ANNUAL REPORT 2017-18

www.gbpihed.gov.in

G.B. PANT INSTITUTE OF HIMALAYAN ENVIRONMENT & DEVELOPMENT

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

SOCIETY

President
Minister In-Charge
Ministry of Environment, Forest and Climate Change
Government of India, New Delhi

Vice President
Minister of State
Ministry of Environment, Forest and Climate Change
Government of India, New Delhi

Members
Two members of Parliament nominated by the Government of India, New Delhi

MP (Lok Sabha) MP (Rajya Sabha)

Minister-in-charges of Environment in the State Governments

Government of Assam, Arunachal Pradesh, Himachal Pradesh, Jammu and Kashmir, Manipur, Meghalaya, Mizorum, Sikkim, Tripura, Uttarakhand, West Bengal

Two MLAs from the State of Uttarakhand nominated by the Government of India

Five non-official Members nominated by Govt. of India

Dr. Kuldeep Chandra
Vice Chancellor
Central University of Himachal Pradesh
Distt. Kangra, Himachal Pradesh

Dr. S.P. Mishra
Vice-Chancellor
Uttarakhand Ayurved University Station Road, Harrawala, Dehradun, Uttarakhand

Dr. N.C. Gautam
Vice-Chancellor
Mahatma Gandhi Chitrakoot Gramodaya University Chitrakoot, Satna, Madhya Pradesh

Prof. Yogesh Singh
(Former Director, Netaji Subhas Institute of Technology)

Vice Chancellor
Delhi Technological University (DTU)
Shahbad Daulatpur, Delhi

Prof. (Dr.) Anil Kumar Gupta
(Former Director, Wadia Institute of Himalayan Ecology)
Professor, Geology and Geophysics & Head, Centre for Oceans, Rivers, Atmosphere and Land Science, Indian Institute of Technology Kharagpur, West Bengal

A representative of the Indian Institute of Forest Management

Director
Indian Institute of Forest Management, Nehru Nagar, Bhopal, Madhya Pradesh

Secretaries of Govt. of India

Ministry of Environment, Forest and Climate Change, Ministry of Finance (expenditure), Department of Science and Technology, Council of Scientific and Industrial Research, Ministry of Human Resource Development (Department of Higher Education), Ministry of Rural Development, Department of Urban Development, Ministry of New & Renewable Energy, Department of Mines, Ministry of Water Resources, River Development and Ganga Rejuvenation, Department of Agricultural Research and Education, Planning Commission/Niti Aayog

Chief Secretary, Govt. of Uttarakhand

Director General
Indian Council of Forestry Research and Education Forest Research Institute, Dehradun

Director General of Forest and Special Secretary
Ministry of Environment, Forest and Climate Change

Director, Botanical Survey of India, Kolkatta

Chairman, Indian Council of Social Science Research, New Delhi

Director, Wildlife Institute of India, Dehradun

Member Secretary
Director
GBPIHED, Kosi-Katarmal, Almora

GOVERNING BODY

Chairman
Secretary
Ministry of Environment, Forest and Climate Change, New Delhi

Members

Secretary
Department of Biotechnology
CGO Complex, Lodi Road,
New Delhi-110 003

Chief Secretary
Govt. of Uttarakhand
Uttarakhand Secretariat, Dehradun

Director General of Forest and Special Secretary
Ministry of Environment, Forest and Climate Change Indira Paryavaran Bhawan, New Delhi

Additional Secretary and Financial Adviser
Ministry of Environment, Forest and Climate Change Indira Paryavaran Bhawan, New Delhi

Additional Secretary
Ministry of Environment, Forest and Climate Change Indira Paryavaran Bhawan, New Delhi

Adviser
Ministry of Environment, Forest and Climate Change Indira Paryavaran Bhawan, New Delhi

Experts

Prof. R.K. Kohli, Ph.D. FNA, FASc, FASc, FNAAS
Certified Sr Ecologist ESA, USA, JC Bose National Fellow
Vice-Chancellor,
Central University of Punjab, Bathinda, India

Prof. Saroj Kanta Barik
Director, CSIR-National Botanical Research Institute Rana Pratap Marg
Lucknow

Dr. Rakesh Kumar
Director, CSIR- National Environmental Engineering Research Institute (NEERI)
Nehru Marg, Nagpur

Shri Ramesh Negi, IAS (Rtd.)
Former Chief Secretary, Arunachal Pradesh
Chairperson, Delhi Commission for Protection of Child rights,
Kashmere Gate, Delhi

Member Secretary
Director
GBPIHED, Kosi-Katarmal, Almora

SCIENTIFIC ADVISORY COMMITTEE

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

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

Dr. Kishor Kumar
Chief Scientist and Adviser (E&C)
Geotechnical Engineering Area
CSIR - Central Road Research Institute
Delhi- Mathura Road, New Delhi

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

Peer Institutions
Director/ or his representative
Director
Botanical Survey of India, CGO Complex, Salt Lake City, Kolkata, West Bengal

Director/ or his representative
Director
Forest Research Institute, Dehradun

Institute Faculty
Dr. R.C. Sundriyal
Scientist - F and Group Head (SED and KCB)
G.B. Pant Institute of Himalayan Environment and Development Kosi-Katarmal, Almora, Uttarakhand

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

Dr. Sarla Sashni
Scientist - C
G.B. Pant Institute of Himalayan Environment and Development Himachal Regional Center, Mohal, Kullu, Himanchal Pradesh

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

PROJECT EVALUATION COMMITTEE

Chairman
Prof. Saroj Kanta Barik
Director
CSIR-National Botanical Research Institute
Rana Pratap Marg, Lucknow

Members
Prof. R.M. Pant
Director
National Institute of Rural Development (NIRD) & Panchayati Raj, North Lane, Jawaharnagar, Khanapara
Guwahati, Assam

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

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

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

MoEF&CC Representative
Dr. Subrata Bose
Scientist-E
Ministry of Environment, Forest and Climate Change, Mountain Division,
Indira Paryavaran Bhawan, Jorbagh Road, Aliganj, New Delhi

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

GBPIHED

G.B. Pant Institute of Himalayan Environment & Development

ANNUAL REPORT 2017-18

FOREWORD

The Institute with a strong commitment for sustainable development of the IHR region is the only National Agency of its kind which addresses physical, biological, social and economic issues of the region and its people in an integrated manner. The R&D mandate of the Institute is broad and covers all the facets of environment and development. Towards achieving this, multi-disciplinary approach and integration are the guiding principles. The emphasis on interlinking of natural and social sciences is the major thrust of all the programmes in the Institute. It has also made sincere efforts in identifying problems, developing region-specific approaches, demonstrating their efficacy in the field and disseminating information to various stakeholders.

During the reporting period, i.e. Year 2017-18, the year witnessed new challenges and opportunities to pursue R&D activities keeping in interest the core Himalayan issues in mind. To strengthen the R&D activities of the Institute, the Institute mechanism was reinforced by up-grading its present strategic structure and focusing on the thematic and regional priorities. Following this strategic direction, the existing themes have been re-strategized and upgraded to four distinct Himalayan theme-dedicated "Centres of Eminence" at the HQs of the Institute. These four Himalayan theme-dedicated centres include (1) Centre for Land and Water Resource Management (CLWRM); (2) Centre for Socio-Economic Development (CSED); (3) Centre for Biodiversity Conservation and Management (CBCM); and (4) Centre for Environmental Assessment and Climate Change (CEA&CC). Similarly, to address the regional priorities, the regional units of the Institute have also been upgraded and renamed as Regional Centres (RCs) viz., (1) Himachal Regional Centre; (2) Garhwal Regional Centre; (3) Sikkim Regional Centre; (4) North-East Regional Centre; and (5) Mountain Division Regional Centre.

The Institute made considerable advancement in achieving its R&D objectives. Some of the major achievements include Mapping geo-morphological characteristics of Chipa glacier; Recording continuous water discharge data of springs and mapping recharge zone using isotope technique, remote sensing and GIS application; Mapping of climate sensitive Timberline across the IHR; Linking pilgrimage tourism with socio-economic aspect for development of the disaster-affected Kedar rural landscape; Development of model villages through technology transfer for livelihood enhancement in the Central Himalaya; Assessment of sub-alpine and alpine ecosystems in Great Himalayan National Park, Himachal Pradesh; Developing ex-situ conservation efforts and mass production of high value plants and their field plantation; Capacity building and training programmes. In addition, increasing pace and presence of the Institute's R&D results in peer-reviewed scientific journals, of national as well international repute, are examples of conscientious efforts, overall indicating a testimony of its raising standards.

As the Head of this premier Institute, I take this opportunity to acknowledge consistent support and strategic directions provided by all eminent members of the Apex Bodies, the Society, the Governing Body (GB) and the Scientific Advisory Committee (SAC). I am sure that with the persistent efforts of colleagues in the Institute HQs and Regional Centres along with consistent support from the well-wishers, the Institute shall succeed in achieving the targets set in its Vision Document for the Himalaya.

(Kireet Kumar)

Director In-charge

CONTENTS

Foreword

Major Achievements

Executive Summary

Introduction

Major Events

Research and Development Programmes

(i) Centers of Eminence

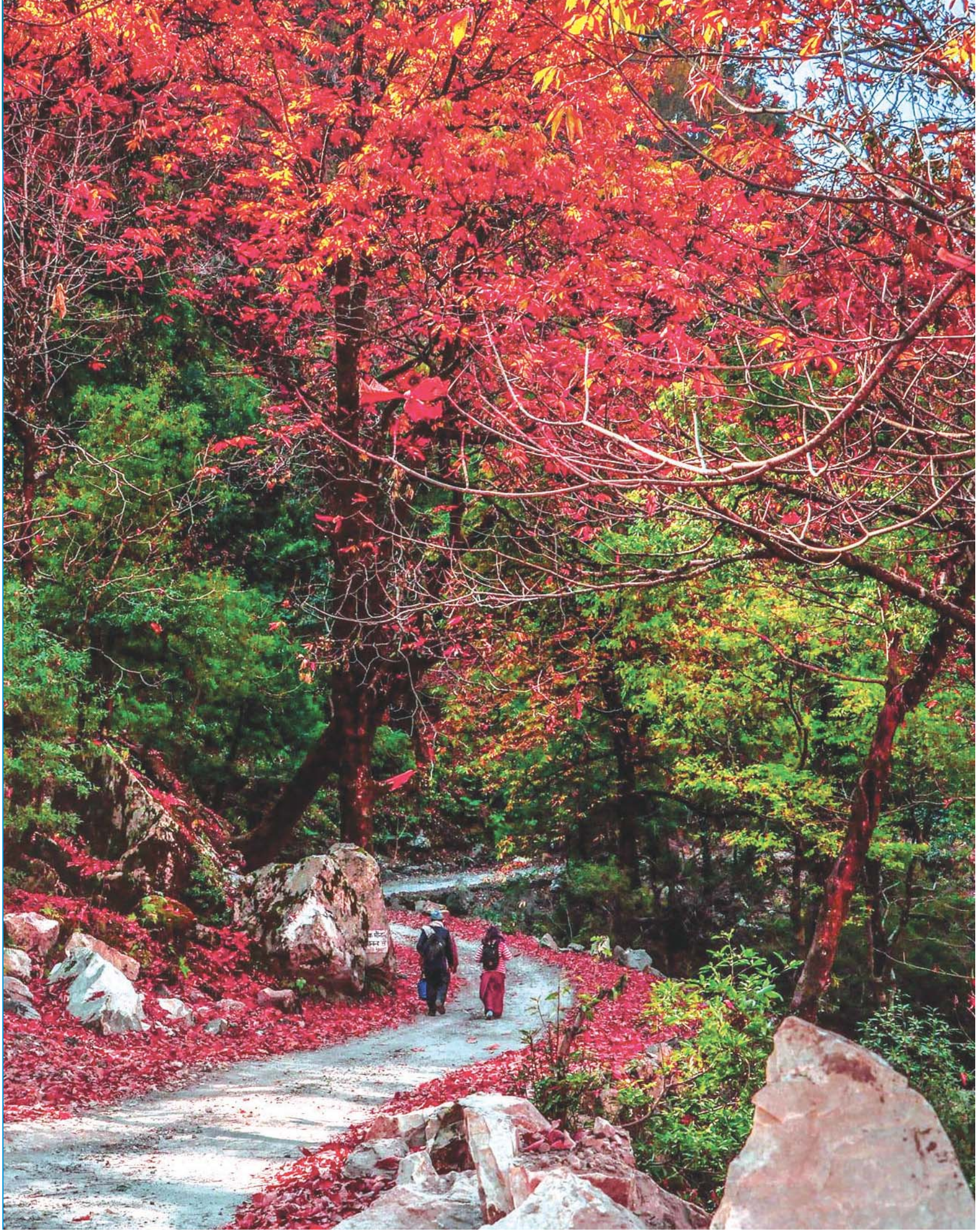
- Center for Land and Water Resource Management (CLWRM)
- Center for Biodiversity Conservation & Management (CBCM)
- Center for Socio-Economic Development (CSED)
- Center for Environmental Assessment and Climate Change (CEA&CC)

(ii) Regional Centers

- Garhwal Regional Center (GRC)
- Himachal Regional Center (HRC)
- Sikkim Regional Center (SKRC)
- North East Regional Center (NERC)
- Mountain Division Regional Center

Application of R&D Outputs in Demonstration & Dissemination

Miscellaneous Items



MAJOR ACHIEVEMENTS
(2017-2018)

1. Geo-morphological characteristics of Chipa glacier were mapped using multi spectral 4-band Sentinel 2A data at 10m resolution, Planetscope 3B Stellite data at 3m resolution, and DEM at 30 m (ASTER and SRTM data) for preliminary classification, and for DEM differencing between 2011 and 2014.

2. Towards understanding alternative boundary layer scaling properties, study of energy exchange in convective boundary layer in the Chaotic Dynamical System approach using non-local parameters along with traditional set of parameters was used with partial success.

3. *Ex-situ* conservation efforts were strengthened for the mass production of medicinal, wild edibles and ecologically important plants and their field plantation. *Rhododendron leptocaprpum, Phoenix rupicola, Hedychium spicatum,* etc. were successfully planted in the natural sites.

4. Following preliminary surveys and stakeholder consultation, a Long-term Ecological Monitoring (LTEM) site in Gaula Catchment of the Kumaun Himalaya ranging from 500 - 2500 m asl has been established. A total of 13 forest sites have been screened based on their community characteristics, such as community structure, regeneration, soil, etc.

5. Towards development of model villages through technology transfer for livelihood enhancement in the Central Himalaya, three villages in different geo-environmental conditions were identified and various activities for livelihoods improvement through rural technologies such as yield increasing, income generating, life supporting and value addition and other technologies have been initiated. Baseline data using in-depth rapid rural appraisal approaches has been collected.

6. Assessment of sub-alpine and alpine ecosystems in Great Himalayan National Park between 2800-4500m and agro-ecosystem in Upper Beas Valley was completed. Four populations of *Gentiana kurroo* were assessed between 1423-1821 m asl and Ecological Niche Model developed. Fifteen populations of *B. utilis* from three sites representing dominant shady moist habitats and North West aspects have been assessed and soil and microbial diversity were analyzed.

7. Long-term data base generated on 'aerosols climatology, radiative forcing and temperature rise' in the Kullu valley of Himachal Pradesh. Base line information on 'Land use and Land Classification (LULC)' generated for the five river basins (Sindh, Parbati, Dhauliganga, Ranganandi and Imphal) of the IHR under the project 'Anthropogenic impacts and their management options in different ecosystems of the Indian Himalayan Region'. Environmental flow studies in terms of water quality, discharge, use pattern and management aspects were completed for the Satluj basin.

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

9. Potential options of linking and supplementing pilgrimage tourism with other form of tourism (rural/agro tourism, heritage tourism, nature/eco-tourism and community based tourism) for socio-economic development of the disaster affected Kedar rural landscape have been identified. In this context, and realizing the growing demand of flowers during pilgrimage season, large scale floriculture of Marigold (*Tagetus* spp.) in Triyuginarayan village cluster has been promoted.

10. Long Term Ecological Monitoring (Climate and Vegetation parameters) sites in critical mountain ecosystems (Timberline and Alpine) in Uttarakhand, Himachal Pradesh, Sikkim, and Jammu & Kashmir have been established. Regional mapping of climate sensitive Timberline across the IHR, and detailed temperature lapse rate along altitudinal gradient was investigated. Chronology of Tree ring width (TRW) has been developed for indicator species *Cedrus deodara* (407 year old: AD1609 to 2015) and *Pinus roxburghii* (307 year old: AD1709 to 2015).

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

PUBLICATIONS		
1. Peer Reviewed Scientific Journals		
National	-	26
International	-	61
2. Chapters in Books/Proceedings	-	14
3. Authored/Edited Books/Booklets/Bulletins/Monographs	-	09
4. Popular Articles	-	19
5. Policy papers	-	02

EXECUTIVE SUMMARY

The institute with a strong commitment for sustainable development of the Indian Himalayan Region (IHR) is the only institute of its kind, which addresses physical, biological, social and economic issues of the region and its people in an integrated manner. The R&D mandate of the Institute is broad and covers all the facets of environment and development. Towards achieving this, multi-disciplinary approach and integration are the guiding principles. The emphasis on interlinking of natural and social sciences is the major thrust of all the programmes in the Institute. In this effort, special attention is placed on the intricate balance between fragility of mountains, indigenous knowledge and sustainable use of natural resources. Design and implementation of R&D activities on priority environmental problems, development and demonstration of best practices, technology packages and delivery systems for improved livelihood of the people is the core issues covered under most programmes conducted by the Institute. A conscious effort is made to mobilize a variety of stakeholders (i.e. Students, Researchers, Academicians, Farmers, Citizens, Policy makers, and others) together with the development processes through different initiatives. Therefore, training, education and awareness of a variety of stakeholders is the essential components of all the R&D programmes. To strengthen the R&D activities of the Institute, recently, w.e.f. November 16, 2017, as a follow up of the approved up-gradation structure, the existing themes have been merged and upgraded as 4 centers at the HQs of the Institute: (i) Center for Land and Water Resource Management (CLWRM); (ii) Center for Socio-Economic Development (CSED); (iii) Center for Biodiversity Conservation and Management (CBCM); and (iv) Center for Environmental Assessment and Climate Change (CEA&CC). The regional units of the Institute have also been upgraded and renamed as regional centers, such as, (i) Himachal Regional Centre; (ii) Garhwal Regional Centre; (iii) Sikkim Regional Centre; (iv) North-East Regional Centre; and (v) Mountain Division Regional Centre. A brief summary of aim and vision alongwith R&D activities of different centers of the Institute during the reporting year 2017–18 is as follows.

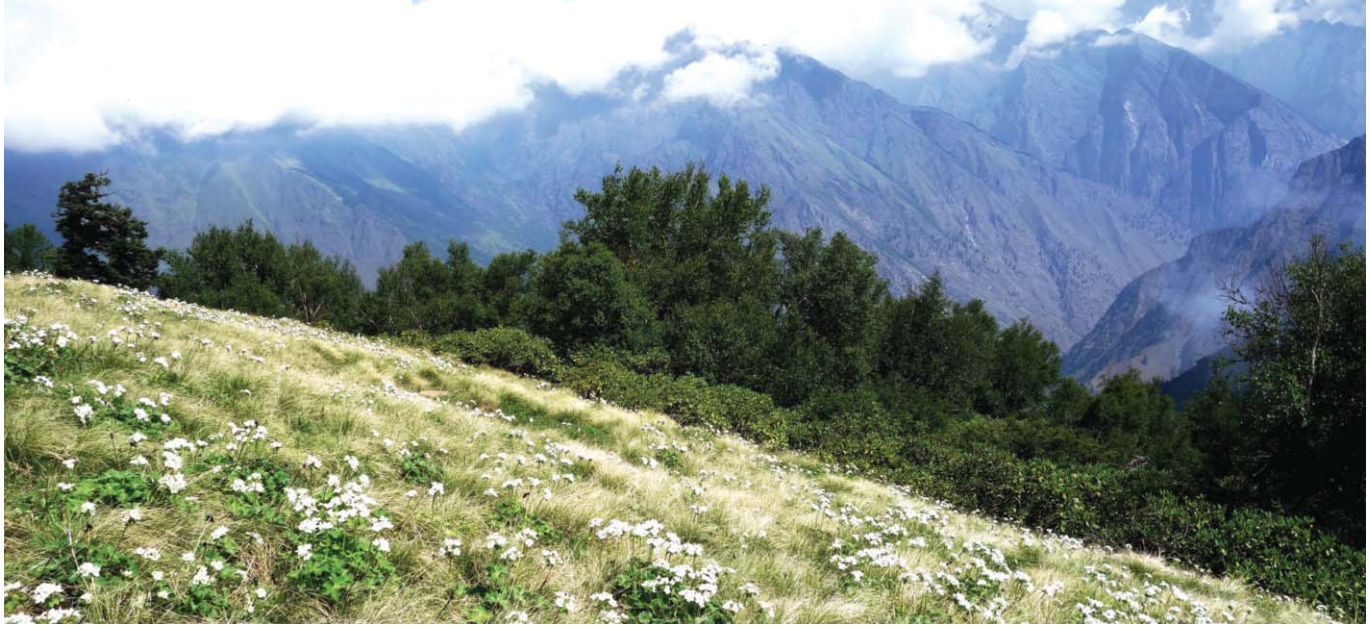
CENTERS OF EMINENCE

i CENTER FOR LAND AND WATER RESOURCE MANAGEMENT (CLWRM)

The center was created with the aim to work on integrated management and sustainable use of goods and services in a watershed along with advancement of science-based solutions for conservation and access to resource. The focal areas of activities of the center are land and soil management, water sustainability, glacier system and climate and geo-hazard assessment. The vision of the center is to integrate land and water resources management to support sustainable development in IHR. The mission of the center is to develop action plan for land and water resource sustainability in IHR through intensive research on mapping of resource dynamics, hydrological and geological processes, and analyses of socio-ecological issues to provide sustainable solutions towards optimal resource use, participatory interventions, technological solutions, and policy recommendations. The center aim to (i) conduct studies of water and related eco-sociological processes operational at watershed level including upstream- downstream linkages, (ii) develop tools and techniques of sustainable land management considering various developmental interventions, and (iii) provide inputs to government and other policy makers for bringing in mountain perspective in LWRM policies. During reporting year, center initiated activities on In House project "Water Sustainability Mapping - Options, Issues and Impacts" with the aim to study the water sustainability in Kosi and Kali Watersheds in Kumaun Himalaya in light of water availability for agriculture and household use, hydropower development/ potential, and its sacred value as pilgrimage/ religious tourism. The reconnaissance surveys in the target sites have been initiated and the instrumentation sites for hydrological monitoring along Kali and Kosi watershed is identified. Information on demography, land-use, agri-biodiversity, crop production, cultural assets, social infrastructure, occupational structure etc., of the nearby villages of Pancheswar Dam has been collected.

ii CENTER FOR SOCIO-ECONOMIC DEVELOPMENT (CSED)

This center was created with the aim to promote activities that lead to ecological and economic security, and sustainable development in the IHR. Poverty, out-migration, natural resource management for sustainable livelihood, technology development and demonstration are the focal areas of activities of the center. The Centre for Socio-economic Development aims to promote equitable, inclusive, and sustained growth by safeguarding economic and social development of communities along with environmental protection in the IHR. It would take up interdisciplinary R&D investigations, blend traditional ecological knowledge and scientific knowledge for livelihood improvement and natural resource management, develop location/problem specific demonstrations and skill development programs, facilitate linkages between knowledge providers, knowledge seekers and users to effectively utilize available knowledge resource/products, and undertake policy advocacy on NRM and sustainable development issues of IHR. The center envisages to (i) develop database on indigenous knowledge system on bioresources, (ii) upgradation of on-farm and off-farm models for livelihoods, (iii) identify indicators of sustainable development and (iv) establish "Entrepreneur Cell". During 2017-18, center focused on identification of sites and preliminary surveys for generating baseline information for implementation of the project "Development of model village through technology transfer for livelihood enhancement in the Central Himalaya" for achieving the multi-sectoral and integrated development approach for the village that have a direct effect on drudgery reduction and overall well being of rural population.



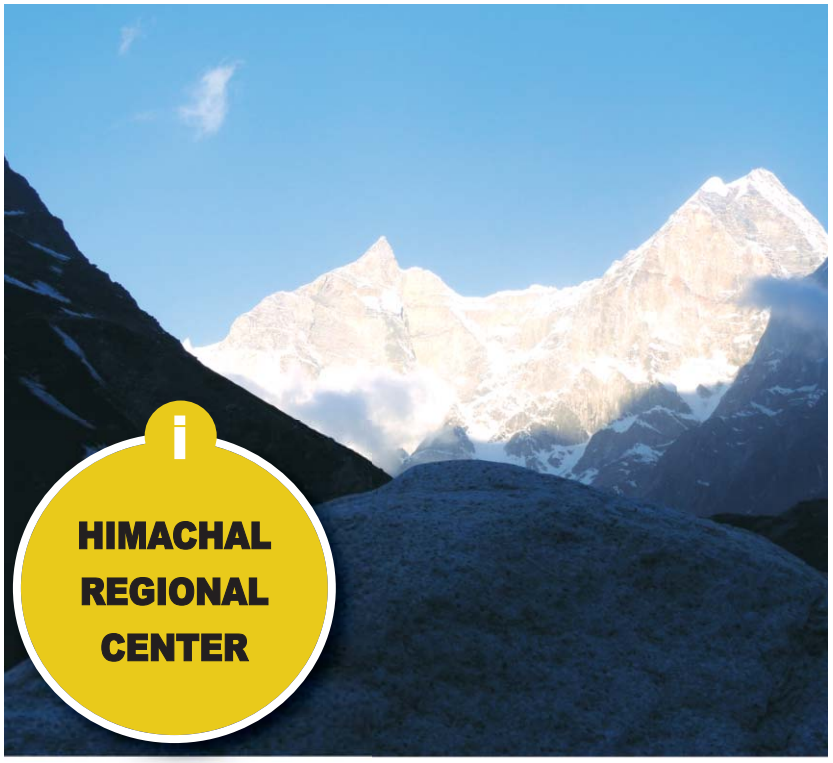
iii CENTER FOR BIODIVERSITY CONSERVATION AND MANAGEMENT (CBCM)

The center has been created to assess and monitor Himalayan biodiversity using state-of-art approach, and transform data and information into knowledge that supports sustainable management of biodiversity. Collaborative and multidisciplinary research on biodiversity, ecosystem services and biotechnological applications are the focal areas of R&D activities of the center. The aim is to further strengthen science based understanding on Himalayan biodiversity to promote its conservation and to ensure sustained flow of its services for human well-being under change scenario. The center envisages to (i) emerge as a core contributor for promoting integrative biodiversity science in the Himalaya to support decision making and foster science-policy-practice linkages, and (ii) act as a nodal referral and capacity building center on Himalayan Biodiversity Conservation and Sustainable use. During reporting period, CBCM succeeded in establishing one major long term ecological monitoring (LTEM) site to realize objective of in house project " Long-term Ecological Monitoring in Western Himalaya and Knowledge Generation for Decision Making" so as to understand intensity and direction of on-going and potential changes on structure and functioning of biodiversity.

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

Realizing that the environmental assessment and climate change are fast emerging areas of investigation in the Himalaya, the focal areas of activities of the center are assessment of environmental parameters, impact of CC on resources, critical ecosystem, develop knowledge to combat CC. The vision of the center is "By 2025, the Centre shall try to be self sustaining and playing a leading role in Environmental assessment and climate change research and advisory in the Indian Himalayan Region". The mission include to bridge gap between research and practice on impacts of climate change in identified key sectors in the Himalaya. The center aims to (i) assess and monitor physical, biological and socio-economic environmental parameters for the development in IHR and (ii) design measures for climate change mitigation and adaptation by communities and developing ecosystem resilience to cope up with climate change risks; and (iii) secure community and ecosystem resilience with appropriate adaptation strategy to cope with climate change risk. The center initiated work on the project "Establishment and conservation of *Ginkgo biloba* and *Taxus wallichiana* using microbial technology: Field evaluation" for demonstrating the benefits of eco-friendly microbial technology in propagation and conservation of medicinally important plant species.

REGIONAL CENTERS



The geographic focus of center is entire Himachal Pradesh and Jammu & Kashmir state covering parts of north western Himalayan Bio-geographic province. The region is recognized for its ecological and economic values manifested by ecosystem integrity, adaptability and ecosystem services. Its protective and productive functions for both upland and lowland dwellers are well known. The major thrust areas of activities for this center include (i) vulnerability assessment of biodiversity of the ecosystems in Trans and North Western Himalaya under biological, anthropogenic and climate scenarios and developing strategies for conservation management, (ii) assessment, monitoring and management of agricultural crops/farming systems for sustainability under chemical contamination and climate change scenarios along an altitudinal gradient in North Western Himalaya, (iii) assessment, characterization and valuation of ecosystem services for sustainable development of the native communities under changing climate scenario, (iv) development of strategies for monitoring and management of water resources under climate change scenario, (v) assessment and sustainable management of eco-tourism in the changing climate scenario through entrepreneurship development, (vi) assessment, monitoring and analysis of the anthropogenic and natural environmental impacts for developing management strategies under climate change scenario, and (vii) development and strengthening of institutional mechanism for information sharing and capacity building of the stakeholders for environmental management. During the reporting period, the center initiated a project "Community driven solid waste management in Himachal Pradesh: A step towards Swacch Bharat Mission "so as to an integrated approach for the management of solid waste could be developed. Initially, various training-cum-capacity building workshops have been organized in Kullu and Manali for awareness generation about the solid waste management. Secondary data relevant to project was collected from Kullu, Manali, Mandi, Bilaspur and Hamirpur from relevant Government Departments have been collected.

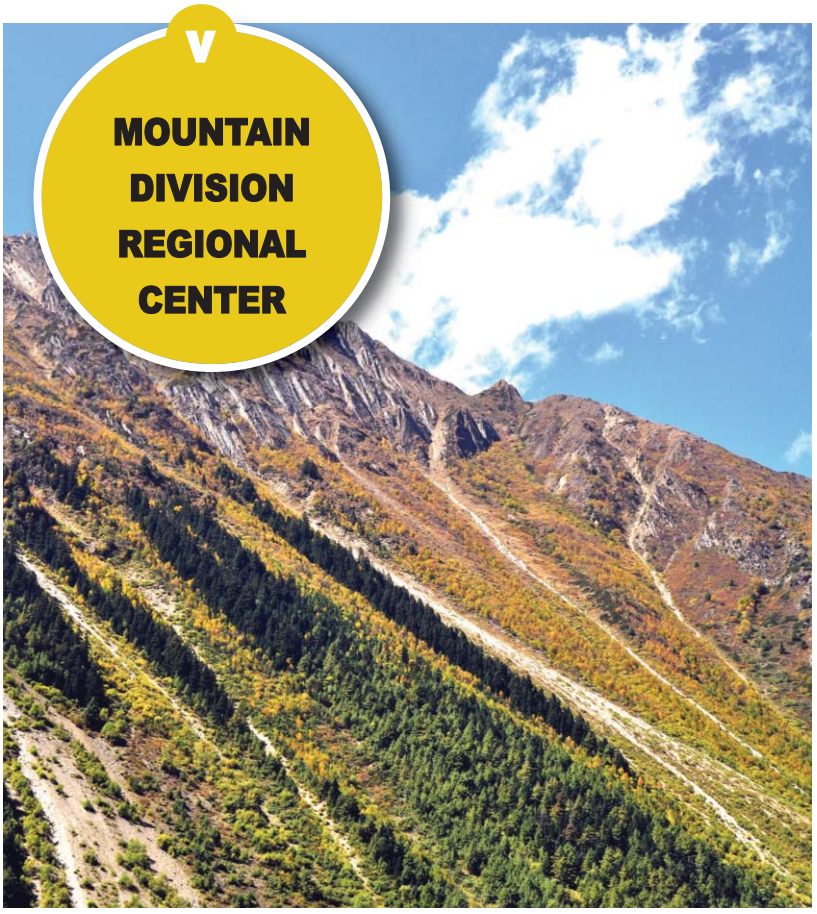
Diversification of hill economies to high value activities is now considered essential for both poverty alleviation and checking degradation of natural resources in the Himalayan Mountains. Moving away from subsistence based agriculture on marginal lands in high-value farm and non-farm products with comparative advantage in hill areas is seen as being a central element to the strategy for sustainable development. Due to the constraints imposed by inaccessibility to markets and services, and environmental sensitivity to some of the useable resources, the choices of activities, technology and scale need to be carefully applied to ensure sustained income generation and environmental conservation. Activities have already been initiated in some of the programmes in the Unit, and hence must be continued and expanded to cover a larger areas, and sectors for integrated development of the rural ecosystem. The center envisage to (i) understand climate change impact in rural landscape and adaptation and livelihood strategies (agriculture, horticulture, pastoralism and traditional livestock husbandry, NTFPs including MAPs), (ii) identify sustainable tourism (nature/community based rural tourism, pilgrimage, river rafting and camping on Ganges) and its environmental, economic and socio-cultural impacts, (iii) approaches for water resource assessment, use and management, (iv) appropriate technology interventions for sustainable development of rural ecosystem, and (v) development of plant propagation packages for conservation, management and large scale cultivation using biotechnological and microbiological tools. The center initiated the project "Reinventing pilgrimage potential for tourism development in the sacred landscape of Garhwal Himalaya, Uttarakhand" with the aim to ensure that the local population in Uttarakhand region should be benefitted by tourism development. Initially, SWOT analysis (strength, weakness, opportunities and threat) with regard to reinventing pilgrimage potential for tourism development has been carried out and identification of potential options of linking and supplementing pilgrimage tourism with other form of tourism has been initiated.

iii SIKKIM REGIONAL CENTER

Sikkim state supports rich floral and faunal diversity varying in different eco-climatic ranges (300 m to 8685 m). There are high endemic and threatened species covering diverse ecosystems and habitats that represent the uniqueness of biodiversity. Local people are largely depended on natural resources for their livelihood. However over-extraction and utilization of the natural resources demands immediate measure to reverse the trend of degradation. Besides, it also needs strengthening participatory management, enhancement of livelihood and self sufficiency and policy review/analysis and capacity building. Major thrust area of Sikkim Regional center would be (i) biodiversity safeguarding at ecosystems, species and genetic level, including ecosystem services, (ii) natural resource use and sustainability, (iii) enhance implementation of strategies through participatory planning and Policy analyses, and (iv) socio-economic improvement/extension and knowledge management through capacity building. The center has initiated a major in-house project "Gridded biodiversity database for conservation and development in Sikkim Himalaya (focus: woody taxa)" for assessing and quantifying the geographic distribution, conservation status and phytogeographic aspects of plant resources of Sikkim Himalaya. Vegetation of Sikkim Himalaya was sampled using grid-based inventorization and the grids with prominent vegetation types were sampled. For generating distribution map using ecological niche modeling various information and datasets downloaded from free web resources viz., Worldclim, MODIS, NDVI etc.

iv NORTH EAST REGIONAL CENTER

Shortening of fallow cycle & changed practices; changes in land use pattern, land tenure and ownership pattern, and customary laws; lack of appropriate policy packages and technological intervention for soil conservation, soil nutrient management and yield enhancement; loss of agro-diversity & promotion of mono-cropping, improper policies; lack of marketing, depletion of traditional knowledge base and policy deficiency in promotion of alternative & innovative livelihoods have been biggest constraint for the North East region. Similarly inventorization of biodiversity, sacred groves, community conserved areas, village forests, hotspots and keystone species is not complete which is a major constraint in addressing the issue of biodiversity conservation. There are alternative employment opportunities based on biodiversity based tourism. Therefore, strengthening of alternative and innovative livelihood options, conserving indigenous knowledge system, capacity building and human resource development are key areas to work on. The major thrust areas of the Center is to study on (i) sustainable socio-economic development and livelihood security (focus on shifting cultivation), (ii) conservation of biological diversity and ecological security, (iii) adaptation/mitigation of Climate Change (CC) impacts, (iv) ecotourism, and (v) sustainable technologies and capacity building. During the reporting period the center initiated a project entitled "Enhancing eco-cultural livelihoods in biodiversity rich areas of Arunachal Himalaya". Various stakeholders' consultation workshops were organized and possible role of the community in project implementation and outcomes has been identified.



V
MOUNTAIN DIVISION REGIONAL CENTER

The GBPIHED has established a dedicated unit as 'Mountain Division' within the MoEF&CC as fifth center of GBPIHED to address specific issues of the mountain ecosystem in an integrated manner through its Institutions, across the relevant key Ministries, and with NGOs and Academia to ensure conservation of mountain ecosystem and sustainable development of the mountain regions. The main objectives of the division are to (i) deal comprehensively with sustainable and integrated development of mountain ecosystems, (ii) sharpen focus on mountain issues and bring these regions in the main stream of development, (iii) foster linkages between upstream and downstream regions by influencing policy & planning based on mutual dependence, (iv) create recognition and awareness regarding dependence of non-mountain ecosystems on mountains. The center through different fellowship projects has initiated to develop a GIS based land use modeling for studying the future projection and dynamic impact on Indian Himalayan Region, understanding eco-physiology of selected medicinal plants with changing environment for better adaptation, and studying on the tradeoffs between conservation and livelihood outcomes in protected area management.

1. INTRODUCTION

During the year 2017-18, various R&D activities were executed by the Institute at different locations of the Indian Himalaya Region (IHR) through its HQs at Kosi-Katarmal (Almora) and five regional center, viz., Himachal Regional Center (Kullu), Garhwal Regional Center (Srinagar-Garhwal), Sikkim Regional Center (Pangthang), NE Regional Center (Itanagar) and Mountain Division Regional Center (New Delhi). Over the years, the Institute has taken significant strides in identifying problems, developing region-specific approaches, demonstrating their efficacy in the field and disseminating information to various stakeholders. The diverse problems thus addressed were related to ecology, resource conservation, traditional practices, livelihood opportunities, land restoration, propagation protocol development, biotechnological interventions, etc. The Institute implements its activities through core funds provided by the Ministry of Environment, Forest & Climate Change (MoEF&CC), Govt of India, and the projects financed by external funding agencies (National and International). The Institute also supports activities of various partner Institutions situated in different Himalayan states through Integrated Eco-development Research Programme (IERP) and National Mission of Himalayan Studies (NMHS). The Science Advisory Committee (SAC) of the Institute reviews the progress of existing projects and provides guidance to develop new R&D programmes. All the projects fall under different thematic areas in the center of eminence such as (i) CLWR, (ii) CSED, (iii) CBCM, and CEA&CC and region specific problems by regional center such as (i) HRC), (ii) GRC, (iii) SRC, (iv) NERC, and (v) Mountain Division Regional Centre.

During the reporting period, activities under besides ongoing projects/programme various activities/projects were concluded. Summaries of such completed projects are included at appropriate places in the text. In due course of time, relevant detailed documents will be published and made available for the public. The progress made during the year 2017–2018 on various in-house and externally funded projects under different thematic and regional centers, a brief account of academic and other activities, along with the statement of accounts, has been presented in this report. The Institute would be most grateful to receive critical comments and suggestions for improving the quantum and quality of outputs of various R&D activities.

2. MAJOR EVENTS

CITIZEN'S SCIENCE PROGRAMME

The GBPIHED Himachal Regional Center, in collaboration with Earth Watch International, organized a Citizen's Science Programme under the project "Scientific Research on Changing Climate and its impact on Floral Diversity and Ecosystem Services (Pollination) at Kullu region of IHR – a Citizen Science initiative" on 3- 12 April, 2017. The programme focused on training and subsequent use of participating trainees for recording of observations and field data, data synthesis, and report work for the GBPIHED-EWI Himalayan Ecosystems Service Research project. The volunteer groups generated information on qualitative and quantitative assessment of biodiversity, density and diversity of pollinators and their preferential foraging plants, phenology, etc.

INTERNATIONAL DAY FOR BIOLOGICAL DIVERSITY

The International Day for Biological Diversity was celebrated at Institute headquarters and its regional centers on May 22, 2017. The celebrations at Institute headquarters focused on awareness building on biodiversity values and conservation, and a SWOT analyses on Biodiversity and Sustainable Tourism in the contextof Uttarakhand. For this event at GBPIHED Kosi-Katarmal (Almora), Shri Narayan Ashram (Dharchula), and a 2-day awareness pro-

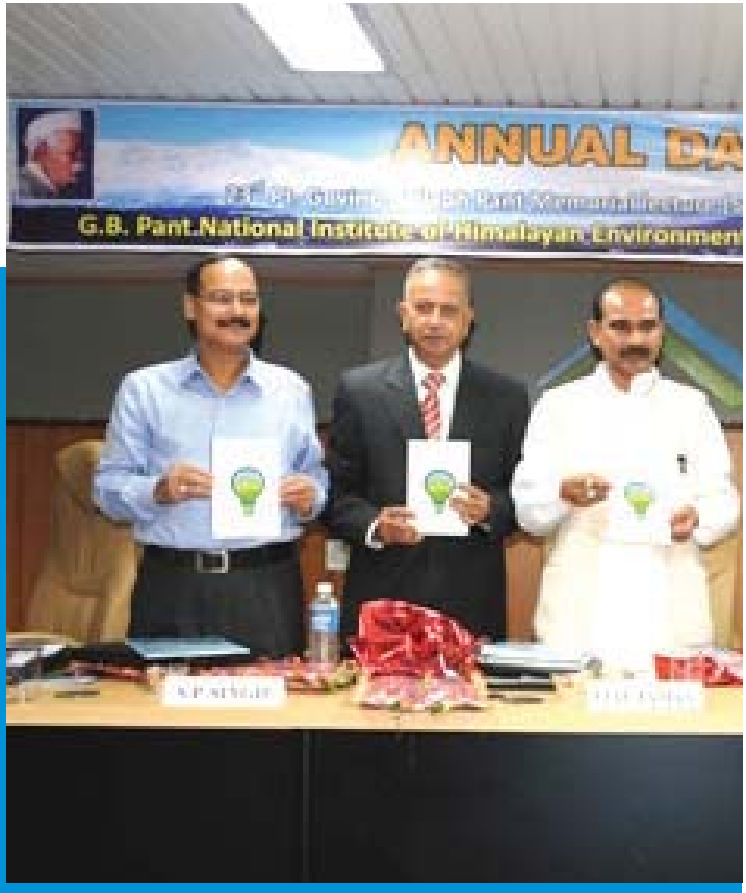
gramme with school teachers and students at GIC Gangolihat were organized. In Himachal center, the day was celebrated with the students and teachers, and declamation contest and painting competition for school students were organized. In Skkim center, the celebration aimed at awareness raising, modalities of linking biodiversity and sustainable tourism in Khangchendzonga Landscape, and the opportunities and challenges for sustainable tourism and biodiversity in Sikkim Himalaya. Lectures by invited resource persons from different places of Sikkim and West Bengal, were delivered and extensive discussions on pros and cons of tourism, and its sustainable development were held. The entire faculty, research scholars and staff of unit participated in the event. In north east center, the day was celebrated at Ziro, Lower Subansiri District in collaboration with Nature Care and Disaster Management Society (NCDMS) for the students of Ziro valley school.

WORLD ENVIRONMENT DAY

GBPIHED celebrated the World Environment Day (June 5, 2017) at its headquarters and 4 regional centers. At headquarters, celebration was clubbed with Popular Lecture Series Programme wherein a popular lecture was delivered by Dr D. K. Agarwal, Former Member of National Green Tribunal. In Himachal center, the event was organized at Dohranala Herbal Garden of the Institute; nearly 105 students and Teachers from 3 Government Schools were participated. In Sikkim center, plantation and campus cleaning was performed, and photography and quiz contests was the part of celebration. The participants expressed their views on climate change and survival scenario, technological interventions, poor knowledge of nature and natural process, and the personal and organizational efforts required to make people come closer to Nature. In NE center, the day was celebrated along with 'Nature Guide' trainees, scientific staff of ZSI-APRC and the scientific and research scholars of GBPIHED. On this occasion, a pledge to protect environment and depletion of natural resources was also administered in the Institute HQs and its units.

VALUE ADDITION OF WILD EDIBLES

GBPIHED, Himachal center in collaboration with JAGRITI (a community based organization) organized a '2-days training programme' on value addition of available wild edibles of the region for women of Kullu Valley at the Institute campus, Mohal-Kullu on 25-26 June 2017. The programme focused on value addition through pickle making and revival of traditional recipes of pickle such as Lingri (*Diplazium esculentum*), Garlic (*Allium sativum*), Apple (*Malus pumila*), Wild Peach (*Prunus persica*), Plum (*Prunus*), Tomato (*Lycopersicon esculentum*), Gulwasa (*Mirabilis jalapa*), Chukh (*Capsicum annum*), Beedana (*Cydonia oblonga*), Galgal (*Citrus psedolimon*), etc. The training programme was attended by 60 women members of the various Self Help Groups of the valley; the value addition also can also provide earnings and livelihood to rural women.



ANNUAL DAY AND PANT MEMORIAL LECTURE

The Institute at its HQs, Kosi-Katarmal, Almora and all the regional centers (Garhwal Regional Center, Srinagar; Himachal Regional Center, Kullu; Sikkim Regional Center, Pangthang; NE regionalCcenter, Itanagar; Mountain Division Regional center, New Delhi) celebrated its annual day and organized 23rd G B Pant Memorial Lecture on 10th September 2017. At HQs Prof. S.P. Singh, Former Vice Chancellor, H.N.B. Garhwal University, Srinagar was the speaker of 23rd G.B. Pant Memorial lecture. While deliberating on "Climate change in Himalayas: Research findings complexities and institutional roles", he requested all to focus their research on mitigation of the climate change as this could be one of the severe problems in future, which will not only affect the vegetation patterns but also a major threat to the society. He indicated that such efforts will lead towards achieving the sustainable development goal. On this occasion, Mr. Ajay Tamta, Minister of State for Textiles; Dr. Dhan Singh, Education Minister, Govt. of Uttarakhand, Shri Raghunath Singh Chauhan, MLA Almora, Former Admiral D.K. Joshi, A.S. Nayal, Director ATI, Dr. Subrata

Bose, officials of MoEF&CC Govt. of India; dignitaries from various organizations, scientists and staff of the Institute participated. At GRC, Himalayan Popular Lecture entitled "Concept and implementation of water conservation and accumulation in mountainous areas" was delivered by Mr. Sachida Nanda Bharti (JalYodha). He stressed that traditional conservation practices should be coupled with advance practices to save the water. The event was attended by around 145 participants comprising of students from Govt. Polytechnic College Srinagar, Scholars and Professors from HAPPRC and Garhwal University, NGOs and other stakeholders. In HRC, Prof. S. K. Sharma, Emeritus Scientist, CSIR – IHBT & former Vice Chancellor, CSKHPKV, Palampur was the chief guest of the function. In SRC, a popular lecture on "Himalayan Way of Life in the context of climate change" was delivered by Prof. T.B. Subba, Vice-Chancellor, Sikkim University. Prof. R.M. Pant, Director, NIRD & PR-NERC Guwahati, Assam delivered a popular lecture at NE RC on the topic "Rural tourism for sustainable development: Insights from North East India".

SKILL AND CAPACITY BUILDING FOR IMPROVED TOURISM SERVICES

A five day long training cum exposure visit was organized from 20th-24th September, 2017 focussing to improve the tourism services in the three pilot sites of Khangchendzonga landscape (KL) in India. Ten participants each from the four villages of three pilot sites were identified based on predefined criteria. The programme continued with various themes under ecotourism development and many experts from various fields related to ecotourism poured their knowledge and shared experiences. The programme was based on providing such basic knowledge and training to the participants on every sphere for a successful ecotourism development in the respective pilot sites. The experts from various fields related to ecotourism discussed on the related themes with practical demonstration and onsite visits. The purpose of the training at Yuksam, in collaboration with KCC was to add up to the training as an exposure visit to the site. The classroom lessons for generating the basic knowledge about ecotourism and its different wings, accompanied by the practical demonstration by involving the participants along with the exposure visits formed power pack learning cum training session for the participants. Experts for various Ecotourism related activities, birds and butterfly experts, experts on waste management, camping, hiking, imparted their knowledge and experiences to the participants.

ANIMAL NUTRITION AND HEALTHCARE FOR IMPROVING DAIRY PRODUCTION

A three day long training and exposure visit on animal nutrition and health care for improving dairy production was organised by the Institute in collaboration with The Mountain Institute-India, Gangtok, Diocesan Integrated Society for Holistic Action (DISHA)-Kalimpong (West Bengal), Animal Husbandry Department, Govt. of Sikkim and International Centre for Integrated Mountain Development (ICIMOD) Nepal at Panchayat Bhawan, Ribdi-Bhareng, West Sikkim from 16 – 18 November, 2017 under Khangchendzonga Landscape Conservation and Development Initiative (KLCDI) programme. The main objective of the training and exposure was to strengthen the participants' knowledge/understanding on nutrient-rich feeding preparation/practices for milking cattle, animal healthcare/medication (home remedies) and also to provide exposure experiences on successful dairy farming practices at local level. Total 45 local farmers from Ribdi-Bhareng GPU participated in the training and exposure visit programme. Several deliberations and technical sessions were imparted during the event and exposure visit to successful dairy entrepreneur was conducted to make event interactive and learning. Besides, five number of fodder chopping hand machines, nutrient-rich food supplements including multivitamins and basic medicines were also distributed to the local participants and an interactive meeting with recently elected panchayat members of the GPU was organized for ensuring their contribution to implement the KLCDI-India activities in the pilot site (Barsey-Singalila).

LONG TERM ENVIRONMENTAL AND SOCIO-ECOLOGICAL MONITORING

Stakeholders' meeting on long term environmental and socioecological monitoring (LTESM) under implementation of Khangchendzonga Landscape Conservation and Development Initiative (KLCDI-India) was held at Chumbi Residency on 14th November, 2017. The meeting was organized by SRC Pangthang and ICIMOD. Participants from Nepal and members from the partner organizations like forest, environment and wildlife management department (FEWMD); Sikkim University; The Mountain Institute-India (TMI-India); Asoka Trust for Research in Ecology and the Environment (ATREE); Himalayan Nature and Adventure Foundation (HNAF); Mutanchi Lom Aal Shezum (MLAS); and Wildlife Institute of India, Dehradun were present in the meeting. The aim of the consultation was to form a standard protocol for Long-Term Environment and Socio-Ecological Monitoring (LTESM), which could be feasible in the Khangchendzonga Landscape (KL), India. The team discussed various aspects that need to be analysed for the establishment of Long-Term Monitoring Sites for the study of the Forest ecosystem and Agro-ecosystem. Discussion was held within the groups and identified the parameters or variables for long-term monitoring. Also, most representative species (flora and fauna) in the different types of forest zonation for long term monitoring site and socio-ecological interaction or ecosystem services were identified.

LINGDEM HOTSPRING NATURE AND CULTURE TOURISM FESTIVAL

The Khangchendzonga Landscape Conservation and Development Initiative (KLCDI)-India programme intends to contribute to the sustainable development of the Khangchendzonga Landscape (KL) through resource management and strengthening livelihood initiatives. The SRC of the Institute in collaboration with Songbing Tourism Development and Management Committee (STDMC) and Mutanchi Loam Aal Shezum (MLAS), Dzongu, organized a "Lingdem Hotspring Nature and Culture Tourism Festival 2017" in Lingdem (Dzongu), North Sikkim from 3 November to 2 December 2017 under KLCDI-India programme coordinated with The Mountain Institute (TMI)-India, Gangtok. Hon'ble Member of Legislative Assembly (MLA), Smt Tilu Gurung, Govt. of Sikkim andHon'ble Dy. Speaker cum area MLA, Shri Sonam Gytatso Lepcha, Govt. of Sikkim was actively participated in the festival and addressed the gathering. Several Sikkim Government officers were participated to support the tourism festival. Several cultural and traditional showcases (stalls) were demonstrated during the event to promote unique Lepcha culture foods (wild edibles, beverages and others) including traditional handicrafts. In addition, several cultural (dance and traditional practices) and sight seen events were organized for promoting community-based tourism.

STAKEHOLDER'S CONSULTATION WORKSHOPS

The NERC organized 2 Stakeholder's Consultation Workshops under (i) NMHS sponsored project entitled "Anthropogenic impacts and their management options in different ecosystems of the Indian Himalayan Region" and (ii) In-house project entitled "Enhancing eco-cultural livelihoods in biodiversity rich areas of Arunachal Himalaya", at Mother's Home Museum Hall, Ziro (Lower Subansiri District, A.P.) on the same day (i.e. 7th December, 2017). The objectives of the workshops were to introduce the project stakeholders regarding the aims and objectives of the project, targeted activities, stakeholder's role in project implementation and expected outcomes. A total of 30 persons from local community, government departments, NGOs, Biodiversity Management Committees (BMCs) etc. participated in both the workshops.

PROJECT EVALUATION COMMITTEE (PEC) MEETING CUM IERP WORKSHOP

Project Evaluation Committee (PEC) meeting cum IERP workshop were organized by Institute jointly with Tripura University, Agartala, Tripura on February 27-28, 2018. Various projects sponsored under IERP were evaluated and sanctioned for funding. It was suggested and highlighted that there is a need of implementation of quality action oriented research, development and extension projects for North Eastern Region. A total 42 projects proposal were invited from North-Eastern states for presentation in the meeting, out of which 38 projects PIs presented their project proposal before PEC members. The PEC meeting cum workshop was successfully conducted in collaboration with Department of Botany, Tripura University.

HANDS-ON TRAINING ON BEEKEEPING

NERC Itanagar organized a hands-on training on Beekeeping under the Inhouse project "Enhancing eco-cultural livelihoods in biodiversity rich areas of Arunachal Himalaya", at Mother's Home Museum, Ziro, Lower Subansiri district (A.P). The resource person for the training programme was Mr. J.P. Saikia, Beekeeper at Department of Arts & Handicrafts, Govt. of Arunachal Pradesh. Mr. Saikia demonstrated different tools and techniques required for Beekeeping and the skills required for colony capture, honey extraction, etc. The training programme was attended by local people and members of Biodiversity Management Committees, various NGOs, youth organizations and Gao Buris of different villages of Ziro valley.

DISASTER RESILIENCE ACTION PLAN

A stakeholders' workshop on 'Developing disaster resilience action plan through GIS and prioritizing actions for natural disaster risk reduction in urban agglomerations of Shillong and Gangtok' was organized by the project proponent, Integrated Research and Action for Development (IRADe) in collaboration with North-Eastern Space Applications Centre (NESAC), Meghalaya and SRC Pangthang at Summit Denzong, Gangtok. The main aim of the workshop was to provide decision-support tools for disaster risk reduction in the urban areas of the north east region of India, development of cadastral maps for micro zonation of hazard and action plan for disaster resilience for Shillong and Gangtok. The workshop was attended by participants from various departments and organizations viz., Land Revenue and Disaster Management, Govt. of Sikkim; Gangtok Municipal Corporation; Geological Survey of India, Sikkim Unit; Met Centre, Gangtok; Urban Development and Housing Department; United Nations Development Programme; Save the Hills; Department of Geology and Geography, Sikkim University.

SWACHH BHARAT MISSION CAMPAIGN

The Institute at its HQs and all the regional centers organized Swachh Bharat Abhiyan in line with the National campaign by the Government of India to clean the streets, roads and villages of the country. Various programme such as 'Swachhta Pakhwada (June 1-15, 2017) Swchhta hi sewa (Septemeber 15 - October 2, 2017), special drive on swachh bharat mission (October 13-18, 2017), etc. were organized time to time by HQs Kosi-Katarmal, Almora and its regional centers.

DIVERSITY - OUR IDENTITY OUR HERITAGE

The Institute in collaboration with Indian partners in KSLCDI project organized various showcasing events, including state level science-policy dialogues during November 22-26, 2017 at Pithoragarh. The aim of the programme was to cater to the need of diverse stakeholder groups ranging from school students/teachers to researchers to farmers, and community organizations to implementers to policy planners. The events included, (i) Exposure cum learning visit to successful interventions for representative cultural groups & departmental representatives (22-23 November 2017; pre event exercise), (ii) Mainstreaming & showcasing Kailash initiative dialogue forum for peoples representatives (24 November, 2017), (iii) My viewing of Kailash landscape contest of expressions and exhibition (25-26 November 2017), (iv) Diversity - our identity our heritage workshop for students and teachers (25-26 November 2017), and (v) Innovative thinking for conservation and development in KSL- policy and programme inputs - Consultative meeting (26th November 2017). All these events were conducted as (i) final delivery (phase I) on efforts and achievements under KSLCDI during 5 years implementation, and (ii) an opportunity to seek guidance from diverse stakeholder groups for next phase of KSLCDI.

CONSULTATION IN KLCDI-INDIA PROGRAMME

A Stockholders' consultation was organized on the implementation of Khangchendzonga Landscape conservation and development Initiative (KLCDI) India at Gangtok on 13th February 2018 by SRC Pangthan. The consultation was focused to share the progress of KLCDI-India initiatives and to discuss the future plan among the stakeholders. Shri Ujjal Ghosh, Chief Conservator Forest (CCF), Govt. of West Bengal, as a chief guest highlighted the problems and opportunities in the Bandapani pilot site of KLCDI-India. He elaborated on the steps taken by North Bengal Forest department particularly in corridor development, water and soil conservation, and land erosion and dolomite mining in the pilot site. Shri C. S. Rao, CCF Forest, Environment and Wildlife Management Department, Govt. of Sikkim delivered his talk on the KLCDI India programme in Sikkim context and emphasized on the prioritization of the indigenous species for the distribution and plantation of fodder species in the pilot site. Shri Rao suggested that the human-wildlife conflict issues in the KLCDI pilot sites (Dzongu and Ribdi) especially black Beer and wild boar needs to be addressed through this programme with the involvement of local community. Dr. Nakul Chettri, International Center for Integrated Mountain Development (ICIMOD) elaborated on the genesis and progress of the KLCDI programme across different countries associated with the KLCDI programme. He emphasized on regional cooperation frameworks, which was endorsed by the three nations, (Bhutan, India and Nepal) for implementing the KLCDI programme in the three countries. The event was largely participated by the various institutes and line departments of the Sikkim and North Bengal states, Non-Government Organizations (NGOs) and community people of three pilot sites of KL-India.

TRAINING ON VEGETATION ASSESSMENT AND STATISTICAL ANALYSIS

Recognizing the need of basic scientific knowledge on collection of plant samples, assessment of vegetation and use of statistical tools for establishment / monitoring of mountain sites in Indian Himalayan Region, under its in-house project 'Long-term ecological monitoring in western Himalaya and knowledge generation for decision making', as capacity building event the Centre of Biodiversity Conservation Management (CBCM) of G.B. Pant Institute of Himalayan Environment & Development organized two week long hands-on training courses entitled 'Vegetation assessment, Herbarium methods and Statistical analysis for Long-Term Ecological Monitoring" at Nature Interpretation and Learning Centre, GBPIHED during 13-19 March, 2018. A total of 60 scholars / students participated from nine different organizations / institutions. The training courses provided basic exposure on (i) methods of field surveys, data collection, analysis and interpretation; (ii) herbarium specimen collection, preparations, preservation, accessioning and the record keeping; and (iii) effective use of statistics for analyzing field datasets.

3. RESEARCH AND DEVELOPMENT PROGRAMMES

CENTER FOR LAND AND WATER RESOURCE MANAGEMENT (CLWRM)

Land and water resource management has been a major R&D activity of the Institute since its inception and pursued under the Core Programme of 'Land and water resource management' during the period 1991 to 2005, and as 'Watershed Processes and Management& Knowledge Products and Capacity Building (WPM-KCB)' and 'Watershed Processes and Management, Environmental Assessment and Management, & Environmental Policy and Governance (WPM-KCB-EAM)' Group Programmes in the later years. The geological fragility & high landslide susceptibility of Himalaya, its value as water tower of Asia, acute water scarcity & low agricultural productivity of Himalayan mountains, and the ecosystem service benefits of Himalayan waters for North Indian plains in terms of growth of settlements/agriculture/hydropower/industries makes it imperative that the land and water resources of IHR be properly harnessed, conserved and utilized by - devising optimal technological solutions at the local level, promoting participatory action for conservation, improving allocation efficiency and use efficiency, and providing policy solutions at state and regional levels. In last few decades, the global warming and climate change have exacerbated the prevalent water scarcity in the high and mid altitude regions of IHR, and melting of glaciers and extreme events induced threats have increased the vulnerability of human settlements, agricultural growth& sustainability and developmental infrastructure, etc., to waterborne and drought related climatic hazards and disasters. There is also a need to develop adaptations and resilience to such changes and challenges.

Over the years the institute has gained widespread experience in mountain hydrology and water resource augmentation works, glacier retreat and glacial discharge studies, land & landslide restoration, and catchment area treatment & soil and water conservation technologies. This experience and the expertise of the Institute can be best utilized in a dedicated centre for 'Land and Water Resource Management' for a more focused R&D on the subject for better understanding of complex issues of mountain hydrology, glacier dynamics, providing decision support for optimal land use, policy prescriptions at state and regional levels, and development of suitable technologies to suit with various requirements of land and water resource management in the IHR..

WATER SUSTAINABILITY MAPPING - OPTIONS, ISSUES AND IMPACTS
(IN HOUSE, 2017-20)

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

ACHIEVEMENTS

1. During this year, the reconnaissance survey in Kali watershed was carried out, and instrumentation sites for hydrological monitoring along Kali were finalized; also instrumentation for hydrological monitoring for study of hydro-dynamics at selected micro-watersheds in Kosi watershed was initiated.

2. In Pancheshwar dam area survey of 134 villages, likely to be affected by construction of dam ,was carried out and information on demography, land-use, agri-biodiversity, crop production, cultural assets, social infrastructure, occupational structure etc., was collected. Also, secondary data on river inflow and discharge at certain points (TawaGhat), water scheduling and flow management, etc. was collected, and compilation initiated. Village wise inventory of assets, and people to be displaced etc. was prepared.

3. The basic maps including location map of Pancheshwar dam, slope map, drainage map, river stream ordering map, map of area/ villages to be submerged and digital elevation model of the Kali Watershed were prepared for assessment of expected loss of land, house/ property, and infrastructure, etc.

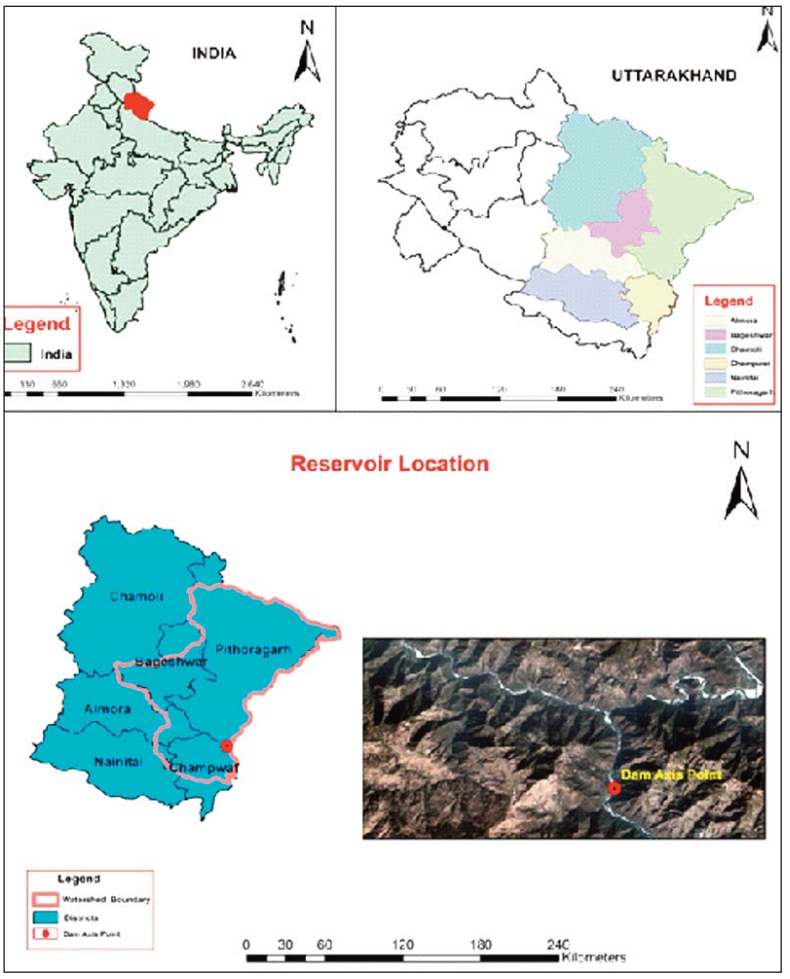


Fig. 1. Location map of Pancheshwar dam in the Kali Watershed

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

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

OBJECTIVES

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

ACHIEVEMENTS

1. Comparison of the CDS model non-local scaling parameter with traditional local velocity parameter for the on-slope site indicates that the new non-local scaling parameter is a good proxy of standard model.

2. A smooth collapse of u, v and w wind velocity spectra on the frequency axis could not be achieved using standard turbulence scaling parameters for convective atmosphere, (Fig. 2 left panel a, b, c). However, as predicted by the CDS model, a satisfactory smooth collapse of u, v and w wind velocity was noted in the wave number axis using non-local parameters of CDS model ***(****Fig. 2 right panel a, b, c****).***

3. The CDS approach, as tested for the first time over complex terrains of Himalaya, was found to perform better than the standard statistical fluid mechanical approach of explaining convective boundary layer turbulence, and is a promising parameterization that could be used in weather prediction models of turbulence.

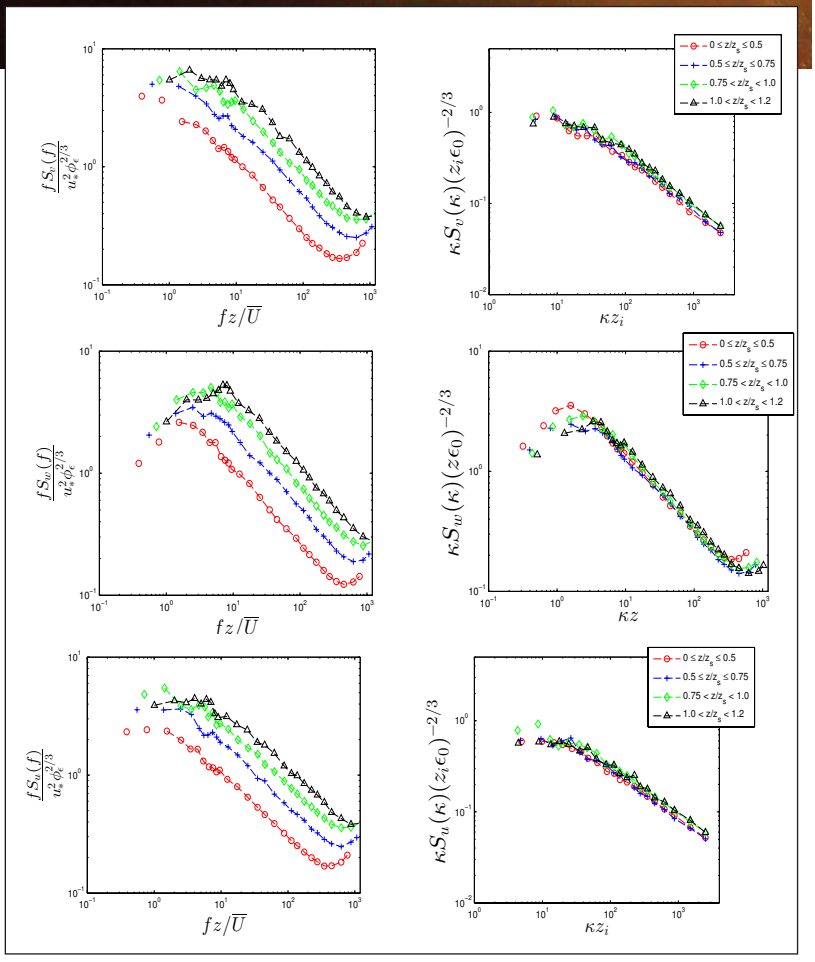


Fig. 2. Comparison of winter time (subplot a) u-spectra (subplot b) v-spectra and (subplot c) w-spectra obtained from (left panels) local and (right panels) non-local scaling parameters for on-slope site.

Integrated Studies of Himalayan cryosphere in Uttarakhand and Arunachal Pradesh (SAC – ISRO, Ahmadabad, 2016-2019)

A Glacier is a mass of ice, snow, water and rock debris flowing down a gradient. Glaciers located across the world region play a critical and vital role in the complex interaction of geological, cryospheric, atmospheric, hydrological and environmental processes that bear special significance for the Earth's biodiversity, climate and water cycle which in turn have a direct impact on human life. Himalaya, the youngest mountain system on earth, has 17% of its area covered by glaciers. Most glaciers in the Himalayan region are retreating due to accelerated global warming during the last century causing long-term loss of natural freshwater storage. This project on integrated study of Himalayan Cryosphere is ISRO-Space Application Centre sponsored project to understand glacier dynamics and mass balance in Himalayan Region. The Institute is working on both field and space based input from two valleys one is Dhauliganga Basin (Uttarakhand) and other one is Tawang Basin (Arunachal Pradesh). For detailed field data, the study is being carried out on two glaciers from above basins, namely, Chipa Glacier (Baling Glacier) from Dhauliganga Basin Uttarakhand and Khangri glacier from Tawang Valley, Arunachal Pradesh.

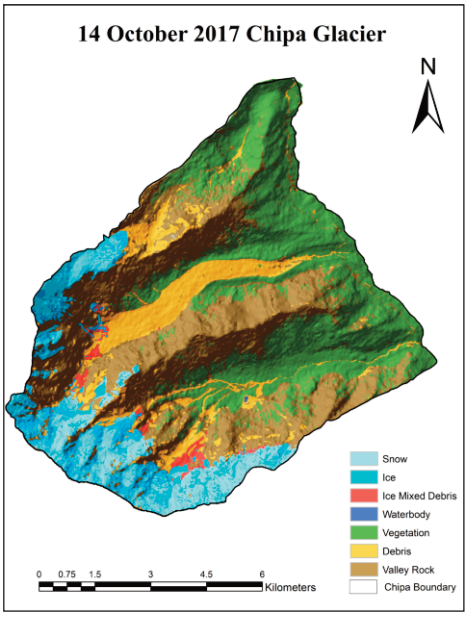


Fig 4. Classified image of Baling glacier using MLC method

OBJECTIVES

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

Fig. 3. Snout of Khangri Glacier

ACHIEVEMENTS

1. In Chipa glacier (Baling), DGPS survey in rapid static and kinematic mode was carried out for study of glacier retreat rate and stakes were installed on the glacier for velocity measurement. Also for measurement of discharge, velocity and water level of melt water stream measurements were recorded at 9:00am, 1:00pm and 5:00pm on regular basis.

2.In Khangri glacier, field survey along the snout was conducted during July 2017 (Fig 3) and reconnaissance was carried out for nearby areas of Tawang to assort potential site for glacier study. Also, rock samples from glaciated basin were collected for the geochemical analysis, and samples of 'Glacier melt water 'at multiple elevations were taken to determine the correlation between geochemistry of surrounding rocks and the water chemistry. The volume of melt water discharge was estimated using area velocity method.

3. Geo-morphological characteristics of Chipa glacier were mapped using multi spectral 4-band Sentinel 2A data at 10m resolution, Planet scope 3B Satellite data at 3m resolution, and DEM at 30 m (ASTER and SRTM data) for preliminary classification and for DEM differencing purpose between 2011 and 2014. For surface analysis, slope, contour, aspect, hill-shade maps were generated using digital elevation model and several spectral indices like NDVI, NDWI, NDGI, NDSI, and NDSII using sentinel 2A imagery for statistical applications and extraction of different feature classes (Fig 4).Supervised and Hierarchical Knowledge based classifications were performed for Chipa and Khangri glacier.

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

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

OBJECTIVES

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

ACHIEVEMENTS

1.The survey of villages was carried out to document detailed procedures of the ethnic cuisines that are being prepared by the villagers that were compiled. Selected grains have been collected from villagers for their further nutritional analysis.

2. Proximate nutritional analysis (Total Protein, Total Carbohydrate, Total Moisture Content, and Total Ash) and antioxidant properties of all the raw grains as well as grains after processing step like soaking with variable factors temperature (5,15,25˚C) and time (4,8,12 h) were determined. **(Fig. 5)**

3.Protein content of raw grains (Horse gram (H) 4.02±0.03%, Rice bean (R) 4.59±0.03%, Black Soybean (BS) 2.59±0.06%, Barnyard Millet (BMS) 0.513±0.02 was comparatively higher than the soaked; whereas Total Carbohydrate, Moisture content and Ash Content of soaked samples were greater than raw grains showing a decreasing pattern with increase in soaking time. **(Fig. 6)**

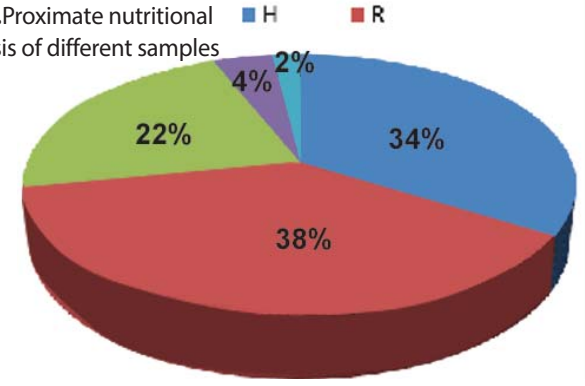


Fig. 5. Proximate nutritional analysis of different samples

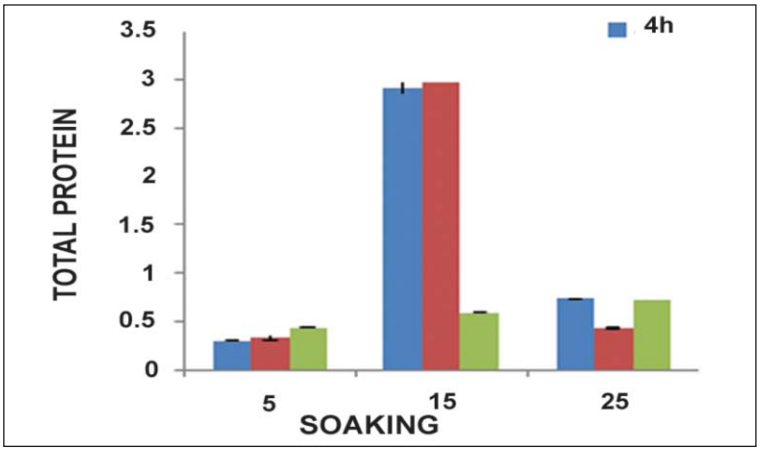


Fig. 6. Total protein percentage of Horse gram grains

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

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

OBJECTIVES

1. Preparation of activated carbon (AC) and biological activated carbon (BAC) using pine needle and microbes (in case of BAC)
2. Estimation of AC/BAC efficiency for the removal of detergent metabolites, plasticizers pharmaceutical components from model fed system.
3. Regeneration studies of AC/BAC.

ACHIEVEMENTS

1.On the basis of plate experiments, bacterial strains were selected for batch mode experiment. Effect of variables such as temperature, pH, RPM, inoculums volume and different concentration of target PPCP compounds (up to maximum harmful limit) were studied for microbial degradation studies in batch mode.

2. These bacterial strains have shown the ability to grow in mineral salt media at temperature range 4°C-25°C (25°C opt.) and pH range 6.5-8 (7 opt.).

3.These bacterial strains have shown the ability to grow in mineral salt media at temperature range 4°C-25°C (25°C opt.) and pH range 6.5-8 (7 opt.).

4.The selected bacteria showed positive response for the degradation of caffeine, bis- phenol A, Ibuprofen and Estriol.

5.The bacteria have shown degradation up to 93 % in 96 hours (Fig. 7) at different concentration ranging from 5-180 ppm for Bis-phenol A, Caffeine, Ibuprofen and Estriol.

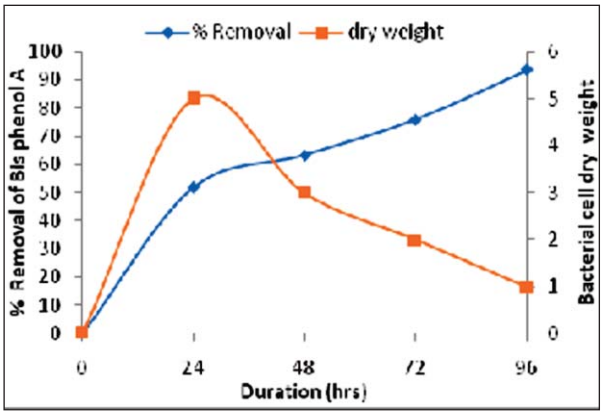


Fig. 7. Degradation of bacteria at different concentration Bis-phenol A

SUMMARY OF COMPLETED PROJECT/ACTIVITY

Ecological, social and policy implications of changing water resource scenario in Indian Himalayan context (In house, 2012-2017)

Recent development in industries, booming urbanization and agriculture system alters the land use/land cover that increases the demand of water in manifolds, which puts extreme pressure on mountain water resources. In this fragile mountain ecosystems of Himalaya, changes in the timing and volume of available water for rural water supply and irrigation can threaten water security and agriculture production. This further creates water use conflict in the area. With established facts of severe water scarcity in hills for agriculture as well as for domestic and industrial use, the water demand-supply assessment studies still lack in this regions. With the aim of closing the gaps between water management and catchment hydrology by addressing both bio-physical factors influencing the river and socio-economic factors affecting the level of domestic, agriculture and industrial demand; this project has run Water Evaluation and Planning (WEAP) tool in Kosi and Mohalkhad watershed for evaluating the water demand status of the area and water allocation strategy is formed. Major findings of the project are suggested below:

- Water scarcity in more than 70% villages of Kosi watershed is found to be an important indicator of changing water scenario. Further, the changes in rainfall quantity and timing in rainfall are also experienced by the peoples living in the area. Community perception indicates that precipitation pattern has changed. Decrease in rainfall quantity and change in rainfall timing is experienced by 100 % respondent of this region.Majority villagers (>48%) in Mohalkhad watershed felt that less investment on development and maintenance of water resources could be the reason of less water availability in recent years. Villagers face maximum water scarcity in May and June.

- It is observed that there is increase in impervious area (2 times in 51 years) along with the encroachment of barren areas into forest land in Kosi watershed which has affected the hydrological response of the watershed.

- Hydrological study shows that Qmax/Qmin is varying greatly in different years. From the hydrograph, it was observed that the river flow responses the rainfall pattern over the Kosi watershed on daily and seasonal scale, with time lag of few hours to a day. The watershed hydrographs show the generation of sporadic peak flows which indicates the limited surface retention of the area.The Flow Duration Curve (FDC) analysis clearly indicates that the river flow at present demand level can supply water for nearly 290 days only in a year. This means water storage of 75 more days is required for meeting domestic demand of the watershed.

- The Water Quality Index (WQI) map for Kosi watershed has been prepared in GIS environment. WQI of Kosi watershed is 25.22, which falls under good category, signifying that the quality of groundwater for drinking and other purpose is safe. The percent of ground water samples in excellent category (0 – 20) is 15.45 percent, 81.82 percent of samples falls under good category (20 – 40), 1.82 percent in moderate water quality category (40 – 60) and 0.91 percent in bad category (60 – 80). There exists zero percent of groundwater sample in very bad (80 – 100) water quality category in Kosi watershed.

- The per capita water use for domestic purpose in Kosi watershed as a whole is 26.15 l/day/person. The amount of total per capita water use by human in Kosi watershed is 30.35 l/day/person, which is below than the national rural water demand coefficient (40 l/day/person). Overall the demand for water for livestock in Kosi watershed has increased to 10910 Cu m/day (2014) from 8836 Cu m/day (2007), showing an increase of 2074 Cu m/day. In 2007, the use of water for livestock purpose in Kosi watershed was 6110Cu m/day, which has increased to 7393 Cu m/day (2014), showing increase of 1283Cu m/day.

- WEAP model is customized for Upper Kosi and Mohalkhad watershed using available datasets. An attempt has been made to demonstrate the capability of the WEAP model to simulate the demand and resource assessment of the area. The WEAP model is run for the two different agricultural scenarios (1. Reference and 2. Deficit irrigation) with future climate data (2015-2030) of GCM GFDL-ESM2M under RCP 4.5.Overall, the customized WEAP model performs satisfactorily and able to simulate the climatic variation and corresponding water demands and available options to meet out unmet demands of the different sectors.

SUMMARY OF COMPLETED PROJECT/ACTIVITY

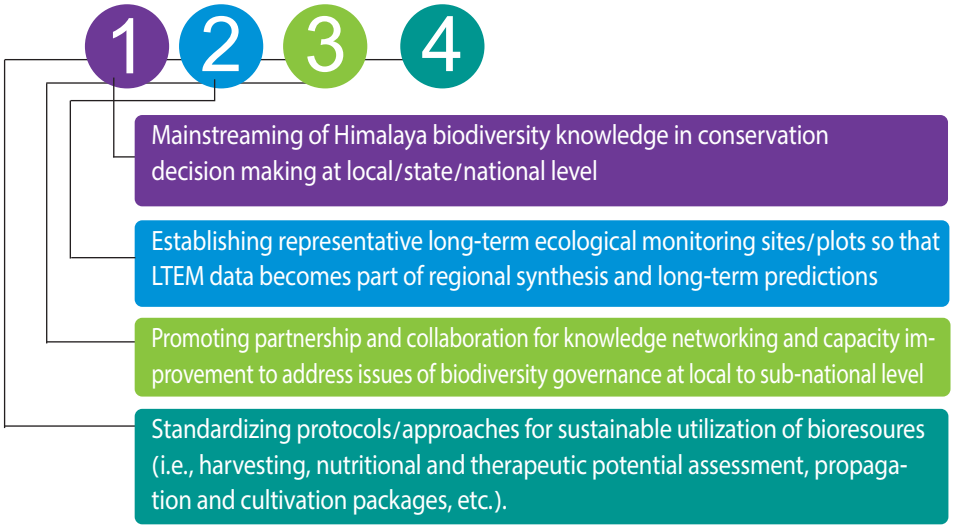
Farming system and changing climate regime: Impact of biophysical and socioeconomical drivers on the farm yields of central Himalaya (Inhouse, 2012-2017)

Around 70% population in the central Himalaya is dependent mainly on agriculture, horticulture and animal husbandry and, about 85% of the total agriculture of the central Himalayan region comes under rain-fed category. Although in recent past, a decreasing trend in the agro-productivity of major crops of this region has been observed. Changes in the socio-economy, agro-practise, landholding, governmental policy along with few bio-physiological and climatological parameters are presumed to be responsible for this decline. However, knowledge of accurate and significant drivers and their degree of influence on the decline of the agroproductivity is ambiguous. Therefore, identification and quantification of drivers affecting agro-productivity of this region is of superior importance and requires multiplicity of approaches with detail knowledge of the system. Hence, this project aims at addressing the following objectives: (i) quantification of biophysical and social drivers affecting rain fed land based agro-productivity in central Himalaya; (ii) assessment of vulnerability of the agro-productivity with respect to changes in significant drivers; and (iii) sensitivity assessment of the agro-productivity with respect systematic changes in the identified drivers. The study area selected for the project was Almora district, and impact of changing biophysical and socio-economical parameters on the yield of three traditional rain-fed crops (rice, wheat and madua) was assessed. Results of this study indicate that critical low yields of rice and madua were attributed to decrease in cropping area followed by decline in number of cultivators and decreased total rainfall. Similarly, for wheat yield reduction, soil pH and increased livestock number were the most significant parameters indicating farmers shifting to animal husbandry during winter months. When futuristic climate change impact (i.e. temperature increase greater than 2°C and rainfall decrease by 10% of climatology) on crop yield was assessed using Generalized Linear Model predictions, yield of rice and wheat was found to increase with increasing temperature and rainfall while yield of madua was found to decrease. Results from a two-step Logistic regression model, developed to analyse and identify key determinants of farmers' perception and adaptation to climate change, indicated that that farmers' perception was significantly influenced by age and education of head of the household and information on climate change. Farmers' adaptation to climate change was significantly determined by gender, household size, farm size, economic investments, dependency ratio, distance from market, irrigated land, and livestock ownership. It was also noted that socio-economic factors play more important role in farmers' decision for adaptation than the institutional factors. Although, climate change was perceived by most of the farmers (78%), yet due to various limiting factors, only 22% have responded to change through various adaptation measures.

CENTER FOR BIODIVERSITY CONSERVATION AND MANAGEMENT (CBCM)

Recognizing that the Himalaya is: (i) one of the hotspots for biodiversity, and (ii) provider of goods and services to large population in Indian subcontinent, biodiversity conservation and management remains 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 select 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 impact oriented role in Himalayan biodiversity sector. The aim is to further strengthen science based understanding on Himalayan biodiversity to promote its conservation and to ensure sustained flow of its services for human well-being under global change scenario.

OBJECTIVES



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

The Himalaya is recognized as (i) hotspot for biodiversity, and (ii) provider of goods and services to a large population living within and outside the region. This, however, represents a highly complex and diversified system which is highly sensitive towards natural (e.g., climate change) and human induced perturbations. In the recent years climate change has posed a new threat to biodiversity. The magnitude and consequences of the impacts of climate change and loss of biodiversity are still poorly understood. Arguably the future of biodiversity in the region would define the future of local communities and downstream dependent people. Therefore, understanding intensity and direction of on-going and potential changes on structure and functioning of biodiversity attributes becomes important. However, in absence of Long-term Ecological Monitoring Site(s) the region lacks mechanism for continuous flow of robust data-sets/information required for taking informed decisions. Also, the available data-sets on biodiversity are fragmentary. Realizing these gaps, with a focus on west Himalaya, the project broadly attempts to: (i) Establish Long-term Ecological Monitoring Site(s), representing three altitude zones, for continuous monitoring and response studies to ensure effective flow of information for decision-making, (ii) Synthesize available biodiversity information to make it utilizable for effective conservation planning and suggesting sustainable use of biodiversity.

OBJECTIVES

To establish long-term ecological monitoring site (s) for (i) continuous monitoring (structural and functional feature) of selected plant biodiversity components, and selected goods and services, and (ii) developing mechanisms for effective flow of information for decision-making on conservation and sustainable use of bio-resources at local and regional scales.

To document response patterns of selected biodiversity elements for (i) enhanced understanding on change sensitivity, individually and collectively; and (ii) suggesting best possible options for long term conservation and livelihood promotion.

To collect, collate and synthesize available biodiversity information to make it utilizable for (i) effective conservation planning (i.e., unique & threatened species, conservation areas, and sensitive habitats), (ii) suggesting sustainable use (i.e., medicinal plants, wild edible plants, and biodiversity based livelihoods options).

To promote partnership for knowledge networking and capacity improvement for (i) effective flow and sharing of research and evidence based information/knowledge; (ii) better connected knowledge on biodiversity and ecosystem services with decision-making; (iii) enhance capacity of stakeholders to understand linkages between biodiversity and sustainable development in the region.

ACHIEVEMENTS

1. Extensive field-visits, phytosociological studies for vegetation assessment and stakeholder's discussions across various forest types in river Gaula catchment (Dist. Nainital) for selection of representative forest sites for long-term ecological monitoring (LTEM) were carried out by the Project team.

2. An altitudinal transect (679-1861 m asl) representing four major forest types was identified for establishment of LTEM plots from Bhujiaghat to

Kailakhan falling in the Gaula catchment (Dist. Nainital). In this transect 1 ha LTEM plots have been marked in the forests of Sal (*Shorea robusta*), Pine-mixed braodleaf (Pine-Oak), Pine (*Pinus roxburghii*) and Oak (*Quercus leucotrichopohora*) (Table 1; Fig. 8).

3. Vegetation studies revealed that in the Gaula catchment a total of six forest types (viz., Cocculus-Murraya mixed forest, Pine-Sal mixed forest, Pine forest, Oak-Pine mixed forest, Deodar forest and Oak forest) are found along an altitudinal gradient of 700 - 2300 m asl. Locational details and importance value index (IVI) of the dominant tree species are given in Table 2. Across the 12 altitudinal bands (100 m interval) the IVI of dominant forest tree species varied from 72.2 (*C. deodara*) and *P. roxburgh*ii (IVI = 289).

4. List of plants (trees, shrub, herbs, climbers, ferns etc.) was prepared for these LTEM plots established across four different forest types. Phenological observations carried out across the four LTEM sites revealed that at the low altitude Sal and Pine forest sites budbreak, leafing and flowering in herbs, and leaf senescence and leaf drop in trees was recorded in more number of individuals than the high altitude Oak forest. Detailed phenological data collection and synthesis is in progress.

Fig. 8. Long term ecological monitoring sites in different forest of Gaula catchment. A-Oak forest, B – Mixed forest, C- Chir-Pine and D – Sal Forest

Table 1. List of LTEM sites with location details, forest types and dominant tree species

Forest type	Site	Altitude (m asl)	Latitude (N)	Longitude (E)	Dominant / Co-dominant tree species
Sal	Bhujiaghat	679	29°17'56.7"	79°32'14.5"	*Shorea robusta* *Mallotus philippensis*
Mixed Broadleaf	Nalaina	1502	29°20'13.5"	79°27'20.3"	*Pinus roxburghii* *Quercus glauca*
Pine	Patwadangar	1498	29°20'25.4"	79°27'05.6"	*Pinus roxburghii* *Myrica esculenta*
Oak	Kailakhan	1861	29°22'37.5"	79°28'50.2"	*Quercus leucotrichophora* *Rhododendron arboreum*

Table 2. Qualitative and quantitative details of different forest types in Gaula catchment

S.N.	Altitudinal range (m asl)	Lat. & Long.	Forest types	Dominant/co-dominant /other species	IVI
1	700-800	N29°15'27.0" E79°39'55.4"	Cocculus-mixed forest	*Cocculus laurifolia* *Rhus sp.* Other species	108.88 104.50 74.48
2	1000-1100	N29°17'47.7" E79°44'59.0"	Sal-Pine mix	*Pinus roxburghii* *Shorea robusta* Other species	205.00 86.00 8.99
3	1200-1300	N29°17'57.2" E79°44'43.2"	Pine dominated	*Pinus roxburghii* *Shorea robusta* Other species	234.35 65.65 -
4	1400-1500	N29°18'14.1" E79°44'27.2"	Pine dominated	*Pinus roxburghii* *Shorea robusta* Other species	243.69 47.52 8.80
5	1500-1600	N29°19'03.4" E79°44'12.3"	Pine forest	*Pinus roxburghii* *Lyonia ovalifolia* Other species	288.98 11.02 -
6	1600-1700	N29°19'21.1" E79°43'51.9"	Pine forest	*Pinus roxburghii* Lyonia ovalifolia Other species	274.83 25.17 -
7	1700-1800	N29°19'39.4" E79°43'54.9"	Pine dominated	*Pinus roxburghii* *Myrica esculanta* Other species	225.50 44.04 30.46
8	1800-1900	N29°20'04.5" E79°43'41.2"	Pine dominated	*Pinus roxburghii* *Myrica esculanta* Other species	198.89 38.36 62.73
9	1900-2000	N29°20'13.8" E79°43'43.2"	Pine mixed	*Pinus roxburghii* *L. ovalifolia* Other species	86.72 55.20 158.05
10	2000-2100	N29°20'30.9" E79°43'34.6"	Deodar mixed	*C. deodara* *Myrica esculenta* Other species	72.20 36.29 191.49
11	2100-2200	N29°25'31.0" E79°42'34.2"	Oak forest	*Q. leucotrichophora* *Q. floribunda* Other species	107.01 56.26 136.72
12	2200-2300	N29°23'39.3" E79°39'59.4"	Oak forest	*Q. leucotrichophora* *Pinus species* Other species	128.78 75.91 95.29

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

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

OBJECTIVES

- To characterize and map timberline zone in the IHR using satellite and ground based observations including smart phone applications
- To determine the temperature lapse rate (TLR) and pattern of precipitation along altitudinal gradients in different precipitation regimes across the IHR
- To study plant diversity, community structure, tree diameter changes and natural recruitment pattern along the three principal sites in the IHR
- To understand tree phenological responses, nutrient conservation strategies and tree-water relations in response to warming climate
- To study relationship between tree ring growth and past climatic changes in different climate regime across IHR
- To understand the impact of depletion of snow-melt water on growth of tree seedlings, grasslands species composition and selected functional processes
- To promote participatory action research (Citizen Science) on innovative interventions to improve livelihoods, women participation in conservation and management of timberline resources

ACHIEVEMENTS

1. In Chopta-Tungnath timberline ecotone (altitude, 2955-3700 m asl) timing of major phenophases, leaf growth and leaf nitrogen dynamics were studied in five timberline tree species (viz., *Abies spectabilis*, *Betula utilis, Quercus semecarpifolia, Rhododendron arboreum* and *R. campanulatum*). In addition micro-climatic data and soil physico-chemical analysis was undertaken.

2. Observed that Tungnath is characterized by a markedly higher mean Observed that growing season temperature than the climatic treelines of the world (11.2°C vs. 6.7°C) and mean soil temperatures (6.4°C at 10 cm depth vs. 9.8°C at 30 cm depth at Tungnath). The atmospheric temperature and soil temperature were positively correlated. The soil C:N ratio was recorded ranging from 9.8 (*R. campanulatum*) to 14.6 (*B. utilis*). Both soil organic C ($r = 0.223$) and N ($r= 0.301$) decreased with increasing altitude of the five forest stands and the reverse were true for C: N ratio. The peak relative humidity was recorded in August and the peak soil moisture in July.

3. The tree line species were characterized by delayed budbreak and leafing, slow leaf expansion, short growing period (2-4 months), lower period of steady-state in peak leaf mass and rapid leaf mass loss, low nitrogen concentration in leaves (1.7% vs. 2.5%), a greater N mass resorption efficiency (34% in *A. spectabilis* to 63% in *R. arboreum*), slow shoot growth, lower shoot length (5.6 cm vs. 9.5 cm) and higher leaf density in shoots (1.2 vs. 0.8 leaves/cm shoot length) than the mid-altitude forest trees. The expansion rate of *R. campanulatum* population (seedlings and saplings) in Tungnath was found 1.4

m/yr (Fig. 9). It is expected that with the increasing rate of warming in Tungnath the phenological behaviour of tree line species would change markedly in future leading to changes in ecosystem properties.

4. Geodatabase for Uttarakhand state has been developed in relation to timberline mapping and characterization of spatial attributes. Landsat 8 images of year 2015 were used to determine timberline in the state.

5. Timberline in the state runs 2750 km in the mountains. In rare locations of the state, high altitude timberline may occur between 2600m asl altitude (negligible but present) and may ascend up to 4,365 m asl. Nearly one third of the total timberline in the region occurred between 3400m and 3600m altitude (Fig. 10).

6. Maximum expression of TLE (57.6% of the total timberline) was in between the 3400-3800m asl, hence this elevation band can be considered as a regional timberline ecotone for the Indian Central Himalaya. A sharp decline in length of total timberline below 3200 and above 4000m asl indicates unfavorable conditions, at both the ends, for growth of tree species occurring in high altitude Himalayan forests.

7. Increase in temperature from winter to monsoon was found across the entire altitude transect. Highly significant correlations ($p<0.05$) was found between altitude and temperature indicate that the relationship between temperature and elevation is strong (Fig. 11).

8. Temperatures lapse rates (TLR) for two different aspects (North-West and South-East) of the Tungnath-Chopta (CT) transect were analyzed. Variation in mean temperature along elevations of all locations is shown in Figure 11.

9. For maximum temperatures, the TLRs are found to be varying between -0.14 ±0.13°C/100m in December to -0.84±0.42 °C/100m in March. Whereas, for minimum temperatures, TLR varied between -0.18±0.37°C/100m in December to -0.54±0.02°C/100m in May.

Fig. 9: Seedling growth and internodes measurements to determine the age of plants and rate of expansion of *R. campanulatum* Krummholz in Tungnath tree line ecotone.

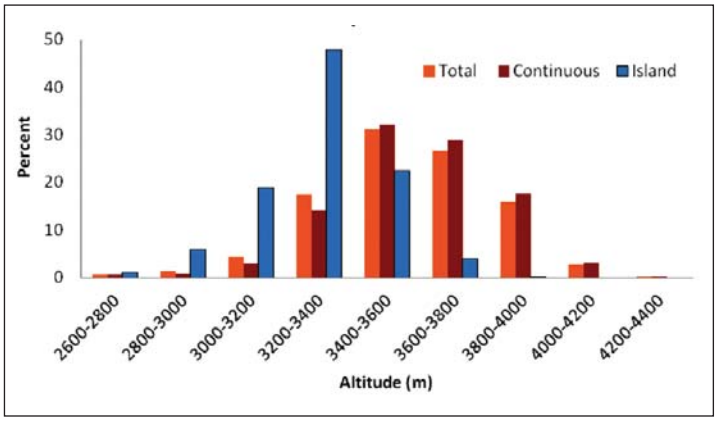


Fig. 10: Distribution of different types of timberline in different altitudinal bands

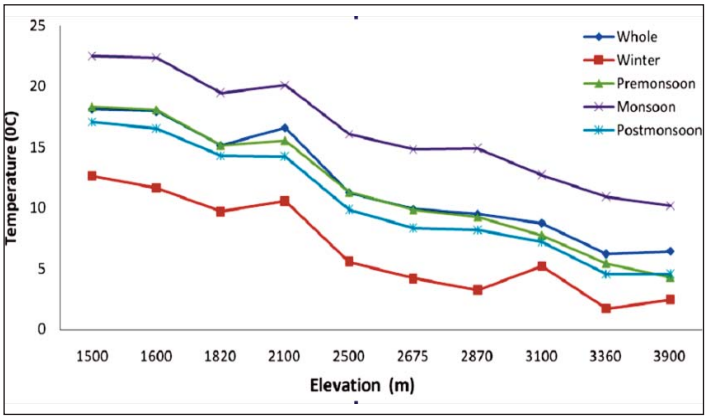


Fig. 11: Mean temperature at all locations for entire transect plotted against elevation for annual, pre-monsoon, monsoon, post-monsoon, and winter period

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

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

OBJECTIVES

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

ACHIEVEMENTS

1. A field survey was conducted during Jun and Aug 2017 at Valley of Flowers National Park (VoFNP) and July at Great Himalayan National Park (GHNP) for ecological assessment of floristic diversity. A total of 177 specimens collected and identified from Valley of Flowers National Park. Out of 42 families, Asteraceae was the dominant family with 17 species and family Rosaceae was the co-dominant with 19 species.

2. In VoFNP, fifteen density of Threatened Medicinal Plants (TMPs) namely *Aconitum balforii* Stapf (0.20 ind/m^2), *Aconitum violaceum* Jacquem. ex Stapf (0.25 ind/m^2), *Angelica glauca* Edgew. (1.58 ind/m^2), *Arisaema jacquemontii* Blume (0.47 ind/m^2), *Bergenia stracheyi (*Hook. f. & Thomson) Engl. (0.73 ind/m2), *Dactylorhiza hatagirea* (D. Don) Soo (0.49 ind/m^2), *Fritillaria roylei Ali* (0.39 ind/m^2), *Juniperus communis* L. (0.24 ind/m^2), *Malaxis muscifera* (Lindl.) Kuntze (1.00 ind/m^2), *Meconopsis aculeata* Royle (0.13 ind/m^2), *Nardostachys jatamansi* (D. Don) DC. (0.1 ind/m^2), *Polygonatum verticillatum* (L.) All. (1.56 ind/m^2), *Rheum australe* D. Don (0.23 ind/m^2) *Saussurea obvallata* (DC.) Edgew. (0.3 ind/m^2) and *Sinopodophyllum hexandrum* (Royle) T.S. Ying (0.87 ind/m^2) were recorded.

3. In GHNP, the density of TMPs of nine species namely *Angelica glauca* Edgew. (0.2 ind/m^2), *Bergenia stracheyi* (Hook. f. & Thomson) Engl. (0.75 ind/m^2), *Juniperus communis* L. (0.013 ind/m^2), *Meconopsis aculeata* Royle (0.28 ind/m^2), *Picrorhiza kurrooa* Royle ex Benth. (0.28 ind/m^2), *Rhododendron anthopogon* D. Don (0.17 ind/m^2), *Rhododendron campanulatum* D. Don (0.1 ind/m^2), *Saussurea obvallata* (DC.) Edgew. (0.4 ind/m^2) and *Sinopodophyllum hexandrum* (Royle) T.S. Ying (0.25 ind/m^2) were recorded.

4. There are total elevan invasive species in GHNP and only one species namely, *Cuscuta reflexa Roxb* (Cuscutaceae) recorded from VoFNP.

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

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

OBJECTIVES

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

ACHIEVEMENTS

1. Development of propagation protocol through seed germination for mass multiplication of *H. spicatum* and a A total of 10000 plants were produced through seed germination and rhizome cutting. 8000 *V. jatamansi* plantlets of tissue culture raised plants are in hardening condition.
2. Higher below ground biomass was observed in full sunlight but higher above ground biomass was observed in 50% shade. Stress related antioxidant and biochemical were found higher in plants under full sunlight
3. 4500 plants of H.spicatum and 2200 plants of *V.jatamansi* were distributed to interested farmers for promotion of cultivation. Now more than 500 Villagers of Chaudas valley are awared about cultivation of medicinal plants.
4. After awareness and training programmed for cultivation of medicinal plants now total 134 farmers of 9 villages were agreed for cultivation of medicinal plants. 31 farmers adopted the techniques and started cultivation of medicinal plants in 33 Nali land.
5. 20 x 5m demonstration plot was developed in Sri Narayan Ashram (2750 m asl) and Suryakunj (1150 m asl). A total of 70 small beds (2x2m) have been developed for plantation of target species.

SUMMARY OF THE COMPLETED PROJECT

Climate change impacts on ecosystem services in the Indian Himalayan region (In house, 2013 - 2017)

The Himalayan region is important on account of its unique topography, micro-climatic conditions and strategic location, and represents one of the 34 "Global Biodiversity Hotspots'. The biodiversity rich forests with a range of ecosystem goods and services of this region are highly valuable for the global community in general, and for the regional inhabitants (both highland-lowland), in particular. However, in the recent decades under the influence of climate change (CC) the structural and functional attributes of forest ecosystem services are likely to have altered having implications to the ecosystem functioning. Realizing the above, the present project was undertaken across an altitudinal gradient (300 – 2100 m asl) on major forest ecosystems (*Shorea robusta, Pinus roxburghii, Quercus leucotrichophora and Quercus floribunda* forests) of Kumaun Himalaya. This project integrates all these aspects to improve understanding on the impacts of CC on mountain forest ecosystems and come up with certain mitigating mechanisms.

ACHIEVEMENTS

- In the study region (Nainital district) between 1980 and 2012 linear trends of increasing for both the maximum and minimum air temperature ware found to be significan ($p< 0.05$) (0.025 and 0.066°C/decade). The pre-monsoon (March - June) rainfall was found to decline @ 1.08 mm/yr. However, the long term linear trends of rainfall was significantly ($p < 0.05$) increasing.
- Phenological response of forests recorded as date of vegetative bud-break in the 8 major tree species of west Himalaya revealed that it has advanced by 9 days (i.e., 0.30 d/yr) in the last three decades, might be due to increase in temperature in the study area. Similarly, mean date of peak leaf drop has advanced by 12 days (i.e., 0.40 d/yr) shortening the leaf life span by over one week. Leaf production, leaf area and leaf mass at mature leaf

stage recorded for the forest trees was found significantly greater at south aspect indicating that atmospheric warming favours leaf expansion and carbon gain at south aspects of the forests hence the Souths aspects hold greater importance for CC mitigation and adaptation.

- Revegetation of wastelands with enrichment plantation (MPTs) in an experimental plantation at Nandavan (Almora) revealed that it leads to carbon sequestration and improvement of overall soil fertility that improves the ecosystem services supplied by the soil. The enrichment plantation led to better management of natural forests that can influence economic and practical issues and have a long term effect on sustainability both in terms of environmental quality and profitability.

- Eco-tourism in the mountains is an aesthetic service offered by the forested landscapes. The climate is a major deriving factor responsible for tourism in IHR. Thus, with increased temperature, warmer winter would improve the tourists incursion in this region yet the threat of extreme events/ and climate aggravated disasters would diminish the tourism prospects such as witnessed by a dip in annual tourist inflow in 2013 in Uttarakhand as fallback of Kedarnath Tragedy of 2013.

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

SUMMARY OF COMPLETED PROJECT

Assessing the Floristic Diversity and Ecosystem value of selected High altitude wetland of Indian Trans Himalaya (Funded by Ministry of Environment, Forest and Climate Change, GoI 2015 -2018)

The Indian Trans Himalaya, which spans over 1,86,000 km^2 and characterized by high solar intensity, high aridity, low temperature, lack of adequate soil and short growing season. As a result, the zone is recognized as one of the most ecologically fragile biogeographic zones in India (Rodgers & Panwar, 1988). The region harbors a number of wetlands and lakes with high biodiversity potential. These wetlands are classified under High Altitude Wetlands (HAWs) of India. HAWs of Trans Himalaya are of great importance, especially for the endemic and threatened species of plants, migratory birds, wild animals and also for the people living in and around the region. Considering ecological functions, these HAWs play significant role in defining the hydrological regime of mighty rivers like the Indus, Chandra, Spiti, etc., and act as a buffer between glacial melt waters and outflows to smaller rivers and streams. These wetlands have, however, received very little attention in terms of biodiversity assessment, ecosystem values and conservation. Towards achieving the targets of any conservation and management initiative of any ecosystem, the floristic diversity analysis and assessment of ecosystem values is prerequisite, which plays essential role in implementation of the conservation programme. The objectives of the project include (i) to document and assesses the floristic diversity components of target wetlands, (ii) to investigate trends of changes in plant diversity, (iii) to analyse the ecosystem services emanating from the wetlands, and (iv) to inculcate awareness and sensitize local inhabitants on issues pertinent for conservation of these wetlands.

ACHIEVEMENTS

Chander Tal: A total of 75 plants belonging to 60 genera and 22 families were recorded. Among these only one species namely Ephedra intermedia belongs to Gymnosperm., Considering threat categorization of plants, *Aconitum violaceum* and *Rhodiola heterodonta* are considered as Vulnerable (VU) and *Ephedra intermedia*, *Phleum alpinum, Poa annua, Veronica beccabunga* as Least Concern (LC) are reported in (IUCN) and (CAMP) for wild medicinal plants in Himachal Pradesh., where Aconitum violaceum was found in minimum density and *Veronica beccabunga* found in maximum density. More than 42% were used for different medicinal purposes and leaves are commonly (>32%) used for medicinal uses. Three Bryophytes namely, *Brachypodium crispatum* (Hedw.) Brid. (Ptychomitriaceae), *Funaria hygrometrica* Hedw. (Funariaceae) and *Marchantia polymorpha L.* (Marchantiaceae), and three fungi namely, *Bovista sp.* (Agaricaceae), *Hygrocybe sp.* (Hygrophoraceae) and *Peziza craterium* Schwein. (Agaricaceae) were identified from Chandertal wetland area.

Suraj Tal: A total of 63 taxa belonging to 43 genera and 20 families were recorded. Among these only one species namely *Ephedra intermedia* belongs to Gymnosperms. While analyzing the diversity of medicinal plants, a total of 32 species (51%) are used for different ailments and flowers and leaves were commonly (>38%) used for medicinal purposes. Considering threat categorization, *Rheum speceforme* and *Rhodiola heterodonta* are considered as Vulnerable, *Saussurea gossypiphora* considered as Critically Endangered and *Ephedra intermedia*, *Carex borii*, *Eleocharis palustris*, *Poa annua* as Least Concern categories. A total of 623 sheep / goat and 22 horses / donkey / mule were recorded during field visit in 2016 & 2017.

Pangong: A total of 109 plant species belonging to 81 genera and 28 families were recorded. Among angiosperms, dicots and monocots were represented by 95 and 14 species respectively. *Ephedra gerardiana* the only gymnosperm recorded in the wetland. *Asteraceae* is the largest family represented by 21 species. While analyzing the diversity of medicinal plants in the wetland, a total of 55 species (15 families) are used for different ailments and leaves were highly used for medication by the local inhabitants. Considering threat categorization of plants, *Artemisia oelandica* (Besser) Krasch., is considered as Near Threatened (NT) and *Ranunculus sceleratus* L., *Potentilla anserina* L., *Hippuris vulgaris* L., *Achillea millefolium* L., *Koenigia islandica* L., *Potamogeton nodosus* Poir., *Triglochin palustris* L., *Carex orbicularis* Boott, *Cyperus rotundus* L., and *Eleocharis uniglumis* (Link) Schult. were reported as Least Concern (LC) in different threat categories. *Artemisia oelandica* (Besser) Krasch. was found in minimum density and Carex orbicularis Boott found in maximum density. As per the record received from District Tourism information centre, Leh, a total of 114804 from our country and 12476 foreigners were visited during 2017. Further, during the field survey, we calculated the livestock population (on field observation basis only) around the wetland area and found a total of 2062 livestock were utilizing the floristic resources. Wild fauna were also recorded from the region, namely, *Equus kiang*, Lizard, Marmot, Himalayan Hare and Bharal. Pangong Tso is an important breeding ground for a number of migratory birds like Black necked cranes (VU) Brahmani Ducks (LC), Common Hoopoe (LC), Indian cuckoo and Black redstart (LC).

Tso Moriri: A total of 113 plant species belonging to 72 genera and 27 families were recorded. Among angiosperms, dicots and monocots are represented by 92 and 21 species respectively. Asteraceae is the largest family represented with 19 species and eighty eight percent of the total flora is belonging to these fourteen dominant families. While analyzing the diversity of medicinal plants, a total of 51 species (45%) are used for different ailments and Leaves are highly utilized for medicinal determinations by local people. Considering threat categorization eight species namely, *Ranunculus sceleratus* L., *Potentilla anserina* L., *Koenigia islandica* L., *Juncus bufonius* L., *Potamogeton nodosus* Poir., *Carex orbicularis* Boott, *Carex pseudofoetida* Kük., Calamagrostis pseudophragmites (Haller f.) Koeler are listed in Least Concern threat categories. As per the record received from district tourism and information centre, Leh, a total of 8981 from India and 3765 foreigners were visited during 2017. Tso-Moriri is an important breeding ground for a large variety of migratory birds like black necked cranes (VU) and Bar-headed Goose (LC). Marshy areas near wetland (20-50%) are having higher biomass of species. Further, during the field survey, we calculated the livestock population (on field observation basis only) around the wetland area and found a total of 2483 livestock were utilizing the floristic resources. There are number of wild fauna were also recorded from the region, namely, Equus kiang, Lizard, Marmot, Himalayan Hare and Bharal.

Tso Kar: A total of 133 plants belonging to 90 genera and 28 families recorded. Among angiosperms, dicots and monocots are represented by 97 and 36 species respectively. Asteraceae and Poaceae are the largest family represented with 20 species. While analyzing the diversity of medicinal plants, a total of 80 species (60.1%) are used for different ailments. and Leaves are highly utilized for medicinal determinations by local people. Considering threat categorization of plants, 20 species are listed in Least Concern threat categories. Tso kar is also an important breeding ground for a large variety of migratory birds like black necked cranes (VU) and Bar-headed Goose (LC). Further, during the field survey, we calculated the livestock population (on field observation basis only) around the wetland area and found a total of 1376 livestock were utilizing the floristic resources. Wild fauna were also recorded from the region, namely, Equus kiang, Lizard, Marmot and Himalayan Hare.

Chushul and Tisgul: A total of 90 plants belonging to 64 genera and 27 families were recorded. Among angiosperms, dicots and monocots are represented by 65 and 25 species respectively. Poaceae are the largest family represented with 15 species. While analyzing the diversity of medicinal plants, a total of 50 species (55%) are used for different ailments and usage are almost similar with Tso Kar wetland and Leaves are highly utilized for medicinal determinations by local people. Considering threat categorization of plants, 9 species are listed in Least Concern threat categories. Chushul and Tisgul Tso marshes are also an important breeding ground for a large variety of migratory birds like black necked cranes (VU) and Bar-headed Goose (LC). During the field survey, we recorded the livestock population around the wetland area and found a total of 3212 were utilizing the floristic resources. Wild fauna were also recorded from the region, namely, Equus kiang, Lizard, Marmot and Himalayan Hare.

SUMMARY OF COMPLETED PROJECT

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

Among the world mountain ecosystems, the Himalayan Ecosystems have special significance as they are young, fragile, dynamic, most complex and diverse and range from wettest to the driest regions and has been recognized amongst the 34 global biodiversity hotspots. In addition, the components of the Himalayan ecosystem exhibit a great dynamism on account of its evolving state. The Indian Himalayan Region (IHR), constitutes a significant part of the Himalayan hotspot and it is very well known for the unique topography, climatic conditions, diverse habitats and a large altitudinal range, that represents tropical, sub-tropical, temperate, sub-alpine, alpine and tundra biomes/ecosystems. The biodiversity of these ecosystems is utilized by the inhabitants directly and indirectly for their sustenance and income generation. The reports, however, suggest biodiversity of these ecosystems is depleting fast due to habitat degradation caused by various anthropogenic activities, over exploitation and changing environmental conditions. In such circumstances, assessment of status, changing patterns and processes of biodiversity components and their conservation and socio-economic values including nutritional, anti-nutritional and antioxidants properties of the traditional crops and medicinal and wild edible plants; evaluation and comparison of ecological integrity, stability and resilience of representative ecosystems and their components, analysis of impacts of climate, and development of management and sustainable use plans with policy briefs are highly needed for understanding biodiversity and process of changing resource use. The objectives of the study include, (i) to generate robust datasets on status, changing patterns and processes of biodiversity components, as well as their conservation and socio-economic values, including nutritional (traditional crops and wild edibles) and therapeutic potential (medicinal plants) of selected landscapes, (ii) to evaluate and compare ecological integrity, stability and resilience of representative ecosystems and their components in the target landscapes, (iii) to analyze impacts of climate and resource use changes on the biodiversity components, and assess its socio-economic consequences, and (iv) to establish Himalayan Biodiversity and Climate Change Knowledge Network (HBCC-KN) to build on existing knowledge and enhance information generation through robust globally accepted protocols, and develop management and sustainable use plans with policy briefs.

ACHIEVEMENTS

1. Diversity and density of vegetation patterns in different forest communities of Kanawar wild life sanctuary was investigated. Results reveals presence of 654 plant species of vascular plants i.e., Angiosperms (92 families, 317genera and 585 species), Gymnosperms (03 families, 07 genera and 10 species) and Pteridophytes (15 families, 22 genera and 69 species) has been recorded. Species richness, highest in *Pinus wallichiana* community (15Trees; 35 Shrubs; and 145 Herbs), followed by *Picea smithiana* community (13Trees; 35 Shrubs; and 143 herbs) and so on.
2. The fuel wood consumption patterns in different villages of the sanctuary was investigated and collection patterns of the fuel wood species was identified. Similarly, forest vegetation patterns of Haat Kalika watershed at different altitudinal level revealed the presence of total 67 plants (14 tree, 14 shrubs and 39 herbs) belonging 35 families. Fuel wood consumption pattern showed *Pinus roxburghii* was highly preferred species at upper altitude zone.
3. Two long-term monitoring plots (GLORIA sites) were established in Chaudans Valley for future monitoring of the vegetation.
4. Biodiversity assessment in Yuksom-Black Kabru transect (Khangchendzonga Biosphere reserve) showed 98 woody species, 41% shrub species and 59% tree species.
5. In Ziro Valley of Lower Subansiri, Arunachal Pradesh, a total 23 sites have been surveyed for the assessment of plant diversity in the study area. A total of 61 species have been recorded.
6. Assessment of nutraceutical values of traditional crops and wild edibles and Theraputical potential of medicinal plants were investigated. Results reveals that Himalayan plants have potential source of nutritional and nutraceuticals compounds.
7. Himalayan Biodiversity and Climate Change Knowledge Network (HBCC-KN) was established among the researchers working in Indian Himalayan Region. In addition, different training programmes and workshop have been organized to establish the functional network.
8. Various outreach programme were conducted with the teachers and school students especially for promoting conservation education. The National Nature Camping Program (NNCP) was organized for establishing knowledge network through school children of Uttarakhand region. Three hands on training programme on Field Surveys and Herbarium Methods were conducted.

CENTER FOR SOCIO-ECONOMIC DEVELOPMENT (CSED)

Sustainable development of rural ecosystem has been a challenging task in the Himalayan region in view of diverse environmental, socio-cultural or economic setups across the length and breadth of the IHR. Since its inception the Institute has been working on location-specific problems, such as generating mountain specific knowledge on priority problems, management of natural resource, demonstrating appropriate land use models, promoting good practices through peoples' participation, undertakes policy advocacy, and ensuring capacity building of communities. World Sustainable Development Goals (SDGs) that comprises of 17 goals and 169 targets are devised to target entire global population. Rural communities are still facing problems related to unsustainability, poverty, land use change, degradation of natural resources, livelihood and migration. There is lack of a proper understanding on rural poverty, diverse causes of natural resource degradation, socio-economic constraints, and other issues concerning Himalaya. The linkages of forest and agriculture, poverty and social capital are multifaceted and need more investigation with location-specific focus. This makes socio-economic development, poverty alleviation and sustainable development a huge challenge. Therefore, the Centre for Socio-economic Development (SED) aims to promote equitable, inclusive, and sustained growth by safeguarding economic and social development of communities along with environmental protection in the IHR. It would take up interdisciplinary R&D investigations, blend traditional ecological knowledge and scientific knowledge for livelihood improvement and natural resource management, develop location/problem specific demonstrations and skill development programs, facilitate linkages between knowledge providers, knowledge seekers and users to effectively utilize available knowledge resource/products, and undertake policy advocacy on NRM and sustainable development issues of IHR. The Group works with network of partners at regional, national and international level to facilitate all activities. The centre would significantly contribute to (i) generate and document mountain specific indigenous knowledge on natural resource management, community livelihood, socio-economic databases, and drivers of change, (ii) strengthen sustainable livelihood through promotion of on-farm and off-farm activities, (iii) demonstrate and disseminate specifically designed models, and appropriate knowledge products, (iv) develop and strengthen entrepreneurial skills and self employment opportunities through capacity building, (v) intensive research on broad themes- poverty, migration, livelihood diversification, rural enterprises, community forestry, infrastructure development, community participation and village institutions, green economy, energy use, etc., (vi) develop and strengthen resources and land use planning, and management strategies, (vii) undertake research and demonstration of new technologies for natural resource management and non-timber forest products, resilience, adaptation, services and applications, human development and other livelihood promotion strategies across the IHR, (viii) secure and revive sustainability of traditional mountain farming systems and dependent livelihoods, document innovation in agriculture, and build on policies to support such approach, (ix) assure food and nutrition, health and education security for mountain regions, opportunities and challenges, (x) develop indicators of sustainable development, green productivity and socio-economic development, (xi) technology demonstration for livelihood upgradation, natural resource management, sustainable habitats and cities, disaster risk reduction, energy, medical, etc., and (xii) promote responsible tourism.

Development of model village through technology transfer for livelihood enhancement in the Central Himalaya (In house, 2017-2020)

The Indian Himalayan region (IHR), which extends to twelve states (ten fully and two states partially), covers an area of 591000 sq km with a population of about 486 lakh with over 170 ethnic communities that have distinct socio-cultural milieu, demographic setups, societal ethos, resource endowment and reliance. Despite of rich indigenous wisdom to manage resources the productivity of agricultural lands is low with minimal use of modern technologies. Forests are important and integral part of local livelihoods in the Himalaya and the status of forests are strongly influenced by farmers' socio-economic status and on governance of formal and informal institutions. These forests supply of goods and services to millions of people living within and outside the region. Despite of that the people of the region are poor, marginalized and disadvantaged. Degrading of forests, abandonment of agricultural land due to low soil status and limiting water availability, and growing animal human conflicts are important concerns for all. Main challenges to find solutions to im-

prove quality of livelihood by increasing income for rural poor along-with protecting the environment. Significant efforts have been made in the area which refers to improve quality of life at local level. Almora district has been selected for this study, which comprises just 6% of total land area of Uttarakhand state with a population of 6,22,506 persons as per 2011 census. The district is well-known for its socio-cultural setting. Administratively the district constitutes 7 Tahsils and 11 Developmental blocks; it has 50% land area under forest, 17.41% under cultivation, 6.36% permanent pasture, and 7% land under miscellaneous tree crops and grooves. The forests and vegetation varies with elevations, and dominated with chir-pine between 800-1500 m, pine-oak mixed forest at 1500-2000 m, and oak-cedar forest between 2000-2700 m elevations. These forests include Reserve forest (managed by Forest Department), Civil Soyam forest (Revenue department), and Van-Panchayat forest and privately owned forest (by community and individuals). Majority of the population depend on agriculture for their livelihood. As such the economy of the area is subsistence with low productivity of farming systems, therefore people often look for off-farm employment opportunities. For the purpose of this project villages at different altitude in Almora district are being targeted to consider the location specific needs. The main emphasis is to develop 'model village' using a progressive approach for benefit of rural people, wherein the community acts as decision maker, partner, and beneficiary; and use multi-sectoral and integrated development approach for the village that have a direct effect on drudgery reduction and overall well being of rural population.

OBJECTIVES

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

ACHIEVEMENTS

1. The pilot surveys of 32 villages covering a population size of 13949 were conducted to assess the village-level livelihood development issues, farming system related problems, climate change impacts on the resources, and need of technological interventions along with identification of sites for 'model village' development.

2. It was interesting to note that 80% of the community was facing the consequences of agricultural land abandonment (at least some parts) due to climatic factors, crop damage by wild animals (i.e. monkey and wild boars), and stray animals.

3. The community demanded training and material support for adopting protected cultivation (49%) and other income generating measures (38%). Selected progressive farmers were earning Rs 6000-20000 per season from vegetable cultivation (n=12), up to Rs. 21000-50000 per season from vegetables+ medicinal plants cultivation (n= 14), and >Rs 50000 per season from vegetables+ medicinal plants+ integrated fish and poultry farming (n=13).

4. The broad framework for model village development is provided in Fig. 12. So far two villages, viz. Bhetuli village (no. of households 150, population 750, area 202 ha, elevations 1600-1840 m, Block Takula) and Malera (no. of households 24, population 98, elevations 1200-1300 m, Block Hawalbagh) have been selected. An analysis of socio-economic profile of these villages along with detailed village management plans are under progress.

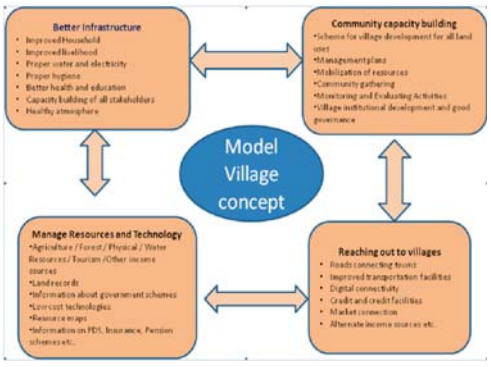


Fig. 12. Framework for development of model village

Fig. 13. Capacity building programme on the different livelihood enhnacement technologies

5. A total of 40 technologies maintained/demonstrated at Rural Technology complex (RTC) of the institute. During the reporting year a total of 20 trainings (no. of beneficiaries 771 with 362 males and 409 females) were conducted for diverse stakeholders on simple and low-cost technologies for the enhancement of livelihood as well as for the optimum land use and sustainable management of natural resources (Fig. 13).

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

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

OBJECTIVES

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

Fig. 14. Land use and irrigation practices in Arunachal Pradesh

ACHIEVEMENTS

1. Land and soil management practices: Communities of Arunachal Pradesh exhibits very efficient land use management of forest, agriculture, gardens and settlements. All these categories have many sub-types showing tremendous TK on land management such as micromanagement of land by Apatani tribe. Bamboo plantation (Bije) are maintained just above the agriculture fields (Jabe-Aji) and settlement area by Apatani tribe (Fig. 14). Settled agriculture, mixed cropping, mulching, application of crop residue and FYM practices were adopted for soil fertility management.

2. Nepali, Limboo and Lepcha communities of Sikkim and Darjeeling district practice settled cultivation and use almost similar land and soil management, water conservation practices comprising land terracing, bund making, retention wall, broom grass cultivation, fodder plant and other plant materials at the ridge of crop-fields. From the household survey it has been observed that the 20% of the total respondents has shifted their traditional land use pattern and 35% have changed thier traditional agriculture practices mainly due to water crisis and wild birds and animals encroachment.

3. More than 70% indigenous farmers of study sites of district Bageshwar, Uttarakhand only use FYM to increase the soil fertility and to retain water holding capacity. Spreading of FYM, use of mixture of ash and manure, crop rotation and fallow land are best practices of soil management. The left of lend (fellow land) during rainy season is the method to reduce soil erosion and to enhancing organic nutrient in the soil. Documenting experiential knowledge based on community culture; bio-diversity knowledge based on nature; gender division of labour, etc. and made a season related agricultural activity of farmer's of surveyed area and documented major transformation in agriculture and associated resource management.

4. The high demand for manure in the Spiti valley of Himachal Pradesh is met by recycling night-soil into farmyard manure (FYM). People built traditional toilets on the first floor of the house attached to their living rooms. To avoid extra moisture content during composting, the use of water in these toilets is strictly disallowed. After defecating, villagers cover the faeces with the materials locally known as 'fot'. This 'fot' serves two main purposes: firstly, it makes the compost rich in nutrients, secondly, it prevents bad odor and keeps the flies away. This composting process for preparing FYM takes 6–8 months to complete. NSC from compost room is normally emptied twice a

year, first in October/November and second in March/April. After the snow melts, the farmers spread the NSC properly in their respective fields.

5. Water conservation practices: The community of Arunachal Pradesh has managed to effectively utilize the limited water resources to feed their agricultural fields which require stagnant water for 4-5 months to support rice-cum-fish cultivation. With their local knowledge, they have mastered the art of channelizing the water from the stream (Killey) and rain water to their agriculture field. The wet rice fields are fed with canals (Hirong), flow from one field to another is maintained through a ditch (Muhgo) on bund and two outlet pipes. In the middle of rice field a small depression (Siikho/Parkho/Hehte) is made for water and soil management in olden time but is best suited for fish culture in present day.

6. Detailed survey to the different selected villages of Sikkim, Uttarakhand and Himachal Pradesh states revealed that few systems of traditional water conservation practices are common among the locals. Agriculture practices in the areas, mostly dependent on rain water and some irrigation method have been adopting by the farmers like canal irrigation, pond irrigation, rainfall runoff harvesting ponds etc. Though there are some religious conservation practices in the name of Devithan. Most of natural water resources are conserved as Devithan where villagers practice plantation around water source and use to offer puja for water source revival. In Sikkim, traditional Ubhauli and Udhauli Puja also performed at some Devithan twice a year, before sowing and after harvesting of crops especially by Rai community

7. In Upper Kullu valley, rain water irrigation has decreased from 72.27% to 58.82%, whereas the use of hydrams increased from 15.13% to 18.07% since 2000. In Beas valley, 50% farmers are using stream water, 31% farmers use the rain water and 19% respondents are using hydrams for their irrigational need. Changes in water sources in upper Beas valley has been observed, 56% respondents mentioned that changes in traditional crops to cash crops is the major reason for water source uses. 20% respondents pointed out that change in precipitation is the second change observed in study site.

8. Bio-resources: Documentation of wild bio-resources use by different communities exhibited that 701 spp. used by tribal communities of Arunachal Pradesh, 107 spp. in Nagaland, 456 spp. in Sikkim, 452 spp. in W.B. Hills, 1226 spp. in Uttarakhand and 323 spp. in Himachal Pradesh of IHR.

9. The Adi, Apatani and Monpa community used a wide variety of plant species as ethnomedicine, fruits, vegetables, and spices. A total of 12, 11 and 10 wild edible species were documented, respectively for these communities. Local plants used for curing different ailments therefore, a total of 32 spp., 26 spp. and 13 spp. to be used by Apatani, Adi and Monpa community respectively for traditional health care system. Out of these Kiwi fruit and cardamom plantations were the recent introduction into the agricultural systems of the community. A total of 7 animals were used for traditional healing practices by the Adi tribes of Upper Siang district.

10. The tribal communities possess significant knowledge regarding bamboo resource use and management. Arunachal Pradesh comprised 58 species of bamboo in 18 genera. A detailed investigation on the use of bamboo species by Apatani, Adi and Tangsa tribes revealed that all communities have the adaptive capacity and socio-ecological contemplation regarding the bamboo resource. It was interesting to learn that though the communities live in distinct areas and the choice of bamboo species vary among them, there was a remarkable similarity in TEK and governance for use, manage and conserve the bamboo resources.

11. Tribes of Sikkim and Darjeeling district use 55 species as medicinal plant, 35 as wild foods, 19 species in construction, 12 in rituals and 8 in traditional healing. Communities also used fermented food prepared from local resources such as Gundruk, Sinki, Khalpi, Kinema and Mesu (Fig. 15).

12 Agricultural systems in the Uttarakhand and Himachal Pradesh were observing a change from traditional to intensive farming. In recent years some progressive farmers of Uttarakhand have adopted cultivation of cash crops, such as Tea and fish farming. An average farmer use 17.50 nali land for tea cultivation and 4.13 nali lands for fish farming. The major problems in continuing traditional agriculture are due to lack of labor availability, an abundance of wild animals (monkey and wild boar), migration, availability of alternate employment opportunities, and climate change impacts.

13. Of the total cultivated area in Kullu Valley, Himachal Pradesh, 36% area is used for cultivation of maize, 32% for wheat, 13% for vegetables, 8% for pulses, 5% for barley, 4% for potato, 3% for rice and 1% under ragi, respectively. Investigation in Upper Beas valley revealed that 28% farmers cultivate wheat, 31% pulses, 19% maize, and 22% cultivate other crops (barley, paddy, etc.). In the valley maximum production was recorded for pulses (kidney beans), which also give good economic return to the farmers.

Fig. 15. Fermented food prepared from local resources of Sikkim

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

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

OBJECTIVES

- Manage natural resource sustainability in targeted villages by introducing innovative approaches and practical models by participatory management
- To extend technical help and packages for demonstrating of on-farm and off-farm activities for improving livelihood and environmental health
- Increase capacity of community for integrated and adaptive natural resource management at village level by developing knowledge and skills and strengthening local institutions
- Empower local community at, particularly women and weaker section, by promoting local governance mechanisms that enable rural people to advocate for change that better their lives
- Create public awareness for implementation of integrated natural resource management strategies through enabling policy and institutional framework

ACHIEVEMENTS

1. An assessment of problems related to agriculture were ascertained, which comprised wild animal threats, adaptation to climate change, unemployment (male out migration), unsatisfactory economic returns from agriculture, lack of appropriate technologies, poor infrastructure facilities, rain fed agriculture, fragmented and small land-holdings and predominance of waste lands.
2. Various technologies have been identified for sustainable use and management of resources and enhancing livelihood of the people and are grouped under four categories i.e. (1) Yield increasing (polyhouse, vermi-compost, bio-compost, etc.), (2) Income generating (cash crop cultivation, vegetable cultivation, horticulture, integrated fish farming, etc.), (3) Life supporting (multipurpose tree plantation, making decorative items from chir pine needle and cone, etc.) and (4) Value addition and other supporting activities (bio-briquetting from chir pine needle).
3. Mainly marginal and resource poor farmers have been made beneficiaries of the project i.e. 21.2% from SC community and 39.2% from lower income group. Similarly, majority of line department schemes beneficiaries were from lower income group (34.04 %) and SC community (22.5%).
4. A total of 216 persons (75% women) were trained on various technologies viz. protected cultivation, integrated fish farming, bio-briquetting from chir pine needle, vermi-composting etc. Trainees include 32.8% SC and 52.7% lower income group.
5. A total of 15 On-farm technology models i.e. protected cultivation, ginger cultivation on abandoned land, cash crop production on low productive agricultural land, cultivation of high value vegetable crops in kitchen garden, and vermi and bio-composting, etc. were demonstrated in the study area.
6. The yield of low productive farm lands of 305 farmers have been increased by 40-50% through cultivation of high value cash crops (ginger, onion, garlic and turmeric etc.) in place of traditional crops i.e. paddy, wheat and finger millet.
7. A seven days training and capacity building programme was organized for 32 women from two village clusters on making decorative items from chir pine needle, cone and bio-briquettes.
8. A total of 29 households have started making bio-briquettes and decorative items from chir pine needle and cone as an Off-farm activities; during the reporting period they have earned about Rs. 6000.00.
9. Successfully established a pine needle processing unit at Rural Technology Complex. The unit has already started making various products (File cover, envelops, diary etc.) from chir-pine needles.

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

Non-timber forest products (NTFPs) constitute an important source of livelihood for millions of people from forest fringe communities across the world. NTFPs provide food, income, and nutritional diversity for an estimated one in five people around the world, notably women, children, landless farmers and others in vulnerable situations. In India, NTFPs are associated with socio-economic and cultural life of forest dependent communities inhabiting in wide ecological and geo-climatic conditions throughout the country. There is high dependence of communities to fulfil their subsistence needs all across the Himalayan region. Access to forest products, goods and services is vital for the livelihoods and resilience of the rural and marginal households, acting as safety nets in difficult times.There is need to investigate NTFPs and related traditional knowledge for improvising community livelihood and mitigating negative effects of climate change. The present study is taken up with such focus.

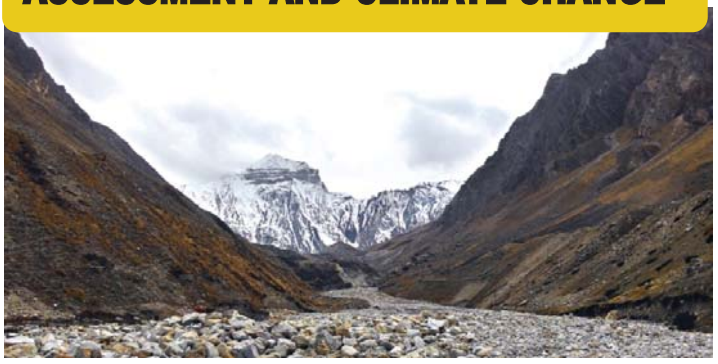
OBJECTIVES

- Inventories of NTFP species and diversity of land management practices.
- Status on marketing, value chain, value addition and enterprise development.
- Governance, policies and regulations related to NTFPs and their impact.

ACHIEVEMENTS

1. Comprehensive inventory, comprising of 354 plant species of the Himachal Pradesh, known to be used as NTFPs, have been documented from the published sources.
2. Out of 354 NTFPs, there are 106 threatened NTFPs in the state, in which 13 are according to IUCN, 2017 whereas 93 NTFPs were mentioned as threatened by different stakeholders of the state.
3. Annual status of royalty collected and quantum of NTFPs harvested from past six decades in Himachal Pradesh.
4. Species wise harvests level of important NTFPs from past five decades in Himachal Pradesh.
5. List of NTFPs collected by primary and secondary collectors and there mode of collection, time of collection, parts used and its rates.

CENTER FOR ENVIRONMENTAL ASSESSMENT AND CLIMATE CHANGE



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

OBJECTIVES

- To assess and monitor physical, biological and socio-economic environmental parameters for the development in IHR.
- Design measures for climate change mitigation and adaptation by communities and developing ecosystem resilience to cope up with climate change risks.

Establishment and conservation of *Ginkgo biloba* and *Taxus wallichiana* using microbial technology: Field evaluation (In house, 2017-2020)

Ginkgo biloba (English name: Maiden hair tree; Hindi name: Balkuanri; Family Ginkgoaceae; referred as the living fossil) and *Taxus wallichiana* (English name: Himalayan Yew; Hindi name: Thuner; Family Taxaceae) are medicinally important trees that grow under temperate locations of Indian Himalayan region (IHR). Mentioned in IUCN red list, both the species need attention for propagation and conservation in Forest sites. In this background, based on the rhizosphere studies conducted in the Microbiology laboratory of the Institute on *G. biloba* and *T. wallichiana,* the microbial formulations have been developed for propagation of these plant species. In this project, *G. biloba* and *T. wallichiana* is raised using stem cuttings and microbial formulations in the net house of the Institute and examined for the microbial colonization pattern. The colonized plants then will be transferred to the field in collaboration with Forest Department, DRDO, ITBP and NGOs. The transferred plants will be evaluated with respect to their rhizosphere, plant growth and physico-chemical parameters.

OBJECTIVES

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

ACHIEVEMENTS

1. Stem cuttings of the target species (*Ginkgo* and *Taxus*) have been planted in the net-house using microbial formulations (Fig. 17).
2. Sampling from *Ginkgo* rhizosphere plants that were transferred at Kalika nursery in 2011 has been performed. Rhizosphere studies on Ginkgo roots showed enormous colonization by endophytic fungi (Fig. 18).

Fig. 17. Establishment of target species in net-house: A. *Ginkgo,* and B. *Taxus*

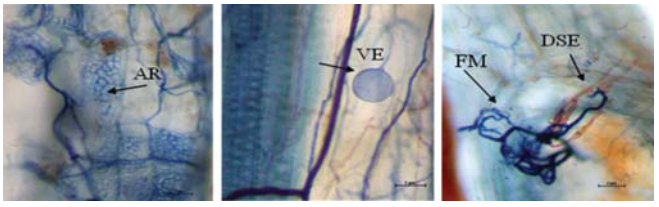


Fig. 18. Colonization of *G. biloba* roots: Arbuscules (AR), Vesicle (VE), fungal mycelium (FM), and Dark septate mycelium (DSM)

Conservation and sustainable use of biodiversity with particular reference to microbial diversity (NMHS, 2016-2019)

In this project a focused study entitled ''Plant microbe-interactions in *Taxus wallichiana* Zucc.'' has been designed with respect to microbial associates of *T. wallichiana* and their biotechnological applications. *Taxus wallichiana* (Zucc.) Pilger (English name: Himalayan Yew; Hindi name: Thuner; family Taxaceae) is recognized as a medicinally important evergreen tree that grows under temperate locations of Indian Himalaya. The species has received considerable attention on account of its existing exploitation for the extraction of the drug (taxol) and also the removal of old forests. While the species is well recognized as source of anti-cancerous drug Taxol ® (paclitaxal) that is useful in treating various forms of cancers, it still needs attention in antimicrobial prospective. The present study is, therefore, based on the plant microbe-interactions with respect to *Taxus wallichiana.* Rhizosphere studies have been planned on the colonization of Taxus roots by plant growth promoting microorganisms and their subsequent use in Taxus propagation. The extract of Taxus plant parts (needle, stem and bark) will be investigated for their antimicrobial potential against bacteria, actinobacteria and fungi.

OBJECTIVES

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

ACHIEVEMENTS

1. Culturable fungal endophytes isolated from the roots of *T. wallichiana* have been identified following morphological and molecular methods. The fungal isolates belonged to the species of Penicillium and Aspergillus. The endophytic fungi have been investigated for their ability to solubilize insoluble phosphates through production of organic acids, and phytase and phosphatase enzymes in alkaline and acidic pH with the substrates (aluminium (AP), tricalcium (TCP) and iron phosphate (IP) at different temperatures. All the fungal endophytes solubilized phosphate by utilizing the substrates as iron, calcium and aluminium phosphate along with the production of phosphatase and phytase enzymes. Phosphatase production was higher in acidic conditions in comparison to alkaline (Fig. 19). Out of five different organic acids quantified through HPLC, succinic acid was produced in maximum quantity, followed by malic acid, oxalic acid, and lactic acid.

2. Antimicrobial potential of different plant parts (needle, stem and bark) of *T. wallichiana* has been investigated with particular reference to selection of solvents and extraction methods (Fig. 20). Two extraction methods (maceration and soxhlet), seven solvents (methanol, ethanol, acetone, chloroform, ethyl acetate, di chloro methane and Petroleum ether), and 3 groups of microorganisms (bacteria, actinobacteria and fungi) were considered for detection of antimicrobial activity. While qualitative estimations were done using agar well diffusion method, quantitative analysis was based on dilution method. All the plant part showed significant activity against all 3 groups of microorganisms in qualitative bioassays; maximum being in case of needles. Among solvents, ethanolic extract of needles (maceration) showed highest antibacterial activity. The most affected group among the test microorganisms was bacteria which may be due to their prokaryotic organization. This was also supported by the low minimum inhibitory concentration (MIC) values.

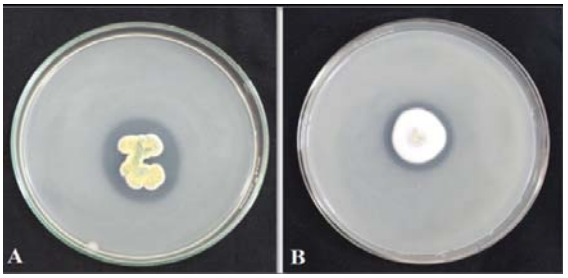


Fig. 19. Endophytic Penicillium sp. (A), and Aspergillus sp. (B) showing phosphate solubilization potential

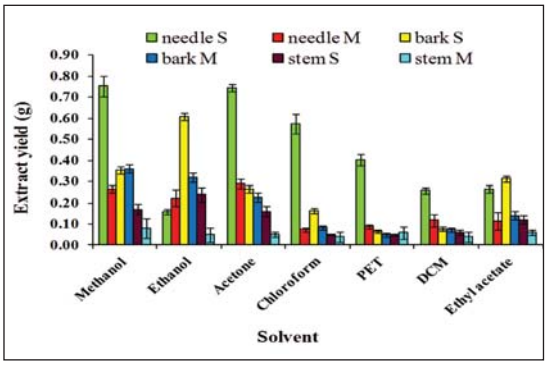


Fig. 20. Extract yield of stem, needle and bark of *T. wallichiana*; S = soxhlet, M = maceration, PET= petroleum ether, DCM =di chloro methane extract

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

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

OBJECTIVES

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

ACHIEVEMENTS

1. Establishment of permanent sites for Long Term Monitoring of Tree line Vegetation in Pindar Valley of Uttarakhand State - 2 new plots of 20x20 meter at two different locations at an altitude of 2850m and 3100m asl were established (location and geo-spatial attributes) for long term monitoring, thus making a total of 10 permanent sites. Vegetation in each plot was marked and measured for density of trees, sapling, and seedlings. These new plots had 6 tree species and 38 individuals, and 9 tree species 27 individuals. In total 11 tree species were noted and 4 were common in both the plots. Saplings were limited to few only (6 species.)
2. Occurrence of woody patches (largely formed by *Rhododendron campanulatum* with or without tree species of timberline) in the alpine, using high resolution image of year 2015, was mapped in both the flanks (eastern and western) of Pindar valley (beyond timberline). Patches were distributed between altitude of 3238 m to 3950 m asl, and area of a woody patch may range from 0.02 ha to 10.2 ha.
3. Above timberline total 98 woody patches were mapped in the river valley, and warmer flanks (western slopes) had higher number of woody patches (59%), however, total area of the patches was almost similar **(Table 3).**
4. Pattern assessment of vegetation in high altitudes (up to 4100m) of Great Himalayan National Park in Himachal Pradesh.

Table 3. Distribution of woody patches above timberline in Pindar river valley.

SIZE	EAST FACING SLOPE		WEST FACING SLOPE		TOTAL	
(ha)	Area (ha)	Number	Area (ha)	Number	Area (ha)	Number
<1	9.30	34	11.24	52	20.54	86
1 to 5	6.55	4	9.09	5	15.64	9
5 to 10	14.87	2	-	-	14.88	2
> 10	-	-	10.28	1	10.28	1
Total	30.72	40	30.61	58	61.34	98

Clean energy development to mitigate impacts of climate change in the Indian Himalayan Region (NMHS Fellowship, 2016-2019)

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

OBJECTIVES

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

ACHIEVEMENTS

1. Increased focus on electrification of remote areas especially in the Ladakh Region of the North West Himalayan Region carried out by joint efforts of government and non-government organizations.
2. Several villages became self-sustainable in terms of income after deploying small solar plants and individual panels in order to ameliorate the standard of living through improvement in the level of education and employment, with the help of NGOs.
3. Several households are becoming self-sustainable in terms of energy requirement by installing roof-top solar photo-voltaic plants, the energy generated through which is not only consumed by the household but may also be sold to the power generating (or distributing) plants that have a shortage.
4. Identified best practices - (a) Generation of solar energy in cold deserts, for example, Ladakh region of Jammu and Kashmir. (b) Generation of electricity through micro hydro power plants in environmentally unstable regions of Uttarakhand and Himachal Pradesh, (c) Solar panels used at schools in remote villages of the Indian Himalayan Region, (4) Roof-top solar photo-voltaic plants as a source of energy and income.

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

The National Action Plan on Climate Change (NAPCC), which includes a comprehensive set of mitigation and adaptation measures, aims to promote India's development objectives while yielding co-benefits for addressing climate change effectively. The NAPCC, among others, recognizes the Himalayan ecosystem as vital for preserving the ecological security of the country. Also, it underlines intense vulnerability of this ecosystem towards both anthropogenic and environmental perturbations. With this realization, NAPCC sets out 'Sustaining the Himalayan Ecosystem' (NMSHE) as one and the only area-specific missions among the eight National Missions. This mission envisages measures for sustaining and safeguarding the glaciers and mountain ecosystems. Considering the relevance of mandate, G. B. Pant Institute of Himalayan Environment & Development (GBPIHED) has been identified as coordinating institution for Task force 3: Forest Resources and Plant Biodiversity. The project covers three major aspects on Mission Approach include (a) enhanced monitoring through observational and monitoring network, (b) promoting community based management, and (c) strengthening regional cooperation

OBJECTIVES

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

ACHIEVEMENTS

1. Data base for 1049 species of shrubs in western Himalaya was prepared. Of these, 916 species were represented in Uttarakhand, 542 species in Himachal Pradesh and 573 species from Jammu and Kashmir. Information of Botanical Name, synonyms, basionyms, altitudinal distribution, global distribution, uses, nativity, endemism, status, etc. of over 500 species has been entered in data base.
2. A list of 1061 herbs (40 Families and 246 Genera) of Trans and North Western Himalaya has been prepared. From Arunachal Pradesh, based on the available literature, a total 982 plant species has been listed. These species belongs to 158 families and 532 genera.
3. The altitudinal distribution of the 1061 herbs of Trans and North Western Himalaya indicates that the maximum number of species was distributed in the altitudinal range of 2800-3800m followed by 1800-2800m, < 1800m and > 3800m asl.
4. Development of Web portal with domain name http://www.ihrplantresources.com for database on plant diversity in IHR has been initiated and is under process.
5. Rapid vegetation sampling in campaign mode was completed in Western Himalaya (Bhagirathi valleys in Uttarakhand) and Eastern Himalaya (Teesta valley of Sikkim) along altitudinal gradient (1000-4000 m asl) to see the forest structure, composition and regeneration status of different forest types. Following the outcomes of these rapid sampling, altitude transect assessment has provided quantitative detail on availability, distribution and abundance of 75 tree species (31 families) in Eastern Himalaya and 29 species (21 families) in Western Himalaya.
6. Assessment of pattern of changes in forest cover and uses of forest resources in the IHR was carried out between 2001-2017. Nearly 41.47% of (2, 21,305 km2) the total area of the IHR is covered with forests. An increase of 2.26% in forest cover of IHR was observed between 2001 and 2017 with an increment of 4,898 km2 area. Canopy cover categories indicate that maximum forest in IHR in 2017 is moderately dense (44%) while very dense is limited to 18% of the total forest cover. Open forest (canopy cover <40%) is also preponderant in the IHR (38% of the total forest cover).
7. Vegetation sampling was carried out in 27 Van Panchayat forests (represented five blocks namely Berinag, Gangolihat, Didihat, Dharchula, Munsyari) of Pithoragarh district in Uttarakhand to understand the status and forest health, and management of forest resources in Van Panchayats. The overall plant species richness in temperate region was found maximum (32 species) for VPFs that were established before 1980 and have large size, however, minimum (22 species) was reported for medium size forest which established after year of 1980.
8. The distribution of invasive species has been monitored in the IHR using published literature. A total of 302 naturalized alien plants have been recorded in IHR. Himachal Pradesh has the maximum number (232) of invasive species followed by Jammu & Kashmir (192) and Uttarakhand (181).
9. Using tree ring samples of *Pinus roxburghii,* chronology of 309 years (AD 1707-2015) is developed for climate-growth relationship studies. Based on the developed tree ring chronology, past climate analysis of reconstructed relative humidity has been done. 166-year old tree ring width chronology was developed for *Betula utilis* extending back to 1849-2015 from high

altitude site Sepu in Darma valley. Tree growth and climate relationship for *Betula utilis* shows significant positive correlation ($p<0.05$) with temperature in November of previous year and current year of February-April, while in case of precipitation significant relationship was found only for the month of May.

10. To assess impact of changing climatic/meteorological parameters on ecosystem exchange of a LTM site in western Himalaya, predominantly occupied by Banj (*Quercus leucotrichophora*) having crown height 8-10 m, daily averaged net ecosystem exchange (NEE), measured using an eddy covariance flux tower for a period of 313 days of 22 Mar, 2016 to 28 Feb 2017, was correlated with daily average air temperature and vapor pressure deficit (VPD) measured at 10 m height using wavelet spectral analysis, particularly cross wavelet and wavelet coherence analysis.

11. People's perception on climate change impacts and adaptation measures was carried out in Western Himalaya (Uttarakhand-Bhagirathi valley; Himachal Pradesh - Sutlej and Parvati valley) and Eastern Himalaya (Sikkim-Zuluk, Rumtek, Sadam-Melli, Mamlay watershed, Dhanbari and Namrang villages under Tumin Gram Panchayat Unit (GPU), East Sikkim and Lachen-Lachung in west Sikkim; Arunachal Pradesh - East Siang, West Siang and Upper Siang. Perception based studies shows that there is a huge gap in information and knowledge base on climate change which impacts decision making at the local level.

12. Capacity building training programme were organized in Uttarakhand, Sikkim, Itanagar and Himachal Pradesh (a total 15) on various issues of forest management and climate adaptation/mitigation. Participants (a total 806) were sensitized on various issues and causes of environment degradation. The participants were also made aware with forest resource management and biodiversity conservation w.r.t. climate change.

13. Using tree ring samples of *Pinus roxburghii,* chronology of 309 years (AD 1707-2015) is developed for climate-growth relationship studies. Base on the developed tree ring chronology, past climate analysis of reconstructed relative humidity has been done.

14. The reconstructed relative humidity data shows 20 high humidity periods and 16 low humidity periods with significant decreasing trend in reconstructed relative humidity during recent years has been observed.

15. 166-year old tree ring width chronology was developed for *Betula utilis* extending back to 1849-2015 from high altitude site Sepu in Darma valley (Fig. 21).

16. Tree core samples of Abies spectabilies, *Pinus wallichiana* and *Rhododendron arboretum* have been collected form high altitude site in Pithoragarh District. The collected samples will be used for development of tree ring chronology and reconstruction of past climate for high altitude site.

SUMMARY OF THE COMPLETED PROJECT

Preventing extinction and improving conservation status of threatened plants through application of biotechnological tools (DBT New Delhi, 2012-18)

The Indian Himalayan Region (IHR), recognized as one among the 34 biodiversity 'hot spots' in the world, is known for its uniqueness, richness and representatives at all levels (gene, species and ecosystem). But, in recent years, rapid increase in human populations, habitat fragmentation, over exploitation of natural resources, changing climatic conditions and invasion of alien species, have resulted in degradation of various ecosystems across the IHR. About 142 species of vascular plants have been listed in the Red Data Book of Indian Plants and 120 species of medicinal plants in different IUCN threat categories. In view of the importance and conservation of threatened plants of India, the Dept. of Biotechnology (DBT), Govt. of India, New Delhi, under the National Networking Programme envisaged this project. The project was carried out in over 37 institutes/universities involving 76 scientists all across the country and has undertaken 171 threatened plants species across the country with prime aim to prevent extinction and promote conservation thereby improving their threat status. With tested past work experience on conservation and management of the threatened Himalayan medicinal plants, GBPIHED focused on four important plant species namely, *Angelica glauca*, *Dactylorhiza hatagirea*, *Paris polyphylla* and *Podophyllum hexandrum* , all high value Himalayan medicinal herbs. The project focuses on (i) Population inventory and mapping using Ecological Niche Modeling (ENM), (ii) Biochemical and molecular profiling of the populations, and (iii) Standardizing the macro- and micro-propagation techniques and development of appropriate approaches for reintroduction of the species in the areas identified through ENM.

Based on the secondary data collected from different sources and results obtained by running ENM programmes, various field surveys were conducted in different alpine and sub-alpine regions of Uttarakhand Himalaya. A total of 85 distributional records along with nineteen bioclimatic variables were utilized for the prediction of potential areas of occurrence/distribution of all the four target species with the help of ENM packages. Biochemical profiling of active constituents and polyphenolics were done from the root and rhizome samples for *P. hexandrum* and *A. glauca* along the altitudinal gradient. Podophyllotoxin, an active constituent of *P. hexandrum*, content ranged from 0.238-0.489% (on dry wt. basis) in root samples to 0.221%-0.961% in rhizomes. Maximum podophyllotoxin in roots (0.489%) and rhizomes (0.961%) was found in sample collected from Martoli Bugyal (3640m) and minimum in root (0.238%) and rhizome (0.221%) collected from Dunyadong (2653m), whereas, a wide variation in polyphe-

nolics was observed among the populations. For *P. hexandrum* maximum polyphenolic content (22.23±0.32 mg/ g dw) was found in Milam population and minimum (20.52±0.48 mg/ g dw) in Katheliya populations, while in case of A. glauca maximum polyphenolic content (9.66±1.5 mg/ g dw) was examined in Dhoratoli population and minimum (4.91±4.6 mg/ g dw) in Martoli populations.

In order to scale the existing propagation protocols, embryo culture of *P. hexandrum* was performed. The medium was supplemented with various concentrations of PGRs. A prominent cotyledon tube with cotyledon leaves and distinct radicular portion were observed when the medium was supplemented with 1.0 µM BAP and 2.0 µM BAP, whereas the cotyledon leaves along with roots developed more rapidly in combination of GA3 + BAP (0.5 µM +0.5µM) and GA3 +BAP (0.1 µM +0.1µM).

Further, efficient rhizome fragmentation method was developed for propagation of *Paris polyphylla* using different concentration of GA3 and IBA, as a result of which, best concentration was found to be GA3 + IBA (100µM; 24h) with 83.33% sprouting and 73.33% rooting rate respectively. This concentration was subsequently used for mass multiplication. For field re-introduction, a germplasm repository of plants (raised through tissue culture and conventional methods) were maintained at Sri Narayan Ashram (Distt. Pithoragarh; 2,734 m), an established ex-situ site under the project. Simultaneously, several Training programme were also conducted in the Sri Narayan Ashram and Chaudas valley on field demonstration of cultivation practices, raising awareness towards depleting status of these threatened and high value medicinal plants, and strategies that can be adopted to improve their economic conditions, as well as to promote cultivation and conservation.

GARHWAL REGIONAL CENTER

The Garhwal Regional Centre (GRC) is devoted to undertake innovative R&D actions 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 people conflict resolution, ecotourism, skill development of stakeholders in simple technologies for natural resource management and livelihood enhancement, etc. The some on-going major R&D thrust areas includes climate change impact, adaptation and coping strategies, tracer technique in spring recharge, bioprospecting of wild resources, promotion and cultivation of medicinal and aromatic plants, sustainable tourism, conservation and management of protected areas and eco-sensitive zones and reconstruction of disaster affected rural landscape of Kedar valley.

OBJECTIVES

- Empowering local communities in social, legal and local level governance on natural resource management.
- Promoting environmentally sustainable income generating activities for livelihood enhancement and socio-economic development.
- Model demonstration on innovative, improved and best practices and skill development of farming communities through on-site action research and training.
- Organizing an open and continuing dialogue between diverse stakeholders (local people, NOGs, scientists, educationists and policy planners) across various levels and layers for developing hill/mountain specific policies.

Reinventing pilgrimage potential for tourism development in the sacred landscape of Garhwal Himalaya, Uttarakhand (In house, 2017-2020)

The Devbhoomi Uttarakhand is a mountainous state and is one of the unique and sacred landscapes, with high ecological, cultural, religious, spiritual values and rich in biodiversity and has a long history in attracting pilgrim's, nature lovers or eco-tourists. It is a land where traditions and culture blend and continue to live in harmony and has great tourism potential. However, many economic benefits of this industry do not accrue to local communities because they do not own and control the key assets. Pilgrimage tourism activities are often seasonal and characterized by unpredictability due to changes in demand, climate, and other external factors. The pressure of religious/pilgrimage tourism has been increasing in the region and 2013 Uttarakhand disaster is the glaring example of this. Therefore, state is in the process of reinventing pilgrimage/ religious potential for tourism development in sacred landscape of Chardham. The current realities of pilgrimage tourism raise several fundamental questions mostly related to local employment, local economy and over all socio-economic development of the area. To ensure that the local population in Uttarakhand region has a share in the economic benefits generated by tourism development, it is important that any such development need to be community-based. First and foremost, pilgrimage tourism activities and entrepreneurial initiatives need to be developed in ways that benefit local people, particularly the most disadvantaged, and initiate activities that includes capacity building and skills development training for local entrepreneurs and others who wish to work in the tourism sector. It also pays attention to a region's cultural heritage and unique assets, so that development activities integrate local knowledge and expertise and recognizes the varied and rich bio- cultures that local hill communities have developed over centuries or longer. With this in mind, there is an urgent need for activities that help diversify economies, provide alternative livelihood opportunities for locals, develop entrepreneurship skill among the locals to manage and operate tourism travel chain or tourism products, promote biodiversity conservation and over all address the issues related pilgrimage/ religious tourism in the Chardham sacred landscape connecting with all weather roads.

OBJECTIVES

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

ACHIEVMENTS

1. Developed checklist for resource inventory and impact assessment (environmental, economic, and socio-cultural) before and after 2013 disaster in Kedar valley that includes Physical resources, Human resource, Cultural resources, financial resources, Institutional resources and Assessment of potential & needs for sustainable tourism development.
2. Literature and secondary data/information collection such as number of tourist visited and percentage change at two points of time before and after 2013 disaster, listing/ identification of model eco-trekking/eco-expedition routes in few potential sites.
3. SWOT analysis (strength, weakness, opportunities and threat) with regard to reinventing pilgrimage potential for tourism development has been worked out.
4. Initiated studies on identification of potential options of linking and supplementing pilgrimage tourism with other form of tourism (rural/agro tourism, heritage tourism, nature/eco-tourism and community based tourism) for socio-economic development of the disaster affected Kedar sacred/ rural landscape.
5. Developing & expanding tourism/eco-tourism knowledge network with various R & D institutions (H.N.B. Garhwal University, Tourism department, GMVN, District Adventure Tourism office, Health Department, Forest Department, etc.), line departments (Zilla Panchayat, Mandir Samiti, ChardhamYatraSamiti etc.), village institutions (Triyuginarayan, Toshi, Majoshi, Joshi, Sitapur, Rampur, Sarsi etc.) and NGOs i.e. ATI, Guptakashi and Swarajay bahu deseya sanstha, etc.
6. Tourism/ecotourism interpretation centre as well as small bioprospecting unit has been established through the financial support of DST as well as participatory approaches at Triyuginarayan for imparting training and capacity building programme to the stakeholders.
7. Initiated programme activities on capacity building and skill development of local stakeholders in homestay accommodation, agro-production system, bioprospecting and tourism product development

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

Uttarakhand is known for its rich spiritual and religious tourism, ecological richness and diversity, and cultural ethos rooted in tradition, but it also known for growing frequency and intensity of natural disasters due to its fragility of ecological and geological system. Unprecedented rains (400 mm) for more than four days during mid-June 2013 resulted in flash floods followed by landslides at many places, killing more than 6000 pilgrims, tourists and damaging huge property in Kedar valley and down streams. Overflowing rivers destroyed many lodges/hotels, human settlements and thousands of hectares of agricultural and forest land. This environmental disaster also has claimed the lives of many locals (950) working in Kedarnath and nearby areas. In Post-disaster scenario, local inhabitants in the Kedar valley are facing challenges due to food, livelihood insecurity and poverty about the future as the economy of the region was totally tourism dependent. Lack of livelihood options for the landless and those with small land holdings force them to extract and exploit natural resources found in and around the area and in that situation there is an urgent need to identify and suggest location specific appropriate options and strategies for livelihood enhancement & income generation. Therefore, there is an urgent need to empower and develop the capacity and skills of these people in harnessing the potential of bio-resources available in the region through the application of simple, cost-effective technological interventions for diversification of land-based and other livelihood options in order to develop the socio-economic condition of the disaster affected areas. It will help the disaster affected people to change their attitudes considerably towards the role, value and usefulness of these simple hill specific and climate resilient technologies for harnessing the locally available potential bio and land base resources for their income generation and livelihood enhancement.

OBJECTIVES

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

ACHIEVEMENTS

1. Established nursery (under 20 nail) of high value medicinal plant species i.e., *Picrorhiza kurooa, Saussurea costus, Valeriana* wallichii and *Inula racemosa* under different micro-climatic conditions (polyhouse, shade net and open condition) and so far raised about 1.20 lakhs seedlings of which about 0.50 lakhs seedlings were distributed to 60 households (HH) of Tarsali and nearby villages for large scale cultivation. The marketing and by back arrangements of the product has been initiated with pharmaceutical industry (Emami Pvt. Ltd, Calcutta).
2. Off seasonal vegetable cultivation under the protected conditions has been adopted by 72 households which provided an additional of income of Rs. 6760/hh/yr.
3. Sustainable harvesting practices and value addition of 12 potential wild bioresources has been demonstrated and promoted for edible product development and benefited about 56 HH.
4. Promoting large scale floriculture for household income generation while developing huge nursery of Marigold (*Tagetus minuta)* in Triyuginarayan village cluster to meet the growing demand of flower particularly during pilgrimage season.
5. Organized six skill development programme (each of 2 days) between 2017-18 and trained about 289 farmers (192 male & 97 female) in the field of vegetable cultivation under protected condition, bioprospecting of wild edibles, medicinal plant cultivation, biocomposting, floriculture, water harvesting, etc.
6. Low-cost water harvesting tank technology demonstrated at RTC by using plastic sheet to store rain water by diverting surface runoff from upstream as well as rainwater in water deficit area. Besides, water harvesting tank without polythene were used for fish cultivation.

Identification of land and bio-resources based potential options for livelihood enhancement and diversification through simple technological interventions for sustainable development of the disaster affected rural landscape of Kedar valley, Uttarakhand (ICSSR, 2016-2020)

The traditional societies of upper Kedar valley are facing a range of socio-economic and environmental problems after flash flood (disaster) of June 2013 striving to cope up with food and livelihood security. Thus, in view of the above background, a generalized and uniform action plan cannot be much useful for this region because of vast diversity in respect of topography, natural and bio-cultural landscape, diverse climate, water and bio-resources availability, etc., and in that situation only location specific livelihood management plans can be useful. At a juncture when development is constrained by natural disaster (resource depletion and environmental degradation), the role of sustainable utilization of bio-resources and land based activities through simple, cost-effective and appropriate technological interventions which promote and ensure ecologically sound development of the rural areas/village cluster becomes crucial. Lack of livelihood options for the landless and those with small land holdings compel them to extract and exploit natural resources found in and around the area. Therefore, there is an urgent need to empower and develop the capacity and skills of these people in harnessing the potential of bio-resources available in the region through the application of simple, cost-effective technological interventions for diversification of land-based and other livelihood options in order to develop the disaster affected areas. There is also an urgent need for linking developmental organizations with village institutions like the village panchayat for rebuilding infrastructure and to provide opportunities in the disaster- affected regions of the state. Capacity building and skill development through on-site training programmes, live demonstrations and interactions between stakeholders and scientists is urgently required and need to be facilitated. It is hoped that if people of disaster affected villages implement and replicate bio-resources based income generation activities which will not only improve their own socio-economic conditions in short and long term basis but certainly will make themselves self reliance in the future.

OBJECTIVES

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

ACHIEVEMENTS

1. Prepared a detail list of potential bioresources as an appropriate option for livelihood improvement of the disaster affected villages in upper kedar valley.
2. Nursery of high value low volume medicinal plant species such as Puskarmul (*Inula racemosa*), Tagar (*Valeriana wallichii*), Kutki (*Picrorrahiza kurooa*) and Kut (*Sassurea costus*) were initiated at small scale at Triyuginarayan village cluster at 2200m asl since climatic conditions are more conducive for their large scale cultivation and has been considered one of the potential options for income generation and adaptation in changing climate scenarios.
3. Community based adaptation and coping mechanism particularly in agriculture, livestock and forestry sectors (i.e. collection of forest based bioresources such as *Rhododendron arboretum, Ficus auriculata, Diplazium esculentum, Peonia emodi, Vibarnum mullaha, Allium humile, Angelica glauca, Carum carvi, Cinnanomum tamala,* etc. and medicinal plant cultivation for food and income generation) were identified as an appropriate livelihood options and strategies to reduce vulnerability and increase resilience to 2013 disaster.

Rejuvenation of springs and spring-fed streams in Mid-Himalayan Basins using spring sanctuary concept (NMHS, 2016-2019)

The Indian Himalayan Region (IHR) is one of the most diverse and versatile mountain systems of the world considering the physical, biological and socio-cultural attributes. The sensitivity of these attributes towards changes (anthropogenic and climatic) is recognized world over. Among others, the water resources in the Himalayan Mountains have been recognized as most sensitive systems, which are subject to changes. One such conspicuous change is the drying-up of the springs/streams due to due to global climate change as well as anthropogenic onslaught on mountain woodlands. Water being a fundamental constituent of environment and vital for the living beings, sensitivity of water recourses has long-term consequences for mountain ecosystem properties and human societies. Water stress and sustainability are functions of the available water resources and their withdrawal and consumption. In view of the expanding footprints of water scarcity zones throughout the Indian Himalayan region, this action oriented project will attempt to develop field level demonstration models to rejuvenate the life-supporting springs and spring-fed streams for selected watershed of the IHR in collaboration with state implementing agencies using spring sanctuary concept as well as initiating the long-term-ecological monitoring networks in four watersheds across Indian Himalayan Region.

OBJECTIVES

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

ACHIEVEMENTS

1. Village wise spring inventory, and creation of Geodatabase in GIS Domain (Fig. 22).
2. Stable isotope investigation in collaboration with National Institute of Hydrology (NIH) in Garhwal and Kumaon.
3. Participatory interventions in Garhwal and Kumaon through State Implementing Agencies.
4. Landuse/landcover mapping and change detection using high resolution satellite data of 2008 and 2017 (Fig 23).
5. Over Senkhi watershed of NE, data collected from AWS (Automatic Weather Station) shows highest temperature of 31-30°C during month of June 2017 and June 2018. The lowest temperature in December 2017 (15°C).
6. A total of 20 springs have been mapped from the Senkhi watershed Out of the total 20 springs, only 8 are perennial. The highest spring discharge was observed Near Rajiv Gandhi polytechnic college as 0.85 liter per second which is a non perennial spring. The lowest discharge was measured at the spring located at Ganga lake 0.009 litre per second.
7. The highest Senkhi river discharge was recorded at the cross-section located Near Chandra Nagar Bridge as 295.12 (ft^3/s) and lowest discharge at Iron Bridge 285.60 (ft^3/s) (appx. 1 km upstream of water treatment plant) Senkhi View. Water quality analysis of all springs and Senkhi river found to be within permissible limit except for water sample collected from near senkhi park showing higher pH value of 8.7.
8. Created awareness among the community regarding importance of spring and its future prospect. The morphometric analysis of the Senhki river was done using RS-GIS.

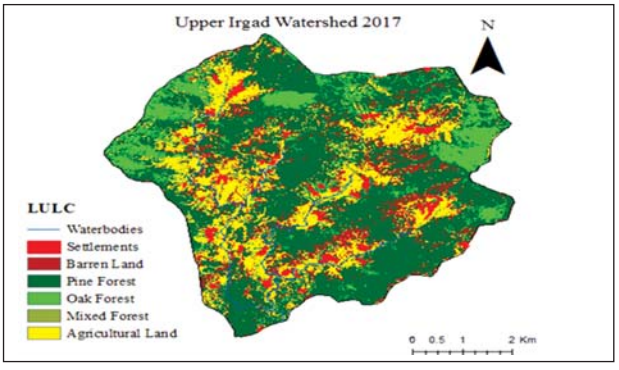


Fig. 22. Map of the study sites

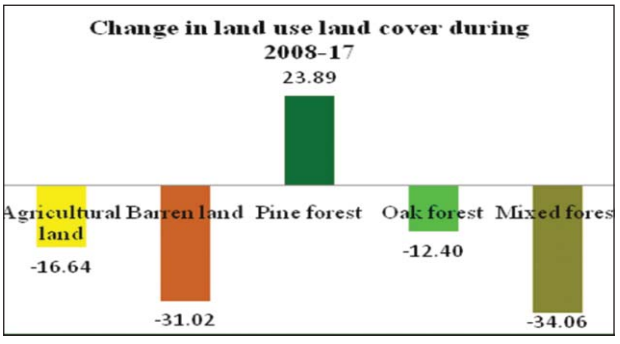


Fig. 23. Change in land use and land cover during 2008-2017

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

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

OBJECTIVES

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

ACHIEVEMENTS

1. An extensive review of relevant literature pertaining to epiphytic bryophytes and a preliminary field survey was carried out for selection of different forest types ranging between 1400 m asl to 3400 m asl along an altitudinal gradient in Kedarnath Wildlife Sanctuary to conduct the present study.
2. An inventory was made to collect the primary information of prevalent epiphytic bryophytes with regards to habitats, slope, aspect, life strategies, growth forms, altitudinal range and supporting host tree species of woody plant in KWLS for establishing permanent plot to study distribution pattern and phytosociological aspect of the tree vegetation along altitudinal gradient.

Fig. 24. Study area and different habitats of epiphytic bryophytes; A-B – Study area, C,D,E- Habitats

3. Two sub-sites (A) Kalimath (30^0 54' 12'' N - 79^0 08' 20'' E)-Tungnath (30^0 48' 93'' N - 79^0 21' 62'' E) and (B) Sonprayag (30^0 38' 05'' N - 78^0 58' 12'' E) - Triyuginarayan (30^0 38' 07'' N - 78^0 58' 8''E) were selected for conducting detail study and these sub-sites were again divided in 5 altitudinal zones (1400-1800, 1000-2200, 2200-2600, 2600-3000 and 3000-3400 m asl) at 400 m intervals along an altitude to identify the diversity and distribution pattern of epiphytic bryophytes with increasing altitude (Fig. 24).
4. During the preliminary survey a total of 28 prominent woody plant species has been reported in the present study and emphasized that the recorded species belongs to 19 genera and 10 families. The

Pinaceae and Betulaceae represent 4 genera and 5 species followed by Ericaceae having 2 genera and 4 species, Sapindaceae having 2 genera and 3 species, Fagaceae having 1 genera and 5 species, however, Buxaceae, Cupressaceae, Juglandaceae, Myricaceae, Symplocaceae, Taxaceae having single genera single species in the study sites.

5. In the initial phase of survey, a total of 37 species of epiphytic bryophytes belonging to 14 families and 30 genera were found along an altitudinal gradient of KWLS. The family Meteoriaceae is recorded the largest family represents maximum number of species (8) and genera (7) of epiphytic bryophytes followed by Bryaceae having 3 genera and 7 species of epiphytic bryophytes, Dicranaceae and Pottiaceae having 3 genera and 3 species, Hypnaceae represents 2 genera and 3 species while Sematophyllaceae, Brachytheciaceae, Neckeraceae represents 2 genera and 2 species. Orthotrichaceae represents 1 genus and 2 species, Leucodontaceae, Trachypodaceae, Leskeaceae, Thuidiaceae, Entodontaceae represents 1 genera and 1 species.

6. The observation made in the present study revealed that the population and biomass of the epiphytic bryophytes are more at middle altitude (2000-2500m asl) altitude as compared to higher altitude due to dense canopy and higher moisture content at middle altitude.

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

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

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

OBJECTIVES

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

ACHIEVEMENTS

1. An extensive literature review and a preliminary field survey were carried out for selection of indigenous agro-forestry models in Indian Central Himalaya. Three village clusters e.g. Saknidhar, Jakhand and Dagar in Tehri district along an altitudinal gradient ranged from 800 to 2200 m asl were selected for conducting the present study.

2. A total of 30 woody agro-forestry species and 31 food crops have been recorded and ranking of 10 species for plantation based on their multiple

use value and their traditional uses were documented in all three selected village clusters.

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

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

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

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

7. Based on the results obtained so far from the present study highlight that quantity of fuelwood and fodder consumption increases with increasing altitudes however, the biomass and carbon stock was decreased with increasing altitudes.

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

SUMMARY OF COMPLETED PROJECT

Capacity Building of Mountain Communities for Use and Management of Natural Resources through Rural Technology Complex (RTC) (Inhouse, 2012-2017)

1. A total of 18 technologies were in-housed, tested/modified revalidated and maintained at the RTCTriyuginarayan, district Rudraprayag, with a view to demonstrate, replicate and/or disseminate to user groups particularly rural people and women folk in the mountains.

2. Developed and demonstrated an unique model for the first time on integration of medicinal plants cultivation (*Picrorhiza kurooa, Saussurea costus, Valeriana wallichiiand Inula racemosa)* together with horticultural system (apple, Juglans regia) as a potential option to increase per unit area production, provide higher economic return and represent sustainable land use system particularly for high altitudinal region between 1600-2800 masl where climatic conditions are favorable for such kind of intervention.

3. Developed huge nursery of high value-low volume economically important medicinal plants having conservation priorities e.g. *Valeriana wallichii* (1.5 lakh seedlings), *Inula racemosa* (0.25 lakh), *Picrorhiza kurooa*(0.20 lakh) and *Saussurea costus* (0.15 lakh) under different micro-climatic conditions (polyhouse, shade net and open condition) for large scale cultivation.

4. The assessment of survival, growth and biomass of two important medicinal plants such as *Valeriana wallichii and Inularacemosa* has been carried out at low (560 masl) and high altitude (2200 masl) under different micro-climate conditions (polyhouse, shadenet and open conditions) so as to develop suitable package of practice for promoting large scale cultivation in farmers fields.

5. During this year an amount of Rs 6.0 lakhs was generated from the Sponsored Trainings and other activities of the RTC.

6. During the demonstration and training programme the participants were imparted technical know-how on technologies enhoused at RTC. i.e. protected cultivation (Polyhouse, Nethouse, etc.), vegetable cultivation, vermicomposting model, water harvesting integrated with fish farming, me-

dicinal plants cultivation, bioprospecting of agro and wild bioresources and provided them ready hands-outs for easy understanding as well as for adopting these technologies in their homestead.

7. About 75000 (seventy five thousands) seedlings of *Valeriana wallichii* were distributed to the interested farmers of village Tarsali (district Rudraprayag) and village Pokhri (Pauri district) for large scale domestication and cultivations in the farmers field and facilitated marketing of the final product through Emami Pvt. Ltd.

8. About 2.5 lakhs plants of *Valeriana wallichii* and Inula racemosa were raised in nursery at RTC, Triyuginarayan of which about 1 lakh plantlets were distributed to the interested farmers from different areas of the region for promoting large scale cultivation of MAPs for livelihood enhancement of the local people.

9. The below and above ground biomass (gm/dry wt./plant) of *Valeriana wallichii* and Inula racemosa under different micro-climatic conditions (polyhouse, shade-net house and open) was estimated at 2200 m asl (RTC, site). The yield of below ground part was obtained 3 to 6 times higher under polyhouse condition as compared to shade and open conditions because of higher temperature inside the polyhouse.

10. During the reported period (2012-2016), a total of 38 training and awareness programmes (4 each of 5 days, 8 each of 3 days, 12 each of 2 days and 14 each of 1 day) were conducted for different user groups (farmers/officials selected by Govt. organizations, Non Government organizations, Institute programme, students, etc.) in which a total of 2354 farmers (Female, 949 and Male 605), 510 students, 155 SHGs, 55 Army persons and 45 representatives from NGOs and 35 representatives from different line departments) imparted training covering 6 districts and 46 villages of Garhwal part of Uttarakhand.

SUMMARY OF COMPLETED PROJECT

Experiment to understand the spring low and development of hydrological model (ISRO Ahmedabad)

Remoteness, inaccessibility, low population densities and high cost for drilling programme in hilly area hinders the generation of water-table elevation measurements and sub-surface hydraulic data which is very essential for any water resource planning project. Spring and stream hydrograph provides an excellent opportunity to decipher subsurface hydrogeological processes. Since the catchment area is degrading in rural watershed due to lack of protection and management and urban area is ever expanding, it will be crucial to know & protect the source area for the life sustaining springs & spring-fed-streams. Groundwater protection in fracture media is a pertinent issue in Himalayan region which needs to be addressed through proper multidisciplinary approach. Geological, geohydrological, geophysical as well as hydrodrological investigation are required to define the zone of contribution of springs, spring fed streams or ground water well. The project was focused on (i) hydrological experiment for the estimation of aquifer characteristics and spring flow measurement, and (ii) development of conceptual modeling framework for understanding the spring flow in the Himalayan region. The following results were obtained during the project period:

1. Depth to water level data collected for April 2016 to March 2017 period highlights the dynamic nature of shallow groundwater system which feeds the springs, seeps and low-order streams. The precipitation and water level data indicate the dominance of preferential recharge in this hydro-geological setting.
2. The results of aquifer testing through slug test, pump test recovery data and geological mapping indicate double porosity model for the fractured metasedimentary formations. The slug test (rising head) suggest fracture hydraulic conductivity ranges between 0.001 to 0.06m/day with an average value of 0.02m/day for BW1, 2, 3, 5 whereas the BW4 records a high hydraulic conductivity of 2.36m/day. The storativity values ranges between 10-2 to 10-10 for fractures and matrix blocks.
3. Groundwater model was setup for hardrock aquifer using a close basin single continuum concept which incorporates spring flow, stream flow and water head records with initial assumption of recharge and evapotranspiration values. Steady and transient modelling showed under prediction of measured and calculated head. Our preliminary results are less conclusive due to limited information, one-year water level data and hard rock heterogeneity.

HIMACHAL REGIONAL CENTER (HRC)

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

Community driven solid waste management in Himachal Pradesh: A step towards Swacch Bharat Mission (In house, 2017-2020)

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

OBJECTIVES

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

ACHIEVEMENTS

1. Review of literature was done and relevant information gathered. Sites namely, Kullu and Manali in Kullu district, Mandi in Mandi district, Bilaspur in Bilaspur district, Hamirpur in Hamirpur district, Kangra in Kangra district and Chamba in Chamba district were selected for the detailed study. Reconnaissance survey of the Kullu area was done.
2. Training-cum-capacity building workshops were organized in two urban towns i.e., Kullu (24-02-2018) and Manali (22-03-2018) and 200 participants representing diverse stakeholders were made aware about the solid waste management (Fig. 25).
3. Secondary data relevant to project was collected from Kullu, Manali, Mandi, Bilaspur and Hamirpur from relevant Government Departments i.e., Municipal council, Department of Tourism and Civil Aviation, State Pollution Control Board and Town and Country Planning (Table 3).

Table 3. General information of municipal councils

S. No.	Place	Area under M.C. jurisdiction (km^2)	Population	Total Numbers of the wards in the area under jurisdiction	Total numbers of households in the area under jurisdiction	Number of households covered by door to door collection	No. of shops/ commercial establishments in the jurisdiction area	Quantity of inert waste sent to landfill sites during the period
1.	Kullu	6.68	18536	11	10760 approx.	10760	1240	1850 tons approx. yearly
2.	Mandi	4.263	27058	13	6307	6307	1450	24 metric tons per day
3.	Manali	3.5	8096 (local)	7	1832	1832	249	20 metric tons per day
4.	Bilaspur	10.62	13654	11	3233 (approx.)	3233	-	4 metric tons per day
5.	Hamirpur	5.24	17064	11	-	Not established	-	6 metric tons per day

4. Soil samples were collected from dumping sites and nearby locations of Pirdi (Kullu), Saat Meel (Mandi), Kharian (Bilaspur) and Dagneri (Hamirpur) (Fig. 25).
5. Interactions with 98 hoteliers of Kullu Planning Area i.e., Manali and nearby areas, Kullu, Bhuntar and Banjar having > 25 rooms were done and information on their solid waste management was generated.

Preventing Extinction and Improving Conservation Status of Threatened Plants through Application of Biotechnological Tools (DBT, 2012-2018)

The Himalayan region is amongst the identified Global Biodiversity Hotspots. The Indian Himalayan Region (IHR) forms the major part of Himalaya and comprises of three bio-geographic zones and 8 bio-geographic provinces due to its typical physical features and environmental conditions. The unique topography, diverse habitats and large altitudinal range (200-8,000m, asl) support the representative, natural, unique and socio-economically important biodiversity. The region represents tropical, sub-tropical, temperate, sub-alpine, alpine and Tundra ecosystems/biomes. The major population of this region is largely dependent on wild plant diversity as it provides various livelihood options such as medicine, food (wild edibles), fodder, fuel, timber, etc. for their sustenance. But, it is being lost at an unprecedented rate as a consequence of human induced environmental change. The extinction of a species is the result of local extinctions of its populations. Therefore, studies on quantitative assessment, mapping, monitoring of the populations of threatened plants are urgently required. So that actual status of the species could be identified and mass multiplication and conservation (ex situ & in situ) be ensured.

OBJECTIVES

- To assess, map and monitor the populations selected threatened plants viz. in Himachal Pradesh, North Western Himalaya
- To develop Ecological Niche Models for predicting the potential areas of distribution of the selected species
- To develop seed germination and vegetative propagation protocols
- To establish and maintain threatened species in ex situ and in situ condition

ACHIEVEMENTS

- Total 4 populations of *Gentiana kurroo* were studied between 1423-1821m asl in Himachal Pradesh, representing West, Northeast and North aspects, and dry and rocky habitats. Among the populations, richness of species ranged from 12-25; total trees density 17-162 Ind ha-1; total shrubs density 530-710 Ind ha-1; total herbs density 45.35-73.10 Ind m-2; Concentration of dominance trees 0.03-1.00, shrubs 0.25-0.34 and herbs 0.05-0.44 and Species diversity (H') for trees 0.0-0.52, shrubs 1.23-1.53 and herbs 1.02-2.36. Mean density of *Gentiana kurroo* populations was 80.75per $100m^2$ and range varied from 63.0-110.0 Ind $100m^{-2}$.

- Among the populations, moisture content ranged from 5.05-14.70%, pH 7.99-8.31, total nitrogen 0.65-0.81%, organic carbon 2.56-5.34% and organic matter 4.41-9.21%.
- Twelve (12) distributional records, Bioclimatic and DEM variables were utilized for the prediction of potential areas of *Gentiana kurroo* with the help of ecological niche modeling packages. The model test for *Gentiana kurroo* yielded satisfactory results (AUCtest= 0.826 ± 0.110). Amongst the predictor bioclimatic variables Precipitation of Driest Period (BIO 14); Ttemperature Annual Range [BIO 7 (Max Temperature of Warmest Period - Min Temperature of Coldest Period)] and Temperature Seasonality (BIO 4, Coefficient of Variation) were the most influential and contributed 38.1%, 35.4% and 24.4%, respectively to the Maxent Model (Fig. 26).
- The interview of three farmers revealed that *Aconitum heterophyllum* is cultivated in Upper Beas Valley and Parvati valley in Kullu districts. These farmers belong to Janna, Kutla and Tauk villages and actively cultivating the species for last 10 to 15 years. These farmers are cultivating *Aconitum heterophyllum*, *Angelica glauca* and *Picrorhiza kurrooa* between 2737 - 3100m asl.

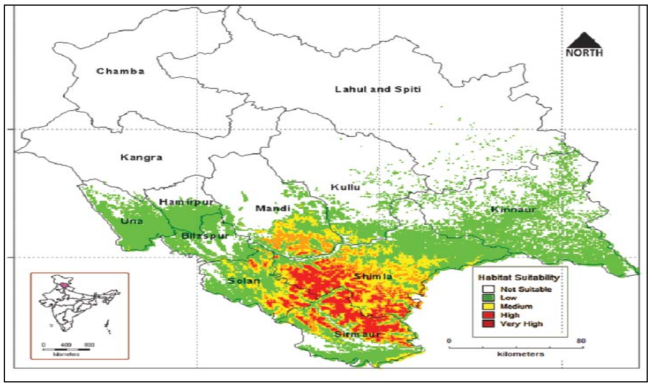


Fig. 26. Habitat suitability and distribution of *Gentiana kurroo* in Himachal Pradesh

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

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

OBJECTIVES

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

ACHIEVEMENTS

1. In vitro micropropagation of the medicinal plants *Delphinium denudatum* and *Polygonatum verticillatum,* MS culture medium containing 0.3 mg/ml BAP gave the best rate of shoot initiation in *Delphinium denudatum.*
2. MS medium containing 0.5 mg/ml and 0.3mg/ml BAP gave the best rate of shoot initiation in *Polygonatum verticillatum.*
3. Callus formation in *Polygonatum verticilla*tum in MS medium with IAA & BAP (0.3mg/ml and 0.5mg/ml) and IAA and BAP (0.5mg/ml) with MS Media gave the best result and in *Delphinium denudatum* MS medium with 2,4-D & Kinetin (0.5mg/ml and 1mg/ml). 20% seed germination of *Delphinium denudatum* was observed in ½ MS Medium with Kinetin (0.3 mg/L).

Scientific research on changing climate and its impact on floral diversity and ecosystem services (pollination) at Kullu region of IHR – a Citizens' Science initiative

(Earthwatch Institute India, 2015-2018)

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

OBJECTIVES

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

ACHIEVEMENTS

1. Two Citizen Science Programmes (CSPs), CSP XVII (03- 12 April, 2017) & CSP XVIII (05- 14 October, 2017) were organized. Qualitative assessment of the vegetation in and around the orchard sites was done, 79 species of plants representing trees, shrubs and herbs including ferns were recorded out of these 34 species were found to be bee/pollinators foraging resources based on the visitation of bees/pollinators on the flowers of these plant.

2. Six sites/plots were selected and sampled for the quantitative assessment of vegetation. Across these study sites, *Cedrus deodara* (05 sites) and *Pinus wallichiana* (1 site) tree communities were delineated based on the Importance Value Index (IVI). *Sarcococca saligna, Elaeagnus conferta* and *Berberis lycium* in shrubs and *Fragaria nubicola, Oplismenus compositus, Trifolium repens, Poa annua,* etc. in herbs were dominant.

3. The insect pollinators' diversity and density were assessed in and around selected orchards of apple by scan and visual sampling method. The results showed highest visitation rate of *Apis ceranna*, followed by *Apis mellifera,* Drone, butterflies, syrphids, etc. in all orchards except in Hirni and Kradsu where highest visitation rate of Apis mellifera was observed (Fig. 27).

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

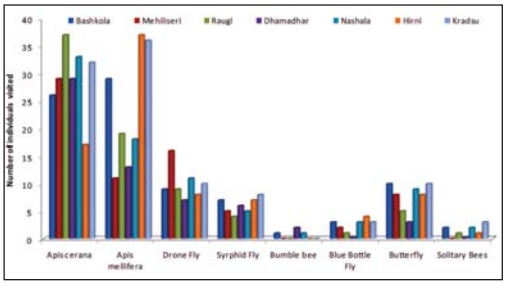


Fig. 27. Diversity and density (visitation/15 minutes) of Insect/pollinators on apple crop in the different orchards in April 2017

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

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

OBJECTIVES

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

ACHIEVEMENTS

1. Ten Gram Panchayats namely Naggar, Nathan, Bastori, Karadshu, Jallugran, Mangarh, Jagatsukh, Prini, Halan -1 and Shanag were surveyed. Maps and demographic profiles of the Gram Panchayats were prepared.
2. Information on wild biodiversity i.e., forest types, habitats, plants diversity, animal diversity, medicinal, wild edible, fodder, fuel, timber, fiber and religious plants was collected and documented.
3. Information on domesticated biodiversity (Plants diversity, Animal diversity (Mammals & Birds), Cultivated Medicinal plants diversity, Ornamental plants diversity, Religious plants, Agricultural crop diversity, Horticultural crop diversity was collected and documented.

Vulnerability Assessment of Mountain Ecosystems due to Climate Change: Ecosystem Structure and Functioning (IIRS, 2015-2019)

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

OBJECTIVES

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

ACHIEVEMENTS

1. Total 44 sites were surveyed in Great Himalayan National Park between 2803-4480 m asl. Six (06) Trees, Sixteen (16) Shrub and Eight (8) herb communities were identified. Maximum sites were represented by *Quercus semecarpifolia* (8 sites) and *Betula utilis* (5 sites) communities. The total trees density ranged from 10.00- 930.00 Ind ha^{-1}; total basal area 0.015-17.84 m^2 ha^{-1}; total shrubs density 100.00-2430.00 Ind ha^{-1}; total herb density 31.40-281.22 Ind m^{-2}; total saplings density 30.00-552.00 Ind ha^{-1} and total seedlings density 50.00-562.00 Ind ha^{-1}. Species richness was maximum in *Betula utilis* (129 spp.) community; followed by *Quercus semecarpifolia* (127 spp.) community. Species Diversity (H') of trees ranged from 0.06–0.68, shrubs 0.08-2.97, and for herb 1.93-3.99. Concentration of Dominance (Cd) was ranged from 0.51-1.00, shrubs 0.15-1.00, and herbs 0.044-0.235.

2. Maximum sites were represented by *Quercus semecarpifolia (8* sites) and *Betula utilis* (5 sites) communities. In *Quercus semecarpifolia* community, 127 species (Trees: 9; shrubs: 28 and herbs: 90) were recorded. The total trees density and total basal area were 926.25 Ind ha^{-1} and 6.91 m^2 ha^{-1}, respectively. Total seedlings and saplings density were 512.73 Ind ha^{-1} and 355.00 Ind ha^{-1}, respectively. Among the seedlings, highest density 346.25 Ind ha^{-1} was shown by *Quercus semecarpifolia*. Saplings density was also highest for *Pinus wallichiana* (290.00 Ind ha^{-1}).

3. In *Betula* utilis community, 129 species (trees: 02; shrubs: 24; and herbs: 103) were recorded. The total trees density and total basal area were 476.00 Ind ha^{-1} and 17.84 m^2 ha^{-1}, respectively. Total seedlings and saplings densities were 562.00 Ind ha^{-1} and 552.00 Ind ha^{-1}, respectively. Among the seedlings, highest density was shown by *Betula utilis* (554.00 Ind ha^{-1}). Highest saplings density was also shown by *Betula utilis* (554.00 Ind ha^{-1}) (Fig. 28).

4. The pH was ranged from 4.39-6.76, moisture content, 11.93-47.31 %, total organic matter, 4.91-16.47 %, total organic carbon, 2.85-9.56 and available phosphorus, 0.10-0.51 mg kg^{-1}.

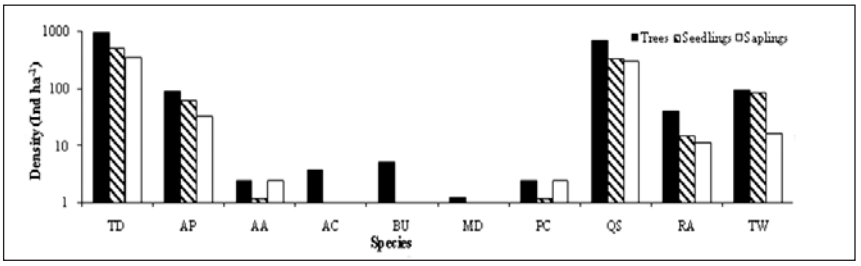


Fig. 28. *Picea smithiana-Pinus wallichiana* mixed community

Community based conservation and long term monitoring of pollination projects in Kullu, Himachal Pradesh (Earthwatch Institute India, 2017-2018)

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

OBJECTIVES

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

ACHIEVEMENTS

1. 1800 seedlings of bee flora i.e., *Pyrus pashia, Berberis aristata, Callistemon citrinus, Pittosporum eriocarpum, Rosa moschata, Aesculus indica* and *Bauhinia variegata* developed in the nursery and planted in Kais, Archandi, Nashala and Nathan villages.

2. Seeds of Bee forage/ cultivated crops i.e., *Brassica camprestris* (45 kg) and *Coriandrum sativum* (17 kg) were distributed to the farmers in Kais, Karadsu, Archandi, Hirni, Nashala, Katrain and Dobi villages for promoting insect pollinators in different seasons.

3. 22 Bee hives with bee colonies distributed to the farmers in Kais, Seobagh, Archandi, Nagar, Nashala and Karadsu villages.

4. Evaluation of Insect pollinator density and diversity on mustard crop was done in which maximum insect diversity was found of syrphid flies followed by Indian honeybee.

Impact assessment of National Highway expansion on floral biodiversity and evaluation of air pollution tolerance of selected plant species in North Western Himalayan region (SERB-DST - NPDF, 2017-2019)

The development of National Highways can have wide range of environmental impacts compared to many other developmental projects. The road construction and expansion activities may lead to clearance of vegetation and other ecological resources resulting in to habitat fragmentation. Since, the construction and expansion of roads in mountainous region of Himalaya lead directly or indirectly to the loss and degradation of natural habitats thereby affecting biodiversity of the region. It therefore, becomes essential to address the impacts of construction and expansion activities of National Highway-21 on structure and floristic composition of vegetation communities. The plants growing in the polluted environment show changes in their morphology, physiology and biochemistry. The regular monitoring of the various biochemical and physiological parameters can indicate the level of pollution as plant species are more sensitive and act as biological indicators of air pollution. The present study is being conducted for assessing the effect of construction /expansion activities of National Highway-21 (Kiratpur – Nerchowk Expressway) in Himachal Pradesh a North Western Himalayan state. The said highway in Northern India connects Chandigarh to the most popular tourist destinations of the state like Kullu, Manali and Rohtang Pass. This road also serves as a connecting link to famous tourist area of Leh- Ladakh which is also important on defense point of view. The National Highway -21 is being upgraded from its present two-lane layout to a four- lane divided carriageway. The design of road is between Kiratpur - Ner Chowk section 73.2 Km in Punjab and 186.5 Km in Himachal Pradesh. Therefore, the present study can help to screen out the effect of road expansion activities on native vegetation and could help in making a strategy for a selection of plant species with high tolerance index during a fresh planting alongside the newly constructed four lane expressway as well as guidelines for other Himalayan roads with similar geo-climatic conditions.

OBJECTIVES

- To assess the effect of road construction/expansion activities on diversity of native flora growing alongside the National Highway.
- To study the effect of dust and air pollution on agriculture crops
- To study the effect of dust and vehicular pollution on biochemical and physiological parameters of native vegetation and to evaluate the air pollution tolerance index of selected plant species.
- To evaluate the anticipated performance index of selected plant species and to develop green belt plan for roadside plantation.

ACHIEVEMENTS

1. Four sites namely, Swarghat, Barmana, Sundernagar and Dadaur were selected between Kiratpur and Nerchowk on express highway (NH-21). Surveys and samplings of native flora were conducted at 12 sites adjacent to National Highway upto 100 meter distance from the edges of road for estimating the impacts of project activities on floral diversity. For comparative analysis of impacts, the floral diversity was also studied on non impacted sites at approximately 4km away from the edges of road where construction activities were going on.
2. Agricultural crops, major cereal and vegetable crops were also identified and selected for further sampling and biochemical analysis.
3. Dominant plant species of broad leaf category were identified and selected for further biochemical analysis and air pollution tolerance indexing.

Standardization of post harvest technology for wild rose hips and promotion as sustainable livelihood option among poor self help women groups in Kullu Valley, Himachal Pradesh (DST, 2015-2018)

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

OBJECTIVES

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

ACHIEVEMENTS

1. Rosehip tea and rosehip oil (Fig. 29) were analyzed for the biochemical composition and antioxidant activity (FRAP, ABTS and DPPH assay), total phenolic, total flavonoids and vitamin C content. The product showed good antioxidant activity having IC50 values as FRAP- 1.22µg/ml) ABTS-0.035 µg/ml, DPPH -1.35µg/ml, good phenolic (15.39 mg/g) and flavonoid contents (7 mg/g) and high vitamin C content (0.025 mg/g DW). The fatty acid composition of seed oil was identified and measured as palmitic acid (4.71 %), stearic acid (2.56 %), oleic acid (10.28 %), linoleic acid (54.84 %), α-linolenic acid (21.46%), ϒ-linolenic acid (<0.01 %) using ISO 5508:1990 & 5509: 2000 method.
2. Three (3) Training Programmes were organized in which 103 women were trained with total 17 women groups on the harvesting and processing of rosehips. Income generation was estimated around Rs. 1,49,000/- for rosehip tea and Rs. 37,000/- for seed oil respectively in second year.
3. The plant cuttings were monitored for the regeneration aspects from different altitudes with different treatments and replicates. Result shows good regeneration with the normal soil condition as compared to treated. Seed germination was also observed.
4. Resource mapping of the species at four different altitudes has been done for its morphological changes and its availability for the entire season i.e., flowering to harvesting.

Fig. 29. Rosehip products

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

Tropospheric or surface ozone (O_3) is an important air pollutant threatening human health, vegetation growth and increasing local temperature as one of the important greenhouse gases. O_3 is a secondary pollutant. It is the key species affecting the chemical properties of the atmosphere where it is a precursor for the highly reactive hydroxyl radical. O_3 and its precursors play an important role in affecting regional climate and causing adverse effects on human health and vegetation. The relation between O_3 and its main precursors represents one of the major scientific challenges associated with gaseous pollution. Ozone concentration depends on the absolute and relative concentration of its precursors and the intensity of solar radiation. An analysis of the influence of meteorological parameters on O_3 and its precursors at a specific site can contribute to a better understanding of the local and regional causes of O_3 pollution. Nitric oxide (NO) is emitted from soils and natural fires, and is formed in situ in the troposphere from lightning, and is emitted from combustion processes such as vehicle emissions and fossil fueled power plants. NO is a short lived because it oxidizes to produce nitrogen dioxide (NO_2) and plays a major role in O_3 production. Biomass burning, combustion of fossil fuels, and oxidation of hydrocarbons released from automobiles and industrial solvents are the main sources of atmospheric carbon monoxide (CO). Its oxidation leads to O_3 formation or destruction, depending upon the level of NO concentration.

OBJECTIVES

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

ACHIEVEMENTS

1. Observation of surface O_3 and its precursors like nitrogen oxides (NO+ NO_2) was carried out at Kothi (2500 m asl). During a period from October 2017 to March 2018, higher concentration of surface ozone was observed in March, which was maximum as 47.60±1.15 ppb. However, its minimum value stood to be 39.45 ± 1.47 ppb in December. This is because of increase in NOx precursor due to inflow of vehicles and solar irradiance.

2. Maximum concentration of NO was 3.28 ± 0.16 ppb in December, NO_2 4.12 ± 0.87 ppb in January and NOx 7.14 ± 0.15 ppb in December. While minimum concentration of NO, NO_2 and NOx was during March (Fig. 30a). This is due to stagnant flow of pollutants in winter time and less solar irradiance as a result NOx could not dissociate in producing surface ozone.

3. During a reporting period, higher concentration of CO_2 was observed in February, which was maximum as 361.35±6.87 ppm and minimum was found to be 206.84±11.45 ppm in October. This is due to burning of wood and biomass in households in winter by people.

4. The concentration of O_3 was found to be increasing gradually after sunrise (07:00 - 08:00 h IST), attaining maximum concentration during afternoon (14:00 - 16:00 h IST). In presence of strong solar irradiance, production of surface ozone increases. However, thereafter it showed a gradual decreasing trend (Fig. 30b). Precursors' of surface ozone are mainly considered to be emitted into the atmosphere mainly due to anthropogenic emissions such as vehicular and biomass burning which are considered to be primary pollutants.

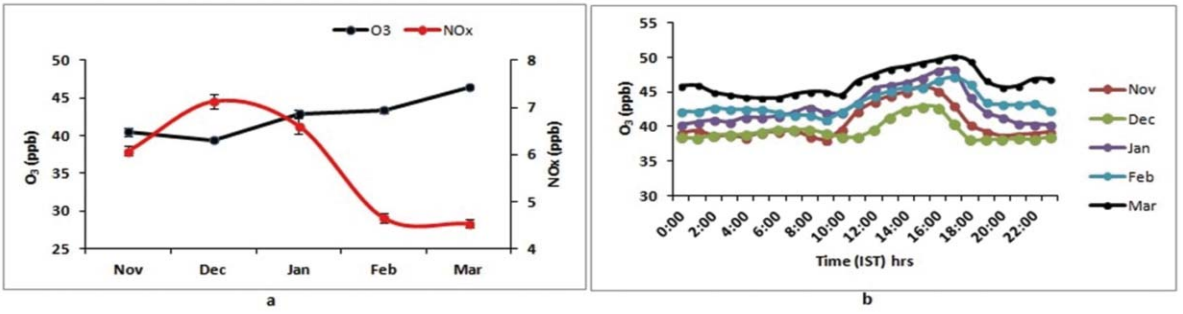


Fig. 30. (a) Monthly concentration of O_3 and NOx; and (b) diurnal concentration of surface O_3 at Kothi

Anthropogenic impacts and their management options in different ecosystems of the Indian Himalayan Region (NMHS, 2017-2020)

The Himalayan ecosystem as a whole is facing a variety of changes in terms of its current environmental scenario. These changes from mountain top to valley base are faster melting of glacier/snow, erratic seasonal surface run-off, and its effect in down slope regions. As a result, two different parts of ecosystems such as snow and/or headwater region on the top of mountains and riverine basins in down slope regions are going to be adversely affected from northwestern to northeastern Himalayan Indian Region (IHR). Knowing the primary status of such issues under a current scenario is a difficult task without any data. As a result, monitoring of the major impacts due to anthropogenic pressure within these ecosystems in the IHR for a long duration is must from a viewpoint of mitigation, management and sustainable development. The faster melting of the glaciers and snow causes erratic distribution pattern of surface run-off over the seasons in the river basins wherein some pockets, lot of developmental and economic activities are in full swing. Most of the activities are entirely dependent on water for drinking, irrigation, power generation, etc. If the water demands for a range of economic activities and land use practices could not be adequate, its situation becomes erratic affecting adversely a variety of economic activities of the local communities in the downstream regions. So understanding alike inter linkages from top glacier/snow and headwater environment to down slope riverine basin and changes in either of the ecosystem due to anthropogenic impacts, mitigation and management options for sustainable development in these sensitive parts of the IHR would be an important effort to address under the present context.

OBJECTIVES

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

ACHIEVEMENTS

1. Five ecosystems representing the IHR were selected for a study. These study areas from northwest to northeast are: (i) Sindh Basin (1563 to 5375 m asl) (ii) Parbati Basin (1074 to 6582 m asl) (iii) Dhauliganga Basin (1144 to 6672 m asl), (iv) Ranganadi Basin (72 to 2910 m asl), and (v) Imphal Basin (777 to 2685 m asl).

2. Among these five basins, the three glaciers fed river basins, namely, Sindh, Parbati and Dhauliganga cover about 1658 km2, 1765 km2 and 1366 km2 area respectively. On the other hand, the non- glacier fed river basins, namely, Ranganadi and Imphal river basins cover 2981 km2 and 303 km2 area, respectively (Fig. 31). The drainage patterns of all the study sites are dendritic.

3. Land use and land cover (LULC) of all the river basins in study site is given in Table 4. The forest cover ranged in two rainfed basins from 57% to 72% in Imphal and Ranganandi basins respectively, while its share was lower in glacier fed basins, i.e., Sindh (24%), Parbati (13%) and Dhauliganga (11%). As far as the snow area in glacier fed region is concerned, it occupied 25% in Sindh, 12% in Parbati and 6% in Dhauliganga.

4. Based on people's perceptions specifically in the Parbati basin, majority of the persons (100%) said that there is a great change in the scenario of the snowfall trend in the valley. According to them, due to climate change glaciers are melting (75 to 80%), sources of the drinking water are drying up (70 to 75%), agricultural activities and tourism are being adversely affected (80 to 85%). There is a great need to develop local embroidery as well as tourism practices to develop livelihood options for the rural women.

5. Regarding adaptive strategies for combating the climate change threat, four consultation meetings / capacity building in their respective five sites were organized. An outcome of these consultation/capacity building programmes showed that majority of the problems were oriented to climate change and their impacts on different ecosystem services.

Table 4. Salient features and LULC characteristics in different River basins of the IHR

Parameters / Basin	Sindh	Parbati	Dhauliganga	Ranganadi	Imphal
Total area (km2)	1658	1765	1366	2981	303
Altitudinal range (m)	1563-5375	1074-6582	1144-6672	72 - 2910	777-2685
Villages / Towns (no.)	43	40	26	74	44
Hydro Power projects (no.)	3	13	11	12	1
Land use (%)	100	100	100	100	100
Glacier surface	25	12	6	-	-
Water bodies	1	2	8	1	4
Forest area	24	13	11	72	57
Grassland	8	22	25	-	-
Agricultural area	5	-	-	-	-
Bare Soil	16	23	16	26	39
Settlements	2	-	-	-	-
Unclassified land	19	28	34	-	-
River Beds	-	-	-	1	-

-Indicates data not available

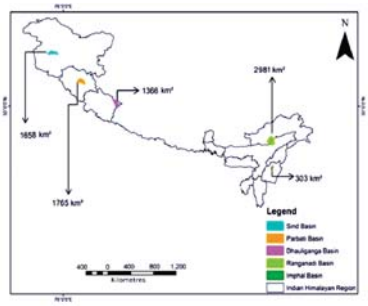


Fig. 31. Map showing the study area in IHR

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

The Kullu valley in Himachal Pradesh is a unique geographic in the Indian Himalayan Region (IHR). This valley is a world famous for tourist destinations, apple cultivation, other orchards and hydropower energy. The management of the fragile ecosystem like Kullu-Manali, varies with altitudes and climatic characteristics. The region therefore requires a detailed study regarding the adverse forms of pollution due to ever-growing human interferences. As a result, a greater awareness is required recently to assess pollution level, its probable sources and its adverse impact on the different ecosystems. The ambient air pollution studies particularly in sensitive locations where breathing air (oxygen) decreases with increasing altitude such as snow bound locations of the Kullu valley have much significance to unfold a current status of air quality. Air pollution parameters among gaseous pollutants included trace gases like sulphur dioxide (SO_2), nitrogen dioxides (NO_2), ammonia (NH_3) and acid rain which are critically dangerous to human beings, plants and crops. Particulate matter included total suspended particulates (TSP) matter, i.e. below 10 microns in size (PM10) and below 2.5 microns in size (PM2.5). Such studies will help in maintaining and regulating a level of clean air for the residents and tourists. Moreover, this study will also have positive impacts on agro-horticultural crops including apple by way of suggesting options to reduce impact of climate change in the valley.

OBJECTIVES

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

ACHIEVEMENTS

1. The monthly mean concentration of TSP at Mohal was observed to be 79.5± 4.34 and at Kothi 56.8 ± 10.23 µg m^{-3}. The mean concentration of PM10 was observed to be 46.6 ± 4.26 µg m^{-3} at Mohal, while at Kothi it was 31.1 ± 9.27 µg m^{-3}. On the other hand, the average concentration of PM2.5 at Kothi was 22.9 ± 4.72 µg m^{-3}, while its average concentration at Mohal was found 33.7 ± 2.44 µg m-3. The concentration of the pollutants was more at Mohal compared to Kothi. It is because transport activities and human population at Mohal are relatively high as compared to Kothi (Fig. 32).
2. The average NO_2 concentration at Mohal was 3.8 ± 0.29 µg m^{-3} and at Kothi 2.8± 0.27 µg m^{-3}. NO_2 concentration at both the locations is due to contribution of transport activities. On the other hand, average SO_2 concentration is relatively low on monthly basis which was observed as 0.7 ± 0.30 µg m^{-3} at Mohal and 1.9 ± 0.34 µg m^{-3} at Kothi. On the other hand, the average concentration of NH_3 was observed to be relatively higher at Kothi because it is a rural area where apple orchards are a predominating land use feature along with seasonal tourism activities. Use of fertilizer and rearing of animal husbandry could be the primary source of ammonia.
3. The monthly mean temperature at Kothi was found to be maximum 16.9 °C in July and minimum 4.9 °C in February. The maximum relative humidity was found to be 94.6% at Kothi in July and minimum 48.2% in February. The monthly mean temperature was 18.1 ± 1.8 °C at Mohal. The relative humidity was found to be highest 96.6% on 21st June 2017. The windiest month at Mohal was March. The total rainfall at Mohal was 890 mm, while at Kothi it was 1100.10 mm.
4. On average, it was found that Mohal is followed by Kothi in terms of different concentration of pollutants. Mohal has semi-rural land use characteristics while Kothi has rural but is on the way to Rohtang Pass, a tourist picnic spot.

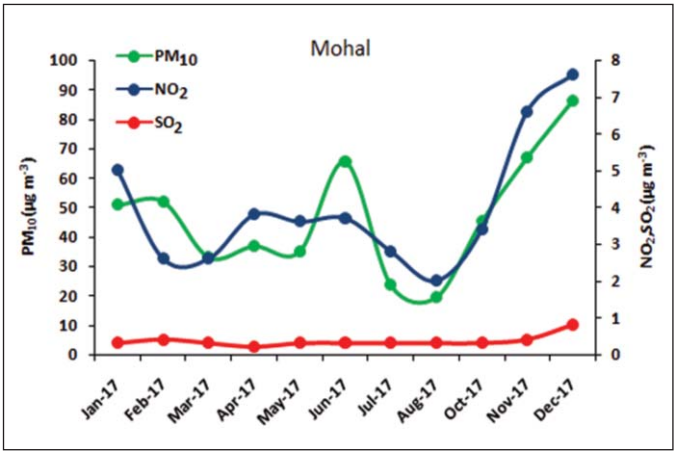


Fig. 32. Concentration of PM10, NO_2 and SO_2 at Mohal

SUMMARY OF COMPLETED PROJECT/ACTIVITY

Climatic variables and their impacts on Environmental Flow in the River Satluj basin in Himachal Pradesh (2014 – 2017, In-house)

The Indian Himalayan Region is rich in water resources. However, this is going to be threatened due to anthropogenic stress, over-exploitation, and lack of management techniques. The availability of freshwater on land is scarce and it is used for a variety of uses such as drinking, irrigation, water mills, and hydropower generation. Aquatic ecosystem is as such that connects with other ecosystems, carries water, transports dissolved minerals and sediment deposits and make available nutrients to maximum places before draining into its natural outlet. On account of anthropogenic stress in many forms, freshwater resource is continuously depleting. The first selected control site is Khab which is the confluence point of River Spiti and River Satluj. Keeping in mind the same, the objectives of the study were: (i) to generate a database on climatic variables in terms of environmental flow including river water quality using physico-chemical, biological and socio-economic methods to take urgent action to combat climate change and its impacts, (ii) to find changes in water resources due to climate change, (iii) to estimate water discharge, and (iv) to suggest mitigating measures for sustainable management of water and sanitation.

1. The overall Water Quality Index (WQI) indicates that water in the study region is not fit for drinking and other purposes without proper treatment (Table 5). During different years, WQI varied from good (B) to poor (C; 39.08-53.76) quality seasonally for different selected sampling sites. Also, Total Coliform (T.C.) shows a great decadal percentage change in all the water sampling sites.
2. Further, the decadal change (Census 2001-2011) of drinking water in terms of different facilities were found 6.90% by tap water, 0.8% by handpump, tube-well and bore well, 10.5% by latrine and by 22.30% bathing. There were a number of open-air defecation practices found usually in Kinnaur (29.3 %) followed by Shimla (29.2 %) districts. These practices highly need to be turned towards hygienic.
3. The discharge at Rampur from 2006-2017 is maximum during July and August with 123-1300 cumecs and 70-80 minimum in April. Water level at Nathpa is increasing while at Khab and Rampur, it was found decreasing (CWC, 2006-17). The long-term decreasing trend of rainfall with time was negatively correlated, while rise in temperature with time was positively correlated. This could lead to increased evaporation and less water from melting of the glaciers.
4. It was found from the field survey that 90% of the total respondents in the region were not dependent directly on the River Satluj for their livelihood and other agricultural practices. About 55% the total respondents said that fishes in the basin were found mostly a decade before. The road construction, dumping of debris and other wastes entering into river water, tunnel construction and deforestation are accelerating many disasters like landslides, flash floods, etc.
5. In addition, there is a need for regular monitoring of water quality in order to detect changes in physico-chemical properties, flow of river water at different sites, implementation of remediation measures and public awareness.

Table 5. Water quality index (WQI) of different years

Year	Pre-monsoon		Monsoon		Post-monsoon	
	WQI		WQI		WQI	
	values	rating	values	rating	values	rating
2015	49.69	B	52.29	C	40.22	B
2016	50.93	C	53.26	C	39.08	B
2017	50.27	C	53.76	C	42.77	B

'B' = Good water quality, 'C' = Poor water quality

SIKKIM REGIONAL CENTER (SKRC)

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 depended on natural resources for their livelihood. However over-extraction and utilization of the natural resources demands immediate measure to reverse the trend of degradation. Besides, it also needs strengthening participatory management, enhancement of livelihood and self sufficiency and policy review/analysis and capacity building. Major thrust area of Sikkim Regional centre would be (i) biodiversity safeguarding at ecosystems, species and genetic level, including ecosystem services, (ii) natural resource use and sustainability, (iii) enhance implementation of strategies through participatory planning and Policy analyses, and (iv) socio-economic improvement/extension and knowledge management through capacity building

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

Biological resources are viewed as 'resource capital' of a nation. Cataloging, mapping and geographical distribution of these natural resources are perhaps the most important information needed for any country in the post-CBD era. Documenting biological resources and construction of bio-resource maps reflecting the spatial distribution at an eco-regional level would serve several purposes, but such maps are rarely available. Thus, there is an urgent need for cataloging and mapping of natural plant resources datasets especially in globally hotspot area, for converting our bio-resources into economic wealth. Sikkim Himalaya represents the uniqueness of the bio-socio-climatic integrity symbolized along the elevational gradients, which offers a very high diversity of ethnobiological plants interlinked with traditional practices of the local community. Several mixed diversity enforcing to representative cultural paradigms are recognized, which are historically interlinked with the significance of the landscape. Nevertheless, such entity of the region is rapidly degrading and shrinking with the traditional practices and knowledge base losing ground under changing climatic regime. This invariably indicates an alarming signal for sustainability of biotic and abiotic assimilates vis-a-vis linkages being disturbed between natural and cultural entity. In addition, the region is a home of diverse and endemic assemblages of plants, reptiles, mammals, insects and amphibians. Broad representative vegetation types of this region were classified into tropical moist deciduous, subtropical broad-leaved forests, broad-leafed and conifer mixed forests, wet temperate forests, sub-alpine forests, and alpine meadows (moist and dry alpine scrubs). Despite the ecological, economical and cultural importance of this region, the ecosystems have been subjected to a variety of assaults causing a high degree of threat to many plant and animal species. As our biological heritage fritters away, we find ourselves without a comprehensive conservation and management plan, and without an adequate institutional and policy framework to implement the plans. Lack of complete and consolidated information on plant resource is a major stumbling block in the whole process of conservation and utilization. Documenting the plant resource base is also imperative in the age of the intellectual property rights. Further, intensive data on Endemic, Rare, Endangered and Threatened plant species are specially required for drawing suitable management plans to conserve these species under the climate change phenomena. Earlier surveys have not specifically focused on uniform cataloging and spatial distribution of these species. With a view to accelerating the conservation and utilization of the natural plant resources, the aim of this study to assess and quantifying the geographic distribution, conservation status and phytogeographic aspects of plant resources of Sikkim Himalaya. The grid-based spatial inter-operable datasets will be the main outcome of this proposal. This will have important implications for the conservation, sustainable utilization and management of our plant resources.

OBJECTIVES

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

ACHIEVEMENTS

1. Vegetation of Sikkim Himalaya was sampled using grid-based inventorization. For this, the geographical area of Sikkim Himalaya was divided into small sampling grid. The sampling grids were generated using Survey of India (SOI) toposheet of 1: 50,000 scale. Each toposheet of 25 km × 25 km or 625 km2 area of 1:50,000 were divided into sixteen sampling grids. Hence, a sampling grid correspond 3′45″ latitude × 3′45″ longitude, which nearly represents 6.25 km × 6.25 km geographical area. For example, 78A04, a toposheet of 1 :50,000 scale covering an area of West Sikkim district of Sikkim state with West Bengal, is divided into equally sixteen parts. The sampling grids marked on the basis of direction, i.e., north-western 78A04NW1, 78A04NW2, 78A04NW3, 78A04NW4; north-eastern 78A04NE1, 78A04NE2, 78A04NE3, 78A04NE4; south-western 78A04SW1, 78A04SW2, 78A04SW3, 78A04SW4 and south-eastern 78A04SE1, 78A04SE2, 78A04SE3, 78A04SE4. Thus the whole state of Sikkim has been divided in to approximate 209 sampling grids (Fig 33).

2. The grids with prominent vegetation types were sampled depending upon the similarity of terrain, accessibility and other geographical and socio-political factors. The vegetation was sampled by laying a line transect of 500 m × 10 m. Till date seven transect (1.75 ha) have been sampled covering namely moist-deciduous forests, oak-mixed forests and sub-tropical evergreen forests of West Sikkim ranging elevation 2000m to 2700m asl. All individual stems ≥ 10 cm girth at breast height (1.37 m from the ground) were measured. The height of each stem was recorded to the nearest meter. The specimens of all species added into transects were collected and assigned an ID. These specimens were identified by consulting herbaria, regional flora and e-flora. The sampled transects contained 3,267 individuals of about 96 woody species, where 52 species identified using regional flora and e-flora.

3. A cover page of database information of each sampled grid designed for generation of spatial interoperable database (Fig. 34). All information of each transects viz., number of species, fauna, disturbance etc. was filled and this information is hyperlink with the cover page. For generating distribution map using ecological niche modeling various information and datasets downloaded from free web resources viz., Worldclim, MODIS, NDVI etc.

4. Under In-house project eight days workshop and field orientation training on Biodiversity Conservation, Vegetation Sampling, Climate Change and Species Distribution Modeling from 17th to 25thMarch 2018 have been organized. This workshop includes 4 days hands on training from 17th to 21st March, 2018 at GBPIHED, SRC, Campus at Pangthang and 4 four days field orientation training from 22nd to 25th March, 2018 at Ribdhi-Bhareng, West Sikkim. The objectives of this workshop were; i) to generate awareness on biodiversity conservation, vegetation assessment, long term database management using modern tool and techniques ii) to enhance knowledge and build capacity of researchers and foresters for systematic data and specimen collection. iii) to provide hands-on training on Remote sensing and GIS, ENM and Climate Change Scenario Projection and iv) to build capacity of unprivileged youths and local peoples towards long term biodiversity assessment to sustain their livelihoods. A total of 30 participants (research scholars, project staffs and M.Sc. students) from different organization attended the Hands-on training programme, and 72 participants (16 research scholars and 56 local peoples) actively participated in field orientation training at Ribdhi-Bharang, West Sikkim.

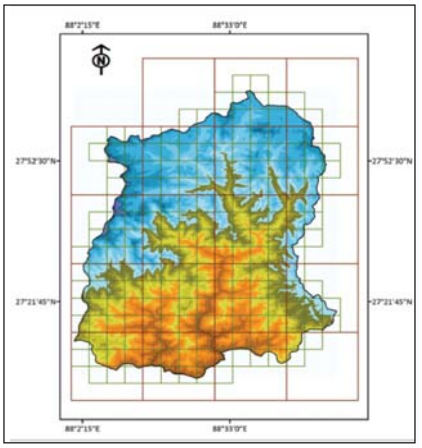


Fig. 33 Map of study area showing grid-based design with elevation gradients of Sikkim Himalaya

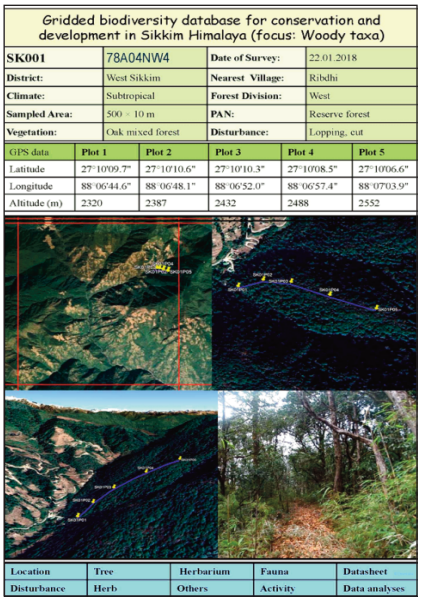


Fig 34. Representation and detail information of sampling grid of Sikkim Himalaya.

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

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

OBJECTIVES

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

ACHIEVEMENTS

1. Total 108 households (HHs) of KL–India were benefited under promotion of livelihood diversification and economic development [distributed- 03 polyhouses to 03 HHs, 05 fodder cutter machines to 05 HHs, 200 saplings of Peaches and 700 saplings of Yakon (ground apple) [Peaches saplings to 11 HHs, Yacon saplings to 14 HHs and both Peaches and Yacon saplings to 30 HHs) and nutrient-rich food supplements including basic medicines to 45 HHs].
2. Distributed/constructed waste disposal bin/dustbin in three Pilot Villages (Dzongu-Lingdem: 01 constructed and 10 eco-friendly dustbins distributed, Bandapani-Garochira: 40 dustbins distributed, and Barsey-Singalila: 02 constructed).
3. Under skill and capacity building programme for livelihood improvement, total 251 local people (LP) of KL-India were benefited through the training on animal nutrition and healthcare for improving dairy production, demonstration cum training on solid waste management, training for ecotourism service providers under the KLCDI-India programme (Fig. 35).
4. Local committees like Songbing Tourism Development and Management Committee" (STDMC) and "Gorkhey Ecotourism Committee (GEC)" were formed.
5. Songbing a potential spot of tourist attraction was identified and included in the ecotourism map of Dzongu for promoting the ecotourism of the region
6. Lingdem Hotspring Nature and Culture Tourism Festival was organized first time in Lingdem (Lingthem-Lingdem GPU), Dzongu site under KLCDI-India programme
7. Demand and supply of the fodder species in Lingdem-Lingthem GPU, Dzongu was evaluated. The important fodder species of the region were identified and availability of those important species was also, analyzed, and based on which emphasis could be given for conservation and sustainable utilization of fodder species in the region.
8. Total 03 sites (02 in the forest ecosystem and 01 in the agro-ecosystem) for LTESM from Lingdem to Tholung (1200m to 3000m asl) were identified.
9. Developed dissemination materials and event reports.

Fig. 35. Training cum exposure workshop for ecotourism service providers

Ecosystem services in changing biodiversity state: A comparative study of western and eastern Himalayan forest stands (MoEF&CC, 2017-2019)

The wellbeing of humans is integrally linked to biodiversity, ecosystem processes and ecosystem services. It is now well recognized that if the current rate of loss of biological diversity is continued, the coming human generations are going to face problems in sustenance of livelihood, some of which are visible now. The biggest challenge is to decipher the impacts of loss of biodiversity change on ecological processes, and ecosystem services and its interaction. Considering that Himalayan ecosystems are most sensitive to climate change and anthropogenic stresses, and the local extinctions of species may have more drastic ecosystem consequences, the present project aims to investigate biodiversity status of selected forest stands that are under threat of biotic pressure with relation to recent past. To investigate the impact of the change in forest biodiversity on ecosystem processes and services, Mamlay watershed in Sikkim is selected for the study in eastern Himalaya. It is situated at the southern part of the state (about 80 kms from State capital Gangtok). It extends from 27°12'3" to 27°16'14" N and 88°19'2" to 88°23'30" E, covering an area of 30.09 sq km. and elevation ranges from 300-2600 m asl. The project will investigate current status of biodiversity (species richness, evenness, composition, abundance, functional types, etc.) of selected forest stands at subtropical and temperate zones along with selected ecosystem functions and processes (viz., biomass of tree, shrubs and herbs, and litterfall), supporting services (viz., net primary productivity and litter decomposition), the regulating services (viz., climate regulation through carbon sequestration), and provision services (food, fiber, fuel, fodder, genetic resources).

OBJECTIVES

- To investigate temporal and spatial variation in vegetation cover at selected forest stands in Western and Eastern Himalayan region.
- To study species composition, richness, functional traits, regeneration and distribution pattern of the above selected forest stands under changing biodiversity state.
- To analyse dynamics of aboveground biomass, productivity, litterfall and forest floor nutrient pool, and carbon sequestration under changing biodiversity state for selected forests.
- To quantify various ecosystem provisioning services by the selected forest types and their dynamics of use by local residents.
- Quantify environmental vulnerability and directional changes in selected ecosystem processes and ecosystem services, and suggest suitable conservation approaches.

ACHIEVEMENTS

1. Project was initiated with sites identification in different forest type's viz., temperate and Sub tropical forests of Mamlay watershed, South Sikkim district.
2. The review of literature suggested that in Mamlay watershed various aspect of work has been carried out viz., biodiversity assessment, argo-forestry, socio-economic issues, hydrology and few remote sensing and GIS based studies, etc.
3. Forest Composition in Mamlay watershed (Based on the secondary information) in the Temperate forest of the watershed, the dominant species regeneration was observed for *Symplocos theifolia* with 1518 seedlings/ha, other species had relatively lesser number of seedlings, *Eurya acuminata* was with 415 individual seedlings/ha, least number of seedling was recorded for *Brassaiopsis mitis, Casearia glomerata, Elaeocarpus sikkimensis, Ficus nemolaris* etc with only 3 seedlings/ha. In the Sub-Tropical Natural forest of the watershed, the regeneration pattern were seen and the species with maximum Number of seedling was *Castanopsis indica* with 1194 individuals/ha, followed by *C. tribuloides* with 786 individuals/ha and *Shorea robusta* with 636 individuals/ha. The least regeneration was seen for species like *Ficus hirta* with only 12 seedlings/ha, *Albizia odoratissima* and *Emblica officinalis* with 21 and 25 seedlings/ha respectively. Further, the current regeneration of different species will be assessed in coming years.
4. The Functional analysis of forest stand biodiversity is under process in Temperate and Subtropical forests under Mamlay watershed.

SUMMARY OF COMPLETED PROJECT

Preventing extinction and improving conservation status of threatened plants through application of biotechnological tools (DBT, Govt. of India)

- In this project, an integrative approach to conserve two threatened plants of Sikkim Himalaya viz. *Rhododendron leptocarpum* and *Phoenix rupicola* has been proposed.
- Maximum entropy based (MaxEnt) Ecological Niche Modelling (ENM) technique was used to predict the potential suitable habitat for *Rhododendron leptocarpum*, a critically endangered plant species of the Sikkim Himalaya. MaxEnt model performed better than random with an average test AUC value 0.931±0.042 under the predicted current climatic condition. Under future climatic change scenario, the MaxEnt model predicted complete habitat loss in North and South districts of Sikkim Himalaya. For sustaining the population of this climate sensitive species in Himalayan region, large scale reintroduction in suitable habitats is highly required. To achieve this, an efficient in vitro propagation technique was developed using nodal segments that were obtained from six weeks old in vitro aseptic seedlings. Among different media combinations, Anderson medium (AM) supplemented with 2-iP (2-isopentenyladenine) was found to be the best medium for axillary shoot multiplication. In vitro grown individual shoots were separated from the shoots of the primary culture and placed in AM-liquid medium containing different type and concentrations of auxins. Regenerated shoots rooted spontaneously with 100 % frequency in AM-liquid medium supplemented with IBA (Indole-3-Butyric Acid). In vitro grown plantlets were acclimatized successfully with 87 % survivability.
- A significant success has been achieved in the case of *Phoenix rupicola*. Seed germination protocol for the *Phoenix rupicola* was developed with various presoaking treatments of plant growth regulators (PGRs), nitrogenous compounds and systemic fungicide (Bavistin) under different conditions. Out of various used treatments, Bavistin was significantly effective treatment regarding seed germination of *Phoenix rupicola*. Germination is initiated four week after sowing and can be increase over 6 week. Rapid (38 to 40 days) and complete (92 %) germination is promoted by presoaking treatments with 0.1 % Bavistin and incubation at high temperatures (25 °C). In the present study out of thirteen used pre-treatments, the lower concentration of Bavistin (0.1%) and lower concentration of GA3 (125.0 µM) showed best germination response in laboratory and nursery conditions, respectively. Maximum entropy based (MaxEnt) Ecological Niche Modelling (ENM) technique was also used to predict the potential suitable habitat for *Phoenix rupicola*.
- Seedling of both the plants produced through macro and micro-propagation procedures were planted at different ENM identified suitable habitats of Sikkim.

SUMMARY OF COMPLETED PROJECT

Nutraceutical potential of wild edible plants of Sikkim Himalaya and their conservation through biotechnological interventions (DBT, Govt. of India)

- Sikkim Himalayan wild edible fruits viz. *Baccaurea sapida, Diploknema butyracea, Elaegnus latifola, Machilus edulis* and *Spondia axillaris* were studied mainly for (i) phytochemicals (total phenolic, flavanoid, lcopene, β-carotene and ascorbic acid content), (ii) mineral composition and (iii) antioxidant properties (ABTS and DPPH). Sowing pretreatments were also performed to improve seed germination response of selected fruits.

- Amount of macro minerals namely calcium, magnesium, potassium, phosphorus and sodium in these fruits varied from 1.92 to 46.67 mg/100 g, 24.93 to 74.44 mg/100 g, 301.35 to 711.43 mg/100 g, 52.89 to 228.99 mg/100 g and 0.68 to 1.73 mg/100 g, respectively. Among the analysed fruits, *S. axillaris* contained the highest amount of magnesium (74.44 mg/100 g) and potassium (711.43 mg/100 g), whereas *E. latifolia* contains the maximum amount of calcium (46.67 mg/100 g), sodium (5.58 mg/100 g) and phosphorus (228.99 mg/100 g). *E. latifolia* also contained the second highest amount of potassium (610.13 mg/100 g) and magnesium (42.82 mg/100 g). Contents of micro minerals viz. manganese, iron, copper, and zinc varied from 0.16 to 8.57 mg/100 g, 3.64 to 25.17 mg/100 g, 1.32 to 5.77 mg/100 g and 0.08 to 0.41 mg/100 g, respectively. Manganese, copper and zinc were found to be highest in M. edulis, whereas iron highest content was detected in *S. axillaris.*

- The carbohydrate and reducing sugar content in the fruits of studied species varied from 44.63 % to 13.82 % and from 19.67 % to 9.96 %, respectively. The carbohydrate was determined highest in *B. sapida,* whereas maximum amount of reducing sugar was determined in *D. butyracea.*

- The mean lycopene content ranged from 3.00-2057.14 µg/100g edible portion. E. latifolia contain the highest amount of lycopene whereas the minimum amount of lycopene was detected in B. Sapida. β Carotene contents varied from 27.60 to 830.07µg/100g edible portion in the following order: *E. latifolia >M. edulis>S. axillaris>D. butyracea>B. sapida*.

- The ascorbic acid content in the investigated fruits ranged between 631.90 and 781.90 mg/100 g methanolic extract of edible portion. *D. butyraceae* had the highest content of ascorbic acid.

- The total phenolic content ranged from 3.81±1.37 to 341.99±4.00 mg GAE/ g extract. The *S. axillaris* contained the highest total phenolic content, followed by *M. edulis*, *D. butyracea* and *B. sapida*. The total flavanoid content ranged from 0.86±0.02 to 3.14±0.04 mg QE/g extract. The highest flavanoid content was found in B. sapida (3.14±0.04 mg QE/g extract) followed by *M. edulis* and *D. butyracea.*

- Amongst investigated fruits, in both the assays, *S. axillaris* extract exhibited the highest scavenging activity, followed by M. edulis and *D. butyraceae*. B. sapida exhibited the lowest antioxidant capacity. *S. axillaris* ethanolic extract even showed higher DPPH radical scavenging activity than the commercial antioxidant BHT.

NORTHEAST REGIONAL CENTER (NERC)

Shortening of fallow cycle & changed practices; changes in land use pattern, land tenure and ownership pattern, and customary laws; lack of appropriate policy packages and technological intervention for soil conservation, soil nutrient management and yield enhancement; loss of agro-diversity & promotion of mono-cropping, improper policies; lack of marketing, depletion of traditional knowledge base and policy deficiency in promotion of alternative & innovative livelihoods have been biggest constraints for the North East region. Similarly inventorization of biodiversity, sacred groves, community conserved areas, village forests, hotspots and keystone species is not complete which is a major constraint in addressing the issue of biodiversity conservation. There are alternative employment opportunities based on biodiversity based tourism. Therefore, strengthening of alternative and innovative livelihood options, conserving indigenous knowledge system, capacity building and human resource development are key areas to work on. The regional center will focus on (i) sustainable socio-economic development and livelihood security (focus on shifting cultivation), (ii) conservation of biological diversity and ecological security, (iii) adaptation/mitigation of climate change (CC) impacts, (iv) eco-tourism, and (v) sustainable technologies and capacity building

Enhancing Eco-cultural Livelihoods in biodiversity rich areas of Arunachal Himalaya (In house 2017-2020)

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

OBJECTIVES

- To augment multidisciplinary research and knowledge base on ecosystems, cultural diversity and socio economic status of the region including understanding on drivers of change.
- To promote biodiversity conservation, natural resource management and community development through direct efforts and capacity building.
- To address poverty and climate change threat through alternative livelihood options, capacity development and good practices.
- To strengthen policy environment through national and state policy analysis and develop village level cooperation framework and mainstreaming in the national conservation and development agenda.

ACHIEVEMENTS

1. Organized stakeholder's consultation workshops at Ziro, Lower Subansiri District (A.P.) on 7th December, 2017 to discuss the project's aims/objectives and activities along with possible role of the community in project implementation and possible outcomes. A total of 30 participants from local community, government departments, NGOs, and Biodiversity Management Committees (BMCs) participated in the workshops.
2. Identified major issues such as: (i) need for promotion of organic farming practices, (ii) need for capacity building on organic farming including trainings on vermin-compost, etc. (iii) Promotion of Ecotourism as an alternative livelihood opportunity; (iv) need for training and capacity building on home-stay development, tour

guides, trekking/hiking.

3. Socio-economic baseline study is under progress through census data and other sources along with field surveys. Collection, compilation and analysis of data on agricultural and other livelihood practices, agro-diversity of the study areas are partially completed.

4. Developed a low cost rural technology centre (RTC) at Study site (i.e. Lower Subansiri Dist.). Demonstration of various low cost technologies at RTC is ongoing.

5. Questionnaire based household survey has been partially completed in both the study sites (i.e. Lower Subansiri and East Sian districts).

6. SWOT analysis for eco-tourism development has been done. Lack of profession expertise seems to be a weakness which can be overcome by proper training. Inner Line Pass (ILP) and Restricted Area Permit (RAP) is another hurdle in effective ET development in the study area.

7. Organized a hands-on training) on Beekeeping at Mother's Home Museum, Ziro, Lower Subansiri district (A.P) on March 16, 2018. Resource person Mr. J.P. Saikia, Beekeeper, Department of Arts & Handicrafts (Govt. of A.P.) demonstrated the different tools and techniques required for colony capture, beekeeping and honey extraction, etc. The training programme was attended by local people and members of Biodiversity Management Committees, various NGOs, youth organizations and villagers/farmers.

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

The high altitude wetlands (HAWs) are an important category of natural wetlands found mainly in the higher elevations (above 3000 m asl) in the Himalayan region. They are extreme ecosystems, characterized by adverse climate and presence of a seasonal or diurnal permafrost layer. At present, high-altitude wetlands are suffering from degradation, habitat fragmentation, desertification, soil erosion and anthropogenic disturbances, which are further aggravated by climate change impact. However, very little information is available for most of these wetlands due to the remoteness, harsh climatic condition and inaccessibility of the terrain of the region. Therefore, comprehensive information is urgently required for developing and implementing plans for conservation and sustainable management of these unique ecosystems. High altitude floral species, especially in the transition zone between sub-alpine and alpine are more vulnerable to climate change. In-depth scientific information on climate change impacts on floral diversity and dependent tribal community of high altitude wetland is unavailable for the Eastern Himalayan region so far. Therefore, an urgent need has been felt to study the floristic diversity and assess the climate change impacts on floral biodiversity, floral diversity utilization pattern of dependent communities and change in land use & land cover of high altitude wetland region of Eastern Himalaya.

OBJECTIVES

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

ACHIEVEMENTS

1. The Maxent ecological niche modelling predicted potential distribution of *Rhododendron anthopogon* in southern, northern and western parts of the Tawang district. The area under not suitable category constitutes 68.57% of the total area followed by low suitable with 13.01%, medium suitable, high and very high suitable constitute 11.77%, 5.69% and 0.96% respectively. Analysis of variable contributions indicated that BIO 15 (19.5%) followed by BIO 5 (19.1%), BIO 13 (16.1%), BIO 18 (15.8%), BIO 14 (12.3%), BIO 1 (9.1%), BIO 2 (3.9%), BIO 7 (2%) to the Maxent model. The jackknife test of variable importance in Maxent identified the Precipitation of wettest quarter (BIO 16) and Precipitation of warmest quarter (BIO 18) as the most important environmental variable in model development. Potential distribution maps show various possibilities for conservation and management of

Rhododendron anthopogon species.-

2. A total 281 flowering plant species belonging to 136 genera and 69 families recorded during the field survey of high altitude wetlands areas of Tawang district. Out of total recorded species 9 species were trees, 41 shrubs and 231 were herbs and climber. The largest number of species was noted from the family Asteraceae (40 spp.), followed by Ericaceae (23 spp.), Gentianaceae (20 spp.), Rosaceae (19 spp.), Polygonaceae (17 spp.), Primulaceae (15 spp.). Whereas, *Rhododendron* (17 spp.), *Primula* (14 spp.), *Gentiana* (9 spp.) and *Potentilla* (8 spp.), *Swertia, Saussurea* (6 spp. Each), represented the species rich genera.

3. Ethnobotanical uses of Rhododendron species were recorded during the field survey. *Rhododendron* species are mainly used as fuelwood (55%) followed by wild edible in form of juice (11%), medicinal (10%), religious purpose such as incense (8%), wood handicraft(8%), packaging (2%) and insect repellents (2%) by Monpa community living in the high altitude areas of Tawang.

4. Soil samples were collected from 9 wetlands of Tawang during monsoon season. Overall in the study sites, the soil moisture content ranged from 33.80% to 132.88%, pH 4.53 to 6.44, total nitrogen 0.10% to 0.57%, sodium 0.18% to 1.74%, potassium 0.32% to 2.68% and total organic carbon 1.27% to4.35%. The texture of the soil is very coarse with high gravel content

5. During the monsoon season water quality monitoring of 9 wetlands were also carried out, water quality parameters pH was varied from 5.43 to 7.08, TDS varied from 2 mg/l to 18 mg/l. Other water quality assessment parameters such as total hardness ranged from 6-22mg/l, CO2 from 4.4-79.2mg/l, TS and DO of the wetlands were within the desirable limit.

6. Community level education cum awareness program on Conservation of floral biodiversity of high altitude wetlands and climate change impacts were also carried out in the Jung, Urgelling, Sharoo, Kharsa villages of study area during 2017-18.

Assessment of biochemical and phytochemical content of selected threatened and high value plants with diverse environmental conditions (NMHS fellowship, 2016-2019)

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

OBJECTIVES

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

ACHIEVEMENTS

1. The proximate analysis of fruits of *Illicium griffithiifrom* two location i.e. Dirang and Shergaon shows protein content was higher in fruits from Shergaon (5.00 g/100g dw) as compared to Dirang (1.75g/100g dw). The Ash content was similar (4.81 g/100g dw) in fruits from two different locations while fat content was higher in fruits from Shergaon (4.86 g/100g dw) as compared to Dirang (1.41 g/100g dw).The slight variation in the proximate composition of the fruit content of *I. griffithii* may be due to different climatic conditions of the two locations. While the mineral composition i.e. Na, K, Ca, P of the fruits from two different locations was in similar range.

2. Phytochemical analysis of *Illicium griffithii* from Shergaon area of West kameng district with different solvents at different concentrations shows that total phenolic content (TPC) was highest (49.062 mg GAE/g dw) at 80 % methanol followed by (36.865 mg GAE) at 60% Ethanol. While Total flavonoid content (TFC) was highest (6.582 mg QE/ g dw)) at 100% ethyl acetate and similar (in the range of 2-4 mg QE/g dw) in other solvents (methanol, ethanol, acetone).

3. The biochemical analysis of *Curcuma caesia* from Dirang area shows that protein content was highest (9.94 g/100g dw) followed by Ash content (4.28 g/100g dw) amongst proximate composition, while potassium (3.13 g/100g dw) was highest amongst the minerals.

4. Phytochemical analysis of the *Curcuma caesia* shows that TPC was highest at 80% methanol (119.95 µg GAE/g dw) while TFC was higher in methanol at 60 % methanol and 80% methanol (776 79 µgGAE/g dw and 760.68 µg GAE/g dw respectively).

Anthropogenic impacts and their management options in different ecosystems of the Indian Himalayan Region (NMHS 2017-2020)

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

OBJECTIVES

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

ACHIEVEMENTS

1. The Ranganadi basin is a non-glacier-fed river which extends over an area of 2981 km2 catchment area in the basin. Of the total identified area of the basin, 72% area is occupied by forest cover. While, 26% of the total area comes under the bare soil and 1% each covered by water bodies and river bed in the Ranganadi basin.

2. During the reporting period, two community consultations cum training workshops were organized in the

study area to build the capacity of local community and creating awareness on climate change adaptation and mitigation.

3. Water samples were collected from four different sites i.e., Lower Yazali, Upper Yazali, Kail River and Ranganadi reservoir to observe the different water quality parameters. Different parameters like pH, total solid (TS), total dissolve solid (TDS), Acidity, Alkalinity, Hardness, Dissolve oxygen (DO), Ammonia and Chloride were analyzed. From the analysis it was found that the value of pH ranges from 7.33 to 7.44, TS value ranges from 0.05 to 0.10, TDS value ranges from 0.07 to 0.11, Acidity value ranges from 25 to 37, Alkalinity value ranges from 23 to 43, Hardness value range from 31 to 38, DO value from 7.50 to 10.06, Ammonia value from 0.56 to 1.12 mg/l and Chloride value ranges from 15.98 to 53.25. The water quality test result shows that the water of Ranganadi river is fit for human consumption and other household uses as per permissible limit of Bureau of Indian Standard (BIS) and other parameters like TDS, Alkalinity, Hardness, Chlorine, etc. are found within the permissible limit.

4. To understand the different parameter of agricultural and forest soil, samples were collected at the depth of 30 cm. Different parameters were analysis of carried out viz. soil moisture content, pH, conductivity, nitrogen phosphorous etc. in overall study moisture content agriculture soil is 3.41g while that of forest soil is 1.22g, texture in agriculture soil are 74% sand, 25% silt, 1% clay whereas in forest soil are sand 70%, 26% silt and 4% clay. Other parameters study are pH 5.147, conductivity 101.95, nitrogen 0.12%, phosphorous 0.33%, potassium 2.77%, sodium 0.88%, calcium 1.65% and carbon 1.44% in agriculture soil while in forest soil pH 5.222, conductivity 86.75, nitrogen 0.07%, phosphorous 0.25%, potassium 2.92%, sodium 0.85%, calcium 1.29% and carbon 1.28%.

5. According field survey 65.52% respondents perceived that the climate change is taking place due to anthropogenic impacts. From the total respondents, 31.03% view that the major anthropogenic impacts are due to dam construction and same as (31.03%) on both dam and road construction.

6. As per field survey, there is a major change due to climate change in the summer temperature (82.76%) but only 34.48% response on increase in winter temperature. Change in the cropping pattern was response by 96.55%, plant composition by 96.55% but only 6.9% response that there is variation in flowering and fruiting in plants, majority of the respondents (51.72%) said that there is no changes in flowering and fruiting in plants. The responses in change in the stay of migratory birds is 100%, occurrence of new and strange human diseases (100%), and increase in flies and mosquitoes (100%)

MOUNTAIN DIVISION REGIONAL CENTER (MDRC)

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

A GIS Based Landuse Modeling, Future Projection and dynamic impact on Indian Himalayan Region (Mountain Division, 2017-2020)

Himalaya is known for its unique and sensitive and fragile ecosystem having diversity. The sensitivity towards changes especially anthropogenic and climatic over the ecological security has been recognized world over. Expansion of urban area due to increase in population and migration from rural areas is bound to create the impact on urban areas in terms of infrastructure, environment, water supply and other vital resources. The expansion of cities entails the abandonment of forest and agricultural lands, and conversion of these lands into urban areas results in substantial impacts on ecosystem. There has been tremendous increase in size, area, number and complexity of urban settlement in the region resulting in expansion of urban cluster and urban sprawl. The uncontrolled and unplanned growth is further acting as the trigger to severe problems including the increased population density over a small area, rapid consumption and consequent depletion of natural resources, manmade disasters such as landslides, etc. It therefore becomes crucial to have a thorough understanding of past, present land use changes to predict potential future land use changes in order to better manage and plan against expected potential impacts. The task can be effectively achieved suing remote sensing and GIS technique to monitor these changes using multi-temporal remote sensed datasets, spatial metrics and modeling. GIS based land use modeling can be used to support planning, policy and aiding in the decision making process. Two sites have been selected for the study viz. Almora city, Uttarakhand located at 1600 m asl and Gangtok city, the capital of Sikkim located at an elevation of 1650 m asl.

OBJECTIVES

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

ACHIEVEMENTS

1. Pixels based and object based classifications were adopted to perform the Land use Land Cover classification in accurate manner to carry out the change detection study between 2005 and 2013. Accuracy assessment and Kappa coefficients were calculated to validate the classification. The built-up expansion map has been prepared using the change analysis.
2. Dispersion of settlement based on the elevation of the region has also been performed to observe the dynamics of change pattern with respect to elevation.
3. Topographic maps (Slope, Aspect, Hill shade, contours) have been prepared for both cities using the freely available Digital Elevation Model (DEM) at 30 m and 12.5 m (Fig. 35). This would help in estimating the topographical changes due to urbanization and also to understand the unplanned urbanization and the potential disasters the settlement cluster is vulnerable with.
4. Landscape metrics of LULC for year 2005 and 2013 including class area, number of patches, largest patch index, edge density, Area weighted mean patch fractal dimension, etc. have been calculated to estimate the percentage change to understand the dynamics associated with the change.

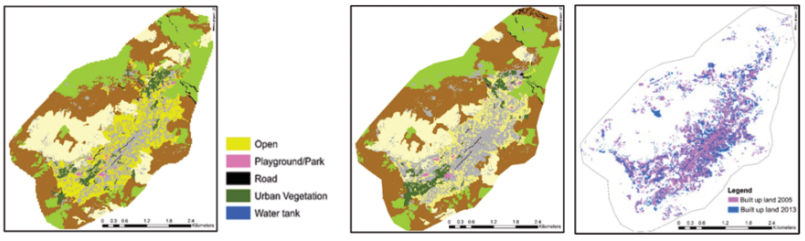


Fig. 35 (A) LULC Map of Almora (2005); (B) LULC Map of Almora (2013); (C) Built-up change during 2005-13

Eco-physiological assessment of selected medicinal plants with changing environment for understanding adaptation mechanism (Mountain Division-RA scheme, 2016-2019)

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

OBJECTIVES

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

ACHIEVEMENTS

1. Literature related to Himalayan plants has been reviewed and a review article related to biotic and abiotic stress in Himalayan plants is prepared.
2. To determine the effect of microbial colonization on Himalayan plants, the beneficial microbes (e.g. Trichoderma) have been isolated from the rhizospheric soil of *Valeriana jatamansi* and their identification is under process. Once identified, the effect of their colonization on growth dynamics of plants is studied. Experiments are under progress.
3. To identify suitable environmental conditions for plant growth and metabolite production, *Valeriana jatamansi* was grown (Fig. 36) under different light intensities (full sunlight and 50% shade) and their morphological, physiological and biochemical response was evaluated. Antioxidant compounds like m-coumaric acid, chlorogenic acid, 3-hydroxy benzoic acid, caffeic acid, ferulic acid, vanellic acid and gallic acid etc. were also analyzed by HPLC and compared in different plant parts of *Valeriana jatamansi* under light and shade conditions.

Fig. 36. Plant growth of *Valeriana jatamansi* under shade and full sunlight (A) at reproductive stage (B) at vegetative stage

Trade-offs between conservation and livelihood outcomes in protected area management: an assessment based on stakeholders analysis (Mountain Division- 2017-2020)

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

OBJECTIVES

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

ACHIEVEMENTS

1. The study reveals that the Binsar Wildlife Sanetuary is being visited by an average of 20027 tourists/year that generating an average annual income of 3186469 INR to the forest department. Similarly, the Corbett National Park is being visited by an average number of 64780 tourists/year that generating an average annual income of 10814202 INR.
2. Data collected on livestock predation shows that on an average 40 numbers of cow, bullock and goats are being killed each year by leopard in the villages located in and around the Binsar WLS. Furthermore, between 1997 and 2017, a total of 60 peoples were injured by leopard and wild boar and 5 persons (including 2 children's) were killed by leopard in these villages.
3. In the case of Corbett National Park, there were 13 cases of human casualty, 42 cases of human injury and 3524 cases of livestock predation and 5661 cases of crop loss was recorded between 2001 and 2012.
4. Based on primary data collected through questionnaire surveys in 6 villages located inside the sanctuary, 2 villages, at the sanctuary outskirts, 2 villages and around 10-15 Km away from the sanctuary boundary (2 villages), a high rate of crop damage was recorded in the villages located inside and at the sanctuary outskirts as compared to villages located far from the sanctuary boundary.
5. Based on villagers perception study, the livelihood impact of resource use restrictions was found to be moderate, high and low in the villages located inside the sanctuary, at the sanctuary outskirts and at a distance of around 10-15 Km away from the sanctuary boundary, respectively. The moderate impact of resource use restrictions in the villages located inside the sanctuary might be due to proximity to the forest resources and difficulty in monitoring their activities by the forest guards.
6. Villager's perception on the livelihood impact of livestock predation and crop raiding was found to be high in the case of villages located inside and at the sanctuary boundary and low in the village's located farm from the sanctuary boundary (Fig 37).

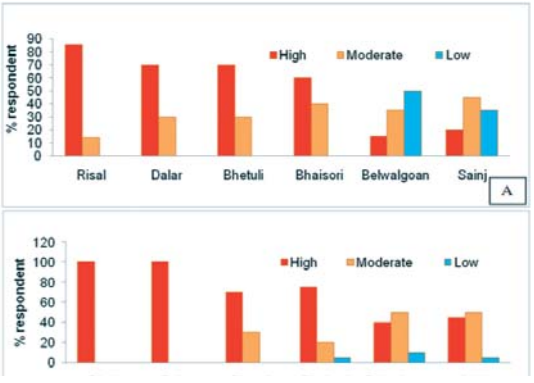


Fig. 37. Villager's perception (BWLS) about the impact of livestock predation & crop raiding on rural livelihoods

SUMMARY OF COMPLETED PROJECT

Assessment of floristic diversity and microbial association of the Birch – *Rhododendron* forests in Himachal Pradesh, North Western Himalaya, India

- The present study has been conducted on "Assessment of floristic diversity and microbial association of the Birch–Rhododendron forests in Himachal Pradesh, North Western Himalaya, India". The objectives of the study were to; i) assess the floristic diversity of *Betula utilis* and *Rhododendron campanulatum* forests/communities in Himachal Pradesh, ii) analyze the impact of climate change on the biodiversity, iii) collect soil samples and analyze for physico–chemical properties, iv) identify the microbial diversity and their association with vegetation pattern, v) assessment of microbial activity of selected plants and vii) suggest management option. To achieve these objectives, standard methods have been followed.
- 16 populations of *B. utilis* from Rohtang Pass, representing 03 habitats and 05 aspects between latitudes 32°19.577′ N–32°17.628′N and longitudes 77°11.979'E-77°13.463′E and altitude range 2,79°–3,748 m asl were sampled. The degree of inclination ranged from 10°-60°. In SolangValley, 15 populations of *B.utilis* were sampled representing 03 habitats and 04 aspects between latitudes 32o21.261′ N–32°21.937′N and longitudes 77°06.966'E-77°08.382′E and altitude 3,049–3,548 m asl with the degree of inclination from 30°-65° whereas, in Hamta Pass, total 13 populations were sampled representing 04 habitats and 05 aspects between latitudes 32°15.691′N–32°15.951′N and longitudes 77°14.990'E–77°15.032′E and altitude 3,109 – 3,760 m asl with the degree of inclination 20°-60°.
- Rapid sampling was done for the qualitative assessment of floristic diversity. A total of 272 plant species of vascular plants i.e., Angiosperms (53 families, 114 genera and 251 species), Gymnosperms (03 families, 05 genera and 07 species) and Pteridophytes (04 families, 09 genera and 14 species) has been recorded in the studied populations. Amongst angiosperm families, Asteraceae, Ranunculaceae, Apiaceae, Rosaceae, Caprifoliaceae, Lamiaceae, Poaceae and Polygonaceae had represented maximum species.
- Of the total speciesrecorded, 185species were native to the Himalayan Region, 66 species were non-natives, 8 species were endemic and 65 species were near endemic.
- The Importance value index (IVI) for B. utilis in Rohtang Pass, Solang Valley and Hamta Pass was ranged from 66 – 300, 21 – 300 and 21 – 275, respectively.
- The Concentration of dominance (Cod) for trees, shrubs and herbs was ranged from 0.22-1, 0.17-1.00 and 0.02–0.08, respectively in Routing Pass. Whereas the Cod for trees, shrubs and herbs in Soling Valley was ranged from 0.27-1, 0.05-0.59 and 0.02–0.08, respectively and in Hanta Pass the Cod was ranged from 0.20 – 0.85, 0.34 -1.00 and 0.03 –0.16, respectively.
- The species diversity (H′) in Rohtang Pass for trees, shrubs and herbs was ranged between 0- 1.67,0.00-1.83 and, 2.56–3.80, respectively. In Solang Valley, the species diversity (H′) for trees, shrubs and herbs was ranged between 0-1.63, 0.00-1.74 and 3.01 –4.93. Whereas, in Hamta Pass it was ranged between 0 -1.70, 0.00-1.17 and 1.89 – 3.78, respectively.
- The maximum density for all (trees, saplings and seedlings) was recorded in altitude range 2800-2900, followed by 2900 – 3000 and 3400 -3500 m asl.
- The maximum R:S ratio for actinomycetes was recorded in Rohtang Pass (0.73), followed by Solang Valley (0.28) and Hamta Pass (0.27).The R:S value for all three sites was recorded <1 which exert suppressive effect on microbial colonization in rhizosphere soil of *B. utilis*.
- The total percent root colonization ranged between 66–91 in active stage and 68-73 in dormant stage. The maximum average fungal mycelium and dark septate endophytes was observed in dormant and active stage, respectively.
- The bark and root samples were macerated in different solvent (Ethanol, Methanol, Ethyl acetate, Chloroform, n-hexane and water). The maximum yield of plant extracts was found in bark (25%) followed by roots (0.5).

SUMMARY OF COMPLETED PROJECT

Climatic variables and their impacts on Environmental Flow in the River Satluj Basin in Himachal Pradesh

The present study is conducted on 'Climatic variables and their impacts on Environmental Flow in the River Satluj Basin in Himachal Pradesh'. The river valley schemes may cause adverse flow-related impacts due to storage, flow diversion, tunneling and spoil disposal. There may be critical reaches in which altered flows are not able to sustain the river channel ecology and riparian environment that existed prior to implementation of the storage and diversion schemes.

- Keeping in mind the same, water quality samples were collected periodically by seasons from 10 November 2014 to 09 November 2017. The water quality parameters were analyzed and water quality index was estimated for the River Satluj Basin. Water quality index (WQI) during pre-monsoon, WQI rating falls under 'C' (considered to be very poor quality) in the year 2016 (50.96) and 2017 (50.27) while in 2015 (49.69) falls under 'B' rating. In monsoon, WQI rating falls under 'C' rating in the year 2015 (52.29), 2016 (53.26) and 2017 (53.76). In post-monsoon, WQI rating falls under 'B' WQI in the year 2015 (40.22), 2016 (39.08) and 2017 (42.77) respectively. Overall, WQI indicates for the present study region that water is not fit without treatment for drinking purpose.
- In terms of pH of river water, it was found to be alkaline (more than 8.5). The other water quality parameters like hardness, chloride, and calcium were within the desirable limit for drinking water as per Indian Standard Specifications. However, it is found that physical parameters for different seasons such as alkalinity (152.88 mg l-1, 169.16 mg l-1, 149.06 mg l-1) were not within its permissible limit for post-monsoon, winter and pre-monsoon respectively. Whereas in pre-monsoon season, maximum pH stands to be 8.89 which results in bitter taste of water, affects mucous membrane, cause corrosion and adversely affects aquatic life.
- pH and B.O.D. were within their permissible limits whereas T.C. and D.O. exceeded their permissible limits. A trend of water quality parameters namely, pH, D.O., B.O.D., and T.C. from 2005 to 2016 was analyzed for different seasons of a year. Among all, T.C. shows a great decadal rate of percentage change in all the sites or locations.
- During a field survey, of the total respondents interviewed it revealed that the people in the region are not directly dependent on the River Satluj for their livelihood and other agricultural practices. However, 55% of the total villagers said that the fishes were found mostly a decade before in a basin.
- According to a questionnaire for a prioritize matrix, the most destructive activities that affect the environmental flow of the River Satluj in the Himalayan villages are mainly road construction, dumping debris and other wastes into river water, tunnel construction and deforestation.
- There is a long-term decreasing trend in rainfall that could have major implications with regard to drinking water supply from springs. The rise in temperature could lead to increased evaporation. Decreased rainfall and rise in temperature (and hence evaporation) may have an adverse effect on soil moisture in the long run. Since there have not been many experiences in implementation of E-Flow in India, adaptive management options would be helpful.

SUMMARY OF COMPLETED PROJECT

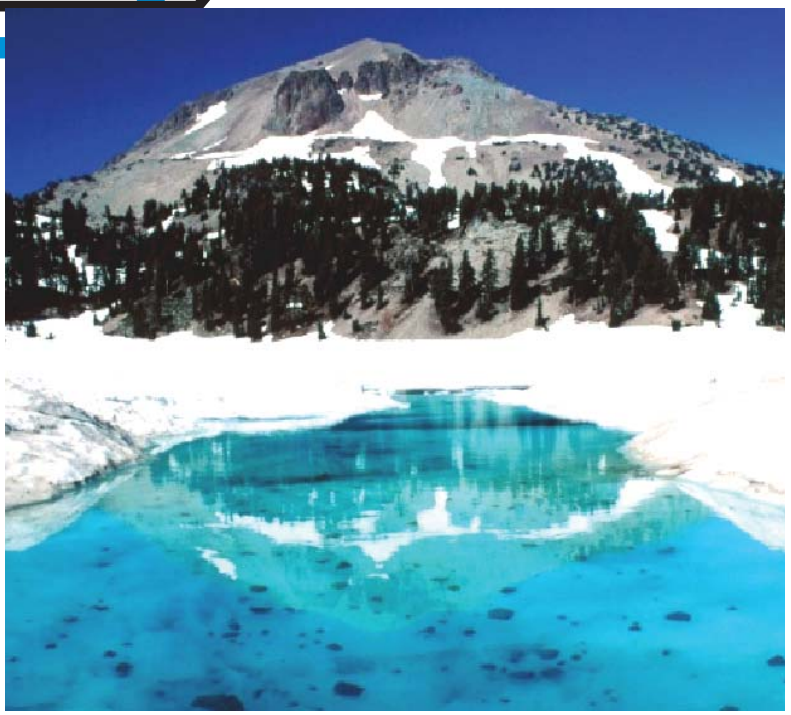
Tree Diversity of Indian Himalayan Region

Forest and tree cover in India accounts for about 23.4% of its total geographic area, and India stands 10thin the list of most forested nations of the world. The IHR contributes nearly one third (32.1%) of India's total forest cover. Therefore, it assumes a significant position while describing forests of India. Larger proportion of IHR forest cover comes from NE states. The West Himalayan states together account for 25% of IHR's total forest area. However, the West Himalaya contributes significantly for diversity of forests and tree species.

- A total of 1,491 trees have been inventorized, out of which 1,407 taxa are angiosperms (1,321 wild, 86 cultivated) and 84 taxa (21 wild, 63 cultivated) are gymnosperms. The maximum tree diversity is found in the state of Arunachal Pradesh (903- 849 angiosperms (790 wild and 59 cultivated), 54 gymnosperms (18 wild and 36 cultivated)) followed by Meghalaya (894- 880 angiosperms (816 wild and 64 cultivated), 14 gymnosperms (4 wild and 10 cultivated).
- Lauraceae (135) among angiosperm and Pinaceae (12) in gymnosperm are invariably the most species rich families across the IHR among wild trees.
- Among cultivated angiosperm and gymnosperm, Myrtaceae (15) and Pinaceae (22) are the most species rich families.
- In IHR, out of total 1,321 wild trees (angiosperm), over 67.14% trees are represented in 501-1000m altitude range. While 21 wild trees (gymnosperm), fall in 2001-2500m range with highest percent (71.43%).
- Tree flora of states of Indian Himalayan Region exhibit high similarity among wild angiosperm trees (39.27-97.3), 25-100 among wild gymnosperm trees, 40-98.11 in cultivated angiosperm trees and 2.94-100 in cultivated gymnosperm trees.
- As per the analysis, 1001-1500m is the range where various colour of flowers bloom at maximum. Trees with white flower are dominant among all colors.
- Summer season (Apr-Jun) and rainy season (Jul- Sep) are the peak flowering and fruiting periods in IHR among wild trees (angiosperm).
- Among the total tree taxa inventorized, 97 (96 Angiosperms, 1 Gymnosperm) tree taxa (88 species, 1 subspecies, 8 varieties) are found endemic to Indian Himalayan Region.
- 26 tree species (6- critically endangered, 10- endangered, 10- vulnerable) are coming under various categories of threats.

APPLICATION OF R & D OUTPUTS IN DEMONSTRATION AND DISSEMINATION

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



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

OBJECTIVES

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

ACHIEVEMENTS

1. The Project Evaluation Committee (i.e., 20h meeting of IERP-PEC) held at Tripura University, Agartala on February 27-28, 2018. In this PEC meeting, a total of 38 new projects were presented from different region of the IHR.
2. The project proposal invited this year were mainly focused on Northeast region of the Indian Himalayan region.
3. At present thirty eight IERP projects are on-going in 8 States (namely; Assam, Arunachal Pradesh, Himachal Pradesh, Jammu & Kashmir, Manipur, Sikkim, Uttarakhand and W.B) of the IHR. A total of two projects were completed in the reporting year.

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

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

OBJECTIVES

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

ACHIEVMENTS

1. The Centre has regularly collected, collated and synthesized the quantitative and qualitative databases on various aspects of Himalayan Ecology from authentic data sources. These databases covers the temporal trends across important segments, e.g., demography, literacy, land, water, agriculture, horticulture, forest cover, protected areas, weather profiles, etc., which would help in decision-making and policy planning of Indian Himalayan states.
2. In addition, the center is involved in developing database for IHR, including (i) Panels of Subject Experts; (ii) glossary database on environmental related issues; (iii) important web links related to Himalayan Ecology (i.e., Disaster Portal, Meteorological data, Forest Fire Information, e-flora, Indian Medicinal Plants, e-books on Himalaya, reports/documents on Himalaya, world of biodiversity, etc.; (iv) web directory of Indian Himalayan states; and (v) repository of frequently asked questions (FAQ).
3. The center during the reporting period published (i) four thematic ENVIS Newsletters Vol. 14(1-4), 2017; (ii) ENVIS Bulletin Vol. 25, 2017; (iii) state at a glance: Tripura Vol. 1(10), 2017 and Assam Hills and West Bengal Hills Vol. 1 (11 & 12), 2017. The ENVIS Bulletin has been in University Grants Commission (UGC) approved journal list.
4. The centre organized different awareness programme and some of these include, (i) World Ozone Day, 2017; (ii) World Wetland Day (2 February 2018); (iii) Swachhta Pakhwada, 2017, etc.

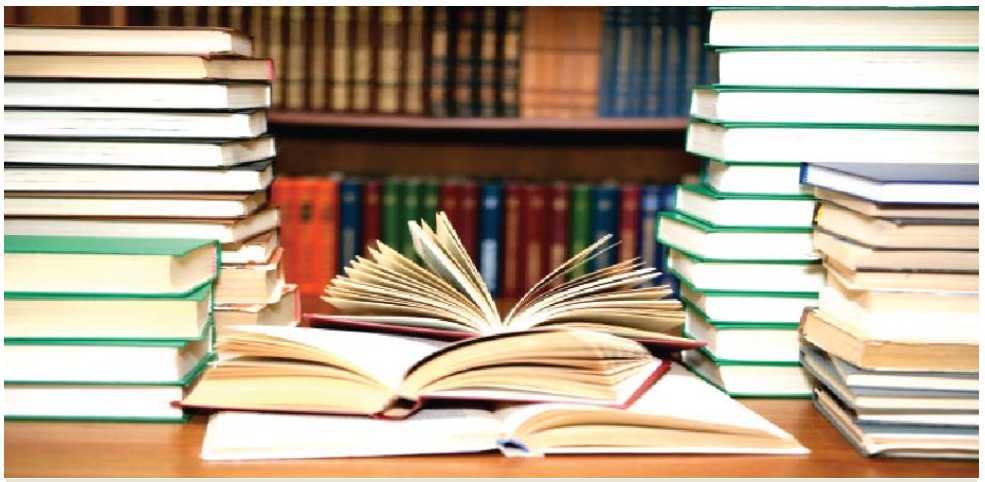
CENTRAL LABORATORY SERVICES

Institute has strengthened the facilities of physico-chemical, biological, heavy metal analysis of drinking, raw, waste water and quantification of volatile compounds of soil and plant samples. The heavy metals in the water and soil samples are detected through Atomic Absorption Spectrophotometer (Make- Varian AA280Z, equipped with graphite tube atomizer). Quantification of aromatic and volatile compounds are carried out using Gas chromatograph (make- Chemito, Ceres 800 plus). Institute is also having the facility of analyzing carbon, hydrogen, nitrogen and sulfur through CHNS-O analyzer (make- Elementar, Vario EL-III). Facility of UV-Vis spectrophotometer (make- UV 5704, Electronics Corporation of India Ltd.) is available for soil, water & plant analysis. The Institute has extended these services for other organizations (NGOs and other Government Organization) on payment basis. In the financial year 2017-18, Institute has collected Rs.1.52 lakh as a central laboratory service charge from 15 organizations (4 - Govt. Organization, & 11 - NGOs). Apart from this, the Central Lab has also facilitated Institute research work (In-house and external funded projects) in the form of sample analysis using AAS, GC & CHNS.

Strengthening and Maintenance of the Central Library at HQs

The Central Library of the Institute at its headquarters, at the end of financial year 2017-2018, had 17015 books. The library is subscribing a total of 69 periodicals (35 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 the human resources. The Library of the Institute is accessible through the Institute's web site (http://gbpihed.gov.in). During the reporting year, 278 new book titles were added to the Library. R & D achievements of the Institute were disseminated through its regular in-house publications, namely Hima-Paryavaran – a biannual newsletter and Institute Annual Report to various academic and scientific institutions, Government departments, NGOs, policymakers, planners and individuals working on various aspects of mountain environment and development.

MISCELLANEOUS ITEMS



MISCELLANEOUS ITEMS

SCIENTIFIC PUBLICATIONS

(I) SCIENTIFIC JOURNALS

NATIONAL

Adhikari P., A. Pandey (2017) *Taxus wallichiana* Zucc. (Himalayan Yew): Antimicrobial perspective. Advances in Biotechnology and Microbiology. DOI: 10.19080/AIBM.2017.04.555650.

Barman T., J. Anjana, S. Marpa, M. Lal, A. Singh, P. Sharma, S.S. Samant (2016) Diversity, distribution and status of orchids in Upper Beas Catchment and Parbati Valley of Kullu district, Himachal Pradesh. J. Orchid Soc. India. 30: 57-64.

Bodh M., S.S. Samant, L.M. Tewari, V. Kumar (2017) Diversity, distribution pattern, indigenous uses and conservation of the economically important floristic diversity in Shikari Devi Wildlife Sanctuary, North Western Himalaya, India. Journal of Non-Timber Forest Products 24(2): 109-126.

Chauhan S., S. Sharma (2017) Comparing feasibility of long distance transmission and locally generated solar energy over a period of 25 years in remote locations of the Indian Himalayan Region.International Journal of Science, Engineering and Management 2(8): 128-134.

Joshi R., V. Agnihotri, S.K. Nandi (2017) Modeling of thin layer drying kinetics of Picrorhiza kurroa under different drying conditions. Nonlinear Studies 24 (1): 79-88.

Kanwar N., J.C. Kuniyal, A. Kumar, S.K. Nandi (2017) Understanding Climatic Variability and Forest Vulnerability due to Hazards and Anthropogenic Activities: A Study from the Northwestern Himalaya, India. Journal of Himalayan Ecology and

Sustainable Development 12: 44-56.

Kumar D., P. Kumari, S.S. Samant, S. Paul (2016) Assessment of Orchid diversity in Sacred Groves of Kullu district, Himachal Pradesh, India. J. Orchid Soc. India, 30: 89-95.

Kumar K., P.C. Joshi (2017) Variation in population density and biomass of grasshoppers (Orthroptera) in Nanda Devi Biosphere Reserve, West Himalaya, India. Journal of Environment & Bioscience 32 (1): in press.

Kumar V., O. Prakash, A. Singh, M. Lal, S. Marpa, S.S. Samant, M. Bodh (2017) Status, distribution and conservation of Orchids in Great Himalayan National Park of Himachal Pradesh, North Western Himalaya. J. Orchid Soc. India 31: 1-8.

Kumari A., S.S. Samant, S. Sharma (2016) A study on traditionally used medicinal plants and associated practices in Anni Khad Watershed of district Kullu, Himachal Pradesh, Western Himalaya. Journal of Non-Timber Forest Products 23(4): 199-219.

Kumari A., S.S. Samant, S. Sharma (2017) Seed germination behavior of *Berberis lyceum* Royle from Anni Khad Watershed area, Kullu (Himachal Pradesh. Journal of Indian Botanical Society 96 (1 and 2): 18-27.

Lepcha J., S. Sinha, K.S. Gaira, H.K. Badola (2017) Assessing socioeconomic status of the indigenous Lepcha community: a case study from Dzongu in Khangchendzonga Landscape, India. Journal of Agroecology and Natural Resource Management 4(2): 84-188.

Maikhuri R.K., V.S. Negi, L.S. Rawat, D.S. Pharswan (2017) Bioprospecting of medicinal plants in Nanda Devi biosphere reserve: Linking conservation with livelihood. Current Science 113(4): 571-577.

Nath S., S. Rawat, I.D. Bhatt, R.S. Rawal, B. Pathak, M.H. Fulekar (2017) Effect of edaphic factors on phytochemical and nutritional contents of *Wrightia tinctoria* in different populations of North Gujarat. Indian Journal of Plant Physiology 22(2): 197-205.

Negi M. (2016) Ecology and Management of an Invasive Species, *Eupatorium adenophorum* in Kumaun Himalaya. ENVIS Bulletin Himalayan Ecology 24: 128-132.

Negi V.S., R.K. Maikhuri, A. Maletha (2017) *Polygonum polystrachyum*: peril to biodiversity of the alpine ecosystem, Western Himalaya, India. Current Science, 113(12): 2249-2251.

Sekar K.C., R.S. Rawal, A. Chaudhery, A. Pandey, G. Rawat, O. Bajapai, B. Joshi, K. Bisht, B.M. Mishra (2017) First GLORIA site in Indian Himalayan Region: Towards addressing issue of Long-term data deficiency in the Himalaya. National Academy Science Letters 40(5): 355-357. DOI: DOI 10.1007/s40009-017-0584-z.

Shahid M., L.K. Rai (2017) Opportunities for reaping the benefits of REDD+ in Sikkim Himalaya for conservation and enhancement of carbon stock. Indian Journal of Forestry 40(3): 209-215.

Sharma A., S.S. Samant, S. Bhandari, J.S. Butola (2017) Diversity, distribution and conservation status of Orchids along an altitudinal gradient in Himachal Pradesh, North Western Himalaya. J. Orchid Soc. India 31: 23-32.

Sharma L., S.S. Samant, A. Kumar (2017) Fodder resources of Cold Desert Biosphere Reserve in Trans Himalaya. Journal of Non-Timber Forest Products 24(2): 79-92.

Sharma L., S.S. Samant, A. Kumar (2017) Fuel yielding species of Cold Desert Biosphere Reserve in the Indian Trans Himalaya. Journal of Non-Timber Forest Products 24(1): 21-27.

Sharma P., S.S. Samant (2017) Diversity, Distribution, Indigenous Uses and Conservation of Orchids in Parvati Valley of Kullu District, Himachal Pradesh, Northwestern Himalaya. J Biodivers Endanger Species 5: 177. DOI: 10.4172/2332-2543.1000177.

Sharma S., H. Pant (2017). Vulnerability of Indian Central Himalayan forests to fire in a warming climate and a participatory preparedness approach based on modern tools. Current Science 112(10): 2100-2105.

Shashni S., S. Sharma, S. Rathore, S.S. Samant, R.C. Sundriyal (2017) Traditional uses and potential to develop an enterprise of Wild Rose Species *Rosa brunonii* syn. *Rosa moschata* in Kullu district of North Western Himalaya. Journal of Non-Timber Forest Products 24(3): 137-139.

Sinha S., H.K. Badola, B. Chettri, K.S. Gaira, J. Lepcha, P.P. Dhyani (2018) Effect of altitude and climate in shaping the forest compositions of Singalila National Park in Khangchendzonga Landscape, Eastern Himalaya, India. Journal of Asia-Pacific Biodiversity. DOI: 10.1016/j.japb.2018.01.012

Bungla P.S., G. Tewari, R.S. Rawal, I.D. Bhatt, L.M. Tewari, A.K. Ju-

gran, B. Mohan (2017) Comparative in vitro antioxidant activity, morphological and phytochemical profiling of traditional crops from Kumaun Himalaya. J. Indian Chem. Soc. 94: 181-189.

INTERNATIONAL

Arya S.C., S.S. Samant (2017) Assessment of vegetation and prioritization of communities for conservation in Latakharak alpine meadows of Nanda Devi Biosphere Reserve, West Himalaya, India. International Journal of Advanced Research 5(9): 1349-1366.

Bahukandi A., A. Pandey, K. Chandra Sekar, I.D. Bhatt (2017) Polyphenolics, nutrients and antioxidant activity of *Gaultheria trichophylla* Royle: A high value wild edible plants of Trans Himalaya. Horticulture International Journal 1(2): 1-6. DOI: 10.15406/hij.2017.01.00007.

Bahukhandi A, P. Dhyani, A.K. Jugran, I.D. Bhatt, R.S. Rawal (2017) Total phenolics, tannins and antioxidant activity in twenty different apple cultivars growing in West Himalaya, India. Proc. Natl. Acad. Sci., India, Sect. B Biol. Sci. DOI: 10.1007/s40011-017-0915-3.

Banu F.S., D. Rubini, S. Rakshitaa, K. Chandra Sekar, R. Murugan, A. Wilson, S. Gowrishankar, S.K. Pandian, P. Nithyanand (2017) Antivirulent Properties of underexplored *Cinnamomum tamala* essential oil and its synergistic effects with DNAse against *Pseudomonas aeruginosa* biofilms - An in vitro study. Frontiers in Microbiology 8: 1-14. DOI: 10.3389/fmicb.2017.01144.

Bhatt I.D., S. Rawat, A. Badhani, R.S. Rawal (2017) Nutraceutical potential of selected wild edible fruits of the Indian Himalayan region. Food Chemistry 215: 84-91.

Dhyani P., A. Bahukhandi, S. Rawat, I.D. Bhatt, R.S. Rawal (2018) Diversity of bioactive compounds and antioxidant activity in delicious group of apple in western Himalaya. Journal of Food Science & Technology. DOI:10.1007/s1 3197-018-3179-x).

Dolma K., M.S. Rishi, R. Lata, R. Herojeet (2017) Participatory tourism: an inclusive developmental approach encompassing all stakeholders, in Leh district, India. Interdisciplinary Research for Sustainable Development 5(1): 1-4.

Giri L., T. Belwal, A. Bahukhandi, R. Suyal, I.D. Bhatt, R.S. Rawal, S.K. Nandi (2017) Oxidative DNA damage protective activity and antioxidant potential of Ashtvarga species growing in the Indian Himalayan Region. Industrial Crops and Products 102: 173-179.

Gode K., K.S. Kanwal, Y. Lod (2018) Ethnomedicinal plants used by Galo community of West Siang district, Arunachal Pradesh. International Journal for Research in Applied Science and Engineering Technology 6(1): 438-444.

Herojeet R., M.S. Rishi, R. Lata, K. Dolma (2017) Quality characterization and pollution source identification of surface water using multivariate statistical techniques, Nalagarh Valley, Himachal Pradesh, India. Applied Water Science 7(5): 2137-2156.

Ichii K., M. Ueyama, M. Kondo, N. Saigusa, J. Kim, M.C. Alberto, J. Ardo, E.S. Euskirchen, M. Kang, T. Hirano, J. Joiner, H. Kobayashi, L.B. Marchesini, L. Merbold, A. Miyata, T.M. Saitoh, K. Takagi, A.Varlagin, M. S. Bret-Harte, K. Kitamura, Y. Kosugi, A. Kotani, K. Kumar, S. G. Li, T. Machimura, Y. Matsuura, Y. Mizoguchi, T. Ohta, S. Mukherjee, Y. Yanagi, Y. Yasuda, Y. Zhang, F. Zhao (2017) New data-driven estimation of terrestrial CO2 fluxes in Asia using a standardized database of eddy covariance measurements, remote sensing data, and support vector regression. J Geophys Res Biogeosci doi:10.1002/2016JG003640.

Jade S., T.S. Shrungeshwara, K. Kumar, P. Choudhury, R.K. Dumka, H. Bhu (2017) India plate angular velocity and contemporary deformation rates from continuous GPS measurements from 1996 to 2015. Nature Scientific Reports 7: 11439. DOI: 10.1038/s41598-017-11697-w.

Joshi G., G.C.S. Negi (2017) Soil and water conservation services of western Himalayan forests, India. International Journal for Water & Wastewater Treatment 34:1-3.

Jugran A.K., R.K. Joshi, I.D. Bhatt, R.S. Rawal, L.M.S. Palni (2017) The relationship of visiting insect diversity and density of *Valeriana jatamansi* with increasing altitude in western Himalaya. Proc. Natl. Acad. Sci., India, Sect. B Biol. Sci. DOI: 10.1007/s40011-017-0954-9.

Kalita B.C., S.C. Arya, H. Tag (2017) Wild edible and medicinal plants used by Apatani community of Lower subansiri district, Arunachal Pradesh, India. International Journal of Current Research in Biosciences and Plant Biology 4(3): 64-70.

Kanwal K.S. (2017) Climate Change Impact on Forest and Biodiversity of Indian Eastern Himalaya: an Overview. International Journal of Advance Engineering and Research Development

4(12): 178-184.

Kumar D. (2017) Monitoring and assessment of land use and land cover changes (1977 - 2010) in Kamrup district of Assam (India) using remote sensing and GIS techniques. Applied Ecology and Environmental Research 15(3): 221-239.

Kumar P., M. Pant, G.C.S. Negi (2017) *Lantana camara* leaf litter mulching improves availability of soil nutrients and yield of rainfed Rice in Himalayan Mountains. International Journal of Environment & Agricultural Science 1(1): 1-9.

Kundra R., S.S. Samant, S.K. Nandi, R.K. Sharma (2017) Investigation of antioxidant properties of *Withania somnifera* (L.) Dunal and influence of physico-chemical properties of soil along the topographic gradients in sub-tropical region of the Indian Himalaya. International Journal of Phytomedicine 9: 407-415.

Lal M., R. Devi, V. Singh, R.K. Rana (2017) Distribution and Morphological Variations in Allopatric Populations of *Hippophae tibetana* in Trans Himalaya India. The Journal of Ecology 112: 479-486.

Lal M., S.S. Samant (2017) Niche Modeling: an approach to predict habitats for conservation of Hippophae species in Trans and North Western Himalaya. International Journal of Science and Nature 8(3): 437-446.

Lal S., S. Venkataramni, M. Naja, J.C. Kuniyal, T.K. Mandal, P.K. Bhuyan, K.M. Kumari, S.N. Tripathi, U. Sarkar, T. Das, Y.V. Swamy, K.M. Gopal, H. Gadhavi, M.K.S. Kumar (2017) Loss of crop yields in India due to surface ozone: an estimation based on network of observations. Environmental Science and Pollution Research International 24(26): 20972-20981.

Lata R., M.S. Rishi, R. Herojeet, K. Dolma (2017) Environmental and Social Impact Assessment: A Study of Hydroelectric Power Projects in Satluj Basin in District Kinnaur, Himachal Pradesh, India. International Journal of Earth Sciences and Engineering 10(02): 270-280.

Lata R., M.S. Rishi, R. Herojeet, K. Dolma (2017) Environmental Implications of the Hydropower Projects in District Kinnaur, Himachal Pradesh, India: A Review. The Research Journal 3(6): 8-13.

Lata R., M.S. Rishi, R. Herojeet, K. Dolma (2017) Socio-economic Vulnerability and Environmental Implications of Major Hydropower Projects in District Kinnaur, Himachal Pradesh, India. International Journal of Earth Sciences and Engineering, 10(04): 826- 832.

Maikhuri R.K., A. Nautiyal, N.K. Jha, L.S. Rawat, A. Maletha, P.C. Phondani, Y.M. Bahuguna, G.C. Bhatt (2017) Socio-ecological vulnerability: Assessment and coping strategy to environmental disaster in Kedarnath valley, Uttarakhand, Indian Himalayan Region. International Journal of Disaster Risk Reduction 25:111-124.

Maikhuri R.K., P.C. Phondani, D. Dhyani, L.S. Rawat, N.K. Jha, L.S. Kandari (2017) Assessment of climate change impacts and its implications on medicinal plants-based traditional healthcare system in central Himalaya, India, Iran. J. Sci. Technol., Trans. Sci. DOI: 10.1007/s40995-017-0354-2.

Mukherjee S., A. Hazra, K. Kumar, S.K. Nandi, P.P. Dhyani (2017) Simulated projection of ISMR over Indian Himalayan region: assessment from CSIRO-CORDEX South Asia experiments. Meteorol Atmos Phys DOI: 10.1007/s00703-017-0547-4.

Negi D., S.S. Samant, L.M. Tewari (2017) Assessment of Antioxidant properties of *Arnebia euchroma:* an endangered medicinal plant of cold desert biosphere reserve in trans Himalaya, India. International Journal of Medicinal Plants 111: 825-836.

Negi D., S.S. Samant, L.M. Tiwari (2017) Investigation of antioxidant activity of methanolic extracts of Hippophae rhamnoides ssp. turkestanica across habitats in cold desert biosphere reserve, trans Himalaya, India. International Journal of Pharmaceutical Sciences Review & Research 46(1): 146 - 155.

Negi G.C.S., D. Punetha (2017) People's perception on impacts of hydro-power projects in Bhagirathi river valley, India. Environmental Monitoring & Assessment 189: 138-153.

Negi M., R.S. Rawal (2018) Species Spotlight: *Quercus semecarpifolia* Sm. Oak News and Notes: The Newsletter of the International Oak Society 22: 3-4.

Negi V.S., B. Joshi, R. Pathak, R.S. Rawal, K. Chandra Sekar (2018) Assessment of fuel wood diversity and consumption patterns in cold desert part of Indian Himalaya: Implication for conservation and quality of life. Journal of Cleaner Production. DOI: 10.1016/j.jclepro.2018.05.237.

Negi V.S., P. Kewlani, R. Pathak, D. Bhatt, I.D. Bhatt, R.S. Rawal, R.C. Sundriyal, S.K. Nandi (2018) Criteria and indicators for promoting cultivation and conservation of Medicinal and Aromatic Plants in Western Himalaya, India. Ecological Indicator. DOI: 10.1016/j.ecolind.2018.03.032.

Negi V.S., R. Pathak, K. Chandra Sekar, R.S. Rawal, I.D. Bhatt, S.K. Nandi, P.P. Dhyani (2018) Traditional knowledge and biodiversity conservation: a case study from byans valley of Kailash Sacred Landscape, India. Journal of Environmental Planning and Management. DOI: 10.1080/09640568.2017. 1371006.

Negi V.S., R.K. Maikhuri, A. Chandra, A. Maletha, P.P. Dhyani (2018) Assessing sustainability of farming systems in mountain agroecosystems of Western Himalaya, India. Agroecology and Sustainable Food Systems. DOI: 10.1080/21683565.2018.1427175.

Negi V.S., R.K. Maikhuri, A. Maletha, P.C. Phondani (2018) Ethnobotanical knowledge and population density of threatened medicinal plants of Nanda Devi Biosphere Reserve, Western Himalaya, India. Iranian J. Sci. Technol. Trans. Sci. DOI: 10.1007/s40995-018-0545-5.

Pandey A., K. Chandra Sekar, S. Tamta, R.S. Rawal (2017) Assessment of Phytochemicals, Antioxidant and Antimutagenic activity in micropropagated plants of *Quercus serrata*, a high value tree species of Himalaya. Plant Biosystems. DOI: 10.1080/11263504.2017.1395372.

Pandey N., R. Jain, A. Pandey, S. Tamta (2018) Optimization and characterization of the orange pigment produced by a cold adapted strain of *Penicillium* sp. (GBPI_P155) isolated from mountain ecosystem. Mycology. DOI: 10.1080/21501203.2017.1423127.

Pant M., G.C.S. Negi, P. Kumar (2017) Macrofauna contributes to organic matter decomposition and soil quality in Himalayan agroecosystems, India. Applied Soil Ecology 120: 20-29.

Phondani P.C., R.K. Maikhuri, L.S. Rawat, A.K. Jugran, A. Bhatt, N.S. Bisht (2017) Policy implications of utilizing indigenous tree species as agroforestry systems in Himalayan states of India: case study of Uttarakhand. Energy Pol. 110: 202-209

Rai S., A. Pandey, H.K. Badola (2017) Biomass and carbon stock estimation across the timberline of Khangchendzonga National Park, Eastern Himalaya, India. Taiwania 63(4): 311-320, 2018

Rawat L.S., R.K. Maikhuri, D. Dhyani, Y.M. Bahuguna, D.S. Pharswan (2017) Ecological restoration of village common degraded land through participatory approach for biodiversity conservation and socio-economic development in Indian Himalayan Region, Acta Ecologica Sinica 37: 240-252.

Rawat L.S., R.K. Maikhuri, Y.M. Bahuguna, N.K. Jha, P.C. Phondani (2017) Sunflower allelopathy for weed control in agriculture systems J. Crop Sci. Biotech 20(1): 45- 60.

Rawat S., A.K. Jugran, I.D. Bhatt, R.S. Rawal (2018) *Hedychium spicatum:* A review on traditional uses, phytochemistry, pharmacology and conservation status. Journal of Pharmacy and Pharmacology. DOI: 10.1111/jphp.12890.

Rawat S., A.K. Jugran, I.D. Bhatt, R.S. Rawal (2018). Influence of the growth phenophases on the phenolic composition and anti-oxidant properties in Roscoea procera Wall. in western Himalaya. Journal of Food Science and Technology 55: 578-585.

Rawat S., A.K. Jugran, I.D. Bhatt, R.S. Rawal, H.C. Andola, U. Dhar (2017) Essential oil composition and antioxidant activity in Valeriana jatamansi Jones: Influence of seasons and growing sources. Journal of Essential oil Research 29 (1): 101-107.

Rawat S., A.K. Jugran, I.D. Bhatt, R.S. Rawal, S.K. Nandi (2017) Effects of genetic diversity and population structure on phenolic compounds accumulation in *Hedychium spicatum.* Ecological Genetics and Genomics 3(5): 25-33.

Sati P., P. Dhyani, I.D. Bhatt, A. Pandey (2018) *Ginkgo biloba* flavonoid glycosides in antimicrobial perspective with reference to extraction method. Journal of Traditional and Complementary Medicine. DOI: 10.1016/j.jtcme.2017.10.003.

Sen A.S., Y. Abdelmaksoud, N. Ahammed, M.A. Alghamdi, T. Banerjee, M.A. Bhat, A. Chatterjee, A.K. Choudhuri, T. Das, A. Dhir, P.P. Dhyani, R. Gadi, S. Ghosh, K. Kumar, A.H. Khan, M. Khoder, K.M. Kumari, J.C. Kuniyal, M. Kumar, A. Lakhani, P.S. Mahapatra, M. Naja, D. Pal, S. Pal, M. Rafiq, S.A. Romshoo, I. Rashid, P. Saikia, D.M. Shenoy, V. Sridhar, N. Verma, B.M. Vyas, M. Saxena, A. Sharma, S.K. Sharma, T.K. Mandal. (2017) Variations in particulate matter over Indo-Gangetic Plains and Indo-Himalayan Range during four field campaigns in winter monsoon and summer monsoon: Role of pollution pathways. Atmospheric Environment 154: 200-224.

Shahid M., N. Verma (2017) Implication for biodiversity conservation and monitoring under REDD+ climate change mitigation programme in India. International Journal of Science and Nature 8(4): 908-915.

Sharma A., D. Paul, D. Dhotre, K. Jani, A. Pandey, Y.S. Shouche (2017) Deep sequencing analysis of bacterial community struc-

ture of soldhar hot spring, India. Microbiology 86(1): 126-132.

Sharma G., J.C. Kuniyal, N. Ram, R. Lata, S. Shashni (2017) Aerosol radiative forcing and Heating rate on the foothills of Rohtang Pass in Northwestern Indian Himalayas, Research Expo. International Multidisciplinary Research Journal 7(6): 95-102.

Sharma L., S. S. Samant, A. Kumar, D. Negi, K. Devi, M. Lal, L.M. Tewari (2017) Diversity, distribution pattern and indigenous uses of medicinal plants of cold desert biosphere reserve in Trans Himalaya. The Journal of Ethnobiology and Traditional Medicine 128: 1320-1345.

Sharma P., S.S. Samant, M. Lal (2017) Assessment of plant diversity for threat elements: A case study of Nargu Wildlife Sanctuary, north western Himalaya. Ceylon Journal of Science 46(1): 75-95.

Sharma R.K., R. Kundra, S.S. Samant, S.K. Nandi (2017) Antioxidant properties of Methanol Extracts from *Olea ferruginea* Royle seeds. National Academy Science Letters. DOI: 10.1007/s40009-017-0587-9.

Shashni S., S. Sundriyal (2017) Assessment of ecotourism activities and its potential in Corbett tiger reserve, India. International Journal of Environmental Science 7(1): 37-42.

Soni S., S. Mukherjee, K. Kumar (2017) Regional scale investigation of net primary productivity associated to dominant land cover classes of Indian Himalayan region. Tropical Plant Research 4(2): 264-273

Upadhyay S., A. Bahukhandi, A.K. Jugran, Y. Joshi, I.D. Bhatt, R.S. Rawal (2017) Solvent system influence polyphenolic content measurement and antioxidant activity of three common Kumaun Himalayan macrolichens. Sydowia. DOI: 10.12905/0380.sydowia69-2017-0123.

Upadhyay S., A.K. Jugran, Y. Joshi, R. Suyal, R.S. Rawal (2018) Ecological variables influencing the diversity and distribution of macrolichens colonizing *Quercus leucotrichophora* in Uttarakhand forest. Journal of Mountain Science 15(2): 307-318.

Yomgam Y., Rohita Sharma, O.P. Arya, Yumbi Yomgam (2017) Phytochemical screening and antifungal activities of three medicinal plants from Arunachal Pradesh, India. Journal of Medicinal Plant Studies 5(3): 278-283.

(II) CHAPTER IN BOOKS/PROCEEDINGS

Joshi R. (2017) Temperature lapse rate and patterns of precipitation along altitude gradient. In: S.P. Singh and R.S. Rawal (eds.), Manual on field methods Indian Himalayan Timberline project (IHTP). pp: 22-38.

Joshi R., R. Dhyani (2017) Tree Growth Models in Forest Ecosystem Modeling – A Tool for Development of Tree Ring Width Chronology and Climate Reconstruction. In: M. Ram and Joao Paulo Davim (eds.), Advanced Mathematical Techniques in Science and Engineering; River Publishers, Denmark, pp: 201-217.

Joshi R., R.S. Rawal, R. Upadhyay (2017) Approaching Spring-Shed Management in Pilot Sites of Kailash Sacred Landscape, India-Assessment, Monitoring and Convergence Perspectives. In: Rawat G.S. and Gopi G.V (eds.), Comprehensive Environmental and Socio-Economic Monitoring in Kailash Sacred Landscape, India. pp: 59-83.

Kanwal K.S. (2017) Status and conservation of High altitude wetlands of Indian Himalaya: A review. In: Society of Wetland Scientists Annual Meeting (SWS2017), Celebrating Wetland Diversity Across the Landscape: Mountains to Mangroves Organized by Society of Wetland Scientists, Madison, USA at San Juan, Puerto Rico, from June 5-8, 2017.

Kanwal K.S., P.K. Samal, M.S. Lodhi (2017) Jal Vayu Parivartan ka Arunachal Pradesh Rajy ki Jaiv Vividhta Par Prabhav: Ek Aankalan. Jal Vayu Parivartan Visheshank, Parayavaran Patrika. Parayavarn, Van aur Jal Vayu Parivartan Mantralay (MoEFCC), New Delhi 68: 8-10.

Kumar D., M. Singh, L.K. Rai, S. Sharma, P.P. Dhyani (2017) Predicting the impact of climate change on the distribution of Swertia chirayita (Roxb. ex Flrming) H. Karst. – A medicinally important plant species in Sikkim Himalaya. In: Biodiversity Conservation for Sustainable Use and Development in Northeast India. Vol. 1. Tripura Biodiversity Board, Agartala, Tripura. (In Press).

Mylliemngap W., A.K. Das, R.C. Sundriyal, M.S. Lodhi (2017) Traditional knowledge innovations Panchayati Raj, North Eastern Regional Centre, Guwahati (In Press).

Nidhi K., J.C. Kuniyal (2018) Himachal Pradesh ke Kinnaur Jile mai vano ka paridrisya, unko parbhavit karne wale karak aur parbhandhan In: Forest resources and Plant Biodiversity (S. Shashni, S. Sood, S.S. Samant, J.C. Kuniyal, V.E. Gosavi, R.C. Sundriyal, S.K. Nandi), GBPNIHESD, HRC, Mohal-Kullu. pp: 53-60 (in Hindi).

Pandey A., D. Kumar (2018) Assessment of Vegetation Patterns and Community Structure along the Elevation Gradient in the Sikkim,

Eastern Himalaya, India in 2nd International workshop on biodiversity and climate change, IIT Kharagpur, West Bengal.

Sekar, K.C., R.S. Rawal, V.S. Negi (2017) GLORIA Sites for Alpine Vegetation Monitoring in Kailash Sacred Landscape, India. Rawat G.S. and Gopi G.V. (Ed) Manual for comprehensive environmental and soci0-economic monitoring in Kailash sacred landscape, India. WWI, India. pp: 100-110.

Shahid M., (2018) Landscape approach for the implementation of REDD+ climate change mitigation programme and support for ecosystem services in the Indian Himalayan Region. Ecosystem Services Partnership World Conference, 11-15 December 2017, China.

Sharma S. (2018) Climate Change, Natural disasters and People – Role of Citizen Science in Preparedness. Proceedings of the 105th Indian Science Congress- Environmental Sciences. pp.5-17.

Shashni S., S. Sood, S.S. Samant, J.C. Kuniyal, V.A. Gsaivi, R.C. Sundriyal, S.K. Nandi (2018) Van Sansadhan evam Padap Jav vividhta, Himachal Regional Centre, GBPNIHESD, Mohal, Kullu, Himachal Pradesh.

Singh S., A. Pandey, L.M.S. Palni (2017) The role of arbuscular mycorrhizal fungi in tea cultivation. Burleigh Dodds Science Publishing Limited. DOI: 10.19103/AS.2017.0036.10.

(III) Authored/Edited Book

Gaira K.S., J. Lepcha, S. Sinha, B. Chhetri, G. Sharma, U.P. Lepcha, A. Bose, M. Singh, N. Chettri, K. Kumar (2018) Khangchendzonga Landscape Conservation and Development Initiative (KLCDI) - India: Implementation Phase. GBPNIHESD, India.

Gaira K.S., J. Lepcha, S. Sinha, B. Chhetri, R. Lepcha, M. Singh, N. Chettri (2018) Training and Exposure Visit Programme on Skill and Capacity Building for Improved Tourism Services: Process and Outcome. GBPNIHESD, Sikkim Regional Centre, Gangtok, India. Produced by Highlanders Communications Private Limited, New Delhi.

Kireet, K., R. Joshi, R. K. Verma, P.P. Dhyani. (2017). Governance for Sustaining Himalayan Ecosystem: Guidelines and Best Practices (G-SHE An Updated Version). 64p.

Kuniyal J.C., E. Lata (2017) Scientific Project Report on Aerosol Climatology over the northwestern Indian Himalayan region: Case Studies in Kullu Valley. Proceedings of the Project Review Meeting held at Space Physics Laboratory, Vikram Sarabhai Space Centre, Indian Space Research Organization, Thiruvananthapuram on 20- 21 March, 2017.

Kuniyal J.C., H.K. Thakur, P. Sharma, R. Kumar (2017) Aerosols and temperature rise in the northwestern Indian Himalayan Region: A case study at two semi-urban sites in the Kullu valley, Himachal Pradesh, In: Spehia, R.S. and Upadhyay, G.P. (eds.) Precision farming and Climate Change- Imperatives of Indian Agriculture, Bishen Singh Mahendra Pal Singh, Dehradun..

Samant S.S., P.P. Dhyani, A. Sharma, N. Sharma, K. Kumar, P. Mehta, R. Saxena (2016) Promoting pollinators using community based conservation approach in the Indian Himalayan Region. GBPNIHESD, Himachal Unit, Mohal –Kullu, Himachal Pradesh.

Sharma S., H Pant, P.P. Dhyani (2017) Conserving the Himalayan Landscape: Perception and coping with the climate change impacts on food, water, disease, and facilities. 2017. G.B. Pant National Institute of Himalayan Environment and Sustainable Development, Kosi-Katarmal, Almora.

Sharma S., R. Joshi, H. Pant, P.P. Dhyani (2017) Climate Change and North Western Himalayan: Prioritization of Agriculture based livelihood actions. G.B. Pant National Institute of Himalayan Environment and Sustainable Development, Kosi-Katarmal, Almora.

Singh M., D. Kumar (2017) Capacity Building Training Programme on "Biodiversity Conservation & Climate Change" A Training Manual cum Bulletin. G.B. Pant National Institute of Himalayan Environment & Sustainable Development, Sikkim Regional Center, Gangtok 737 101, Sikkim India.

(IV) Popular article

Arya S.C. (2017) Swachhta: Man evam soch ke shudhi awashyak. Dainik Purvoday, Guwahati, Assam. Thursday, June 15, 2017.

Bisht K., K. Chandra Sekar, R.S. Rawal (2017) Towards Long-term monitoring in Alpines of Indian Himalaya: First of its kind

Long-Term Observation Sites (LTOS) in Kailash Sacred Landscape - India. Sangju: Sacred Attempt for Natural Growth and Joyful Union 3(I&II): 18-21.

Chandra H., R. Joshi, K. Kumar (2017) 'Mere Bujurg Mere Tirth' EkAham Sandesh. Him-Prabha 8: 43-47.

Joshi R., S. Mukherjee (2017) Jalwayu Pariwartan-Anukulan Ewam Ranneetiya. In: Sustainable Community Forest Management with reference to climate change mitigation and adaptation. NMSHE Task Force-3, G. B. Pant National Institute of Himalayan Environment and Sustainable Development, Kosi-Katarmal, Almora. pp: 39-45.

Kanwal K.S. (2017) Conservation & Management of High Altitude Wetlands of Eastern Himalaya. Echo of Arunachal. Vol. 30 No. 300, December 31, 2017, page no. 4

Kanwal K.S. (2017) Opportunity of community based bird-watching ecotourism in Arunachal. The Arunachal Times. Vol. 29 No. 201, December 31, 2017, page no. 3

Kumar K., S.S. Samant (2017) Paragn and Paragankartao Ka Satat Krishi Vikash mein Mahattawa. In : Sarala Shashani, Sagar Sood, Sher Singh Samant, Jagdish Chandra Kuniyal, Vaibhav Eknath Gosavi, Rakesh Chandra Sundriyal and Shyamal Kumar Nandi (eds.) Ban Sanshadhan Evam Padap Jaiv Vividhata. G.B. Pant National Institute of Himalayan Environment & Sustainable Development, Himachal Regional Center, Mohal-Kullu, HP. pp: 34-42.

Kumari K., L. Sharma, S.S. Samant, A. Pandey (2017) *Delphinium denudatum* Wall. ex Hk. f. & Th.: A Critically Endangered plant of the Indian Himalayan Region. Hima Paryavaran 29(2) & 30(1): 17-18.

Kuniyal J.C., R. Lata, A. Kumar, B. Chand, N. Kanwar, S. Chaudhary, K. Kumar, P.P. Dhyani (2017) Strategic Environmental Assessment of Hydropower Projects, Current Science 113(12): 2239-2240.

Lata R., S.S. Samant (2017) Environmental and Livelihood Issues of Major Hydropower Projects in district Kinnaur of Himachal Pradesh, Northwestern Himalaya, India. Hima Paryavaran 29(2) & 30(1): 18 - 20.

Maikhuri R.K., L.S. Rawat, P. C. Phondani, A. Maletha, Y.M. Bahuguna (2017) Livestock: The engine and inspiration of mountain economy. LEISA India, September 2017.

Maikhuri R.K., L.S. Rawat, V.S. Negi, A. Maletha, P.C. Phondani, P.P. Dhyani (2017) People's knowledge: Key to adaptation. LEISA India, pp:17-20.

Mylliemngap W. (2017) Swachh Bharat Abhiyan in Arunachal. The Arunachal Times Vol. 29 No. 9, June 14, 2017.

Negi G.C.S. (2017) Ecological considerations in mountain agriculture. In: Ecological Agriculture for Sustainability. Published by G.B. Pant University of Agriculture & Tech. Pantnagar. pp: 12-16

Negi G.C.S., P.P. Dhyani (2017) Uttarakhand mein jalwayu parivartan ke prabhaw. Vigyan Paricharcha 7(3): 50-53.

Nidhi K., J.C. Kuniyal (2018) Himachal Pradesh ke Kinnaur zile mein vano ka paridrishya, unko prabhavit karne vale kaarak aur prabandhan, In: Forest resources and Plant Biodiversity (Shashni, S., Sood, S., Samant, S.S., Kuniyal, J.C., Gosavi, V.E., Sundriyal, R.C. and Nandi, S.K., eds.), GBPNIHESD, HRC, Mohal-Kullu, pp.53-60 (in Hindi).

Shahid M., Y.K. Rai, L.K. Rai and M. Singh 2017. Organic Agriculture as a Climate Change Mitigation and Adaptation Strategy, Him Paryavaran.

Sharma L., S.S. Samant (2017) Jaiv Vividhata Sanrakshan and Prabandhan. In : Sarala Shashani, Sagar Sood, Sher Singh Samant, Jagdish Chandra Kuniyal, Vaibhav Eknath Gosavi, Rakesh Chandra Sundriyal and Shyamal Kumar Nandi (eds.) Ban Sanshadhan Evam Padap Jaiv Vividhata. G.B. Pant National Institute of Himalayan Environment & Sustainable Development, Himachal Regional Center, Mohal-Kullu, HP. pp: 9-14.

Shashni S., S. Rathore, S. Sood, V. Thakur, J.C. Kuniyal (2017) Environment and Projects in Himachal Pradesh, Him Prabha

(V) Policy papers

Kumar K., G.C.S. Negi, A. Tiwari, R. Joshi, S. Mukherjee, D.S. Rawat, K. Chandra Sekar (2017) Sustainable development in mountains of Indian Himalayan Regions. Working Group on 'Data / information availability for informed decision making by multiple stakeholders'. Policy Draft Report submitted to Niti Aayog (Rural Development Division), Government of India. pp: 1-169.

Maikhuri R.K., L.S. Rawat, P.P. Dhyani, P.C. Phondani, Y.M. Bahuguna, A. Maletha (2017) Emerging concern of Hill agriculture of Uttarakhand; Policy issues and priorities for sustainable development, G B Pant National Institute of Himalayan Environment and Sustainable Development, Uttarakhand. pp: 22.

AWARDS AND HONOURS

1. Ms Priyanka Lohani, JRF, conferred with Young Scientist Award for her presentation on "Characteristics of Convective Surface Layer Turbulence of Spring and Autumn Seasons over Central Himalaya" in 12th Uttarakhand State Science and Technology Congress (Mar 7-9, 2018).
2. Ms Pooja Rani Sinha, Himalayan RA, conferred with Young Scientist Award for her presentation on "Water Quality Analyses Emphasizing on Nitrate Nutrient Dynamics using WASP in Almora of Kosi Watershed" in 12th Uttarakhand State Science and Technology Congress (Mar 7-9, 2018).
3. Ms. Meenakshi Negi awarded with BEST RESEARCH PAPER AWARD (Applied Science) in 3rd National Conference on Recent Advances in Sciences & Technology (NCRAST) from 11th -12th November, 2017.
4. Dr. Anita Pandey, Scientist-F received Vishisht Mahila Vaigyanik Sammaan (Eminent Woman Scientist Recognition) for outstanding contribution in Microbiology and Biotechnology by USERC (Uttarakhand Science, Education and Research Center, Dept. of Science and Technology, Govt. of Uttarakhand) on the occasion of International Women's' Day 2017.
5. Dr. S.S. Samant received S. P. Vij Memorial Award 2017 in recognition of outstanding contribution to Indian Orchidology in the National Conference cum Workshop on Recent Trends in Biology, Culture, Conservation, Commercialization and Sustainable Utilization of Medicinally and Floriculturally Important Orchids and Orchid Show, organized by The Orchid Society of India (TOSI), Department of Botany, Panjab University, Chandigarh jointly with Department of Biotechnology, Graphic Era University (GEU), Dehradun at Graphic Era University (GEU), Dehradun, Uttarakhand (24 - 26 March, 2017) on 24 March, 2018 by The Orchid Society of India (TOSI), Chandigargh.
6. Dr. Kishor Kumar awarded by "Swami Maheshanand Giri Gold Medal" of Indian Academy of Environmental Sciences, Haridwar, India on the occasion of the National Conference on "Biodiversity Conservation and Coastal Management" organized by department of Zoology, Vivekananda College, Agastewaram, Kanyakumari held during August 10-12th, 2017.

PARTICIPATION IN DIFFERENT EVENTS

Events	HQ	REGIONAL CENTERS				Total
		NE	Sikkim	Garhwal	HP	
National						
Symposia/Conference/Workshop	50	6	11	10	43	110
Training Courses	35	2	6	7	7	57
Meetings	56	5	14	30	3	108
Participation as a Resources Person	60	11	13	15	32	131
Any Other	45	4	2	8	2	61
International	13	2	5	-	1	21

RTI CELL, GBPNIHESD

Details of applications received under RTI Act, 2005 (Year : 2017- 2018)

SN	Date of receipt of application	Name of the Applicant	Received directly from the applicant	Transferred from other authority	Fee received	Reply/ Information given or not	Rejected
1	13.04.2017	Shri Rahul Nemagouda, 1387/5A/16B, Vikrampur Street Athani, TQ : Athani, District : Belagavi, PIN-591 304	No	Yes, transferred from MoEF&CC, New Delhi.	No	Application was forwarded to other authority under Section 6(3) of the RTI Act 2005 on 25th April 2017 by e-mail/Speed Post with a copy to the Applicant for information.	---
2	24.04.2017	Shri Kush Sharma, F-51, Second Floor, Lajpat Nagar-I, New Delhi-110 024	No	Yes, transferred from MoEF&CC, New Delhi.	No	Information sent by e-mail/Speed Post on 19.05.2017 and also uploaded on RTI portal.	---
3	29.05.2017	Shri Yogesh Kumar, 42 Subhash Road, Dehradun, Uttarakhand	No	Yes, transferred from MoEF&CC, New Delhi.	No	Information sent by e-mail/Speed Post on 20.06.2017 and also uploaded on RTI portal.	---
4	17.08.2017	Ms. Utsa Singh, 510/44 New Hyderabad, Dr. Deen Dayal Gupt Marg, Lucknow-226 007	No	Yes, transferred from MoEF&CC, New Delhi.	No	Information sent by Speed Post on 25.08.2017/by e-mail on 28.08.2017 and also uploaded on RTI portal.	---
5	05.09.2017	श्री अयोध्या प्रसाद 'भारती' (पत्रकार), रॉयल स्टैंप सिस्टम, गुरूनानक कॉम्पलैक्स, वीर हकीकत राय मार्ग, निकट–तराई फोटोस्टेट,रूद्रपुर–263153 (उधमसिंह नगर), उत्तराखण्ड	हां	नहीं	रू. 10/– भारतीय पोस्टल ऑर्डर	सूचना 14 सितम्बर 2017 को स्पीड पोस्ट तथा 18 सितम्बर 2017 को ई–मेल द्वारा भेजी गई।	---
6	12.09.2017	Dr. K.N. Krishnakumar, Professor, Communication and Extension Management, Indian Institute of Forest Management, Nehru Nagar, Bhopal-462 003, M.P.	Yes	No	Rs. 10/- IPO	Information sent by Speed Post on 20.09.2017/by e-mail on 31.09.2017.	---

SN	Date of receipt of application	Name of the Applicant	Received directly from the applicant	Transferred from other authority	Fee received	Reply/ Information given or not	Rejected
7	09.10.2017	Mr. Tejas Ganesh Iyer CS New Moti Bag Block C2, New Delhi	Yes - Recd. Online	No	---	Information sent by Speed Post on 31.10.2017 and also uploaded on RTI portal.	---
8	21.11.2017	Dr. Subrat Sharma, Scientist-D, GBPNI-HESD, Kosi-Katarmal, Almora	Yes	No	Yes – Rs. 10.00	Information provided by Hand on 20.12.2017.	---
9	22.11.2017	Dr. Subrat Sharma, Scientist-D, GBPNI-HESD, Kosi-Katarmal, Almora	Yes	No	Yes – Rs. 10.00	Information provided by Hand on 21.12.2017.	---
10	08.12.2017	Dr. Subrat Sharma, Scientist-D, GBPNI-HESD, Kosi-Katarmal, Almora	Yes	No	Yes – Rs. 10.00	Information provided by Hand on 22.12.2017.	---
11	11.12.2017	Mr. R.K. Singh, Scientist-D, GBPNIH-ESD, Kosi-Katarmal, Almora	Yes	No	Yes – Rs. 10.00	Information provided by Hand on 08.01.2018.	---
12	21.12.2017	Mr. Kash Babu, E-1 Dum Colony Gali No. 3, Ibrahim Pur, Delhi-110 084	Yes - Recd. Online	No	---	Information sent by e-mail/Speed Post on 10.01.2018 and also uploaded on RTI portal.	---
13	29.12.2017	Dr. Subrat Sharma, Scientist-D, GBPNI-HESD, Kosi-Katarmal, Almora	Yes	No	Yes – Rs. 10.00	Information being collected. Last date of reply is 27.01.2018. Reply sent on 24.01.2018 by e-mail/by hand.	---
14	05.01.18	Dr. Subrat Sharma, Scientist-D, GBPNI-HESD, Kosi-Katarmal, Almora	Yes	No – This application is appeal to the Appellate Authority.	No	Appeal disposed Off on 25.01.2018	---
15	05.01.18	Dr. Subrat Sharma, Scientist-D, GBPNI-HESD, Kosi-Katarmal, Almora	Yes	No – This application is appeal to the Appellate Authority.	No	Appeal disposed off on 29.01.2018	---
16	01.02.2018	श्री भुवन सिंह, मकान नं. 8/9, भोलानाथ गार्डन, हल्द्वानी	हां	नहीं	रू. 10/ भा.पो.ऑ.	1. दिनांक 30 जनवरी 2018 को अभिलेखों की छायाप्रतियों के लिए रू. 16/– जमा करने करने हेतु पत्र भेजा गया। 2. सम्बन्धित सूचना तथा छायाप्रतियां स्पीड पोस्ट द्वारा दिनांक 08 मार्च 2018 को भेजी गई।	---

SN	Date of receipt of application	Name of the Applicant	Received directly from the applicant	Transferred from other authority	Fee received	Reply/ Information given or not	Rejected
17	01.02.2018	Dr. Gaurav Bhardwaj, House No. 224, Ward No. 11, Bhardwaj Niwas, Gandhi Nagar, Kullu, Himachal Pradesh-175 101	Yes – Recd. on-line	No	Yes	1. Letter sent on 05.02.2018 to deposit Rs. 62.00 towards the Xerox copies of records. 2. Related information and Xerox of records sent on 15.02.2018 by E-mail/Speed Post/Online.	---
18	01.02.2018	Dr. Gaurav Bhardwaj, House No. 224, Ward No. 11, Bhardwaj Niwas, Gandhi Nagar, Kullu, Himachal Pradesh-175 101	Yes – Recd. online	No	Yes	Information sent on 05.02.2018 by E-mail/Speed Post/ Online.	---
19	01.02.2018	Mr. Narendra Lokwani, 226 B Block, Pratap Nagar UIT Colony, Near Kendriya Vidyalaya, Udaipur, Rajasthan, Udaipur-313 001	Yes – Recd. online	No	Yes	Information sent on 06.02.2018 by E-mail/Speed Post/On-line.	---
20	09.02.2018	श्री कमल किशोर पाण्डे, ब्व श्री आर.सी. तिवारी, हाउस नं. 2, लेन नं. 2, वसन्त विहार एन्कलेव, वसंत कुंज, देहरादून–248 006	हाँ	नहीं	रू. 10/– भा.पो.ऑ.	सूचना स्पीड पोस्ट द्वारा दिनांक 06 मार्च 2018 को भेजी गई।	---
21	26.02.2018	Mr. R.K. Singh, Type IV-7, G.B. Pant Institute Campus, Kosi-Katarmal, Almora-263 643, Uttarakhand	No	Yes, transferred from MoEF&CC, New Delhi.	Yes	Information sent on 27.03.2018 by E-mail/Speed Post.	---
22	26.02.2018	Mrs. Ranjana Singh, Type IV-7, G.B. Pant Institute Campus, Kosi-Katarmal, Almora-263 643, Uttarakhand	No	Yes, transferred from MoEF&CC, New Delhi.	Yes	Information sent on 27.03.2018 by E-mail/Speed Post.	---

ANIL SHALINI & ASSOCIATES
CHARTERED ACCOUNTANTS

B.O. Vill. Naithana, Post Naubara, Almora-263 660,
Uttarakhand
H.O.94D, Pocket-F, Mayur Vihar,Phase-2,Delhi-011091
011-22787142, 9871100394
anilshaliniandassociates@gmail.com

INDEPENDENT AUDITOR'S REPORT

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

We have audited the attached Balance Sheet of G.B. PANT NATIONAL INSTITUTE OF HIMALAYAN ENVIRONMENT AND SUSTAINABLE DEVELOPMENT which comprise the Balance Sheet as at March 31, 2018, and the Income and Expenditure Account, Receipt & Payment account for the year then ended and a summary of significant accounting policies.

Management's Responsibility for the Financial Statements

Management is responsible for the preparation of these financial statements in accordance with The Law of India. This responsibility includes the design, implementation and maintenance of internal control relevant to the preparation of the financial statements give true and fair view of financial position, financial performance and cash flow and that are free from material misstatement, whether due to fraud or error.

Auditor's Responsibility

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

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

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

Opinion

In our opinion and to the best of our information and according to the explanations given to us, the financial statements of G.B. PANT NATIONAL INSTITUTE OF HIMALAYAN ENVIRONMENT AND SUSTAINABLE DEVELOPMENT for the year ended March 31, 2018 are prepared, in all material respects, in accordance with The Law of India.

The said account gives the information required and gives a true and fair view.

(a) In the case of Balance Sheet, of the State of Affairs of the Institute as at **31st March 2018.**

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

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

Emphasis of Matter

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

Our opinion is not qualified in respect of this matter.

Report on Other Legal and Regulatory Requirements

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

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

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

Date: 13.08.2018

Place: Almora

For Anil Shalini & Associates
(Chartered accountants)

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

G.B.PANT NATIONAL INSTITUTE OF HIMALAYAN ENVIRONMENT & SUSTAINABLE DEVELOPMEN
KATARMAL, KOSI (ALMORA) UTTARAKHAND
BALANCE SHEET AS ON 31ST MARCH 2018

PARTICULARS	SCHEDULE	CURRENT YEAR (₹)	PREVIOUS YEAR (₹)
LIABILITIES			
CORPUS / CAPITAL FUND	1	51184908.16	154562559.99
RESERVE AND SURPLUS	2	472081748.42	436363145.07
EARMARKED / ENDOWMENT FUNDS	3	0.00	0.00
SECURED LOANS & BORROWINGS	4	0.00	0.00
UNSECURED LOANS & BORROWINGS	5	0.00	0.00
DEFERRED CREDIT LIABILITIES	6	0.00	0.00
CURRENT LIABILITIES AND PROVISIONS	7	1120755089.79	880498907.66
TOTAL		**1644021746.37**	**1471424612.72**
ASSETS			
FIXED ASSETS	8	472081748.42	436363145.07
INVEST. FROM EARMARKED/ENDOWMENT FUND	9	32566711.95	143122867.99
INVEST. OTHERS	10	0.00	0.00
CURRENT ASSETS , LOANS, ADVANCES ETC.	11	1139373286.00	891938599.66
MISCELLANEOUS EXPENDITURE			
TOTAL		**1644021746.37**	**1471424612.72**
SIGNIFICANT ACCOUNTING POLICIES	24		
CONTINGENT LIABILITIES & NOTES ON ACCOUNTS	25		

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

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

DATED : 13.08.2018
PLACE : KOSI- KATARMAL, ALMORA

(DR. R. S. RAWAL)
DIRECTOR

(DR. ANITA PANDEY)
D.D.O

(SURYA KANT)
FINANCE OFFICER

G.B.PANT NATIONAL INSTITUTE OF HIMALAYAN ENVIRONMENT & SUSTAINABLE DEVELOPMENT
KATARMAL, KOSI (ALMORA) UTTARAKHAND
INCOME & EXPENDITURE A/C FOR THE YEAR ENDED 31ST MARCH 2018

PARTICULARS	SCHEDULE	CURRENT YEAR (₹)	PREVIOUS YEAR (₹)
INCOME			
Income from Sales/Services	12	271623.00	308855.00
Grants/Subsidies(net off exp)	13	395777538.52	224820366.32
Fees/Subscriptions	14	0.00	0.00
Income from Investment	15	0.00	0.00
Income tfr from Fixed Assets fund	-	29443354.48	27741768.16
(to the extent of depreciation & WDV of asset sold)		0.00	0.00
Income from Royalty, Income from Inv. Publication et	16	0.00	0.00
Interest Earned	17	14481130.92	15209306.28
Other Income	18	8168550.00	5369448.00
Increase (decrease) in stock of Finished goods and work in progress)	19	0.00	0.00
TOTAL (A)		**448142196.92**	**273449743.76**
EXPENDITURE			
Establishment Expenses: a) Institute	20	120430075.00	115752311.00
b) Projects		40246377.00	25741179.70
c) F.C (Projects)		5020295.00	3059539.00
Administrative Expenses :a) Institute	21	42490886.17	46344732.62
b) Projects (As per Annexure)		159710566.35	20229044.00
c) F.C (Projects)(As per Annexure)		19717808.00	6428951.00
Expenditure on Grants, Subsidies etc.	22	8161531.00	7264609.00
Interest			
Depreciation (Net Total at the year-end-as per Sch. 8)		29443354.48	27741768.16
TOTAL (B)		**425220893.00**	**252562134.48**
Balance being excess of Income over Expenditure (A - B)		**22921303.92**	**20887609.28**
Transfer to special Reserve			
Transfer to/ from General Reserve			
BAL.BEING SURPLUS TRF.TO CORPUS FUND (Other Income)		**7495248.21**	**7339145.00**
BAL.BEING SURPLUS TRF.TO CORPUS FUND (Corpus Interest Incon		**8403654.71**	**9594659.28**
BAL.BEING SURPLUS TRF.TO NMHS- PMU (Interest Income)		**7022401.00**	**3953805.00**
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 & Associates
CHARTERED ACCOUNTANTS

(Anil Kumar Shukla)
FCA PARTNER
M.N0.075418
FRN: 009960C
DATED : 13.08.2018
PLACE : KOSI- KATARMAL, ALMORA

(DR. R. S. RAWAL) 13/8
DIRECTOR

13/8
(DR. ANITA PANDEY)
D.D.O

13/8/18
(SURYA KANT)
FINANCE OFFICER

G.B. PANT NATIONAL INSTITUTE OF HIMALAYAN ENVIRONMENT & SUSTAINABLE DEVELOPMENT
KATARMAL, KOSI (ALMORA) UTTARAKHAND
RECEIPTS & PAYMENTS A/C FOR THE YEAR ENDED 31ST MARCH 2018

RECEIPTS	CURRENT YEAR	PREVIOUS YEAR	PAYMENTS	CURRENT YEAR	PREVIOUS YEAR
I. Opening Balances			**I. EXPENSES**		
a) Cash in hand	65695.72	130098.50	**a) Establishment Expenses**	122124139.99	85049117.70
			I) Institute		
b) Bank Balances			**b) Administrative expenses**		
			a) Institute	28930287.17	29900117.62
i) In current accounts	0.00	0.00	b) R&D(Rev) expenses	13422870.00	15770508.00
ii) In deposit accounts (Corpus Fund)	43332194.71	21602229.71	c) Payments for current liabilities(gratuity/leave)	0.00	0.00
iii) Savings accounts	448145165.67	122457182.15	**C. Capital expenditure**		
c) Advances & Others	392976876.71	275228785.78	a) Purchase of Fixed Assets	11346961.00	12560030.00
(As per annexure Attached)			b)Expenditure on Capital Work in Progress	23088000.00	10900000.00
F.C. ACCOUNT			c) Acquirement of land (Lease money)		
A) Cash in hand	36870.33	4305.33	**II Payments made against funds for various proj.**		
b) Cash at bank	8487057.27	7967378.44	**Expenditure State govt. projects**		
c)FC Advances	13127678.93	12928662.89	a) Capital	20299697.00	30566691.00
II. Grants Received			b) Revenue:		
a) From Government of India	200000000.00	180000000.00	Establishment exp	39969612.70	25665744.00
i) Institute & IERP			Administration exp	157141340.35	18776178.00
			Expenditure FC projects		
b) From Other agencies	523199894.00	507242377.00	**a) Capital**	105905.00	540220.00
c) From other sources [from FC]	12538492.58	11690326.87	**b) Revenue:**		
III. Income on Investments from			Establishment exp	4733407.00	3264994.00
a) Corpus Fund(Received from Institute)	7339145.00	11026673.00	Administration exp	19402775.00	6428951.00
IV. Interest Received			**IERP grant released**	8161531.00	7264609.00
a) On Bank deposits savings a/c	12245338.21	9807255.00	**III Investments and deposits made**		
b)On term deposits a/c	2168742.71	1645126.00	Corpus Fund	170312760.75	37600000.00
c) Loans, Advances etc.	433709.00	181218.00	**IV Refund of Surplus money/Loans**		
			a) To the Government of India	2787627.50	953567.00
V. Other Income			b)To Others/ security/ caution money)	0.00	40922.00
			Refund to MoEF&CC (HBA/MCA)	9977800.00	
(As per annexure Attached)	4483214.00	5329003.00	**V Other payments**		
VI. Amount Borrowed			Other Payment to Instt. FC Proj.	0.00	704902.00
VII. Any other receipts.			Unspent Balance (FC)	3063714.16	0.00
			Payment of Current Libilities	2100.00	2177900.00
			Refund of EMD	438000.00	0.00
			Fund transfar to Corpus fund	7339145.00	11026673.00
a) Other Receipt FC a/c	0.00	0.00	**VI Closing balances**		
b) Receipts Current Liabilities	0.00	0.00	**a) Cash in hand**	91023.78	65695.72
c) IERP grants refunded by grantee Org.			**b) Bank Balance**		
d)Construction Fund			i) In Current account		
e) Corpus Fund FDR'S	122404578.29	39348801.00	ii) In deposit accounts (Corpus Fund)	5770666.96	43332194.71
f) Caution Money	3000.00	8000.00	iii) In savings accounts	173503753.46	448145165.67
g) Security Deposit	46000.00	401240.00			
h) EMD	25500.00	310675.00	**C) Advances and others**	951290838.10	392976876.71
i) Royalty	0.00	0.00	**FC Project**		
j) Sales Tax / VAT	25066.00	22714.00	a) Cash in hand	17846.33	36870.33
k)Service Tax	2143.00	2218.00	b) Bank Balance	5809273.66	8487057.27
			c) Advances and others	1058177.96	13127678.93
			Adjustment of previous year closing Advances	10897108.26	1971606.01
TOTAL	**1791086362.13**	**1207334269.67**	**TOTAL**	**1791086362.13**	**1207334269.67**

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

(Anil Kumar Shukla)
FCA PARTNER
M.NO.075418
FRN: 009960C
DATED : 13.08.2018
PLACE : KOSI- KATARMAL, ALMORA

(Dr. R. S. RAWAL)
DIRECTOR

(Dr. ANITA PANDEY)
D.D.O

(SURYA KANT)
FINANCE OFFICER

G.B.PANT NATIONAL INSTITUTE OF HIMALAYAN ENVIRONMENT & SUSTAINABLE DEVELOPMENT
KATARMAL, KOSI (ALMORA) UTTARAKHAND
ANNEXURE FORMING PART OF BALANCE SHEET AS ON 31 MARCH 2018

CURRENT ASSETS

BANK BALANCES (SAVINGS A/C)

ANNEXURE"D"

PARTICULARS	CURRENT YEAR (₹)
C.B.I Kosi A/c No. 3173366206	6477610.30
S.B.I Almora A/C No. 10861359986	2655002.67
S.B.I Tandong A/c No. 11226047758	3088607.07
S.B.I Kullu A/c No. 10792147561	4675748.81
S.B.I Itanagar A/c No.10940060114	2556401.86
S.B.I Srinagar A/c No. 10972182864	1617161.49
S.B.I Tandong A/c No. 37000934072 (NMHS IHTP DK	722021.10
C. B. I. Kosi A/c No. 3604013559 (Core Grant New Account)	18436816.21
S. B. I. Kosi A/c No. 36883992887 (NMSHE TF-03 New Account)	2455687.00
S.B.I Srinagar A/c No. 3690636305 (NMHS ST KK)	394033.65
S.B.I Almora A/c No.10861359975 (F.C)	5809273.66
C.B.I Kosi A/c No. 3561532026 (ENVIS New Account)	317046.00
C.B.I. Kosi A/C No. 3530505520 (NMHS-PMU)	98148484.00
S. B. I. Kosi A/c No. 36959540111 (NMHS ST KK)	3226384.00
S. B. I. Kosi A/c No. 36935490949 (NMHS Fellowship)	7501676.30
S. B. I. Kosi A/c No. 36935414822 (NMHS JCK)	5895911.00
S. B. I. Kosi A/c No. 36935498701 (NMHS IHTP GCSN)	1340239.00
S. B. I. Kosi A/c No. 36944701949 (NMHS IHTP S. Sharma)	1509224.00
S. B. I. Kosi A/c No. 36944702502 (NMHS IHTP Rajesh Joshi)	1784858.00
S. B. I. Kosi A/c No. 36944702987 (NMHS IHTP R. S. Rawal)	2045922.00
S. B. I. Kosi A/c No. 36959556518 (NMHS D. S. Rawat)	6604346.00
S. B. I. Kosi A/c No. 36959540698 (NMHS BSI K. C. Sekar)	241114.00
S. B. I. Mohal A/c No. 36998149642 (NMHS JCK H.P.)	1300254.00
IDBI Itanagar A/c No. 0161104000055514 (NMHS JCK N. E. Unit)	509205.00
Cheque in transit: N. E. UNIT (IERP)	940.00
H. P. Unit	150100.00
G.Unit	0.00
Fund Transfer to Core Grant Account	0.00
	179464067.12

DUE FROM STAFF

ANNEXURE"E1"

PARTICULARS	CURRENT YR. (₹)
Adv. a/c	0.00
	0.00

DUE FROM OTHERS

ANNEXURE"E2"

PARTICULARS	CURRENT YR. (₹)
Adv. a/c of TATA Motors Ltd.	2836.00
Adv. a/c of Meterological Department	8000.00
Adv. a/c of NRSC Hydrabad Proj. 04	24000.00
Adv. a/c of M/s International Trade link	34328.00
Adv. a/c of VPKAS Almora	26560.00
Adv. a/c of STUP Consultant Haldwani	(7435.00)
Adv A/C E.E. RES Almora	1571000.00
Adv. a/c of E. E. CCU N. Delhi	5666158.00
Adv. a/c of NIH Roorkee	100000.00
Adv a/c NICSI New Delhi	35106.00
Employment news New Delhi	48287.00
Adv a/c M/S Sigma Aldrich Chemicals	10590.00
Adv A/C NRSA Hydrabad	35300.00
Adv a/c M/S R.K. Nanda & Sons	28517.00
Adv. a/c of Sh. Manoj Tiwari (Advocate)	20000.00
Adv. a/c of INSA New Delhi	30000.00
Adv. a/c of M/s Sai Nath Automobiles	0.00
Recoverable from Unit	4772.00

Adv. a/c Dir. M.S. Sawaminathan (NNRMS)	0.00
Adv. a/c NRSA Hydabad (DST LMS ILTP)	48000.00
Adv. a/c of WWF New Delhi (UNDP CCF PKS N. E. Unit New)	(31930.00)
Adv. a/c of E E. RES Almora (HRDI IDB)	59000.00
Adv. a/c of NRSC Hydrabad (Grant)(MoE&F NNRMS)	0.00
Adv. a/c of NRSC Hydrabad (DST SERB GCSN)	635.00
Adv. a/c of E. E . RES Almora (MoE & F Lead Garden RSR)	0.00
Adv. a/c of Airport Handling Services (SERB JCK H. P. Unit)	18371.00
Adv. a/c of E. E. Const. Div. II Pay Jal Nigam (MoE & F B.G. (RSR))	0.00
Adv. a/c of Partners NMHS enclose **Annexure 'X'**	933437510.30
Adv. a/c of NRSA Hydrabad (ISRO GBP S. Sharma)	350000.00
Adv. a/c of M/s vankta Enterprises (Cop 11 MoE & F NBA)	7100.00
Adv. a/c Siltep Chemicals Ltd. (Biotech-III)	408.00
Adv. a/c of NRSA Hyerabad (DST KK I)	7400.00
Adv. a/c of Ms. Poonam Mehta (SAC Subrat Sharma)	0.00
Adv. a/c of NRSC Hydrabad (NMHS IHTP S. Sharma)	121430.00
Adv. a/c of M/s Current Science (NMHS IHTP S. Sharma)	13400.00
Adv. a/c of Indian Institute of Technology (NMHS-ST)	530000.00
Adv. a/c of D. F. O Almora (NMHS-ST)	379197.00
Adv. a/c of Mahila Haat New Delhi (NMHS-DSR)	239000.00
Adv. a/c of M/s Airport Handling (DST WTI V. Agnihotri)	65670.00
Adv. a/c of H.N.B Gharwal University, Srinagar (ICSSR RKM G. Unit-New)	485411.00
Adv. a/c of M/s Airport Handling (NMSHE TF-03 Old)	230000.00
Adv. a/c of University of Kashmir (NMHS JCK)	2564600.00
Adv. a/c of NEIST, Manipur (NMHS JCK)	1484600.00
Security Deposite CET Sikkim	11000.00
Security Deposite N.E. Unit	1750.00
	947660571.30

INSTITUTE SUPPORTING STAFF

HEAD QUARTERS	
Anil Kumar Yadav	Administrative Officer
Surya Kant Langayan	Finance Officer
S.P. Maikhuri	Account Officer
L.M.S. Negi	Office Superintendent (Admn.)
Sanjeev Higgins	Technical Gr. – III(2)
Mahesh Chandra Sati	Technical Gr. – IV(1), Lib.
Sarita Bagdwal	Stenographer
Jagdish Kumar	Stenographer
Mamta Higgins	U.D.C.
Heera Singh	U.D.C.
K.K. Pant	U.D.C.
Hema Pandey	U.D.C.
Suraj Lal	L.D.C.
Atul Bisht	L.D.C.
Jagdish Singh Bisht	Technical Gr. – II(1)
Chandra Lal	Driver
K.N.Pathak	Technical Gr. – I(3)
Pan Singh	Group 'Ç'
Nathu Ram	Group 'Ç'
Ganga Joshi	Group 'Ç'
Govind Singh	Driver
Gopal Singh Bisht	Group 'Ç'
GARHWAL UNIT	
D.P. Kumeri	L.D.C.
M.P. Nautiyal	Driver
J.M.S. Rawat	Driver
R.C. Nainwal	Field Assistant
R.P. Sati	Group 'Ç'
HIMACHAL UNIT	
Daulat Ram	Group 'Ç'
Bhuwan Chandra	Group 'Ç'
SIKKIM UNIT	
R.K. Das	L.D.C
Jagnnath Dhakal	Technical Gr. – I(3)
P.K. Tamang	Technical Gr. – I(3)
Musafir Rai	Group 'Ç'
Shyambir	Group 'Ç'
NE Unit	
Brajesh Kumar	L.D.C.

INSTITUTE FACULTY

HEAD QUARTERS		
P.P.Dhyani (upto 28.9.2017)	Director	Plant Physiology; Restoration Ecology
Kireet Kumar	Scientist-G	Environmental Engineering; Hydrology
S.K. Nandi	Scientist-G	Plant Physiology; Biochemistry
R.C. Sundriyal	Scientist-F	Plant Ecology; Rural Ecosystems
Anita Pandey	Scientist-F	Microbiology
D.S. Rawat	Scientist-F	Settlement Geography; Rural Ecosystems
R.S. Rawal	Scientist-F	High Altitude Ecology; Conservation Biology
R.C. Prasad (upto 30.11.2017)	Scientist-F	Library & Documentation
G.C.S. Negi	Scientist-E	Forest Ecology; Watershed Management; EIA
Subrat Sharma	Scientist-D	Agroecology; Remote Sensing / GIS

Paromita Ghosh	Scientist-D	Plant Science; Soil Science
I.D. Bhatt	Scientist-D	Plant Physiology; Phytochemistry
R.K. Singh	Scientist-D	Information Technology
Ranjan Joshi	Scientist-D	Ecology Economics; Resource Valuation
Rajesh Joshi	Scientist-D	Mathematical Modeling
K.C. Sekar	Scientist-D	Plant Taxonomy; Animal Taxonomy
Vasudha Agnihotri	Scientist-C	Soil Science; Plant Analysis; Instrumentation
Ashutosh Tiwari	Scientist-C	Remote Sensing & GIS
Sandipan Mukherjee	Scientist-C	Climate Change; Ecosystem Services
Harshit Pant	Scientist B	Forest Ecology
B.S. Majila	Tech. Grade IV (3)	Forest Ecology; Restoration Ecology
Subodh Airi	Tech. Grade IV (2)	Forest Ecology; Biotechnology
HIMACHAL UNIT		
S.S. Samant	Scientist-F & In-charge	Plant Taxonomy; Conservation Biology
J.C. Kuniyal	Scientist-E	Development Geography; Waste Management
Sarla Shashni	Scientist-C	Rural Entrepreneurship and Small Business
Renu Lata	Scientist C	Environmental Goverance and Policy
Vaibhav Eknath Gosavi	Scientist-B	Hydrology; Watershed Management
Kishore Kumar	Tech. Grade IV (1)	
SIKKIM UNIT		
H.K. Badola (upto 30.4.2017)	Scientist-F & In-charge	Morphoanatomy; Conservation Biology
K.S. Gaira	Scientist - E (Contractual basis)	
Mithilesh Singh	Scientist-C	Plant Tissue Culture; Bioprospecting
Devendra Kumar	Scientist-C	Climate Change
L.K. Rai	Tech. Grade IV (3)	Plant Taxonomy
Y.K. Rai	Tech. Grade IV (3)	Rural Ecosystems
GARHWAL UNIT		
R.K. Maikhuri	Scientist-F & In-charge	Plant Ecology; Rural Ecosystems
A.K. Sahani	Scientist-D	Social Science; Anthropology
S. Tarafdar	Scientist-D	Weather & Climate Change; Glaciology; Hydrology
Arun Kumar Jugran	Scientist -C	Plant Biotechnology
Lakhpat Singh Rawat	Tech. Grade IV (1)	
NORTH-EAST UNIT		
M.S. Lodhi	Scientist-D	Environmental Assessment
S.C. Arya	Scientist-C	High Altitude Ecology
K.S. Kanwal	Scientist-C	Strategic Environmental Assessment
Wishfully Mylliemngap	Scientist - B	Ecosystem Services
Om Prakash Arya	Tech. Grade IV (1)	Biotechnological Applications

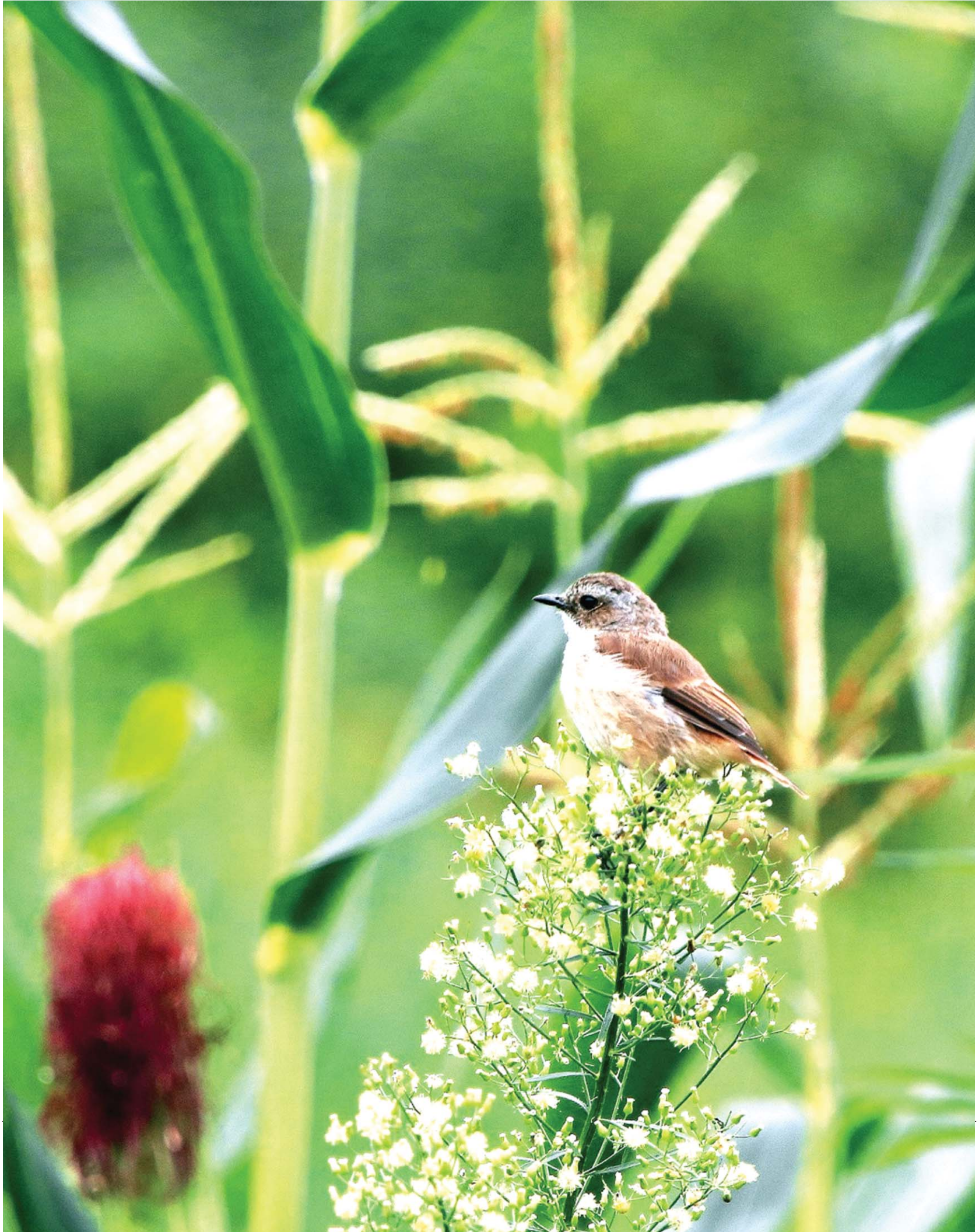
G.B.PANT NATIONAL INSTITUTE OF HIMALAYAN ENVIRONMENT & SUSTAINABLE DEVELOPMENT
KATARMAL, KOSI (ALMORA) UTTARAKHAND
SCHEDULE FORMING PART OF BALANCE SHEET AS ON 31ST MARCH 2018

SCHEDULE 8 - FIXED ASSETS

(DETAILS AS PER ANNEXURE ATTACHED)

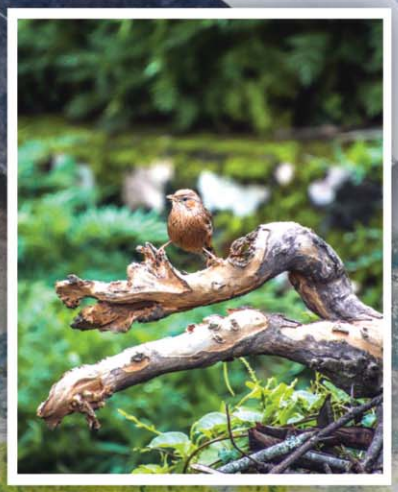
(In Rupees)

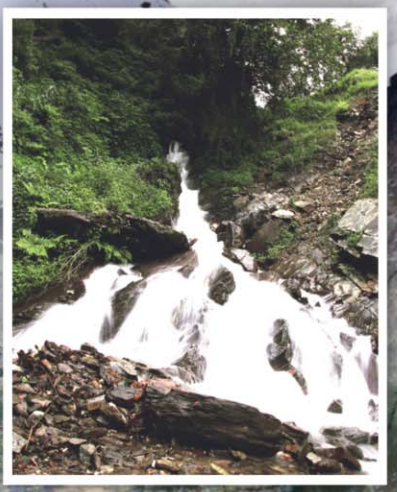
S NO.	DESCRIPTION	GROSS BLOCK				DEPRECIATION				NET BLOCK	
		Cost as at beginning of the year	Additions during the year	adj/deduction during the year	Cost at the end of the year	depreciation for prior periods	depreciation for current year	adj/deduction for previous years	Total up to the end of the year	As at the current Year end	As at the previous year-end
	A. FIXED ASSETS:										
1	**LAND:**										
	a) Freehold	75639.23	0.00	0.00	75639.23	0.00	0.00	0.00	0.00	75639.23	75639.23
	b) Leasehold	4069026.00	0.00	0.00	4069026.00	949438.00	135634.00	0.00	1085072.00	2983954.00	3119588.00
2	**BUILDING:**										
	a) On Freehold Land	245847866.00	0.00	0.00	245847866.00	51194324.03	4007320.22	0.00	55201644.25	190646221.75	194653541.97
	b)D.B.Manag.Centre(NMHS -PMU)	6570636.00	47444.00	0.00	6618080.00	107101.37	107874.70	0.00	214976.07	6403103.93	6463534.63
	c)MoE&F Lead Grarden RSR	0.00	3402000.00	0.00	3402000.00	0.00	55452.60	0.00	55452.60	3346547.40	0.00
	d)MoE&F Botanical Garden RSR	0.00	2493000.00	0.00	2493000.00	0.00	40635.90	0.00	40635.90	2452364.10	0.00
3	**PLANT MACHINERY & EQUIPMENT**										
	a) Scientific Equipments	235068700.11	23338254.00	0.00	258406954.11	128350019.78	11842315.89	0.00	140192335.67	118214618.44	106718841.48
4	**VEHICLES**	11469967.30	1567610.00	0.00	13037577.30	10343160.94	882430.93	0.00	11225591.87	1811985.43	1126806.36
5	**FURNITURE FIXTURES**	33720215.40	2111756.00	0.00	35831971.40	25272472.35	2268163.79	0.00	27540636.14	8291335.26	8447743.06
6	**OFFICE EQUIPMENT**	35263478.35	2080272.00	0.00	37343750.35	26736390.12	3547656.28	0.00	30284046.41	7059703.94	8527088.23
7	**COMPUTER/PHERIPHEARLS**	3870396.00	1100759.00	0.00	4971155.00	500918.43	236129.86	0.00	737048.30	4234106.71	3369477.57
7	**ELECTRICAL INSTALLATION**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	**FIRE FIGHTING EQUIPMENTS**	60962.00	0.00	0.00	60962.00	60809.63	151.38	0.00	60961.01	1.00	152.37
9	**LIBRARY BOOKS**	124717197.50	5933024.00	0.00	130650221.50	66163170.44	6205885.52	0.00	72369055.96	58281165.54	58554027.06
10	**TUBE WELLS & W. SUPPLY**										
11	**OTHER FIXED ASSETS**										
	GLASS / NET HOUSE	3911549.00	0.00	0.00	3911549.00	3596701.89	113703.41	0.00	3710405.30	201143.70	314847.11
	TOTAL OF CURRENT YEAR	**704645632.89**	**42074119.00**	**0.00**	**746719751.89**	**313274506.99**	**29443354.48**	**0.00**	**342717861.47**	**404001890.42**	**391371287.07**
	PREVIOUS YEAR	**629971367.89**	**75679529.00**	**1005264.00**	**704645632.89**	**286537841.66**	**27741768.16**	**1112365.37**	**313167244.46**	**391371287.07**	**343433528.22**
	B CAPITAL W I P										
	Acquirement of land (Lease money)	0	0.00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	CCU Delhi	**44991858.00**	23088000.00	0.00	68079858.00	0.00	0.00	0.00	0.00	68079858.00	44991858.00
	ASSET UNDER INSTAL/TRANSIT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	TOTAL	**749637490.89**	**65162119.00**	**0.00**	**814799609.89**	**313274506.99**	**29443354.48**	**0.00**	**342717861.47**	**472081748.42**	**436363145.07**



About Institute

G.B. Pant Institute of Himalayan Environment and Development was established in 1988-89 as an autonomous Institute of Ministry of Environment Forest and Climate Change (MoEF&CC), Govt. of India. The Institute has been identified as focal agency to advance scientific knowledge, evolve integrated management strategies, demonstrate their efficacy or conservation of natural resources, and ensure environmentally sound management in the entire Indian Himalayan Region (IHR)





For Further Details, Please Contact

Director

Tel: 05962-241015; **Fax:** 05962-241041

Email: psdir@gbpihed.nic.in

website: www.gbpihed.gov.in