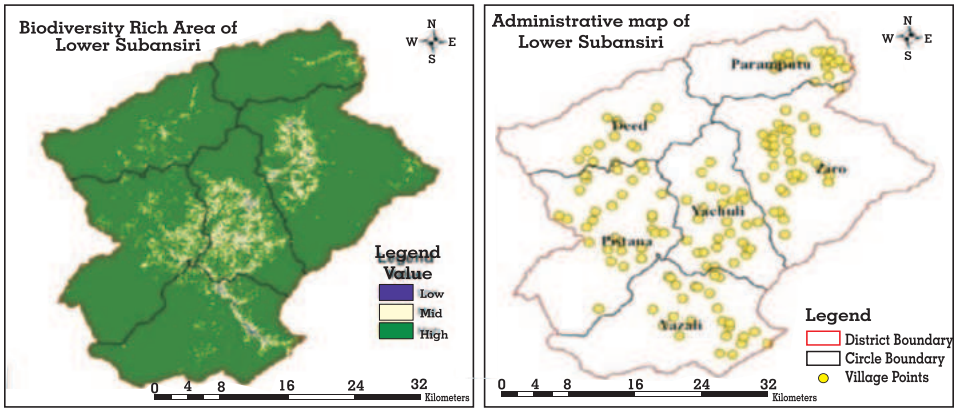


Fig. 16: Potential biodiversity rich area map of Lower Subansiri.

Mainstreaming Landscape Approach for Biodiversity Conservation, Improved livelihoods and Ecosystem Health in Kailash Sacred Landscape Part of India (NMHS-GOI, 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. The Institute is involved in Objective No. 2 of this multi-partner project and 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 communica-tion, outreach and policy dialogues for long-term networking among key stakeholders of the landscape.

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. Seven restoration models were developed in Naikina (1 ha), Digtoli (2.5 ha) villages of Chandak-Aunlaghat watershed, and Chitgal (2 ha), Rawalgaon (1 ha), Kamad (3 ha) and Jajut (1 ha) villages of Hat- Kalika watershed, and Lumti village (3 ha) of lower Gori river valley through plantations involving people from 34 surrounding villages.

2. Across these plantations, *Quercus leucotricophora* and *Q. glauca shows maximum survival in Naikina, Digtoli,* and *Cinnamomum tamala, Ligustrum nepalensis* shows maximum growth response, and *Alnus nepalensis* shows maximum survival in Jujut, and *C. tamala* in Rawalgaon and Digtoli villages (Fig. 17).

3. Climate resilient agriculture- water conserving root zone irrigation technique was implemented in Chitgal, Naikina and Digtoli villages.

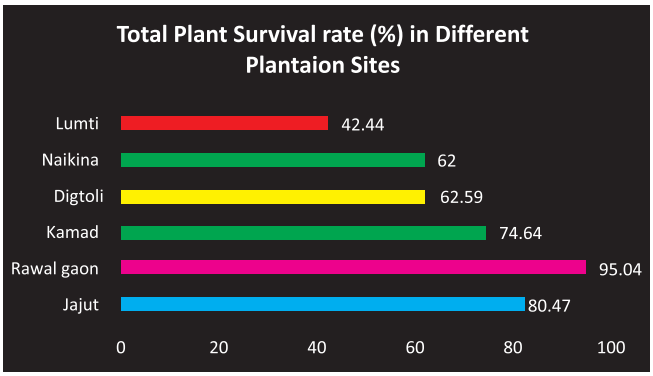


Fig. 17: Details of plant survival rate in all the restoration sites in Pithoragarh District.

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

Over the last three decades, climate warming has been a major concern for ecologists and environmentalists. All ecosystems will experience CC, but ecosystems of the alpine zone are considered to be particularly sensitive to warming because they are adapted to low temperature conditions. However, due to lack of long-term monitoring in alpine regions, data sets and evidence are not available for Himalayan alpines in terms of climate monitoring (IPCC, 2007). Towards addressing these data gaps in the IHR, especially in alpine areas, the project targets to establish LTEM sites in the alpine region of Uttarakhand, West Himalaya for continuous monitoring following the GLORIA procedure and understand floristic diversity patterns in alpine regions under the influence of CC as well as provide conservation implication and generate awareness on floristic studies.

Objectives:

- To analyze the floristic diversity and its composition patterns along representative altitude zones in different alpine landscapes of West Himalaya.
- To establish and strengthen Long-Term Ecological Monitoring site(s) following the 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. A LTEM site was established in the Lata-Kharak region of Chamoli district following multi-summit approach of GLORIA protocol consisting of four summits, namely Kharak (KHR), Sainikharak (SAI), Donidhar (DON) and Pulan (PUL) along an altitude gradient above natural tree line (Table 3).

2. Lata target region (summit area sections) was inhabited by a total of 133 plant species belonging to 94 genera and 37 families. The most represented families were Asteraceae (16 spp.) and Rosaceae (13 spp.). There was a significant decrease in species richness with increasing altitude, with maximum species in KHR (88 spp.), followed by SAI (80 spp.), DON (67 spp.) and PUL (40 spp.)

3. Physico-chemical analysis of the soil of summit sites indicated that soil moisture increases along altitude with minimum at KHR (39.7%), followed by SAI (39.9%), DON (42.9%) and PUL (47.4%). Soil bulk density (g/cm^3) ranged from 0.81 in KHA to 1.0 in PUL, while pH ranged from 4.69 in KHA to 5.44 in DON. The soil moisture and soil temperature decreased with increasing depth, whereas bulk density increased with depth. pH did not exhibit any significant trend with depth and ranged from 5.58 (KHA) to 6.53 (SKN). Soil moisture ranged from 31.2% (SKN) to 36.2% (GAN), bulk density from 0.62 gm/cm^3 (KHA) to 0.98 gm/cm^3 (BHT).

Table 3: Summits of GLORIA active target region in Lata valley, India.

Locality (Summit code)	Altitude (m)	Geographical Location	Vegetation zone
Kharak (KHR)	3820	30°29'41.47" N 79° 45'12.20" E	Lower alpine-above tree line; *Danthonia* and *Bistorta* dominated
Sainikharak (SAI)	3923	30° 29'28.79" N 79° 45'14.97" E	Transition between the lower and upper alpine; *Bistorta* and *Geum* dominated
Donidhar (DON)	4030	30° 29'35.14" N 79°45'20.16" E	Upper alpine-the top region; *Bistorta* and *Trachydium* dominated
Pulang (PUL)	4269	30°29'39.01" N 79°45'42.63" E	Transition between the upper alpine and nival; *Potentilla* and *Kobresia* dominated

Promoting Conservation of Threatened Plant Species in West Himalayan Region – A Participatory Approach (NMHS, GoI, 2018-2021)

Conservation of medicinal plants is receiving high priority and attention across the globe keeping in view the resurgence of interest in herbal and cosmetic medicines. The increasing demands, over exploitation for trade, paucity of knowledge for sustainable harvesting has led several Himalayan species threatened. Considering the high rate of 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 MPs so as to improve the populations of threatened species in natural habitats, which will reduce pressure on wild resources, conserve biodiversity and uplift the socio-economic condition of local inhabitants. Keeping this in view, seven potential MP species (i.e., *Allium stracheyi, Angelica glauca, Cinnamomum tamala, Hedychium spicatum, Picrorrhiza kurroa, Saussurea costus* and *Valeriana jatamansi*) were targeted for cultivation at farmer's field (900-2750 m asl) of Chaudas valley, Distt. Pithoragarh.

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 farmer's fields.
- To develop market linkages for selling of cultivated produce.
- To sensitize diverse stakeholders' groups towards promoting conservation of threatened medicinal plants.

Achievements:

1. In Chaudas area a total 179 farmers initiated cultivation of targeted species in around 4 ha land under our technical guidance (Fig. 18). Further, 6 demonstration plots in different altitudes were established and germplasm of 15 Himalayan species were maintained in demonstration plots (0.8 ha) at Sri Narayan Ashram.

2. Two school conservation models at GIC Pangu and Primary School, Sosa were established and organized 4 training programmes that benefitted 400 stakeholders (farmers, students, and teachers) in Chaudas valley.

3. Market linkages for selling cultivated produce was facilitated with Human India, Srinagar, Surkunda Jadi-Buti Samuh, Bageshwar and MGNREGA activities. Certification of cultivated produce was initiated under Voluntary Certification Scheme for medicinal plant produce.

Fig. 18 : Technical guidance to farmers for medicinal plants cultivation in Chaudas valley.

Hyperspectral Imaging for Sharper Definitions of Himalayan Ecosystems and its High Value Plant Species Under Climate Uncertainties (NMHS, GoI, 2019-2021)

The IHR is one among the world's unique mountain systems. The variations in topography, climate and a vast altitude range <100 m to >7000 m asl provide habitats for different life forms to grow and flourish. Plant diversity is an integral element of the global ecosystems and provides stability to the ecosystem and maintains the ecological balance. The Himalaya, which represents one of the global biodiversity hotspots, is rich in diversity of such high value plant species. They play an integral role in structure and functioning of the forest ecosystem. Quantification of biophysical and biochemical parameters are very crucial for monitoring the high value plants in Himalayan region, its sustainable utilization as well as the conservation of related resources. Thus information generation on diversity, distribution and availability of the high value (ecologically, medicinally or economically) plant species is of prime importance.

Objectives:

- Creation of spectral library and standardization for selected medicinal and threatened species.
- Spectral and image analysis for discrimination of selected economically important plant species.
- Model building for retrieval of biochemical and biophysical properties of selected species.
- Projection and scenario for distribution of selected species.
- Fine scaling of space-time map of the high value species in the Himalaya.
- Development of knowledge-based planning of an appropriate management system to safeguard medicinal and threatened species.

Achievements:

1. Field expeditions were conducted in Gwaldam area of Chamoli district and Munsiyari area (Khaliya top, Kalamuni, Thamrikund, Jeoljibi, Askot, Baram, Lumti, Madkot) of Pithoragarh district (Uttarakhand) and sampled a total of 42 species (including 12 lichen spp.) represented by 25 families (6 lichen families) and 36 genera (11 lichen genera). Out of the sampled 42 species, 17 were trees, 10 were shrubs, 3 were herbs and 12 were lichens.

2. *H*yperspectral signatures of threatened plants of IHR namely, *Taxus wallichiana* and *Pittosporum eriocarpum* were recorded (Fig.19), and preliminary phytochemical analysis of two species viz. *Hippophae salicifolia* and *Ilex dipyrena* were carried out.

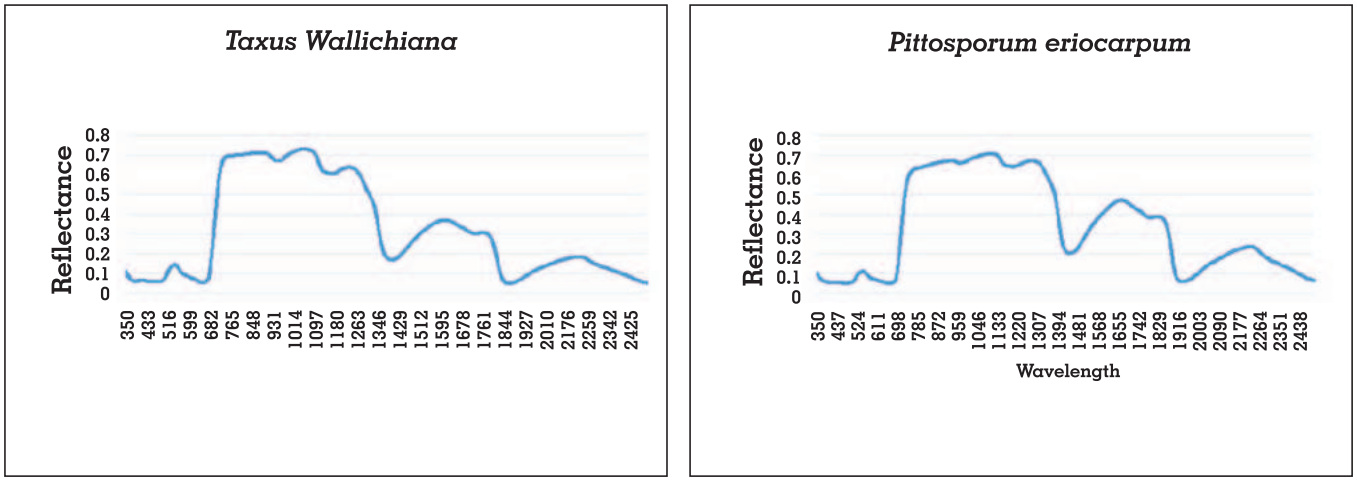


Fig. 19: Hyperspectral signature of *Taxus wallichiana* and *Pittosporum eriocarpum.*

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

Forests, the sentinels of mountain biodiversity face several threats in the form of over exploitation, unmanaged utilization, illegal trade, increased demand for fuel, fodder, timber, fibre, wild edibles, MAPs, land use changes, forest fire, climate change, etc. The above-mentioned factors have resulted in degradation and depletion of forests and biodiversity resources. Restoration is likely to reverse the loss of biodiversity, improve ecosystem resilience, enhance the ecosystem services, and mitigate the effects of climate change. Therefore, it would be pertinent to undertake land restoration, which will be helpful in reducing pressure on natural resources, and play an important role in conservation of biodiversity and uplift the economic condition of people and provide ecosystem goods and services for well-being of people. The GBPNIHE, under NMPB funded project initiated land restoration activities on the degraded land through plantations of MPs.

Objectives:

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

Achievements:

1. In 11.5 hectare degraded land planted by us under this project, out of 3,853 medicinal tree species planted the survival was recorded 76%, and out of 5,800 medicinal herb species planted the survival was recorded 95% (Table 4).

2. In the 3 pilot sites under the project area a total of 13 awareness, plantation and training programmes were organized on restoration interventions through medicinal plants in which 315 village people (186 M; 129 F) from 15 villages participated benefitting 34 people those were directly engaged under this activity.

Table 4: Details of pilot sites and land area procured for restoration interventions.

Target sites (Pithoragarh Distt.)	Village	Altitude (m asl)	Human population	Land area put for restoration (ha)
Hat-Kalika watershed (Gangolihat Block)	Chitgal	1620-1630	903	1
	Rawal gaon	1652-1670	347	1
	Kamad Gaon	1431-1450	80	3
Chandak-Aunlanghat watershed (Bin Block)	Digtoli	1670-1700	375	2.5
	Naikina	1760-1775	99	1
Upper & Lower Gori watershed (Munsiyari Block)	Lumti	950 -980	386	3

Promotion, Conservation and Utilization of *Dactylorhiza hatagirea* (D. Don) Soo and *Paris polyphylla* Smith Using Biotechnological and Ecological Approaches in Western Himalaya (UCOST, 2019-2021)

The Himalaya is credited all over the world as a trove of medicinal herbs, accounting for 1748 species of known medicinal value. The growing demand of the Himalayan medicinal plants has put immense pressure on them as >90% medicinal plant raw material is drawn directly from the wild and a small fraction (~20%) of it is under commercial cultivation. Since majority of MPs of the IHR are endemic to the region, hence more vulnerable to extinction. The selected species in the project (i.e., *Dactylorhiza hatagirea* & *Paris polyphylla*) have high medicinal value and used since the early times. The project envisages taking up: (a) germplasm collection from different eco-zones, (b) plant multiplication using conventional and *in vitro* propagation methods, (c) eco-physiological performance in diverse altitudinal range for better growth and survival, (d) cultivation packages development, and (e) reintroduction and restoration of degraded habitats.

Objectives:

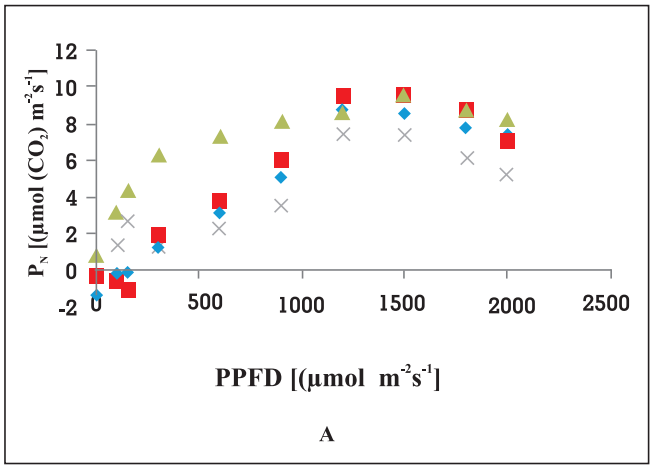
- To develop propagation and multiplication techniques for mass propagation.
- To assess the eco-physiological responses and determine inherent mechanism of survival, growth and development of progeny.
- To promote reintroduction of the target species and development of species-specific recovery plan.
- To raise awareness and imparting training on the conservation and utilization of the target species.

Achievements:

1. Field survey was conducted in September /October for collecting planting materials (i.e. seeds and tuber/rhizome) of target species and used for various macro and micro-propagation experiments. Studies to develop *in vitro* propagation protocol for both these species are currently under way.

2. To assess eco-physiological responses, studies involving gas exchange characteristics (effect of light, CO_2 and water vapor exchange rate) were conducted along the gradients of elevation (3200 - 3800 m asl) and habitat types for *D. hatagirea*. Net photosynthetic rate (P_N) of *D. hatagirea* under different habitat types such as moist grassy slopes (3254 m), swampy habitat along the stream (3435 m), and open grassland (3784 m) was saturated at 1200 µmol $m^{-2}s^{-1}$ photosynthetic photon flux-density (PPFD), whereas under canopy of *Berberis jaeschkeana* and *Rhododendron campanulatum* trees (3657 m) it was able to photosynthesize even at higher PPFD, i.e. 1500 µmol $m^{-2}s^{-1}$ PPFD (Fig. 20a).

3. In the under canopy vegetation (3657 m) with highest PPFD and stomatal conductance (Gs) and lowest transpiration rate (E) it was able to better modulate photosynthetic activity than at swampy habitat and moist grassy slopes and open grassland (Fig. 20b, c&d). Open grassland with highest transpiration rate, lowest stomatal conductance and net photosynthetic efficiency was least suited habitat condition for this species.



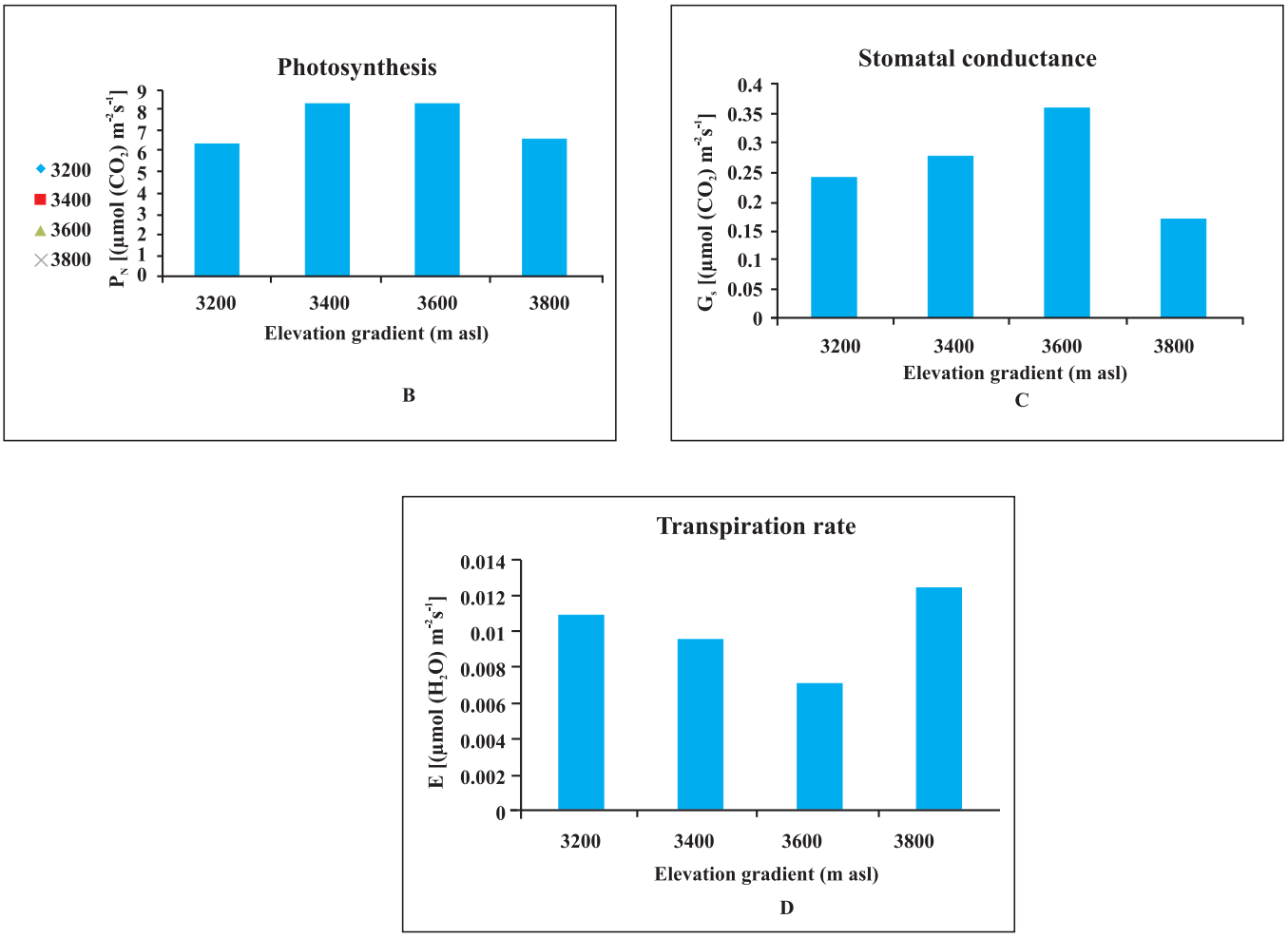


Fig. 20: Eco-physiological responses of *D. hatagirea* in changing in habitat types and elevation gradient: (**A**) Light response curve of the species, (**B**) Rate of photosynthesis (P_N), (**C**) Rate of stomatal conductance, and (**D**) Transpiration rate.

Himalayan Alpine Biodiversity Characterization and Information System – Network (NMHS, GoI, 2020-2023)

The high-altitude Himalaya, encompasses a distinct alpine zone spread over 33% land area of the IHR. Himalayan alpine zone is remarkably rich in plant biodiversity and the alpine zone in Western Himalaya alone supports more than 1675 species of flowering plants. Globally, ecologists and space agencies have stressed upon development of a space-based monitoring system for tracking changes in biodiversity and under the Group on Earth Observations – Biodiversity Observation Network, it has been agreed to define Essential Biodiversity Variables (EBVs) that can be routinely monitored from space. Three aspects of biodiversity − composition, structure and function, integrates six classes of EBVs: genetic composition, species populations, species traits, community composition, ecosystem structure and ecosystem

function. Hence, we need to initiate development of satellite-based approach and methodologies for tracking some of the above defined EBVs for alpine region in IHR.

Objectives:

- To characterize spatial extent and patterns of alpine plant communities in Western Himalaya (Pithoragarh and Bageshwar District, Uttarakhand) using multi-scale EO data.
- To assess alpine vegetation composition and diversity following a unified systematic and multistage sampling protocol.
- To determine EO-based environmental proxies of alpine biodiversity and ecosystem dynamics.
- To develop predictive models for multi-scale prediction of IHR alpine plant diversity patterns linking environmental proxies and habitat variables.
- To develop a web-based information system on IBIN supporting species and spatial database, web analytics and data/information dissemination for planning and management.

Achievements:

1. Quadrat based observations on alpine plant diversity recorded in Chiplakedar and Milam (Johar valley, Uttarakhand) from 42 different habitats. Around 760 quadrats (1x 1 m) were laid and plant information thus collected was incorporated as per the proforma provided by Indian Institute of Remote Sensing (IIRS), Hyderabad.

2. Collected plant and soil samples and its analysis for phytochemical properties are in progress.

Summary of Completed Projects / Activity

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

The fact that Himalaya is warming at a rate higher than the global rate, research on timberline of the Himalayan region assumes great significance. As an impact of climate warming, structural and functional changes in timberline vegetation are likely to occur that have implications on phenological shifts, upward movement of plants and tree line, biodiversity, wildlife habitats, populations of medicinal plants, ecosystem provisioning services, invasion of alien species etc. which is least understood. Tree line, a conspicuous change in vegetation from tree growth form to herbs and other short forms, represents a major physiognomic discontinuum along temperature gradient in high mountains. In this context, among others, the timberline at three sites (J&K, Uttarakhand & Sikkim) was investigated 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 (iii) of the contradictory reports on its responses to climate change and other anthropogenic factors. Findings of this multi-site and multi-partner project involving six leading organizations working in the Himalayan region with a team of a dozen Investigators from 5 R&D organizations and regional Universities (viz., GBPNIHE, WII Dehradun, BSIP Lucknow, Kumaun and Kashmir Univ. and coordinated by CHEA, Nainital) are summarized as: (i) In this study 2500 km long East-to-West Himalayan arc was analyzed for tree line species distribution, and attributes of tree line elevation, to characterize and map timberline zone using satellite and ground based observations and smart phone applications to use ground-based observation (himalyancitizen.co.in). Mapping of past and present timberline position was derived for J&K, HP, Uttarakhand, Sikkim, and AP. Two principal timberline types were identified (a) island or isolated strip timberline, in outer ranges near summits; and (b) long continuous timberline, running parallel to snowlines for hundreds of kilometres. Geodatabase for J&K, HP, Uttarakhand, Sikkim, and AP was developed in relation to past and present timberline mapping and characterization of spatial attributes. Detailed mapping of tree line ecotone considering timberline, tree line, woody patches (above timberline), individual trees, was done and characterized for its various spatial attributes for Sinthan (J&K), Tungnath (Uttarakhand) and Dzongri (Sikkim); (ii) Along the Daksum-Sinthan, Kashmir, Western Himalaya (WH); Chopta-Tungnath, Central Himalaya (CH) and Yuksam-Dzongri, Eastern Himalaya (EH) transects,

mean monthly temperature and elevation were negatively correlated, strongly during May-September ($p<0.01$), and weakly during winter ($p<0.05$). The annual temperature lapse rate (TLR) increased from moist to dry sites, the value being -0.50^{0}C/100 m, -0.52^{0}C/100 m and -0.66^{0}C/100 m for EH, CH and WH transects, respectively (Table 5), which is distinctly lower than the commonly used value of -0.65 ^{0}C/100 m. (iii) In the tree line of Tungnath, Uttarakhand (Fig. 21) leafing, flowering and fruiting in 2020 delayed by about one month in *Abies spectabilis*, *Rhododendron campanulatum* and *Quercus semecarpifolia,* respectively likely due to extremely low atmospheric temperature (~ 7 ^{o}C during April-June in 2020 compared to 2019). Leaf and shoot growth characteristics of these tree line species at mature stage varied considerably: Leaf number per shoot (4.4 in *R. campanulatum* to 143.5 in *A. spectabilis*, a conifer), mature leaf area (0.48 in *A. spectabilis* - 35.8 cm^2/leaf in *R. arboreum*), mature leaf mass (0.009 *A. spectabilis* - 0.95 g/leaf in *R. campanulatum*), shoot length (3.9 in *R. arboreum* to 13.4 cm in *B. utilis*) and shoot diameter (2.1 in *B. utilis* to 6.7 mm in *A. spectabilis*); (iii) In altitudinal transect (2100-3200 m amsl) in Tungnath area a total of 474 species of vascular plants (Angiosperms and Gymnosperms), 42 species of Pteridophytes, 108 Lichens and nearly 120 species of Bryophytes were recorded. The tree, sapling and seedling density, diversity and species richness decreased with increasing altitude and vice-versa for herb species, without a definite trend for shrub species (Fig. 22). (iv) In the Yuksam-Dzongri transect in Sikkim the plant species richness (248 species) for trees (74 species), shrub (51) and herbs (123) and lichen (128) declined significantly with increasing elevation. Out of the 128 lichen species, 14 were new records for Sikkim, and one new record for India. Along this transect average tree density was 1324 ind/ha, and maximum density (2587 ind/ha) was recorded at 3,300m. The species diversity and dominance showed significant quadratic relation with elevation. The total species richness showed humped relationship with elevation and peaked at 3000-3100m. The Shannon's diversity index (*H'*) was 3.18 at 1700m, 1.9 at 3000m and 1.21 at the tree line at 4000m.

Fig. 21: Tree line of Tungnath (Uttarkhand) with bushes of *R. campanulatum* and trees of *A. spectabilis* and *Q. semecarpifolia* in the background.

Table 5: Monthly TLR (°C/100m) values and correlation coefficient (r) between mean temperature and elevation for three study sites across the IHR.

Month	WH Transect		CH Transect		EH Transect	
	TLR	*R*	TLR	*r*	TLR	*r*
January	-0.3	-0.86**	-0.42	-0.94*	-0.54	-0.87**
February	-0.38	-0.89**	-0.52	-0.96*	-0.53	-0.91*
March	-0.54	-0.94*	-0.63	-0.95*	-0.52	-0.92*
April	-0.64	-0.93*	-0.67	-0.98*	-0.53	-0.93*
May	-0.63	-0.95*	-0.68	-0.99*	-0.52	-0.94*
June	-0.62	-0.97*	-0.63	-0.99*	-0.5	-0.96*
July	-0.65	-0.98*	-0.52	-0.99*	-0.51	-0.95*
August	-0.9	-0.91*	-0.49	-0.98*	-0.5	-0.94*
September	-0.8	-0.92*	-0.54	-0.98*	-0.49	-0.95*

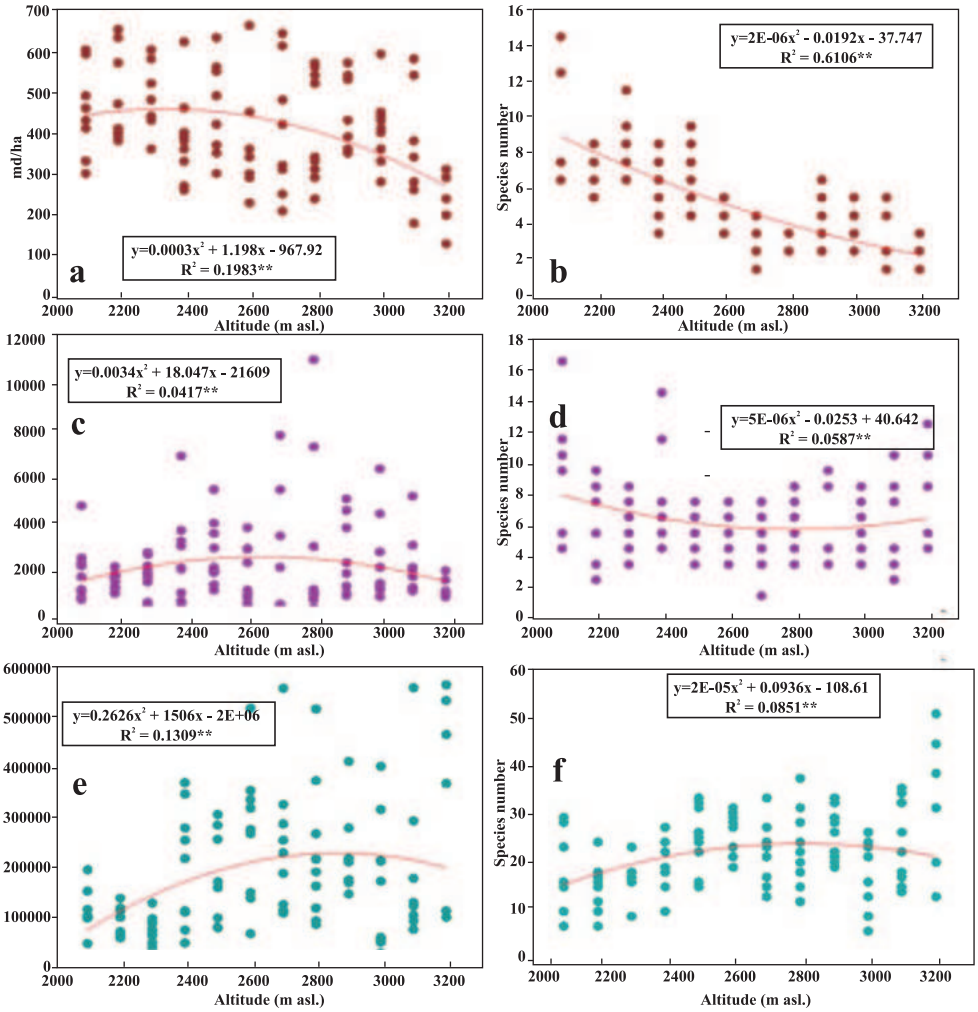


Fig. 22: Density distribution pattern (a, c, e: tree, shrubs and herbs, respectively) and species richness patterns (b, d, f: tree, shrubs, and herbs, respectively) along altitude gradient.

CENTER FOR SOCIO-ECONOMIC DEVELOPMENT (CSED)

In the Himalayan mountains rural ecosystems are the major features of the landscape and people's livelihood is intricately linked with agriculture, animal husbandry, forests, grasslands, water and other components in a dynamic manner. On a regional scale the farm produce meets only about half of the annual food demand of the people, triggering migration of youth to plains for better livelihood opportunities leaving women back to bear the brunt of carrying out almost all livelihood activities. At this juncture when socio-economic development is constrained by resource depletion and environmental degradation in the IHR, the role of appropriate technologies, which promote ecologically sustainable development, becomes indispensable. Sustainable development of rural ecosystem has always been a challenging task in the IHR in view of diverse environmental, socio-cultural and economic setup. It is notable that the IHR is rich in natural capital but economic poverty is the biggest hurdle in achieving sustainable development. In spite various programmes / projects of both Central and State Govts. rural communities are still facing problems related to infrastructure, technical know-how, livelihood skills, poverty, degradation of natural resources, migration etc. Therefore, CSED aims to promote equitable, inclusive, and sustained growth by safeguarding economic and social interests of communities along with environmental protection in the IHR. To meet this huge gap the Institute R&D has been focused to devise environment-friendly, cost-effective and scalable NRM technologies to find sustainable solutions to foster socio-economic development of the rural ecosystems. In this endeavour demonstrating appropriate land use models, promoting good practices through peoples' participation, ensuring capacity building of communities on various green skills makes the important activity area of CSED that also addresses the Sustainable Development Goals (SDGs). CSED thus works as an effective conduit of dissemination and demonstration of best management practices emerged out of the Institute R&D among the mountain communities and network of partners at regional, national and international level to achieve the overall mandate of the Institute. The overarching vision of CSED is "Promoting ecological and economic security and sustainable development in the IHR".

Community Driven Eco-smart Model Village Development to Improve Livelihoods and Foster Ecological Security in the Himalaya (GBPNIHE In House Project-2, 2020-2025)

In the IHR over 70% populations still live in the villages. Govt. of India has employed several approaches for development of model villages through interventions in livelihood, education, infrastructure, agriculture, water, forests, health and sanitation and other sectors with a vision of New India by 2022 "*Sabka Saath, Sabka Vikaas, Sabkaa Vishwas*". Countrywide 117 Districts (17 districts from IHR) are chosen by Niti Aayog based on poverty, poor health, education and basic infrastructure deficit as "Aspirational Districts" for "Transformative Change" to comply to the SDGs. MoEF&CC has given us the mandate for 2020-25 to prepare *"Eco-smart model village"* development plans (200 nos. 50 villages each across H.P., Uttarakhand, Sikkim and A.P.), household / village database and resource-use maps (50 villages; 10 villages each across the 4 States) and development of eco-smart model villages (4 village clusters) that will serve demonstration purpose for various stakeholders including Govt. Line Depts. through community-driven process follwoing Input, Output, Outcome and Impact (IOOI) framework.

Objectives:

- Identification of representative villages/village clusters for community-led planning process for preparation of eco-smart model village plans across the IHR.
- Preparation of baseline datasets and resource-use maps of the target villages through stakeholder's participation.
- Capacity building of rural communities to implement "Eco-smart model village" plans for integrated natural resource management for livelihood improvement.
- Demonstrate and develop 'Eco-smart model villages' for enhancing livelihood, and up scaling by Govt. Line Depts. to foster ecological security in the region.

Achievements:

HQs (Kosi-Katarmal, Almora)

1. In Jyoli village cluster (Hawalbagh Block, Almora) selected for eco-smart model village development socio-economic and environmental baseline data across 6 villages (312 HH) was collected for village resource use mapping through building capacity of CBOs and rural youth (Change Leaders) following a “Citizen's Science” approach. Also, inventory of flora of this village cluster was prepared through field survey.

2. Total 63 events (training workshops, hands-on at farmer's fields, meetings etc.; Fig.23) were organized to demonstrate environment-friendly, income generating and livelihood enhancing technologies thus increased outreach to 1513 stakeholders (M=800, F=713). Need assessment and exposure visits of people was carried out at RTC. As an outcome, 705 people (178 HH; General= 488; SC= 217; COVID returnee= 2) adopted these technologies. The number of beneficiary HH under various R & D based interventions are given in Table 6. Plantation of *Oak* (100), *Alnus* (50), *Cinnamomum* (50) and *Salix* (60) were planted in 1.5 ha land in village Jyoli.

3. In Jyoli village cluster 40 polyhouses constructed by people yielded 471 kg vegetables/spices of 8 species consumed by them equivalent to Rs.16,100.00. Chickbirds (Kuroiler & Vanraj varieties) given to 49 HH registered ~70% survival that earned Rs. 24,675.00 from sale of birds. Pine tree parts were used by them for making 475 *Rakhis* and *Aipan* sold for Rs. 6500/- and Pine needles biobriquette made by them were sold for Rs. 1000/-. In addition, 25 farmers were given bee keeping training and bee boxes and colonies (*Apis cerana*), and 930 fruit plants of six species were planted in the villages. The Pine needle based products (e.g., file covers, folders, envelops, carry bags, biobriquettes etc.) at RTC were popularized and sold among 43 organizations /NGOs / locals and earned Rs. 1,15,059.00 thus avoiding the risks of forest fire in the Institute Campus.

Table 6: Capacity building and demonstration on various environment-friendly and low-cost technological packages adopted by people in the Jyoli village cluster.

S. No	Village name	Bee keeping	Poultry faming (chicks distributed) (HH)	Pine needle bio-briquetting	Protected cultivation (Polyhouse constructed)	Biocomposting /vermi-composting models	Green Skill (Aipan / Rakhi)	Horticulture (fruit plants) (HH)
1.	Jyoli	05	-	-	-		08	190 (24)
2.	Khadkuna	04	-	-	-	-	04	100 (16)
3.	Kujyari	10	780 (26)	16	18	-	01	160 (54)
4.	Dilkot	02	270 (07)	01	03	02	03	50 (7)
5.	Kaneli	01	235 (10)	07	13	01	04	210 (28)
6.	Bisra	03	170 (06)	06	06	-	05	220 (19)
	Total	**25**	**1450 (49 HH)**	**30**	**40**	**03**	**25**	**930 (148 HH)**

Fig. 23: Various training and outreach activities in Jyoli village cluster (Almora).

Himachal Regional Centre

- In five villages of Khadihar Panchayat (Pachahli, Buragran, Kareri, Pahnalah, Muthal) and one village of Balh-II Panchayat (Sarach) of Kullu block selected as cluster/project intervention site questionnaire survey for baseline dataset and resource use maps generation was completed in 213 HH.
- Based on the indicators of ecological security, economic efficiency and social equity complied for 11 hilly districts of H.P. 50 villages were identified for eco-smart model village development planning. Reconnaissance survey was done for the Dogri, Nathan, Shaidhar and Joli villages of Mangharh, Nathan, Raila and Bhallan-II Panchayats of Kullu district and secondary data was collected for all the villages of Kullu district.
- Skills and capacity of the stakeholders and representatives of the project villages from Nathan, Mangharh and Raila Panchayats were built through organizing hands-on trainings on livelihood improvement through mountain specific eco-smart rural technologies (Fig. 24).

Fig. 24: Field survey and training-cum-capacity building workshop in H.P.

Garhwal Regional Centre

1. After a few initial brainstorming sessions among stakeholders to select pilot sites for project activities, 10 villages were selected in Jakholi block (Rudraprayag Distt.) and surveyed for baseline data collection on different aspects related to livelihood with HH details on population, income, livestock, landholdings, agriculture system and natural resources (Fig. 25).

2. Three training and demonstration programmes focusing on skill development & capacity building for scoping for livelihood options were organized in project villages (Chandi, Kothiyara, Bachchwad and Kapaniya). Among these, demonstration on "bio-briquettes" preparation using Pine needles was particularly useful.

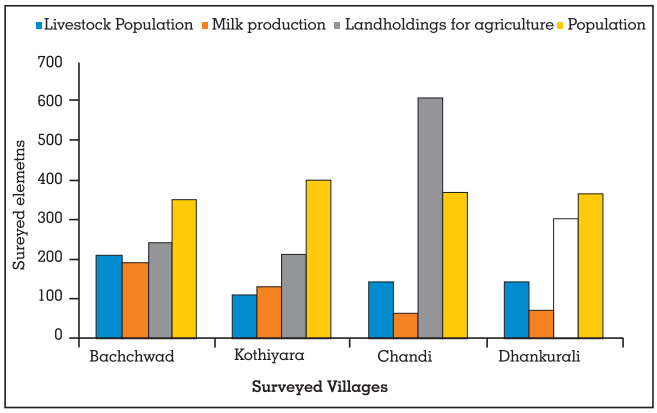


Fig. 25: General socio-economic characteristics of the selected villages (Jakholi village cluster)

Sikkim Regional Centre

- Organized 5 consultative meetings in Mamlay watershed for feasibility assessment of project activities. Survey among 40 HH of Tingrithang GPU (5 villages), Kamrang-Mamlay GPU (5 villages) and Damthang GPU (5 villages) of Mamlay watershed was conducted to understand village profile, demography, available resources, livelihood options and current State & Central Government schemes/ programmes (Fig. 26).
- Compiled indicators for ecological, economic, sociological and poverty criteria for eco-smart village selection out of 451 villages of Sikkim state from census and other available secondary literature considering parameters such as village population, SC/ST/BPL population, distance from district HQs, nearest town, wage employment under MGNREGA etc.

Fig. 26: Consultative meetings with different stakeholders in Juabari village (Sikkim).

North-East Regional Centre

- Collection and compilation of secondary data on indicator framework for selection of villages for model village development for all 25 districts of Arunachal Pradesh has been undertaken. A cluster of 5 villages falling under Dikopita, Byapin and Sichusii Gram Panchayats in Ziro block has been selected for development of 'eco-smart model village'.
- Training on "PRA tools and techniques – with special reference to village resource mapping" was conducted at Sopo village, Papumpare district, and facilitated by A.P. State Rural Livelihood Mission (ArSRLM) to build capacity of selected participants of different districts of A.P. in ToT mode (Fig. 27).

Fig. 27: PRA activities conducted for the stakeholders.

Himalaya Calling- Bridging Science, Policy and Practice to Foster Sustainable Development in the Indian Himalayan Region (NMHS, GoI, 2019-2022)

The IHR is important in terms of natural resource richness and provisioning of indispensable goods and services. In the IHR a wealth of data base/knowledge exists across 145 Universities, 38 R&D Institutes, 75 state owned Institutes and 7000+ voluntary organizations with 500 scientists and 2000+ faculty, still the region is referred to as data-deficient (IPCC, 2007), which calls for science-policy-practice interface to ensure ecological and economic security of the IHR. There exists a gap in synergy and convergence across disciplines, sectors and actors working in the region. NITI Aayog, Govt. of India, has identified GBPNIHE as a Centralized Data Management Agency. This has necessitated establishment of "Himalayan Knowledge Network" (HKN) under which collection and syntheses of data/information from various sources, establishment of State Chapters and Youth Forums in each IHR states/UTs, preparation of state-specific policy documents on priority thematic areas on environment and development issues based on stakeholders consultations are some of the main activities

Objectives:

- To foster an effective and collaborative network of different constituencies (from policy, science and practice), academic institutions and universities, and local communities working within and outside of IHR for sustainable mountain development.
- To create evidence-based knowledge and learning that is communicated to influence policies and practices bringing decisions that enhance sustainable development in the IHR region.
- To transfer evidence-based knowledge and expertise in key sectors into policies and practices in the IHR region.

Achievements:

1. A dedicated link (http://www.gbpihed.gov.in/PDF/GBPIHED-Initatives/HKN_Document.pdf) of HKN has been hosted in the Institute website. To establish HKN State Chapters Letter of Agreements (LoA) were signed between GBP-NIHE and State Councils for S&T Arunachal Pradesh (27 Nov. 2020), Himachal Pradesh (30.12.2020), and Uttarakhand Space Application Centre, Dehradun (26.2.2021). In other states LoA signing process is progressing. At NERC a network of 25 government organizations and 120 NGOs working in Arunachal Pradesh was established.

2. Prepared a list of 143 Universities and 78 R&D institutes, 364 departments of Universities/ institutions/organizations with details of 9400 HODs / faculty, 7278 NGOs' (Uttarakhand 1404, Himachal Pradesh 617, J&K 1228, Ladakh 133, Sikkim 90, Arunachal Pradesh 390, Assam 20, Manipur 2084, Meghalaya 236, Mizoram 196, Nagaland 352, Tripura 397 & West Bengal 131) along with their expertise, areas of interest and contact details. Also, an inventory of 898 alien and invasive species and 1000 endemic plant species of the IHR was prepared. PAN IHR maps have been prepared using satellite data (Landsat 8 at 30 m) on DEM, aspect and GIS datasets for administrative boundary map for state/UTs, District, Sub Division Level, drainage network, geology and natural

hazard map has been compiled for entire IHR. Total 215 universities, R&D & Academic institutions have been geo-tagged.

3. Over a dozen stakeholder consultations, workshops, strategic meets and Youth Forum activities were organized involving over 500 stakeholders including subject experts, Govt. organizations, policy makers, 8 S&T councils, people's representatives, researchers from 75 organizations across the IHR states. For H.P. two priority areas (biodiversity and water) were identified for preparation of thematic documents. Youth Forums on large cardamom, nature conservation, and solid waste management were formed and a Yak Stakeholders Network in Sikkim was initiated.

Estimation of Economic Lossess in Real Term Per Hectare Basis Due to Forest Fire in Uttarakhand and Madhya Pradesh (CAMPA- MoEF&CC, 2020-2022)

Fire is one of the major causes of forest degradation in India, and has wide ranging adverse ecological, economic and social impacts. In the IHR, on average 3908 FF events occur annually with average burnt area of 1129 km^2. In Uttarakhand Chir Pine (*Pinus roxburghii*) is prone to FF due to resin-rich inflammable leaf litter accumulated on forest floor during summer. Most of the FF are anthropogenic (both accidental and intentional) and natural fire is a rare phenomenon. In the aftermath of FF of 2016 summer in Uttarakhand (2069 FF incidents affecting 4423 ha forests and an estimated loss of Rs. 4.62 million only) the Parliamentary Standing Committee on S&T, Environment & Forests, Govt. of India visited Uttarakhand and held consultations a range of stakeholders and mandated to a consortium of R&D organizations (GBPNIHE, FRI, FSI, ICFRE, WII Dehradun, TFRI Jabalpur and NIH Roorkee) to come up with proper methodology to arrive at the realistic monetary loss due to FF in Uttarakhand and Madhya Pradesh.

Objectives:

- To identify the valued ecosystem component affected due to forest fire for the specific ecosystem.

- To generate baseline /ground truth data on the status of the identified quantifiable valued ecosystem components affected due to fire incidents.
- To quantify the forest loss in terms of total economic value using the data generated for real time monetary value on per hectare basis.

Achievements:

1. Out of the total 342 FF affected areas (polygons) due to fire in 2019 in UK (164) and MP (178), measurements in burnt and unburnt sites (42 sites in UK, 5534.0 ha; and 49 sites in MP, 8016.9 ha) was carried out on loss of timber, fuel wood, fodder, NTFPs and MAPs. A total of 1720 quadrates for trees, 3440 for shrubs and 5160 for herbs were laid out in these polygons in UK and MP. The size of burnt plots ranges from 4.0-883.0 ha in UK and 3.6-3108.0 ha in MP. Tree species and wild edibles richness was greater in MP forests, whereas shrubs, herbs and medicinal plants species were more in UK forests (Table 7).

2. Mean timber wood volume severely damaged due to FF across all the studied sites was measured 5.86 m^3/ha in Uttarakhand and in 1.74 m^3/ha in Madhya Pradesh. Monetary loss using the rates of Forest Dept. was computed Rs. 88521/ha and Rs. 22629/ha for UK and MP, respectively. Similarly, the fuel wood and fodder loss was computed Rs. 14315/ha and Rs. 8450/ha in UK and Rs. 1622/ha and Rs. 3036/ha in M.P. respectively.

3. To estimate the local monetary value of loss due to FF stakeholders 66 meetings/consultations were organized in Uttarakhand (35) and Madhya Pradesh (31) involving forest officers/field-level staff (173 in UK and 150 in MP) and local people (475 Male/Female- 198/277 in UK and 342, Male/Female- 313/29 in MP) around the sampled burnt forest sites (Fig. 28).

Table 7: A summary of various parameters of field work/data collected in 2019 forest fire affected forests of Uttarakhand and Madhya Pradesh.

S. No.	Parameters	Uttarakhand	Madhya Pradesh
1.	Number of polygons of 2019 forest fire identified for study	42	49
2.	Number of polygons studied	39	47
3.	Area of polygons (ha)	4.23 - 883.12	3.607 - 3108.53
4.	Altitudinal ranges of polygons (masl)	230 - 2488	252 - 930
5.	Tree species Shrub species Herb species Wild edibles Medicinal and aromatic plants	40 43 51 11 (6 trees/ 5 shrubs) 48	56 36 31 24 30
6.	Total basal area (m^2/ha)	21.0 (5.0 – 53.0)	25.9 (11.1 – 50.6)
7.	Tree density (ind./ha) Sapling (ind./ha) Seedling (ind./ha)	250 - 710 20 - 1150 50 - 1880	10 - 540 94 - 228 57 - 85
9.	Timber/wood volume lost due to 2019 forest fire (m^3/ha) (range & mean)	1.29-20.97 (5.86)	0.53-3.77 (1.74)
10.	Price of timber/wood loss due to 2019 forest fire (Rs. /ha) (range & mean)	30986-288570 (88521)	7086-67357 (22629)
11.	Price of fuelwood loss due to 2019 forest fire (Rs. /ha) (range & mean)	1232.00 - 58660.00 (14315.00)	419-5647 (1622)
12.	Price of ground fodder loss due to forest fire (Rs./ha)	195.00 - 33919.00 (8450.00)	1342-8006 (3036)
13.	Stakeholder's meetings/ Total participants	35 244 (167 M; 77 F)	31 343 (316 M; 29 F)

Fig. 28

Summary of Completed Projects / Activity

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

Sustainable utilization and management of natural resources in the Central Himalayan region has become a top priority with the increasing population pressure, environmental degradation and changing climatic conditions. In this project a sustainable approach for livelihood improvement of poor Himalayan people through efficient management of natural resources and to sustain crop yield using simple, low-cost, eco-friendly, and replicable technology packages was implemented. The project was designed in a way that it brings about changes in life of poor Himalayan people over a period of time through implementation of low-cost eco-friendly and replicable technology packages. To execute this project after an extensive survey, a cluster of eight villages were selected in Almora district (Uttarakhand) that represented typical environmental and socio-economic characteristics of the lesser Himalayan region. Selection of beneficiaries was carefully done with community stakeholder's consultation. A need assessment in the project area was conducted before project implementation. Based on identified problems, an appropriate land use practice was suggested and demonstrated in the project area. Farmers were encouraged to adopt ten technology packages to increase crop yield and optimum use of available land, water and other resources. In the beginning farmers were reluctant to adopt these technology packages due to lack of financial resources as 90% farmers of the study area are marginal land holders. Project activities provided technical and material support to marginal farmers for adopting various technology packages for enhancing livelihood and increase in farm land productivity. Most of the selected technologies were demonstrated on the land of selected beneficiaries with active participation of farmers. The technologies transferred under on-farm sector included protected cultivation of vegetables, integrated fish farming,

waste land development through multipurpose trees, fodder and fruit tree plantation, yield enhancement of low productive agricultural lands and abandoned agricultural land through high value cash crops, off-season vegetable cultivation, poultry farming, vermi-composting and planting compact bio-gas system. Off-farm technology transfer included bio-briquetting and making decorative items using the abundantly available Pine tree needle leaves/cones, which is otherwise a forest fire hazard and causes great loss to forests and biodiversity. Adoption of these simple, environment-friendly and low-cost technologies increased the income of target marginal farmers from 16.6 to 39.5%, and also provided an alternative for diversifying agriculture in the study area. Abandoned and low yielding agriculture land became profitable through technology transfer. Farmers were constantly motivated for collective farming of high value cash crops (ginger, onion, garlic and turmeric) on their abandoned and low productive agriculture lands. About 12 ha low productive and economically non-profitable agricultural land turned to be profitable through high value cash crop cultivation. Also, about 2.5 ha abandoned agricultural land was brought under crop cultivation. Development of 5 ha waste land was taken up by planting multi-purpose tree species. Dovetailing with various schemes/programmes of line departments improved the livelihood of people and changed the farmers' attitude towards technology adoption. Use of dry Chir Pine needles by community people proved impactful to save forests from fire locally. Pine processing unit was successfully established at the RTC of the Institute. Quality of handmade paper produced in this processing unit was made good enough to make various valuable products such as file covers, file folders, envelops, carry bags etc. The bio-briquetting technology hold great potential for converting hazardous dry pine needle into smokeless fuel for household use (cooking and heating) in an affordable, efficient and environment-friendly manner. Through the project activities and trainings 90 HH of the target villages started making briquettes from Chir pine needles. Most of these beneficiaries are using these bio-briquettes at home mainly for heating purposes. Bio-briquetting also provided an additional source of livelihood to beneficiaries. Thus, utilization of dry Chir pine needle not only enhanced the livelihood of farmers but also improved the environmental health of the region. Participatory and interactive approaches were successful in the study area to adopt these technologies with replication potential in the region.

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

In the IHR traditionally people lived in harmony with nature and developed various traditional systems as part of their livelihood that sustained them for generations. In the recent decades the traditional knowledge (TK) systems is eroding at a faster pace and it is now increasingly being felt that the TK can play a key role in the conservation of resources and sustainable livelihood options thus need to be documented soon. Therefore, under the Network Program of NMSHE Task Force-5 coordinated by JNU, New Delhi, documentation of TK on four identified sectors, viz., land and soil management, water conservation, bio-resources and bio-processing among different ethnic groups across 6 IHR states covering 15 districts and 27 communities (A.P. 4 Districts, 5 communities); Nagaland (2 Districts - 2 communities); Sikkim (4 Districts - 5 communities); W.B. Hills (District 1 - 2 communities); Uttarakhand (1 District - 1 community); and H.P. (3 Districts - 12 communities) was carried out. All these communities had different and clearly defined land for settlement, agriculture, livestock, forest, private land and/or sacred groves that is identified with distinct names with a precise use often governed under traditional and customary norms. A total of 16, 11, 24 and 15 good land & soil management practices (related to agriculture) were documented for Northeast, Sikkim, Uttarakhand and H.P., respectively. The vernacular nomenclature of land and its use was found strongly specific to each community and based on type of use, quality of soil and water availability, and management of land as per micro-climate (e.g. *Bije* for bamboo plantation, *Ballu* for kitchen garden, *Jabe-Aji* and *Rek*

for agriculture fields, *Bulu so* for sacred and community forest in Apatani tribe etc.). Significant crop diversity exists in traditional farming systems that varied from 58, 38, 55, and 22 species in A.P., Sikkim, Uttarakhand and H.P., respectively. An inventory of 704 and 381 plant species used in traditional system in A.P. and Nagaland was prepared (Fig. 29). Similarly, a total of 10, 11, 20 and 7 traditional water conservation, management and indigenous irrigation systems were documented for northeast, Sikkim, Uttarakhand and Himachal Pradesh, respectively. Some community specific good practices were: *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. Among the use of bio-resources and bio-processing a total of 704 plant species belonging to 392 genera and 157 families were documented those are utilized by different communities of A.P., and 381 species belonging to 250 genera and 116 families in Nagaland. Animal bioresources comprised of 268 species and 27 species in A.P. and Nagaland, respectively and used for different purposes. In Sikkim, 128 wild edible plants sold in markets of Gangtok, Namchi and Singtam. In Uttarakhand a total of 1630 plant species and 57 animal species were documented those are used by indigenous people. A total of 112 landraces of cereals (55), pseudo cereals (5), millets (9), pulses (10), vegetables (20), spices (7), oil yielding (5) and fibre yielding (1) crops were recorded from Uttarakhand. In H.P. about 234 wild species were used by different communities of Lahaul & Spiti, Kullu and Mandi districts. A total of 66 wild bio-resources were used by 5 communities (*Swangla: 22; Gari: 20; Todpa: 12; Tinnanba: 15; Pitishag: 37*) in which 47 species comprised medicinal plants, 3 wild fruits, 2 wild vegetables and 1 aromatic plants. In case of agro-biodiversity, a total of 22 crop species were cultivated covering vegetables (8), fruits (6) millets and seeds (4 species) and ornamental plants (4). The communities of Kullu district used a total 128 plant species (*Lagaal*: 49; *Jhecha*: 69; *Malani*: 55; *Siraji*: 42) as medicinal (78 species), fodder (30) and fuel (17) etc. The inhabitants of Mandi district used a total of 86 plant species (*Mandyal*: 76 & *Gujjar*: 27 species) comprising medicinal plants (55), fodder (13), fruit species (9) etc. A total of 13, 13, 93 and 38 local fermented foods, beverages, local recipes and delicacies were recorded for A.P., Sikkim, Uttarakhand, and H.P., respectively. Some commonly used fermented foods were*: Ekung, Eup, Namsing, Churpi, Chkchoro, Nanding, Apong, Raksi etc* in northeast, *Sinki, Gnudruk, Kinema, Sale roti* in Sikkim, *Arsa, Singal, Changa* in Uttarakhand, *and Lwad, Babru, Siddu* in H.P. A total of 13 fermented products were documented (9 vegetables and cereals based and 4 milk product based). It is highly desirable to maintain all the traditional practices and the associated TKS in IHR, particularly in the face of climate change adaptation and mitigation and ensuring livelihood and food security of mountain communities

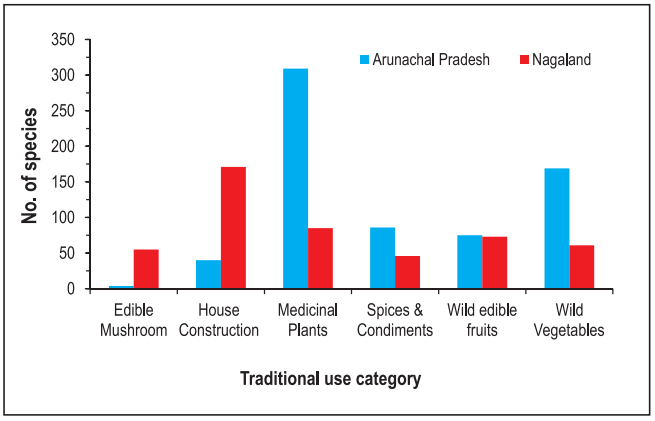


Fig. 29: Inventory of plant species used in traditional system in A.P. and Nagaland.

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

The well-being of humans is integrally linked with biodiversity, ecosystem services and associated processes. 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. Therefore, maintaining species richness in forest communities is critical for sustaining ecosystem services. In this study changes in species diversity, composition, biomass, litter fall and carbon

stock of four selected forests of western Himalaya (*Shorea robusta*, *Pinus roxburghii*, *Quercus leucotrichophora* and *Q. lanuginosa*) and selected forest stands at subtropical natural forest (STNF) dominated by *Shorea robusta*, *Castanopsis indica*, *Castanopsis tribuloides*, *Schima wallichii* and temperate natural forest (TNF) dominated by *Alnus nepalensis*, *Quercus lanata*, *Leucosceptrum canum*, *Cryptomeria japonica* in Mamlay watershed (South Sikkim), were studied about three decades ago by various researchers of Kumaun University and by the SRC, Sikkim were re-surveyed during 2017-2019. In the western Himalayan site, across the four forests tree density was found ranging from 652-884 ind. ha^{-1}, and the total basal area (range= 33.4 - 51.6 m^2 ha^{-1}). An increase of 4-34% in tree density and 4-19% in basal cover was recorded compared to the past data (Fig. 30). Similarly, tree species richness was recorded 50, which was higher as compared to earlier study (37). Out of a total of 50 tree species recorded in four studied forests only 28 species were regenerating. The numbers of seedlings were found ranging from 1696-3086 ind/ha at Sal and Pine forest stands, respectively. Species diversity index (H') also registered an increase from 0.70-1.70 in past to 1.20-3.31 in present investigation. Tree biomass was computed ranging from 217.2-567.1 t/ha across the forests, and recorded an increase 20.8-43.5% over the past values. The carbon stock in selected forest stands ranged from 106.8-271.3 t/ha (an increase of 12.6-19.4% over the past in Sal and Pine forests, respectively) and the carbon sequestration rate was found ranging from 4.01 to 4.98 $tha^{-1}yr^{-1}$ having maximum at Chir-pine stand and minimum at Banj-oak stand. Carbon stock was reduced by 17.5% in Banj oak and 9.8% in mixed oak forests during last 35 years. But the C-sequestration rate in Chir-Pine, Banj-oak and mixed Oak forests increased to 9.8%, 14.1% and 8.7%, respectively, while it was decreased by 3.3% in Sal forest. The total annual litter fall ranged from 7.8-11.7 t/ha among the four forest sites, which recorded an increase (16-54%) over the past (1980-81). In the Mamlay watershed (south Sikkim) *the highest annual litter fall was observed in STNF in Shorea robusta (5.4 t/ha) and minimum in C. tribuloides (4.8 t/ha). Whereas, in TNF highest annual litter fall was observed in A. nepalensis (5.6 t/ha), and minimum in L. canum (4.8 t/ha)*. Species richness was recorded 74 for trees, 55 for sapling and 45 for seedling categories across 90 quadrates (30 m x 30 m) surveyed in different locations and altitude in Mamlay watershed. This study shows that overall forest stands selected for study of this region are in better condition leading to better tree density, basal cover and species diversity, litter fall and tree biomass. This study recommends that long-term monitoring and evaluation of the forests for ongoing changes in biodiversity and ecosystem services are required for forest management and conservation planning in the Himalayan region.

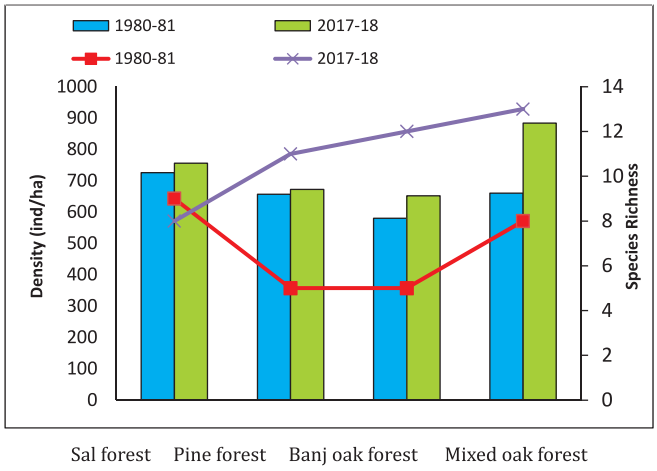


Fig. 30: Temporal changes in tree density and species richness of studies forest stands.

Livelihood Enhancement of Small Farmers of Uttarakhand Hills Through Integration of Simple, Cost-effective, Eco-friendly Rural Technologies (Women Scientist Scheme, DST, GoI, 2017-2021)

A large number of natural resource based hill-specific, low-cost, eco-friendly technologies are available for wellbeing of poor hill farmers. However, majority of the farmers in the region are unaware of these technological interventions and do not realize employment and income generation potential of natural resources available in their surroundings. In the project, natural resource based technology-centric

village development model(s), integrating interventions such as Integrated Fish Farming (IFF), off-season vegetable and mushroom cultivation, green fodder production, bio-composting/vermicomposting and bio-briquetting were introduced among 10 HH in three villages in Almora district (namely, Matela, Kaneli and Kalon villages), located at mid elevation zone (1000-1800 m amsl). In the IFF system different components were integrated in such a way that by-products and waste of each subsystem become valuable input for another subsystem. Four IFF models comprising a fish pond size (80-100 m^2), a poultry house (10'x10'x 6') and surrounding land (200-600 m^2) for vegetable cultivation were constructed at selected sites. Fingerlings of exotic carp species (5.0-15.0 cm), viz., silver carp (*Hypophthalmicthys molitrix* Valenciennes), grass carp (*Ctenopharyngodon idella* Valenciennes) and common carp (*Cyprinus carpio* Linnalus) were stocked into the ponds and 1830 chicks of coloured hybrid layer species Kuroiler/Vanraja were distributed among 36 beneficiaries at the selected sites. Highest growth rate was recorded in grass carp, followed by silver and common carp, and the average fish yield at all the sites ranged between 3044 -5830 Kg/ha/yr. The stocked chick birds grew to 0.950 - 3.50 Kg within 4 months and started laying eggs after 24 weeks. Besides, household consumption, the farmer's gained net profit of Rs. 31,100 -78,000 annually from different IFF components. Nutritional status of farmer's in per day intake of energy, protein and fat increased by about 26%, 35% and 40%, respectively. Two farmers adopted under the project were awarded as “progressive farmer of the region” by State Agriculture Department, Almora. A total of 25 training programmes were organized and imparted training to 718 beneficiary farmers, including 352 women farmers on IFF. As expected, the integrated approach was not only economical but also provided effective recycling of wastes, utilization of farm and forest biomass, energy saving and eventually helping in socio-economic upliftment of rural poor and protecting environment of the target HH / villages. The project was implemented with active participation of rural youth and women. The final outcome of the work proved a cost-effective and replicable model for sustainable village development in this region.

CENTER FOR ENVIRONMENTAL ASSESSMENT AND CLIMATE CHANGE

Different environmental factors including climate change influences an ecosystem, which is further exacerbated by human induced perturbations. Changes in climate regime over the last few decades have already started affecting natural resources worldwide including mountain regions, subsequently, natural resources of the Himalayas have become vulnerable. Now it is known that climate change (CC) is a major global environmental challenge that is going to affect ecosystems in a variety of ways and will pose a threat to social and economic development in the IHR where societies' dependence on natural resources is very high. The Centre for Environmental Assessment & Climate Change (CEA&CC) caters to the Himalayan needs on these issues in tune with MoEF& CC and SDGs (Goal no. 13), which requires urgent action to combat CC and its impacts. The broad approach for achieving these goals include: (i) identification and prioritization of climate sensitive sectors in the Himalaya for research and resources generation, (ii) development of indicators of CC in the Himalaya in identified sectors, (iii) inclusion of Citizen Science approach in research, and adaptation and mitigation strategies, (iv) practice-science-policy-people connect through integration of community level experiences (acclimatization / adaptation / coping mechanism) in policy framework, and (v) collaboration with other organizations / Universities on CC projects. The main objective of the CEA&CC is therefore to assess and monitor physical, biological and socio-economic environmental parameters for the development in the IHR, and to design measures for CC mitigation and adaptation by communities and developing ecosystem resilience to cope up with CC risks. Thus our vision is that by 2025 the Centre become reasonably self-sustaining and playing a leading role in Environmental Assessment and Climate Change research and advisory in the IHR. Our mission is bridging between research and practice on the impacts of CC in identified key sectors in the Himalaya.

Fostering Climate Smart Communities in the Indian Himalayan Region (GBPNIHE In-House Project-3, 2020-2025)

The Himalayan ecosystem is considered to be one of the most fragile and diverse geographical entity vital for India in many respects. Under the future CC scenarios, impacts of CC are projected to exacerbate, thereby increasing the vulnerability of the region. Due to varying altitudes, the IHR experiences extreme weather events, flash floods and droughts, along with high climate variability. These stresses made the Himalayan ecosystem and communities highly vulnerable to both the seasonal and yearly climate variability and the future CC. The continuously changing climate poses threats and increases vulnerability level of the Himalayan communities. This research therefore mainly aims to assess the vulnerability in indigenous and vulnerable Himalayan communities and to design a decision support system for adaptation and resilience building in response to CC.

Objectives:

- Development of climate vulnerability framework for identification of the vulnerable communities in IHR and their mapping.
- Designing adaptation and resilience building mechanism in response to climate change for fostering climate smart communities.
- Nurturing Climate Awakened Society in the Himalaya (CASH), and formulating policy guidelines for the vulnerable communities.

Achievements:

Total 181 indicators have been prioritized for climate change vulnerability assessment (CCVA) of indigenous Himalayan communities under exposure, sensitivity and adaptive capacity and data collection on these aspects at pilot sites have been started. Twelve important climate smart practices (related to agriculture, water, waste management, livelihood and architecture) are documented to strengthen the adaptive capacity of vulnerable Himalayan communities. Four consultative meetings, 3 focal group discussions, 4 seminar/workshops were organized to identify the impact and perception of CC among the Himalayan local communities at Kullu, Almora, Srinagar, South Sikkim and Itanagar. The key achievements / observations based on the different study locations in IHR are as follows:

HQs (Kosi-Katarmal, Almora)

1. Documented bioresources utilization practices from 91 households among the local communities in Jyoli cluster villages, Almora (Fig. 31).

2. A total of 74 plants species which were used by the local communities include 43 medicinal plants, 19 fodder plants, 14 wild edible plants, 11 fuel wood plants, 7 handicrafts plants, 8 plants used in religious activities, 5 dye or fiber, 4 plants used in construction purposes and 2 species used for decorative purposes (Fig. 32).

Himachal Regional Centre

3. A pilot survey was conducted in six villages of Parbati Valley in Kullu district, namely, Tosh, Kalga, Tulga, Pulga, Choj and Kasol for identification of climate resilient practices.

4. Selection of five cluster villages for common intervention site was done and questionnaire survey was conducted in four villages, namely, Pahnala, Muthal, Kareri and Buragran of Kullu district, Himachal Pradesh.

Garhwal Regional Centre

5. Climatic calendar developed to identify the indicators / drivers and their impact on life supporting system for selected villages of Jakholi blocks in Rudraprayag district, Uttarakhand.

Sikkim Regional Centre

6. Large cardamom cultivation drastically declined when compared to 20 years ago in Lower Jaubari, Chemchey and Pakchay ward of Jaubari-Damthang GPU, Sikkim (80% respondents) leading to a shift from large cardamom to vegetable cultivation.

North-East Regional Centre

Increasing demand of organic certified Kiwi due to high economic return has resulted in forest degradation in Ziro Valley, Arunanchal Pradesh.

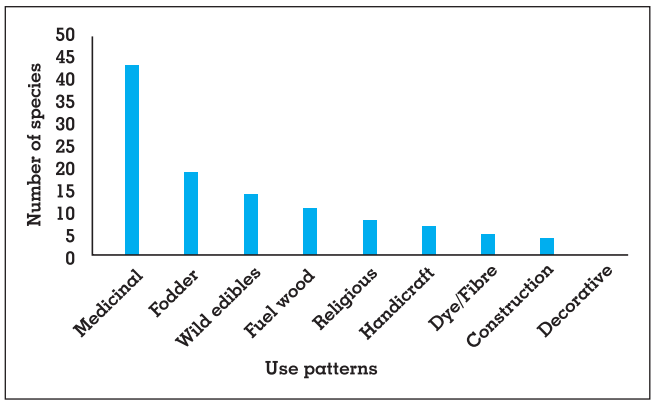


Fig. 31. Different categories of bioresources used by the local people in Jyoli village cluster (Almora).

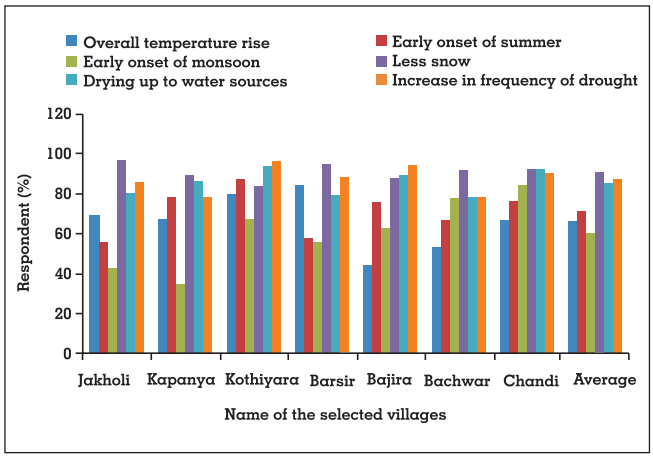


Fig. 32: People's perception related to climate change impacts in the selected villages.

Aerosol Climatology over the North-western Indian Himalayan Region: Himachal Pradesh & Uttarakhand (ISRO-SPL, 2005-06 & Onwards)

Changing climate has become one of the major challenging adversities of our planet. Deteriorating air quality, pollution, and increasing GHG's are responsible to CC. Aerosols are produced by a variety of natural as well as anthropogenic activities and get distributed in the atmosphere through turbulent mixing and transport. The perturbation of the earth's radiative balance results in the scattering and absorption due to anthropogenic aerosols. Also, direct aerosol radiative forcing (ARF) has been estimated globally to be similar in magnitude but opposite in sign to global GHGs forcing. Hence, the shorter atmospheric lifetime of aerosols results in more localized effects and regional differences in aerosol properties. ARF provides us information about the change in radiation budget of the atmosphere or surface. A positive forcing warms the system, while negative forcing cools the surface. Aerosol not only affects the ecosystem and its climate but also human health.

Objectives:

- To obtain variations in aerosol optical depths (AODs) at UV, visible and NIR spectrums (380-1025 nm) using Multi-wavelength Radiometer (MWR) and Microtops-II Sunphotometer.
- To obtain black carbon (BC) aerosol concentrations on land and glaciers using Aethalometer.
- To relate AODs with the meteorological parameters with the help of Automatic Weather Stations (AWSs) installed at Mohal (Himachal Pradesh) and Katarmal (Uttarakhand).
- To estimate radiative forcing using different models.

Achievements:

Mohal-Kullu, Himachal Pradesh

1. Mean AOD_{500nm} at Mohal in 2020 was 0.67±0.77 (range= 0.01-3.61). Seasonally, highest AOD_{500nm}

was observed in summer followed by monsoon and comparatively lower in autumn and winter.

2. Diurnal variation of BC in 2020 showed bimodal peak at Mohal (January–October) with its highest concentration in the morning and evening hours. At Mohal, it peaks around 6:00 hrs IST in the morning with 3789.32 ng m^{-3} and around 19:00 hrs IST in the evening with 2003.08 ng m^{-3} (Fig. 33).

3. The mean concentration of PM_{10} on 8-hourly basis thrice a day was 47.3µg m^{-3} between January and December 2020. While, mean $PM_{2.5}$ on 24-hourly basis was found 31.23µgm^{-3}.

Kosi-Katarmal, Almora, Uttarakhand

4. Average AOD_{500}nm was observed 0.40±0.03 in 2019-20. Maximum AOD_{500}nm was observed to be 0.64 in July 2019, whereas minimum AOD stood to be 0.27 in March 2020.

5. Average maximum and minimum concentration of diurnal BC at Katarmal was 2833 ±294 ng m^{-3} in December, 2020 at 10:00 hrs IST and 133±14 ng m^{-3} in August, 2020 at 16:00 hrs IST, respectively (Fig. 33).

6. The aerosol loading was observed to be high during summer period due to western long-range transportation of aerosol particles by air mass and also due to frequent forest fire events (Fig. 34). Air Quality Index (AQI) found 59.2 in forest fire days and 31.5 in non-fire days while in pre-lockdown period AQI was 28.9 and during lockdown period 18.7.

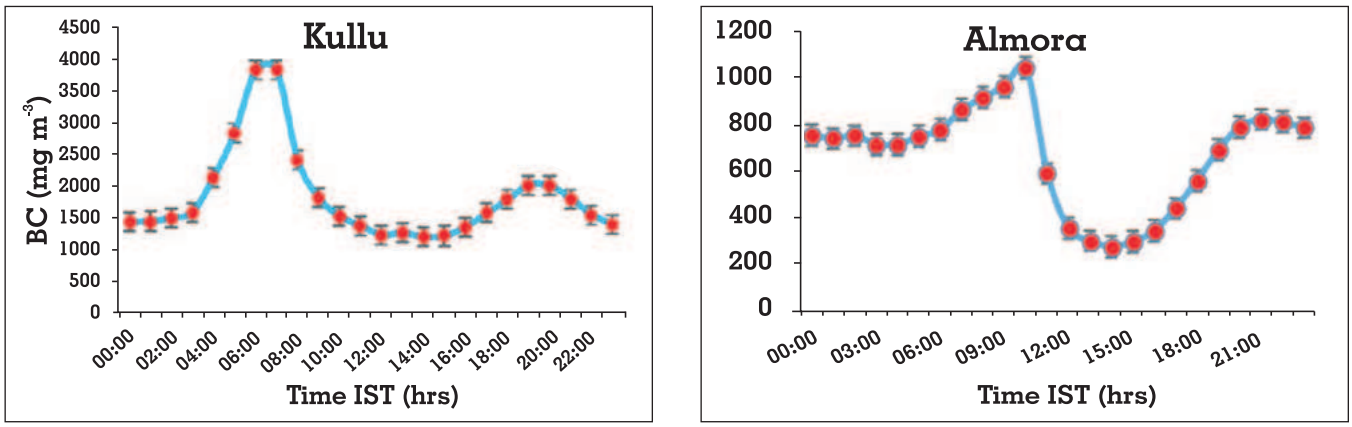


Fig. 33: Black Carbon concentration at Mohal-Kullu, H.P. and Kosi-Katarmal, Almora in 2020.

Fig. 34: Multi-wavelength Radiometer (MWR) and Respirable Dust Sampler (RDS) set ups for aerosol and particulate matter measurements at Mohal, Kullu (H.P.).

Gaseous Air Pollution in the Background Sites of Sprawling Urban Environment in Himachal Pradesh and Uttarakhand (ISRO, EO AT-CTM, PRL, 2008-09 & Onward)

Surface ozone (O_3) is an important secondary air pollutant threatening human health, vegetation growth and increasing local temperature. O_3 is a key species affecting the chemical properties of the atmosphere where it is a precursor for the highly reactive hydroxyl radical. O_3 concentration depends on its precursors and the intensity of solar radiation. The influence of meteorological parameters and its precursors at a specific site can contribute to local and regional level pollution. Nitric oxide (NO) is emitted from soil, forest fire, lightning and combustion processes. NO is short-lived because it oxidizes to produce nitrogen dioxide (NO_2). Biomass burning, combustion of fossil fuels, and oxidation of hydrocarbons released from automobiles and industrial solvents are the main sources of atmospheric carbon monoxide (CO). Its oxidation leads to O_3 formation or destruction, depending on the level of NO concentration.

Objectives:

- To measure the concentration of gaseous pollutants such as Ozone (O_3), Nitrogen Dioxide (NO_2), Carbon Monoxide (CO), Sulfur Dioxide (SO_2) and Carbon Dioxide (CO_2) due to anthropogenic sources such as vehicular congestion and biomass burning as well as natural sources (dust, storm) to establish background values in the Himalayan region.
- To observe local meterological parameters and relate to these with gaseous pollutants and analyze in the background of long-range sources.
- To suggest some feasible mitigating measures for implementation at policy level.

Achievements:

Mohal-Kullu, Himachal Pradesh

1. Surface Ozone monitored in Mohal- Kullu showed highest concentration (31.41±1.23 ppb) in June 2020, and lowest concentration (10.57±1.05 ppb) in August 2020 (Figs. 35 A & 36 a-b). Ozone shows positive correlation with solar flux, temperature, humidity and negative correlation with wind speed. The increase in O_3 concentration from early morning to peak afternoon was noted across all the months.

2. During 2020 the CO concentration was highest (0.54±0.02 ppm) in December, followed by 0.38±0.03 ppm in November, and lowest (0.03±0.01 ppm) in August and April 2020 (0.04±0.01 ppm).

3. Sulphur Dioxide showed highest concentration (1.65±0.10 ppb) in July 2020, followed by 1.39±0.08 ppb in June 2020, and lowest in April 2020 (0.35±0.01 ppb).

Kosi-Katarmal, Almora, Uttarakhand

4. The total columnar O_3 at Kosi-Katarmal showed increasing trend from 7 March 2019 to 7 April, 2020 with (R = 0.003). Average solar flux at 500 nm was high in the month of July with R value 0.0073.

5. AQI calculated during pre-lockdown was slightly polluted compared to clean air during lockdown period. The main reasons of increase in BC, TSP, PM_{10} and $PM_{2.5}$ were transport activities, forest fires and increasing human population in the region (Fig. 35b).

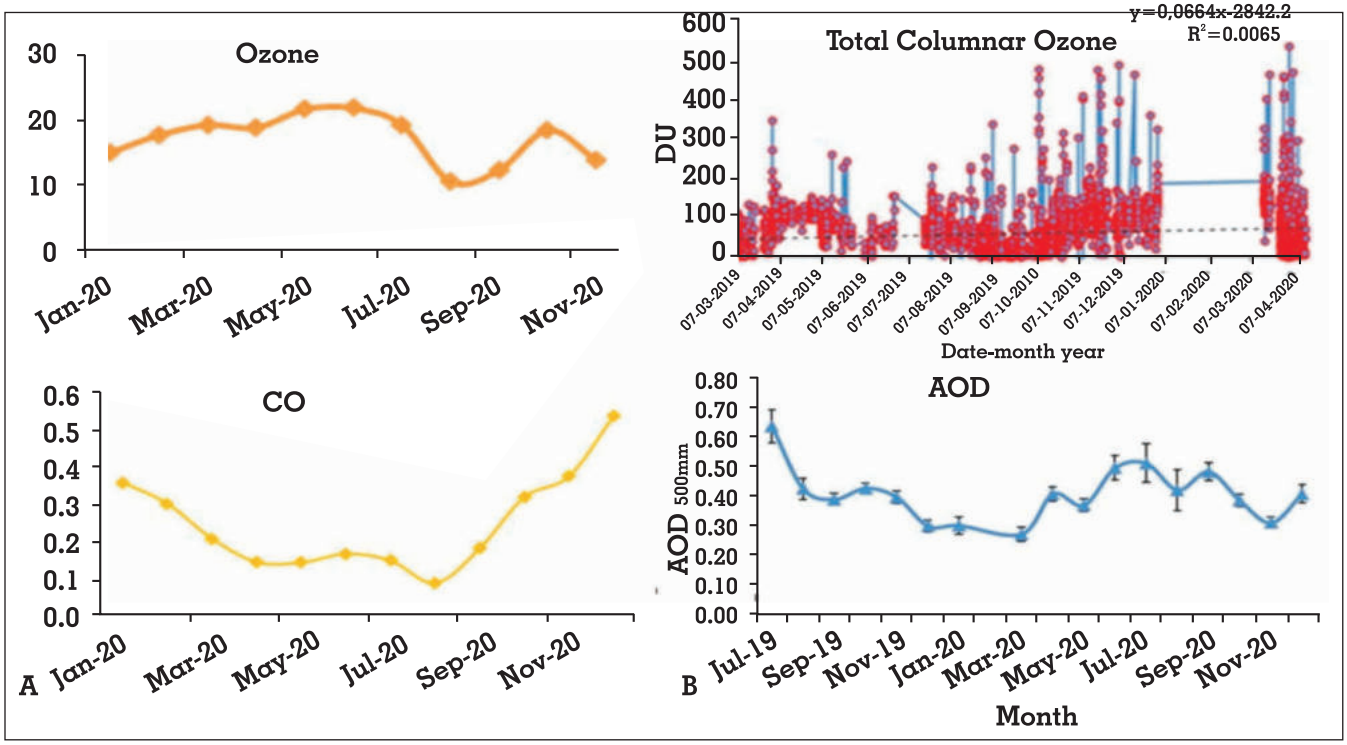


Fig. 35: (**A)** Diurnal pattern of surface O_3 and monthly concentration of CO at Mohal-Kullu, and (B) total columnar ozone and AOD at Kosi-Katarmal, Almora.

Fig. 36: Environmental Observatory at: (a) Katarmal-Almora, and (b) Mohal-Kullu (H.P.)

Preparation of District/State Environment Plan for Uttarakhand (UKPCB, 2020-2021)

Uttarakhand state is one of the most vulnerable to environmental risks as the exploitation of natural resources and other biotic pressure have degraded different environmental components at an alarming rate. The major environmental problems that need to be addressed to ensure sustainable development in Uttarakhand state are: solid waste, bio-medical, industrial, construction, hazardous, household waste including e-waste, water, air, noise, soil, plastic, land and agricultural pollution, illegal sand mining, littering and landfills, non-attainment cities, urban sprawl, over-population and public health issues, increasing polluter stretches in the rivers and groundwater extraction/ contamination, etc. In compliance to the direction given by Hon'ble National Green Tribunal (NGT) vide order O.A. no. 360/2018, dated 26.09.2019, Uttarakhand Pollution Control Board (UKPCB) has been asked to cover the above 15 thematic areas within a District/State Plan. This Institute is preparing 'District/State Environmental Plan for Uttarakhand' in the form of a consultancy funded by the UKPCB.

Objectives:

- To examine current status of the thematic areas as identified, on the basis of the data or information provided by the concerned departments in Urban Local Bodies (ULBs)/districts.
- To assign a desirable level of compliance, identify gaps and its proposal to fill up the gaps as notified within set of rules from different departments in a district/state.
- To prepare the District / State Environmental Plans.

Achievements:

1. Organized 13 brainstorming workshops in all 13 districts of Uttarakhand with different district officials to discuss the above mentioned 15 key issues and ways for collecting the data on these specific issues and an interim report was prepared based on these workshops.

2. Designed data collection format with inputs from UKPCB and shared the format to all district officials of Uttarakhand. Ground observations were also taken in Almora district regarding different environmental aspects.

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 – 2021)

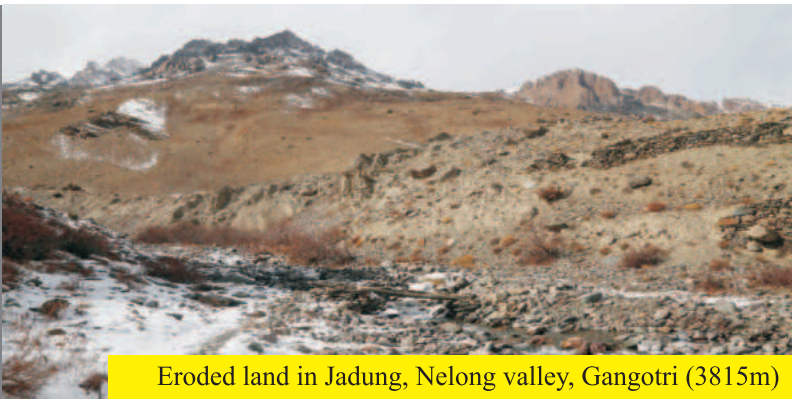
Habitat degradation in sub-alpine and alpine ecosystems with changing climate is a major concern in the present context. The biological diversity, current status of habitat degradation and fast depletion of natural resources in the sub-alpine and alpine areas, realize a necessity to assess the health of these areas, identify the factors leading to the degradation, identify areas where habitat improvement is required and evolve models for effective eco-restoration/mitigation plans.

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.

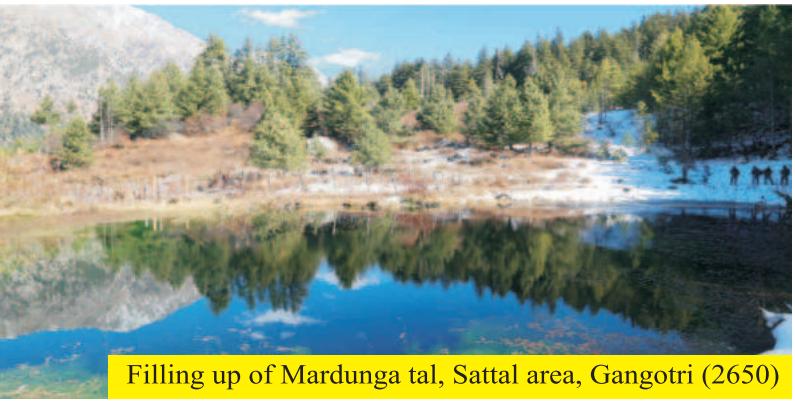
Achievements:

1. Restoration action plan for Gangotri-Govind landscape has been prepared, considering biotic pressure and 5 main reasons for critical degradation identified were: over-grazing, mass or unmanaged tourism, solid waste problem, and poor economy and land hazards. Total 12 Bugyals were evaluated: Tapovan (4315 m), Bhojbasa (3825 m), Nelong (3819 m), Kairakoti (3758 m), Sattal (3023 m), Dayara (3225 m) in Gangotri landscape, and Pushtar (3860 m), Harki-dun (3780 m), Devkyara (3745 m), Ruisara (3500 m), Bhatgair (3306 m) and Kedarkantha (3800 m) in Govind landscape (Fig. 37).
2. A restoration success evaluation model was developed for the assessment of Dayara bugyal (3501 m) and restoration activities were implemented by the Forest Department, Uttarakhand. The model was developed by considering three categories (*viz.*, direct management measure (M), environmental desirability (E) and socio-economic feasibility (SE), and twenty-two individual variables (viz., grazing, tourism and soil erosion under 'M', vegetation diversity, vegetation cover, soil pH, organic carbon, total soil N, P and K, water holding capacity under 'E' and cost-effectiveness, economic efficiency, procedural equity, social preference, adoption lag, replicability of the response, technical sophistication, cultural values, social norms, policy/legislation, governance mechanism under 'SE'.
3. The eco-restoration strategy and their evaluation model could have its future prospects for successful restoration practice in high altitude degraded alpine pastures of the IHR as well as in other similar mountain alpine and sub-alpine ecosystems.



Eroded land in Jadung, Nelong valley, Gangotri (3815m)

Winter tourism in Kedarkantha, Govind (3580m)



Filling up of Mardunga tal, Sattal area, Gangotri (2650)

Grazing near Har Ki Dun Bugyal, Govind (3750m)

Fig. 37: Anthropogenic pressure and habitat degradation in the Gangotri-Govind landscape.

Nano-Pesticide Biosynthesis and their Impact Assessment on Secondary Metabolism of Endangered Medicinal Plant *Picrorhiza kurroa* (DBT-RA Programme, 2020-2022)

Picrorhiza kurroa, an important medicinal plant of the alpine Himalayan region, is well known for its wide array of pharmacological properties, which is attributed to its secondary metabolites especially monoterpene glycosides. In the sustainability of this species unscientific excessive harvesting, limited cultivation and attack of pathogens are major problems. *Alternaria tenuissima* (Alternaria leaf spot disease), a fungal pathogen, is mainly responsible for its yield loss. Although, pathogens attack can be managed with the use of traditional chemical pesticides, but these pesticides create resistance in the pathogens and found harmful to non-targeted plants, humans and the environment. In recent years, nanotechnology is exponentially increasing to develop nano-pesticides that overcome the above-mentioned problems and sequentially improve the crop productivity. In view of this, the present study aims to biosynthesize nano-pesticide against the pathogens of *Picrorhiza* and also to evaluate the impact of formulated nano-pesticide on secondary metabolites production in *Picrorhiza*.

Objectives:

- Green synthesis of bioactive nano-pesticides against phytopathogens of *P. kurroa*.
- Evaluation of nano-pesticides induced cytotoxicity and modulations in physio-biochemical behavior of *P. kurroa* under *in-vitro* conditions.
- Assessment of nano-pesticides impact on secondary metabolites production and expression profiling of their bio-synthesis related functional genes in *P. kurroa*.

Achievements:

1. Selected plants viz. *Ajuga bracteosa, Pittosporum eriocarpum, Alnus nepalensis, Valeriana wallichii, Rhododendron arboreum, Berberis asiatica, Agertina adenophora* were investigated for their antifungal potential against *Alternaria tenuissima,* a phytopathogen of *P. kurroa*.

2. Subsequently, plants having antimicrobial potential were used for biosynthesis of nanoparticles. Initial results, on the basis of colour change and UV-visible spectrum, indicate that *Ajuga bracteosa, Agertina adenophora, Camphora tamala* and *Pittosporum eriocarpum* have potential to synthesize nanoparticles in very small amounts (Fig. 38).

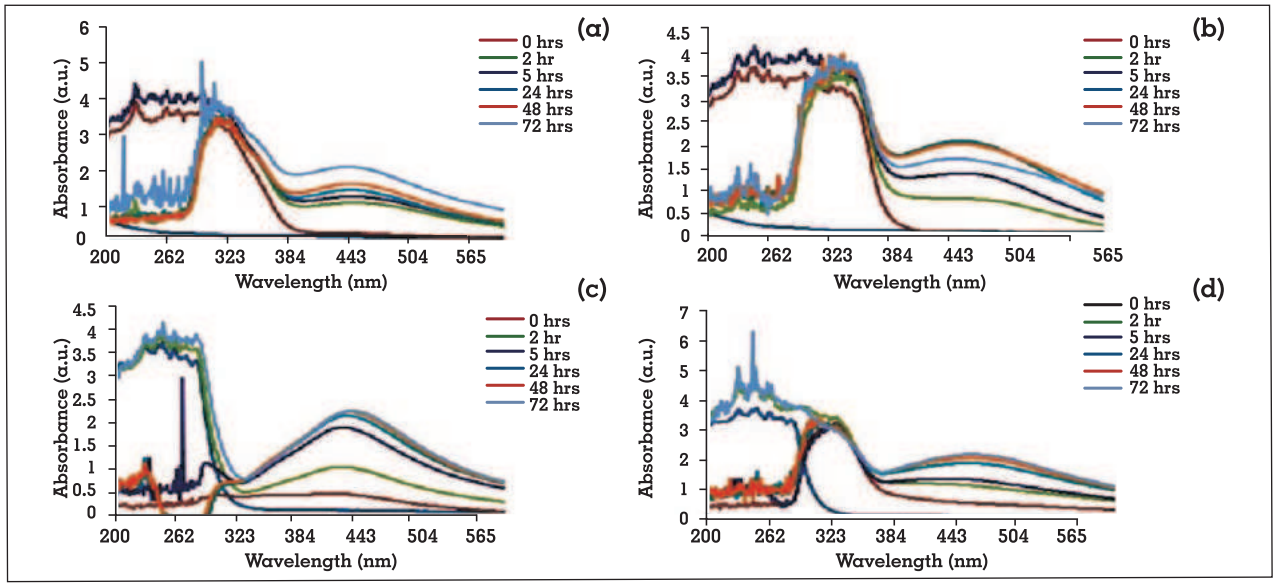


Fig. 38: UV-visible spectra of biosynthesized AgNPs. (a) *C. tamala;* (b) *A. bracteosa*; (c) *R. arboretum;* and (d) *A. adenophora.*

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

Microorganisms are always a crucial part of any ecosystem as they carry out various activities to maintain the sustainability of that ecosystem. Climatic variations at micro-scale, for example, variations due to altitudinal difference, also affect the microbial communities. This is due to change in climatic factors such as temperature, net precipitation, O_2 availability, etc. These changes enable colonization of higher population of microbes which are adapted to particular type of environments causing reduction in the diversity. Such changes may affect the mutual benefits of plants and microbes. Realizing the importance of plant microbe interaction in timberline species, this study is focused on *Betula utilis* D. Don (common Title: Himalayan birch, Hindi Title: Bhojpatra; Family: Betulaceae). Most of the studies on this species have been carried out in isolation and studies integrating different components of *B. utilis* forests have not been carried out so far.

Objectives:

- To assess the representative *Betula utilis* populations in Himachal Pradesh, North-West Himalaya.
- To assess the soil enzymes and microbial endophytes as indicators of climate resilience.
- To assess the contribution of root associated microbes in propagation and conservation of *B. utilis.*
- To create awareness among the local inhabitants, officials of 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. Soil enzymes and physico-chemical attributes were assessed in the rhizosphere soil of *B. utilis* along increasing altitude (2934, 3306, and 3624 m asl cited as S1, S2, and S3, respectively). Acid phosphatase (303.2 ± 11.6 pNP µg/g dry soil/h) and urease (6.2 ± 0.26 pNP µg/g dry soil/h) activity was recorded maximum in lower attitude (S1), whereas β- glucosidase (273.4 ± 17.65 pNP µg/g dry soil/h) and dehydrogenase (0.08 ± 0.003 TPF µg/g dry soil/h) was recorded maximum in S3 and S2, respectively.

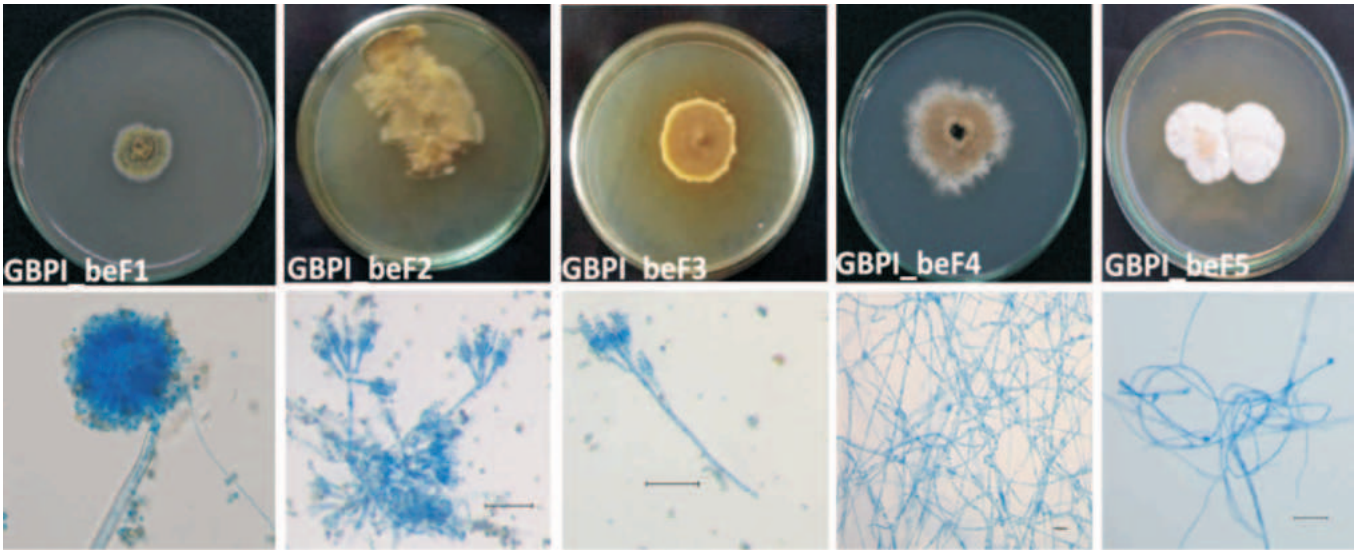


Fig .39: Plate and microscopic images of fungal endophytes.

2. Altitude wise mycorrhizal and dark septate root colonization of *B. utilis* was also assessed. The mycorrhizal colonization ranged from 35±2.4 - 45±2.32%, whereas the dark septate endophytes colonization ranged from 23±1.7 - 34±1.31%. The maximum colonization of both mycorrhizae and dark septate endophytes was recorded at S2.

3. Total five fungal root associated endophytes of genus *Eurotium*, *Penicillium*, *Pezicula* and *Paraconiothyrium* were isolated and identified (Fig. 39). All fungal isolates were qualitatively assessed for plant growth promoting potential and lytic enzyme production potential (Table 8).

Table 8: Qualitative assessment of plant growth promoting activity and lytic enzyme activity by root associated fungal endophytes.

Fungal Isolates	Parameters for plant growth promoting activity						Lytic enzyme activity				
	Ammonia production	HCN production	IAA production	Phosphate solubilization	Siderophore production	ACC deaminase	Amylase	Cellulase	Xylanase	Gelatinase	Lipase
GBPI_beF1	++	-	+	+	+	+	+	+	-	+	-
GBPI_beF2	++	-	+	+	+	+	+	+	-	+	-
GBPI_beF3	++	-	+	+	+	+	+	+	-	-	-
GBPI_beF4	+	+	+	+	+	+	+	-	+	+	-
GBPI_beF5	+	-	+	+	+	+	+	+	+	+	-

Bio-prospecting of Medicinal Plants of Sikkim Himalaya Against Breast Cancer Angiogenesis (DBT, GoI, 2019-2022)

Breast cancer is the most common cancer among women with high mortality rate worldwide. India is no exception for the incidents of breast cancer having 27% patients diagnosed every year and mortality rate has reached to 21.5% indicating its severity. Current anticancer therapies like radio- and chemo-therapies are often met with the burden of high cost, serious side effects, toxicity and tumour relapse; therefore, it is imperative to look for novel therapeutic agents with lesser side effects urgently to address the breast cancer associated angiogenesis. In recent years, use of plant derived compounds has gained tremendous attention for the use as natural anticancer agent. The present study aimed to investigate potential medicinal plants of Sikkim Himalayan region against breast cancer angiogenesis and subsequent identification and isolation of biologically active molecules and lead structures that can be used to develop effective anti-angiogenic or anti-breast cancer drug leads.

Objectives:

- Survey and collection of potential medicinal plants from high altitude region as regard to the anti-angiogenic properties in the state of Sikkim.
- Screening of selected medicinal plants from high altitude region of Sikkim Himalaya based on preliminary bioassays and phytochemical analysis.
- Identification and quantification of major bioactive compounds in extracts showing good activity using different chromatographic techniques like HPLC.

Achievements:

1. Three Rhododendron species namely, *Rhododendron dalhousiae* (RD), *Rhododendron cilliatum* (RC), and *Rhododendron maddenii* (RM) have been investigated for antimicrobial, antioxidant activities and for the presence of secondary metabolites.

2. The highest total phenolic and flavonoid contents were detected in the methanolic extract of *R. dalhousiae* (Fig. 40A). *The DPPH and* ABTS free radical scavenging activities *were also found maximum in R. dalhousiae extract with* IC_{50} *value of 13.58* µg/ml and *8.25* µg/ml, respectively (Fig. 40B).

3. HPLC analysis revealed that the selected Rhododendron species contain substantial amount of phenolic compounds such as gallic acid, vallinic acid, caffeic acid, ferulic acid, etc. *R. dalhousiae accumulated comparatively higher amount of* these phenolic compounds *than the R. ciliatum* and *R. maddenii* extracts.

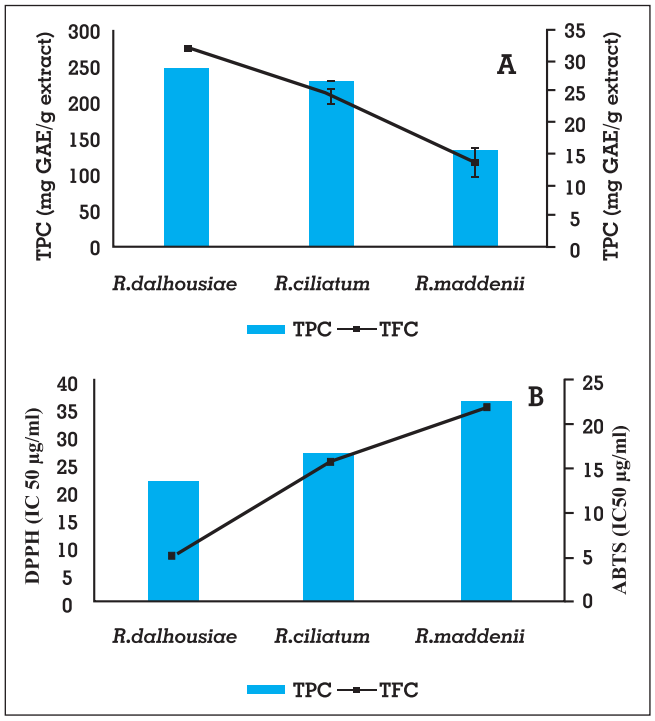


Fig. 40 A & B: TPC, TFC and antioxidant activity of *Rhododendron* species.

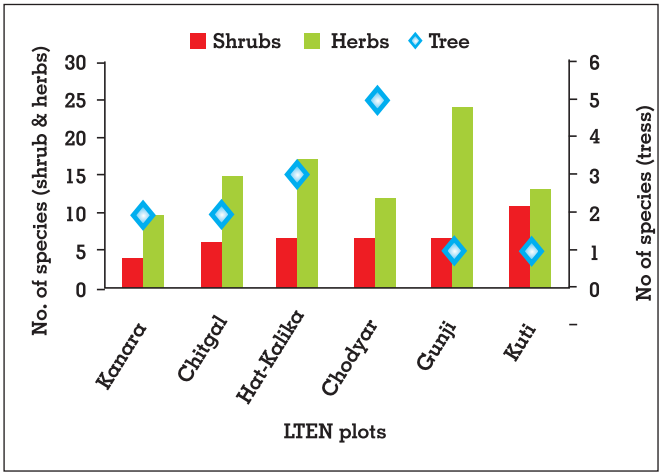
Summary of Completed Projects / Activity

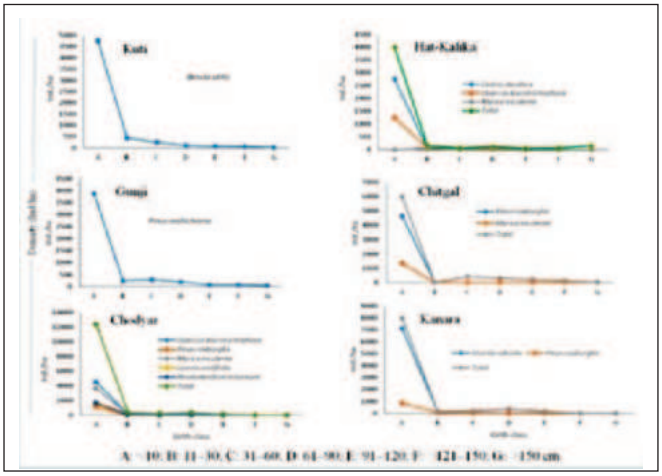
Forest Resources and Plant Biodiversity (NMSHE Task Force-3, DST, GoI, 2014-2020)

The National Action Plan on Climate Change (NAPCC), among others, recognizes the Himalayan ecosystem as vital for preserving the ecological security. Also, it underlines intense vulnerability of this ecosystem towards both anthropogenic and environmental perturbations. The sensitivity of the region is likely to be exacerbated by the impact of climate change (CC). With this realization, NAPCC sets out 'National Mission on Sustaining the Himalayan Ecosystem' (NMSHE) as one and the only area-specific missions among the eight National Missions. This mission envisages measures for sustaining and safeguarding the glaciers and mountain ecosystems. Among six Task Forces (TF), TF3 'Forest Resources and Plant Biodiversity' was coordinated by GBPNIHE. The major objectives were: (i) development of coherent database for forest resources and plant biodiversity of the IHR; (ii) establishment of effective monitoring system for forest resources and plant biodiversity in relation to CC; (iii) validation of Climate Model Projections with reference to forest resources and plant biodiversity in the IHR; and (iv) sensitization and capacity building of inhabitants towards CC adaptation and mitigation. Database of plants of IHR was developed in a standard format through a web portal *(www.ihrplantresources.com)*. The database includes inventory of trees species (1464 species -1384 angiosperms and 84 gymnosperm), shrubs (1015 species belonging to 105 families), wild edibles (1504 species belonging to 173 families), naturalized alien plant species (297 species belonging to 65 families), threatened medicinal plants (112 species in 47 families), and list of 456 threatened (IUCN 2017) plants of the IHR. Under monitoring component, a new knowledge on Long-term Ecological Monitoring (LTEM) of forests was established in relation to CC. A total of six LTEM plots were established along with the elevation gradient (900-3900 m) in the western Himalaya (Fig. 41). Identified criteria and indicators, and developed monitoring protocol for LTEM of forest ecosystems. Two Long-Term Observation Sites (LTOS) in alpines ecosystem of the Greater Himalaya (Chaudas

valley and Byans valley, Distt. Pithoragarh) were established to understand the impacts of CC on alpine vegetation in high altitudes. Baseline information was generated for the established sites (Fig. 42). The data generated from LTEM plots and GLORIA sites that serve as a baseline data will be valuable for understanding future scenarios of change pattern using modelling and simulation to develop better conservation planning in the region. Also, the data sets will feed to global GLORIA network data-base. GBPNIHE has also carried out forest resource assessment in campaign mode in different areas/region of the IHR along an elevation gradient (1000-4500 m). Assessment of pattern of changes in forest cover and uses of forest resources in the IHR was carried out between 2001 and 2017. Pheno Metrics generated for four dominant canopy-forming tree species, *i.e.*, Pine (*Pinus roxburghii* Sarg.), Banj oak (*Quercus leucotrichophora* A. Camus), Deodar (*Cedrus deodara* Roxb. ex D. Don) and Himalayan Birch (*Betula utilis* D. Don). The results showed that there is a notable difference in foliage rhythms among the forest types and tree species across the study area. Altitudinal variation in soil nutrients with relation to forest composition was carried out along an altitudinal gradient (1800-4000 m) to understand the trend of soil nutrients with respect to different forest types. Significant variation was observed in soil nutrients concentration along altitudinal gradient. Under modelling and simulation component, the vulnerability of the IHR forests was assessed in relation to CC. The results reveal that the higher and lower elevation ranges of the IHR are more sensitive compared to the middle ranges. The upper regions of A.P., Sikkim, Uttarakhand, H.P. and J&K are more sensitive and vulnerable compared to other regions according to the trend analysis of the net primary productivity (NPP). The findings of relative humidity reconstruction are unique and clearly display several significant implications for our understanding of the complex RH regimes in the Himalayan mountains. Comparison of daily average net ecosystem exchanges of Chir-Pine and Banj-Oak dominated forests of the Western Himalaya was carried out for the first time. Vulnerability of community forests (42 Van Panchayats forests at pilot scale) based on ground data/information was analyzed that provides most vulnerable VP forests, which needs better management planning. People's perception was documented on CC impacts, and coping mechanism was compiled so that the indigenous knowledge would be integrated with the scientific knowledge for better understanding of CC impacts at local level. The results of pilot studies carried out on bio-resource utilization recommend: (i) steps to be taken to promote use of alternate energy sources, solar energy, wind energy, (ii) invest on improved cook stoves to lessen pressure on the existing resources and improve health benefits, and (iii) launch special drives for education and awareness of community with respect to sustainable harvest and efficient use of bioresources. Capacity and skill building of diverse groups of stakeholders on forest resource management and biodiversity conservation was done through organizing one National Workshop and 27 training programs. As an outcome of this, a total of 28 peer reviewed research papers, and 24 book chapters in proceedings were published that contains valuable recommendations for academicians, planners and policy makers for formulating national policies in relevant areas of CC and also for the purpose of international negotiations.

Baseline information of the established plots in west Himalays





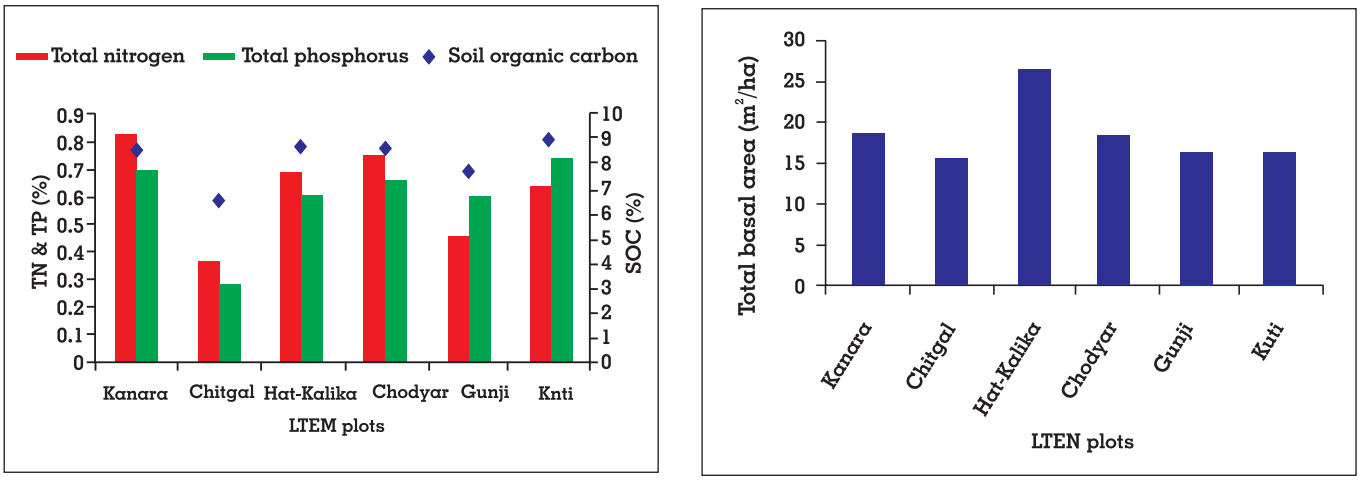


Fig. 41: Baseline information of the established plots.

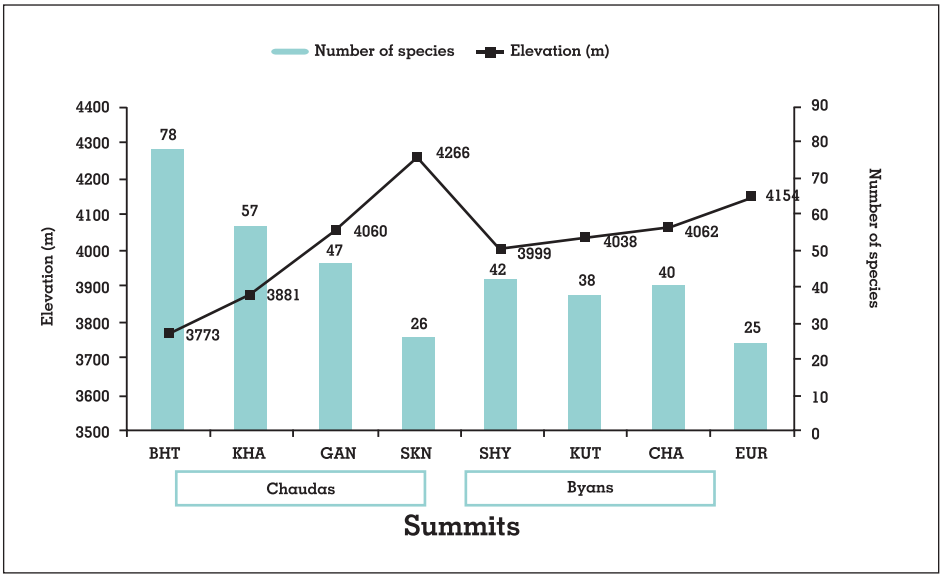


Fig. 42: Baseline information on the GLORIA sites established in alpines ecosystems.

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

The IHR has unique significance in terms of high mountains, steep gradient, rich flora and fauna and socio-cultural diversity from north-east to north-west. The Sind basin of the IHR covers an area of about 1683 km^2 which is located within elevation range of 1563 m to 5375 m. The Parbati river basin covers about 1765 km^2 area. The River Dhauliganga basin is located at an altitudinal range of 1144 m to 6672 m and covers about 1366 km^2 area. The River Ranganadi basin covers 2981 km^2 area with an altitudinal variation from

72 m to 2910 m. The River Imphal catchment area is about 303 km^2 with an elevation range from 777 - 2685 m amsl. These river basins are experiencing direct impacts of CC and are one of the most vulnerable regions in the Himalayan ecosystem. The day-to-day changes from ecological and environmental perspectives occurring in different ecosystems of IHR are a matter of great concern. For this, environmental monitoring of the indicators like stream flow, snow melt and/or headwater contribution in the river water flow and its impact in the downstream regions on the inhabitants' livelihood are helpful in understanding the status of these impacts. The CC impacts on the developmental projects, land use and above all on the community particularly women- the backbone of the regional economy, was also assessed. So much so, the recommendations and mitigation measures will help in formulating guidelines for policy implications, enhancing the capacity of the downstream communities for adaptation and developing more resilience for their sustainable livelihood options. In this background, the study was conducted to understand various aspects of anthropogenic impacts and their management options in the Sindh, Parbati, Dhauliganaga, Ranganadi and Imphal river basins. In Neola watershed of the Dhauliganga Basin in 2018, snowmelt contribution in total runoff was 54.8%, which was reduced to 49.2% in 2019. Similarly, glacier melt contributes to 32.6% of its share in total runoff in 2018, which again reduced to 28.7 % in 2019. Rainfall-runoff showed increased share of 22.1% in its total runoff contribution (Fig. 43). Maximum, minimum and average discharges in the river for the year 2018 were: 115, 55 and 81 cumecs, respectively in the Sindh and 109, 31 and 648 cumecs, respectively in Dhauliganga basin, while in 2019 these values stood to be 123, 21 and 69 cumecs, respectively. In case of river Ranganadi, its discharge was observed as maximum and minimum with 900 and 130 cumecs, respectively. Water quality assessment results revealed that pH, EC, TDS were within drinking water standards except turbidity in all the basins for the year 2018-2020. LULC change in forest land category for all the 12 basins during 2005-2017 showed negative percent change of -17.3% in the Sindh basin and -0.062% in the Dhauliganga basin. In Parbati basin, 19.7% area covered by coniferous forests out of total area (1768 km^2). Thus, given the ecological impacts, the sustainable engineering practices need to be incorporated in the polices while designing the future hydropower and other related projects. Skill building of local stakeholders is required to set-up small scale green skill industries at local level to ensure sustainability of livelihood. In view of alternate livelihood options in the wake of climate change, 5 consultative workshops / awareness programmes (5 each in Sindh basin, 64 participants) and Ranganadi basin (28 participants) and 03 in Imphal basin (135 participants) and 6 training programmes (2 in Parbati basin, 84 participants) 01 in Dhauliganga basin (20 participants) and 01 in Ranganadi basin (54 participants) and 2 in Imphal basin (138 participants) were conducted. The major outcomes were: (i) Aquatic biodiversity in the Sindh basin showed *58 macro-invertebrates and 89 benthic algae species; one of the new insect species Deuterophlibia sp. was identified in the basin; (ii)* In Neola watershed of the Dhauliganga basin, snowmelt contribution in total runoff was found to be reduced from 54.8% in 2018 to 49.2% in 2019 indicating CC impact; and (iii) In view of alternate livelihood options in the wake of CC change, capacity of 523 people as local communities was enhanced through training programmes.

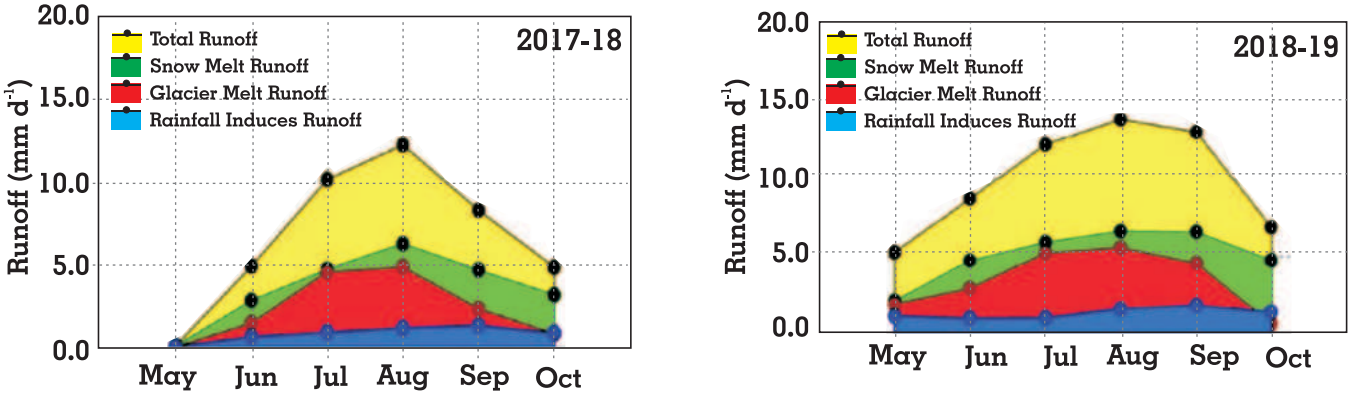


Fig. 43: Mean monthly contribution of the major components of stream flow (snow melt, glacier melt and rainfall induced runoff) to total runoff for the 2017-18 and 2018-19 hydrological years in the Neola Glacier catchment (Dhauliganga River Basin), Uttarakhand.

HIMACHAL REGIONAL CENTRE (HRC)

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

Identification of Elite Planting Material of Selected Temperate Medicinal Plants, Mass Multiplication, Field Demonstration and Post- Harvest Processing (DBT, GoI, 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 from natural habitats has 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 in raw material of medicinal plants. 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. In the present study, high value medicinal plants such as *Picrorhiza kurroa, Nardostachys jatamansi, Rubia cordifolia* and *Swertia chirayita* have been selected for cultivation and conservation.

Objectives:

- Identification of elite planting material of *Rubia cordifolia* and *Nardostachys jatamansi* 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, 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. An elite medicinal plants nursery was established at GBPNIHE, HRC, Kullu for providing planting material of *S. chirayita* and *P. kurroa* to farmers. Seeds of *S. chirayita* treated with GA_3, KNO_3, IAA (concentration: 100 – 400 ppm; time: 24 h) to improve seed germination and reduce mean germination time. *S. chirayita* seed germination was observed only in polyhouse and ~ 12,000 saplings were raised in the polyhouse (Fig. 44). Seeds treated with GA_3 100 ppm show good germination in polyhouse.

2. A total of 5 populations of *P. kurroa* from Chamba, Shangarh, Sainj valley and Jana, Upper Beas valley and 7 populations of *R. cordifolia* from Rumela Dhar, Jana, Kais, Dug, Ghortseri, Shandhar and Magroonala were collected from H.P. for DNA, API and marker compound analysis *and* dried at room temperature for 3-4 weeks. Afterwards, the roots/rhizomes of *P. kurroa* and stems of *R. cordifolia* were sent to Bennett University for DNA and marker compound analysis.

3. Genetic Resource Center (GRC) was strengthened by cultivating other accession of target species. Presently, 9 accessions of *P. kurroa* and 5 accessions of *R. cordifolia* from H.P. and 2 populations of *S. chirayita* from Nepal and Solan, and 1 accession of *N. jatamansi* from H.P. are being maintained at the GRC. A polyhouse has been established for mass multiplication of medicinal plants at Dhoranala nursery site of HRC.

Fig. 44: Optimized *S. chirayita* seed germination at HRC.

Returning Taxus to the Forests and the People: A Study in Shimla and Kullu Districts of the IHR (NMHS GoI, 2019-2022)

The West Himalayan Yew (*Taxus contorta* Griff.) has suffered a population decline of up to 90% in the IHR, mainly because of overexploitation for its medicinal properties, especially for the commercial extraction of the anti-cancer drug Taxol. The last population assessment of *Taxus* in Himachal Pradesh was conducted in 2008 in Khokhan Wildlife Sanctuary, and the current extent and possible locations of this species is not known. Hence there is a need to assess and map the current distribution using species niche modelling technique. There is an urgent need to develop and standardize mass multiplication protocols and plantlet establishment involving the forest department and the local people for successful planting for *ex-situ* conservation of *Taxus* species. Such community based interventions would generate livelihood and income for the local people, conservation of endangered Himalayan yew, and this would develop into a self-sustaining conservation strategy.

Objectives:

- Assessment and mapping of populations of *Taxus* in Shimla and Kullu districts.
- 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. Mass multiplication of *Taxus* was carried out through branch cuttings. The germplasm was collected from different locations of Kullu district. Stem cutting of *T. contorta* ranging from 15-20 cm with 3-4 nodes and 0.5-1.0 cm diameter were also used for mass multiplication. IBA in 500 ppm and 1000 ppm concentration were used for treatment of branch cuttings. Good rooting was observed in the branches treated with 500ppm concentration of IBA. Branch cuttings have also shown rooting in controlled condition (Fig.45). Suitable areas for reintroduction were selected with the help of Maxent modelling in Kullu district.

2. Awareness on conservation and cultivation of *T. contorta* was imparted among local people by conducting meeting and training regarding the traditional knowledge, medicinal uses and threats faced by this plant leading to its endangerment in the wild. Saplings were distributed among the local people and a plantation drive was also organized in the villages involving forest department and local communities.

3. Nursery techniques for mass multiplication of *Taxus* were also demonstrated to local community and staff of Manali forest division following which 800 saplings was raised in the forest department nursery.

(A) IBA treatment- 500 ppm

(B) Controlled condition

Fig. 45: Rooting in *Taxus contorta* cuttings.

Current and Potential Production of Different NTFP and Medicinal and Aromatic Plants and Threats in Conservation and Sustainable Management of Different NTFPs and MAPs in 20VFDs of Kullu & Lahaul & Spiti Districts (JICA, HP Forest Department, 2020-2021)

HP Forest Ecosystem Management and Livelihood Improvement Project has set up a State level Him Jadi-Buti Cell in PMU to coordinate all activities relating to conservation, promotion, sustainable management of NTFPs including medicinal and aromatic plants (MAPs). Eleven cluster-level Him Jadi-Buti Societies/ Producer Groups have been set up to help right holders and growers of NTFPs and MPs for sustainable management of NTFPs and market access. The project interventions on NTFPs improvement include plantation in forest areas, plantation and cultivation in non-forest areas, conservation and sustainable harvesting of NTFPs, R&D, enterprise development and market access. GBPNIHE signed an agreement with H.P. Forest Department through Society for Improvement of Forest Ecosystems Management and Livelihoods in H.P. for the assessment of potential of NTFPs and MAPs in 20 VFDs located in Lahaul-Spiti and Kullu districts of HP.

Objectives:

- Identify the potential areas within the cluster for production of NTFPs / MAPs.
- Estimate the current level of production of different NTFPs.
- Assess the status of regeneration of different NTFPs.
- Identify the issues in conservation, regeneration, harvesting and management of NTFPs in the cluster.
- Prepare a plan for conservation, resource development and sustainable management of NTFPs in the cluster.

Achievements:

1. Based on review of literature, field survey of study area, interviews of Vaidyas/traditional healers, 7 multi stakeholder consultations and discussions with subject experts, potential species have been selected in each cluster for cultivation in Kullu and Lahaul & Spiti districts for assessment and prioritization of medicinal plants.

2. Kullu cluster comprises of 5 ranges viz. Manali, Naggar, Patlikulh, Bhutti, and Kullu. MAPs assessment was carried out in nine VFDs/Panchayats viz. Balh, Brahman, Hallan II, Jana, Pichhalihar, Nasogi, Sari, Palchan and Majhat of Kullu cluster. Total 148 respondents were surveyed for status and potential of medicinal plants in the cluster. A total of 130 MAPs belonging to 56 families were recorded during the survey. Out of these, 22 species were trees, 76 herbs, 28 shrubs, 2 ferns and 2 climbers (Fig. 46). Among the families, Lamiaceae (12 spp.), Asteraceae (8 spp.), Apiaceae (7 spp.), Amaranthaceae (5 spp.), and Rosaceae (5 spp.) were dominant.

3. Cluster level plan for conservation, resource development and management of MAPs in clusters of Kullu & Lahaul & Spiti districts has been prepared and submitted to Jadi-Buti cell of JICA for implementation in various clusters.

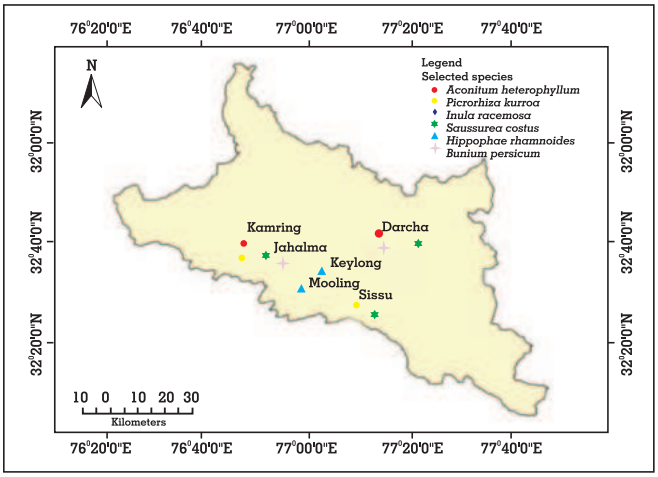


Fig. 46: Distribution of selected species of MAPs in Keylong Cluster of Lahaul & Spiti District.

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

The Seabuckthorn berry, is among the most nutritious fruits with high concentration of pro-vitamins A, B2 and C, flavonoides and omega oil, which is much higher than other fruits and vegetables. In Lahaul, Sea buckthorn is found in abundant quantity and because of its nutrition and medicinal value, climate resilience and high economic value, it can be an alternate source of livelihood for the local people. Therefore, to harness the economic benefits of the species scientific harvesting and post harvesting techniques of the species has to be developed. In this context, a value chain of the species with diverse products has been developed in the project for its further sustainability.

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 IHR.
- 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. Value addition in the Sea buckthorn berries in terms of juice was done and seeds were separated for oil extraction and sent to IIT Delhi for further testing. Also, standardization of drying method of leaves in microwave was done for leaf tea (Fig. 47).

2. Training on value addition processes of Sea buckthorn was imparted to the stakeholders at Technology Incubation Center at Kirting, Lahaul & Spiti.

3. Marketing linkages for the produce has been developed between farmers and marketing agencies. 40 kg of dry leaves of Sea buckthorn and 120 litres of pulp juice was marketed through the Entrepreneurship Cell of the Institute worth Rs. 60,000/-

Fig. 47: Processing and value addition in Sea buckthorn leaves and berries.

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

The rapid increase in the demand of herbal species for preparation of different formulations against the treatment of various diseases is observed at the global level. Due to overexploitation and habitat degradation, a large number of MAPs are under different threat status. Today there is a need for conservation of commercially exploited threatened MAPs not only to reduce pressure on the forest wealth but also to increase opportunities for employment and income generation. Himachal Pradesh has 643 medicinal plants, out of which 269 are native, 374 non-natives, 17 endemic, 131 near endemic, 12 critically endangered, 21 endangered, 27 vulnerable, 2 near threatened and 3 data deficient as per the IUCN category. Therefore, in-situ and ex-situ conservation of these rare, endangered and threatened species of the region is very important. For present study focus was given to three species namely; *Angelica glauca, Carom carvi* and *Armenia euchroma.*

Objectives:

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

Achievements:

1. Rhizomes and seeds of *A. glauca* and seeds of *C. carvi* collected from Kullu and Lahul valley were planted in the field at Dhoranala nursery of the Institute for further multiplication.

2. The rhizome buds of *A. glauca* have been used for *in vitro* establishment and multiplication in tissue culture lab. The concentration and treatment period of different disinfectant has been standardized for the sterilization of the explants. The MS culture media has been standardized for bud initiation having different concentrations and combinations of cytokinin and auxin (Fig. 48).

3. Meeting has been organized with the farmers in the Manikaran valley and Tirthan valley and different locations have been finalized to raise nursery of *A. glauca* and *C. carvi* plants and seeds have been distributed among the farmers to raise nurseries of these plants in their fields.

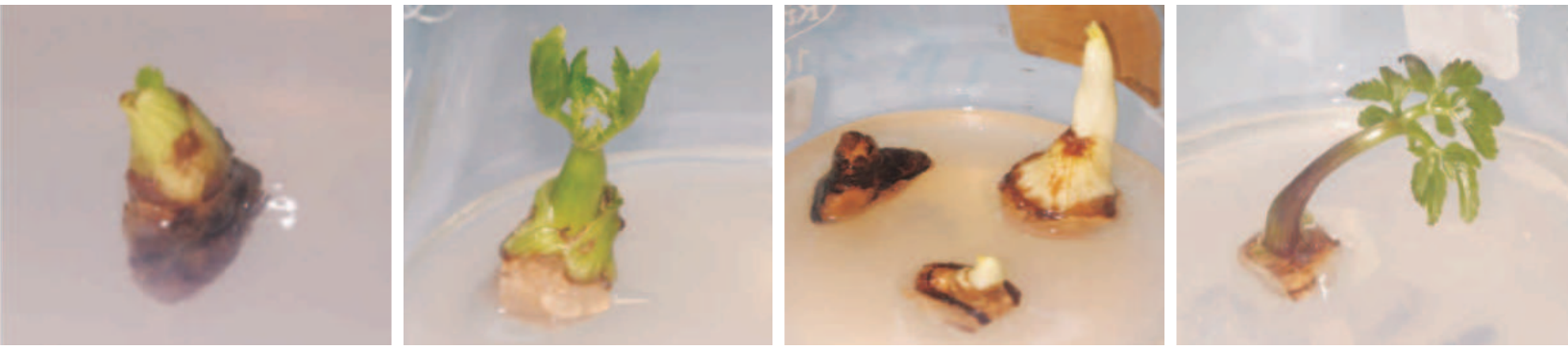


Fig. 48: *In vitro* bud initiation in *A. glauca* plant.

Preparation of Peoples' Biodiversity Register of Selected Panchayats in Mandi and Kullu District, Himachal Pradesh (H.P. State Biodiversity Board, Shimla, 2019-2021)

The National Biodiversity Authority (NBA) of India has initiated formation of Biodiversity Management Committees (BMC) and development of Peoples' Biodiversity Register (PBR) as a follow-up of Conservation of Biodiversity Act (2002). Following the initiatives of NBA, H.P. State Biodiversity Board (HPSBB) has initiated to document PBRs at village, panchayat, block, district and municipality levels in selected districts of H.P. by involving BMCs and Technical Support Groups (TSGs). The present study has been conducted in Kullu and Mandi districts of H.P. to address the overall goal of biodiversity conservation and sustainable utilization in the IHR.

Objectives:

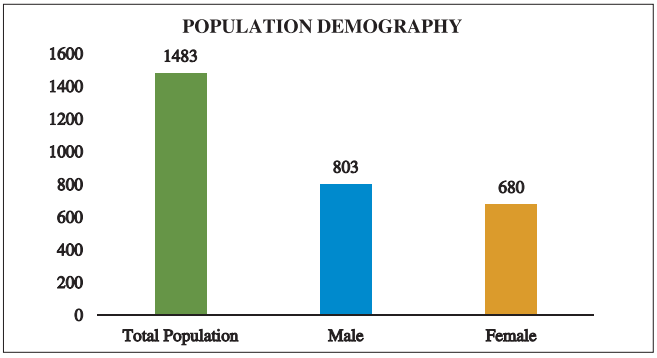
- To document the biodiversity components such as plants, animals, microbes, insects and their possible use by the local communities in the selected BMC's.
- To document topographic and socio-economic features of the selected BMC's with special emphasis on human population, climate, topography, natural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

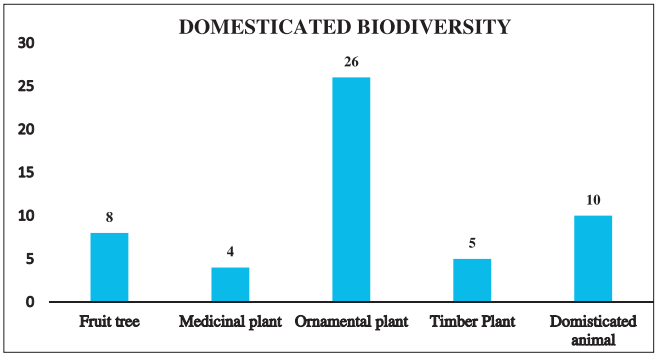
Achievements:

1. A total of 22 Panchayats, namely Bada Gran, Bhalyani, Bajaura, Danogi, Gahar, Garsa, Gojra, Haat, Kothisari, Karjan, Manali, Malana, Nasogi, Neoli and Palchaan of Kullu District and Bobar Chhamyar, Jaral, Lower Riwalsar, Maloh, Nau and Slappar of Mandi district were selected for PBR preparation. Map and demographic profile of each Panchayats were prepared (Fig. 49).

2. Wild biodiversity i.e., forest types, habitats, plants, animals, MAPs, fodder, fuel, timber, fiber and religious plants diversity was documented. Domesticated plant biodiversity i.e., agricultural, horticultural, ornamental and religious and animal diversity (mammals and birds) and cultivated medicinal plant diversity were documented.

3. In some of selected Panchayats unique plant diversity was recorded such as, *Elaeocarpus ganitrus* from Bobar Panchayat, *Cinnamomum tamala* from Neoli Panchayat, *Saccharum officinarum* from Nau and *Phyllanthus emblica* from Haat Panchayat. Some of the important medicinal plants recorded were: *Acorus calamus, Acacia catechu, Bergenia ligulata, Citrus jambhiri, Centella asiatica, Delphinium denudatum, Myrica esculenta, Tinospora cordifolia, Gloriosa superba, Sinopodophyllum hexandrum* and *Zanthoxylum armatum.*





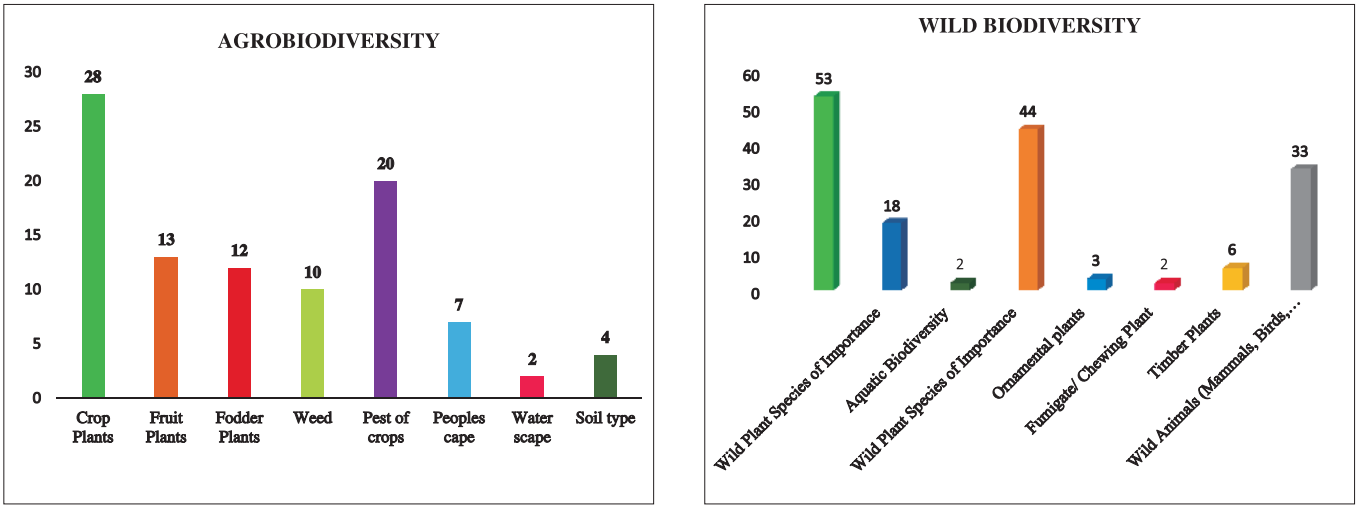


Fig. 51: Demography and biodiversity of Neoli Panchyat.

Preparation of Peoples' Biodiversity Register of Kullu District with all Representative Blocks (H. P. State Biodiversity Board, Shimla, 2020-2021)

The project work was carried out in five representative blocks of Kullu district of Himachal Pradesh. The diverse and large traditional and ethnic knowledge existing with the inhabitants in these blocks will be thus preserved and transferred from one generation to another through formation of BMCs and PBRs that is necessary for sustainable utilization and conservation of biodiversity for 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 area under the selected BMCs, ecosystems and its natural resources.
- To facilitate and engage the trained youth in developing the BMCs.
- To develop the reports on the program using suitable self-monitoring and evaluation tools.

Achievements:

1. Five developmental blocks namely Anni, Banjar, Nirmand, Kullu and Naggar along with whole Kullu district have been selected for PBR preparation. Map and demographic profile of each Panchayats was recorded (Fig. 50).

2. Wild biodiversity i.e., forest types, habitats, plants, animals, MAPs, wild, fodder, fuel, timber, fiber and religious plants along with domesticated biodiversity (agricultural, horticultural, MAPs, ornamental and religious), and animal diversity (mammals and birds) were documented (Fig. 50).

3. In the study area some unique biodiversity (flora and fauna) were also recorded viz., *Stauropus sp.* (Lobster moth), *Ficus carica* (Anjeer), *Cinnamomum tamala* (Tej pata), *Tinospora cordifolia* (Giloy) etc. Some important MPs listed

were: *Trillium govanianum*, *Rhododendron campanulatum*, *Valeriana jatamansi*, *Angelica glauca*, *Saussurea costus*, *Pistacia integerrima*, *Sinopodophyllum hexandrum*, *Rheum australe*, *Meconopsis aculeata*, *Taxus contorta*, *Allium wallichii*, *Acorus calamus*, *Gentiana kurroo*, *Inula racemosa*, *Dactylorhiza hatagirea*, *Zanthoxylum armatum*, *Aconitum violaceum*, *Betula utilis*, *Lilium polyphyllum*, *Hippophae salicifolia*, *Paris polyphylla*, *Skimmia laureola*, *Aconitum heterophyllum*, *Viola pilosa* and *Picrorhiza kurroa*.

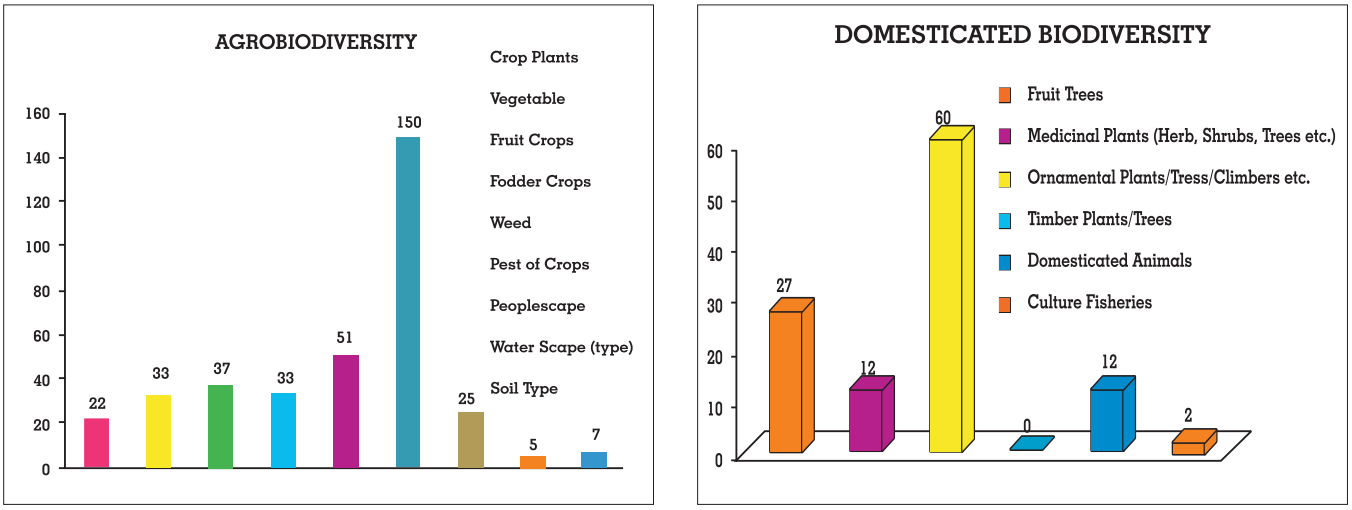


Fig. 50: Demography and biodiversity of selected blocks in Kullu District.

Conservation and Management of Traditional Beekeeping (*Apis cerana*) Practices Through Development of Honeybee Based Sustainable Livelihood Chain in Kullu Valley, H.P. (NABARD, 2021-2023)

Beekeeping with indigenous bee species, *Apis cerana* is an old practice that is still in practice in the rural area of H.P. Traditionally bees are kept in the wooden hives locally called *dhindor* (log hive) and *teere* (wall hive) built in the walls of traditional houses in various high and low altitude rural areas of Kullu valley. The reason towards its decline in the region is also due to their behavioral characteristics such as absconding nature, swarming, low honey production and limited awareness on its management. Therefore, this age-old practice needs to be revived to conserve these species in its natural habitat by building the capacity of locals on its management and making it an entrepreneurial activity. Pollination service of honey bee is another important aspect for conservation and management of horticulture sector.

Objectives:

- Conservation of declining populations of the indigenous honey bee (*Apis cerana*).
- Plantation of prioritized highly preferred native honey bee plants.
- Promotion of high demand and cost effective monofloral honey.
- Promotion of 100% pure honey production using super chamber beehives in native honey bee keeping.

- Value added enterprise development.
- Awareness/capacity building for role of native honey bee pollination aspect.

Achievements:

1. Field visits in the selected sites of Tung *Panchayat* were made for primary data collection on beekeepers and beekeeping practices.
2. Meetings with the people were conducted in Tung *Panchayat* for awareness generation on beekeeping and importance of beekeeping for income generation through value added enterprise development. During these meetings 150 beekeepers were selected for further training on beekeeping. Beehives were prepared for further distribution among beekeepers (Fig. 51).

Fig. 51: One-day interactive meeting and focused group discussion at Tung panchayat.

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

Betula utilis D. Don (common name: Himalayan birch, Hindi name: Bhojpatra) is a broadleaved angiosperm and native tree species of high altitude Himalaya. This species is distributed in sub-alpine region of the Himalayan range between 3,300 - 4,500m amsl and forms tree line all across the Himalaya. Due to natural calamities, changing environmental conditions and over exploitation *B. utilis* habitat alterations have started taking place making the species more vulnerable. Microbial associations may also change with habitat alterations and CC that may affect the mutual benefits of these species. Most of the studies

on this species have been carried out in isolation and studies integrating different components of *B. utilis* forests have not been carried out so far.

Objectives:

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

Achievements:

1. Physico-chemical properties of soil was analyzed for the soil samples collected from different sites of Kullu (14) and Kinnaur District (3) of H.P. Community wise physico-chemical analysis showed soil moisture (range= 16-58.53%), pH (4.5-6.5), available nitrogen (125-539 kg/ha), organic carbon (1.4-5.98%), available phosphorus (0.30-0.78 mg/kg) and available potassium (169-576 kg/ha).

2. Total 19 sites were surveyed in Sangla valley of Kinnaur district located between 3130–3619m amsl. Maximum sites (8) were represented by bouldary, followed by shady moist (6), riverine (4), and dry (1) habitats. Aspect wise, 6 sites represented NE aspect, 4 NW, 4 SW, 3 N, 1 W and 1 SE aspect. The slope of these sites varied from 10^0-46^0.

Spring shed Management: A Strategy for Climate Change Adaptation Through Inventory and Revival of Springs (DEST, Government of H.P., 2019-2020)

Springs are the principal sources of domestic water supply for rural communities in hilly regions, when they dry-up, the resulting water shortage become a major environmental and social issue. There is increasing evidence that springs are drying or their discharge is reducing throughout IHR. Numerous factors including population growth, agricultural intensification, land use change, ecological degradation and CC are responsible for drying of springs. Recently, there has been increasing studies for rejuvenation of springs in parts of Himalaya, but in H.P. such efforts are still required. In this spring rejuvenation study, spring shed management was implemented using hydro-geological research based structural interventions.

Objectives:

- To understand social, cultural and environmental aspects of the springs.
- To develop better understanding of geo-hydrology of the spring shed.
- To develop climate change adaptation strategy through revival of springs by spring sanctuary concept.
- To develop and suggest the replication plan for spring shed management.

Achievements:

1. Extensive field surveys in Barot and Seraj valleys of Mandi district were made to prepare inventory of springs along with geo-database on springs, measurements of spring discharge and physico-chemical water testing in laboratory.

2. Measurements on discharge indicated that 75% of the observed springs have average discharge < 51 L per minute (lpm) and 25% have discharge > 51 lpm in Barot valley (Fig. 52 a). While in Seraj valley 74% of the springs have average discharge < 26 lpm, whereas 26% of the springs have discharge > 26 lpm (Fig. 52 b). Important observations from

discharge, hydro chemical and altitude correlation reveals that these springs are mostly recharged by recent rainfall. Water samples from natural spring sources were analyzed for its yield and quality from Barot and Seraj valleys.

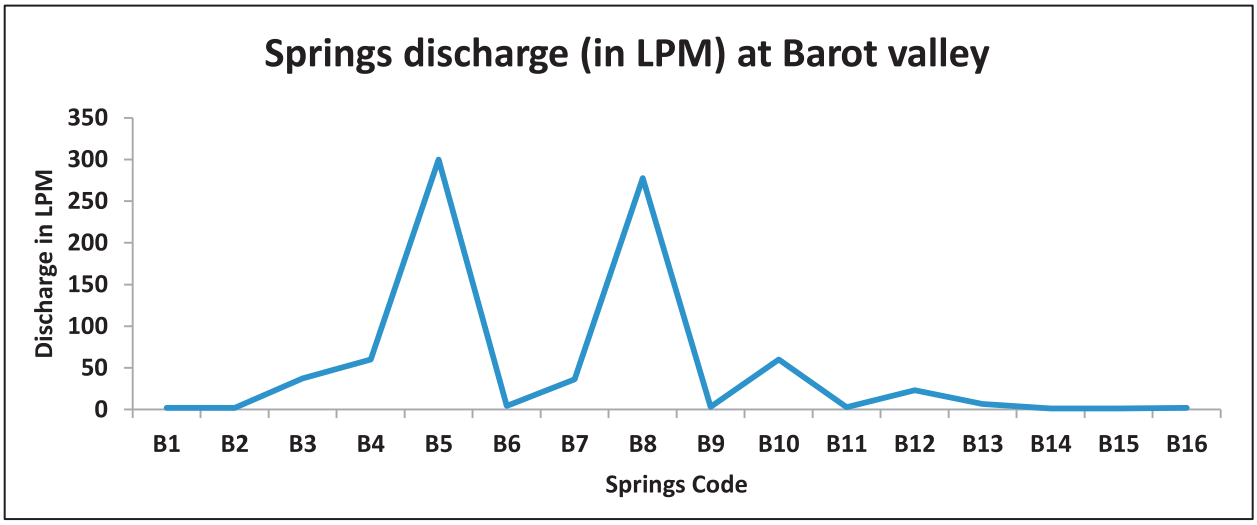


Fig. 52 a : Distribution of spring discharge of sampling sites in Barot valley.

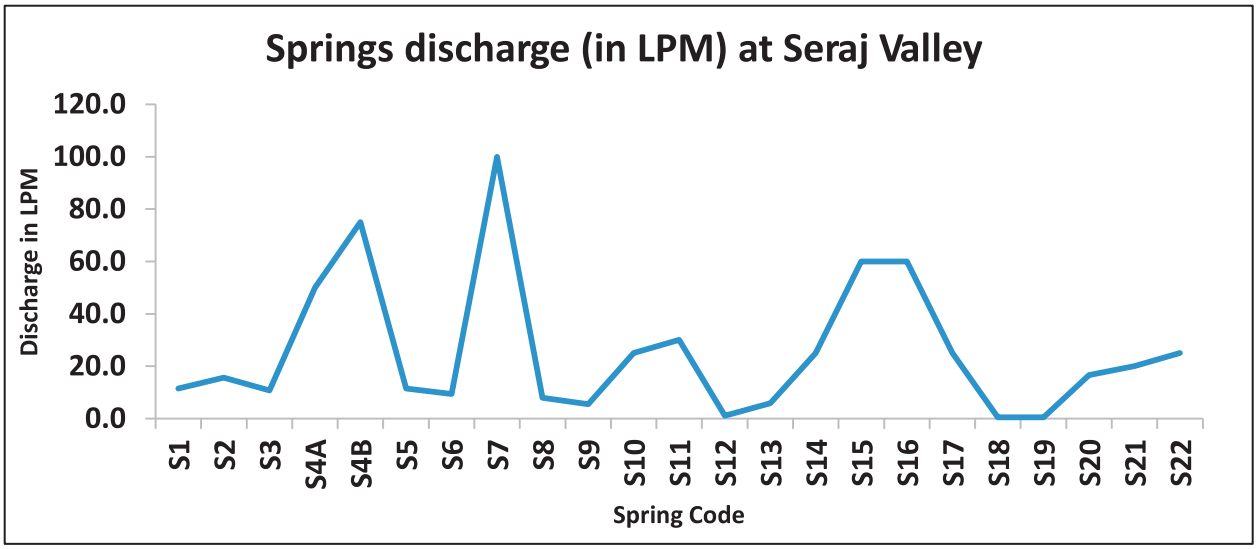


Fig. 52 b : Distribution of spring discharge of sampling sites in Seraj Valley.

Perception of local people (200 respondents) on changing regime of springs using semi structured questionnaire opined that springs are very important for the survival of the people residing in the valley and have significant relevance for social, cultural, religious and environmental fabric.

Modelling and Forecasting of High Impact Weather Events in the Beas Basin, and Designing a Proto-type Advance Warning System for Mitigating their Adverse Impacts (NMHS, GoI, 2019-2022)

The changes in the intensity and duration of weather and climate extreme events due to climate change include cloud bursts, flash floods, landslides, mudslides, torrential rain etc. which is common in the IHR due to its susceptibility and fragile nature. Kullu district in H.P. chosen for the study has always been a potential hazard zone to such disasters. The excess rainfall of 1994 in the Kullu valley took lives of around 20 people in the Fozal village and flash flood of 2018 in the river Beas resulted in immense loss to roads and infrastructure along with loss of human and livestock, agricultural land loss, tourism and accessibility to roads in Beas basin.

Objectives:

- Calibrated forecast configurations with 24-hour lead time over Beas basin (H.P.) with quantitative skill for high impact weather events like cloud bursts, heavy rainfall, flash floods, etc.
- Development of an advanced warning system over H.P. for mitigating adverse impacts of high weather events.
- Integrated disaster assessment and forecast platform over Beas basin (H.P.) on GIS platform for mitigating adverse impacts.

Achievements:

1. Location map of the study area with altitude gradient has been developed in ArcGIS 10.8. Land use land cover (LULC) map of the Beas basin for 2020 has been generated using LANDSAT-8 satellite data and 8 LULC categories were identified.

2. Using Strahler's method of stream ordering system, watershed delineation map of the study area up to 5th stream order drainage network was developed in ArcGIS 10.8 software (Fig.53), which shows maximum frequency in case of first order streams and the stream frequency decreases as the stream order increases. Thus, the basin is dominated by lower order streams. In the Beas basin, a tree-like dendritic type of drainage pattern develops over the soft sedimentary rocks.

3. Questionnaire survey revealed that 41.3% respondents believe that the increase in the intensity of the disaster is due to CC over the years, and 18.4% believe that it is due to deforestation. The 39.5% respondents stated that agriculture areas are most affected by the disasters, while 27.5% people believe that forest products are affected more than the agriculture. Two capacity building-cum-awareness programs were organized involving 50 participants from Fozal Panchayat and 30 participants from Sarsai Panchayat.

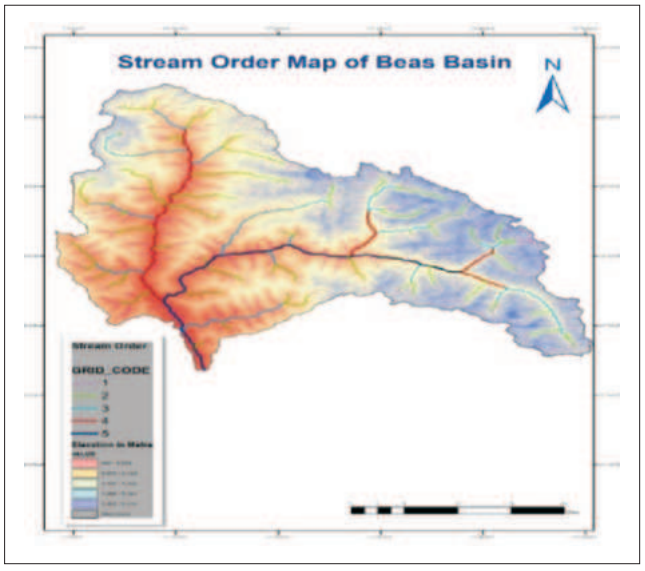


Fig. 53: Drainage pattern of River Beas (Stream order up to 5th Order)

Detailed Assessment of Medicinal and Aromatic Plants Species Including Their Collection, Usage, Demand, Markets, Price Trends and Life Cycle, Focusing on Landscapes in Jammu & Kashmir Under SECURE Himalaya Project (UNDP, New Delhi, 2018-2020)

Detail assessment of MAPs including their collection, usage, demand, markets, price trends and life cycle focusing on changthang landscapes of Ladakh UT was carried out in the *project area in Changthang valley in* upper Indus landscape in eastern Ladakh, with elevations ranging from 4,400 – 6,000 m. The valley consists of alpine dry scrub, desert steppe, marsh meadows and water bodies. The landscape is contiguous with Tibetan plateau. Key faunal assemblage comprised snow leopard, blue sheep, Argali, Tibetan gazelle, and Tibetan wolf. The main aim was to conduct a detailed assessment of MAPs with focus on ensuring sustainable cultivation and harvesting by identifying usage patterns and studying existing value chains. Based on review of literature, field survey, brainstorming workshop, experts suggestions and comments of review committee 5 MAPs each in the two categories – collection (*Saussurea costus, Inula racemosa, Hippophae rhamnoides, Carum carvi* and *Rhodiola imbricata*), and threat perception (*Meconopsis aculeata, Dactylorhiza hatagirea, Arnebia euchroma, Waldheimia tomentosa, Allardia tomentosa* and *Cremanthodium ellisii)* were selected for further study. A list of total 95 MAPs (Angiosperms - 93 and Gymnosperms - 2) belonging to 35 families and 71 genera of Changthang landscape were recorded from the study area. Total 28 sites (altitudinal range 3464 - 5462 m amsl and slope 5° to 65°) were studied in Changthang landscape with 2 populations of *A. euchroma*, 8 populations of *C. carvi,* 2 populations of *C. ellisii,* 1 population of *D. hatagirea*, 8 populations of *H. rhamnoides* ssp. *turkestanica*, 5 populations of *R. imbricata* and 4 populations of *W. tomentosa.* The value chain of *H. rhamnoides* ssp. *turkestanica* has been documented. Brainstorming Workshop entitled "Promoting MAPs sector for conservation of Snow Leopard habitats in Himalaya" was organized at DIHAR, DRDO, Leh-Ladakh. Available agro-techniques and sustainable harvesting protocols for the selected MAPs were documented / developed by reviewing different publications. Access and Benefit Sharing model was also developed by reviewing various publications and consultation with experts and local communities under the project.

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, bio prospecting 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 centre 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 onsite 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.

Characterization of Kidney Beans (Rajmash) Rhizosphere Micro-biome from Higher Altitude of Indian Central Himalaya and its Field Application (NMHS, GoI, 2019-2022)

Kidney bean or Rajmash (*Phaseolus vulgaris* L.) is a herbaceous plant cultivated worldwide for its edible dry seeds or unripe fruits. Rajmash is a high value cash crop in the IHR. It is considered as both rabi and kharif crop. The average productivity of Rajmash is 874 kg/ha as compared to 1217- 1430 kg/ha in plains of India. However, locally growing Rajmash cultivars in hills is known for their premium quality, unique taste and nutritional values. Presently, due to phosphate and nitrogen deficiency in soil, lack of genetic resources and poor agronomic practices has decreased the crop productivity. Therefore, the aim of this study is to select commercial Rajmash land races that are highly adapted to local climatic conditions. Furthermore, characterization and exploration of rhizosphere microbiota from Rajmash growing in higher altitudes will contribute to enhancing soil health and productivity levels for livelihood security to hill farmers.

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. Total 114 Rajmash accessions /germplasms were analyzed for morphological and cooking attributes characterization using standard approach. Also, local accessions of Rajmash were analyzed for various biochemical characteristics like total carbohydrates, total protein and antioxidant activity measurement (DPPH activity).

2. Field trials of bio-inoculants were demonstrated in 20 farmer's field in Triyuginarayan (Distt. Rudraprayag). Seed treatment was done by using two bio-fertilizers, N26 and MP1 in the farmer's field resulted in significantly greater yield of Rajmash compared to control (Fig. 54 & 55).

3. Morphological analysis of N26 & MP1inoculated seeds cultivated at different demonstration sites in Uttarakhand. Rajmash seeds from Triyuginarayan and Pantnagar were measured for weight, length, width and thickness and average seed yield was estimated.

Fig. 54: Growth phase of Rajmash in farmer's field in Triyuginarayan.

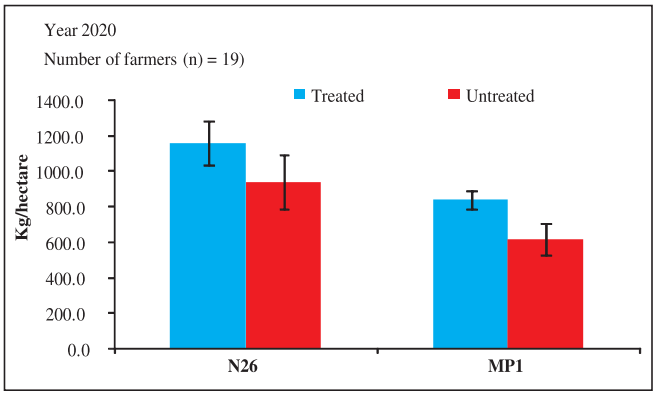


Fig. 55: Production of Rajmash in bio-inoculants treated plots and control at Triyuginarayan.

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)

Conservation of biodiversity is an important aspect of modern research and needs proper attention, planning and management. Recently, identification and accessioning of the elite plant/germplasm and populations are gaining popularity for planning and sustainable utilization of a species. Astavarga is an important group of medicinal plants used for curing various ailments. In the present study qualitative and quantitative analysis of the *M. muscifera* and *M. acuminata* are proposed for germplasm characterization and phytochemical analysis along with germplasm accessioning, standardization of the propagation protocols, mass multiplication, and hardening and domestication practices for their cultivation. The study 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.

Objectives:

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

Achievements:

1. *M. muscifera* and *M. acuminata* were collected from two and six locations, respectively and subjected for morphological and ecological analysis. Morphological parameters (plant height, tuber fresh weight and dry weight) of *M. acuminata* plants exhibited differences among populations. Maximum plant height (6.94±0.59 cm) and tuber weight (5.20±0.38 g/tuber) was recorded in Talwari population.

2. Significant variations in total phenolics, tannins and flavonols in tuber extracts of *M. acuminata* and *M. muscifera* across populations were recorded. Total phenolic content ranged from 1.94-3.4 mg gallic acid equivalent (GAE)/g dry weight

(DW). Similarly, in *M. acuminata* tannin content ranged between 2.95 mg (Pithoragarh) and 4.71 mg tannic acid equivalent (TAE)/g DW (Majkhali), and flavonols from 1.02 mg (Nainital) to 1.42 mg quercetin equivalents (QE)/g DW (Majkhali). In case of *M. muscifera*, higher phenolic content (5.08 mg GAE/ g DW) was recorded in Lata population. However, tannin and flavonol contents were higher in Tungnath population.

3. Antioxidant activity analysis using ABTS, DPPH and FRAP assays revealed significant variations among both the species. Nainital population of *M. acuminata* exhibited maximum value using ABTS assay, while Talwari population exhibited lowest activity. Likewise, maximum DPPH activity was observed in Nainital population and minimum activity in Talwari population. Similarly, Pithoragrah population showed maximum FRAP activity while minimum value of FRAP assay was recorded in Pandukholi population (Fig. 56).

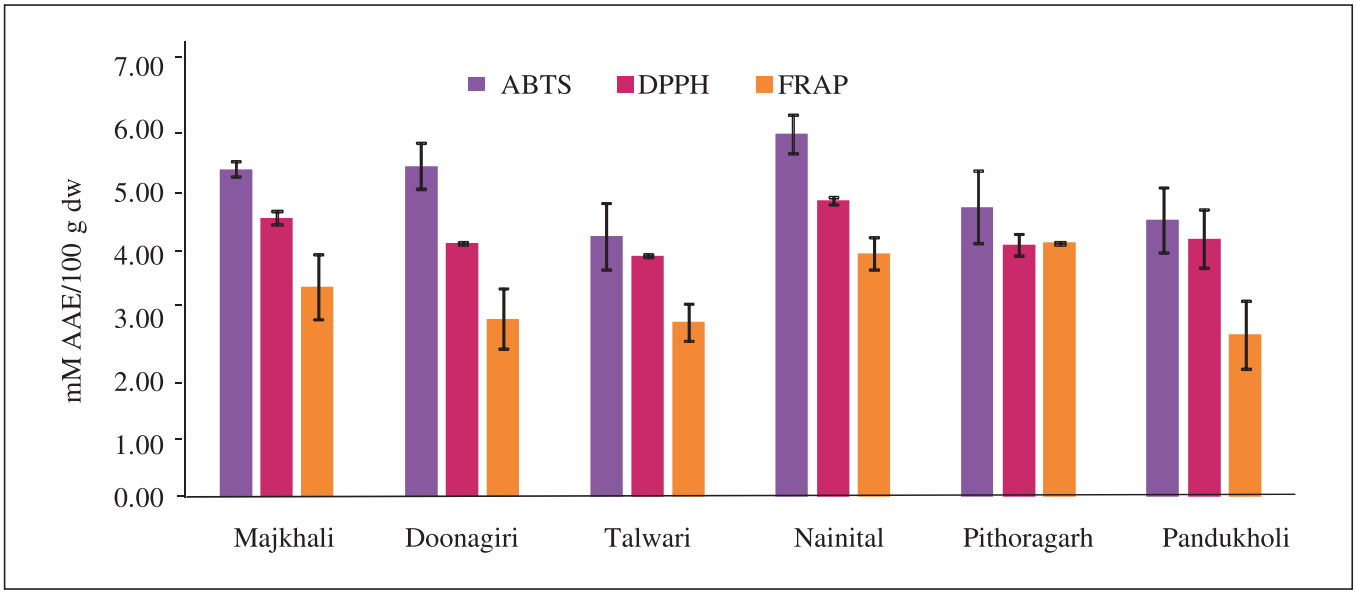


Fig. 56: Analysis of antioxidant activity among different populations of *M. muscifera* using ABTS, DPPH and FRAP assays.

SIKKIM REGIONAL CENTRE (SRC)

Sikkim state supports rich floral and faunal diversity varying in different eco-climatic ranges (300m to 8685m). There are high endemic and threatened species covering diverse ecosystems and habitats that represent the uniqueness of biodiversity. Local people are largely depending on natural resources for their livelihood. Endowed with rich natural resources, Sikkim Himalayan region forms a part of the *Himalayan* global *biodiversity hotspot*. This *region* is exceptionally *rich* in diversity and endemism and harbours wealthy floral and faunal diversity, wetlands, glaciers, rivers, cultural diversity and indigenous knowledge of ethnic communities. However, due to its fragile ecology and disaster prone feature, environmental issues of the region are at the forefront of the scientific debate. Further, over-extraction and utilization of the natural resources demands immediate measure to reverse the trend of degradation. Besides, it also needs strengthening, participatory management, enhancement of livelihood and self-sufficiency and policy review/analysis and capacity building. Considering the above mentioned priorities of the Sikkim state, Sikkim Regional Centre of the Institute has been working on environmental and developmental issues of the Sikkim Himalaya which includes entire Sikkim state and West Bengal hills. 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 analysis.

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

The Khangchendzonga Landscape (KL) is one of the six transboundary landscapes identified by the ICIMOD in the Hindu Kush Himalayan region. With a unique transnational destination, the KL covers a total area of 25,085.8 km^2, shared by India (56%), Bhutan (23%) and Nepal (21%), offering life support systems to over 7.25 million people (87% in India, 11% in Nepal and 2% in Bhutan). It faces many challenges and poses collective opportunities towards the common interests, such as human-wildlife conflicts, limited livelihood options, natural resources management, and climate change. The KL-India covers an area of 14061.7 km^2 with altitudinal gradients of 40 - 8586m, which comprises Sikkim state and northern part of West Bengal (Alipurduar, Darjeeling, Jalpaiguri and Kalimpong). The region comes under the biodiversity hotspot having significant floral (4500-5000 species) and faunal (> 4000 species) diversity and a home of many endemic and threatened species.

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 KL.

Achievements:

1. Developed a Resource Recovery Centre in Gorkhey village through participatory approach for better management of waste materials at village level and effective recovery of resources from it through reuse, recycle and repair of waste materials. Also, an integrated livelihood model was developed and strengthened.

2. Online workshop-cum-brain storming on post-harvest and value-chain management of large cardamom in KL was organized and a total of 26 large cardamom based stakeholders from India, Nepal and Bhutan were networked. Simultaneously, collection of morphological parameters of large cardamom cultivars grown in farmers' fields across KL-India was initiated

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

Tourism development in the IHR has experienced continuous growth, which 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 different forms of tourism those can intervene in areas such as; equity, efficiency, innovations

and carrying capacity. This discourse was brought into the KL which harbours 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 heritages.

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. An inventory of home stay at Dzongu and Barsey-Singhalila pilot sites was completed and linking this information with web-enable resources is under process. A total of 50 home stays were inventoried in two pilot sites (14 in Dzongu and 36 in Barsey-Singhalila).

2. For strengthening the community-based ecotourism, region-specific best practices and developing the home stay model, 8 training programmes were organized at Dzongu and Barsey-Singhalila pilot sites of KL with the support from KLCDI programme. A total, 155 stakeholders benefited through these capacity building/ training programme at both pilot sites of KL.

3. A complete inventory of floral resources for three pilot sites of KL was completed. A total 2,934 plant species were recorded for three pilot sites.

Spring Rejuvenation for Water Security in Himalaya (NMHS, GoI, 2020-2022)

The Indian Himalaya provides water to more than 75 million of people living within the region as well as downstream. In many mountain and hill areas, water for drinking and household consumption is collected mainly from shallow wells (*naula*) and springs (*dhara*). However, discharge from these sources has decreased dramatically in the last few years primarily due to the erratic rainfall, changing geology, warming climate, growing water demand, changes in land use patterns, deforestation, urbanization etc. Deforestation, grazing and trampling by livestock, soil erosion, forest fires, and development activities (roads, mining, construction, etc) reduces rainfall water infiltration capacity. Therefore, water security under the dwindling spring discharge scenario across the Himalaya is drawing attention to understand the spring systems.

Objectives:

- To develop at least one *Jal Abhyaranya* demonstration model.
- To promote replication of field model for rejuvenation of drying springs in the Himalayan states through technology and community based approaches for providing water security to local communities in collaboration with state agencies.

Achievements:

1. Compiled base line (location and physical parameters) data of springs and water demand and utilization pattern with the help of secondary information and primary field surveys.

2. Documentation of adaptation measures by the community towards traditional management of water resources.

3. Organized consultation meetings with the stakeholders and the State Govt. departments for liaising and synergy development for better implementation of project activities. A total of 15 persons, including youth from community and college students, were trained as para-hydrogeologists (Fig. 60).

Fig. 60: Trainees of para-hydrology programme.

Establishment of Nature Learning Centre, Sikkim (NMHS, GoI, 2019-22)

Sikkim state is located in the adobe of Eastern Himalayan biodiversity hotspot, which is rich in floristic biodiversity. However, lack of awareness on biodiversity results in mismanagement and therefore is imperative to educate and create awareness among diverse stakeholders towards nature conservation. There have been few initiatives by various departments towards creating awareness and sensitizing people on nature conservation, however concentrated and focused efforts through a dedicated Nature Learning Centre (NLC) is much required. Keeping in view, a NLC is being established at Pangthang campus of GBPNIHE. The major activities of the NLC include, development of learning models and knowledge products, capacity building of stakeholders on nature conservation; development of conservation and demonstration sites for different representative taxa of the region; promotion of citizen science approach for conservation education; and create a cadre of nature enthusiasts in the state through capacity building.

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, 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 for livelihood generation.
- To build capacity of diverse stakeholders on conservation of resource base and develop knowledge products for dissemination and awareness generation.

Achievements:

1. Initiation of orchid trail with 38 epiphytic and terrestrial orchid species, belonging to 14 genera. The collected species belong to 12 species of *Dendrobium*, 7 *Coelogyne*, 3 each of *Bulbophyllum, Cymbidium* and *Otochilus*, 2 each of *Liparis*, *Eria* and *Pleione* and 1 each of *Acampe*, *Agrostophyllum*, *Cleisostoma*, *Cryptochilus*, *Pholidota* and *Vanda*. Established one herbal garden, with 26 high value medicinal plants of RET categories belonging to 20 families. Inventoried and documented 50 tree species, belonging to 37 genera and 29 families. Further, total 26 shrub species, 43 herb species and 20 regenerating species were also recorded.
2. One bio-composting and vermi-composting model and 2 polythene lined rain water harvesting ponds developed. 49 HH questionnaire and 2 FGDs were conducted for need assessment for development of home stay in fringe villages and 10 schools located around the sanctuary for development of eco-clubs. Training-cum-awareness programme on solid waste management was conducted in which 18 local people were trained.
3. A three-day nature camp on the theme "Exploring Nature Based Solutions" was organized in collaboration with Department of Forest and Environment, Government of Sikkim for students of Sikkim University.

Summary of Completed Projects / Activity

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

India has experienced exponential urban growth in the last few decades. Urbanization exerts environmental stress (including air and water pollution, deforestation, construction activities), which also increases the risk of frequency of natural disasters like food, landslides, water scarcity, etc. Further, urbanization enhances the risk of hazards as well as vulnerability of the urban population. Therefore, there is a need for systematic review to collect evidence relating to impact of urbanization on disaster risk and vulnerability to natural disasters in the IHR. The north-eastern region of India faces three main disasters: earthquake, landslide and flood. A high degree of vulnerability to these disasters will increasingly make the region environmentally insecure unless pragmatic interventions are made. In Sikkim Himalaya, landslides, mass movement and cloud burst are common phenomenon due to its high relief and high monsoon. Sikkim, which falls under the seismic Zone IV is presently undergoing through disproportionate urbanization because of the fast-growing population and tourist influx. This project focused on study of two cities (Shillong and Gangtok) with a view to develop their disaster resilience plans by conducting socio-economic survey in both the cities to identify the factors and collect base line information**.** Study highlighted that in Gangtok Municipal Corporation (GMC) area earthquake is identified as the main hazard (37% people) followed by hailstorm (24%), erosion (15%), landslide (15%) and thunderstorm (8%) (Fig. 57). Whereas, in Shillong Municipal Corporation (SMC) area earthquake is the main hazards (48%) followed by landslide (16%), fire (18%), flash flood (13%) and hailstorm (3%) during the past 20 years (Fig. 58). About 80% people surveyed experienced CC during last 2 decades in GMC including increase in summer temperature (60% respondents), increase in winter temperature (48% respondents), but not much change was felt in monsoon rainfall (55% respondents) and winter rainfall (82% respondents) patterns. In SMC, deforestation was considered as the main reason for CC (48% respondents), followed by urbanization (18%) and natural reasons (8%). People perceived that there is an increase in both winter temperature (63% respondents) and summer temperature (82% respondents). According to 56% of respondents, monsoon rain in Shillong has decreased and high variability in its pattern and seasonality is felt during last two decades.

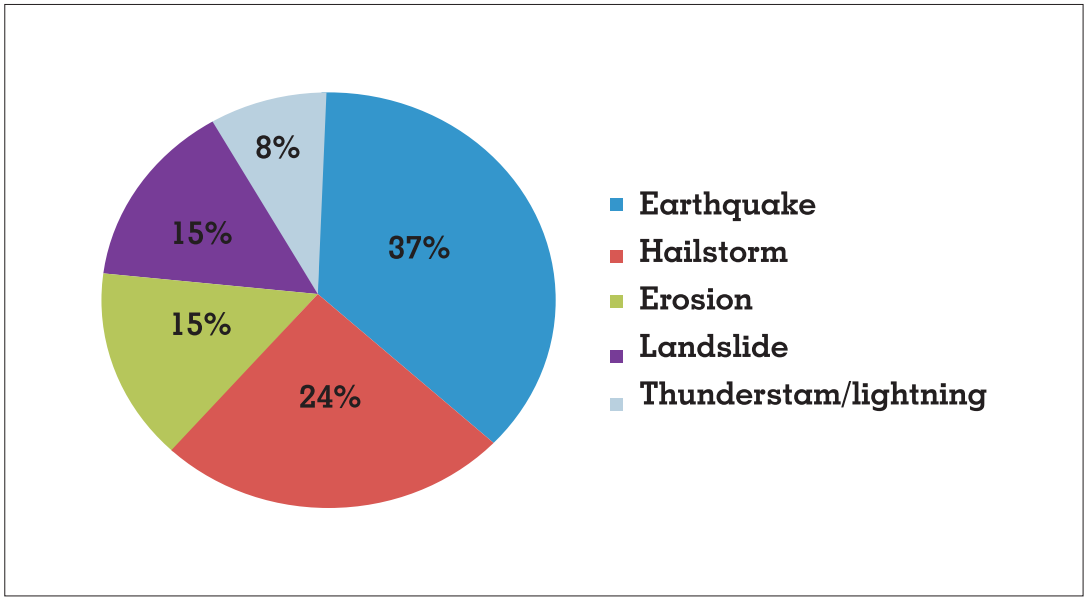


Fig. 57: Different hazards observed by the community in GMC during past two decades.

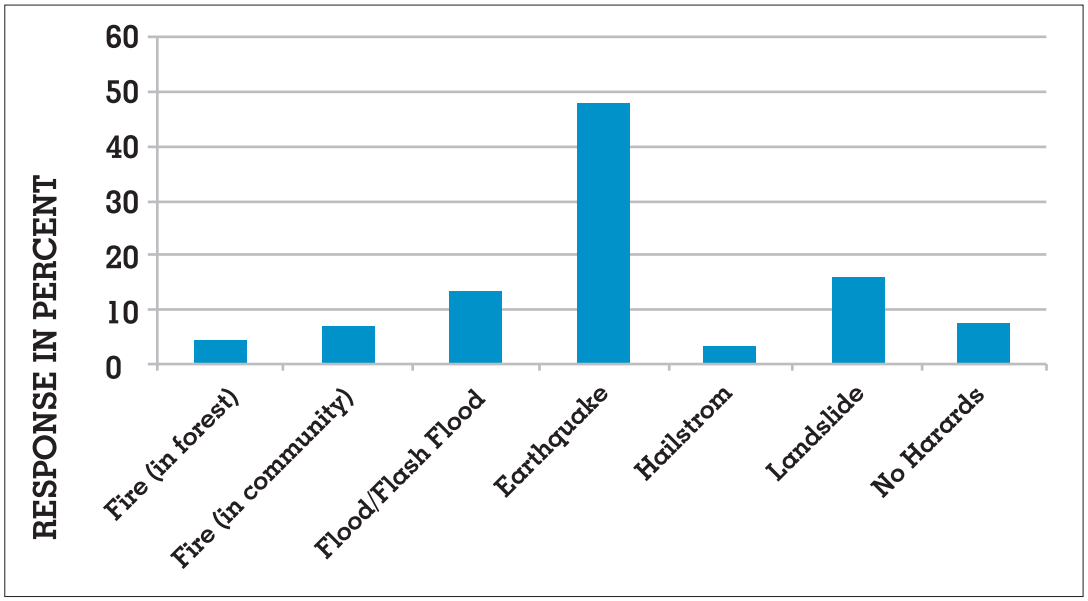


Fig. 58: Main hazards perceived by the community in SMC during last two decades.

NORTHEAST REGIONAL CENTER (NERC)

North East region of India is a global biodiversity hotspot, as well as home to many different ethnic groups with a rich cultural heritage and traditional knowledge of the environment and natural resource management. But in the recent decades the onslaughts of CC may have a significant impact on the population in many ways such as effects on agriculture, water resources, health, flora and fauna, and extreme weather events leading to natural hazards across this region. North East Regional Centre (NERC) of the Institute has been studying these impacts and changes since 1989 in this ecologically sensitive area. The NERC, through wider collaboration with state departments, universities, NGOs and international organizations has implemented more than 39 R&D projects across different north eastern states covering diverse disciplines. Major objectives of NERC are to study (i) traditional knowledge systems and water resource management; (ii) biodiversity conservation; (iii) livelihood enhancement of marginalized communities; and (iv) adaptation practices and mitigation practices to CC. Centre is contributing towards knowledge generation on north eastern Himalayan region through publication of research reports and papers. During the year 2020-21, the NERC published 4 research papers in international journals, 3 in national journals, 4 book chapters and 3 popular articles. During this period NERC organized various awareness and capacity building programmes under its research projects and other initiatives.

Landscape Initiative for Far-Eastern Himalaya (Hi-LIFE) (ICIMOD, Nepal, 2018-2022)

Hi-LIFE is one amongst the six identified trans-boundary landscapes across the Hindu Kush Himalayan region for the development of integrated conservation and initiatives among the three countries viz. China, Myanmar and India. It aims to promote regional collaboration among the three countries to address the various trans-boundary issues and challenges facing conservation and development in the landscape to achieve twin objectives i.e. biodiversity conservation & sustainable development. The landscape spans over an area of 71, 452 km^2 across China (22%), India (12%) and Myanmar (66%). Being an important trans-boundary landscape, effective conservation measures need to be taken up through developing a proper knowledge base, filling information gaps and prioritizing areas for further interventions to achieve the project objectives. The addendum of LoA was signed between GBPNIHE and ICIMOD in the year 2020 with a vision of long-term inventory and monitoring, stakeholder's consultation and institutional cooperation for dealing with the challenges and conservation of the landscape that would prove beneficial towards improving the livelihood status of the local inhabitants.

Objectives:

- Enable resilience-building of local communities through improved delivery system of strengthened network of institutions that promote inclusive livelihood approaches, green technologies and skill building following mutually inclusive conservation and development principles at landscape scale.
- Enhance understanding of biodiversity resources, socio-economic status, and how ecosystem goods and services are used by the communities and conservation partners for effective management of the landscape.
- Improve biodiversity conservation and ecosystem management through capacity building, promoting new technologies and approaches, and institutional strengthening.
- Bring inter-sectoral convergence and develop partnership for achieving common shared vision of integrated landscape management.

Fig. 59: Training on operation and maintenance of home stays.

Achievements:

1. Questionnaire based field survey on crop diversity (cash crops, commercial crops, medicinal plants, wild edible plants etc.), agriculture practices, food and nutritional requirements, income from local produce etc. was conducted in the selected six villages namely M'Pen –II (7th, 8th, 9th mile), Lama, Bodhisatta and Bodhisatta –II in Changlang district.

2. A 'Diversity Fair' was organized in M'Pen-II (8th mile) village in which wild edible vegetables, variety of paddy/maize, handloom and handicrafts items were collected from the local areas with the help of villagers were displayed. Information on various locally available plants used for medicinal purposes by Kobiraj (local healer) of Chakma tribe for healing or curing various ailments was also collected.

3. A 4-days training programme and other linked activities were organized in the field (17 – 20 December 2020) involving lectures of experts/resource persons on home stay operations and management mainly for women participants. They were trained on bakery items other than local cuisine, house-keeping, bed-making and basic interpersonal skills. They were also informed about linking tourism with culture and basic home stay guidelines (Fig. 59).

Anthropogenic Impacts and Their Management Options in Different Ecosystems of IHR (NMHS, GoI, 2017 – 2020)

In Arunachal Pradesh the Ranganadi is a major river in Lower Subansiri district, which is also known as Panyor river. The Rangandi basin lies in the coordinates from lat. 27°20'00" to 27°40'00"N and long. 93°15'00" to 93°50'00" E. The river Ranganadi (Panyor) originates from the foothill of the Himalayas at an elevation of 3400 m. The river flows in steep bed slope of about 1:13 from its source up-to an elevation of 1260 m. After this, the river bed slope becomes flatter. It is one of the major tributary of the river Brahmaputra in the north-eastern part of Assam. The total 2941 km^2 catchment area of the Ranganadi river is divided between Arunachal Pradesh and Assam of which 700 km^2 lies in the Lakhimpur district of Assam and the remaining 2241 km^2 lies in Arunachal Pradesh. This river supports the life of 17 villages with a total of 1354 families having 7650 people. This study was conducted (i) To monitor snow melt and/or headwater contribution in total river water flow, their seasonal behaviour and quality due to CC; (ii) To assess the impacts due to erratic seasonal behaviour of river/stream water flow on overall land use pattern, the developmental projects such as HEPs and riverine aquatic biodiversity; and (iii) To enhance capacity of the stakeholders including women in terms of increasing their resilience and adaptive capacity due to CC for their sustainable livelihood options. Study covered survey among 24 villages (400 respondents) in Ranganadhi basin and based on people's perceptions and sample analysis following findings were made: (i) Climate change is taking place and due to jhum cultivation practices, deforestation is expanding rapidly which is a major cause for CC along with dam construction (Fig. 60); (ii) Increase in summer temperature and length of summer season, and decrease in frequency of rainfall, changes in size and number of water bodies. Small streams and springs are now depleting fast; (iii) Soil and water quality of river was found within recommended level, however, higher value of pH in soil was reported from the Yazali agricultural field, due to excessive use of fertilizers and high value of TDS was found in lower stream of Lichi (85 ppm) during monsoon. Rest of the parameters were found to be within permissible limit as per BIS 2012. Presence of NEEPCO dam in the Ranganadi river cause negative impact on the area, especially in terms of availability of fish population, which is decreasing every year. Absence of proper waste management in the area as majority of people burn the waste and only few people prefer composting of waste material.

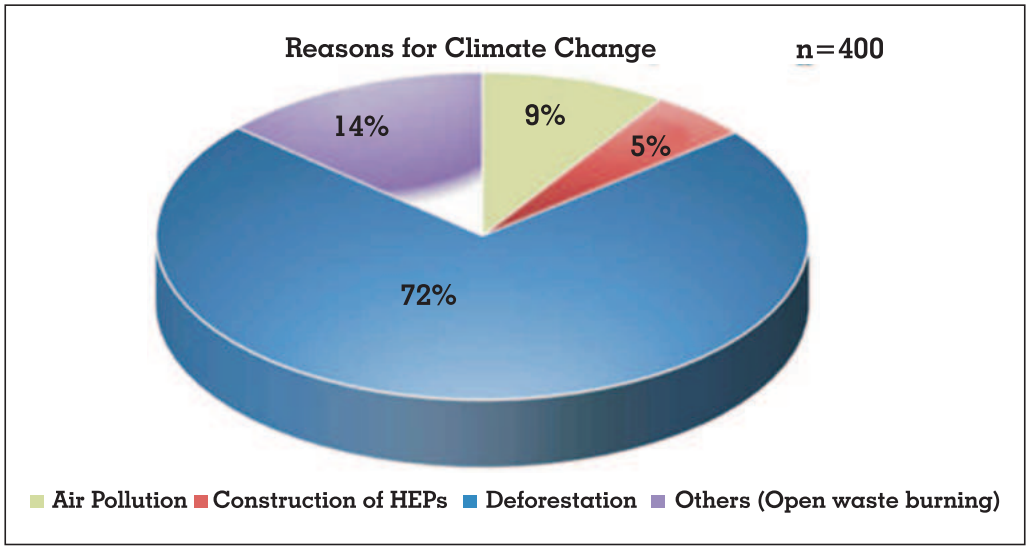


Fig. 60. Major reasons for climate change.

LADAKH REGIONAL CENTRE (LRC)

Ladakh became a Union Territory on the 31st October, 2019. Renowned for its remote mountain beauty and distinct culture Ladakh UT is a unique landscape that has an entirely different climate, sociological characteristics and environmental conditions. Ladakh Regional Centre has been established with a realization that the Trans Himalayan landscape with most of its area lying above 3,000 m asl presents unique ecological, environmental and socio-cultural characteristics evolved over the harsh climate of the region in terms of extreme cold, minimal rain (90-100 mm annual) and 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.

Natural Resources Based Livelihood Options and Off-farm Employment in Rural Landscape of Ladakh (GBPNIHE In-House Project, 2020-2021)

In the high altitudes of Ladakh (usually above 3000m asl) the growing season for plants is restricted between April to September, thus agriculture too is confined within this period. However, Ladakh is largely devoid of natural vegetation (often referred to as Cold Desert), some of the natural/grown plants (for example, Sea buckthorn, Fescue grass, Salix, Poplar, etc.) are available at many places, and cultivation of Apple and Apricot is common. Various local products are in use from these natural resources initially for self-use and few have begun commercialization on a smaller scale. So, the main aim is to utilize time (other than agricultural activities) available with village women of Ladakh in developing skills through hands-on training /value addition techniques to utilize locally available natural resources in their surroundings.

Objectives:

- Green skill development in participatory mode through awareness, use of unutilized local resources, introduction of new techniques/ technologies, value addition to the products, and establishing branding, and market linkages
- To develop local resource-based entrepreneurship through capacity building
- To create off-farm livelihood employment opportunities using local resources

Achievements:

1. Due to COVID 19 Pandemic related restrictions, field activities were limited. Under these circumstances, five off-farm activities on skill development were conducted by adopting participatory approach with different stakeholders. Each programme was initiated by a call from the people's representatives from different areas of Leh District. Initial meeting was held in each village with Councillor of that Constituency, representatives of village council, members of self-help groups, and other villagers to identify potential individuals and promising groups in a village. After prioritizing the demands through consultations with stakeholders, interested groups were identified (Table 9).

Table 9: Details of training and capacity building programmes.

S. No.	Trainings	Village (s)	Partici-pants (no.)	Details of products made during training	Duration (days)
1	Create livelihood options through tailoring operations during Pandemic lockdown	Stok	20	• Double layered cotton face masks • Cotton carry bags for daily use/ conference bags	10
2	Introduction of new products and value addition to existing products from locally available Apricot	Chamshen Yulkham, Charasa, Sumoor	37	• Apricot jam • Apricot juice • Sapricot (mix squash)	3
3	Plant based utility products (basket, etc.)	Matho	27	• Eco-friendly dustbins • Back baskets • Multi-purpose containers	10
4	Value addition to food -based products from Seabuckthorn and introduction of new products	Chamshen	41	• Seabuckthorn jam , juice, squash and leaf tea	2
5	Introduction to products from Sea buckthorn	Matho, Stakna	22	• Seabuckthorn jam, juice, squash and leaf tea	2

2. Skill building and new knowledge on available natural resources and their use were provided to 163 participants belonging to 7 villages of two constituencies through these programs (Table 9; Fig. 61), and market linkages were developed for their products.

Fig. 61: Different natural resources-based livelihood training and capacity building programmes conducted in various villages of Ladakh.

Low- Cost Farming Techniques for Extended Cultivation in Ladakh (GBPNIHE In-house project, 2020-2021)

Most of India's cold arid area (90% to be precise in Ladakh) remains cut-off for more than five months during the winter season. Major populations are socially and economically marginalized and are more vulnerable to food shortages due to isolation. However, Ladakh imports high volume of vegetables/fruits from other parts of the country but most people do not have much access to get leafy and fresh vegetables during winters, which may lead to nutritional issues. To overcome the production and availability during winters, there is a need to develop some innovative and low-cost technologies to address above issues, and also create additional livelihood opportunities in the region.

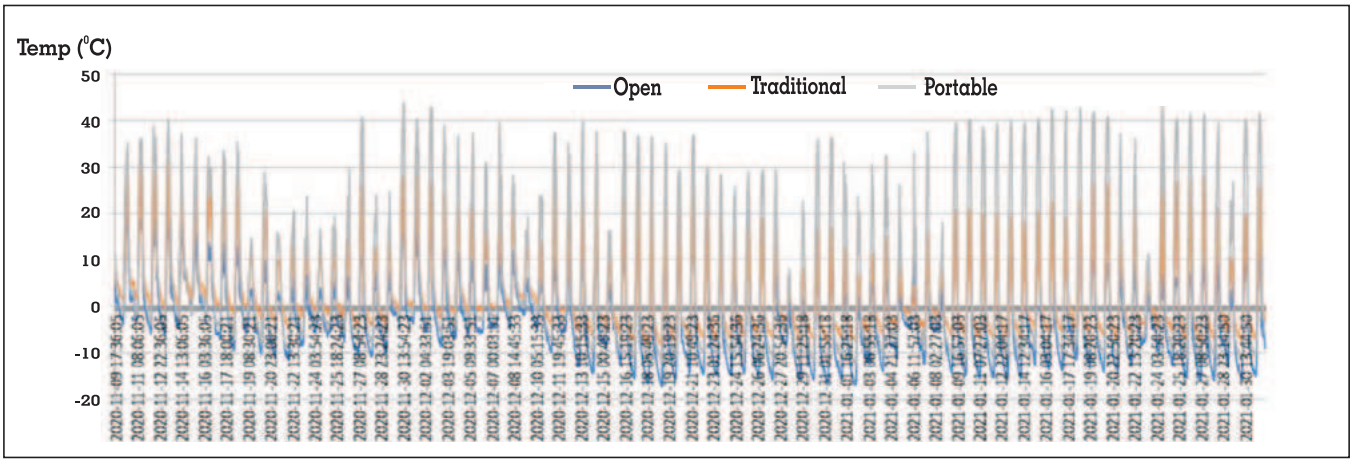
Objectives:

- To develop additional rural livelihood opportunities through simple and low-cost technologies in cold arid environment.
- Strengthening approaches to address issues of limited agro-cultivation.
- Exploring new avenues for extended cultivation during harsh winters.

Achievements:

1. Addressing the availability of leafy fresh vegetables as nutritional demand and exploring the new agriculture-based livelihood opportunity in winters, strategies were developed and technologies were tested to extend crop cultivation through simplified low-cost inputs for adoption by the common man. Technologies used for plant growth during sub-zero temperature in winters include (i) low-cost portable polyhouse for extended cultivation in agricultural fields, which are un-utilized during winters, and (ii) indoor soilless cultivation through simplified household hydroponics to grow leafy vegetables during winters, and also otherwise.

2. Various parameters of traditional Ladakhi polyhouses were compared with new low-cost portable polyhouses (air temperature, RH, cost effectiveness, etc.; Fig. 62 and Table 10). While comparing the cost inputs, low-cost portable polyhouse has more merits than the traditional one and is also affordable for a common man.



9th November 2020 to 31st January 2021

	Outside open	Traditional polyhouse	Portable polyhouse
Min. Temp (°C)	-17.2	-8.3	-12.3
Max. Temp (°C)	20.0	31.0	43.9

Fig. 62: Pattern of variation in air temperature, traditional and portable polyhouse between 9 November 2020 to 31 January 2021.

Table 10: Comparative analysis between traditional polyhouse and low-cost portable polyhouse

Parameters	Traditional polyhouse	Low-cost portable polyhouse
Landuse	Dedicated land	Agricultural field
Size (ft) (LxWxH)	60x20x8	30x10x7.5
Area (m^2)	111	27
Cost (Rs.)	> 1,50000/-	11, 750/-
Per m^2 cost (Rs.)	1351	435
Days required to make the polyhouse	10-15 days (4 man power) Dismantling: No	01 Day (02 man power) Dismantling: 2 hours by 2 persons
Materials	Stone, polythene, mud, wooden pole, iron, wooden door, etc.	Polythene, iron rod (10mm), wooden pole, blankets.
Type of Infrastructure	Permanent structure	Portable/reusable

- Various crops were screened to check the feasibility of winter growth in portable polyhouse i.e., Chinese cabbage (Napa), Chinese cabbage (Pakchoy), fenugreek, coriander, local leafy vegetable (*mongol*, *saag*) and spinach. Since November, 2020 (when there is no cultivation in open) three harvests were taken in some of the crops, and production of different vegetables ranged from 0.140-1.85 kg/m^2 (Fig. 63).

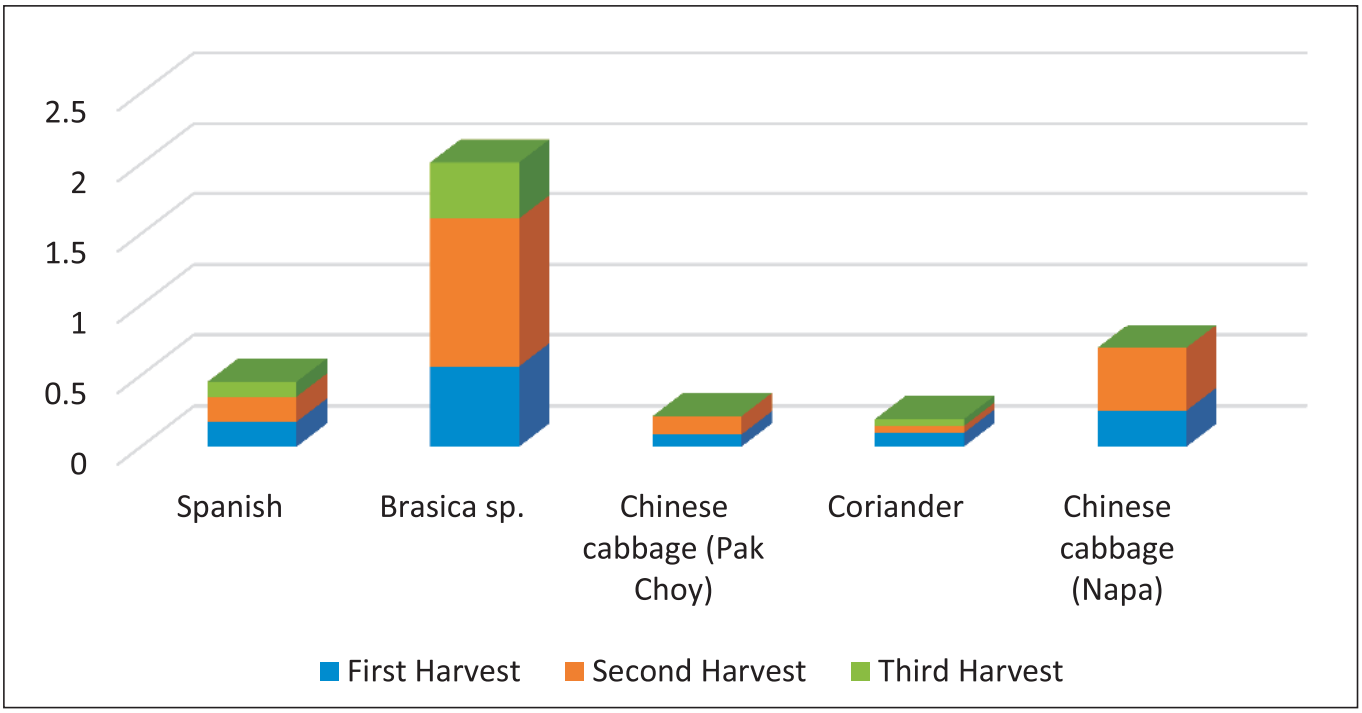


Fig. 63: Total crop productivity of different vegetables in Kg/m^2 at low-cost portable polyhouse

- Two different family models on hydroponics (Nutrient Film Technique, NFT and Deep-water) were tested and standardized as local needs in indoor conditions. Various leafy vegetables like *pakcho*, spinach, coriander, fenugreek, *mongol* were screened to check their feasibility of winter growth.
- Water medium of both models worked in outside sub-zero winter temperature and one harvest (fresh weight) was achieved for fenugreek (NFT, 2.2 kg/m^2) and *pakcho* (Deep Water, 3.46 kg/m^2) (Fig. 64).

Fig. 64: Different vegetables grown in different hydroponics models: (a) Fenugreek in NFT; (b) Pakcho in deep water.

Swachh Bharat Mission - Solid Waste Management Strategies in Rural Areas (GBPNIHE In-House project, 2020-2021)

Trekking and expedition as part of adventure tourism are popular among national and international tourists visiting Ladakh. These activities involve large number of tourists visiting the pristine Himalayan ecosystems for recreational purposes, and generate waste in the form of tin, glass, plastic, paper, etc. Big deposits of these materials can be witnessed around camping sites of trekking routes. Keeping in view this, a clean-up drive along the famous Markha trek, visited by 6000 persons in a year, was

organized in collaboration of All Ladakh Tour Operators Association, Ladakh Women's Travel Company, Tourism Department, Leh. In addition, general information regarding the trek route (biodiversity, geo-spatial characteristics, etc.) was also documented.

Objectives:

- To generate spatio-biodiversity information of trek route to develop knowledge and awareness among visitors.
- To make inventory and quantify solid waste accumulated along the trek, and appropriately dispose at recycling unit.

Achievements:

- A detailed trek route map was developed for Markha trek depicting location of different camping sites, villages, and elevations of trek (Fig. 65). 41 plant species (34 herbs, 5 shrubs, and 2 trees) and 7 animals (3 mammals and 5 birds) were recorded along the trek during trek period.

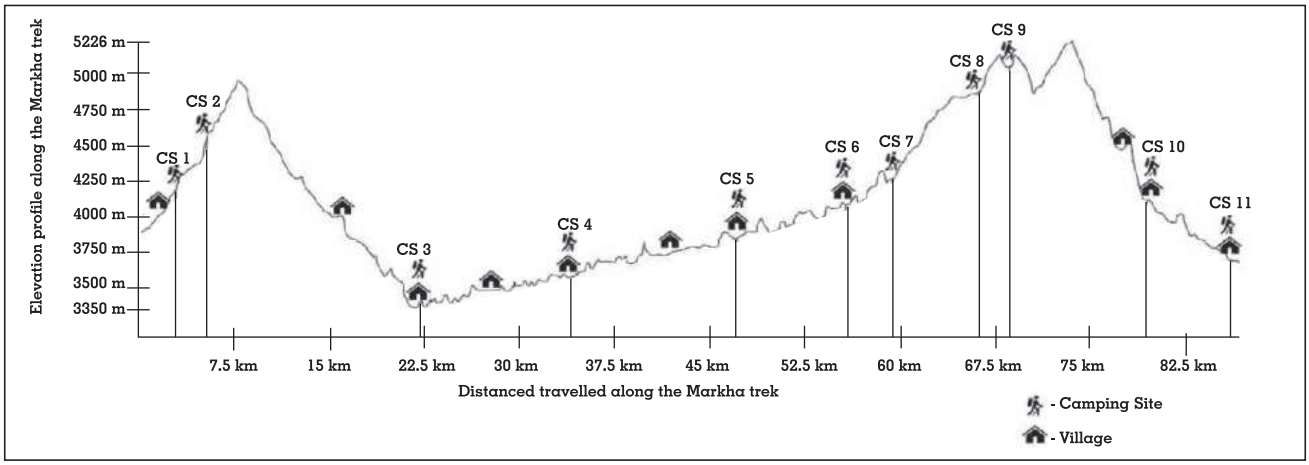


Fig. 65: Trek route map developed for Markha trek (CS1- Yurutse Village; CS2 Shingo Village; CS3- Skiu Village; CS4- Chalak Village; CS1- Markha Village; CS6- Umlung Village; CS7 Hankar Village; CS8-Thochuntse Village; CS9- Chukirmo Village; CS10- Chokdho Village; CS11- Shang Sumdo Village)

- Different types of solid waste from different camping sites along the Markha trek was collected (837.4 kg), segregated and brought back to the Solid Resource Management Centre, Choglamsar for further processing during the trek. This waste comprising tin (44%), glass (26%), and miscellaneous waste (30%) (Fig. 66a), and the miscellaneous waste included coloured plastic bottles transparent plastic bottles, hard plastic (plastic containers, broken crates), tetra packs, plastic wrappers, cardboard, bottle caps and paper (all together 23% of miscellaneous), while remaining 77% included items viz., cloth, aluminium foil, fibre bags, shoes, rubber, remains plastic bags, jute bags, medicine strips, etc. (Fig. 66b).

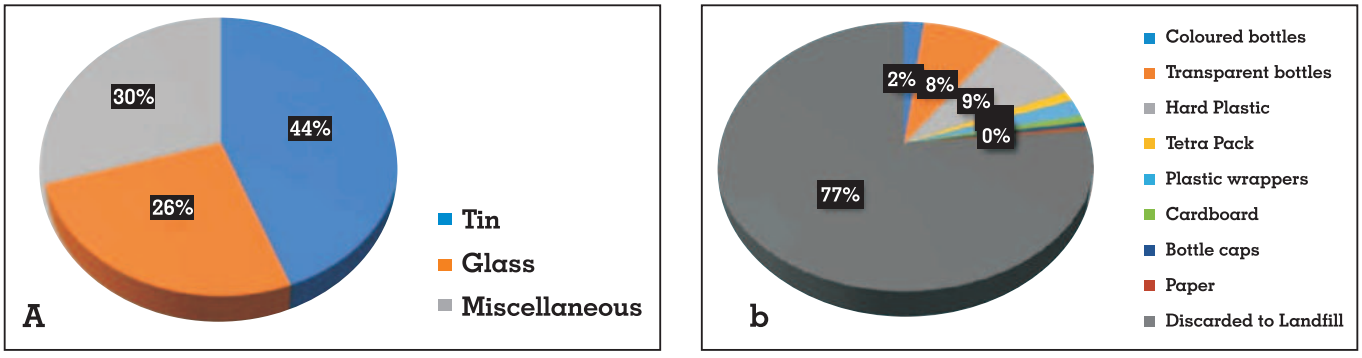


Fig. 66: Solid waste collected from the Markha trek: (a) major waste types, and (b) miscellaneous wastes.

Sustainable Development: Prioritization of Issues and Environmental Education (GBPNIHE In-house Project, 2020-2021)

For the development of knowledge and actions oriented towards sustainable development, environmental education is a prerequisite to achieve environmental protection and economic sustainability, and field-based education is necessary part of environmental education. Education and discussion dialogue are two pillars to address issues of sustainable development in the region. Various activities were initiated in this year with diverse stakeholders to realize path of the development in the Ladakh.

1. A collaborative event on "*Disasters and Vulnerability of Ladakh*" was organized in collaboration with 'National Institute of Disaster Management, New Delhi', and 'Ladakh Science Foundation', Leh, where domain experts interacted with students of Ladakh to educate young generation on different aspects of preparedness and mitigation measures in case of disastrous events. A strong need was felt for developing a framework by institutionalizing documented memory on disasters due to climate change in Ladakh (*Himalayan Popular Lecture-Ladakh Series*).

2. High altitude ecology is unique, particularly in the trans-Himalayan region where livestock is nucleus of human activities, and around Yak many societies exists throughout the IHR. In high Tibetan Plateau of Ladakh, Yak remains in focus and societies facing new challenges arising from climate change. Hence a video documentation (*Living with Yak in Highlands of Ladakh*) was made with herder society, and depiction of issues was screened in a regional transboundary event on Yak organized by Sikkim Regional Center. This event led to collaborative activities among various institutions of IHR to address the issues in Ladakh.

3. Prioritization of developmental issues of Ladakh were filtered from meetings with diverse stakeholders (university, research and other academic organizations, NGOs working in Ladakh, and women groups) including a brainstorming workshop on "*Environmental and Developmental Perspectives: Women in Ladakh*", which recommended (i) strong contextual elementary education on local ecology to connect the young minds with their landscape, (ii) energy access to women in achieving sustainable development, along with creation of sport bodies for women representation at higher level, (iii) development of a framework, vision and roadmap for collection/analysis/dissemination and use of existing knowledge as input to policy formulation and to take evidence-based decision, and (iv) conducting thematic research to support developmental interventions through collaborative efforts and to reduce overlapping activities to support developmental challenges in Ladakh.

MOUNTAIN DIVISION REGIONAL CENTRE (MDRC)

In order to establish a science-policy-practice interface within the Ministry the MoEF&CC, GoI, approved a Regional Centre of GBPNIHE within the Ministry as "Mountain Division" that is dedicated to address specific issues of the mountain ecosystems in an integrated manner within divisions of the MoEF&CC and across the relevant key Ministries, along with NGOs and Academia. The Mountain Division is expected to ensure conservation of mountain ecosystems and sustainable development of the IHR with the following broad objectives: (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) to develop a suitable framework of incentives for providers of ecosystem services. To achieve the objectives of the division the following project based studies are launched through Himalayan Research Fellows and Associates.

A GIS Based Approach to Delineate Spring Ecosystem in Middle Himalayan Region (GBPNIHE Hqs., 2019-2022)

Springs are one of the most important sources of fresh water in the IHR. The region has millions of springs which are also important sources to many big and small rivers. There are studies that show the declining trend of spring discharge along the Himalayan region. Subsequently, in the past few decades, efforts are made to rejuvenate springs in different areas but scientific lacunas exist related to the ecological importance of springs. Since a healthy spring possess great potential for thriving flora and fauna, and the extent of this ecosystem surrounding a spring is not yet studied in detail. This study focuses on the delineation of spring ecosystem mainly with respect to socio-cultural dependency.

Objectives:

- Collection and compilation of spring information and activities of two different regions of Kumaun Himalayas.
- Development of a protocol to delineate the spring ecosystem boundaries based on the ecosystem functions and services provided by them.
- Recommendation of policies and practices that help in enhancing the productivity of a spring ecosystem with regard to socio-cultural services.

Achievements:

1. Compilation and collation of questionnaire data, collected for 649 springs in villages of Champawat district was completed. The relationships of spring discharge and degree of threat and land-use type were analyzed. Similarly, a total of 933 geo-tagged springs of upper Kosi watershed, Almora district were analyzed for assessing people's freshwater dependency on springs based on the questionnaire data collected by us (Fig.67).

2. The relation between the spring discharge and threat in surroundings was found negative, whereas the land cover types on high to low discharge springs varied from place to place.

3. A detailed questionnaire has been prepared for further assessing the spring ecosystem boundary and its dependency on all the aspects of socio-cultural environment keeping in view the traditional conservation and management techniques.

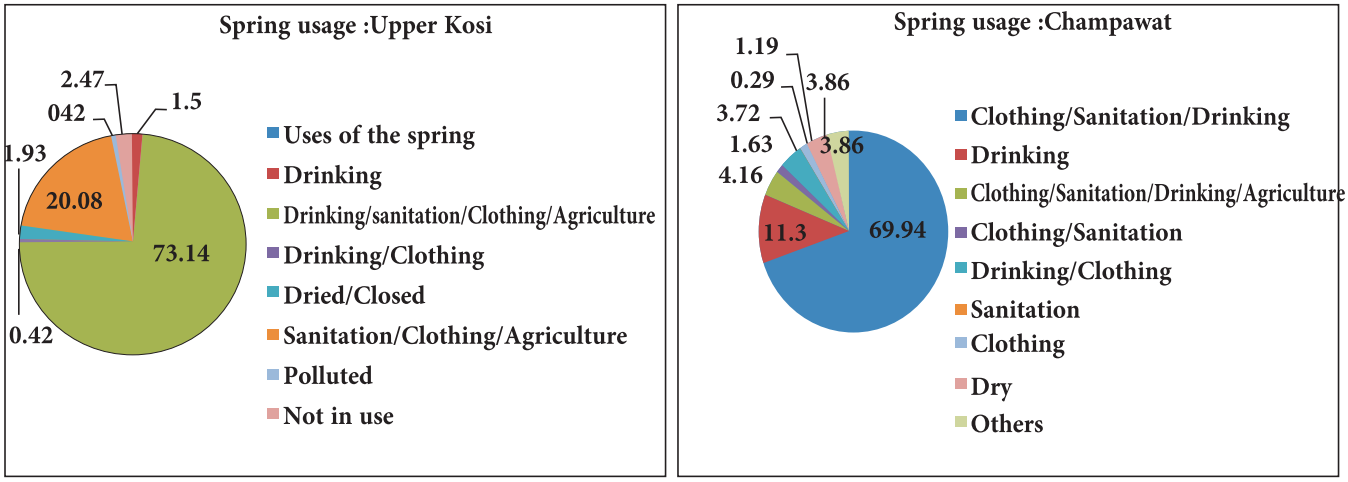


Fig. 67: Spring water usage pattern in two regions of Kumaun Himalaya.

GIS Based Land Use Modelling for Deriving the Trends of Urban Sprawl in the Cities of Indian Himalayan Region (GBPNIHE SRC, 2019-2021)

The IHR is tectonically active and having a fragile ecosystem is home to 75% rural population and 25% urban population. 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. The uncontrolled and irregular urbanization in the region is becoming a severe problem leading to low standard of living environment and acute problems of drinking water, garbage mounting, pollution, etc. It, therefore, becomes crucial to have a thorough understanding of past and present land use changes to predict potential future land use changes in order to better manage and plan against expected potential impacts. The task can be achieved using remote sensing and GIS technique and using multi-temporal remotely sensed datasets, spatial metrics and modelling. 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:

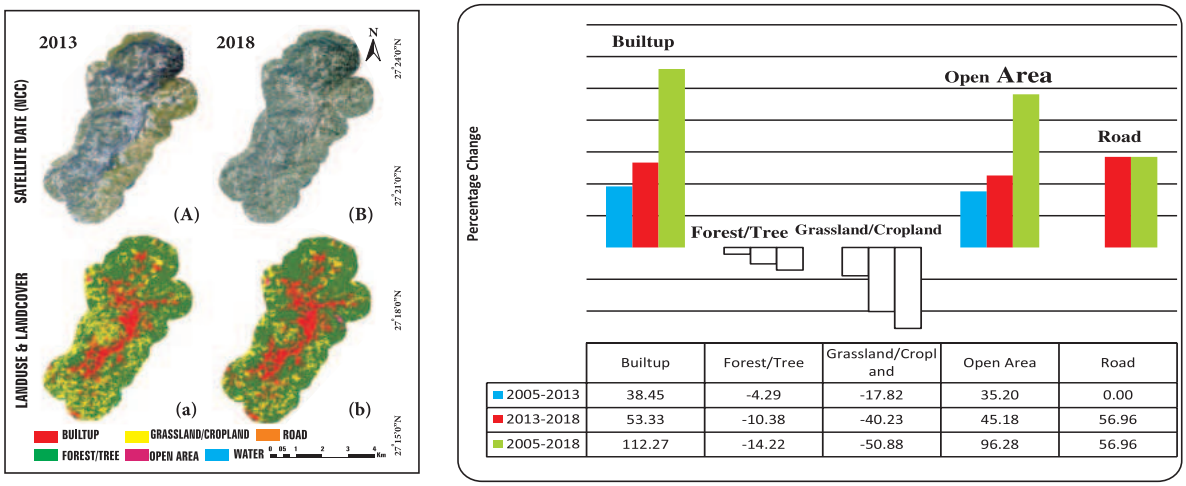
- Analysis of land use dynamics in the context of irregular urban sprawl in IHR.
- Land use modeling for future prediction of two growing cities using remote sensing and GIS and stochastic (statistics) model.
- Assessment of impact of increasing urban sprawl using multi-criteria analysis.

Achievements:

1. The 2013 & 2018 land use and land cover (LULC) classification for LISS IV & Pleiades 1A was generated for Gangtok. A time series trend analysis was carried out to study the urban sprawl pattern from 2013- 2018. The LULC classification of very high resolution 4 band (red, green, blue, and infra-red) Pleiades 1A satellite imagery at 0.5 m and LISS IV (5.8 m) is completed for Gangtok for the year 2018 and 2013 using object based classification method along with its change detection (Fig. 68).

2. The classified datasets of 2013 & 2018 for Almora were utilized for determining seven landscape metrics (total area, no. of patches, largest patch index, edge density, fractal dimensions, Euclidean nearest neighbour distance, contagion) using Fragstat tool (Table 11).

3. A multi criteria analysis was done to attain potential built-up zones and its impact over the region. The future prediction of the potential urban sprawl of Gangtok city was achieved for the year 2030 through Cellular Automata Markov model.



	Builtup	Forest/Tree	Grassland/Cropland	Open Area	Road
2005-2013	38.45	-4.29	-17.82	35.20	0.00
2013-2018	53.33	-10.38	-40.23	45.18	56.96
2005-2018	112.27	-14.22	-50.88	96.28	56.96

Fig. 68: Land use and land cover classification for Gangtok.

Table 11: Comparative analysis of built-up class metrics for the year 2005, 2013 & 2018.

Year	TYPE	CA	NP	LPI	ED	FRAC_AM	ENN_MN	CONTAG
2013	Built-up	339.2022	736	2.9481	136.1282	1.3017	34.3011	59.9309
2018		389.2249	2866	2.9641	193.2573	1.3092	22.7741	53.7177

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

The far-eastern landscape, while rich in its natural resources, is also equally known for its extreme vulnerability to changing forces 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 CC and well-being of people. The study will also help in formulating plans/policies for sustainable livelihood development and CC 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 CC 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 based surveys were carried out in M'Pen II (7th, 8th, 9th mile); Lama, Bodhisatta I, Leewang and Phup villages, respectively to obtain information related to religious practices, brief history, taboos along with the use of handloom and handicraft products and their making procedures. Information was collected from the villagers living in the fringe villages and in the buffer area of Namdapha National Park (Fig. 69).

2. Among the people belonging to different tribes, viz. Chakma, Lama and Singpho community, residing in the surveyed villages the Chakma people have their own handicraft and weaving so as Lama and Singpho people. Some of the Chakma handloom products are: Pinon, Hadi, Hojal, Jhola etc. and handicraft are: Bera, Bareng, Halung, Tholoi, Khurum, Hasing, etc. Some of the hand-loom products prepared by Singpho community are: Buba, Bukang, Numsa, Baka, Ningwad, Singde, Lidh, Jhola etc. and handicrafts are: Karan, Paniap, Sthaiyi, Khang, Lidh, Singdo etc.

3. Handloom culture is increasing in Chakma and Singpho community because younger generation are involved and taking interest in weaving and accepting it as an alternate livelihood option, whereas it is decreasing in Lama community as availability of raw material is decreasing in the forests and skilled people are also decreasing in the villages.

Fig. 69: Questionnaire based survey and handicraft practices in the field site of Arunachal Pradesh

Mapping and Promoting Conservation of Medicinal Plants of Sikkim Himalaya (GBPNIHE SRC, 2019-2022)

Many of the medicinal plant 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 (1992). 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 total of 638 species of medicinal plants belonging to 169 families have been documented from the Sikkim state (Fig. 70). The dominant families of medicinal plants were recorded as, *Asteraceae, Ranunculaceae, Zingiberaceae, Euphorbiaceae* and *Poaceae*.

2. Among the documented plant species from the state, a total of 53 species were recorded as threatened under different categories of IUCN at regional level.

3. In order to develop the gene-bank of the species, a herbal garden was established and enriched with medicinal plants and more than 25 species of medicinal plants have been planted including 6 threatened species.

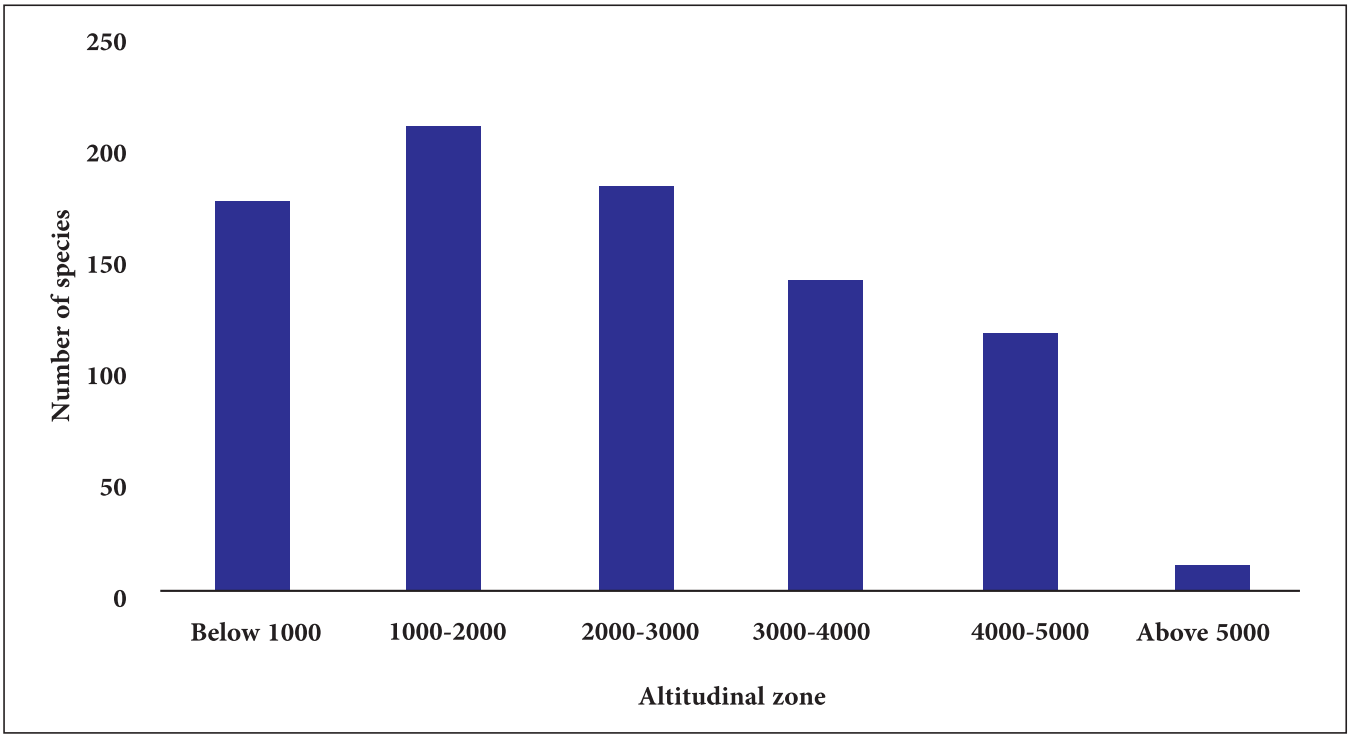


Fig. 70: Distribution of medicinal plant species in different altitudinal zones in Sikkim state.

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

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 IHR is rich in water resources; however, this is threatened due to anthropogenic stress, over-exploitation, and lack of management techniques. On account of anthropogenic stress in many forms, freshwater resources are continuously depleting. Sustainable management of water resources requires long-term planning considering future as well as present needs. Sustainable water resource systems are those designed and managed to fully contribute to the present and future requirements of society. So, there is a need to analyze the water quality of fresh river water systems and the other sources which will help in the management of water in the Parbati basin.

Objectives:

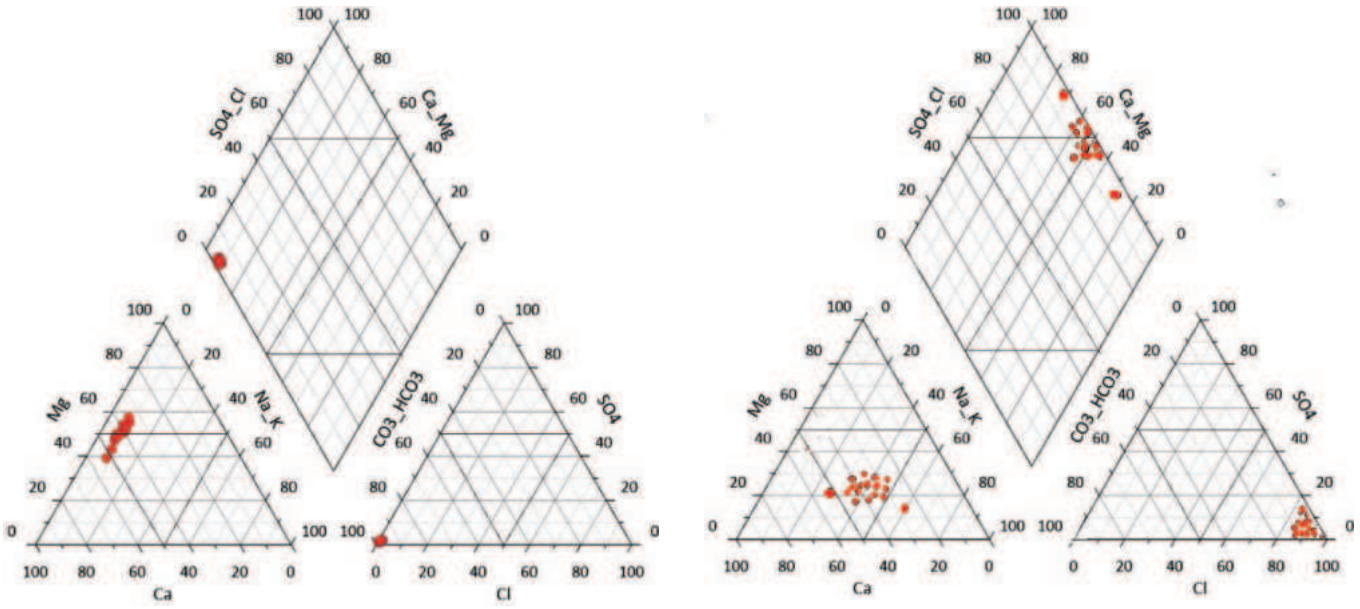
- Assessment of status of water sources like river, streams, springs, hand pumps, etc.
- Assessment of topographic, anthropogenic and climatic impacts on water resources.
- Assessment of changing water quantity and quality (physico-chemical and biological) of existing water resources.
- To delineate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

Achievements:

1. A total of 70 water samples from Parbati river basin were collected in the month of September and December 2020 from river (18), spring (27) and stream (15) for the physio-chemical analysis. The water quality of all the collected samples was well within the permissible limit prescribed by BIS (2012) for drinking and domestic purposes.

2. The cross plots in piper highlighted the geochemical processes including rock weathering and dissolution of minerals and dominance of alkaline earth metals over the alkalis and weak acidic anions over strong acidic anions in the study area (Fig. 71)

3. The overall water quality index in the month of September and December was 46.8 and 40.4, respectively that falls under good water quality index. As per the classification of WQI, 88% of water samples fall under good category and 12% water samples belong to poor category for drinking purposes.



(a) (b)

Fig. 71: Piper diagram of water quality for the month of (a) September and (b) December

Assessment and Valuation of Alpine and Sub-alpine Ecosystems of Himachal Pradesh in Relation to Climate Change (GBPNIHE HPRC, 2018-2021)

Climate change has been recognized as one amongst the most confounding factors in shaping the future of mountain ecosystems, and also the rural communities. The biodiversity components of the sub-alpine and alpine ecosystems are severely affected by anthropogenic activities. The floristic diversity varies along altitudinal gradients, and across the habitats, aspects and vegetation types. The sub-alpine and alpine ecosystems are very sensitive to global CC. Change in vegetation patterns are expected in the changing climate scenario. Therefore, assessment and valuation of floristic diversity becomes important. Very few studies have been carried out on qualitative and quantitative assessment of sub-alpine and alpine ecosystems. In view of the above, an integrated study to

assess floristic diversity, community structure, and distribution pattern of the native and endemic species in relation to CC, identification of economically important species and impact of CC on floristic diversity is undertaken.

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 (2 sites in Sainj valley and 5 sites near Rohtang Pass, Kullu) were surveyed along an altitudinal gradient ranging from 2511m–4340m amsl. Habitat conditions varied from moist (4), boulder (2), and scree (1). Three sites were having NW aspect, 1 NE, 2 S and 1 W aspect. Slope varied from 30°-65°. Five (5) plant communities identified in the study sites were represented by *Taxus contorta* community (2 sites), followed by *Lagotis cashmeriana- Ranunculus sarmentosus- Poa alpina* mixed community (1 site), *Trifolium repens- Carex nubigena - Rumex hastatus – Morina longifolia* mixed community (1 site), *Rhododendron anthopogon - Rosa macrophylla* mixed community (1 site), *Anaphalis triplinervis - Poa alpina- Polygonatum verticillatum - Lagotis cashmeriana* mixed community (1 site). Maximum species richness was recorded at alpine sites (42 species) in *Rhododendron anthopogon- Rosa macrophylla* community. Total 2 tree, 8 shrubs and 114 herbs were identified from the surveyed sites (Table 12; Fig. 76).

2. For tree layer at sub-alpine sites, total basal area (TBA) ranged from 43.2 - 245.2 $m^2 ha^{-1}$. Maximum TBA was recorded in *Taxus contorta*. Site wise tree density ranged from 110-190 ind./ha^{-1}. Site wise species diversity (H') ranged from 0.62-0.69. Maximum species diversity (H') was recorded for *T. contorta* community. Concentration of dominance (Cd) ranged from 0.50- 0.57 and maximum Cd was recorded in *T. contorta* community. Species richness ranged from 16-21 species. Species richness was maximum in *T. contorta* community (21) at site 1. For shrubs at sub-alpine sites, site wise tree density ranged from 260-440 ind./ha^{-1}. For herbs at sub-alpine sites, density of herbs species ranged from 28.9-51.85 ind./m^2 in the identified communities. Species diversity (H') of herbs ranged from 1.01-1.23.

Table 12: Species richness, density, concentration of dominance (Cd) and species diversity (H') at alpine sites of Rohtang Pass, Kullu.

Alpine sites	Community Type	Species richness	Shrub			Herb		
			Density (ind./ha^{-1})	Cd	H'	Density (ind./m^2)	Cd	H'
Site 1	LC-RS-PA	16	-	-	-	81.8	0.15	2.15
Site 2	TR-CN-RH-ML	32	-	-	-	85.0	0.10	2.73
Site 3	RA-RM	42	290.00	0.30	1.28	84.0	0.06	3.12
Site 4	AT-PA-PV-LC	35	-	-	-	88.9	0.08	2.88
Site 5	CG-PA	14	-	-	-	41.3	0.17	2.09

Abbreviations: Cd - Concentration of dominance; H'- Species diversity; LC-RS-PA *Lagotis cashmeriana - Ranunculus sarmentosus - Poa alpina*; TR-CN-RH-ML - *Trifolium repens - Carex nubigena - Rumex hastatus - Morina longifolia*; RA-RM - *Rhododendron anthopogon - Rosa macrophylla*; AT-PA-PV-LC - *Anaphalis triplinervis - Poa alpine - Polygonatum verticillatum -Lagotis cashmeriana*; CG-PA - *Corydalis govanniana - Phleum alpinum*

APPLICATION OF R & D OUTPUTS IN DEMONSTRATION AND DISSEMINATION

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 ENVIS Secretariat, 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 / Hubs / Resource Partners 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 quantitative and qualitative database on various aspects of Himalayan Ecology from authentic data sources. This database covers the temporal trends across important segments, e.g., demography, literacy, land, water, agriculture, horticulture, forest cover, protected areas, weather profiles, etc. Also, information was collected on subject experts and important web links related to Himalayan Ecology.

2. ENVIS Centre also published ENVIS Bulletin Himalayan Ecology (Vol. 28, 2020) on the theme of (i) Environment & Ecology; and (ii) Covid-19 Impacts on Himalayan Ecology and Environment. In addition, four thematic ENVIS Newsletters Vol. 17 (1-4), 2020 on (i) Preparation of Peoples, Biodiversity Register; (ii) COVID-19 and Livelihood Options in Himalaya; (iii) Lower Plants of High Altitude of Western Himalaya; and (iv) Eco-smart Village Development were published.

3. The Centre participated in World Water Day (22 March 2020) organized by GBPNIHE (Fig. 72). In the past we conducted six certificate courses on Green Skill Development Programme (GSDP) namely (a) Value Addition and Marketing of NTFPs (Animal Origin): Wild Bee Keeping and Processing (b) Bird Identification and Basic Ornithology; (c) Preparation of People's Biodiversity Register (3 Batches); and (d) Nature Interpretation. Total 80 trainees from 13 districts of Uttarakhand were trained under GSDP and 65 trainees so far have been placed as, nature/tourist guide, bee keeper, field assistant, teaching, agriculture, bird watcher, master trainers, resource persons, higher education etc.

Fig 72: Cleanliness drive surrounding Kosi river.

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

Ministry of Environment, Forest & Climate Change (MoEF&CC), Government of India entrusted the responsibility of Integrated Action Oriented Research, Development and Extension Programme (named as Integrated Eco-development Research Programme - IERP) in the IHR to the Institute in 1992. Through this scheme the Institute extends R&D support to Universities, R&D organizations and NGOs working in the IHR under two broad thrust areas (i.e., Technology Development and Research for Integrated Eco-development, and Technology Demonstration Extension) covering 4 thematic areas (viz; land and water resource management, biodiversity conservation and management, environmental assessment and climate change and socio-economic development) of the Institute. IERP has set-out a format (Hindi/English) and guidelines for applying under this scheme by various stakeholders across the IHR.

Objectives:

- To provide extra mural funds to different Universities/Institutions/NGOs/Voluntary agencies for the support of location-specific R&D activities in the 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.

Achievements:

1. A total of 369 R&D projects have been supported by IERP so far, to various Universities, Institutions, NGOs and Government organizations across IHR, out of them 337 projects have been successfully completed.
2. At present 32 R&D projects are under various stages of implementation, covering 7 States (namely; Assam, Arunachal Pradesh, Meghalaya, Mizoram, Sikkim, Tripura and Uttarakhand).
3. Regular monitoring of project activities is carried out and feedback is received from project implementing agencies and communicated to project PIs.

Central Laboratory Services

Institute has centralized facilities for analysis of soil and plant samples, physicochemical, biological, heavy metal analysis of fresh and wastewater, quantification of organic compounds (mainly volatiles) of water and

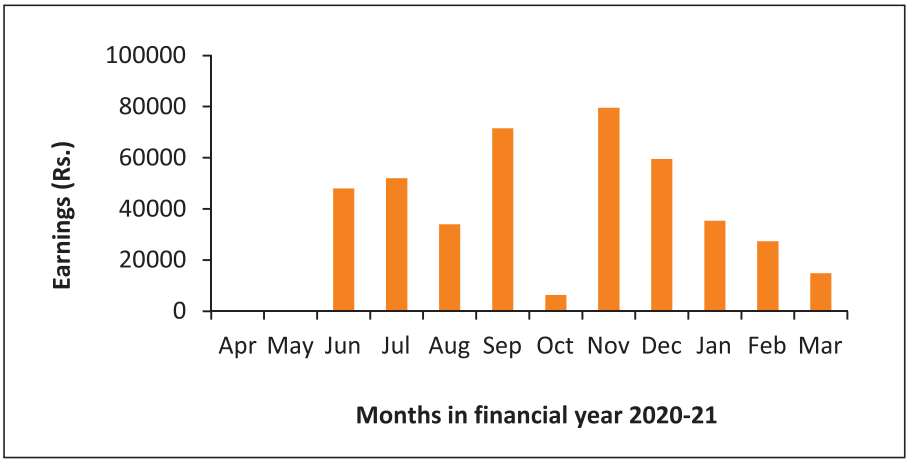


Fig. 73: Month-wise income generated through sample analysis in Central Lab

elemental analysis (carbon, hydrogen, nitrogen, and sulphur) of solid materials. 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. 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 various Govt. organizations and NGOs on payment basis. Individuals (researchers, village people) are also using the facility for sample analysis. In the financial year 2020-21, Institute earned Rs. 4,28,576/- as a Central Laboratory service charges from different organizations including four public organizations, one private organization and one individual (Fig. 73). Apart from this, the Central Lab. also facilitated Institute research work in the form of sample analysis using AAS, GC and CHNS.

Strengthening and Maintenance of the Central Library at Hqs

The Central Library of the Institute at its headquarters, at the end of financial year 2020-21, had 18098 books. The library is subscribing a total of 52 periodicals (18 Foreign and 34 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 human resources. The Library of the Institute is accessible through the website (https://librarygb pnihesd. weebly.com/). During the reporting year, 490 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 (Hindi Magazine), ENVIS Newsletters and Bulletin 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

Participation in Different Eevents by Institute Faculty

Events	HQ	Regional Centres						
National		NERC	SRC	GRC	HPRC	LRC	Mountain Division	Total
Symposia/Conference/Workshop/ Webinar	61	23	20	8	22	5	23	**162**
Training Courses	68	11	7	5	18	5	11	**114**
Meetings	56	5	13	8	22	-	23	**127**
Participation as a Resources Person	47	9	12	7	29	-	1	**105**
Any Other	4	10	2	1	14	2	-	**33**
International	4	7	6	-	-	-	-	**17**
Total	**240**	**65**	**60**	**29**	**105**	**12**	**58**	**558**

MISCELLANEOUS ITEMS

SCIENTIFIC PUBLICATIONS

1. SCIENTIFIC JOURNALS:

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V. POLICY PAPERS

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Liniger HP, Bandy J, Bhuchar S & Joshi R (2020). Spring revival with sustainable land management (SLM) practices in the mid-hills of Uttarakhand, India: North-western Himalayas.WOCAT working paper. 1-7.

List of misc. items

1.	International Scientific publications	57
2.	National Scientific publications	20
3.	Chapters in books/proceedings	33
4.	Authored/edited books/booklets/bulletins/monographs	15
5.	Popular articles	27
6.	Policy papers	02
	Total publications	**154**

ANIL SHALINI & ASSOCIATES
CHARTERED ACCOUNTANTS

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INDEPENDENT AUDITOR'S REPORT

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

Opinion

In our opinion and to the best of our information and according to the explanations given to us, the financial statements of **G.B. PANT NATIONAL INSTITUTE OF HIMALAYAN ENVIRONMENT (A Institute of Govind Ballabh Pant Himalaya Paryararan Evam Vikas Society)** for the year ended **March 31, 2021** are prepared, in all material respects, in accordance with The Law of India.The said account gives the information required and gives a true and fair view in conformity with the Accounting Principles generally accepted in India.

(a) In the case of Balance Sheet, of the State of Affairs of the Institute as at 31st March 2021.

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

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

Bases of Opinion

We conducted our audit in accordance with Standard on Auditing (SAs). Our responsibilities under those Standards are further described in the Auditors's Responsibilities for the audit of the Financial Statements section of our report. We are independent of the Institute (Govind Ballabh Pant Himalya Paryavaran Evam Vikas Societys) in accordance with the Code of Ethics issued by the Institute of Chartered Accountants of India (ICAI) 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 judgement 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 not provide a separate opinion on these matters. In addition to the matters described in the basis of 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
None	None

Emphasis of Matters or Other Matter

Institute has ordered for procurement of Scientific Equipment from abroad against which in the books of Institute Rs. 87,64,193.00 is standing in the Head of Current Assets (FDR's & LC Margin). Out of

this balances some are old balances against which Scientific Equipment are already received, so this amount should be booked in fixed assets and total balance to be reduced to that extant.

Institute has not booked bank charges debited by bank related issuance of pass book etc. since past years with contention that they have requested to bank to waive the same being Government Institute, we are of the view that same should be booked in the Books of Accounts as these are standing since long time.

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

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 the Institute of Chartered Accountants of India. This responsibility also includes maintenance of adequate accounting records in accordance with the provision of the Act for safeguarding of the assets of the Society and for preventing and detecting fraud and other irregularities, selection and application of appropriate implementation and maintenance of accounting policies, making judgements 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, managements is responsible for assessing the Institute's ability to continue as a Going Concern, disclosing, as applicable, matters related to going concern and using going concern basis of accounting unless management either intends to liquidate the Institute or to cease operation, 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 Responsibility

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

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

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

Report on Other Legal and Regulatory Requirements

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

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

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

d. In our opinion, the Balance sheet, the Statement of Income and Expenditure and the Receipt and Payment account comply with the Accounting Standards referred to in Societies Act 1860.

e. Observation reported in previous period audit report corrected to the extent not reported hereinabove.

Date: 13-08-21

Place: Almora

For Anil Shalini & Associates
(Chartered accountants)

13/08/2021

Anil Kumar Shukla
FCA,DISA
M NO.075418
FRN. 009960C

UDIN: 21075418AAAACU2473

G.B.PANT NATIONAL INSTITUTE OF HIMALAYAN ENVIRONMENT
KATARMAL, KOSI (ALMORA) UTTARAKHAND
BALANCE SHEET AS ON 31ST MARCH 2021

PARTICULARS	SCHEDULE	CURRENT YEAR (₹)	PREVIOUS YEAR (₹)
LIABILITIES			
CORPUS / CAPITAL FUND	1	3,08,94,764.45	5,01,69,557.17
RESERVE AND SURPLUS	2	42,83,48,583.79	42,53,78,585.35
EARMARKED / ENDOWMENT FUNDS	3	-	-
SECURED LOANS & BORROWINGS	4	-	-
UNSECURED LOANS & BORROWINGS	5	-	-
DEFERRED CREDIT LIABILITIES	6	-	-
CURRENT LIABILITIES AND PROVISIONS	7	1,45,40,39,455.31	1,60,20,56,433.80
TOTAL		**1,91,32,82,803.55**	**2,07,76,04,576.32**
ASSETS			
FIXED ASSETS	8	42,83,48,583.79	42,53,78,585.35
INVEST. FROM EARMARKED/ENDOWMENT FUND	9	1,79,34,931.17	4,25,89,138.17
INVEST. OTHERS	10	-	-
CURRENT ASSETS , LOANS, ADVANCES ETC.	11	1,46,69,99,288.59	1,60,96,36,852.80
MISCELLANEOUS EXPENDITURE			
TOTAL		**1,91,32,82,803.55**	**2,07,76,04,576.32**
SIGNIFICANT ACCOUNTING POLICIES	24		
CONTINGENT LIABILITIES & NOTES ON ACCOUNTS	25		

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

(Anil Kumar Shukla) 13/08/21
FCA PARTNER
M.NO.075418
FRN: 009960C

DATED : 13.08.2021
PLACE : KOSI- KATARMAL, ALMORA
UDIN: 21075418AAAACV2473

(ER. KIREET KUMAR)
DIRECTOR IN CHARGE

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

(L. M.S. NEGI)
ACCOUNTS OFFICER

G.B.PANT NATIONAL INSTITUTE OF HIMALAYAN ENVIRONMENT
KATARMAL, KOSI (ALMORA) UTTARAKHAND
INCOME & EXPENDITURE A/C FOR THE YEAR ENDED 31ST MARCH 2021

PARTICULARS	SCHEDULE	CURRENT YEAR (₹)	PREVIOUS YEAR (₹)
INCOME			
Income from Sales/Services	12	4,67,314.00	2,50,359.00
Grants/Subsidies(net off exp)	13	60,89,63,494.67	73,53,28,023.61
Fees/Subscriptions	14	-	-
Income from Investment	15	-	-
(to the extent of depreciation & WDV of asset sold)		-	-
Income from Royalty, Income from Inv. Publication etc.	16	-	-
Interest Earned	17	11,75,398.00	4,29,255.01
Other Income	18	49,82,433.28	70,33,227.00
Increase (decrease) in stock of Finished goods and work in progress)	19	-	-
T O T A L (A)		**61,55,88,639.95**	**74,30,40,864.62**
EXPENDITURE			
Establishment Expenses: a) Institute	20	12,18,75,008.00	11,61,28,616.00
b) Projects		3,63,26,949.00	4,70,54,947.00
c) F.C (Projects)		9,56,200.00	29,98,125.00
Administrative Expenses :a) Institute	21	4,79,77,005.77	7,58,44,469.61
b) Projects (As per Annexure)		39,48,08,908.74	47,67,52,795.52
c) F.C (Projects)(As per Annexure)		55,22,162.00	42,76,946.00
Expenditure on Grants, Subsidies etc.	22	14,97,261.16	1,22,72,124.48
Interest			
Depreciation (Net Total at the year-end-as per Sch. 8)		4,57,08,448.60	14,50,36,294.36
T O T A L (B)		**65,46,71,943.27**	**88,03,64,317.97**
Balance being excess of Income over Expenditure (A - B)		**(3,90,83,303.32)**	**(13,73,23,453.35)**
Transfer to special Reserve			
Transfer to/ from General Reserve			
BAL.BEING SURPLUS TRF.TO CORPUS FUND (Other Income)		**(4,02,54,074.32)**	**(13,74,55,875.36)**
BAL.BEING SURPLUS TRF.TO CORPUS FUND (Corpus Interest)		**11,70,771.00**	**1,32,422.01**
Add: Transferred from General Reserve Fixed Asset Fund		**4,57,08,448.60**	**14,50,36,294.36**
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: Anil Shalini and Associates
CHARTERED ACCOUNTANTS

13/08/2021

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

DATED : 13.08.2021
PLACE : KOSI- KATARMAL, ALMORA
UDIN: 21075418AAAACU2473

(ER. KIREET KUMAR)
DIRECTOR IN CHARGE

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

(L. M.S. NEGI)
ACCOUNTS OFFICER

G.B. PANT NATIONAL INSTITUTE OF HIMALAYAN ENVIRONMENT
KOSI-KATARMAL, (ALMORA) UTTARAKHAND
RECEIPTS & PAYMENTS A/C FOR THE YEAR ENDED 31ST MARCH 2021

RECEIPTS	CURRENT YEAR	PREVIOUS YEAR	PAYMENTS	CURRENT YEAR	PREVIOUS YEAR
I. Opening Balances			**I. EXPENSES**		
a) Cash in hand	88,374.34	2,06,511.64	**a) Establishment Expenses**		
	-	-	**I) Institute**	10,97,84,604.41	11,51,65,535.36
b) Bank Balances		-	**b) Administrative expenses**	-	-
	-	-	a) Institute	5,66,97,854.80	5,05,52,452.79
i) In current accounts	-	-	b) R&D(Rev) expenses	94,36,029.60	1,49,50,879.79
ii) In deposit accounts (Corpus Fund)	4,25,89,138.17	27,25,298.17	c) Payments for current liabilities(gratuity/leave)	1,48,61,681.00	58,56,429.00
iii) Savings accounts	32,96,04,045.52	42,48,89,948.00	**C. Capital expenditure**	-	-
c) Advances & Others	1,26,46,64,382.26	1,08,13,44,058.59	a) Purchase of Fixed Assets	2,02,01,267.04	2,45,57,720.00
(As per annexure Attached)	-	-	b)Expenditure on Capital Work in Progress	30,52,411.00	4,08,87,658.00
F.C. ACCOUNT	-	-	c) Acquirement of land (Lease money)	-	-
A) Cash in hand	4,976.33	4,976.33	**II Payments made against funds for various proj.**	-	-
b) Cash at bank	57,81,763.46	46,25,994.18	**Expenditure State govt. projects**	-	-
c) FC Advances	13,15,331.00	33,86,785.25	a) Capital	2,51,17,089.00	52,55,313.00
II. Grants Received	-	-	b) Revenue;	-	-
a) From Government of India	16,70,00,000.00	26,00,00,000.00	Establishment exp	3,55,16,897.00	4,94,54,411.00
i) Institute & IERP	-	-	Administration exp	39,44,55,517.74	47,94,11,603.88
Contribution corpus from CPF	27,05,613.00	30,57,179.00	**Expenditure FC projects**	-	-
b) From Other agencies	37,35,95,999.80	62,84,59,515.00	**a) Capital**	3,07,680.00	1,14,957.00
c) From other sources [from FC]	81,55,008.41	77,49,850.22	**b) Revenue;**	-	-
III. Income on Investments from	-	-	Establishment exp	9,56,200.00	29,98,125.00
a) Corpus Fund(Received from Institute)	-	1,03,95,947.00	Administration exp	53,89,812.00	51,24,856.00
IV. Interest Received	-	-	**IERP grant released**	14,97,261.16	1,22,72,124.48
a) On Bank deposits savings a/c		40,10,274.00	**III Investments and deposits made**	-	-
b)On term deposits a/c	-	-	Pension trust (out of corpus fund)	2,86,05,551.00	30,57,179.00
c) Loans, Advances etc.	4,627.00	2,59,182.00	**IV Refund of Surplus money/Loans**	-	-
d) Interest income Corpus Fund	11,70,771.00	1,47,12,629.00	a) To the Government of India	2,78,64,419.00	2,30,99,648.00
V. Other Income	-	-	b)To Others/ security/ caution money)	-	-
Received in Corpus Fund	3,18,200.00	-	Refund to MoEF&CC (HBA/MCA)	9,60,025.00	-
(As per annexure Attached)	-	-	**V Other payments**	2,43,240.00	-
VI. Amount Borrowed	-	-	Other Payment to Instt. FC Proj.	-	-
VII. Any other receipts.	52,27,844.28	72,79,011.00	Unspent Balance (FC)	-	-
Interest Received in NMHS Payable to Government	1,79,63,253.73	1,91,40,894.00	Payment of Current Libilities	-	-
	-	-	Refund of EMD	-	-
Other Receipt FC a/c	-	-	Fund transfar to Corpus fund	3,18,200.00	1,03,95,947.00
a)Performance Guarantee	-	-	**VI Closing balances**	-	-
b) Receipts Current Liabilities	-	-	**a) Cash in hand**	1,04,076.70	88,374.34
c) IERP grants refunded by grantee Org.	-	-	**b) Bank Balance**	-	-
d)Construction Fund	-	-	i) In Current account	-	-
e) Corpus Fund FDR'S	-	1,47,55,264.00	ii) In deposit accounts (Corpus Fund)	1,79,34,931.17	4,25,89,138.17
f) Caution Money		-	iii) In savings accounts	14,78,43,362.41	32,96,04,045.52
g) Security Deposit	-	-		-	-
h) EMD		1,99,533.00	**C) Advances and others**	1,31,28,02,693.12	1,26,46,64,382.26
i) Royalty	-	-	**FC Project**	-	-
j) Sales Tax / GST	-	-	a) Cash in hand	4,026.33	4,976.33
k)Service Tax/GST	-	-	b) Bank Balance	37,69,774.03	57,81,763.46
	-	-	c) Advances and others	15,15,331.00	17,42,928.19
		-	Adjustment of previous year closing Advances	9,49,393.79	(4,27,597.19)
	-	-			
-	-	-			
	-				
TOTAL	2,22,01,89,328.30	2,48,72,02,850.38	TOTAL	2,22,01,89,328.30	2,48,72,02,850.38

AUDITOR'S REPORT

As per our separate report of even date annexed.
For: Anil Shalini and Associates
CHARTERED ACCOUNTANTS

13/08/2021

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

DATED : 13.08.2021
PLACE : KOSI- KATARMAL, ALMORA
UIN: 21075418AAAACU2473

(ER. KIREET KUMAR)
DIRECTOR IN CHARGE

(Dr. I.D. BHATT)
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(L. M.S. NEGI)
ACCOUNTS OFFICER

G.B.PANT NATIONAL INSTITUTE OF HIMALAYAN ENVIRONMENT
KOSI-KATARMAL, (ALMORA) UTTARAKHAND
ANNEXURE FORMING PART OF BALANCE SHEET AS ON 31 MARCH 2021

CURRENT ASSETS

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

PARTICULARS	CURRENT YEAR (₹)
C.B.I Kosi A/c No. 3173366206	6,15,93,252.07
S.B.I Almora A/C No. 10861359986	1,42,92,094.67
S.B.I Tandong A/c No. 11226047758	56,13,401.09
S.B.I Kullu A/c No. 10792147561	62,46,099.14
S.B.I Itanagar A/c No.10940060114	2,09,153.37
S.B.I Srinagar A/c No. 10972182864	19,90,512.31
S.B.I Ladakh A/c No. 39128027055	10,41,950.00
S.B.I Tandong A/c No. 37000934072 (NMHS IHTP DK	31,23,707.60
C. B. I. Kosi A/c No. 3604013559 (GIA- General)	71,53,697.18
C. B. I. Kosi A/c No. 381883348 (GIA -Creation of capital assets)	4,19,878.00
C. B. I. Kosi A/c No. 3818842358 (GIA -Salaries)	81,18,983.42
S. B. I. Kosi A/c No. 36883992887 (NMSHE TF-03 New Account)	6,60,003.00
S.B.I Srinagar A/c No. 3690636305 (NMHS ST KK)	18,06,479.68
S.B.I Almora A/c No.10861359975 (F.C)	37,69,774.03
C.B.I Kosi A/c No. 3561532026 (ENVIS New Account)	1,16,679.00
C.B.I. Kosi A/C No. 3530505520 (NMHS-PMU)	93,15,073.23
NMHS GIA GENERAL TRIBAL SUB PLAN A/c	13,45,141.00
NMSH GIA GENERAL SCHEDULE CASTE A/c	6,37,090.00
NMHS GIA CREATION OF CAPITAL ASSETS	99,87,721.00
S. B. I. Kosi A/c No. 36959540111 (NMHS ST KK)	61,29,111.85
S. B. I. Kosi A/c No. 36935490949 (NMHS Fellowship)	40,41,712.30
S. B. I. Kosi A/c No. 36935414822 (NMHS JCK)	3,12,528.34
S. B. I. Kosi A/c No. 36935498701 (NMHS IHTP GCSN)	46,029.00
S. B. I. Kosi A/c No. 36944701949 (NMHS IHTP S. Sharma)	17,479.00
S. B. I. Kosi A/c No. 36944702502 (NMHS IHTP Rajesh Joshi)	34,054.00
S. B. I. Kosi A/c No. 36944702987 (NMHS IHTP R. S. Rawal)	2,40,575.00
S. B. I. Kosi A/c No. 36959556518 (NMHS D. S. Rawat)	89,310.00
S. B. I. Kosi A/c No. 36959540698 (NMHS BSI K. C. Sekar)	-
S. B. I. Mohal A/c No. 36998149642 (NMHS JCK H.P.)	-
IDBI Itanagar A/c No. 0161104000055514 (NMHS JCK N. E. Unit)	-
Cheque in transit: Regional Centre N.E.	11,82,625.76
Regional Centre H.P.	-
Regional Centre Sikkim	20,79,021.40
Regional Centre Garhwal	
Fund Transfer to Core Grant Account	-
	15,16,13,136.44

DUE FROM STAFF **ANNEXURE"E1"**

PARTICULARS	CURRENT YR. (₹)
Adv. a/c of Tribhuwan Rana (GRC Unit)	25,000.00
PI Adv a/c of Mamta Higgins (GIA General)	1,000.00
PI Adv a/c of Sanjeev Higgins (GIA General)	5,000.00
PI Adv. a/c of Hema Pandey (GIA General)	10,000.00
PI Adv. a/c of Hema Pandey (GIA Salaries)	10,000.00
PI Adv. a/c of Hema Pandey (Project a/c)	10,000.00
Adv. a/c of Vasudha Agnihotri (NMHS-NIH Roorkee VA) (Project A/c)	50,000.00
Adv. a/c of Shri Heera Singh Computer Advance(GIA Salaries)	35,000.00
Total:	**1,46,000.00**

DUE FROM OTHERS **ANNEXURE"E2"**

PARTICULARS	CURRENT YR. (₹)
Adv. a/c of TATA Motors Ltd. Core	2,836.00
Adv. a/c of Meterological Department Core	8,000.00
Adv. a/c of NRSC Hydrabad Proj. 04 Core	24,000.00
Adv. a/c of M/s International Trade link Core	34,328.00

Anil Shalini & Associates, Chartered Accountants, DELHI, FRN. 009960C

Adv. a/c of VPKAS Almora Core	26,560.00
Adv. a/c of STUP Consultant Haldwani Core	(7,435.00)
Adv A/C E.E. RES Almora Core	15,71,000.00
Adv. a/c of E. E. CCU N. Delhi GIA Creation of Capital Assets	16,20,000.00
Adv. a/c of NIH Roorkee Core	1,00,000.00
Adv a/c NICSI New Delhi Core	35,106.00
Employment news New Delhi Core	48,287.00
Adv a/c M/S Sigma Aldrich Chemicals Core	10,590.00
Adv A/C NRSA Hydrabad Core	35,300.00
Adv a/c M/S R.K. Nanda & Sons Core	28,517.00
Adv. a/c of Sh. Manoj Tiwari (Advocate) Core	20,000.00
Adv. a/c of INSA New Delhi Core	30,000.00
Recoverable from Unit Core	4,772.00
Adv. a/c NRSA Hydrabad (DST LMS ILTP)	48,000.00
Adv. a/c of WWF New Delhi (UNDP CCF PKS N. E. Unit New)	(31,930.00)
Adv. a/c of E E. RES Almora (HRDI IDB)	59,000.00
Adv a/c of E.E Sikkim (NMSHE-TF-03)	29,91,000.00
Adv. a/c of NRSC Hydrabad (DST SERB GCSN)	635.00
Adv. a/c of Airport Handling Services (SERB JCK H. P. Unit)	18,371.00
Adv a/c of Airport Handling Noida (NMHS-MG- S. Mukherji)	(7,788.00)
Adv a/c of Airport Handling Noida (SERB-Dr. Sandeepan Mukharjee)	1,87,154.00
Adv. a/c of Partners NMHS enclose **Annexure 'X'**	1,23,47,32,259.72
Adv. a/c of NRSA Hydrabad (ISRO GBP S. Sharma)	3,50,000.00
Adv. a/c of M/s Vankta Enterprises (Cop 11 MoE & F NBA)	7,100.00
Adv. a/c Siltep Chemicals Ltd. (Biotech-III)	408.00
Adv. a/c of NRSA Hyerabad (DST KK I)	7,400.00
Adv. a/c of M/s Current Science (NMHS IHTP S. Sharma)	13,400.00
Adv. a/c Forest Vardhanik Uttaranchal (NMHS-IDB)	3,60,000.00
Adv. A/c M/s Moets Catering Services, New Delhi(Mount. Divn.)	64,574.00
Adv. a/c of Sustainable Development (Mountain Division)	25,000.00
Adv. a/c IMI New Delhi.(Mount. Divn.)	10,00,000.00
Adv. a/c Mizoram University (IERP)	3,00,000.00
Adv. a/c of Finance Officer Mizoram University (Core)	92,250.00
Adv. a/c of H.N.B Gharwal University, Srinagar (ICSSR RKM G. Unit-New)	9,70,822.00
Adv. a/c of M/s Airport Handling (NMSHE TF-03)	2,30,000.00
Adv. a/c of Meghalaya (GIA General)	3,98,125.00
Adv. a/c of NEIST, Manipur (NMHS JCK)	41,830.00
Adv. a/c of B.S.N.L. Ltd	99,415.00
Adv. a/c of Jal Adhyaran (GIA General)	(60,000.00)
Security Deposit CET Sikkim Core	11,000.00
Adv. a/c of D S Bisht (NMHS-DSR)	(40.00)
Security Deposite N.E. Unit Core	1,750.00
Adv. a/c of IIT Guwahati (NMHS-S.Tarafdar)	48,578.00
Adv. a/c of National Remote Sensing Centre, Hydrabad (UNDP-JCK)	69,738.00
Adv. a/c of Executive Engineer CE-IICCU(NMHS-NILC-IDB)	43,11,247.00
Adv. a/c of IIT-ROORKEE(NMHS-PINE OAK-SM)	44,06,760.00
Adv. a/c of NIT-ROURKELA(NMHS-PINE OAK-SM)	8,76,760.00
Adv. a/c of JNU NEW DELHI(NMHS-PINE OAK-SM)	13,51,280.00
Adv. a/c of IIT MUMBAI (NMHS-PINE OAK-SM)	12,91,280.00
Adv. a/c of DIRECTOR U SAC DEHRADUN (NMHS-HIMALAYA CALLING	3,00,000.00
Adv. a/c of National Remote Sensing Agency Core)	73,544.00
Adv. a/c of Regional Science Centre (Core)	89,936.00
Adv. a/c of Sikkim College (Core)	4,30,000.00
Adv a/c of IIT Mandi(NMHS Vaibhav E. Gosavi Project (New) Project A/c)	13,61,600.00
Adv. a/c of FRI Jorhat (NMHS Vaibhav E. Gosavi Project (New))	13,61,600.00
Adv. a/c of Sikkim University (NMHS Vaibhav E. Gosavi Project (New))	13,61,600.00
Adv. a/c of NIT Silchar (NMHS Vaibhav E. Gosavi Project (New))	13,61,600.00
Adv, a/c of Institute of Nature Res Meghalaya (NMHS Vaibhav E. Gosavi Project (New))	13,61,600.00
Adv. a/c of Institute of Technology Manipur (NMHS Vaibhav E. Gosavi Project (New))	13,61,600.00
Adv. a/c of NIT, Nagaland (NMHS Vaibhav E. Gosavi Project (New))	13,61,600.00
Adv. a/c of Univesity of Mizoram (NMHS Vaibhav E. Gosavi Project (New))	13,61,600.00
Adv. a/c of Univesity of Tripura (NMHS Vaibhav E. Gosavi Project (New))	13,61,600.00
Adv. a/c of SKUAST, Srinagar J&K (NMHS Vaibhav E. Gosavi Project (New))	13,61,600.00
Adv. A/c of NIRDPR (Mount .Div)	(1,23,019.00)
Adv. a/c of Delhi Productivity Council (Core)	1,14,932.00
Adv. a/c of Manipur Institute of Technology (core)	2,73,125.00
Adv. a/c of Airport Handling Services (Core)	2,40,000.00
Adv. a/c of Nagaland College (Core)	1,20,000.00
Adv. a/c of NIT Assam (Core)	6,50,000.00
Adv. a/c of Tripura College (Core)	1,55,000.00
	1,27,37,96,757.72

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

Garhwal Regional Centre

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

Himachal Regional Centre

27.	Er. Rakesh Kumar Singh	Scientist- E & Head	Information Technology
28.	Dr. K.S. Kanwal	Scientist-D	Strategic Environmental Assessment
29.	Mrs. Sarla Shashni	Scientist-D	Rural Entrepreneurship and Small Business
30.	Dr. Renu Lata	Scientist-C	Environmental Governance and Policy
31.	Dr. Kishore Kumar	Tech.-IV (2)	Pollination Biology; Conservation Education

Sikkim Regional Centre

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

North-East Regional Centre

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40.	Dr. Wishfully Mylliemngap	Scientist-B	Ecosystem Services
41.	Dr. Mriganka Shekhar Sarkar	Scientist- B	Ecology, Genetics
42.	Mr. Om Prakash Arya	Tech-IV (2)	Biotechnological Applications

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43.	Dr. Subrat Sharma	Scientist-F & Head	Agro Ecology; Remote Sensing/GIS
44.	Dr. Suresh Kumar Rana	Scientist- B	Biogeography; Evolutionary Ecology; Biocuration
45.	Dr. Lalit Giri	Tech-IV (I)	Biotechnology

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3.	Mr. L.M.S. Negi	Accounts Officer
4.	Mr. Mahesh Chandra Sati	Tech. Gr. IV (2), Lib
5.	Mr. S. Higgins	Tech. Gr. III (3)
6.	Mrs. Sarita Bagadwal	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. Mayank Verma	U.D.C.

S.N.	NAME	DESIGNATION
13.	Mr. Atul Bisht	L.D.C.
14.	Mr. Nitish Mathpal	L.D.C.
15.	Mr. Vipin Sharma	L.D.C.
16.	Mr. Chandra Lal	Tech. Gr. II (2)
17.	Mr. K.N. Pathak	Tech. Gr. I (4)
18.	Mr. Govind Singh	Technical II (1)
19.	Mr. Pan Singh	Group 'C'
20.	Mrs. Ganga Joshi	Group 'C'
21.	Mr. Gopal Singh Bisht	Group 'C'
22.	Mr. Govind Singh Malwal	Group 'C'
23.	Mr. Lachi Ram	Group 'C'

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24.	Mr. D.P. Kumeri	U.D.C.
25.	Mr. M.P. Nautiyal	Tech. Gr. II (2)
26.	Mr. J.M.S. Rawat	Tech. Gr. II (2)
27.	Mr. R.C. Nainwal	Tech. Gr. I (4)
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29.	Mr. Daulat Ram	Group 'C'
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32.	Mr. R.K. Das	L.D.C.
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34.	Mr. P.K. Tamang	Technical Group I (4)
35.	Ms. Vaishali Patwa	L.D.C.
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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 KosiKatarmal, Almora (Uttarakhand) and six Regional Centres, namely, Ladakh Regional Centre (LRC) at Leh, Himachal RegionalCentre (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).

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