Template/Pro forma for Submission

NMHS-Himalayan Institutional Fellowship Grant

FINAL TECHNICAL REPORT (FTR)

NMHS Reference No.:	GBPI/NMHS/HF/RA/2015-16/8483

Date of Submission:	3	0	0	5	2	0	2	2
	d	**d**	**m**	**m**	**y**	**y**	**y**	**y**

FELLOWSHIP TITLE (IN CAPITAL)

HIMALAYAN RESEARCH FELLOWSHIPS 2015-16

Sanctioned Fellowship Duration: *from* (**18.04.2016**) *to* (**17.04.2019**).

Extended Fellowship Duration (if applicable): *from* (01.04.2019) *to* (31.03.2020).

***Submitted to*:**

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***Submitted by*:**

[*Dr. GCS Negi)*]
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GENERAL INSTRUCTIONS:

1. The Final Technical Report (FTR) has to be commenced from the date of start of the Institutional Fellowship (as per the Sanction Order issued at the start of the Fellowship) till its completion. Each detail has to comply with the NMHS Sanction Order.
2. The FTR should be neatly typed (in Arial with font size 11 with 1.5 spacing between the lines) with all details as per the enclosed format for direct reproduction by photo-offset process. Colored Photographs (4-5 good action photographs), tables and graphs should be accommodated within the report or should be annexed with captions. Sketches and diagrammatic illustrations may also be given giving step-by-step details about the methodology followed in technology development/modulation, transfer and training. Any correction or rewriting should be avoided. Please give information under each head in serial order.
3. Training/ Capacity Building Manuals (with detailed contents of training programme, technical details and techniques involved) or any such display material related to fellowship activities along with slides, charts, photographs should be sent at the NMHS-PMU, GBP NIHE HQs, Kosi-Katarmal, Almora 263643, Uttarakhand. In all Knowledge Products, the Grant/ Fund support of the NMHS should be duly acknowledged.
4. The FTR Format is in sync with many other essential requirements and norms desired by the Govt. of India time-to-time, so each section of the NMHS-FTR needs to duly filled by the Fellowship Coordinator/ PI and verified by the Head of the Implementing Institution/ University.
5. Five (5) bound hard copies of the NMHS-Institutional Fellowship Final Technical Report (FTR) and a soft copy should be submitted to the **Nodal Officer, NMHS-PMU, GBP NIHE HQs, Kosi-Katarmal, Almora, Uttarakhand** *via* e-mail nmhspmu2016@gmail.com.

The FTR is to be submitted into following two parts:

Part A – Cumulative Fellowship Summary Report

Part B – Comprehensive Report

Following Financial and other necessary documents/certificates need to be submitted duly signed and verified along with Final Technical Report (FTR):

Annexure I	Consolidated and Audited Utilization Certificate (UC) & Statement of Expenditure (SE), including interest earned for the last Fiscal year including the duly filled GFR-19A (with year-wise break-up)
Annexure II	Consolidated Interest Earned Certificate
Annexure III	Consolidated Manpower Certificate and Direct Benefit Transfer (DBT) Details showing the education background, i.e. NET/GATE etc. qualified or not, Date of joining and leaving, Salary paid per month and per annum (with break up as per the Sanction Order and year-wise).
Annexure IV	Details and Declaration of Refund of Any Unspent Balance as Real-Time Gross System (RTGS) in favor of NMHS GIA General
Annexure V	Details of Technology Transfer and Intellectual Property Rights developed.

***DSL:** Date of Sanction Letter*

3	0	0	3	**2**	**0**	**1**	**6**
d	d	m	m	y	y	y	y

***DFC:** Date of Fellowship Completion*

3	1	0	3	**2**	**0**	**2**	**0**
d	d	m	m	y	y	y	y

Part A: CUMULATIVE SUMMARY REPORT

(to be submitted by the Coordinating Institute/Coordinator)

1. Details Associateship/Fellowships

1.1 Contact Details of Institution/University

NMHS Fellowship Grant ID/ Ref. No.:	GBPI/NMHS/HF/RA/2015-16/8483
Name of the Institution/ University:	GBP-NIHE, Kosi Katarmal, Almora, Uttarakhand
Name of the Coordinating PI:	Dr. GCS Negi
Point of Contacts (Contact Details, Ph. No., E-mail):	Contact: (0592) 241041(O) Extension :35 negigcs@gmail.com

1.2 Research Title and Area Details

i.	Institutional Fellowship Title:	Himalayan Research Fellowships					
ii.	IHR State(s) in which Fellowship was implemented:	Arunachal Pradesh, Himachal Pradesh, Jammu andKashmir, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura and Uttarakhand; and Hilly districts of Indian States of West Bengal (Darjeeling) and Assam (Kachar Hills and Karbi Anglong)					
iv.	Scale of Fellowship Operation	Local:		Regional:		Pan-Himalayan:	x
iii.	Study Sites covered (*site/location maps to be attached*)	The project study sites were distributed across the IHR States					
v.	Total Budget Outlay (Crore) :	INR 2,24,65,080/-					

1.3 Details Himalayan Research /Project Associates/Fellows inducted*

Type of Fellowship	Nos.	Work Duration	
		From	To
Research Associates	3	26-12-2016	31-03.2020

		03.03.2017	31-03.2020
		09-02-2017	31-03.2020
Sr. Research Fellow		-	-
Jr. Research Fellows	08	16-08-2017 & 16-10-2017 & 16.01. 2019	31-3-2020
		26-09-2016	31-3-2020
		21-10-2016	31-3-2020
		08-07-2016	31-3-2020
		21-11-2016	31-3-2020
		08-02-2017	31-3-2020
		17-10-2016 17-01-2019	25-9-2018 22-10-2019
		11-01-2017, 13-10-2017 & 26-11-2018	31-3-2020
Project Fellows	-	-	-

* *Out of 10 HJRFs proposed only 8 were recruited except HJRF003 and HJRF0010.*

2. Research Outcomes

2.1. Abstract : Himalayan research fellowships (not more than 1000 words) (it should include background of the study, aim, objectives, methodology, approach, results, conclusion and recommendations based on the institutional fellowship proposal sanctioned under the NMHS).

Background

Indian Himalayan region (IHR) with its diverse ecosystems plays an important role in shaping the sustainable development in the country. Despite being ecologically rich and diverse the region is relatively poor in terms of many requisite socio-economic developmental indices and remains excluded from mainstreaming development. Moreover, the region is often termed as data deficient necessary for planning and development and desired policy-practice connect. GBP-NIHE, an autonomous body of MoEF&CC with its decentralized setup across IHR and multidisciplinary skills/expertise which is mandated for R&D on Himalayan Environment and Development, underpins the necessity and aligns its research endeavors with the NMHS thematic areas to undertake in-depth R&D work across IHR by developing human resources in quality research and collection of useable scientific data-sets for decision making and planning. The fellowship attempted to address the following aspects of IHR, viz. Water management and soil conservation including ground water and aquifers etc.; Conservation and Sustainable Use of Biodiversity; Supplementary livelihood option; Sustainable infrastructure & Energy

security; Environmental Assessment and Management and Awareness & Capacity Building for enhanced conservation and inclusive development of ecosystems along with improved livelihoods.

Objectives/aim (combined for all 11 fellowships)

- Inventories of NTFP species, diversity and management practices
- Status on marketing, Value addition and enterprise development
- Governance, policies and regulations related to NTFPs and their impact
- To conduct numerical modeling of hydrological responses of a central Himalayan watershed to changing environmental controls.
- To establish multi-stakeholder and inclusive mechanism to acquire and exchange information and knowledge, generated through scientific as well as evidence based research on biodiversity and climate change in IHR.
- To explore immediate to medium to long term societal implications of changing hydrological and land resources of a central Himalayan watershed
- To monitor atmospheric pollutants and generate a long-term data base of meteorological parameters
- To establish relationship between pollutants and their impact on climate change,
- To assess climate change impact on apple orchards, and
- To suggest mitigation and adaption strategies
- 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).
- To develop a Village Information System (VIS) to support for decision making for villagers.
- To build capacity of stack-holders on VIS.
- To generate database to provide relevant information for villages.
- To promote research on microbial diversity (an important component of biodiversity) with particular reference to biotechnological applications
- To generate human resource in this specialized research area
- Documentation and conservation of microbial diversity of IHR with particular reference to their applications
- To identify the causes of weakening traditional livelihood in the mountain.
- To identify the relationship between land abatement and out migration.

- To identify the supplementary livelihood option for the rural areas in changing scenario
- To support R & D activities under ES theme mandate and proposed activities (short-term and long term)

Methodology(ies) & approach: To achieve the objectives of combination of methodologies were employed for data collection, experimentation, synthesis, analysis, simulation and drawing conclusions and recommendations. Methodologies primarily involve collections of baseline data from various online and offline resources for review and gap analysis. Followed by site selection, samplings, development of questionnaires, use of (Participatory Rural Appraisal (PRA) tools, household surveys, simulation modelling of hydrological processes using WEAP model, equipments selection such as Respirable Dust Sampler (RDS; Envirotech NL-460), molecular characterization, analysis of root colonization by trypan blue staining method, macro dilution method, chromatographic method, bioautographic and GS-MS, LC-Ms, NMR, FTIR technique, statistical tools, calibration & validation and development of web portal.

Results:

HRA001 - Title: *Study and Quantification of Non-timber Forest Products (NTFPs) and related value chains from the Western Himalaya.*

About 61% of the flora of the study region had medicinal value.137 NTFPs are under diverse level of threat falls under various threat categories of IUCN, 2019 while 105 are under threat as per stakeholders due to excessive exploitation.

HRA002- Title: *Water Quality analysis emphasizing on nitrate nutrient dynamics using WASP model in Kosi Watershed*

20 springs in Almora sampled for its potability along with data from 31 sampling points across river Kosi (the main source of water for Almora town). Most of the springs are found not suitable for drinking where nitrate contamination was observed at few sampling sites of river Kosi. The contamination of naulas as Khatyari, Thapalya, Kapina (RS), Kapina (SM) was found to be above 60 mg/l with the nitrates and Sunehri, Gurani and both the Champa naulas were found to be with nitrate 20-30 mg/l. Dharanaula, Makeri, was found to be less with the amount of Dissolved Oxygen and nearly all the naulas showed high contamination of bacteria although *E. coli* was not traced in the samples. The expected outcome of the model by the parametric analysis of surface water would give the future prediction of the quality of the region and help to take remedial steps to mitigate/decrease the contamination levels. 31 sampling points in the entire stretch of the river helped to estimate 4 points for daily sampling. 4 points selected estimated that DO is highest in Kantli and with very least variation in Kosi and least in Ramnagar. BOD is least in Kantli and highest in Ramanagar whereas nitrate too is highest in Ramnagar and least in Kantli with variations in Kwarab and Kosi.

HRA003- Title: *Establishing the knowledge network through scientific as well as evidence based research on biodiversity and climate change in Indian Himalayan Region (IHR)*

Database on Himalayan Biodiversity and climate change prepared and featured in Himalayan Biodiversity and Climate Change- Knowledge Network (HBCC-KN) web portal.

HJRF001 – *Title: To explore immediate to medium to long term societal implications of changing hydrological and land resources of a central Himalayan watershed*

The societal implications of changing hydrological, climatological and land resources was studied using Water Evaluation and Planning modelling system in Kullu district of Himachal Pradesh and Almora district in Uttarakhand state. The WEAP model was customized using Current Year (2015) data sets and future climate datasets (2016-2030) of GCM GFDL-ESM2M under RCP 4.5. The study evaluated and analyzed

the existing and future water balance and possible impacts on the water demands and supply in the watersheds and generated the trends of water demand and supply as well as the scenarios for water resources management till year 2030 to see the possible implications on society or on their needs. Results are divided into three section (i) Hydrologic analysis, (ii) Water allocation and (iii) Scenario generation (two different agricultural scenarios, 1. Reference scenario, and 2. Deficit irrigation) for each watershed. Further water allocation strategy was formed in WEAP for water demand analysis and for future adaptive water management action plan based on the WEAP outputs.

HJRF002- Title: *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 orchard*

The Air Quality Index (AQI) study reveals that air quality of Mohal (Kullu, HP) falls under good to moderate category. However, PM_{10} was observed beyond its permissible limit during spring season when flowering in apple orchards are at peak.

HJRF04- Title: *Sustainable and Clean Energy in the Indian Himalayan Region*

There are no state level policies which are primarily focused upon solar photo-voltaic technology despite the huge solar potential in the IHR. If the focus of the state and national policies is compared, the national policies tend to have more weightage in terms of various solar energy policy formulations. If the focus of the policies of central and state governments is compared, it is observed that the central government is more focused towards the generation of solar energy through various technologies, while the state government is more focused upon the generation of hydro power.

HJRF005- Title: *Development of Village Information System (VIS) for Management & Planning of Rural Areas for Sustainable Development*

It has been found that the people in the mountains preferring the nuclear families now-a-days so that the landholdings division increases, which leads to minimize the average landholding size per house hold and it is directly decreasing the production. People are looking for other options for the livelihood generation and they are getting psychologically ready for out migration. The man-wild life conflict is reaching such a limit that farmers are not interested to continuing the agriculture practice and not even to go their farms and fields in distant locations to hoeing and sowing. The surveyed villages have a high rate of literacy but the male literacy rate is dominant in all the villages. Main cause of this fact is that many of females are staying in the villages are much older and illiterate and high literate females are preferring to live in any city areas of the districts not in the villages. The land use patterns is changing very fast as the fallow land is increasing and the cultivated areas and irrigated land is decreasing. Stakeholders are facing problems but some of them are very interested and willing to continuing the particular livelihood practice they are doing, but they want some technological inputs and government aids. Most of the farmers are marginal and small farmers and economically they are not so strong, so they want to adopt some low cost technologies and their training in their villages. Some of farmers are really doing very good in their areas they are following market mechanism and growing as per the market needs. There is a lot of scope in the village ecotourism it can be very good supplementary livelihood options in the rural areas of the Uttarakhand that needs to be developed appropriately.

HJRF06- Title: *Plant microbe interaction in Taxus wallichiana*

Two bacteria and five fungi species were isolated from the roots of *T. wallichiana*. The phenotypic and genotypic characters designated these bacteria and fungi to the species of *Burkholderia, Enterobacter* and *Penicillium*, *Aspergillus,* respectively. All the endophytes showed phosphate solubilization with production of phosphatases in aluminium, calcium and iron phosphate based medium and phytases in calcium and sodium phytate based medium. *Burkholderia* sp. also produced yellow pigment with antagonistic or antimicrobial activity. In antimicrobial activity section, according to GC-MS and LC-MS

analysis of extract, compound responsible for antimicrobial activity may belong to the group of compounds such as phenolics, vitamins and amino Acids. Further bioactive compounds were separated using column chromatography and TLC-bioautography. Separated fractions having antimicrobial activity were identified by GC-MS, LC-MS, FTIR and NMR. Identified compounds having antimicrobial activity were fatty acids (arachidic acid, behenic acid, palmitic acid, stearic acid), vitamins (nicotinamide), and alkaloids (cinchonine, timolol), aminobenzamides (procainamide), carbocyclic sugar (myoinositol) and alkane hydrocarbon.

HJRF007- Title: *Weakening of traditional livelihood in the mountains*

For development of village information system (VIS) in targeted villages of district Almora, namely Jyula, Gawalakote, Darmikhola and Sakar, datasets on population composition (sex ratio & age wise population), Education, Literacy, ICT Literacy, Landholding size, Livestock, Occupation, Infrastructure, Social Composition, Income group, etc. were collected and webpages of the website was developed using using HTML and CSS pages using notepad and Macromedia Dreamweaver 8.

HJRF008- Title: *Valuation of wild bio-resources as provisioning services from forest ecosystem: A case study of Chamoli district, central Himalaya, Uttarakhand*

A total of 16 wild resources are collected by 4 targeted village clusters. The resources were divided into three categories based on their availability in nature and economic value such as (i) high value low volume, (ii) low value and high volume (iii) low value low volume. *Ophiocordyceps sinensis, Morchella esculenta, Origanum* vulgare and *Carum carvi* fall under the category of high value low volume products, Jhula (lichen), Moss, *Diplazium esculentum* and *Paeonia emodi* under low value high volume and *Saussurea obvallata, Taxus wallichiana, Pleurospermum anglecoides, Angelica glauca, Saussurea costus, Hippophae rhamnoides, Allium stracheyii* and *Rhododendron arboreum* in low value low volume category. The total monetary value of the provisioning services provided by these sixteen wild bio-resources was estimated about Rs. 344.4±.35 lakh/yr for Sutol– Kanol village cluster (Rs.109.8±0.03 lakh/yr) followed by Vaan village cluster (Rs. 103.9±0.03 lakh/yr) and Urgam cluster (Rs. 638.6±0.12 lakh/yr).

HJRF0010- Title: *Assessment of biochemical content of selected threatened and high value plants with diverse environmental conditions*

A total of 21 species of threatened and high value plants along with their distribution and present status as well as the traditional uses in Arunachal Pradesh and global bioactive potential was documented. The proximate analysis of the selected species has shown that Na, K, P and Ca content was highest in *Zingiber zerumbet* followed by *Curcuma caesia.* The sodium and calcium content were in the range of (0.61-0.68 g/100 g dw) and (2.3 to 2.78 g/100g dw) respectively. The *Z. zerumbet* has highest crude protein (13.0 ±0.05g/100g dw) and ash content (19.87±0.16 g/100g dw). Total phenolic (TP) content was highest in methanol for all the three species. The total flavonoid (TF) content was also found highest in methanol for both the species *C. caesia* (271.57±2.55 mg QE/100g dw) and *Z. zerumbet* (419.30±3.79 mg QE/100g dw). The total tannin (TT) content was also found highest in methanol for all the three species. The ethanolic and methanolic extract of showed the higher activity against *Pseudomonas chlororaphis* (11.00 ± 0.06 mm) and *Serratia marcescens* (11.00 ± 0.12 mm) for, *Curcuma caesia*. The MIC value for bacteria (300-700 µg/mL), actinobacteria (400-600 µg/mL) and fungi (700-900 µg/mL) was wide-ranging for different solvent extracts. The antibacterial analysis of *Curcuma angustifolia* revealed the highest activity in the ethyl acetate extract against *E. coli* (28.3±5.58). *For Zingiber zerumbet* Ethyl Acetate extract have highest activity against *E. coli* (16.7±0.98). The Unique high value compounds viz. gallic acid, catechin, chlorogenic acid, vanillic acid, p-coumaric acid, m-coumaric o-coumaric acid, Rutin, T-cinnamic acid etc. were identified and quantified in methanol extracts of the selected species. The phenolic, aromatic, aliphatic, and alcoholic compounds associated with different functional groups were detected using FTIR. For the demonstration of the targeted species at diverse location across different altitude, the three species viz. *Curcuma caesia, Zingiber Zerumbet, and Curcuma aungustifolia* has shown healthy growth at RTC Ziro and Itanagar, however *Illicium griffithii* could not grow at both the

location. The reason may be different climatic conditions in the case of Itanagar particularly while soil type/growth conditions might be the major factor in Ziro for inability of *I. griffithii* cultivation.

Conclusions

HRA001- High dependence on divine NTFPs that help poorly marginal people to fulfill their domestic needs. Unfortunately no suitable conservation protocol is being implemented. Selected market demanding species can be multiplied and popularized in traditional agroforestry system. Dependence on NTFPs also increases community resilience during adverse environmental conditions. A need to give more emphasis on NTFPs conservational management in forest working plans is strongly desired.

HRA002- According to studies and analysis, it can be seen that the critical time for the oxygen content is in low water season (summer season and early fall) because the decrease in the flow and the slow re-aeration, but in the full water season the condition is good. According to the simulation results can be seen that the applicability of the model for the eight months period between data and model is seen as an almost acceptable. So we can conclude that despite limited data, WASP8 model is an appropriate model for the simulation of water quality in river Kosi. Among the parameters studied in the Kosi River dissolved oxygen (DO) is in reasonable condition. With increasing temperature in the hot months of the year and then reducing the flow of the river, DO reduced. The lowest DO value is 5.38 mg/lit in September for Ramnagar station and maximum DO value is 14.7 mg/lit in March at station of Kantli. Variation tend indicates that the amount of nitrate in the river was higher than standard, maximum in November in Ramnagar (3.6 mg/lit) and lowest in April at the Kantli station (1.63 mg/lit). The model WASP8 major cause of differences between actual data and simulation results can be caused by the lack of coefficients of kinetic and use of the default values, the sampling error, the impossibility of sampling all stations sampled and on the other hand Error in analysis of test samples. It is recommended that users should regularly monitor the river and check the disposal of partially treated waste water into Suyal river which ultimately merges into Kosi river. The necessity of preserving the quality of water in the region has come to the brim now. Be it springs in Almora or river Kosi which is summation of various springs in the entire stretch the water quality has deteriorated and needs immediate attention. The model execution could give more appropriate results if sampled and analysed for longer duration at least for entire one year.

HRA003- Literature/information collection. Total collected information 1046; Researchers database: 650; Total 95 publications; The Himalayan Biodiversity and Climate Change- Knowledge Network (HBCC-KN) web portal; Knowledge network: Total 299 stakeholders; Gap areas: Impact of different ecological variables is still under-explored condition; Diversity of lower group organisms still under-explored condition; It was hypothesized that it can be useful for further studies but only few studies have been found with ground level conclusion; Indicator species analysis; Climate change studies: points for mitigation have been given by many researchers but testing in ground level is still missing; Invasive species: maximum studies shows the impact of invasion on bio-diversity, however only few attempts have been made focusing on their sustainable use; Studies on development of control mechanism for their fast growth and development is still underexplored condition (e.g. Himalayan Thar, which is near threatened in Himalaya but in New Zealand it is an invasive species and for their control, hunting is a single option in front of NZ government); Environmental assessment through lower group.

HJRF001: The societal implications of changing hydrological, climatological and land resources was studied by customizing Water Evaluation and Planning modelling system in Kullu district of Himachal Pradesh and Almora district in Uttarakhand state using available datasets from primary and secondary sources, future climate data (2015-2030) of GCM GFDL-ESM2M under RCP 4.5 and some model based scientific assumptions. The societal implications in terms of water demands (demands of population, livestock and agriculture) and to meet out the unmet water demand from available sources with-in-year and years to come, was examined and water allocation strategy using WEAP has been framed and demonstrated here. The study reveals that there has been considerable variability seen in rainfall and

same has been reflected in the respective results of hydrologic analysis, water allocation (demand and supply) and crop yield analysis/outputs of the study. The variation of rainfall in Mohal khad watershed area in coming years showed that the year 2020 may experience low rainfall (322.97 mm) showing the predicated dry year/conditions whereas, 2024 may experience high rainfall (wet year) of about 1889.56 mm respectively. Whereas, in Upper Kosi watershed, the year 2020 may experience low rainfall (592 mm) showing the predicated dry year/conditions; whereas, 2022 and 2024 may experience high rainfall (wet year) of about 1734 mm and 1731 mm respectively. The agriculture scenario study projected the possible crop yield in 2015-2030 for both Upper Kosi and Mohal khad watershed. It was found that the crop yield in Mohal khad watershed doesn't show any promising change in both the scenario but shows the change in crop yield within the reference scenario which is attributed to the projected annual rainfall quantity. However, deficit irrigation scenario shows the increase in crop yield than that of in reference scenario in Upper Kosi watershed due to fact that sufficient water stress is required for many crops for increased yield. Overall, the customized WEAP modelling performs satisfactorily and able to simulate the hydrological, climatological and land resources variation and corresponding water demands and available options to meet out unmet demands of the different sectors. The output of this study may be used to implement groundwater recharge activities, creation of water storage structures, water allocation for unmet water demands domestic use, livestock, and implementing effective agriculture practices; considering the available water or predicted dry or wet years in future. Also, present study or modelling framework may be used in the future studies to carry out site specific and demand driven or Purpose Driven Studies (PDS) in the other Himalayan river basins for the best water management in the context of changing hydrological, climatological and land resources regime.

HJRF002- The ambient air quality monitoring (AAQM) study carried out under the present selected sites showed the Particulate pollution is high at Mohal and Raison as compared to Beasar control site in H.P. Because the Mohal and Raison are nearby National Highway (NH_3); so here the pollutants level is higher compared to the Control site. The concentration of PM_{10} at Mohal and Raison has crossed the permissible limit (100 µg m^{-3}) prescribed by NAAQS which might not be so good from a viewpoint of human's health and plant life. However, it is noted that except for the winter season at Mohal the concentration of $PM_{2.5}$ at study sites were well within the permissible limit set by NAAQS. The gaseous pollutants such as SO_2, NO_2 and NH_3 were found far below the permissible limits. Rainfall is negatively correlated with $PM_{2.5,}$ SO_2 and NO_2 but positively correlated with $PM_{10,}$ TSP and NO_2. Humidity is negatively related with $PM_{10,}$ TSP and SO_2 and positively related with $PM_{2.5}$ and NO_2. Wind has shown negative correlation with all the pollutants except SO_2. TSP and PM_{10} concentrations were greatly influenced by both local and outside sources. The local sources such as vehicles and visitors' influx, burning of fuel wood, coal and solid waste, use of diesel generators, and dust blown from nearby un-metalled roads were the most important ones. The long-distance transport sources of air masses moving in from outside regions can also be considered to be contributing to the existing concentrations of these pollutants in the region. It is also made clear from HYSPLIT and CALIPSO analysis that the local source of pollutants are contribution in the air pollution of the Kullu valley. The AQI study reveals that air quality of Mohal falls under good to moderate category. However, PM_{10} was observed beyond its permissible limit during spring season when flowering in apple orchards are at peak, which might not be so good from viewpoint of apple orchards. The maximum precipitation was recorded during 1988 and minimum was during 2009. Precipitation is decreasing at the rate of 4.3 mm / year. The maximum temperature has been increasing at the rate of 0.07^0 C per year, which is pointing towards climate change. Chilling hours are also decreasing every year which has direct impacts on apple production and diseases have also increased in apple orchards. Therefore, the apple orchard has been shifting from lower region to higher regions in the Kullu valley. Environmental and health impacts of the air borne particles require that authorities urgently step up control of the ever-increasing level of air pollution not only in large cities but also in the towns/villages under study in this ecologically very sensitive and topographically fragile part of the Himalaya.

HJRF004- policies of central government is more focused towards the generation of solar energy through various technologies, while the state government is more focused upon the generation of hydro power.

HJRF005- Development of Village Information System is essential tool for easy access and data retrieval for the basic administrative unit of governance i.e. Village Panchayat. However, the inferences for village development should be drawn through consultative process like Community Driven Environmentally Sustainable Village Development Programm (CESVP) for better impact & visibility.

HJRF006- In view of the very limited regeneration potential of *T. wallichiana*, knowledge on this symbiotic association and bio formulation of the promising endophytes is likely to have implications in enhancing propagation potential of this conifer. Volatile compounds which are responsible for the antimicrobial activity are palmitic acid, stearic acid, arachidic acid, behenic acid, myoinositol and hexadecane. These compounds belong to saturated fatty acid, alkane hydrocarbon and carboxylic sugar. Non-volatile compounds which are responsible for the antimicrobial activity are cinchonine, procainamide, nicotinamide and timolol. These compounds belong to alkaloids, vitamins and flavanols group.

HJRF007- Traditional livelihood in the rural areas is very poor, as it is well known that it is a complex system of many practices supporting each other. The basic resources of traditional livelihood practices are facing very tough situations. The landholdings are being abandoned, many stakeholders are leaving agriculture and allied activities, man-wild life conflict is increasing day by day etc. are some burning issues. There is urgent need of high attention of government towards these issues. There must be some sensitization program in the rural areas to aware the problems and how to meet out these problems. Some hard rules and regulations are much needed for prevention and safety of crops and farmers from the wild animals. There is a need of some kind of infrastructures that can help the rural population for cash earnings. There must be some trainings and workshop on village basis for farmers to fulfill the gap of technological inputs in the potential livelihood practices people are interested in.

HJRF008- Despite the multi-dimensional (ecological, socio-cultural and economic) importance of ecosystems to human society, there have been no serious efforts to assess the ecosystem contribution in terms of primary services of the central Himalayan region in totality. Benefits provided by ecosystems are inadequately recognized and resource users do not take into account the cost of degradation of these services in their resource management decisions. Also, there is very limited understanding of ecosystem dynamics and the values that are being lost through overexploitation of the resources or degradation of the forest ecosystem.

HJRF0010- For the classical or conventional extraction, methanol and ethanol have shown better extractability of the phytochemical contents in all the three species of Zingiberaceae family. Whereas, in the case of *I. griffithii,* acetone has also shown potential apart from alcoholic solvents for the phytochemical extraction. Further, the antimicrobial activities, was found higher in alcoholic solvents. Large scale cultivation would require for conservation of the species which can fulfil the market demand of raw material and provide livelihood options.

Recommendations

HRA001

1. A collection/harvesting protocol should be developed in collaboration with suggestions from experts and similar training must be given to the collectors to ensure sustainable collection methods and processing procedure.
2. A large-scale plan is required to propagate the plantation of elite, high-demand species in government, community, and private forests and lands.
3. Need to develop and upscale community capacity in relation to develop micro-enterprise infrastructure and the necessary skills for processing, adding value, and storage.

4. There is an urgent need to bring together the indigenous knowledge of forest dwellers with the scientific knowledge of ecologists, forest scientists, botanists and experts from other related areas to form an explicit policy for NTFPs.

HRA002

5. There is a need to design a sewerage treatment system for Almora town zone wise considering the topography so that water carriage system of sanitation could be opted for the rapidly increasing clustering of the buildings.
6. The springs need to be conserved on community basis and also should be strictly undertaken by government as most of springs don't exist anymore as they have been collapsed under the construction work undertaken by the people of the region.
7. Frequency of sampling and analysis needs to be done periodically so that a check is maintained in the quality of springs.

HRA003

8. Intensive exploration of diversity particularly of lower groups needs to be taken up for comprehensive and effective knowledge network on biodiversity & climate change in IHR.
9. Promotion of scientific research for management & harvesting the economic value of Invasive species in IHR.

HJRF001

10. There is need to develop water infrastructure in order to cater the unmet water demands of the domestic, livestock or agriculture sectors. Creation of water storage structures to store the extra water in wet years and/or comprehensive soil and water conservation measures or best practices of watershed management to recharge the ground water is recommended.

11. Agriculture practices in terms of irrigation water use need to be properly planned and managed considering the predicted possible dry and wet years in future in order to minimized the negative impacts if any on crop production.

12. To minimize the negative societal implications of changing hydrological and land resources, general awareness of water conservation among the populous is needed and for that purpose various capacity development, training or social programme need to be implemented in the study area.

HJRF002

13. There is a need to inform the local communities regarding the future consequences of polluted air among them and to adopt pollution free technologies.
14. Burning and open dumping of solid waste should strictly be prohibited in the towns to free the environment from toxic air. To manage solid waste in towns, the authorities should be scientifically informed to dispose of the waste properly.
15. The local communities and managing authorities should be aware of the practice of energy driven technologies, the use of quality fuel in the vehicles, and the practice of non-conventional energy sources which need to be supplemented with solar energy.
16. Plantation along roads, streets, open places, and around the towns under a green belt concept should be encouraged as a sustainable option to bring ambient air pollution under control.
17. The management of ambient air pollution needs to be done in a coordinated manner, with active cooperation between local residents, management authorities, research institutions, and local government.

18. Government should conduct programs at community level to sensitize the public about the growing levels of the pollution due to vehicles and promote public transport systems.
19. Tourism activities should be managed properly to control the vehicular movement.
20. Old vehicles should be banned in the state as they cause more pollution.

HJRF004

21. Need to shift the focus from transmitting of energy from faraway places to generation of energy in and around the place of interest itself (centralized to decentralized).
22. Development of State level legislative frameworks is needed for promotion and adoption of renewable energy technologies especially in Nagaland, Tripura, Mizoram, Manipur and Arunachal Pradesh.

HJRF005

23. Village information systems (VIS) need to be updated regularly for understanding the changing socio-economic dynamics and subsequently be used in planning and developing programmes for the rural people.
24. Capacity building of various stakeholder groups is needed for getting familiar with the VIS and its usability.

HJRF006

25. Leaf is renewable part of plant, and shows a good antimicrobial activity. Therefore, utilization of *Taxus wallichiana* leaves instead of bark and stem is recommended for harnessing their antimicrobial potential. For further isolation of the antibacterial and antifungal compounds, maceration and soxhlet are recommended, respectively.

HJRF007

26. Sensitization programs in the rural areas need to be conducted for dissemination of rural technologies for optimizing their farm returns and improved/alternative livelihoods.
27. Policy reorientation is needed to adequately compensate the human and farm loss due wild animal conflict.
28. Facility of cold storages and access to market needs to be facilitated for minimizing the intermediaries and optimizing the benefits.
29. Village information systems need to be updated regularly for understanding the changing socio-economic dynamics and subsequently be used in planning and developing programmes for the rural people.
30. Capacity building of various stakeholder groups is needed for getting familiar with the VIS and its usability.

HJRF008

31. Exploration and mapping of potential wild bio-resources (NTFP) should be done across IHR, which significantly contribute towards economic and food security of the people.
32. Protocols for domestication of high value wild resources need to develop through scientific and technological explorations.

HJRF0010

30. A deeper study on isolation of important bioactive compounds through green processing technology focussing on antimicrobial, anti-cancerous, and antidiabetic agents would definitely increase the market value of the species
31. The analysis of the soil across different altitude of the species would also give a better idea for growth and survival of the species in different climatic conditions.
32. Value addition of the species need involvement of various stakeholders for breaking the barriers at different stages and providing the suitable platform and proper mechanism for farmers produce.

2.2. Objective-wise Major Achievements

S. No.	Cumulative Objectives	Major achievements (in bullets points)
HRA001	1. Inventories NTFP species, diversity and management practices 2. Status on marketing, value, addition and enterprise development 3. Governance, policies and Regulations related to NTFPs and their impact	1. A total of 811 NTFPs were evaluated till date in Himachal Pradesh. 2. Out of these a total of 159 were categorized threatened species (66 species as per IUCN while 93 species as per stakeholder perception). Continuous extraction of NTFPs from these areas has, have put the species in the threatened category e.g. *Aconitum heterophyllum*, *Angelica glauca, Gentiana kurroo, Nardostachys jatamansi, Saussurea costus, Lilium polyphyllum, Trillium govanianum* etc. 3. Increasing trends of revenue generated and collected by the forest department from NTFPs have been observed for 68 years and a constant increase was seen from past 3 decades. 4. The revenue generated in form of royalty from resin tapping has increased subsequently in spite of decline in number of blazes allotted from past 66 years. 5. Due to lack of systematic marketing, the rate of NTFPs is driven mostly by market demand, mediator and bragging power. 6. NTFPs collection is allowed in a specified area after a gap of about four years. 7. With the decrease in quantity and very high demand of NTFPs, forest dwellers are mostly collecting NTFPs for business purpose. 8. Net income of secondary collectors was more than 75% 9. Average collection period of NTFPs in different districts ranged from 34 to 82 days annually 10. Being aware of some of the policy regarding restriction of NTFPs harvesting, forest dwellers still consider the forest as their own property. 11. An appropriate policy framework for the sustainable promotion of NTFPs is necessary to help to ensure an effective development, promotion and sustainable harvesting of NTFPs.

HRA002	1. To conduct numerical modeling of hydrological responses of a central Himalayan watershed to changing environmental controls.	1. Most of the springs of Almora are contaminated and not fit for drinking due to various anthropogenic reasons. 2. The analysis of 31 sampling points have very much fluctuations in water quality shows the variations in water quality in the entire stretch possibly due to scattered and uneven population, geology and topography of the region and variation in the flow of the river. 3. WASPS may be used (with modifications) for constructing a representative dynamic model for rivers with similar characteristics to the Kosi. 4. The hydraulic characterization of this type of river is very difficult and, at the same time, its influence on the evolution of water quality is very important. Limitations have been found in the dynamic model (WASP8) which reduces its possibilities for the simulation of river aquatic systems. The obligation of setting equal rates for the entire river is one of these limitations. 5. Among the parameters studied in the Kosi River dissolved oxygen (DO) is in reasonable condition. With increasing temperature in the hot months of the year and then reducing the flow of the river, dissolved oxygen reduced. The lowest DO value is 5.38 mg/lit in September for Ramnagar station and maximum DO value is 14.7 mg/lit in March at station of Kantli. Variation tend indicates that the amount of nitrate in the river was higher than standard, maximum in November Ramnagar station to the 3.6 mg/lit and lowest in April at the Kantli station 1.63 mg/lit. The model WASP8 major cause of differences between actual data and simulation results can be caused by the lack of coefficients of kinetic and use of the default values, the sampling error, the impossibility of sampling all stations sampled and on the other hand Error in analysis of test samples.

HRA003	1. To establish multi-stakeholder and inclusive mechanism to acquire and exchange information and knowledge, generated through scientific as well as evidence based research on biodiversity and climate change in IHR	1. The preliminary database on various components of Himalayan Biodiversity and Climate Change have been collected and analyses in terms of objectives, methodology adopted, key findings etc. (Annexure- I and II). 2. The Himalayan Biodiversity and Climate Change- Knowledge Network (HBCC-KN) web portal has been developed and tested on different platform for its functioning (Annexure-III). This knowledge network web portal can now be shared and popularize among different stakeholders of IHR for knowledge flow and sustainability. 3. For the database on biodiversity, lichen diversity of Western Himalaya have been compiled and presented in a book form (Annexure IV).

HJRF001	1. To explore immediate to medium to long term societal implications of changing hydrological and land resources of a central Himalayan watershed	1. Water Evaluation and planning modelling system was effectively used to demonstrate implication of changing hydrological, climatological and land resources in selected watersheds of Kullu district of Himachal Pradesh and Almora district in Uttarakhand state. 2. The societal implications were studied using available datasets from primary and secondary sources, future climate data (2015-2030) of GCM GFDL-ESM2M under RCP 4.5 and some model based scientific assumptions; and evaluated and analysed the existing and future water demands and supply in the watersheds and generated the trends of water demand and supply as well as the scenarios for water resources management till year 2030 to see the possible implications on society or on their needs. 3. The present and future analysed datasets for respective study sites has been created for duration of 2015 to 2030 which includes datasets or status of rainfall, flow to groundwater from different land use/land cover, surface runoff from the watershed, population and livestock water demands, agriculture water demand, unmet water demand of population, livestock and agriculture, water supply to population, livestock and agriculture; and crop yield status in both the watersheds. 4. The societal implications in terms of water demands (demands of population, livestock and agriculture) and to meet out the unmet water demand from available sources with-in-year and years to come, was examined and water allocation strategy using WEAP has been framed and demonstrated here for both of the watersheds under study.

HJRF002	1. To monitor atmospheric pollutants and generate a long term data base on meteorological parameters 2. To establish relationship between pollutants and their impact on climate change 3. To assess climate change impact on apple orchards 4. To suggest mitigation and adaption strategies	1. The maximum concentration of TSP was 187.2 µg m^{-3} at Mohal and 93.3 µg m^{-3} at Kothi on 31th December and 11th April 2017, respectively. 2. On daily basis maximum concentration of $PM_{2.5}$ was observed as 77.6 µg m^{-3} on 8th March 2018 and minimum concentration was observed as 21.1 µg m^{-3} on 22nd January. On the other hand, maximum and minimum concentrations of PM_{10} were found as 45.2, 10.6 µg m^{-3} on 17th May and 15th April, respectively. The maximum and minimum concentrations of TSP were observed as 125.3, 42.0 µg m^{-3} on 14th March. 3. At Mohal $PM_{2.5}$ concentration was the highest 92.6 µg m^{-3} during November while lowest was 1.12 µg m^{-3} in December 2018. 4. During winter season the highest ever concentration of PM_{10} (162.6 µg m^{-3}) was observed on January 16, 2019. This value of PM_{10} was recorded minimum 25.7 µg m^{-3} on February 25, 2019. The average concentration of PM_{10} was observed 56.6±5.8 µg m^{3}. While the status of PM_{10} during spring season was observed 106.3 µg m^{-3} as maximum on April 10, 2019 and 37.2 µg m^{-3} minimum on April 20, 2019. 5. PM_{10} concentration at Raison and Beasar sites were observed only in summer season 2019, ranged between 9.6 µg m^{-3} to 31.8 µg m^{-3} with the mean value of 20.9±1.7 µg m^{-3} at Beasar. Highest ever concentration of PM_{10} (31.8 µg m^{-3}) was observed on June 28, 2019. On the other hand, at the Raison site PM_{10} concentration ranged between 34.7 µg m^{-3} to 112.3 µg m^{-3} with the mean value of 64.9±6.2 µg m^{-3}. 6. A study of air quality in terms of gaseous pollutants throughout the year from January 2017 to December 2019 showed that all the parameter such as NO_2, SO_2 and NH_3 were well within the permissible limit. HYSPLIT and CALIPSO analysis revealed that the local source of pollutants are also contributing the air pollution in the region. The AQI study reveals that air quality of Mohal falls under good to moderate category. However, PM_{10} was observed beyond its permissible limit during spring season when flowering in apple orchards are at peak.

7. Long term meteorological parameters (1985 to 2019) such as rainfall and temperature were also analysed. The maximum rainfall was recorded 1304.4 mm during 1988 and minimum was recorded 647.8 mm during 2009 While the mean rainfall was 927.4± 28 mm. Rainfall is decreasing at the rate of 4.3 mm /year.
8. Temperature data of 35 years were analysed from 1985-2019. Temperature is continuously increasing in the study area. The maximum temperature was recorded 29.5^0C during 2019. On the basis of temperature data analysis, the temperature has been increasing at the rate of 0.07^0 C per year.
9. It was found that chilling hours has continuously decreasing in the study area. Chilling hours are decreasing at the rate of 22.7 hours / year. It was found that there is positive correlation between chilling hours and apple production
10. Apple production and area's data were also collected from horticulture department Himachal Pradesh during 1990-91 to 2016-17.
11. In 1991-92 about 7% apple sown area has increased while -9.5% productions have decreased. Similarly, in 2016-17, the area grew by 2.9% while production decreased by -45%.
12. The management of ambient air pollution needs to be done in a coordinated manner, with active cooperation between local residents, management authorities, research institutions, and local government.
13. Government should conduct programs at community level to sensitize the public about the growing levels of the pollution due to vehicles and promote public transport systems.
14. Plantation along roads, streets, open places, and around the towns under a green belt concept should be encouraged as a sustainable option to bring ambient air pollution under control.
15. Tourism activities should be managed properly to control the vehicular movement.
16. Old vehicles should be banned in the state as they cause more pollution.
17. Shift towards new varieties (low chill and high yield varieties)
18. To compensate the loss from the low productivity of apples, farmers can also introduce alternate crops (pears, kiwis, pomegranates, persimmon, cabbage and other vegetables) along with apples.

HJRF004	1. To analyze existing policies and legal instruments for promotion of clean energy development in the Indian Himalayan Region 2. To document and analyze best practices/models for further promotion, and replication of clean energy development 3. 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 INDC	1. A compendium of all national and state level renewable energy acts, regulations and policies and a brief analysis of the same. 2. Document for Clean Energy Best Practices has been prepared indicating presence of off-grid electricity production systems including hybrid energy systems being implemented in the IHR. Adoption of such mechanisms in schools, colleges and households is observed indicating preference of general population towards off-grid energy consumption. 3. Document on Adoption and Promotion of Renewable Energy has been prepared which indicates renewable energy best practices like pine needle gasifiers to produce electricity, concentrated solar cooking systems and micro hydro community based projects are being adopted in many states of the IHR; however Mizoram, Manipur, Arunachal Pradesh, Tripura and Nagaland still lag behind due to lack of policy initiatives. 4. Document on Relevant Supportive Legislative Framework depicts the absence of legislative framework in Nagaland, Tripura, Mizoram, Manipur and Arunachal Pradesh. 5. Document on Situation Analysis on the Progress in Different States suggests that projects which are based on community management are more beneficial as compared to government operated or privately operated projects due to faster response in case of electrical faults and provides employment and skills to the local population, further indicating the advantage that off-grid production has over grid connected technology. 6. A gap between peak demand and peak supply exists in the Indian Himalayan States equivalent of approximately 9% clean energy best practices and developing the legislative framework in the north eastern states. 7. The relationship between energy consumption (kg of oil equivalent per capita) and economic growth (Gross Domestic Product per capita) during the 24 year period of 1991-2014 of India was investigated and feedback hypothesis was confirmed or bidirectional causality was observed. Feedback hypothesis confirms the interdependence between energy consumption and economic growth since both variables affect each other. This encourages the implementation of energy expansion policies for long run sustainable economic growth.

HJRF005	1. To develop a village information system (VIS) to support for decision making for villages. 2. To generate database to provide relevant information for villages. 3. To build capacity of stack holders on VIS.	1. Questionnaire has been finalized for collection of primary data from identified villages through village survey. Primary Data Survey- Major Parameters taken into consideration for primary data survey are: Population, Education, Literacy, ICT Literacy, Landholding size, Livestock, Occupation, Infrastructure, Social Composition, Income group, etc. 2. Designed Conceptual Framework for the development of Village Information System (VIS). 3. Designing the basic architecture for the Information System, i.e., Village Information System (VIS), this was developed using System Requirement Specification (SRS) and Software Development Life Cycle (SDLC).
HJRF006	1. To promote research on microbial diversity (an important component of biodiversity) with particular reference to biotechnological applications 2. To generate human resource in this specialized research area 3. Documentation and conservation of microbial diversity of IHR with particular reference to their applications	1. Two bacteria and five fungi were isolated from the roots of *T. wallichiana*. 2. The phenotypic and genotypic characters designated these bacteria and fungi to the species of *Burkholderia, Enterobacter* and *Penicillium*, *Aspergillus,* respectively. 3. All the endophytes showed phosphate solubilization with production of phosphatases in aluminium, calcium and iron phosphate based medium and phytases in calcium and sodium phytate based medium. 4. *Burkholderia* sp. also produced yellow pigment with antagonistic or antimicrobial activity. 5. Antimicrobial potential of pigment produced by endophytic bacteria isolated from *Taxus wallichiana* root. 6. Mobile phase optimization for separation of antimicrobial compound 7. Volatile compounds which are responsible for the antimicrobial activity are palmitic acid, stearic acid, arachidic acid, behenic acid, myoinositol and hexadecane. These compounds belong to saturated fatty acid, alkane hydrocarbon and carboxylic sugar. 8. Non-volatile compounds which are responsible for the antimicrobial activity are cinchonine, procainamide, nicotinamide and timolol. These compounds belong to alkaloids, vitamins and flavanols group.

HJRF007	1. To identify the causes of weakening traditional livelihood 2. To study the relationship between land abatement and out migration 3. To identify the supplementary livelihood options in the rural areas in the chaining scenario	1. A total of 674 household were surveyed in 12 villages from the nine hill districts of the Uttarakhand and perception of farmers regarding changes in the village in previous 50 years has been recorded. 2. Literature review has been done on historical aspect with the current situation and the impact of changing socio-economic scenario on traditional livelihood practices. 3. Collected data has been analyzed and on the basis of analysis a list of such issues which are responsible for the weakening of traditional livelihood has been prepared. 4. Data has been collected on land abandonment and out migration with the help of secondary sources and as well as primary survey in the selected sites. 5. Focusing the issues of weakening traditional livelihood practices a one day training program has been organized on the title **"**Awareness and capacity building on livelihood enhancement in rural areas"**.**
HJRF008	1. To support R&D activities under ES theme of the Institute to achieve the theme mandate and proposed activities (short-term and longterm)	1. About 16 wild edible plant species viz., *Ophiocordyceps sinensis, Morchella esculenta, Origanum vulgare, Carum carvi,* Jhula (Lichen species), Moss*, Diplazium esculentum, Paeonia emodi, Saussurea obvallata, Taxus wallichiana, Pleurospermum anglecoides, Angelica glauca, Sassurea costus, Hippophae rhamnoides, Allium* stracheyi and *Rhododendron arboreum* were collected by villagers for various purposes for their own use and marketing purposes. 2. Total monetary values provided by the wild bio-resources in terms of provisioning services was estimated ranging from Rs. 1.03 - 6.38 crore/yr in all these four village clusters. 3. 80-85% of the households in all the four village clusters are directly dependent on forest, particularly on wild bio-resources in terms of provisioning services for their livelihoods and income.

HJRF010	1. To investigate phytochemical and biochemical contents in high value plants across altitudinal gradients 2. To study the survival and growth of different plant species among diverse environmental conditions.	1. The four high value plants i.e. *Illicium griffithii, Curcuma caesia, Curcuma aungustifolia* and *Zingiber zerumbet* have been selected for the fellowship objective based on their traditional uses, market potential and work done so far. 2. The biochemical parameters viz. Na, K, P, Ca, Crude protein, and Ash content of the selected species were evaluated. Amongst the phytochemical content i.e. Total Phenolic Content, Total Flavonoid Content, and Total Tannin Content of the selected species were evaluated. The antimicrobial activities of different solvent extracts of the selected species were also evaluated 3. The Unique high value compounds viz. gallic acid, catechin, chlorogenic acid, vanillic acid, p-coumaric acid, m-coumaric o-coumaric acid, Rutin, T-cinnamic acid etc. were identified and quantified in methanol extracts of the selected species 4. All the plant species were analyzed using FTIR for the characteristics of the biomass and associated compounds with different functional groups *5.* The four selected species viz. *I. griffithii*, *C. caesia, Z. zerumbet* and *Curcuma aungustifolia* were cultivated in different climatic conditions at Itanagar and Ziro. 6. The three plants of the Zingiberaceae family have shown healthy growth in both the environmental conditions while *I. griffithii* could not grow in Itanagar area

2.3. Outputs in terms of Quantifiable Deliverables*

S. No.	Quantifiable Deliverables*	Monitoring Indicators*	Quantified Output/ Outcome achieved	Deviations made, if any, and Reason thereof:
HRA001	1. Inventory through Survey (primary/ secondary); Commercial NTFPs; Conservation status 2. Value-chain analysis; Value addition, if any; Management	1. List of species 2. Details of Commercial species; Species under threat. 3. Species potential for market and income generation; Status on	1. A total of 811 species of NTFPs (including Lichens and Moss), 2.66 medicinal plant species of are facing various categories of threat as per IUCN guidelines. 3. Herbs (64%) are the dominant life	

	practices (formal and customary) 3. Tenurial Arrangement studies; Governance structure assessment; Policies , rules & regulation analysis	management strategies 4. Areas of policy intervention; Framework for NTFPs management in IHR	form in the trade followed by shrubs (20%), trees (14%), and ferns, climbers, grasses and mushroom (1%) 4. Areas of policy intervention; Framework for NTFPs management developed	
HRA002	1. Review of literature 2. Collection of hydrological data from primary and secondary sources of study watershed 3. Integration of database to SWAT model 4. Simulation of SWAT model to address objective 1. 5. Simulation of SWAT model to address objective 2.	1. Review report on application of numerical modeling of hydrological processes of central Himalayan watershed. 2. Report of initial results of SWAT modeling exercise related to research question 1 3. Report of initial results of SWAT modeling exercise related to research question 2. 4. FTR of the modeling exercise and societal implications of the modeling results.	1. Water quality fluctuations measured for 31 sampling points. 2. WASP8 used for constructing a representative dynamic model 3. Contamination of naulas as Khatyari, Thapalya, Kapina(RS),Kapina (SM) was found to be above 60 mg/l with the nitrates and Sunehri, Gurani and both the Champa naulas were found to be with nitrate 20-30 mg/l. 4.Dharanaula, Makeri,was found to be less with the amount of Dissolved Oxygen and nearly all the naulas showed high contamination of bacteria although Ecoli was not traced in the samples.	
HRA003	1. Detailed literature/information collection, analysis and synthesis; 2. Knowledge related needs assessment of diverse stakeholder groups 3. Developing	1. Knowledge database developed 2. Stakeholder's needs identified and database linkages developed for flow of knowledge.	1. Bibliographic review on biodiversity and climate change 2. Detailed literature collection, analysis and	

	mechanisms for knowledge flow among stakeholder groups-creating partnership forums 4. Establishing linkages and strengthening knowledge network with other similar global initiatives?	3. Knowledge synthesis based products (e.g., policy briefs). 4. Knowledge synthesis based products (e.g.,Book/Monograph on Himalayan Biodiversity & CC). 5. Knowledge Linkages with other mountain regions established. 6. Knowledge Network updated and long term sustainability worked-out; Final report submitted	synthesis on biodiversity and climate change in IHR. 3. The Himalayan Biodiversity and Climate Change-Knowledge Network (HBCC-KN) web portal has been developed and tested on different platform for its functioning. This knowledge network web portal can now be shared and popularize among different stakeholders of IHR for knowledge flow and sustainability. 4.Lichen diversity of Western Himalaya	
HJRF 001	1. Field survey for water use of study watershed 2. Field measurement of water availability of study watershed 3. Linking long term climatic factors and land resources to water availability of study watershed 4. Numerical modeling of water availability and demand using WEAP model for the study watershed	1. Report of water use and demand of the selected watershed. 2. Database of water use and water availability 3. Initial WEAP model products of natural hydrological processes of selected watershed 4. Initial WEAP model products related to water resources and their allocation when anthropogenic activities are superimposed over the natural	1. Water demand of various sectors viz. domestic, livestock and agriculture in Mohal khad watershed of Kullu district of Himachal Pradesh and Upper Kosi watershed in Almora district in Uttarakhand state for year 2015. 2. Average monthly and annual water demand and water supply status of both the watersheds. 3. The WEAP based present and future datasets that reflects the relationship between climate models derived rainfall data on	

		system 5. Report on established relationships between climatic factors, land resources and water availability 6. Final WEAP model products on water allocation for all the sub watershed and a FTR.	water resources for respective study sites for duration of 2015 to 2030 includes datasets or status of rainfall, flow to groundwater from different land use/land cover, surface runoff from the watershed, population and livestock water demands, agriculture water demand, unmet water demand of population, livestock and agriculture, water supply to population, livestock and agriculture; and crop yield status in both the watersheds. 4. Water allocation strategy using WEAP and reports and publications.	
HJRF 002	1. Monitoring of gaseous pollutants through online Analysers 2. Generating data base from existing weather tower and weather stations 3. Establishing relationship of atmospheric pollutants and meteorological parameters 4. Computing , data interpretation & establishment of relationships 5. Increase in temperature and its impact on chilling hours of apple	1. Status and changing pattern of atmospheric pollutants O3, NOx, SO2, CO, CO_2, etc. 2. Data base on meteorological parameters 3. Extend of climate change scenario 4. Atmospheric pollutants impact level on climate change 5. Climatic data, Apple yield performance 6. Reports, Research Papers, Policy guidelines	1. Particulate and gaseous Pollutants in Mohal during the study period (2016-2019) 2. Particulate Pollutants in Kothi during the study period (2016-2018) 3. Gaseous Pollutants at Mohal during study period (2016-2019) 4. PM_{10} Concentration at Mohal during different season during study period (2016-2019) 5. Rainfall and temperature trend from 1985-2019;	

	production 6. Analysis and interpretation		chilling hours from 2009-2020; yearly change % apple production from 1990-2017 6. Correlation between chilling hours and apple production	
HJRF 004	1. Collection, compilation, and analysis of various acts, legislations, policy documents of concerned National Ministries, and all the states of Indian Himalayan Region 2. Development of IHR State Database Profile on related infrastructure and use pattern of energy 3. Compilation of best practices in the country 4. Analyze relevance of such practices for adoption by the states of Indian Himalayan Region 5. Projection Analysis and different Scenario Development on use of (i) bio-resources,(ii) energy consumption, (iii) likely livelihood opportunities, and (iv) carbon emission and sink	1. Repository' of various National and State level acts/ legislations/policy document 2. 'State level Database' for IHR database 3. Document on 'Best Practices' in the country; Document on 'Potential of adoption/promotion of existing technologies' by the IHR states 4. Document on relevant 'Supportive Legislative Framework' to promote such practices /gap areas 5. Document on 'Situation Analysis' on Progress in different States on account of technologies/tool of identified best practices 6. Statistical projections under different 7. Document on 'Need Analysis and Integrated Solutions' on adoption of technologies/tool to provide integrated solution	1. Relationship between clean energy legislative measures and energy output 2. Determination of energy generation technology as per demand and resource available in the selected areas 3. Gaps in energy demand and supply; relationship between energy and economic growth; prospective measures to increase energy availability in IHR in accordance with the SDGs.	

HJRF 005	1. Survey of villages for collection of primary data 2. Collection of secondary data through correspondence, internet, library search, visiting line departments, etc 3. Designing of architecture for web based Village Information System (VIS). 4. Development of online database on various aspects of villages	1. Web-based Village Information System (VIS) 2. Database on ICT literacy in cluster of villages of Almora District 3. Resource materials (Training manual, Folders, etc.) 4. Linkages and Networking with the stake holders 5. Online availability of database for the cluster of villages 6. Decision and policy planning for a particular village by the district administration with the help of VIS.	1. Village Information System (VIS) developed. 2. Database on Education, Literacy, ICT Literacy, Landholding size, Livestock, Occupation, Infrastructure, Social Composition, Income group, etc. collected for the VIS.	
HJRF 006	1. Characterization and identification of the microbial diversity for comparative assessment / through literature and experimental work. 2. Identification of bioactive compounds produced by the microbial cultures/ through biochemical / molecular Characterization. 3. Identification of microorganisms for their resilience and survival strategies /drawing growth curves and generating the specific spectra Standardization of methodology for preservation of microbial cultures. 4. Accessioning of cultures in International	1. Documentation of microbial diversity. Knowledge on biotechnological applications of microbial communities of IHR. 2. Research publications/ reports, popular articles, etc. 3. Availability of microbial cultures in International Depositories and gene sequences in world data bases for research & teaching communities, industries, etc.	1: Isolation and identification of taxol producing endophytic fungi Five endophytic fungi were obtained from the roots of *T. wallichiana*. 2. Quantitative estimation for taxol production was confirmed qualitative and quantitative by using HPLC. 3. PCR amplification carried out using specific gene BPAT and DBAT. 4. Physicochemical (Influence of incubation time, effect of temperature and pH, Influence of peptone concentration, carbon and nitrogen source) optimization of endophytic isolates	

	Depositories designated by MoEF&CC/ Enriching database through Gene Bank.		to maximize taxol production done.	
HJRF 007	1. Field study 2. Collection of primary and secondary data 3. Organising consultation workshop	1. A report on Identification of causes for weakening traditional livelihood 2. A report on relationship between land abatement and out migration 3. A report on possible options for improving livelihood in the rural mountains	1. A report has been prepared and a total of 13 such issues were reported by the villagers those are directly affecting the traditional livelihood practices. 2. A report has been prepared 3. A report on possible options for improving livelihood in rural mountain has been prepared.	
HJRF 008	1. Conduct Field experimental research on forest ecosystem services (provisioning, supporting, regulating and cultural) in Garhwal region / Uttarakhand	1. Draft review of literature report on information available on forest ES in Uttarakahnd / IHR 2. State-of-art report on the above; and preliminary data set on field experimental research proposed in column 3. Experimental data sets on various forest ecosystem services (including pastureland) based on field research 4. As above continued and Progress Report 5. Document on contribution of NTFPs to livelihood, employment generation and economy 6. Data set on opportunity cost bygone due to conversion of forests to wasteland	1. The cost-benefit analysis of different value added products prepared from the selected forest bio-resources. 2. Quantitative estimation of major and minor bio-resources done. 3. Monetary estimation of major and minor bio-resource enumerated. 4. Village wise sale and income of bio-resources calculated. 5. Trade Link operating in the study area identified.	
HJRF	1. Collection of plant material from diverse localities	1. Selection of plant species and collection of plants	1. The fruit samples of *the I. griffithii*,	The *Paris polyphylla* species

0010	2. Plantation of plants at diverse environmental conditions 3. Standardization of extraction process Quantification of useful compounds 4. Monitoring growth and survival at different habitat and climatic conditions	material 2. Suitable method of extraction 3. Quantification of high value compounds 4. Identification of unique high value compounds 5. Demonstrations at diverse localities 6. Options for sustainable use	rhizomes of *C. caesia, C. aungustifolia, & Z. zerumbet* were analyzed for biochemical content 2. Gallic acid, catechin, chlorogenic acid, vanillic acid, p-coumaric acid, m-coumaric o-coumaric acid, Rutin, T-cinnamic acid etc. were the identified high value compounds 3. The species were cultivated at diverse location at different altitude viz. Ziro, under Lower Subansiri district; and Itanagar under Papumpare district of Arunachal Pradesh. 4. The multifaceted uses in viz. traditional medicine, spices, perfumery, pharmaceutical industry etc. of these species may provide livelihood opportunities to the local communities through large scale cultivation	was dropped from the tentatively selected plants, due to strict collection regulation of the species in Arunachal Pradesh Due to unavailability of Instrument, Microwave Assisted Extraction was not conducted

(*) As stated in the Sanction Letter issued by the NMHS-PMU.

2.4. Strategic Steps with respect to Outcomes (in bullets)

S. No.	Particulars	Number/ Brief Details	Remarks/ Enclosures

S. No.	Particulars	Number/ Brief Details	Remarks/ Enclosures
1.	New Methodology developed:	-	-
2.	New Models/ Process/ Strategy developed:	**HJRF001** – First ever WEAP model use and its customization for study areas in Kullu district and Almora district	-
3.	New Species identified:	-	-

S. No.	Particulars	Number/ Brief Details	Remarks/ Enclosures
	New Database established:	**HRA001**- Database of 811 NTFPs of Himachal **HRA002**-Physiochemical parameters of 20 springs of Almora surface water quality of river Kosi from 31 selected points **HRA003**- Secondary database (1046) for biodiversity and climate change Researcher Database-650 Lichen diversity of Western Himalaya (1191 species) **HJRF001 –** Water Evaluation and Planning modelling framework based datasets of rainfall, flow to groundwater from different land use/land cover, surface runoff from the watershed, population and livestock water demands, agriculture water demand, unmet water demand of population, livestock and agriculture, water supply to population, livestock and agriculture; and crop yield status in both the watersheds for the year 2015-2030. **HJRF002**- Air quality datasets in terms of gaseous pollutants (HP (NO_2, SO_2 and NH_3) from 2017-2019 i.e. long term (1985-2019) meteorological parameters such as	

S. No.	Particulars	Number/ Brief Details	Remarks/ Enclosures
		selected villages of Almora **HJR006-** 02 bacteria and 05 fungi were isolated from the roots of *T. wallichiana*. **HJRF007**- People perception data on various aspect i.e. Demography, agriculture and livestock, resource availability, landholdings and the other issues affecting the traditional livelihood practices from 06 villages of Kumaun and Garhwal region **HJRF008-** Datasets on major forest bio-resources (16 species) utilization, ethno-medicinal knowledge, plants part used phenology and method of preparation of different value added products from the potential wild bio-resources and their market value. **HJRF010-** Biochemical phytochemical, and antimicrobial study of the selected plants	
5.	New Patent, if any:		
	I. Filed (Indian/ International)	-	-
	II. Granted (Indian/ International)	-	-
	III. Technology Transfer (if any)	-	-
6.	Others, if any:	-	-

3. Technological Intervention

S. No.	Type of Intervention	Brief Narration on the interventions	Unit Details (No. of villagers benefited / Area Developed)

1.	Development and deployment of indigenous technology	-	-
2.	Diffusion of High-end Technology in the region	-	-
3.	Induction of New Technology in the region	-	-
4.	Publication of Technological / Process Manuals	-	-
	Others (if any)	-	-

4. New Data Generated over the Baseline Data

S. No.	New Data Details	Existing Baseline	Additionality and Utilisation of New data (*attach supplementary documents*)
1.	Population and energy availability data in several remote villages of Kumaun Region	Population and energy availability as per Census 2011/NSSO	To determine best energy technology for a particular region (in coordination with the updated population and renewable energy source in the selected location).

5. Linkages with Regional & National Priorities (SDGs, INDC, etc.)/ Collaborations

S. No.	Linkages /collaborations	Details	No. of Publications/ Events Held	Beneficiaries

1.	Sustainable Development Goals (SDGs)	The following fellowships directly and indirectly contribute towards the respective SDGs **HRA001**- 1, 2, 3,7, 8, 9, 10, 11, 12, 13, 15, 16, 17 **HRA002**- 3, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17 **HRA003**-1, 2, 3, 5, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17 **HJRF001**-3, 6, 7, 8, 9, 11, 12, 13, 14, 15, 16, 17 **HJRF002**- 1, 2, 3, 8, 9, 10, 11, 12, 13, 15, 16, 17 **HJRF004**- 1, 2, 3, 5, 7 (Affordable and Clean Energy) , 8, 9, 10, 11, 12, 13, 15, 16, 17 **HJRF005-** 3, 4, 5, 8, 11, 13, 15, 16, 17 **HJRF006**- 3, 14, 15 **HJRF007-**1, 2, 3, 5, 8, 9, 10, 11, 12, 13, 15, 16, 17 **JRF008**- 1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16, 17 **HJRF010**-3, 8, 13, 15		

2.	Climate Change/INDC targets	**HRA001**-1.4, 1.5, 1.7, 2.1, 2.5, 2.6, 2.7, 2.8, 2.9 **HRA002**- 1.1, 1.2, 1.4, 1.6, 1.7, 2.1, 2.2, 2.5, 2.6, 2.7. 2.9 **HRA003**- 2.5, 2.6, 2.7, 2.9 **HJRF001**- 1.1, 1.2, 1.4, 1.6, 2.1, 2.2, 2.5, 2.6, 2.7, 2.9 **HJRF002**-2.3, 2.5 **HJRF004**: 1.1, 1.2, 1.4, 1.5, 1.7, 1.8, 2.3 INDC target to install 450 GW of renewable energy by 2030 **HJRF005**: 2.1, 2.2, 2.3, 2.5, 2.6, 2.7, 2.8, 2.9 **HJRF006**: 2.1, 2.2, 2.3 **HJRF007**- 2.1, 2.2, 2.3, 2.6, 2.7 **HJRF008**- 1.4, 1.6, 1.7, 1.8, 2.1, 2.2, 2.3, 2.5, 2.6, 2.7 **HJRF010**- 2.1, 2.3, 2.6, 2.7		
3.	International Commitments	Aichi biodiversity targets 1 & 6		
4.	National Policies	National Biodiversity target 1 & 7; National Water Policy		
5.	Others collaborations	National Solar Mission The National Renewable Energy Policy (ANREP)		

6. Financial Summary (Cumulative)*

*Please attach the **consolidated and audited Utilization Certificate (UC) and Consolidated and ***Year-wise*** Statement of Expenditure (SE)** separately, *ref*. **Annexure IX.**

7. Quantification of Overall Research Progress

S. No.	Parameters	Total (Numeric)	Attachments* with remarks
1.	IHR State(s) Covered:	*12 +1*	
2.	Fellowship Site/ LTEM Plots developed:	-	-
3.	New Methods/ Model Developed:	-	-
4.	New Database generated:	*13*	
5.	Types of Database generated:	*02*	*Primary and Secondary and modelling based datasets*
6.	No. of Species Collected:	*01*	*Taxus wallichiana* samples were collected for plant microbe interaction
7.	New Species identified:	*05*	Two bacteria and five fungi were isolated from the roots of *T. wallichiana*.
8.	Scientific Manpower Developed (PhDs awarded/ JRFs/ SRFs/ RAs):	*04 RAs and 11 JRFS*	*Few researchers left the fellowships in between the designated tenure*
9.	No. of SC Himalayan Researchers benefited:	*02*	
10.	No. of ST Himalayan Researchers benefited:	*03*	
11.	No. of Women Himalayan Researchers empowered:	*09*	
12.	No. of Knowledge Products developed:	*17*	
13.	No. of Workshops participated:	*04*	*Workshop on Mathematical Modelling and System Level Designing held at NIT Manipur* National workshop on "Analytical Phytopharmaceutical Chemistry by High Performance Liquid Chromatography - Mass spectroscopy". Sponsored by Sophisticated Analytical Instrument Facility (SAIF) Central Drug Research Institute (CDRI) Lucknow. Workshop on "Microbial identification and preservation" sponsored by National Centre for Microbial Resources (NCMR) Pune. Workshop on "Microbial genomics" sponsored by National Centre for Microbial Resources

			(NCMR) Pune.
14.	No. of Trainings participated:	*02*	1. WEAP model training at National Institute of Hydrology, Delhi Unit, New Delhi. "Numerical Climate Prediction" at NIT Warangal during 18-29 June, 2018
15.	Technical/ Training Manuals prepared:	-	-
	Others (if any):	-	-

***** Please attach the soft copies of supporting documents word files and data files in excel.

8. Knowledge Products and Publications*

S. No.	Publication/ Knowledge Products	*Number*		*Total Impact Factor*	*Remarks/* Enclosures**
		National	International		
1.	Journal Research Articles/ Special Issue (Peer-reviewed/ Google Scholar)	5	12	**3.007+ 19.040**	
2.	Book Chapter(s)/ Books:	-	-	-	
3.	Technical Reports/ Popular Articles	01	-	-	xksLkkoh oS. dqekjh i**.** eq[kthZ l**.** ,oa dqekj fd**.** (2018) Hkkjrh; fgeky;h ioZrh; {ks= ds tykxe fodkl ,oa izca/ku esa ^okVj bosSY;w,'k u ,aM lykfuax^ ekWMy dh mi;ksfxrk ,oa v/;;u(Himprabha, 2018
4.	Training Manual (Skill Development/ Capacity Building)	-	-	-	
5.	Papers presented in Conferences/ Seminars	12	4	-	**Internationa l** World Conference on Applied Science,

S. No.	Publication/ Knowledge Products	*Number*		*Total Impact Factor*	*Remarks/* Enclosures**
		National	International		
					Engineering). 8th Congress of European Microbiologist (FEMS 2019) **Gosavi, V. E.,** Kumari, P., Mukherjee, S. and Kumar, K. (2017). Customization of WEAP model: A case study for an assessment of climate change impacts on water supply and demands in Mohal khad watershed of Kullu district, Himachal Pradesh. In National Conference on Natural Resources and Environmental issues, organized by Dept. of Geography, Govt. College Kullu, Himachal Pradesh, during 28 – 29 Dec. 2017, Kullu, Himachal

S. No.	Publication/ Knowledge Products	*Number*		*Total Impact Factor*	*Remarks/* Enclosures**
		National	International		
					Pradesh, India.
6.	Policy Drafts (if any)	-	-	-	-
7.	Others (specify)	-	-	-	

9. Recommendation on Utility of Research Findings, Replicability and Exit Strategy

9.1 Utility of the Fellowship Findings

S. No.	*Research Questions Addressed*	*Succinct Answers (within 150–200 words)*
1.	**HRA001** **1.** What factors explain the diversity of management systems and practices in an area? **2.** What tenurial arrangements, policies and governance systems are in place for conserving and promoting trade of NTFPs?	Identification of different NTFPs collected from forests there used by people of the Himachal Pradesh influence both their dynamics and sustainability. This means that the concept of sustainable forest management should incorporate the notion that not only the ecological integrity and social functions of forests should be maintained, but also the indigenous ingenuity and creativity in conserving, enriching or even reconstructing forests. NTFP use, management and trade depend upon a myriad of complex and locally specific ecological, conomic, social, political and cultural factors, a patchwork of local measures may work best for formalization. Policy arrangements incorporating property rights and tenurial arrangements continue to evolve especially within the common's sector. Regions where such arrangements are lacking and where government support is poor, the resource are faced with unsustainable extraction and even thefts. Depending on the traditional access and use arrangements of these resources(or customary rules), statutory rules be put in place such that feeling of ownership is felt which in turn will ensure better management, enforcement of rules and protection of resources, simultaneously maximizing benefits from trade. The Forest Rights Act in India indicates steps in the right direction but its implications on different stakeholders are still under scrutiny.
2.	**HRA002** 1. What is the present water quality standard of the surface as well as underground water?	1. Addressing the research question for the springs of Almora were studied and the water quality index of the springs was calculated to study the water quality situation of the springs. Contamination of

	2. The variations in the water quality standards in Pre as well as Post monsoon period	groundwater with nitrate is a persistent problem especially in areas with intensive agricultural land use, and identifying the sources of nitrate is the first step to reducing groundwater pollution with nitrate. 2. The variations of the water quality of the springs were summarized for the pre and post monsoon season and the comparative analysis of the sample water was done to study the current water quality status. Nutrient pollution in ground water as well as surface waters which is used as drinking water source can be harmful, even at low levels. Infants are vulnerable to a nitrogen-based compound called nitrates in drinking water. Hence the water quality assessment of the basin will help in predicting the future of the water quality as well as help in taking the precautionary step to maintain the serenity and piousness of the water.
3.	**HRA003** **1.** What data exists on Himalayan biodiversity and climate change? **2.** How to collect, collate and analysis existing data? **3.** What could be various mechanism of communicating information to diverse stakeholders? **4.** What kind of policy prescriptions can be brought out from existing Knowledge? **5.** How to promote awareness of diverse stakeholders on knowledge network?	**1.** The preliminary database on various components of Himalayan Biodiversity and Climate Change have been collected and analyses in terms of objectives, methodology adopted, key findings etc. **2.** The Himalayan Biodiversity and Climate Change- Knowledge Network (HBCC-KN) web portal has been developed and tested on different platform for its functioning. This knowledge network web portal can now be shared and popularize among different stakeholders of IHR for knowledge flow and sustainability.
4.	**HJRF001** 1. How can numerical modeling of natural hydrological processes of sub-watershed of central Himalaya achieved? **2.** What happens to numerical modeling of water resources and their allocation when anthropogenic activities are superimposed over the natural system of the study watershed?	1. The numerical modeling of natural hydrological processes of Mohal khad and Upper Kosi watersheds were achieved using available datasets from primary and secondary sources, future climate data (2015-2030) of GCM GFDL-ESM2M under RCP 4.5 and some model based scientific assumptions in Water Evaluation and Planning (WEAP) based modelling framework. 2. Using future climatic data series for superimposing on natural system, WEAP simulation modeling gives the probable futuristic water demand and supply scenarios for the study watersheds.

		3. 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. Gives out opportunity to carry out interventions related to water harvesting by giving overall scenario of water availability through rainfall, run off and groundwater flow within the watershed.
5.	**HJRF002** 1. What area the Impacts of climate change on apple production in the study area?	1. Hill farmers are steadily moving towards other options, particularly in low and mid altitude (1,200-1,800 meters) in Kullu district. Apple farmers in Kullu valley are growing pomegranate, kiwi and vegetables such as tomato, peas, cauliflower, cabbage and broccoli. Apples can be grown at altitudes 1,500 to 2,700 meters above mean sea level in the Himalayan range which provides 1,000 to 1,600 hours of chilling necessary for production of good quality apples. As the region experiences warmer winters and erratic snowfall, the apple growing belt – known as apple line- is shifting to higher altitudes. A warmer winter in lower elevations has resulted into shifting of apple to higher elevations.
6.	**HJRF004** 1. Does any such practice exist or any state has a role model to combat the challenges of clean energy and saving ecosystem health? 2. Whether such practice can be adopted in the Indian Himalayan Region? **3.** Is existing legal framework sufficient to address variability in different states of the Indian Himalayan Region?	1. Yes, several practices related to clean energy production and consumption exist in not only the Indian Himalayan States but also throughout the country. For example, Lossar village in Spiti Valley of Himachal Pradesh is entirely dependent on the solar plant, located in the vicinity of the village itself for all their energy needs and the people of the village have been trained to perform repairs/maintenance of the plant. 2. Yes, several of these practices can be adopted in the Indian Himalayan Region like roof-top solar photo-voltaic plants, micro hydro power plants, roof-top wind energy panels, etc. 3. No, the legal framework is not sufficient to address variability in different states of the IHR because all of these states have multiple renewable energy sources with different potential. For example, Jammu and Kashmir has abundant solar energy potential and therefore the focus of the legislative framework should be greater for developing solar energy as compared to other sources of renewable energy.

		Also, there is a large number of remote villages in this state and hence instead of developing policies to transmit energy, legislative framework should be provided that will help in generation of power within the village itself in order to reduce Transmission and Distribution losses.
7.	**HJRF005** What are the causes of weakening traditional livelihood?	1. Traditional livelihood system is complex form of various practices, which is govern by the natural resources, but the resources are getting limited and population is continuously increases so that the rural areas are facing new challenges towards the generation of livelihood, thus the best option they have seems is going to new places and seeking the some kind of job and employment there. A total of 13 such issues were reported by the villagers those are directly affecting the traditional livelihood practices.
8.	**HJRF006** 1. Plant-microbe interaction in *Taxus wallichiana* root? 2.Biotechnological applications of isolated endophytes?	1. There are good leads in terms of biodiversity of endophytic microbes (bacteria and fungi) in the root of *T. wallichiana*. 2. Isolated endophytes have good PGP activity with specific references to phosphate solubilization and biocontrol activities.
9.	**HJRF007** 1. Web Based Information System	1. The present study is the result of implementation of this software in the village Darimkhola (Distt. Almora), which will further be projected for a cluster of nearby villages as pilot study. Its successful implementation will make it very easier for the policy makers to access data very easily and quickly & frame the policies accordingly, which will in turn be very helpful for rural development. This application could further be carried forward for implementation in other villages, progressing towards in district and state level, resulting in enhancement and development of villages and ultimately the nation.
10.	**HJRF008** **1.** Assessment and quantification of provisioning services provided by potential wild bio-resources **2.** Contribution and role of wild bio-resources as	1. The selected wild bio-resources were divided into three categories based on their availability in nature and economic such as (i). High value low volume, (ii). Low value and high volume (iii). Low value low volume. 2. The total value of the ecosystem services

	provisioning services in village economy and livelihood.	provided by the sixteen wild bio-resources in terms of provisioning services as monetary equivalent estimated ranging from Rs. 1.03 - 6.38 crore/year.
11.	**HJRF10** Suitable method of extraction Quantification of high value compounds Demonstration at diverse localities Options for Sustainable Use	1. For the classical or conventional extraction, methanol and ethanol have shown better extractability of the phytochemical contents in all the three species of Zingiberaceae family. Further, the antimicrobial activities, was found higher in alcoholic solvents 2. The identified and quantified compounds may be optimized through different green extraction technologies for higher yield and separation of value-added chemicals 3. The plant species of Zingiberaceae family can be cultivated at larger scale in diverse environmental conditions. 4. Large scale cultivation would require for conservation of the species which can fulfill the market demand of raw material and provide livelihood options.

9.2 Recommendations on Replicability and Exit Strategy:

Particulars	Recommendations

Replicability of Fellowship, if any	**HRA001:** Similar initiatives can betake up across other States of IHR as the demand of NTFPs and NTFPs based products is growing continuously. The mapping of such resources would help us in delineation of planning and programmes for conservation and sustainable utilization and generating new livelihood avenues. **HRA002:** The scale of the project is confined to a spring-fed river Kosi, which fulfils the demands of people living in its course as well as serve as a lifeline support system of a populous hill town of Almora. Similar research investigations across major spring-fed river systems of mid – Himalayan region would help in understanding the water quality, supply and demand scenario of sprawling urban centres of the region. **HRA003:** The established network can be further strengthened by integrating information on other aspects of IHR, such as agriculture, water resources, demography, etc., to draw planning based inferences. **HJRF001:** The output of this study may be used by line department or relevant stakeholders to implement groundwater recharge activities, creation of water storage structures, water allocation or for effective water management to satisfy the unmet water demands domestic use, livestock, and implementing effective agriculture practices; considering the available water or predicted dry or wet years in future. **HJRF002:** Apple is one of the important cash crops across the horticulture landscape in J&K, Himachal, Uttarakhand and few NR states. The results of the study highlighted the climate sensitivity of the crop and impact on productivity. The fellowship can be replicated further by examining the impact of CC on other temperate crops to develop appropriate strategies for long term sustainability of the horticulture sector. **HJRF004:** Similar initiatives could be under taken across the States of India union for mapping of renewable energy potential and subsequently delineating policy recommendation for providing affordable options to adopt renewable energy alternatives. **HJRF005:** Being a pilot study the project has immense possibilities of developing village information system (VIS) across the country for instant availability of information on different aspects necessary for development of village specific planning and programmes. **HJRF006:** Understanding of plant microbe interaction particularly of highly value and threatened medicinal plants is essential for developing propogation protocols and strengthening conservation efforts. **HJRF007:** Identification of causes detrimental to traditional livelihoods is crucial for devising ways to either reorient or innovate ways for sustaining themselves. Such projects always have potential across IHR where communities have been living in diverse and traditional setups. **HJRF008:** Up-scaling such valuations across IHR would help in mapping extent and market potential of wild bio-resources. **HJRF10:** The variation in bioactive compounds in different climatic conditions, soil type, and altitudinal gradient may be studied for production of quality plant materials.

Exit Strategy:	**HRA001:** The present outcomes could serve a valuable baseline for undertaking similar or region specific R&D programmes. It also helps in understanding the existing value chain and its associated constraints to regularize its trade and bringing them in the ambit of access and benefit sharing mechanism. **HRA002:** The generated information could be helpful in taking up preventive measures for rejuvenation and further contamination of traditional water springs (naulas). As highlighted in the recommendations, setting up of sewage treatment plan would be prioritized in future development planning of the town. **HRA003:** The outputs of the fellowship in term of a developed Knowledge network can be turned into knowledge sharing platform for strengthening biodiversity conservation measures and delineating CC adaption strategies. **HJRF001:** Present study or modelling framework may be used in the future studies to carry out site specific and demand driven or Purpose Driven Studies (PDS) in the other Himalayan river basins for the best water management in the context of changing hydrological, climatological and land resources regime. **HJRF002:** The present work on air pollution is conducted in topographically fragile and ecologically delicate environment of the mountainous topography of the Himalaya. This work can create awareness among the local community as well as strengthen the knowledge of worldwide community. The present work has also much concern for the researchers who are dealing with the similar studies. Moreover, this work may also be used by the state and central governments as the guidelines for the framework and development of policies and plans. The policy implications may have long-term benefits in mitigating environmental pollutions and continuing sustainable development process in the mountain ecosystem. **HJRF004:** The recommendation of the study can assist in reorienting the existing policy regime and could enhance the possibilities of switching towards more eco-friendly options of energy consumption. **HJRF005:** The developed VIS would assist the local governing body (village panchayat) for prioritizing local issues and develop proposal to get financial assistance from line departments. **HJRF006:** The conclusion of the study would be usable for R&D extension activities and optimizing the extraction protocols for pharmaceutical industrial use. **HJRF007:** Land abatement and out migration have been emerged as major phenomena across the study sites and need policy amendments. **HJRF008:** As recommended, regularizing its trade by developing people centric policies and minimizing the role of middle men are needed. **HJRF010:** A deeper study on isolation of important bioactive compounds through green processing technology focusing on antimicrobial, anti-cancerous, and antidiabetic agents would definitely increase the market value of the species.

(**NMHS FELLOWSHIP COORDINATOR**)

(Signed and Stamped)

(**HEAD OF THE INSTITUTION**)

(Signed and Stamped)

Place: ……..
Date: …../……/……..

PART B: COMPREHENSIVE REPORT (including all sanctioned positions of Researchers)

Based on the Fellowship Proposal submitted/approved at the time of sanction, the co-ordinating Principal Investigator shall submit a comprehensive report including report of all individual researchers.

The comprehensive report shall include an **Executive Summary** and it should have separate chapters on (1) **Introduction** (2) **Methodologies, Strategy and Approach** (3) **Key Findings and Results** (4) **Overall Achievements** (5) **Impacts of Fellowship in IHR** (6) **Exit Strategy and Sustainability** (7) **References/ Bibliography** and (8) **Acknowledgements** (It should have a mention of financial grant from the NMHS, MoEF&CC).

Further, description of Technical Activities, List of Trainings/ Workshops/ Seminars with details of trained resources, list of New Products developed under the fellowship, Manual of Standard Operating Procedures (SOPs) developed, Technology developed/Transferred etc should be enclosed as Appendix.

Report (hard copy) should be submitted to:

Er. Kireet Kumar
Scientist 'G' and Nodal Officer, NMHS-PMU
National Mission on Himalayan Studies (NMHS)
G.B. Pant National Institute of Himalayan Environment (GBP NIHE)
Kosi-Katarmal, Almora 263643, Uttarakhand

Report (soft copy) should be submitted at:

E-mail: nmhspmu2016@gmail.com; kireet@gbpihed.nic.in; kodali.rk@gov.in

PART B: COMPREHENSIVE REPORT

EXECUTIVE SUMMARY

The Executive Summary of the fellowship should not be more than 3–5 pages, covering all essential features in precise and concise manner as stated in Part A (Cumulative Fellowship Summary Report) and Part B (Comprehensive Report).

Fellowship Report No.: ***n of N*** *(n = Sequential number; N= Total no. of fellowships granted to the Institute/ University)*

Researchers Details

Type of Fellowship (HRA/HJRF/HJPF)	Name of Himalayan Researcher	Date of Joining	Date of Resignation**	Research Title
HRA001	Dr. Haseeb Massodi	26-12-2016	31.3.2020	Study and Quantification of Non-timber Forest Products (NTFPs) and related value chains from the Western Himalaya'
HRA002	Ms. Pooja Rani	03.03.2017	31.3.2020	Water Quality analysis emphasizing on nitrate nutrient dynamics using WASP model in Kosi Watershed
HRA003	Dr. Tarun Belval Dr. Shashi Upadhayay	09.02.2017 01.04.2019	 31.3.2020	Establishing the knowledge network through scientific as well as evidence based research on biodiversity and climate change in Indian Himalayan Region (IHR)
HJRF001	Mrs. Pratibha Kumari Mr. Rajat	17.10.2016 17.01.2019	25.09.2018 22.10.2019	Exploring immediate to medium to long term societal implications of changing hydrological and land resources of a central Himalayan watershed
HJRF002	Mr. Neetu Ram Ms. Shilpa Thakur Mr. Bheem Chand	16-08-2016 16-10-2017 16.01.2019	9.08.2017 31.09.2018 31.03.2020	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
HJRF004	Ms. Saakshi Chauhan	26-09-2016	31.03.2020	Sustainable and Clean Energy in the Indian Himalayan Region
HJRF005	Ms. Deepika	21-11-2016	31.03.2020	Development of Village

	Bisht			Information System (VIS) for Management & Planning of Rural Areas for Sustainable Development
HJRF006	Ms. Priyanka Adhikari	08-07-2016	31.03.2020	Plant microbe interaction in *Taxus wallichiana*
HJRF007	Mr. Visleshwar	21-10-2016	31.03.2020	Weakening of traditional livelihood in the mountain
HJRF008	Mr. Tribhuwan Singh Rana	08-02-2017	31.03.2020	Valuation of wild bio-resources as provisioning services from forest ecosystem: A case study of Chamoli district, central Himalaya, Uttarakhand
HJRF010	Ms. Yumge Yomgam Mr. Khyoda Rajan Ms. Millo Napi	11-01-2017 13/10/2017 26/11/2018	06/06/2017 20-08-2017 31/03/2020	Assessment of biochemical and phytochemical content of selected threatened and high value plants with diverse environmental conditions
(*in case of continuation of fellowship*)				

*If the appointed researcher resigned in the mid of the fellowship duration, then also mention the name of the Himalayan researcher who carried forward the fellowship.

HRA002: The study of this project is an attempt to understand the water quality of the region. The region is blessed to have underground water as springs in the region. These springs are the only source of water in the region. Groundwater is fresh water (from rain or melting ice and snow) that soaks into the soil and is stored in the tiny spaces (pores) between rocks and particles of soil. Groundwater accounts for nearly 95 percent of the nation's fresh water resources. It can stay underground for hundreds of thousands of years, or it can come to the surface and help to fill Rivers, streams, lakes, ponds, and wetlands. Groundwater can also come to the surface as a spring or be pumped from a well. Both of these are common ways we get groundwater to drink. About 50 percent of our municipal, domestic, and agricultural water supply is groundwater.

Mountainous terrain occupies 20% of the earth's land surface yet little is known of the details of groundwater flow at depth within a mountain massif. Furthermore, mountainous regions promote deep circulation of groundwater, denying access to groundwater outcrops that aid in regional investigation. A further complication arises because mountainous regions are frequently fractured and may be in an active state of compression or extension, suggesting that fracture apertures may be functionally related to the state of stress in the earth's crust. Thus, the elevation of the water table may be intimately related to a changing hydraulic conductivity of the region and the variable climatic factors that influence infiltration. For a given hydraulic conductivity distribution, the lower the infiltration rate, as controlled by climatic

factors, the deeper the water table (GROUNDWATER – Vol. I – Groundwater in Mountain Regions - Gárfias J.).

The study deals with water quality of the region. The project is divided into 4 major objectives
1) The first objective is to see the contamination of the springs in Almora for the physicochemical parameters and to compare it with the study parameters from 1991 and 2017/18.
2) The second objective is to study the surface water quality and for the 31 sampling points from the origination of the springs.
3) The surface water quality datas is fed to WASP model to see the water quality prediction in the region.
4) To suggest the mitigation measures for conserving the water quality of the region.

HJRF002: The present study deals with ambient air quality and long term climatic variable assessment in and around Apple orchards in Kullu valley. Kullu is a broad open valley formed by the Beas River between Manali and Larji. This valley is famous for its temples, beauty and its majestic hills covered with Pine and Deodar Forest and sprawling Apple Orchards. Ambient air quality were monitored at Mohal at the altitude of 1146 m, Kothi (2500m), Beasar (control site) at the altitude of 2181 m and Raison at the altitude of 1359 m. The mountain ecosystem is one of the most vulnerable ecosystems to the climate change and so are the mountain communities, especially those mainly depend on animal husbandry, marginal agriculture and horticulture products. The Himalayan mountain ecosystem, at present, is facing the challenges created due to increasing aridity, warmer winter season, variability in precipitation, and unexpected frosts and storms (Renton 2009; Dash and Hunt 2007) which largely affects the entire range of biodiversity, including agriculture and horticulture crops (Renton 2009; Kala 2013). The main aim of this study was to know the status and source of particulate pollutants and their impacts on apple orchards. Climate is an important environmental variable factor affecting the production of fruit crops. The distribution of fruit crops in Himachal Pradesh is influenced mainly by climate rather than any other factor (Asghar et al. 2012). The study reveals that, particulate pollution is high at Mohal and Raison as compared to Beasar control site. Because the Mohal and Raison are nearby National Highway (NH_3); so here the pollutants level is higher compared to the control site. The concentration of PM_{10} at Mohal and Raison has crossed the permissible limit (100 µg m^{-3}) prescribed by NAAQS. However, it is noted that except for the winter season at Mohal the concentration of $PM_{2.5}$ at study sites were well within the permissible limit set by NAAQS. It is also made clear from HYSPLIT and CALIPSO analysis that the local source of pollutants are also contributing the air pollution. The AQI study reveals that air quality of Mohal falls under good to moderate category. However, PM_{10} was observed beyond its permissible limit during spring season when flowering in apple orchards are at peak, which might not be so good from viewpoint of apple orchards. The maximum precipitation was recorded during 1988 and minimum was during 2009. Precipitation is decreasing at the rate of 4.3 mm / year. The maximum temperature has been increasing at the rate of 0.07^0 C per year, which is pointing towards climate change. Chilling hours are also decreasing every year which has direct impacts on apple production and diseases have also increased in apple orchards. Therefore, the apple orchard has been shifting from lower region to higher regions in the Kullu valley.

HJRF008: Ecosystems are assets that provide a broad range of services and generally classified into provisioning services (food and water), regulating services (regulation of food, diseases and drought), cultural services (spiritual, religious and recreational) and supporting services (soil formation and nutrient cycling). Among four types of services, provisioning services contribute directly to livelihoods and the economy of the local people. Himalayan ecosystems are particularly significant as they offer critical goods and services both upstream and downstream communities. To understand the actual value of services provided by forest ecosystem and to assess their linkages with human well-being, it is important to have the detail information about the availability, current status and economic value of the diverse resources. The main objective of this study was the valuation of important wild bio-resources and their role in livelihood and socio-economic development in four village clusters of Chamoli district of Uttarakhand. The result of the present study brought into light that the most of the forest bio-resources

have an auspicious economic potential in livelihood enhancement since they possess unique food, nutrition, medicinal and nutraceutical values. Forest bio-resources such as wild edibles and spices i.e. *Morchella esculenta, Sassurea costus, Ophiocordyceps sinensis*, Jhula (lichen) and Moss contribute about 34.12± crore /year to the economy of local people. The rising bio-resource prices can have a variety of ecological consequences, including resource depletion and threat to in biodiversity and changes in resource availability and quality.

1 INTRODUCTION

1.1 Background/ Summary of the Associateship / Fellowship Study undertaken (max. 500 words)

HRA001: The contribution of forests to food security, nutrition, community health, energy, employment and in tackling climate change is clearly recognized at international, national and local levels, namely in the Sustainable Development Goals and the Paris Agreement. The socioeconomic benefits of forests, including the role of non-timber forest products (NTFPs) for generating income, food and nutritional security, basic human needs, and improving quality of life were recently documented by FAO in the State of World's Forest 2014 report (SOFO 2014). The report estimates that NWFPs generated US$88 billion in 2011, that about 76 million tonnes of food from the forest were consumed on average in the same year. Moreover, the report suggests that forest products contribute to the provision of shelter for about 1.3 billion people and to human health through the use of medicinal plants that originated in forests. WHO (2002) estimates, in addition, that in 2011 around 2.8 billion people in China, India and Africa used traditional medicines, many of which originated in forests. It is estimated that of the 6.2 billion people on the planet, 25 percent depend to varying degrees on the forest's resources for their livelihood and 350 million people living in or near dense forest depend highly on them for their subsistence or livelihood (Killman, 2003). Some 80 percent of the people living in developing countries depend on non-timber forest products, such as fruits and herbs, for their primary health and nutritional needs (FAO, 2008; www.agroforestry.net). The most used categories of NTFPs are medicine, edible, miscellaneous and fuel wood (Bouri and Mukharjee, 2013). The Indian Himalayan Region (IHR) is a mega hot spot of biological diversity (Myers, 2000). It comprises about 18% of India, is more than 2,800 km long and 220 to 300 km wide, with altitudes from 200–8000 m (Anonymous, 1992). The flora includes about 8,000 species of angiosperm (40% endemic), 44 species of gymnosperm (16% endemic), 600 species of pteridophyte (25% endemic), 1,737 species of bryophyte (33% endemic), 1,159 species of lichen (11% endemic) and 6,900 species of fungi (27% endemic) (Singh and Hajra 1996; Samant *et al*., 1998). These include some 1748 species of medicinal plant with various traditional and modern therapeutic uses (Samant *et al*., 1998), 675 species of wild edible plants (Samant and Dhar 1997), 118 species of medicinal plants yielding essential oils, 279 species of fodder, 155 sacred plants (Samant and Pant 2003) and 121 rare-endangered plants (Nayar and Sastry, 1987, 1988, 1990). Non-timber forest products (NTFPs) such as nuts, mushrooms, herbs, spices, aromatic plants and game have been used for food, health and cultural purposes for millennia, yet there is a tendency to underestimate their role because they are poorly represented in international statistics, as in most cases their use and trade are confined to the informal sector. Recent studies show that NTFPs still form the basis of lives and livelihoods in many parts of the world and play a much more significant role in food and nutritional (FAO, 2016; Rowland *et al.,* 2016; Ickowitz *et al.,* 2014). Non-Timber Forest Products (NTFPs), in addition to forming an important resource base for a variety of industrial products, play a very significant role in the local rural livelihoods. Himachal Pradesh is privileged in having a bountiful of this Nature's gift, which is housed in its varied forests spread across its four major agro-climatic zones. The role the NTFPs play in the day today life of the people of the state, whether in the form of household use or as a source of cash income, is well appreciated. However, the degradation of natural habitats of the NTFPs due to biotic and developmental pressures has put this invaluable resource under threat. The immediate constituency to suffer due to such degradation is the rural poor, who have to spend increasingly more time for wild collections. The present study is taken up with focus to support the sustenance and enhancement of the ecological, natural, cultural, and socio- economic capital assets and values of the IHR.

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

HRA003: The Himalaya is an ecologically important mountain chain system as it provides a wide range of ecosystem services for inhabitants (Rasul 2014; Badola et al. 2015; Chakraborty et al. 2016, 2017) and known for their diverse topography, climate, community, culture, traditions and mainly for their biodiversity. Inhabitants of Himalaya are directly or indirectly depend on the natural resources for their livelihood (Tiwari & Joshi 2015). Dependency on natural resources and other anthropogenic activities, creates a number of environmental issues such as rapid change in climatic conditions over the world. Hence, many biodiversity has been extinct or threatened due to changing in climatic conditions. The mountain chain system of Himalaya is not virgin by the impact of climate change, and it is vulnerable to climate change which is a critical condition for inhabitants of Himalaya (Xu et al. 2009). Still, this region has not been fully explored and data deficient in context of impact of climate change on biodiversity. To some extent, after the fifth assessment report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) which was focussed on the threats to the Himalayan region, scientists have been started to working on that. In this context, importance of biodiversity for human survival is becoming a major international issue with climate change. However, the studies pertaining to these issues are in underexplored condition till date. The Himalaya has been considered as data deficient regarding biodiversity and climate change, and networking among stakeholders of Himalaya is lacking (Singh & Thadani 2015). Various biodiversity and climate change related knowledge network have been developed throughout the World (i.e. biodiversity system information for Europe, knowledge network for biodiversity, biodiversity knowledge Europe, Canadian biodiversity information facility and global biodiversity information facility), however, no such knowledge network has been developed specifically for Himalayan region, which is the need of the hour (Singh & Thadani 2015).

HJRF001: Water demand and supply is one of the most important topic of discussion at present. Increasing population, changing hydrological regime, change in land use, industrialization, and climate change has drawn heavily on water resource system and have many immediate to long term societal implications in the Indian Himalayan Region (IHR). This challenges the water practitioners and planners to frame a sustainable water resource management plan that can cater the demand of water among the population, agriculture, livestock, industry as well as of the ecosystem. This needs the new versatile assessment tools which will evaluate the water resource system and help managers to make a comprehensive water management plan. Present study demonstrated the application of Water Evaluation and Planning (WEAP) model in Mohal khad watershed located in Kullu district of Himachal Pradesh, and Upper Kosi watershed in Almora district of Uttarakhand. An attempt has been made to customize and demonstrate the capability of WEAP model using available datasets from primary and secondary sources, future climate data (2015-2030) of GCM GFDL-ESM2M under RCP 4.5 and some model based scientific assumptions in Water Evaluation and Planning (WEAP) based modelling framework. The model is applied to evaluate and analyze the existing and future water balance and possible impacts on the water demands and supply in the watershed. We generated the trends of water demand and supply as well as the scenarios for water resources management till year 2030. In this first ever attempt of customization of WEAP model in Himachal Pradesh and Uttarakhand for respective watersheds, it was found that WEAP model performs satisfactorily with few exceptions and able to simulate the climatic variation and corresponding water supply and demands of different sectors in context of climate change.

HJRF002: The mountain ecosystem is one of the most vulnerable ecosystems to the climate change and so are the mountain communities, especially those mainly depend on animal husbandry, marginal agriculture and horticulture products. The Himalayan mountain ecosystem, at present, is facing the challenges created due to increasing aridity, warmer winter season, variability in precipitation, and

unexpected frosts and storms (Renton 2009; Dash and Hunt 2007) which largely affect the entire range of biodiversity, including agriculture and horticulture crops (Renton 2009; Kala 2013). Though, the Himalaya harbors rich biodiversity and is one of the most vulnerable mountain ecosystems to climate change (Xu et al. 2009; Bawa et al. 2010), there is paucity of systematic analysis of climate change and its impacts on the Himalayan ecosystems, biodiversity and local people's livelihoods (Shrestha et al. 2012). Farmers of Indian Himalayan region grow many fruit crops, including pomes (apple and pear) and stone fruits (peach, plum, apricot and cherry) in considerable quantity (Ghosh et al. 1999) however apple has the preference over all other horticultural crops (Kala 2007). The main aim of this study was to know the status and source of particulate pollutants and their impacts on apple orchards. Climate is an important environmental variable factor affecting the production of fruit crops. The distribution of fruit crops in Himachal Pradesh is influenced mainly by climate rather than any other factor (Asghar et al. 2012).

HJRF005: India is a country of villages, as 68.84% of the country's population reside in rural areas, which make India, the biggest nation of villages in the world. So the development of villages becomes an important and integral part for the efficient development of the country. Village Information System (VIS) is a gateway towards it. Realizing the importance of rural development, the Institute is going to develop a web based online application called, Village Information System (VIS). In VIS, management of village related information takes place in a technological environment. This application enables global availability of rural information in a single platform, which will help in multi-dimensional development of the villages. It will help the rural planners, district administration and policy makers for the planning & implementation of various existing and upcoming plans for rural development and quick decision making on one hand. On the other hand, it will help villagers and stakeholders by providing details and updating them with every government related scheme. So, the villagers will be able to know about the various schemes initiated by the state and central government. They will be able to identify all the constraints and benefits of the schemes and could be benefitted accordingly. For the development of the country, the development of villages / rural areas is must. For the development of villages to be successful, complete data related to every aspect of village should be available. Most of the information regarding the villages is available in manual form. Most of the information related to villages is available in manual system, which cannot be updated frequently. So, in the absence of updated and accurate information about rural/ village system, government and policymakers feel handicapped in efficient planning, implementation & controlling of govt. schemes. To overcome this, Village Information System (VIS) is being developed as decision support system tool to help policymakers and stake holders. Village Information System (VIS) is the management of village related information in a technological environment. It provides an online database and sharing village level information on census, natural resources, education, employment, social status, health, agriculture, infrastructure, etc. It helps in the analysis of all the above mentioned parameters and their trends in the cluster of villages. Support provision of e-governance services at village, panchayat, block and districts level. It is a bi-directional information system: On the one hand it helps the rural planner for planning & implementation of plans in rural areas and on the other it provides details of various govt. schemes to villagers. It helps in quick decision making to the policymakers by providing information related to every aspect in a single platform.

- To develop a Village Information System (VIS) to support for decision making for villagers.
- To generate database to provide relevant information for villages.
- To build capacity of stack-holders on VIS.

HJRF006: *Taxus wallichiana* Zucc. (English name: Himalayan Yew; Hindi name: Thuner; Family Taxaceae) is a well-known medicinal evergreen tree that grows in temperate forests of Indian Himalaya. In the Indian subcontinent, the species grows in the northern hemisphere with its distribution in the hills of northern Jammu & Kashmir, Himachal Pradesh, Uttarakhand and the states in northeast namely Sikkim, Meghalaya, Nagaland and Manipur, at an altitude range of 1800-3300 m asl. The species has received considerable attention on account of its existing exploitation of bark for the extraction of the drug taxol (Juyal et al., 2014). *T. wallichiana* is also known for its various ethnomedicinal uses such as the leaf paste is used in treatment of asthma and bronchial disorders. Tea, made out of the stem bark of

Himalayan yew, has been popular in Himalayan tribal communities for curing cold, cough and hypertension (Sharma & Garg, 2015; Juyal et al., 2014). Beneficial associations, between endophytes and medicinal plants, is an emerging topic in plant microbe-interaction research (Singh and Pandey, 2017). Endophytic microorganisms, by developing symbiotic association with plants, play important role in plant growth. Endophytic microbes contribute to the plant growth, and also provides resistance to the plant against a range of biotic and abiotic stresses. In plant-microbe association, the bacterial endophytes that colonize the internal tissues of plants are being recognized for their benefits through direct as well as indirect mechanisms. The direct mechanisms involve nitrogen fixation, phosphate solubilization, and IAA production, while in case of indirect mechanisms the endophytes provide defense against pathogen attacks by producing diffusible and volatile antimicrobials, siderophores, ammonia, HCN, and the lytic enzymes (Santoyo et al., 2016). *T. wallichiana* is also known as source of antioxidants (Milutinovic et al., 2015). However, *T. wallichiana* is still needs to be highlighted for its antimicrobial potential. Now a days microbes derived antibiotics initiate resistance phenomenon and side effects which suggest the need for alternate sources for combating the infectious diseases. In this perspective, plant-based antimicrobials are increasingly receiving attention for harnessing their potential in production of antimicrobial substance as safer source of antibiotics (Pandey and Agnihotri, 2015). Considering these two points, proposed objective of the fellowship are:

i): Diversity of endophytic microorganisms associated with *Taxus wallichiana* roots and their biotechnological applications.

- Colonization of *Taxus* w*allichiana* roots by endophytic microorganisms.
- Isolation of culturable endophytes (bacteria and fungi).
- Characterization and identification of cultured endophytes following polyphasic approach.
- Quantitative estimation of plant growth promotion activities of endophytic fungi with particular reference to phosphate solubilization.

ii): Evaluation of bioactive compounds of *Taxus wallichiana* with particular reference to antimicrobial activity (bacteria, actinobacteria and fungi, in particular).

- Optimization of solvents and extraction method.
- Qualitative and Quantitative analysis of antimicrobial properties of *T. wallichiana* needle, stem and bark.
- *S*eparation and screening of antimicrobial compounds and identification of isolated compounds

HJRF007: Uttarakhand has a geographical inequality between the hills and the plains that divides the state critically. The Uttarakhand is one of the Himalayan states." 92.6% of the state is covered by the mountains and 7.4% is tarai plains, the entire region is geographically important and is comprised of the two landscapes, i.e., the Garhwal and Kumaon Himalayas. The Uttarakhand Himalaya characterized by dominance of subsistence cereal crops. It is also a main source of livelihood." (Sati & Singh, 2010).The traditional livelihood practices in the Uttarakhand Himalaya are Agriculture, Livestock, Horticulture and the Forest product gathering. The resources available for the all livelihood practices are landholdings, water, forests and community land. Climate is a natural factor that is affected resources as well as the livelihood practices. However, the land holdings are small and fragmented, and irrigation facilities limited. Soil and water conservation is another issue for inclusive development. For physical, geographical and environmental reasons, the scope for agricultural policies based on modern input-intensive agriculture is severely constrained in the hill regions. As a result, the majority of the rural population in the hills either survives on subsistence agriculture or migrates to other parts of the country for employment. The state faces the challenge of promoting livelihoods to retain people through local employment and income generation and to enhance their quality of life. At the same time, the hill districts of Uttarakhand have tremendous potential. The vast natural resources add to the state's attractiveness as an investment destination, especially for tourism and agriculture- and forest-based industries. Uttarakhand is the first state in the country to have created a Tourism Development Board by legislation. This study is aims to identify the responsible causes for deteriorating traditional livelihood

system, and looking for possible livelihood options that can sustain in the rural mountain to control the rural out migration and suggest better livelihood opportunity for stakeholders.

HJRF008: Ecosystem services, as defined by the Millennium Ecosystem Assessment, are 'the benefits human being obtains from ecosystems' (MA, 2005). The services that ecosystems provide are generally categorized into four types: provisioning services (food and water), regulating services (regulation of flood, drought, diseases), cultural services (recreational, spiritual/religious) and supporting services (soil formation and nutrient cycling). The health of ecosystems and the services provided by them play a crucial role in human survival and wellbeing (Diaz *et. al*., 2018). However, excessive demand for ecosystem services arising from rapidly growing human population and several anthropogenic activities have led to the extensive modification of vital ecosystems of the world (Burkhad *et. al*., 2010).For hundreds and thousands of years, indigenous traditional communities have been utilizing forest products for various purposes i.e. edible, medicinal, food and other purposes and have been considered as the secondary production. Uttarakhand, largely a mountainous state of India, is bestowed with lush green forests, perennial rivers and diversified topography ranging from high alpine glaciers to low-lying plains. The flora and fauna also depict great variations, making it one of the mega reservoirs of biodiversity in the country. The people of this region are well versed with the significance of natural resources and harvest it for meeting the essential livelihood needs.Ongoing development for various purposes in the Himalayan region has resulted in loss of natural capital and is directly responsible for destroying ecosystem services in the long run. The Millennium Ecosystem Assessment (MEA, 2005) highlighted the importance of ecosystem services to human wellbeing and showed that anthropogenic activities have affected the natural process and diminished the capacity to provide services for future in many parts of the world. Furthermore, the United Nations 'Sustainable Development Goals can only be met when ecosystem degradation is halted and further loss of ecosystem services is controlled, and only if the natural capital and assets can be utilized in a sustainable way.In India valuation of ecosystem services is an emerging discipline and has not been comprehensively attempted so far in mountain regions of Uttarakhand except for a few preliminary studies by Maikhuri *et. al*., 2011; Semwal *et. al*. 2007, Singh, D., 2002; Negi and Agarwal (2006); Nautiyal and Nautiyal 2004; Negi et al 2011 and Phondani *et. al.*, (2011). The past decade has witnessed a rapid growth of interest in forest products among conservation and development organizations, in part at least due to the recognition of the contribution that these make to the livelihoods of the marginal communities inhibited in the higher Himalayan region. The present study was undertaken to quantify the prominent wild bio-resources from forest and alpine region by the people of the high Himalayan villages and to estimate their contribution in livelihood enhancement and income generation. Forest products such as Non Timber Forest Products and wild edibles indeed play a very significant role in the rural economy in terms of providing employment, income potential and life support sustenance.

HJRF010: The state of Arunachal Pradesh, in northeast India, occupies a major portion of the Eastern Himalayas and is well-known for its rich bio-cultural diversity. 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 (Haridasan et al. 2003). 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. The beneficial medicinal properties of plants characteristically result from the combination of several compounds present in them. These compounds are mainly secondary metabolites such as alkaloid, tannins, and other phenolic compounds, mostly these phytochemicals serve as plant defense mechanisms against predators and microbes (Reghu et al., 2017). The use of bioactive compounds in different commercial sectors such as pharmaceutical, food and chemical industries signifies the need of the most appropriate and standard method to extract these active components from plant materials (Azmir et al.,2013). Extraction is one of the oldest known chemical operations and represents the key for the recovery and purification of active compounds from plant materials. The purpose of all extraction is to

separate the soluble plant metabolites, leaving behind the insoluble cellular marc (residue). The quality of extraction and specifications like extraction yield and presence of undesired compounds are important factors affecting on the choice of the extraction process, solvents and operational conditions (Ghoreishi et al., 2016). 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.

1.2 Baseline and Scope of the Associateship / Fellowship (max. 1000 words)

HRA001: The baseline of the fellowship was to create a cadre of young and trained Himalayan environmental managers, ecologists and socio-economists and thus help generating information on physical, biological, management and social aspects of Himalayan environment and development. The study provided a comprehensive database that provides baseline information for developing management plans for the conservation of NTFPs and enhancing livelihood of forest dwellers. Focusing on NTFP extraction from natural forests, NTFP exploitation in anthropogenic forest land-use systems policies and NTFP use under changing livelihood conditions. On the basis of this evaluation conclusions was drawn regarding the scope of NTFPs to contribute to improved livelihoods. Due to limited demand and poor infrastructure, trade offers little scope for boosting people's incomes, unless there is an established (export) market. However, the fact that the scope for boosting incomes through commercial extraction of NTFP from natural forests has been found to be relatively low, does not mean that NTFPs do not have any role to play in poverty alleviation. Millions of forest-dwelling people still depend substantially on NTFPs for subsistence, while the sale of forest products may be one of the few opportunities they have of earning an income. Moreover, the option of selling forest products may serve as a means of obtaining money in times of necessity.

HJRF002: Apple farming and its production is directly related to climatic condition of a particular region. At present, the traditional apple farming is under stress due to changes in climate (Basannagari and Kala 2013). Presence of particulate pollutants even in a small quantity can affect the environment by influencing the thermal properties of the environment. Radiative effect is shown by these gases by which they absorb the long wave radiation and reduce the outgoing at the top of atmosphere and this leads to increase in temperature (Wang et al. 1976). Atmospheric pollutants are released into the environment by natural and anthropogenic sources like agricultural, industrial, transportation, residential and natural sources (Barnatrd et al. 2001; Ramathan 2009). Air pollution not only effects the air quality but its acute and chronic effect can create various health problems in human being (Oberdorster et al. 1990). Especially, particulate matter ($PM_{2.5}$) plays foremost role in creating depression, anxiety and many other neurological problems in human being (Calderon et al. 2002; Oberdorster et al. 2004). These particulate matters also affect atmospheric process like reduce visibility, effect precipitation pattern and cloud formation and also plays an important role in making rain, clouds and fog acidic in nature (Celis et al. 2004; Khoder 2002). Gajananda et al. (2005) monitored Total Suspended Particulate (TSP), size-separated atmospheric aerosols and Aitken Nuclei (AN) at Mohal (Kullu) and Manali tourist complex, in the northwestern part of the Himalayas from 1996 and onwards and concluded that level of air pollution is increasing over the sensitive areas of northwestern part of the Himalayas due to high anthropogenic activities. Partap and Partap (2002) studied the various problems concerning apple productivity in apple valleys in Hindu-Kush Himalayas. One of such problems being the climate change. It was concluded in the current study that temperate fruit belt is moving upward and productivity of apple, which is the major fruit crop in Himachal Pradesh, has been adversely affected.

HJRF001: To handle the impacts of climate change or societal implications and to secure the current and future water supply, an integrated water management practices must be adopted (GWP 2007). However, there is a challenge in processing the hydrological and water demand data as well as forecasting the effects of different management strategies under the changing climate (Hollermann et al. 2010). In recent years there has been considerable progress in simulation modeling of hydrological cycle by developing different physical as well as empirical climate and hydrological models at different spatial and temporal

scale. Integrated study of these models helps planners in managing water resources. In the water resources planning and management system, assessment of water availability in the watershed is a basic requirement for watershed conservation. At present, there is inadequacy in developing framework for sustainable management of water resources using scientific solutions that supports the climate change adaptations strategies and development of policies in IHR. With growing attention on sustainable development of water resources, there is a need of assessment tool that can provide a comprehensive, flexible and user-friendly management framework for studying water balance, scenario generation and then by planning and policies making for water management. Water evolution and planning (WEAP) developed by Stockholm environment Institute (SEI) is one such model having Integrated Water Resources Management (IWRM) framework to evaluate planning issues related to water resources. By employing the transparent set of objectives and procedure, and user defined constraints, WEAP can be used in analyzing range of issues and uncertainties faced by water managers that includes climate change, watershed condition, anticipated water demand, need of ecosystem services, operational objectives and infrastructure (Suryawanshi and Shirke, 2014).

HJRF10: The ethnobotanical information serves as a base for new compounds with active principles for phytochemical, pharmacognostical, pharmacological and clinical research (Hussain and Hore 2008). Particularly there is a need of detail study of the medicinal plants used by the community with possible phytochemical investigation which may highlight the true value of these plant species so that they can be managed and conserved for the benefit of the local community as well as for welfare of the mankind (Doley et al., 2010). Ethno-medicinal uses of plants among different tribes of the state had been one of the most researched and documented subject till date. However, very few studies highlighted the associated bioactivity and bioactive compounds present in these plants responsible for effectiveness in curing a particular ailment. Plants act as an attractive source of antimicrobial agents because of the phyto constituents such as Phenolics, alkaloid, tannins and other secondary metabolites which serve as plant defense mechanisms against predators and microbes. Prioritization of medicinal plants based on their phytochemical compounds is likely to direct further selection for prioritization of antimicrobial-rich plants. (Pandey and Agnihotri, 2015; Reghu et al., 2017). The search for antimicrobials from natural sources has received considerable attention and efforts have been put in to identify compounds that can act as suitable antimicrobial agents to replace synthetic ones (Ahmad and Beg, 2001).

1.3 Overview of the Major Issues to be addressed (max. 1000 words)

HRA001: Wild collection:

A large variety of high value NTFPs, including medicinal and aromatic plants, are collected from the wild in Himachal Pradesh. Most of this collection is believed to be exploitative and non-sustainable resulting in negligible returns to the gatherers on one hand and putting the natural resources under tremendous pressure on the other. Some of the reasons for this situation are discussed below:

Un-organised Collection:

Harvest of NTFPs from the wild in the state is an individualistic activity with the focus being ‘to harvest before my neighbour and more than my neighbour’. This situation is perpetuated, as the individuals, usually having taken cash advance from the local commission agent/ trader, are obliged to supply him wild collected NTFPs. This un-organised collection further causes:

- Destructive harvesting, as it is difficult to exercise control.
- Low returns to the collectors, as their bargaining power is compromised.

Authenticity Issues:

Harvest of wild NTFPs suffers from authenticity issues. Many of the collectors are not able to critically identify the target species and in the process also end up collecting similar species resulting in adulteration of material. With higher demands on wild collected material, collection is gradually passing on to hired/ contractual labour that has scanty regard for the authenticity or quality of the material being collected.

Un-scientific Post-Harvest Handling:

Most of the produce collected from the wild needs cleaning, cutting and drying. Not very many households in the state have appropriate facilities to provide good post-harvest handling of the produce. No common facilities for such handling have come up in the villages due mainly to the individualistic way of dealing with the subject. The produce is left to dry on its own and in the process it not only loses its aroma and colour, it also gets infested with fungal attack further reducing its efficacy and quality. It was observed that only 37% of the collected NTFPs was cleaned after harvested.

Lack of Management Control:

The diversity of NTFPs collected from the wild, non-availability of any baseline data about their harvesting potential, non-availability of any field identification guide for their easy identification and lack of trained staff have caused many important NTFP species to become threatened. Most of the harvesting restrictions are on paper only.

Inadequate recognition of the role of NTFPs in local Economy:

The benefits from the NTFPs in the state form a part of life and taken for granted. Their role in the local economy is neither assessed nor taken into consideration. Therefore, the sector as such has lacked desired focus.

Potential and Possibilities of Strengthening NTFP Resource base in the State:

The potential and possibilities of strengthening the NTFP resource base in the state in different situations is discussed below:

Strengthening the NTFP Resource base in the Forests:

With 2/3rd of its areas under forests, the state has a very large potential to strengthen the NTFP resource base in the forests, the largest productive land resource available in the state. Such strengthening is also considered the most effective means of long-term conservation of genetic resources of target species. Each individual wild population of any plant species is assumed to be genetically quite diverse and the sum total of all the wild populations of a species, across its geographical range, constitutes an invaluable genetic resource. In addition to the conservation value, strengthening of NTFP resource base in the forests might be also necessary for sustainable supplies of those NTFPs the wild collection of which is unavoidable or preferred due to their slow growth, difficulties in domestication or sheer adverse economics of cultivation. Sustainable supplies of NTFPs are also necessary as the wild harvest of NTFPs forms a good source of '***cash income***' for the poorest sectors of society.

There is a very strong case for developing NTFPs in forests in the state due to:

- The sheer diversity of NTFPs available in the forests that can not be replicated/ managed outside the forests
- The large quantities of diverse produce required that can not be produced outside forests
- The long gestation period of the typical high value Himalayan NTFPs, a condition not very attractive for their cultivation

- The development of active principles in response to the natural environment, a condition that can not be replicated outside forests
- Better chance of conservation of the germplasm diversity of the various species in their natural habitat, a condition having limited possibility under cultivation
- No need for developing agro-techniques and agro-economics, so necessary for domestication and cultivation of native species, as these species have immense inherent capacity to regenerate under proper management
- The organic production in natural conditions, replication of which under cultivation would require a long process of detoxifying the agriculture land
- The relative small size of land holding by the people of the state, making it difficult for them to divert the land for something that involves an element of risk
- The dependence of a large number of people on the wild harvested NTFPs, who will immensely benefit from strengthening the NTFP resource base in the forests.

HJRF001: In order to explore immediate to medium to long term societal implications of changing hydrological, climatological and land resources of watershed, the major issues that to be addressed are (i) how can numerical modelling of natural hydrological processes of a sub-watershed of central Himalaya be achieved and which is suitable tool/ways to do it? and (ii) What happens to numerical modeling of water resources and their allocation when anthropogenic activities are superimposed over the natural system of the study watershed? Presently, numerous tools are available with requirement of various datasets in hydrological subject. However, The Water Evaluation and Planning (WEAP) model developed by the Stockholm Environment Institute (SEI), USA was selected for the present study. WEAP is a practical tool for water resources planning, which incorporates both the water supply and the water demand issues and guided by number of methodological considerations, integrated planning framework, scenario analysis to understand effect of different developmental activities or to explore societal implications of changing regime.

HJRF002: Pollutants monitoring has been continuously done from 2016 to 2019. Monitoring has been done on midnight-to-midnight basis and the duration for each sample collection is done for 8hours with alternation of 24hrs sampling. Each pollutant has daily three samples on diurnal basis. To see the relationship between pollutants and meteorological parameters Karl Pearson's correlation analysis between pollutants and meteorological parameters (temperature, rainfall,) shows that temperature have negative correlation with $PM_{2.5,}$ $PM_{10,}$ ammonia but positive correlation with TSP and $SO_{2.}$ Rainfall is negatively correlated with $PM_{2.5,}$ SO_2 and NO_2 but positively correlated with $PM_{10,}$ TSP and NO_2. Humidity is negatively related with $PM_{10,}$ TSP and SO_2 and positively related with $PM_{2.5}$ and NO_2.Wind has shown negative correlation with all the pollutants except SO_2. Local meteorological parameters were also observed at Mohal and Kothi. Mostly the wind data Mohal comes from the south-west and south direction. At Mohal, the windiest month was March. The total rainfall from January to December in 2017 was 890 mm at Mohal and 1100.10 mm at Kothi. Mohal received minimum rainfall this is because it falls under rain shadow zone. During 2017, if daily maximum temperature taken into account, it was 32.9 ^{0}C at Mohal on 9th September. On the other hand, daily lowest temperature was 2.5 ^{0}C on 7th January 2017 at Mohal while the monthly mean temperature Kothi found to be maximum 16.9 ^{0}C in July month and minimum temperature found to be 4.9 ^{0}C in February. Average annual temperature and relative humidity were recorded as 16.8 ^{0}C and 59.0 % at Mohal. Apples can be grown at altitudes 1,500 to 2,700 meters above mean sea level in the Himalayan range which provides 1,000 to 1,600 hours of chilling necessary for production of good quality apples. As the region experiences warmer winters and erratic snowfall, the apple growing belt – known as apple line- is shifting to higher altitudes. A warmer winter in lower elevations has resulted into shifting of apple to higher elevations. Lower Kullu valley farmers are steadily moving towards other options, particularly in low and mid altitude (1,200-1,800 meters) in Kullu district. Apple farmers in Kullu valley are growing pomegranate, kiwi and vegetables such as tomato peas, cauliflower, cabbage and broccoli etc.

HJRF010: The growth and development of plants is dependent on abiotic (physical) and biotic (biological) factors. Each plant has certain environmental requirements. Plants are affected by environment during all phases of growth and development. Unfavourable environmental conditions can produce a stress on plants resulting in lower yields (Dennis Decoteau, 1998). The Physical environmental factors affecting plant physiology include the soil, atmosphere and climate. They show extreme variation between different geographic areas (Valkonen 2006). Genetic and environmental factors and their interactions affect the pharmaceutically important secondary metabolites in medicinal plants. A variety of environmental factors, such as season, altitude, radiation, and soil nutrition, have been proven to significantly influence the secondary metabolite profile (Thiyagarajan and Venkatachalam, 2015).

1.4 Brief summary of the activities under taken by the researcher (max. 1000 words)

HJRF001: An attempt was made to explore immediate to medium to long term societal implications of changing hydrological, climatological and land resources of watershed using the WEAP modelling framework for both Upper Kosi watershed (Uttarakhand) and Mohal khad watershed (Himachal Pradesh) based on available datasets. We customized the WEAP model for Upper Kosi watershed area (460 km^2) which comprised of administrative blocks: Dwarahat, Takula and Hawalbagh. For Mohal khad watershed area we customized the WEAP model for the entire watershed area of 54 km^2. The WEAP model was run for the two different agricultural scenarios (1. Reference scenario and 2. Deficit irrigation) with future climate data (2015-2030) from GFDL-ESM2M under RCP 4.5. For WEAP modeling framework, 2015 was set as current year for which all available required information were given to the model and future water demand situation was analyzed for year 2016 - 2030 to see the effect of climate change on water resource system, which in turn helps in developing policy options and adaptive water management action plans.

HJRF002: The present study was carried out during the Winter, Spring and Summer seasons from 2017 to 2019. Mohal-Kullu was selected as a permanent monitoring site. The air quality status of Beasar and Raison was monitoring only in summer and spring season (2019). Respirable Dust Sampler (RDS; Envirotech NL-460) was used to monitor PM_{10} under ambient air quality monitoring based on filtration-gravimetric method where Whatman filter paper (20.3×25.4 cm) was used. Weighing balance (AND GR-202 make) was used for weighing filter papers. Fine Particulate Sampler (APM-550 make Envirotech) was used for $PM_{2.5}$. The Whatman Glass Micro Fibre Filter paper (GF/A (47 mm) was used to expose $PM_{2.5}$. The samples were exposed on 24 hourly basis during winter season (January to March, 2019), Spring season (April 2019) and summer season (May to June 2019).

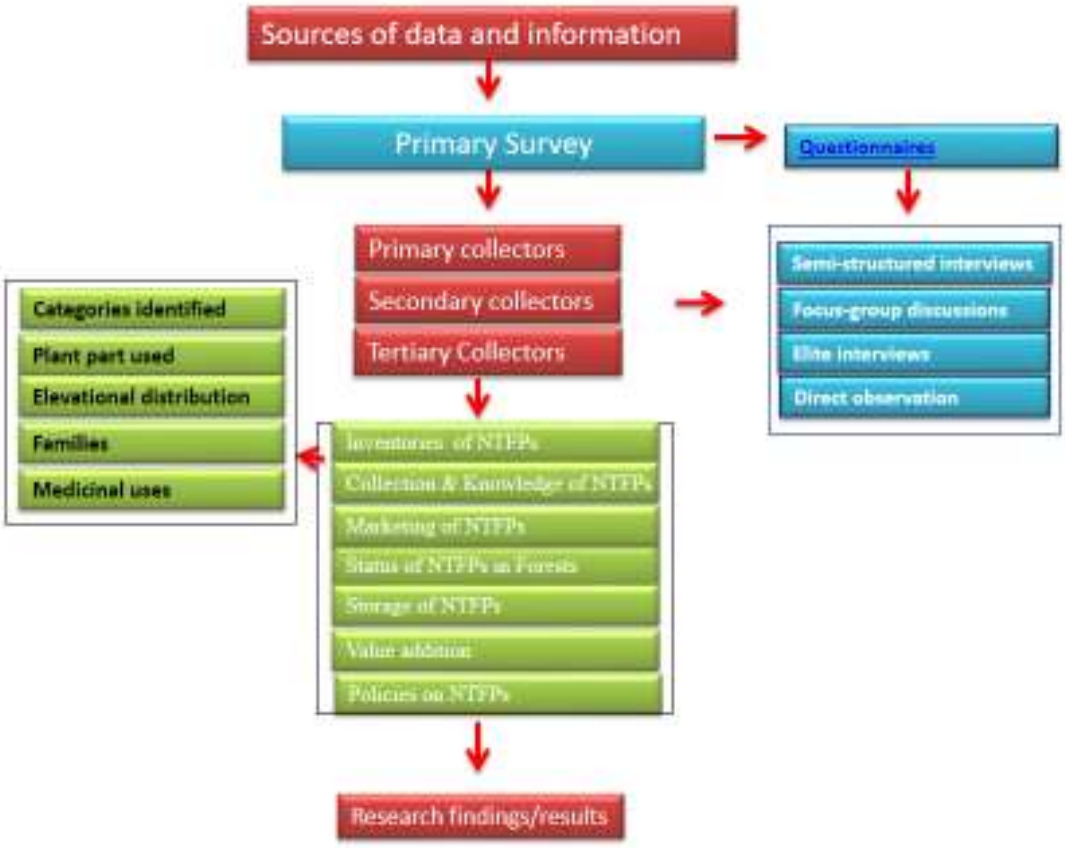
HJRF10: A total of 22 species of high value medicinal plants used by the indigenous community, belonging to 20 families were recorded during the study. The four high value plants i.e. *Illicium griffithii, Curcuma caesia, Curcuma aungustifolia and Zingiber zerumbet* have been selected for biochemical analysis. The biochemical parameters viz. Ash, protein, Na, K, Ca, P, TPC, TFC, TTC etc. were analyzed following the standard methodologies using different instruments. The species were also characterized for identification of high value compounds. The species were cultivated in varied climatic conditions at Rural Technology Centres (RTCs) of North East Regional Centre (NERC) of G.B. Pant National Institute of Himalayan Environment (GBPNIHE) at Suluya village in Ziro and DNGC campus in Itanagar.

[Providing full details of Field study, experimental set up, methods adopted, data collected supported by necessary table, charts, diagrams & photographs (**Data, table and figures should be attached as separate source file (.docx, .xls, jpg, .jpeg, .png, .shp, etc.)].**

2 METHODOLOGIES, STARTEGY AND APPROACH

2.1 Methodologies used for the study (max. 1000 words)

HRA001: Both primary and secondary data have been used for the study. A comprehensive list of NTFP species found in Himachal Pradesh has been drawn based on various published floras, related publications such as journal articles, books and book chapters, reports, conference proceedings, management and development plans, Forest working plans and Ph.D. theses. We analyzed 210 peer-reviewed journal articles relating to NTFPs, which were retrieved from the web platform 'Google Scholar' and other peer-reviewed journals. The precision of species identification in this review was dependent on the original source. Species were verified from there currently accepted name(s) in online nomenclature sources (http://www.theplantlist.org and http://www.tropicos.org). Identifying potential species having market value, their use patterns by communities and trends at a regional scale. A master list was produced providing to assess linnaean taxonomy and vernacular name(s). Data has also been gathered on types and parts used for all NTFPs sold. The market channels were identified through detailed discussions with primary collectors, middlemen (intermediaries), and by visiting existing collection points. Primary Survey were conducted to assess the mode of collection, time of collection, route through which the produces were dispatched, labour involved in transportation and their processing, if any. Data also gathered on types and parts used for all NTFPs sold. Formal and informal interactions were held with the forest staff, traders, and randomly selected herb collectors and farmers during these field visits to understand the pattern of dependence of the local communities on NTFPs, trade of NTFPs, conservation status of NTFPs collected in large volumes. Possibilities and methods of value addition to the potential NTFP species have been worked out on the basis of literature, interviews with local traders and interactions with herbal industry. Possibilities of public-private-community partnership in value addition and marketing of NTFPs have been explored through interactions with the representatives of herbal industry, raw drug traders and exporters. A thorough review of government policies and regulations pertaining to harvest and management of NTFPs in Himachal Pradesh was done. The quantitative analysis was done using the Statistical Package for Social Sciences (SPSS) and Microsoft Excel.



Methodology for primary survey

HRA002: The methodologies adopted for seeing the water quality of region started with the survey of the region for the springs was done and then again the method for sampling was conducted. The sampling is done for all the selected springs which were crowded with the population to see the contamination level of the springs and to see the changes that have springs undergone from 1991 to 2017. The sampling was done for three seasons in a year 2017/2018. The analysis was done for all the three seasons for all the physicochemical parameter and for MPN. The methodology opted was according to APHA prescribed for the analysis. The second objective was to see the surface water quality of the region. The river Kosi which is to see the contamination levels in the 31 points from Kantli the origination pointof the springs. The points selected were according to the previously selected points by project IV. The analysis was done for physicochemical parameters for the 31 points. This process was done to see the most contaminated levels of the 31 points. These 31 points were selected to see and decide the points to be selected for continuous survey of and daily sampling of the selected points for data to be fed in for the model. The third objective was in the continuation for the second objective in which four points were decided after the 31 points survey for three seasons and hence the four points selected were:

1. Kantli
2. Kosi
3. Kwarab
4. Ramanagar

The daily samples from May 2109 to Dec 2109 from all the points selected as a conclusion points from the 31 sampling points. The daily analysis from all the 4 points for parameters pH,DO, BOD, and nitrate were fed in the model with the hydrometerological and meterological parameters to come out with the future prediction of the model for the water quality of the region.The model that works for the future prediction is the model suggested by EPA. The model is WASP(Water quality Assessment Simulation Program) which incorporates the input data hydromet and metrerological data to generate WRDB file which incorporates with waterquality parameter to come out as an output for simulation program. The fourth objective is to suggest mitigation measures for conserving the water quality of the region. The suggestion would be on the basis of the water quality of the springs of Almora.

HRA03: The entire Himalaya in general and in particular Indian Himalayan Region (IHR) has been selected for gathering the data/information and sharing the same. As the knowledge needs to be available to different stakeholder of IHR, the entire IHR has been selected. A detailed literature search with keywords such as 'Biodiversity' and/or 'Climate change' along with Himalaya and Indian Himalayan Region or along with different Himalayan regions of IHR have been conducted. For developing mechanism for knowledge sharing and its flow among stakeholder groups, Himalayan Biodiversity and Climate Change-Knowledge Network (HBCC-KN) web portal has been developed, which can work on SQL and PHP database language as dynamic web portal.

HJRF001: (Includes methodology and data used): The WEAP modelling framework used for present study is shown in Fig. 1. Data set for the year 2015 were used for the present study, which denote the Current Year/Account (water system as it currently exists) in WEAP modeling. Socio-economic data of domestic population, livestock and agriculture were collected from Statistical Department, Patwari (Record keeping department), Agriculture Department of the Himachal Pradesh and Uttarakhand and through filed survey. Watershed map, drainage network and land use/land cover map were prepared using Remote Sensing and GIS. Further, for building future climate change scenario, data (rainfall, temperature and humidity) of GCM model GFDL-ESM2M under RCP 4.5 were used for the years 2016 to 2030. During simulation modeling, in-built assumptions of WEAP model were used wherever necessary. The present study used the WEAP model for both the watershed using available datasets and demonstrate the ability of WEAP model to simulate water demand and supply in context of future climate. Therefore, all the available input data was feed to the WEAP system. A schematic of WEAP for the Mohal khad watershed has been prepared using different nodes and links between different demand and supply sites of the watershed. The demand sites in watershed are population, livestock and agriculture; and the supply sites are river water withdrawal and groundwater schemes. The highest demand priority was fixed to satisfy the requirement of population and livestock and subsequently for agriculture sector. Further to meet out demands of population and livestock, the river water withdrawal schemes were set as a first preference and groundwater scheme with second preference. For water balance simulation, we used Rainfall-Runoff simulation method of WEAP model. For WEAP simulation modeling we used year 2015 as a Current Year/Account for which all the actual datasets were provided to the model; and future water demand and supply scenarios were built from 2016 to 2030 (Reference Scenario) to see the possible impacts of climate change and other factors on water availability and demand management.

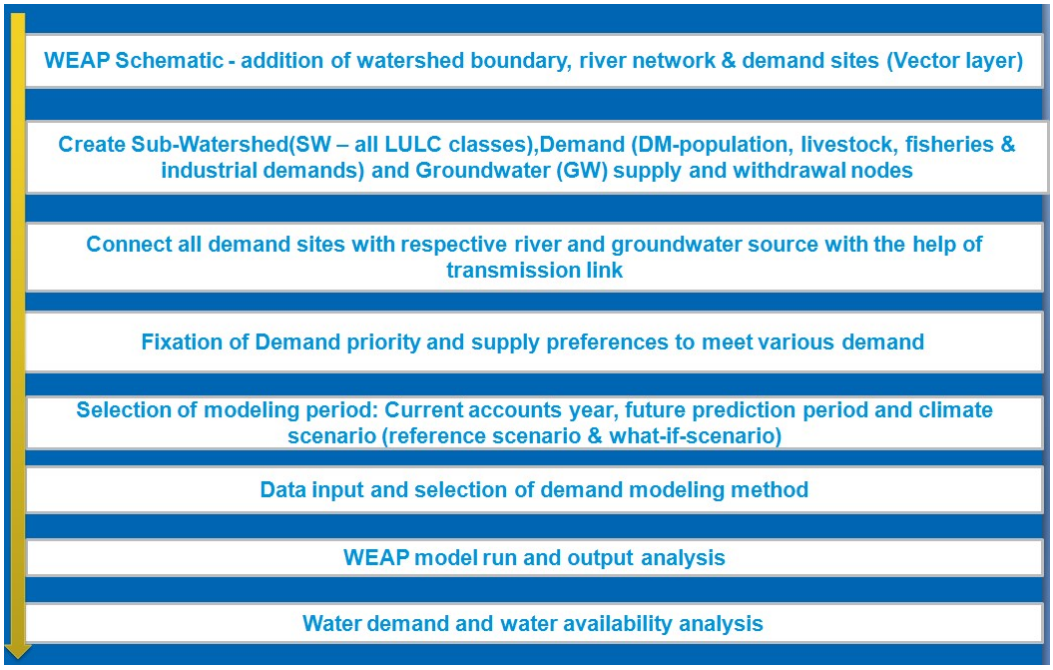


Fig. 1 Flowchart for customization of WEAP for Upper Kosi and Mohal khad watershed

HJRF002: Ambient air quality were monitored at Mohal at the altitude of 1146 m, Kothi (2500m), Beasar (control site) at the altitude of 2181 m and Raison at the altitude of 1359 m.. Respirable Dust Sampler (RDS; Envirotech NL-460) was used to monitor PM_{10} under ambient air quality monitoring based on filtration-gravimetric method where Whatman filter paper (20.3×25.4 cm) was used. Weighing balance (AND GR-202 make) was used for weighing filter papers. Fine Particulate Sampler (APM-550 make Envirotech) was used for $PM_{2.5}$. The Whatman Glass Micro Fibre Filter paper (GF/A (47 mm) was used to expose $PM_{2.5}$. The samples were exposed on 24 hourly bases. The results obtained from PM_{10} concentration and gasesous pollutants were compared with National Ambient Air Quality Standards. Meteorological data were collected from Automatic Weather Tower (AWS) installed in the institutes campus and secondary data like long term rainfall, temperature data and apple production, cultivated area's data were collected from Krishi Vigyan Kender (KVK) Bajura, Himachal Pradesh Horticulture Department respectively.

Air Quality Index (AQI)

Air Quality Index (AQI) was also computed to know the overall pollution status. The AQI was measured modifying the formula used by Bhaskar and Mehta (2010) as follows:

$$AQI = \left(\frac{M_{ob}}{M_{st}} \right) \times 100$$

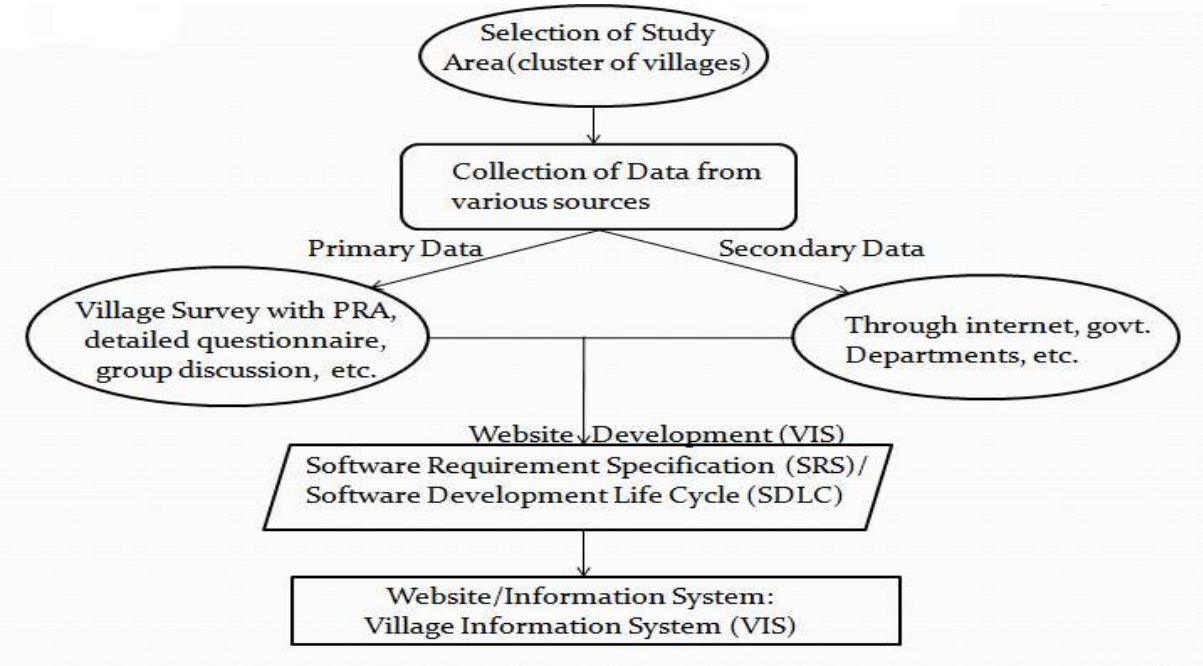
where, M_{ob} = observed value of air pollutants, M_{st} = standard value of permissible limit of NAAQS

In addition, outer source of particulate pollutants for Mohal site was analyzed with the help of HYSPLIT model and CALIPSO data.

2.2 Details of Scientific data collected and Equipments Used (max 500 words)

HJRF004: Secondary data were collected from Horticulture Department Himachal Pradesh and Krishi Vigyan Kender Bajura-Kullu Himachal Pradesh. For primary scientific data collection, the scientific Instruments Respirable Dust Sampler (RDS; Envirotech NL-460) was used to monitor PM_{10} under ambient air quality monitoring based on filtration-gravimetric method where Whatman filter paper (20.3×25.4 cm) was used. Weighing balance (AND GR-202 make) was used for weighing filter papers. Fine Particulate Sampler (APM-550 make Envirotech) was used for $PM_{2.5}$. The Whatman Glass Micro Fibre Filter paper (GF/A (47 mm) was used to expose $PM_{2.5}$.

HJRF005: The methodology followed for the execution of project is shown below:



The Study site of the project consists of 4 villages of Almora district. They are as follows:

Site-1:
Village – Sakar
Post-Bhagtola,
Teshil-Someshwar
Block-*Hawalbagh,* District-Almora

Site-2:
Village - Gwalakote (Bhagtola)
Post-Bhagtola
Teshil-Someshwar
Block-*Hawalbagh,* District-Almora

Site-3:
Village – Darimkhola
Post-Bhagtola
Teshil-Someshwar
Block-*Hawalbagh,* District-Almora

Site-4:
Village - Jyula
Post-Bhagtola
Teshil-Someshwar
Block-*Hawalbagh,* District-Almora

HJRF006: Study site

Plant samples were collected from Jageshwar (29º35´-29º39´ N and 79º59´-79º53´E) area of district Almora of Uttarakhand, India. Herbarium of plant needle were submitted to herbarium record of G. B.

Pant National Institute of Himalayan Environment (NIHE), Kosi-Katarmal, Almora Uttarakhand, India (Voucher number: GBPI 5050) and Botanical Survey of India, Dehradun Uttarakhand, India (Accession number: 122892).

Sample collection

Needle, bark and stem samples (5 replicates from 5 different trees) were collected. Samples were dried at room temperature, grinded into fine powder and stored at 4 °C till further analysis.

For Objective i):

- Total fungal colonization in roots was analyzed by trypan blue staining method. Microscopic observations were recorded on the root segments with respect to fungal colonization including vesicular arbuscular mycorrhizae (VAM), fungal mycelium and dark septate endophytes using Nikon- Eclipse 50i, Japan. VAM colonization was identified on the basis of vesicle and arbuscular structures present in the root segments (Adhikari and Pandey, 2018).
- **PGPR abilities of endophtic bacteria**- The PGP activities namely IAA, ACC deaminase, HCN, ammonia, siderophore production and phosphate solubilization were analysed qualitatively by plate-based bioassays and quantitatively by doing little modifications in previously reported methods. Quantification of IAA production was performed by the method described in Rahman et al. (2010), ACC deaminase by Jasmin et al. (2013), HCN by Bakker and Schipper (1987), Ammonia by Dye (1962), Siderophore by Schwyn and Neilands (1987), and salicylic acid by Meyer et al. (1992) (Adhikari and Pandey, 2019, 2020, 2021).
- **Taxol production by endophytes-** Isolated endophytes were tested for their potential of taxol production. Further, different parameter viz. optimum temperature, pH, incubation time carbon, nitrogen, salt concentration was optimized for the scaling up the taxol production (Appendix I).

For objective ii):

- For preliminary screening of antimicrobial potential, optimization was carried out by taking 7 different solvent (methanol, ethanol, acetone, chloroform, ethyl acetate, dichloro methane and petroleum ether) and two extraction method i.e., maceration and soxhlet. Stem, bark and needle were extracted and tested for their antimicrobial potential against 3 group of microorganisms (bacteria, actinobacteria and fungi) through disk diffusion method and by calculating MIC. (Adhikari et al., 2018)

- Optimization of mobile phase for isolation of antimicrobial compounds
    1) 10 g powdered needle was extracted sequentially in five different solvents (hexane, chloroform, ethyl acetate, methanol and water) through maceration method in the ratio of 1:5 (w/v).
    2) The order of maceration of same sample was in the increasing order of solvent polarity (hexane< chloroform< ethyl acetate< methanol< H_2O).
    3) After extraction, each solvent extract was vaccum dried and redissolved in 2 mL respective solvent. Antimicrobial activity was measured by plate-based bioassay through disk diffusion method followed by estimation of MIC (Minimum Inhibitory Concentration).
    4) After column chromatography and bioautography, column chromatography was used for further purification of fraction for the isolation of compounds responsible for antimicrobial activity using the solvent systems (Appendix 2)
    5) Fractions collected during column chromatography were their screened for antimicrobial activity. Fractions having antimicrobial activity were further analysed for compound identification.
    6) The separated fractions having antimicrobial activity was analysed using GC/MS, LC/MS, FTIR, NMR for elucidating the chemical structure of target compounds.

HJRF007: The state Uttarakhand has been categorised into four altitudinal zone. As per the administrative division garhwal and Kumaun 6 villages have been selected on altitudinal gradient in each division. For detailed study a total of 12 villages are randomly selected and a detailed questionnaire survey has been conducted in the villages. About 40% of the house hold has been selected from each village on the basis of category, economic condition etc. People perception on various aspect i.e. Demography, agriculture and livestock, resource availability, landholdings and the other issues affecting the traditional livelihood practices has been collected using semi structured questionnaire, group discussion and interviews. Secondary data on same aspects has been collected with the help of different published materials and reports of various respective departments.

Methodology and distribution of the villages

Altitudinal Zones (m amsl)	Villages from Kumaun	Villages from Garhwal
<1200	1	1
1200-1800	2	2
1800-2400	2	2
>2400	1	1
Total	6	6

HJRF008: The Participatory Rural Appraisal (PRA) approach was adopted for the detailed field study in the four (4) different village clusters following standard methodologies (Maikhuri *et. al.,* 1994; Negi *et. al*. 2011). The major focus of the study was to collect information on forest bio-resources utilized by the local inhabitants for various purposes such as food, fiber and medicine. Before initiating the field work, a group meeting was organized in target villages regarding data to be collected.The information gathered from the inhabitants comprised local name of plant species, ethno-medicinal knowledge, plantpart used, phenology and method of preparation of different value added products from the potential wild bio-resources and their market value. Information was also gathered through village meetings, group discussions and personal interviews with the head of the household and women towards quantity of collection of selected plant species, their conservation status and ethno-botanical uses. The detail structured and semi-structured questionnaire were developed to collect the information on forest based resources collected by the local people and their economic valuation in terms of monetary equivalent of each bio-resource was evaluated based on prevailing market rate. About 16 wild edible plant species viz., *Ophiocordyceps sinensis, Morchella esculenta, Origanum vulgare, Carum carvi,* Jhula (Lichen species), Moss*, Diplazium esculentum, Paeonia emodi, Saussurea obvallata, Taxus wallichiana, Pleurospermum anglecoides, Angelica glauca, Sassurea costus, Hippophae rhamnoides, Allium* stracheyi and *Rhododendron arboreum* were collected by villagers for various purposes for their own use and marketing purposes. Questionnaire, interviews and field observation methods was applied to collect detailed information on the demographic characteristics of the village clusters. Data were gathered on farmers' household characteristics, occupational and demographic factors including respondent age, gender, level of education, annual income, landholding, occupation, livestock number and categories from bio-resources collection from forest and socio-economic conditions. The respondents were categorized into three different income groups, rich, medium and poor, and were assessed on the basis of their income earned from various sources, such as agriculture, livestock, business and services. The data from secondary sources were collected from government departments, extension officers, local leaders, MAPs collectors, traders, traditional healers and published literatures. About 60% families residing in the villages were interviewed for gathering information on potential wild bio-resources collected, consumed and sold in the market from each cluster. The most of the selected wild bio-resources considered in this study are found in high altitude region and most of them have huge potential for income generation and livelihood improvement of local inhabitants.

Cost-benefit analysis

The cost-benefit analysis of different value added products prepared from the selected forest bio-resources was calculated in Rs/day which includes labour charges for male and female workers in different areas of plant parts/fruit collection and materials/items required for preparation of different edible products such as sugar, preservatives, plastics containers, packaging materials, etc. and that was calculated based on prevailing market rates. The monetary output includes the yield (quantity) of the products and monetary equivalent based on current market rate.

Table 1. General profile of study area.

Name of village Cluster	No of Household	Population	Male	Female
Salud-Dungra	603	2649	1410	1239
Urgam	572	2135	1060	1075
Vaan	850	4182	2480	2395
Sutol-Kanol	909	4875	2198	1984

HJRF0010: The information on threatened and high value plants, distribution of the selected plants in Arunachal Pradesh was obtained through extensive survey of global scientific literature including journals, books, and other published documents. After rigorous literature review of papers on biochemical and phytochemical studies, the West Kameng district of Arunachal Pradesh have been selected as study area having a varied altitudinal range from 650 to 13714 ft. The primary survey was conducted in seven villages of Monpa inhabited Dirang circle and nine villages of Sherduken inhabited Rupa circles under West Kameng district. The four high value plants i.e. *Illicium griffithii, Curcuma caesia, Curcuma aungustifolia* and *Zingiber zerumbet* have been selected for the fellowship objective based on their traditional uses, market potential and work done so far. The Biochemical analysis of the plant material was done following the standard methodology (AOAC, 1990; Bhargava and Raghupathi 2001). Potassium (K), Sodium (Na) and Calcium (Ca) were determined by flame Photometer (Systronic, Model-128). Double Beam UV-Visible Spectrophotometer (UV-2700, Thermo Fisher) was used for phosphorus determination in plant samples (Okalebo et al., 1993; Bhargava and Raghupathi 2001). Soxhlet extraction, and maceration extraction also known as classical extraction technology were selected for suitable method of extraction. The maceration, and Soxhlet extraction of selected plant species using different solvents viz. Acetone, ethyl acetate, ethanol, and methanol were conducted for extraction of phytochemicals. The phytochemical analysis of the plant material was conducted following Folin-Ciocalteu's method for total phenolic content (TPC), aluminium chloride colorimetric method for total flavonoid content (TFC), and Folin Denis method for total tannin content (TTC) using UV-VIS spectrophotometer (Hitachi U-2001, Japan). The antimicrobial activity assays were performed using the standard procedure of the agar disc diffusion method with minor modifications. The High-performance liquid chromatography (HPLC) (model: Alliance e2695, Waters, Milford, USA). The compositions of plant species were analyzed by attenuated total reflectance (ATR)-FTIR (Perkin Elmer). The species were cultivation at Rural Technology Centres (RTCs) of North East Regional Centre (NERC) of G.B. Pant National Institute of Himalayan Environment (GBPNIHE) at Suluya village in Ziro and DNGC campus in Itanagar.

2.3 Primary Data Collected (max 500 words)

HJRF002: Mohal-Kullu was selected as a permanent air quality monitoring site for primary data collection and meteorological data were collected with the help of the AWS which is installed at institutes campus at Mohal-Kullu. The gaseous pollutants such as Sulphur Dioxide (SO_2), Nitrogen Dioxide (NO_2), and Ammonia (NH_3) were also monitored simultaneously in an attached Impinger with the RDS. After 24 hours run the extracted samples were analyzed in the laboratory. These were analyzed following the

modified methods of West and Gaeke (1956), Jocobs and Hochheiser (1958) and Nesseler's Regeant methods respectively.

HJRF0010: Dirang Circle and Rupa Circle under West Kameng District of Arunchal Pradesh were selected for primary data collection. The field survey was conducted through interaction with local knowledgeable persons of the villages from different age-groups. The selected key informants were Headman (Gao Burah) and Traditional Medical Practitioners (TMP) of the target villages. The primary data was conducted using semi-structured questionnaires, informal group discussions and field visit to forest to identify and collect the plant specimens recorded. The questionnaires contain questions about name of the plants, traditional uses, habit, and availability (common/rare), parts used market potential and also on conservation efforts adopted by the villagers or government.

2.4 Details of Field Survey arranged (max 500 words)

HRA01: The project area, covering about half of the geographical area of the state including 2/3rd of the cultivated land in the state, provides very good opportunity to demonstrate the potential of forest based NTFP development in the state.

HJRF02: When Project was started only two Permanent sites Mohal-Kullu and Kothi was selected for Air quality monitoring that's why there no field survey was arranged from 2016 to 2018. Last year on 2019 during summer season the field survey was arranged at two selected sites Beasar and Raison. Beasar was selected as a control site.

2.5 Strategic Planning for each Activities (max. 1000 words)
2.6 Activity-wise Timeframe followed using Gantt/ PERT Chart (max. 1000 words)

3 KEY FINDINGS AND RESULTS

3.1 Major Research Findings (max. 1000 words)

HRA01:

NTFPs Diversity and distribution in the State

There is high dependence of large variety of NTFPs in Himachal Pradesh. A large number of NTFPs were sold in the local markets thus provided cash income to communities. A total of 809 species of NTFPs (excluding Lichens and Moss), belonging to 128 families and 495 genera, were recorded as used in Himachal Pradesh according to the different literature sources. This indicates richness and high socio-economic value in the area. The top ten families (Asteraceae, Lamiaceae, Fabaceae, Rosaceae, Ranunculaceae, Polygonaceae, Apiaceae, Poaceae, Euphorbiaceae, Gentianaceae) contributed 43.9 % of all species. Most of the plants belongs to family Asteraceae (64 species; 7.91% of the total) followed by Lamiaceae (50 species; 6.18 %). A quick analysis of this list of 811 NTFP species found in the state reveals that herbs are the dominant life form in the trade represents 64% followed by shrubs (20%), trees (14%), while ferns, climbers, grasses and mushroom were less than 1 %. The species were distributed from 400m to 5500 m above sea level. Along an altitudinal gradient, the maximum number of NTFPs (27.43%) was found in Warm temperate zone (1001m-1800m), followed by the Temperate (1801m-2800m) (25.33%), Sub-alpine (2801m-3300m) (17.37), Sub-tropical (<1000 m) (15.81%) and Alpine >3300 m (14.07%).

NTFPs Use pattern

Many plants and plant products taken from forests are used as food for humans and animals. These include whole plants, leaves, roots, fruits, nuts and mushroom etc. Different families made very different

contribution to different use categories. Amongst 811 NTFPs maximum species were used for medicinal (61.43%), followed by edible (11.72%), whereas fodder, fuel wood, oil/essential oil, construction, dyes, agricultural tools, religious purpose, spices, Incense, insecticidal, resin, perfumes, beverages, fibre, mushroom and other contributed less than 10%. The major wild edible products were vegetables, mushrooms, root tubers, Nuts, Seed, etc.

Conservation Status of NTFPs in the State

Unsustainable harvesting of NTFPs, mostly medicinal and edible plants, is the major threat to conservation and management of NTFPs in Himachal Pradesh. Listed NTFPs of the state, reveals that 66 medicinal plant species of Himachal Pradesh are facing various categories of threat as per IUCN guidelines. 4 of these species have been assessed as 'Critically Endangered', 4 species have been assessed as 'Near threatened' 9 species have been assessed as 'Endangered' and 3 species have been assessed as 'Vulnerable' and 46 species as least concern. In addition to the species there are 93 NTFP species in the state that are assessment as threatened according to different stakeholders.

Status of NTFPs according to different stake holders

Primary survey was conducted in the entire state to know the current status of NTFPs from different stake holders, and local right holders in the state. The data revealed that according to 93% of respondents there is a decline in NTFPs.The data also showed that 66% of respondents pointed that climatic factor is also responsible for decline in NTFPs. Human interference is also responsible for decline of NTFPs in the state. Around 90% of respondents considered it as one of the major cause for decrease in NTFPs in the wild. 95% of stake holders agree that over harvest of NTFPs from the wild in the state is a major issue which add to decline of the NTFPs. The competition between collectors for harvest of more NTFPs from the wild results in over harvest, around 88 % of stake holders and locals pointed out this is causing serious treat to NTFPS in the wild. Temporary or complete ban is imposed on few species on the harvest or export of threatened species depending on the status of the species.

Status On Marketing, Value Chain, Value Addition And Enterprise Development

The NTFPs market in Himachal Pradesh is an oligopsony, with relatively few well-informed (and secretive) buyers and a very large number of ill-informed sellers. The limits on information from the demand side are intentional for the purpose of artificially manipulating the market price in their favor, whereas the information flow from the sellers is unintentional. Such opaque market structures are disadvantageous to the collectors and cultivators and also lead to over-harvesting of the natural resource in the absence of reliable and accurate information about market demand and price. Most of the NTFPs from the state go to traders/ buyers in Amritsar and Delhi. There are local traders based in Kullu, Paprola/ Baijnath, Rampur, Shimla, Chamba, Shahpur, Solan etc. who buy the NTFPs from the right holders and send them to Amritsar, Delhi and other places. From the interactions with buyers, processing units, pharmaceuticals, local forest officials, it was understood that the major volume of the produces goes to Amritsar. A small amount of NTFPs are being directly bought by the local processing units. The Department of Ayurveda has three Pharmacies in Joginder Nagar Paprola and Majra, which manufacture Ayurvedic medicines for about 1,200 institutions: hospitals, Ayurveda colleges, health centres. There are several prevailing procurement arrangements for marketing of NTFPs.

Governance, Policies And Regulations Related to NTFPs and Their Impact

Policy or management practices to date have given little attention to reconciling multiple forest uses and minimising impacts on forest dependant livelihoods. One of the challenges in legislation surrounding NTFPs is that multiple sectors, agriculture, finance, environment, education and culture impact access to, and use of, non-timber forest products. Weak communication between governmental sectors routinely poses challenges to effective legislation involving NTFPs. Vast social and ecological complexity involving forest resources, minimal legislation which complements and/or builds upon customary regulations is often best for small holders and NTFPs.

- A total of 811 NTFPs were evaluated till date in Himachal Pradesh.

- Out of these a total of 159 were categorized threatened species (66 species as per IUCN while 93 species as per stakeholder perception). Continuous extraction of NTFPs from these areas has, have put the species in the threatened category e.g. *Aconitum heterophyllum*, *Angelica glauca, Gentiana kurroo, Nardostachys jatamansi, Saussurea costus, Lilium polyphyllum, Trillidium govanianum* etc.
- Increasing trends of revenue generated and collected by the forest department from NTFPs have been observed for 68 years and a constant increase was seen from past 3 decades.
- The revenue generated in form of royalty from resin tapping has increased subsequently in spite of decline in number of blazes allotted from past 66 years.
- Analysis of quantum of NTFPs harvested in the past six decades in Himachal Pradesh exhibited a decline trend supposed to be due to depletion of resource base in their natural habitats. On an average there was decline of more than 85% from past 43 years.
- Due to lack of systematic marketing, the rate of NTFPs is driven mostly by market demand, mediator and bragging power.
- NTFPs collection is allowed in a specified area after a gap of about four years.
- With the decrease in quantity and very high demand of NTFPs, forest dwellers are mostly collecting NTFPs for business purpose.
- Net income of secondary collectors was more than 75%
- Average collection period of NTFPs in different districts ranged from 34 to 82 days annually.
- Average annual income of household was highest for district Chamba.
- Being aware of some of the policy regarding restriction of NTFPs harvesting, forest dwellers still consider the forest as their own property.
- An appropriate policy framework for the sustainable promotion of NTFPs is necessary to help to ensure an effective development, promotion and sustainable harvesting of NTFPs

HRA02:

- The contamination of naulas as Khatyari, Thapalya, Kapina(RS),Kapina (SM)was found to be above 60 mg/l with the nitrates and Sunehri, Gurani and both the Champa naulas were found to be with nitrate 20-30 mg/l.
- Dharanaula, Makeri,was found to be less with the amount of Dissolved Oxygen and nearly all the naulas showed high contamination of bacteria although Ecoli was not traced in the samples.
- The expected outcome of the model by the parametric analysis of surface water would give the future prediction of the quality of the region and help to take remedial steps to mitigate/decrease the contamination levels.
- 31 sampling points in the entire stretch of the river helped to estimate 4 points for daily sampling points selected estimated that DO is highest in Kantli and with very least variation in Kosi and least in Ramnagar. BOD is least in Kantli and highest in Ramanagar whereas nitrate too is highest in Ramnagar and least in Kantli with variations in Kwarab and Kosi.

HRA03:

- The preliminary database on various components of Himalayan Biodiversity and Climate Change have been collected and analyses in terms of objectives, methodology adopted, key findings etc. (Annexure- I and II).

3. The Himalayan Biodiversity and Climate Change- Knowledge Network (HBCC-KN) web portal has been developed and tested on different platform for its functioning (Annexure- III). This knowledge network web portal can now be shared and popularize among different stakeholders of IHR for knowledge flow and sustainability.

4. Lichen diversity of Western Himalaya (Annex-IV).

HJRF001: (Includes selected major findings, results and conclusion): The study reveals that great variation in rainfall are going to be occurred in Mohal khad watershed area in coming years. The year 2020 may experience low rainfall (322.97 mm) showing the predicated dry year/conditions whereas, 2024

may experience high rainfall of about 1889.56 mm respectively. Whereas, in Upper Kosi watershed, the year 2020 may experience low rainfall (592 mm) showing the predicated dry year/conditions; whereas, 2022 and 2024 may experience high rainfall of about 1734 mm and 1731 mm respectively. This rainfall variability also reflects in the respective results of hydrologic analysis, water allocation and agriculture scenario analysis of the WEAP modeling. The agriculture scenario study of WEAP modeling projected the possible crop yield in 2015-2030 for both Upper Kosi and Mohal khad watershed. It was found that the crop yield in Mohal khad watershed doesn't show any promising change in both the scenario but shows the change in crop yield within the reference scenario which is attributed to the projected annual rainfall quantity. However, deficit irrigation scenario shows the increase in crop yield than that of in reference scenario in Upper Kosi watershed due to fact that sufficient water stress is required for many crops for increased yield. 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 to understand the societal implication of changing hydrological, climatological and land resources system/regime. At present, this customized WEAP model for Upper Kosi and Mohal khad watershed gives overall idea of how WEAP modelling framework is performing. Future studies on similar account may be carry out to study possible societal implications using site specific and demand driven or Purpose Driven Studies (PDS) in the other Himalayan river basins for the best water management in the context of climate change. Selected results in terms of graphical presentation is shown for representation purpose here (Figs. 1-6).

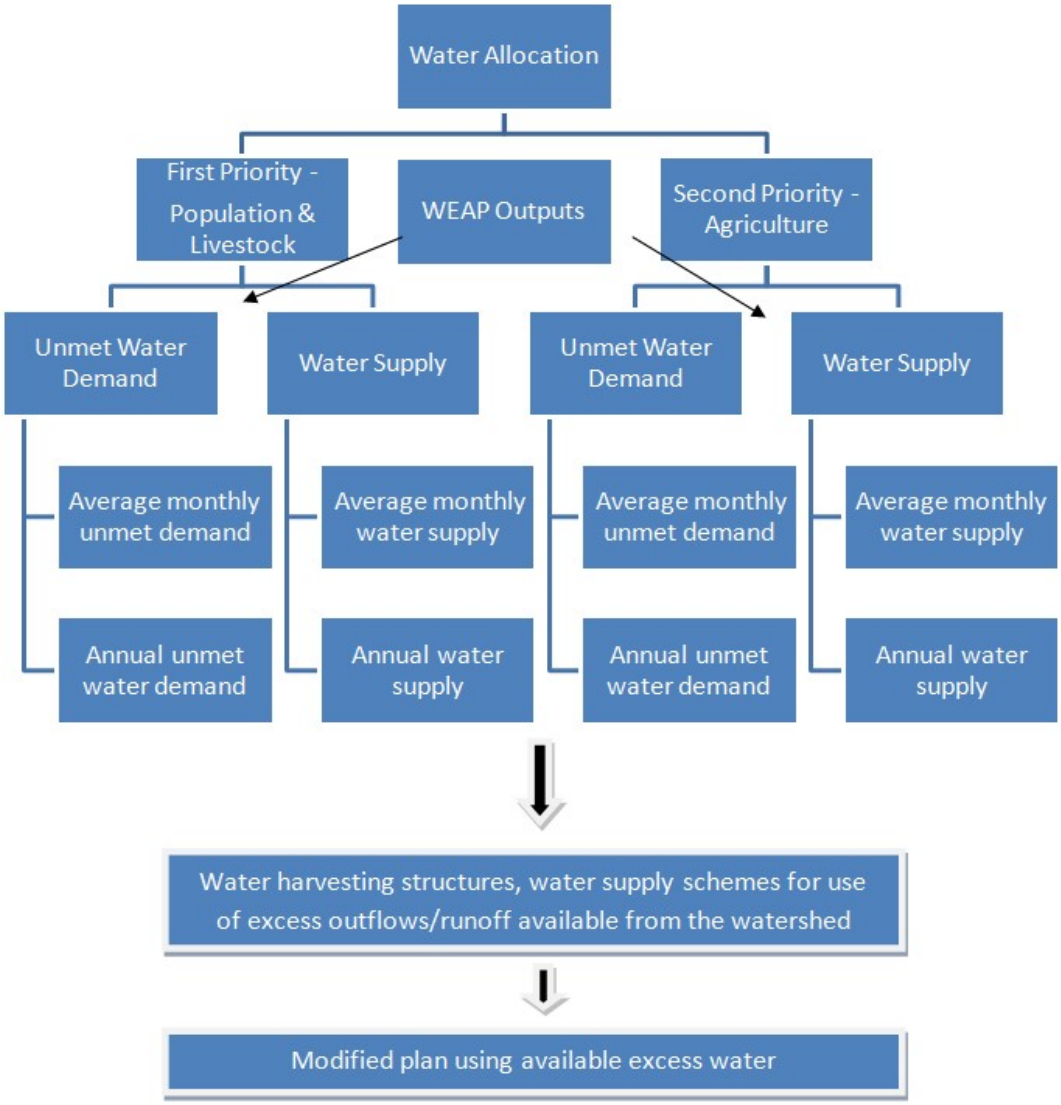


Fig. 1: Water allocation strategy using WEAP modeling for Upper Kosi and Mohal khad watersheds

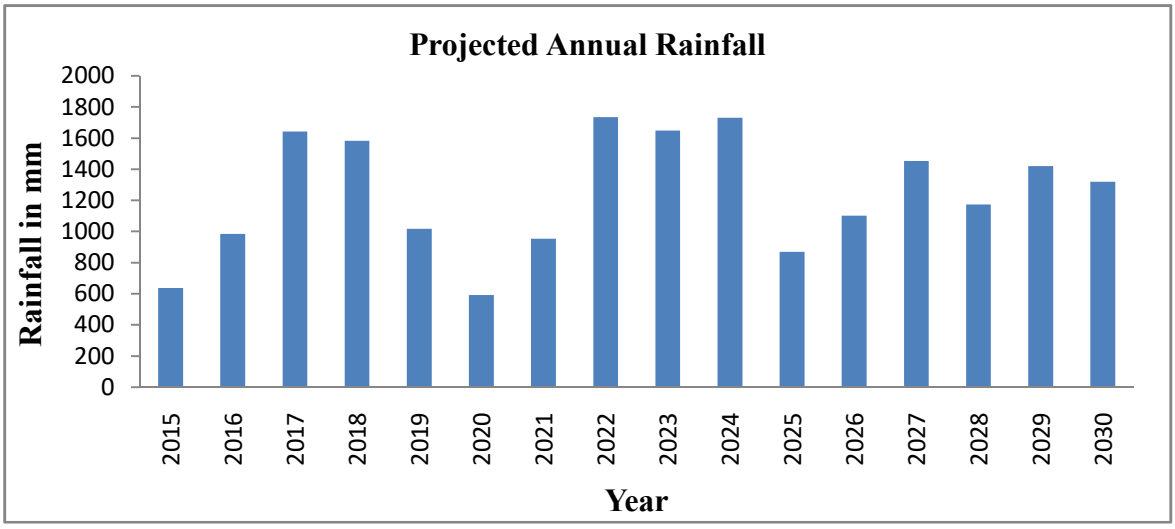


Fig. 2: Projected annual rainfall over Upper Kosi watershed

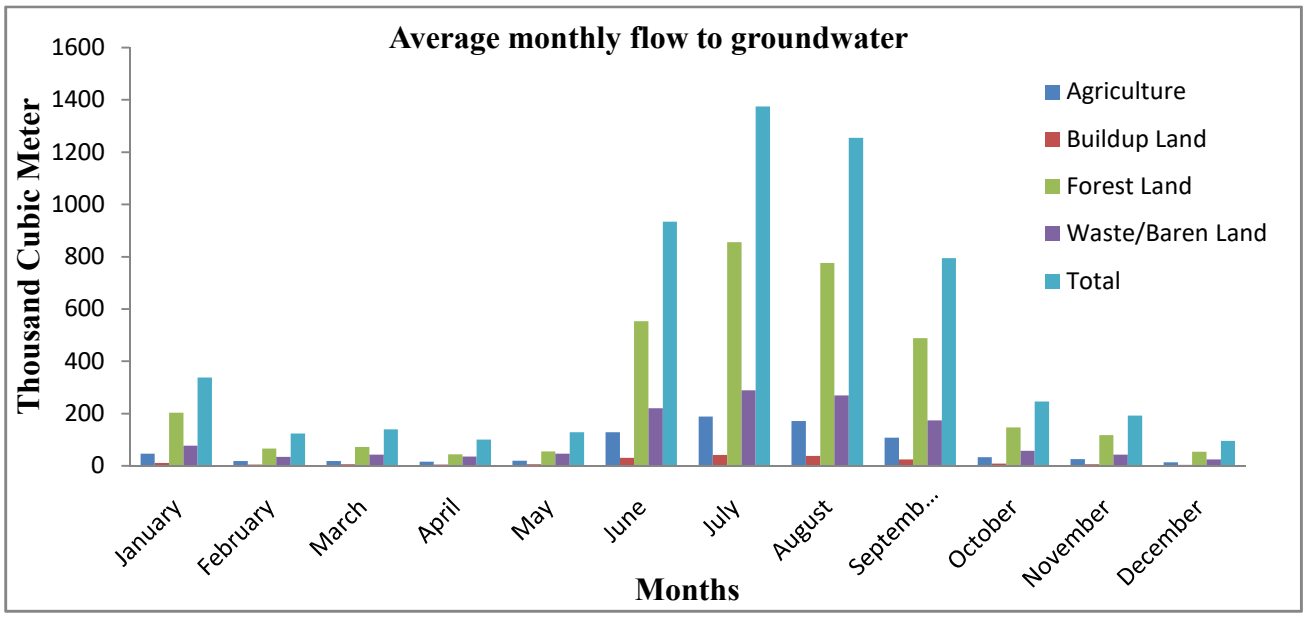


Fig. 3: Average monthly flow to groundwater from watershed

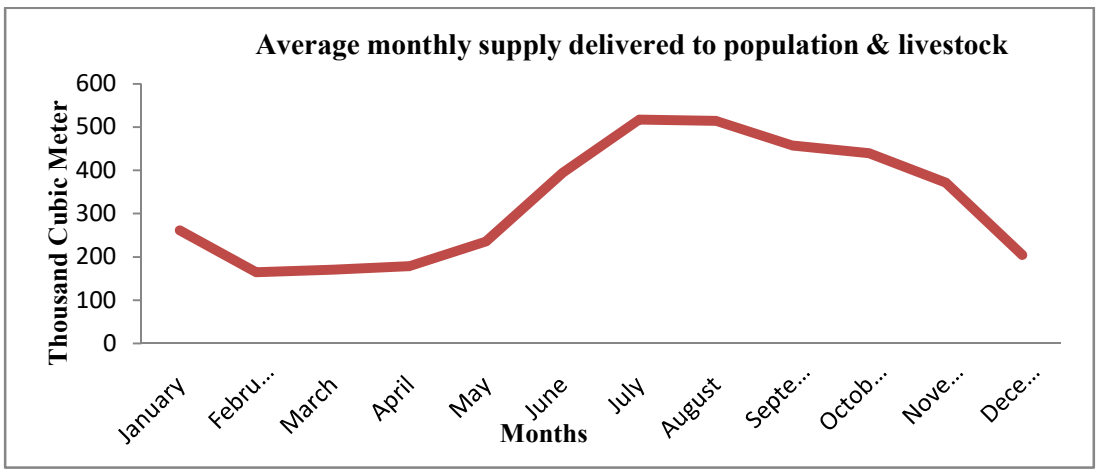


Fig. 4: Average monthly water supply delivered to population and livestock

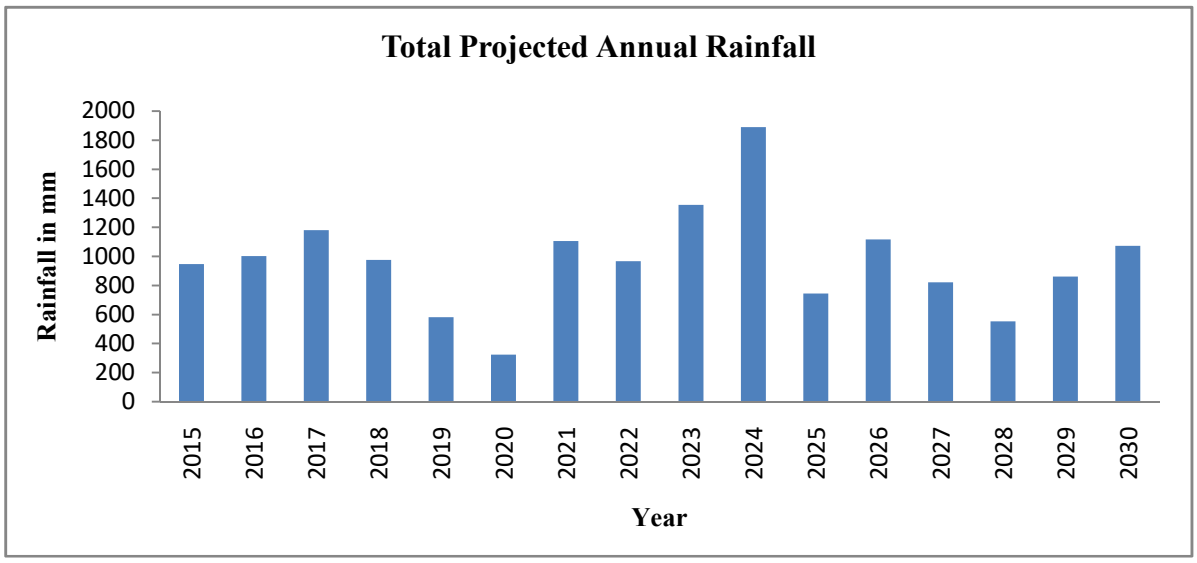


Fig. 5: Projected annual rainfall over Mohal khad watershed

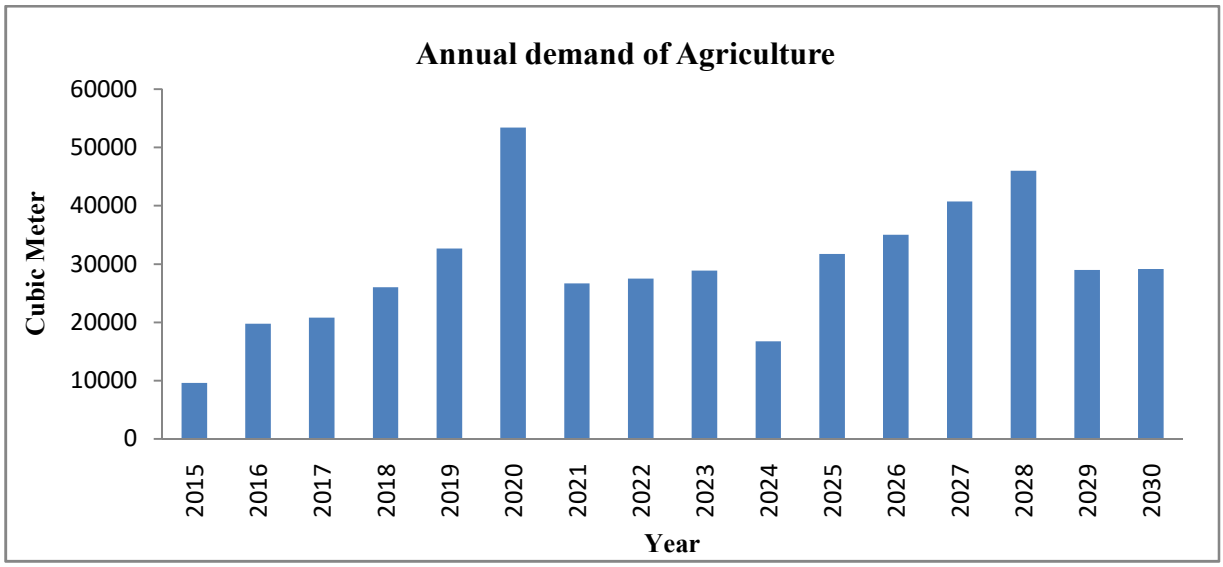


Fig. 6: Annual agricultural demand in Mohal khad

- The present and future analysed datasets for respective study sites has been created for duration of 2015 to 2030 which includes datasets or status of rainfall, flow to groundwater from different land use/land cover, surface runoff from the watershed, population and livestock water demands, agriculture water demand, unmet water demand of population, livestock and agriculture, water supply to population, livestock and agriculture; and crop yield status in both the watersheds.
- The societal implications in terms of water demands (demands of population, livestock and agriculture) and to meet out the unmet water demand from available sources with-in-year and years to come, was examined and water allocation strategy using WEAP has been framed and demonstrated here for both of the watersheds under study.

HJRF002: The monthly mean concentration (January 2017 to December 2017) of TSP at Mohal observed as 76.5± 3.14 and for Kothi it was 47.4 ± 4.19 µg m^{-3} (for three months) respectively. The maximum concentration was 187.2 µg m^{-3} at Mohal and 93.3 µg m^{-3} at Kothi on 31th December and 11th April 2017 respectively. While the minimum concentration at Mohal and Kothi were 7.2 µg m^{-3} on 31th August 2017 and 24.7 µg m^{-3} on 17th May 2017 respectively. The mean concentration of particles below 10 µ (PM_{10}) was observed to be 43.4 ± 1.85 µg m^{-3} from January 2017 to December 2017 at Mohal, while at Kothi it was observed 22.2 ± 2.63 µg m^{-3}(April, May, June), respectively. The maximum and minimum concentration was 96.7 µg m^{-3} on 31th December 2017 and 7.2 µg m^{-3} on 31th August 2017 at Mohal. On the other hand, its maximum and minimum concentration at Kothi was 43.2 µg m^{-3} on 4th June 2017 and 0.4 µg m^{-3} on 19th April 2017, respectively (Fig.1).

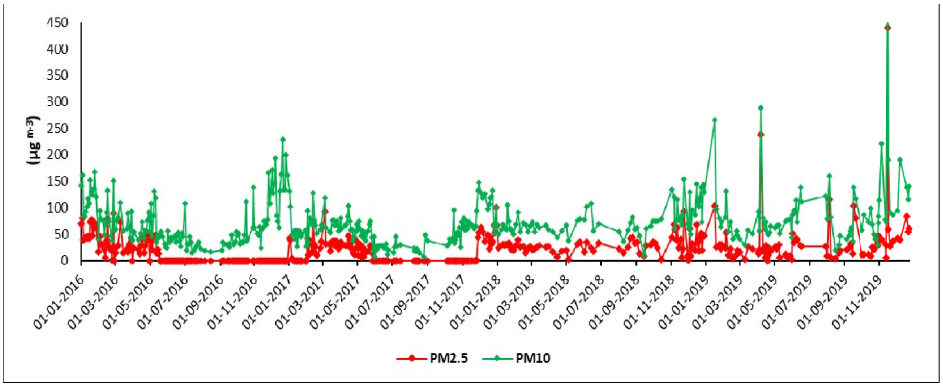
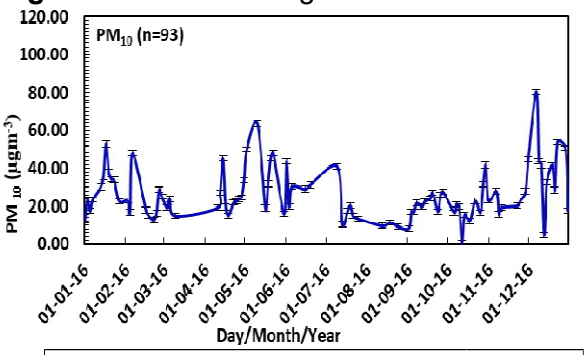
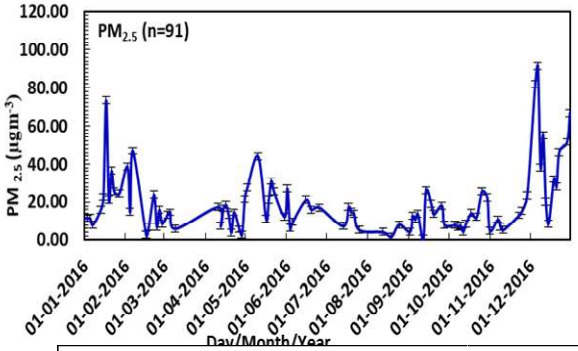
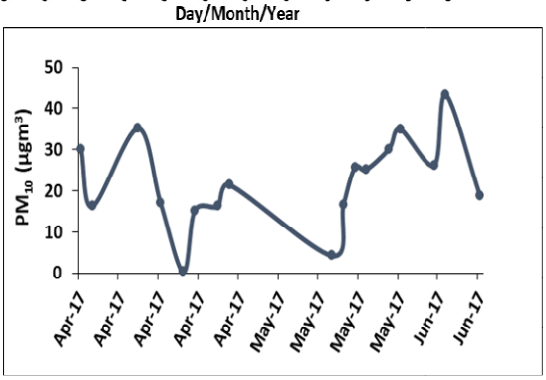
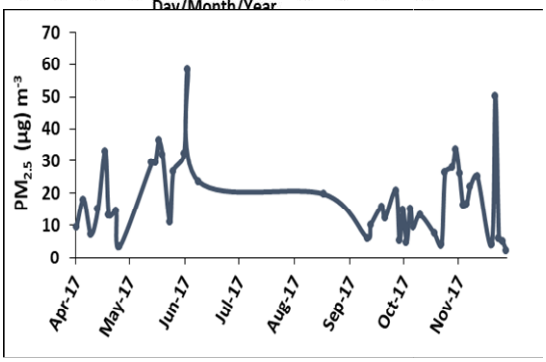


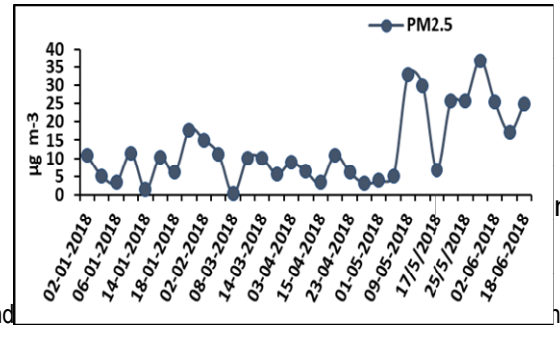
Fig. 1: Particulate and gaseous Pollutants in Mohal during the study period (2016-2019)

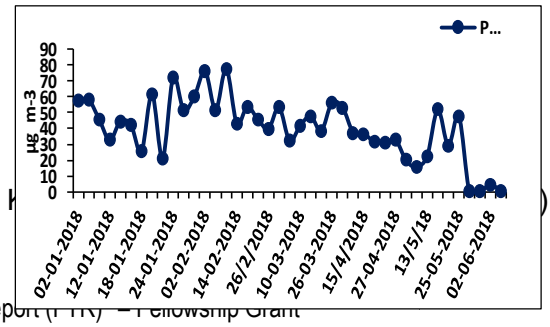












At Mohal $PM_{2.5}$ concentration was the highest 92.6 µg m^{-3} during November while lowest was 1.12 µg m^{-3} in December 2018. The average concentration of $PM_{2.5}$ from January 2018 to December 2018 was 36.2 ± 3.56 µg m^{-3}. The particles below 10 µ (PM_{10}) at Mohal were found to be with maximum concentration in December, while its minimum concentration was in August. Its mean concentration from January 2018 to December 2018 at Mohal was 51.06 ± 3.47 µg m^{-3} at Mohal. PM_{10} at Mohal with maximum concentration was observed 95.2 µg m^{-3} in December 2018 while its lowest concentration was 1.3 µg m^{-3} in November 2018 (Fig.3). The daily maximum concentration of TSP at Mohal from April 2018 to December 2018 was 186 µg $^{m-3}$ on November 15, 2018, while the minimum concentration was 29.2 µg $^{m-3}$ on September 25, 2018. The monthly mean concentration of TSP was 86.2 ± 5.54 µg $^{m-3}$ during observation days at Mohal (Fig.3).

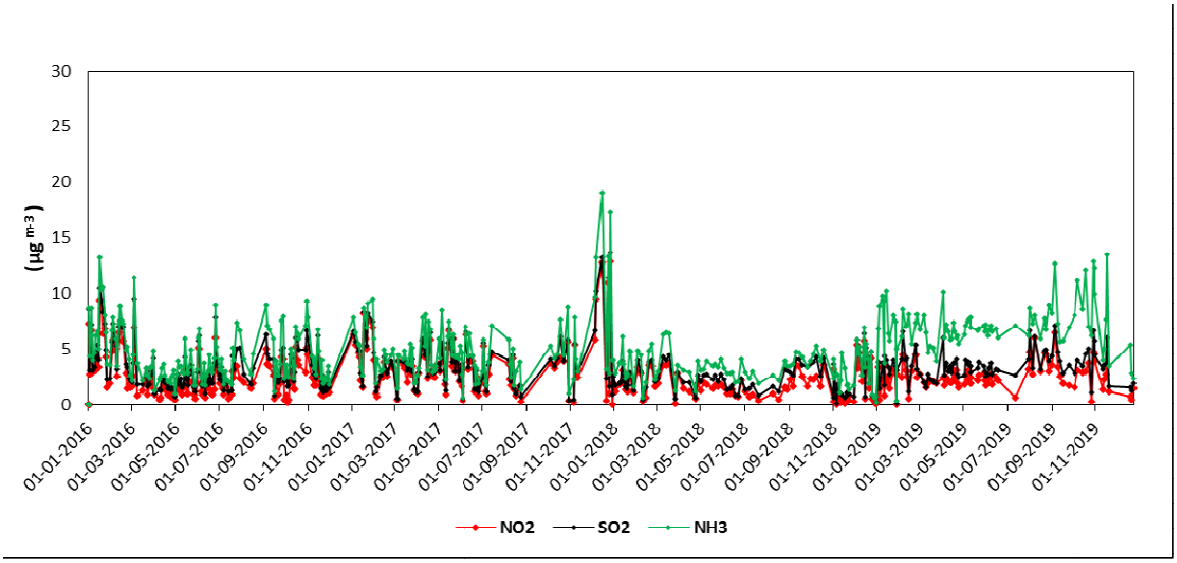
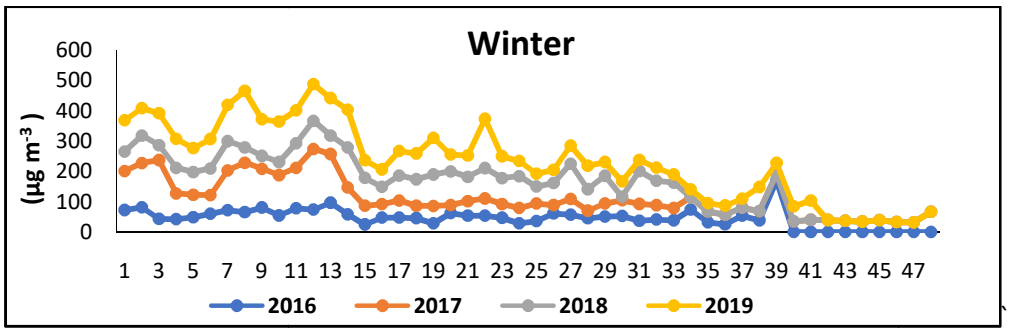


Fig. 3 Gaseous Pollutants at Mohal during study period (2016-2019)

PM_{10} Concentration at Mohal

During winter season the highest ever concentration of PM_{10} (162.6 µg m^{-3}) was observed on January 16, 2019 (Fig. 4). This value of PM_{10} was recorded minimum 25.7 µg m^{-3} on February 25, 2019. The average concentration of PM_{10} was observed 56.6±5.8 µg m^{-3}. While the status of PM_{10} during spring season was observed 106.3 µg m^{-3} as maximum on April 10, 2019 and 37.2 µg m^{-3} minimum on April 20, 2019. The average concentration of PM_{10} was observed 60.4±6.9 µg m^{-3}. On the other hand, during summer season the highest concentration of PM_{10} (110.6 µg m^{-3}) was observed on June 05, 2019 (Fig. 4). This value of PM_{10} was recorded minimum 34.7 µg m^{-3} on June 03, 2019. It has been observed that PM10 concentration has been increasing continuously from the year 2016 to 2019.



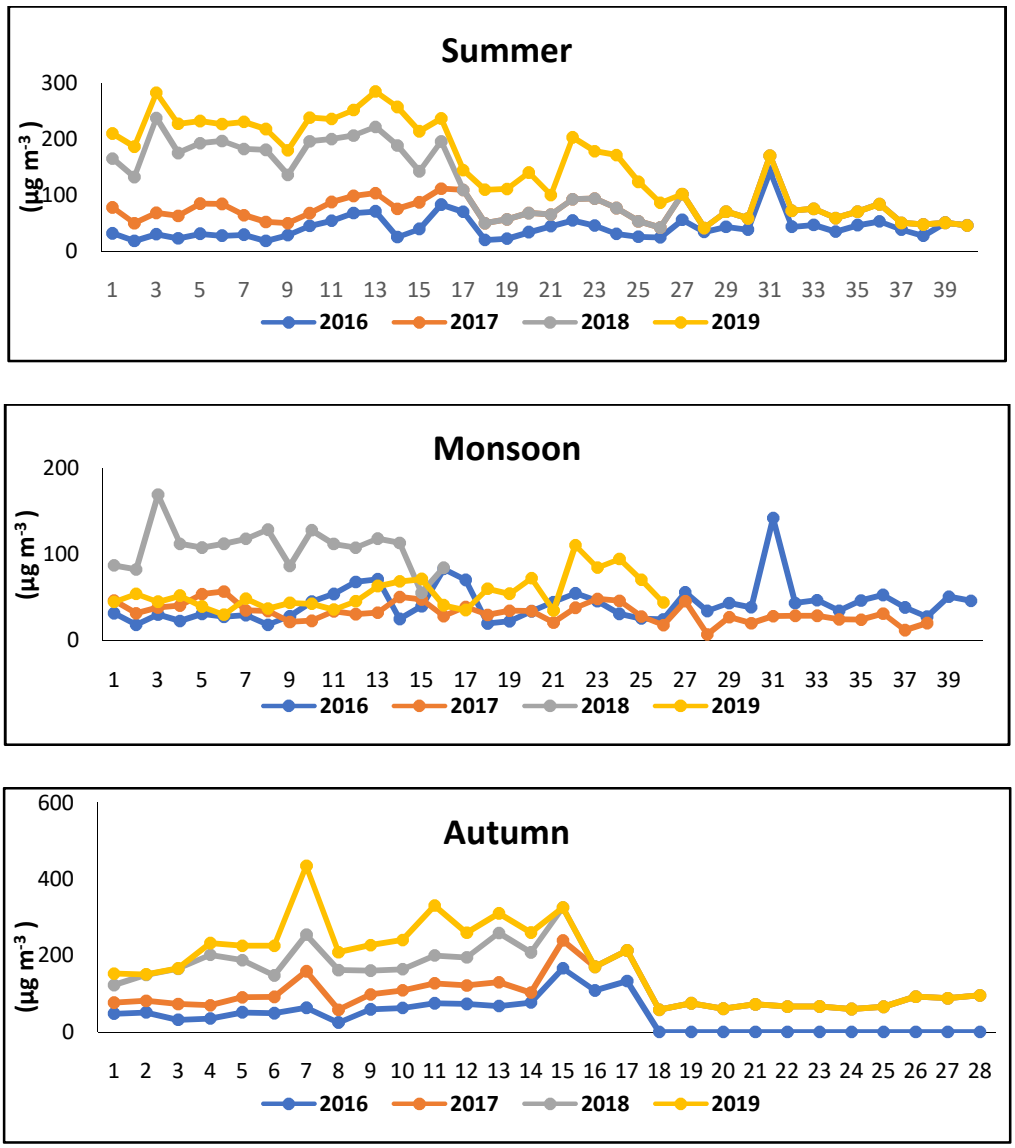


Fig. 4: PM_{10} Concentration at Mohal during different season during study period (2016-2019)

Rainfall

The rainfall is an important parameter within the atmosphere. More importantly, rainfall determines the ecological situation of the specific area. Rainfall plays a major role in determining the humidity level in this region which is again important to determine moisture content within ambient air.

Rainfall at lower Kullu valley

The maximum rainfall was recorded 1304.4 mm during 1988 and minimum was recorded 647.8 mm during 2009. While the mean rainfall was 927.4± 28 mm). Rainfall is decreasing at the rate of 4.3 mm / year (Fig. 5).

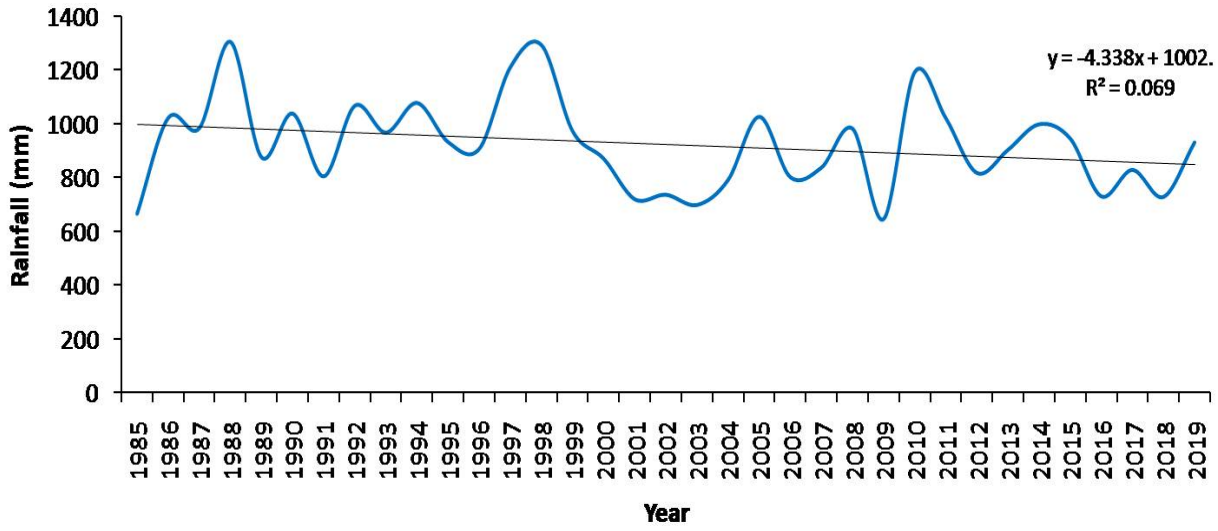


Fig. 5 Rainfall trend in the lower Kullu Valley (Source: KVK Bajura, 2020)

Temperature

The interaction of insulation with the atmosphere and the earth's surface creates heat which is measured in terms of temperature. While heat represents the molecular movement of particles comprising of substance, the temperature is the measurement of degrees of how hot (or cold) a thing (or a place) is. The temperature of air at any place is influenced by the latitude, altitude, distance from the sea of a place and local aspects. Temperature data of 35 years was analyzed from 1985-2019. Temperature is continuously increasing in the study area. The maximum temperature was recorded 29.5^0C during 2019. On the basis of temperature data analysis, the temperature has been increasing at the rate of 0.07^0 C per year (Fig. 6).

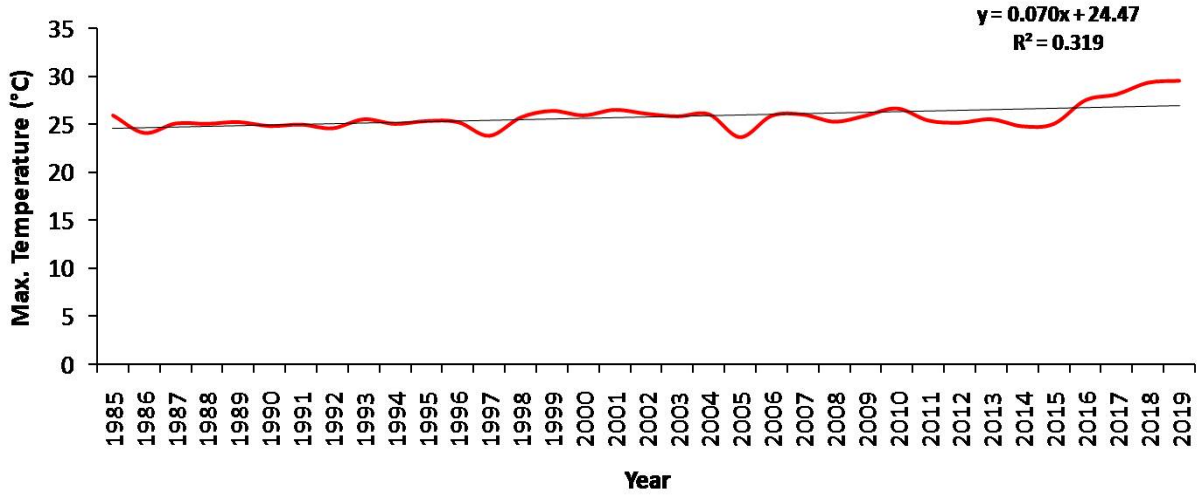


Fig. 6 Temperature trend in the lower Kullu valley (Source: KVK Bajura, 2020)

Chilling hours in lower Kullu valley

The requirement of chilling hours for apple standard variety is 800-11007 and daily temperature of 70°F and higher for 4 or more hours received by the plant during the previous 24 to 36 hours can actually negate chilling in apple. The apple buds remain dormant until they have accumulated sufficient Chilling Units (CU) during the winter season. When required chilling units accumulate, the buds grow in response

to warm temperatures. Different combinations of the temperatures during the dormant phase and the duration of the chilling period fulfill the plant's chilling requirements. But due to lack of sufficient chilling temperatures during winter apple plant develops physiological anomalies viz. delayed foliation, reduced fruit set, increased buttoning and reduced fruit quality. Which affect the yield and quality of apple fruit crop. Among all the productivity reducing factors, climate is one of the most important factor and difficult to manage. Climate change has important implications on fruit crop production and apple is no exception. In this regard, chilling hour's data were calculated during 2009-10 to 2019-20. It is found that chilling hours has continuously decreasing in the study area. Chilling hours is decreasing at the rate of 22.7 hours / year (Fig. 7). Which has direct impacts on apple production in the study area.

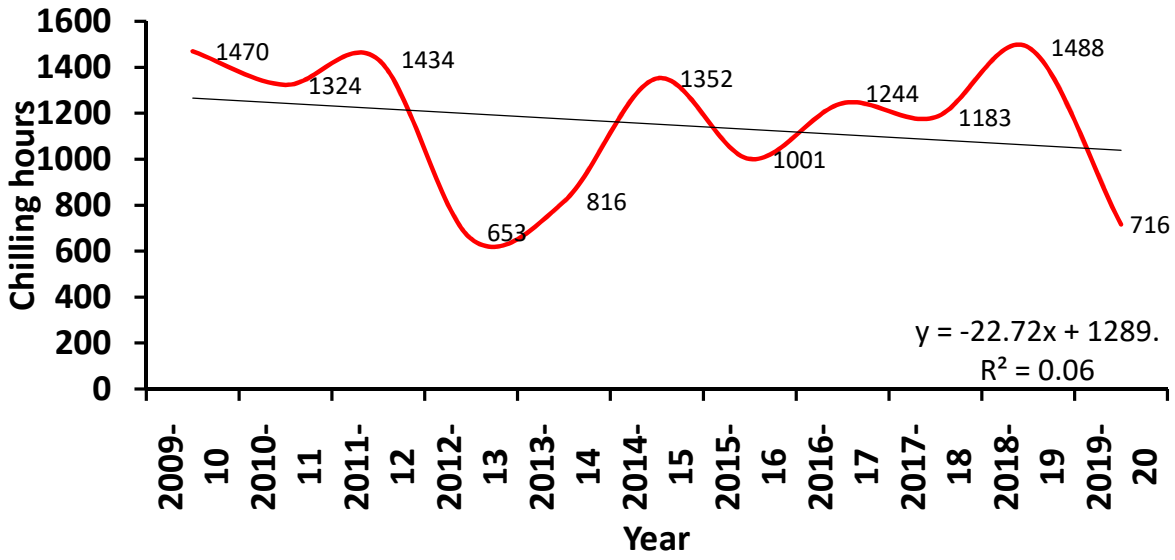


Fig. 7 Chilling hours in Kullu valley (Source: ISRO-AWS, 2020)

Apple Production and Area

Apple production and area's data were collected from horticulture department Himachal Pradesh during 1990-91 to 2016-17. Every year percentage increase rate of the data was calculated. In which it was found that there is variation between the area and production. Despite increasing the area every year, production has not increased. The reason behind this may be due to many factors affecting apple production of which the main factor is climate. In 1991-92 about 7% apple sown area has increased while -9.5% productions have decreased. Similarly, in 2016-17, the area grew by 2.9% while production decreased by -45% (Fig. 8).

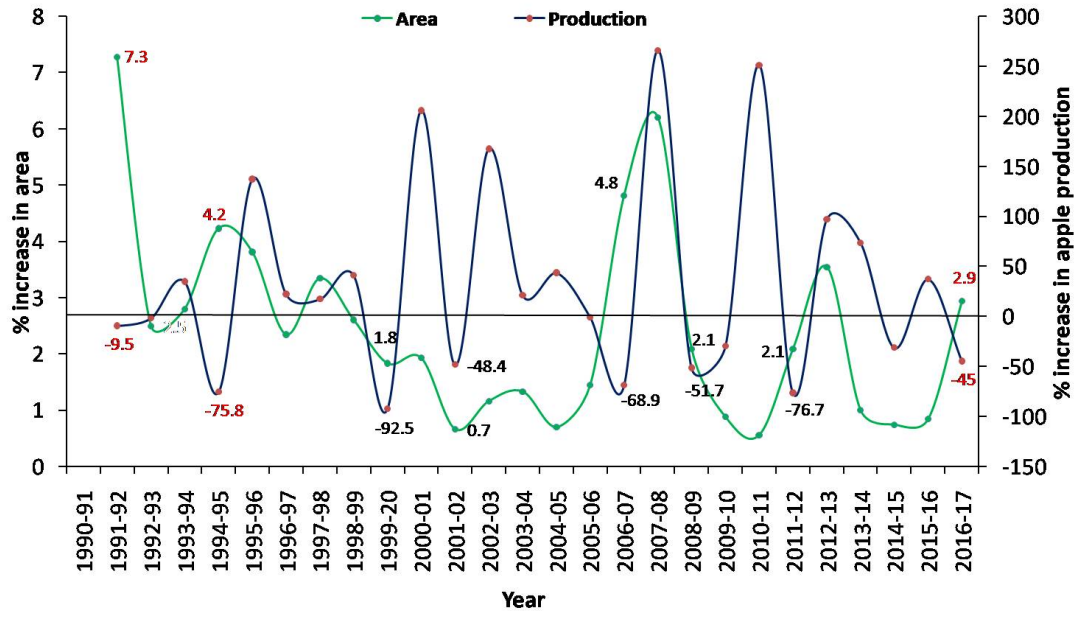


Fig. 8 Yearly percent change in area and apple production

Correlation between apple production and chilling hour

To know the relationship between apple productions and chilling hour, linear correlation among them was calculated. Chilling hour was taken as independent variable and production was taken as dependent variable. The positive correlation was found between chilling hours and apple production (Fig. 9).

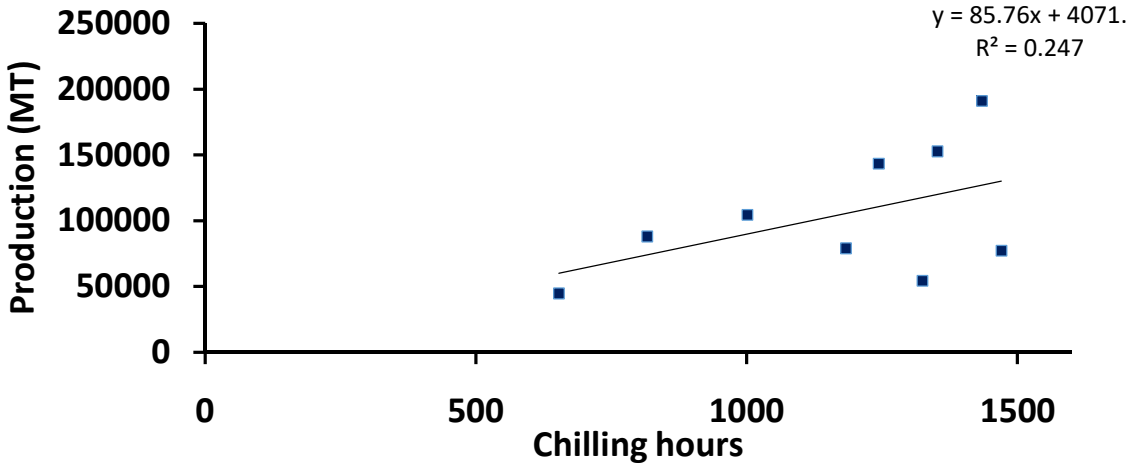


Fig. 9 Correlation between Chilling hours and production

HJRF006:

- Microscopic observations revealed heavy colonization of *T. wallichiana* roots by a variety of endophytic fungi, fungal mycelium colonization was higher in comparison to the dark septate endophytes. Simple dip treatment in distilled water, up to 2-3 weeks, helped in cleaning the melanin like substances from *T. wallichiana* roots and providing clarity to the size and shape of

the fungal structures. In bioassays, the fungi showed tolerance to wide range of temperature (5 to 25 °C), pH (0.5-12.0) and salt concentration (12-14 %) (Adhikari and Pandey, 2018 b).

- Five endophytic fungi, isolated from the roots of *Taxus wallichiana*, were identified following phenotypic and molecular characters. Three fungal isolates showed maximum similarity with species of *Penicillium* (GBPI TWR_F1, GBPI TWR_F2, and GBPI TWR_F3) and two with species of *Aspergillus* (GBPI TWR_F4 and GBPI TWR_F5). All the fungal endophytes solubilized phosphate by utilizing the substrates as calcium, aluminum and iron phosphate along with the production of phosphatase and phytase enzymes. Maximum phosphate solubilization and phytase activity was recorded in case of the fungal isolate GBPI TWR_F2 (*P. daleae*) being 83.42±3.41 µg/mL tri calcium phosphate, 57.63±0.79 µg/mL aluminum phosphate, and 57.76±1.70 µg/mL iron phosphate at 15 °C. GBPI TWR_F2 and GBPI TWR_F5 (*Aspergillus* sp.) produced maximum calcium phytate at 25 and 15 °C, 10.33±0.13 and 10.37±0.37 µM/mL, respectively. Phosphatase production was higher in acidic conditions in comparison to alkaline. In quantification of organic acids through HPLC, malic and succinic acids were determined in maximum quantity 0.97±0.003 and 0.92±0.008µg/mL, respectively, followed by oxalic (0.71±0.006µg/mL) and lactic acid (0.61±0.005 µg/mL). Citric acid was estimated in minimum quantity (Adhikari and Pandey, 2019).
- On the basis of phenotypic and molecular characters, the bacteria were identified as *Burkholderia contaminans* and *Enterobacter asburiae*. Both the bacteria could grow at wide range of temperature (5-40 °C, opt= 25 °C) and pH (1.5-11.0, opt= 25 °C) and tolerate salt concentration up to 12 %. While both the bacterial endophytes possessed antagonistic activity, siderophore, HCN, ammonia and salicylic acid producing abilities, GBPI_TWL also showed IAA and ACC deaminase producing abilities. Both the bacteria were found to be potential phosphate solubilizers at wide temperature range (5-35 °C), by utilizing tricalcium, iron, and aluminium phosphate as substrate. Further, the bacterial isolates produced phytase and phosphatase enzymes in both acidic and alkaline conditions. Effect of bioformulation (GBPI_TWL and GBPI_TWr) were also tested on soil physico-chemical parameter. Control soil phosphorous, nitrogen and potassium content were 2 times lower then endophytic bioformulation treated soil. Phosphorous, nitrogen and potassium content were higher in the soil treated with GBPI_TWr, but water holding capacity and moisture content was higher in soil treated with GBPI_TWL. Bioformulation of these endophytic bacteria enhanced growth of *Oryza sativa* and *Glycine max* under net house experiments (Adhikari and Pandey, 2020; 2021).
- 5 endophytic fungi of *T. wallichiana* were tested for the taxol production by biochemical and molecular method. Out of 5 endophytic fungi, two fungi viz GBPI_TWR F1 (*Penicillium* sp.) and GBPI_TWR F5 (*Aspergillus* sp.) found taxol producing with 31.23±0.83 and 60.56±1.07 mg pt/L taxol, respectively. The genomic DNA samples have been sequenced to confirm the presence of the two genes implicated in taxol biosynthesis, 10-deacetylbaccatin III-10-O-acetyl transferase (DBAT) and C-13 phenylpropanoid side chain-CoA acyltransferase (BAPT). Both the endophytes showed the amplicons of DBAT and BAPT gene. To further improve taxol production different parameter like temperature, pH, incubation time and medium constituents i.e., salt concentration, carbon and nitrogen source were optimized. Maximum accumulation recorded at 2 g/l glucose and 1.5 g/l ammonium ferrous sulphate for GBPI_TWR F1 and 2 g/l maltose and 1.5 g/l potassium nitrate for GBPI_TWR F5 respectively. The fungus produced taxol in S7 liquid medium with maximum production recorded at 25 °C, 3.5 pH and 20 days of incubation (GBPI_TWR F1, 44.67±0.68 mg pt/L) and 15 °C, 5 pH and 10 days of incubation (GBPI_TWR F5 75.74±0.94 mg pt/L) (Annex. VI).
- All the plant part showed significant activity against all 3 major groups of microorganisms in agar well diffusion method; maximum activity was recorded in case of *T. wallichiana* needles. Among solvents, ethanolic extract of needles (maceration) showed highest antibacterial activity (15.33 ± 0.25 mm). Growth of actinobacteria was inhibited maximum (22.0±0.26 mm) by the methanolic extracts of needles (maceration). Ethyl acetate extract of needles (soxhlet) showed higher antifungal activity (7.84±0.21 mm). Antibacterial and antifungal activities were higher in maceration and soxhlet methods, respectively. The most affected group among the three categories of test microorganisms was bacteria which may be due to their prokaryotic organization. This was also supported by the low minimum inhibitory concentration (MIC) values.

Dichloromethane and petroleum ether extracts did not show any antifungal activity (Adhikari and Pandey, 2018 a).

- Preliminary screening of antimicrobial activity: Five solvents (hexane, chloroform, ethyl acetate, methanol and water) were selected to separate compounds in the needles according to the polarity. Then all the extracts hexane, chloroform, ethyl acetate, methanol and water were tested against three group of microorganisms (bacteria, actinobacteria and fungi). Out of 5 only methanol and ethyl acetate extract shows antibacterial, antiactinobacterial and antifungal activity. These two extracts (ethyl acetate and methanol extract) were analyzed by the GC-MS

Identified compounds by GC-MS

List of identified compounds :

Identified compounds in methanol extract

R. Time	Area	Area %	Name
5.303	1286215	0.18	2-Furanmethanol
8.210	1698740	0.23	Phenol
8.253	353183	0.05	2,4-Dihydroxy-2,5-dimethyl-3(2H)-furan-3-one
9.431	1120445	0.15	D-Limonene
13.023	9171307	1.26	Benzoic acid
13.132	3225540	0.44	Catechol
13.878	1021594	0.14	Benzothiazole
17.167	597893	0.08	1-Tetradecene
17.853	2589337	0.35	2-Propenoic acid, 3-phenyl-
18.265	859798	0.12	Methyl 4-hydroxy benzoate
29.061	570074	0.08	Octadecanoic acid
32.093	943477	0.13	Phenol, 2,4-bis(1-phenylethyl)-
34.883	1435730	0.20	Nandrolone
35.445	741672	0.10	4,4'-Dimethoxy-biphenyl-2-carboxylic acid, methyl ester
35.673	1671037	0.23	Estra-5(10)-en-3-one-17-ol, acetate
35.929	1753830	0.24	Oleoyl chloride
43.753	2020345	0.28	(-)-Nortrachelogenin
45.984	4985499	0.68	gamma.-Sitosterol

Identified compounds in ethyl acetate extract

R. Time	Area	Area %	Name
8.148	257466	0.22	Phenol
12.593	2676284	2.28	Benzoic acid
16.467	386091	3.20	Benzaldehyde, 4-hydroxy
18.245	290503	0.16	Salicyl hydrazide
19.237	573763	0.28	Benzoic acid, 4-hydroxy-, pentyl ester
19.010	694722	0.59	beta.-D-Glucopyranose, 1,6-anhydro-
21.608	3754199	3.20	Benzenepropanol, 4-hydroxy-3-methoxy-
22.019	1636357	1.39	4-Hydroxy-3-methoxybenzyl alcohol, di(isopropyl) ether
24.608	2729706	2.32	Neophytadiene

28.740	1416762	1.21	cis-9-Hexadecenal
31.961	170022	0.14	1-Heptacosanol
23.868	5125629	4.36	Papaveroline, 1,2,3,4-tetrahydro-
19.844	2659525	2.26	3-(p-Hydroxyphenyl)-1-propanol
33.838	443833	0.38	Bis(2-ethylhexyl) phthalate
40.458	341871	0.29	gamma.-Tocopherol
41.856	345678	0.49	Vitamin E
45.978	456231	2.95	gamma Sitosterol

- After optimization of solvent and extraction method, next main step was optimization of mobile phase for separation of antimicrobial compounds. For optimization of mobile phase for TLC, bio-autography and column chromatography selectivity triangle was used. After mobile phase optimization, 10 compounds (palmitic acid, stearic acid, arachidic acid, behenic acid, myoinositol, hexadecane cinchonine, procainamide, nicotinamide and timolol) having antimicrobial potential were identified. These compounds belong to saturated fatty acids, alkane hydrocarbons, carboxylic sugars, alkaloids and vitamins (Annex. VII).

HJRF008: Among the four village clusters, Urgam village cluster occupied the maximum (12689.7 ha) forest area of which about 95% area covered by mixed *Oak* and *Rhododendron* forests whereas, Sutol–Kanol village cluster had highest alpine area (4824.3 ha) (information based on the Revenue and Forest Department). The selected village clusters are located in high altitudinal rural landscape and visited by a large number of tourists every year for trekking/ recreational activities which provide seasonal job opportunity to local people as tour guides/daily wage workers. In addition, local people are involved in seasonal collection of some potential wild bio-resources like *Ophiocordyceps sinensis*, Mushroom, Jhula lichen, Moss etc. Jhula includes several species of lichens e.g., *Permalia* sp., *Usnea* sp., *Ramlina* sp., *Solrina* sp.,*Umblicraia* sp., etc. (Nidhi and Deepali, 2013). Among the mosses, the genus *Sphagnum* is found the most commonly collected group (Semwal *et. al.,*2007). Nearly 63–87.41% households in studied village clusters were engaged in collection of wild bio-resources from the alpine areas located between 3300– 4500 masl and about 58–98% households involved in collection of wild bio-resources from the forests adjacent to the village clusters. On an average 2–3 individuals from each household took part in collection of wild bio-resources from the alpine region. Before proceeding to alpine regions for collection of Keera Jadi (*Ophiocordyceps sinensis*), local people usually search suitable sites covering long ranges of about 6–22 km for extraction. They spend about 50-60 days in alpine areas to collect this speciesbetween May to June every year.The selected wild bio-resources were divided into three categories based on their availability in nature and economic value such as (i) high value low volume, (ii) low value and high volume (iii) low value low volume. Out of the sixteen wild plants listed, four species i.e. *Ophiocordyceps sinensis, Morchella esculenta, Origanum* vulgare and *Carum carvi* fall under the category of high value low volume products. Among these species, the overall collection of *Ophiocordyceps sinensis* was recorded maximum (324±0.03 kg/yr) in all the four village clusters and has a total monetary equivalent of Rs 32.4 crore /year. Out of four village clusters, maximum collection (104±0 kg/yr) of *O. sinensis*was estimated for Sutol-Kanol village cluster while minimum (57±0.01 kg/yr) was found in Urgam village cluster.An average collection at per household level was ranged between 0.10 – 0.12 kg/yr from all four village clusters. Therefore, at per household level the average earning was estimated about Rs0.11±0.01lakh/yr from the selling of *O.sinensis)* based on the prevailing market rate). Among the four listed plant species, *Morchella esculenta* was collected least (98±0.03 kg/yr) in all four village clusters and exhibit the monetary equivalents of Rs7.84±0.002lakh/yr. with maximum collection (28±0.01 Kg/yr was reported from Sutol-Kanol cluster and minimum (21±0.01 kg/yr) from Urgam village cluster. In the second category of the wild bio-resources (low value high volume) that also includes four plant species such as Jhula (lichen), Moss, *Diplazium esculentum* and *Paeonia emodi*. Among these resources, the collection of Jhula lichen was recorded maximum (101262±2.35kg/yr) in all four village clusters with monetary equivalent of Rs16.20±0.002lakh/yr. Among the village clusters, maximum (36797±2.35kg/yr) collection of Jhula lichen was estimated fromUrgam village cluster while minimum

(28467±0.12 kg/yr) was recorded in Sutol-Kanol village cluster. It was estimated that on an average a household in these village cluster collect about 31.32–64.33 kg Jhula (lichen) per year. In this region dried Jhula is collected mostly from the sub-alpine and temperate forests on rotational basis which with the due permission from the State Forest Department. It was informed by the villagers that the ban was imposed by the Forest Department on the collection of Jhula and Moss from the forest area in Vaan village cluster between 2015-2018, however, in the year 2019 it was opened for collection now they allowed to extract this resource from reserved forest in all village clusters once in three years and sometimes on yearly basis. Among the four plant species, *P. emodi* was collected minimum (7171±0.35 kg/yr) with monetary equivalent of Rs2.50±0.001lakh/yr. Among the village clusters.Salud-Dungra village cluster collected maximum (2070±0.13 kg/yr) *P. emodi* whereas minimum (1434±0.05 kg/yr)was recorded at Vaan village cluster. Under the category of low value low volume bio-resource products about eight species were collected from the wild from all four village clusters such as *Saussurea obvallata, Taxus wallichiana, Pleurospermum anglecoides, Angelica glauca, Saussurea costus, Hippophae rhamnoides, Allium straheyii* and *Rhododendron arboreum*. Among these species, the maximum (1804±0.22 kg/yr) collection was recorded for *R. arboreum*in all four village clusters with a total monetary equivalent of Rs1.62±0.002lakh/yr. The maximum (651±0.06 kg/yr)collection of *R. arboretum* flower was recorded in Vaan village cluster while minimum (350±0.05 kg/yr) at Urgam village cluster. Of the total species collected under this category, *S. costus* was collected minimum (201±0.23 kg/yr) with a total monetary equivalent of Rs.0.32±0.003 lakh/yr. The maximum (64±0.15 kg/yr) collection of *S. costus* was recorded in Salud-Dungra village cluster while minimum (30±0.04 kg/yr) at Vaan village cluster. The total monetary value of the provisioning services provided by these sixteen wild bio-resources was estimated about Rs 344.4±.35 lakh/yr with maximum value obtained for Sutol– Kanol village cluster (Rs109.8±0.03lakh/yr) followed by Vaan village cluster (Rs103.9±0.03lakh/yr), Rs and least was obtained for Urgam cluster (Rs638.6±0.12lakh/yr). It was also estimated that on an average a household collect the wild bio-resources of worth of Rs1.17±0lakh/yr with maximum value for the household at Sutol-Kanol (Rs1.20±0lakh/yr) and minimum at Urgam (Rs1.11±0 lakh/yr). Among the listed wild bio-resources, only five plant products i.e. *O. sinensis,* Jhula lichen, *M. esculenta*, *S. costus* and Moss are directly sold in the market by the locals or some time by the local traders. It was found that *O. sinensis* alone contribute maximum (Rs 324±0.34lakh/yr) in terms of economy in all four village clusters with highest monetary value was obtainedfor Sutol– Kanol village cluster (Rs 108.8±.03 lakh/yr). Out of the total plant bio-resources collected and were grouped in three categories, only five species such as *Ophiocordyceps sinensis,* Jhula lichen, *M. esculenta*, *S. costus* and Moss contributed maximum (Rs 341.2±0.66lakh/yr) in the local economy. Among the five plant species only *M. esculenta* was consumed (29±0.03 Kg/yr) in by locals in all village clusters and (69 Kg/yr) was sold in the market worth of 0.55±0.05 lakh/yr. It was found that primary collectors collect the wild bio-resources from alpine and nearby forest; but due to their remoteness and limited market access and information they cannot sell their goods directly to the end users or consumers. Between the Primary collectors and the end users stands a host of marketing intermediaries performing a variety of functions and bearing different tags like tradersand commission agents which ultimately reduce the benefits of the primary collectors.

Cost Benefits Analysis of the value added bio-resources

Cost-benefit analysis of a variety of value added edible foodstuffs prepared from different plant parts of various wild edibles (i.e., fruits, flowers, soft twigs, petiole etc.) shown in Table 2, 3 and 4. Among the selected wild edible species, the net monetary return was obtained maximum for spices prepared from *Carum carvi* (410±6.48) followed by *O. vulgare* (360±6.16), *A. stracheyi* (270±2.06) and minimum for *P. anglecoides*(160±1.80). In the category of juice the net monetary return was found maximum from*P. emodi* (195±1.29)followed by *H. rhamnoides*(70±2.97) and minimum for *R. arboreum* (50±1.08). The pickle prepared from*H. rhamnoides provide highest return* (Rs.180±9.1) followed by *P. emodi* (175±1.94) and minimum was obtained for *D. esculentam* (170±2.20).

HJRF0010: The proximate analysis of the selected species has shown that Na, K, P and Ca content was highest in *Zingiber zerumbet* followed by *Curcuma caesia* and others (Fig. 6). The Phosphorus content was highest in Z. zerumbet (3.20±0.25 g/100 gdw) followed by *C. caesia* (2.12 ±0.12 g/100 g dw), C.

angustifolia (1.26 ±0.11 g/100g) and *I. griffithii* (0.41±0.01 g/100g). The sodium content was in similar range (0.61-0.68 g/100 g dw) except *I. griffithii* with slightly low (0.58±0.09 g/100 g dw). The potassium content was highest in Z. zerumbet (1.91 ± 0.06 g/100g dw) and lowest in *I. griffithii (0.25±0.10 g/100 g dw).* The calcium content in Zingiberaceae species was in similar range (2.3 to 2.78 g/100g dw). The Z. zerumbet has highest crude protein (13.0 ±0.05g/100g dw) and ash content (19.87±0.16 g/100g dw) while *I. griffithii* has the lowest amount of crude protein (0.94±0.09 g/100g dw) and Ash content (10.45±0.31 g/100g dw).

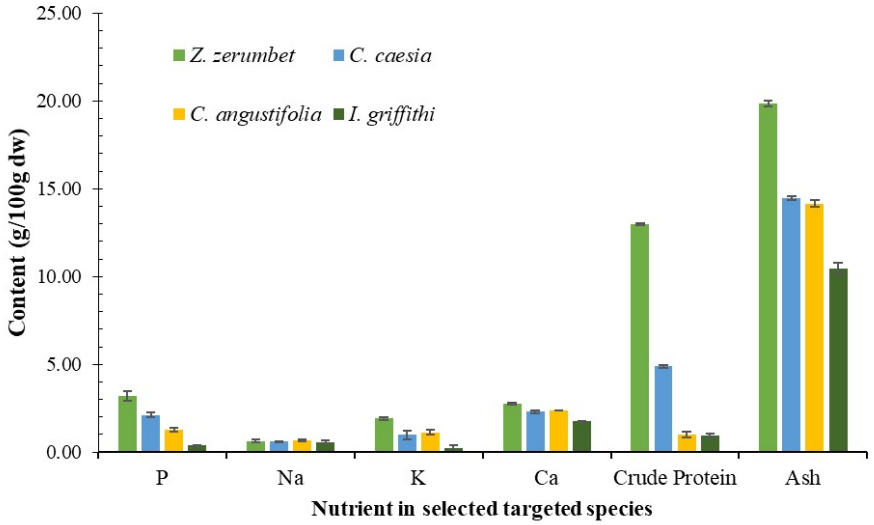


Fig.6. Biochemical content in targeted species

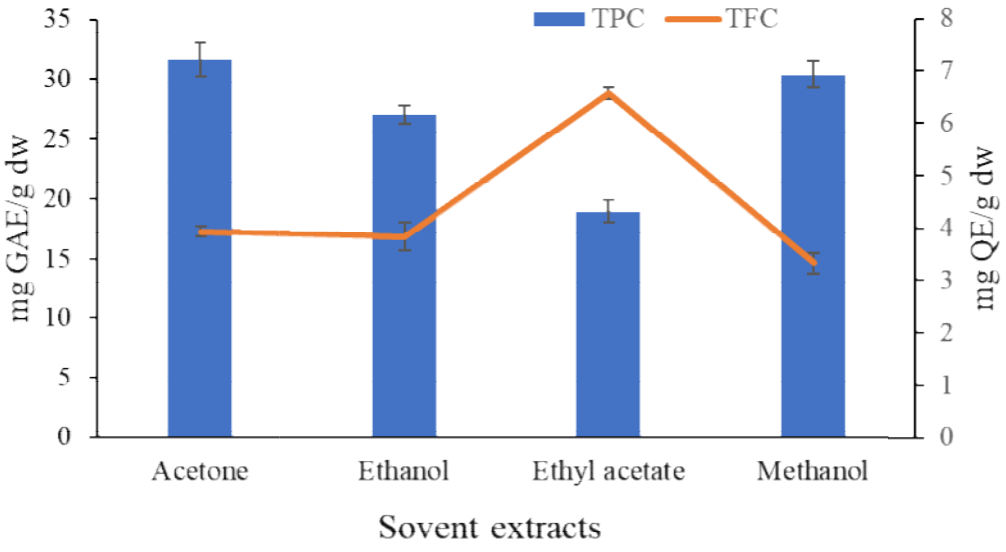


Fig.7. Phytochemical content in different solvent extracts of *I. griffithii*

The phytochemical analysis of *I. griffithii* fruit extracts varied as per the solvent (Fig. 7). The TPC, and TFC was in high amount signifying the potential of the fruits of the species for polyphenolic compounds. The solvent extracts of different species among the Zingiberaceae family showed that TPC, was highest

in methanol among all the three species followed by acetone and ethanol extracts, while lowest in ethyl acetate extracts. The phytochemical analysis of the targeted species (Fig. 9) viz. *C. caesia, Zingiber zerumbet, Curcuma aungustifolia* have shown that total phenolic (TP) content was highest in methanol for all the three species. The total flavonoid (TF) content was also found highest in methanol for both the species *C. caesia* and *Z. zerumbet*; while for *Curcuma aungustifolia* it was highest in ethyl acetate extract. The total tannin (TT) content was also found highest in methanol for all the three species.

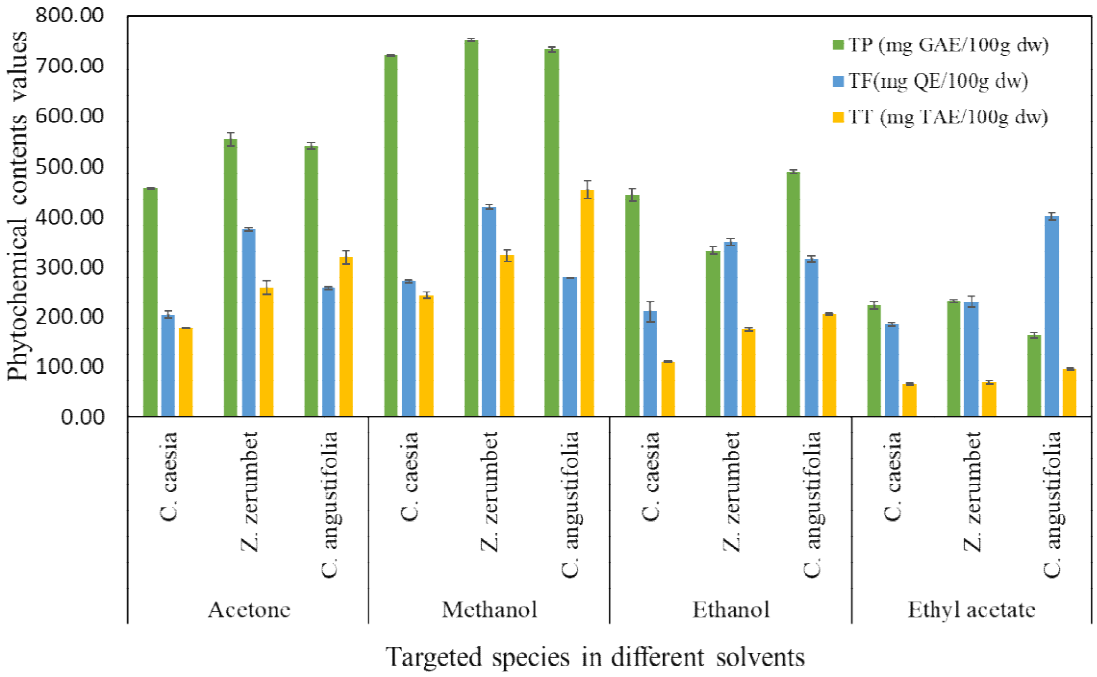


Fig.8. Phytochemical content in three different species of Zingiberaceae family

The antimicrobial activities of targeted differed as per the tested microorganism and utilized extraction solvent. In general, bacteria appear to be more sensitive to antimicrobial constituents, followed by actinobacteria and fungus. For, *Curcuma caesia*, the ethanolic and methanolic extract of showed the higher activity against *Pseudomonas chlororaphis* (11.00 ± 0.06 mm) and *Serratia marcescens* (11.00 ± 0.12 mm). The actinobacterial activity was higher in ethanolic extract (6.15 ± 0.18 mm) against *N. tenirefensis*. Among different tested fungi, antifungal activity was not found against *Pythium afertile* and *Trematis hirsuta*. Different extracts showed antifungal activity against three fungal species, i.e*., F. solani, A. niger,* and *P. variotii*. Ethanolic extract showed the highest inhibition against *F. solani* (4.06 ± 0.12 mm) and *A. niger* (3.15 ± 0.24 mm). *P. variotii* was maximum (8.34 ± 0.28 mm) inhibited by methanolic extract (Fig. 9). The MIC value for bacteria (300-700 µg/mL), actinobacteria (400-600 µg/mL) and fungi (700-900 µg/mL) was wide-ranging for different solvent extracts. The ethanol and acetone solvents extracts have depicted the lowest MIC values against *Pseudomonas chlororaphis* and *Bacillus megaterium,* respectively.

The antibacterial analysis of *I. griffithii* revealed highest activity in Ethanol and Acetone extracts against, *S. marcescens* (14.67±0.86) and *E. coli* (13.33±0.03) respectively. The Acetone extract have exhibited activity (20±0.06) against *B. subtilis*, while other solvent extracts and didn't show any activity against it. For *Curcuma angustifolia*, the ethyl acetate extract has shown highest activity against *E. coli* (28.3±5.58) and *S. marcescens* (24.7±0.27), followed by other solvents extract. The *Bacillus subtilis* was resistant to all the solvent extracts and didn't show any activity by

all the solvent extracts. The MIC values was ranged between 300-500µg/ml in *E. coli* and 300-800 µg/ml in *S. marcescens* for all the solvent extracts. For *Zingiber zerumbet*, the antibacterial analysis has revealed that Ethyl Acetate and methanol have highest activity against *E. coli* (16.7±0.98), and *S. marcescens* (23.3±0.72), followed by ethanol against *E. coli* (16.3±0.27) and methanol against *S. marcescens* (20.0±0.47). Methanol and ethanol extract also exhibited higher activity against *B. subtilis.* Ethanol, methanol and ethyl acetate extracts exhibited antifungal activity only against *A. niger*. The MIC values ranged between 400-700 µg/ml for all the bacteria while for fungus the values vary b/w 450-700 µg/mL.

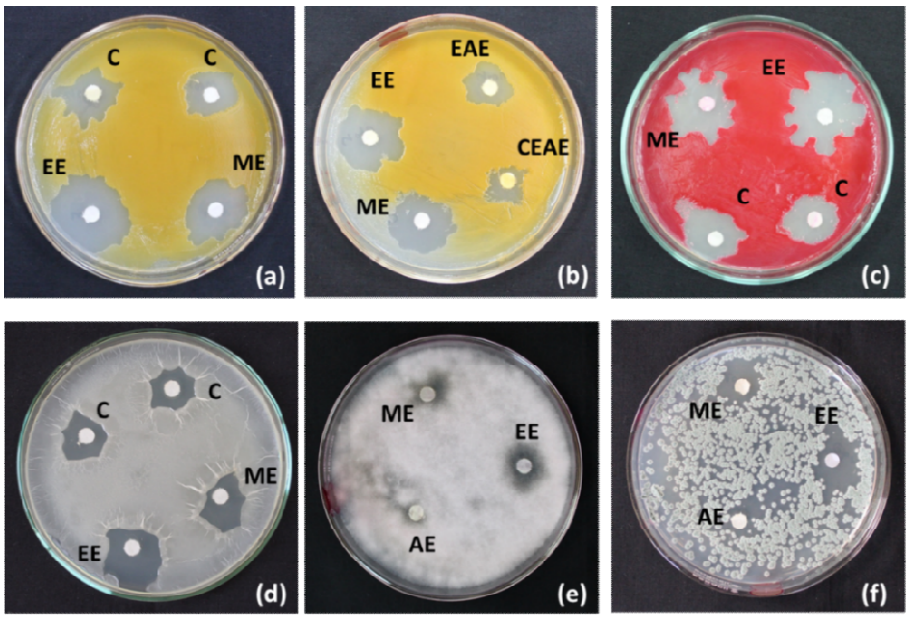


Fig. 9. Antimicrobial activity of *C. caesia* (a-d) Antibacterial activity against *Pseudomonas chlororaphis, Serratia marcescens, Bacillus megaterium* respectively and (e-f) Antifungal activity against *Aspergillus niger* and *Fusarium oxysporum*, respectively;

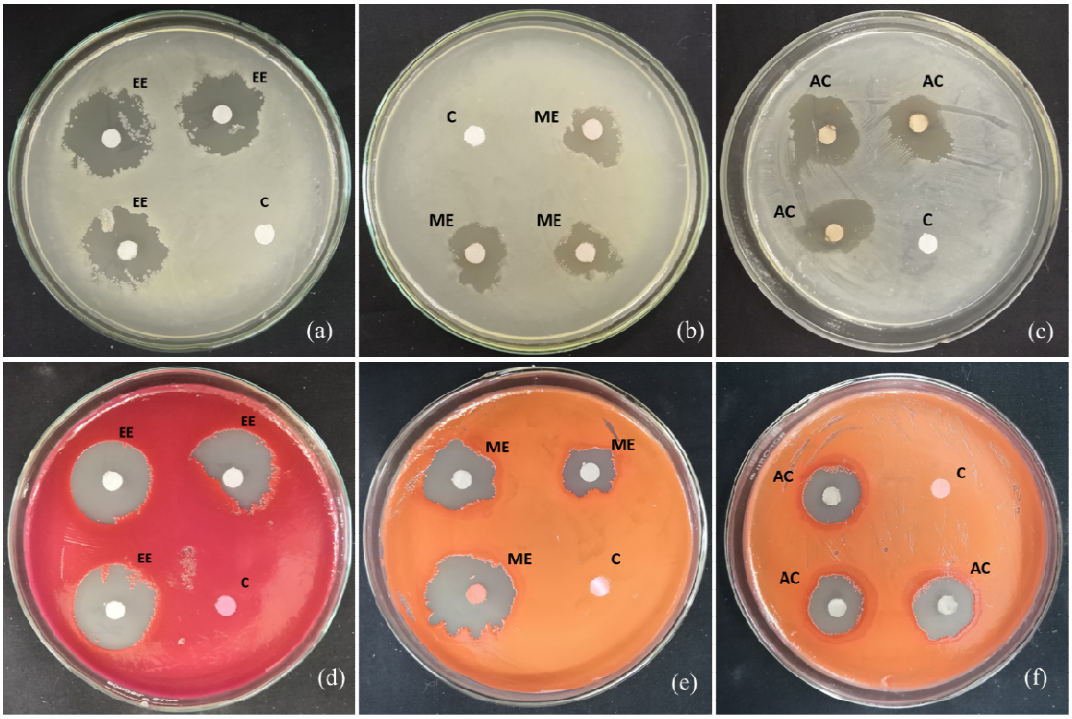


Fig. 10. Antibacterial activity different solvent extracts of *I. griffithii* against *E. coli* (a-d) and *Serratia marcescens (d-f)*

The FTIR-ATR spectra of all the species depicted a broad band around 3289 cm^{-1} followed by a sharp spectrum between 2800 and 3000 cm^{-1} (Fig.11). The peak shows the presence of a hydroxyl group that primarily specifies the occupancy of alcohol, phenol, acid, water, and proteins (Mishra and Mohanty, 2018). The spectra between 2800 to 3000 cm^{-1} at 2929 cm^{-1} corresponds to the asymmetrical (v_a) stretching vibration in aliphatic compounds (C-H) (Masek et al., 2014).The strong spectrum at 1642 cm^{-1} was followed by small and shoulder peak between 1480- 1187 cm^{-1}. The spectra also illustrated sharp and strong peak around 1000 cm^{-1} and several smaller and shoulder peak between 767 and 500 cm^{-1}. The spectra around 1642 cm^{-1} shows the presence of aromatic structure (C=C). The spectra between 1480- 1187 cm^{-1} showed four bands (at 1430, 1373, 1327, 1237 cm^{-1}) signifies the O-H deformation and C-O stretching vibrations of phenols interaction (Abbas et al., 2017). The strong band around 1000 cm^{-1} corresponds to the stretching vibration in phenols (Deus et al., 2021). The several bands between 767 and 500 cm^{-1} associated to out-of-plane deformation vibration of C-H group are crucial in determining the type of aromatic substitution (Abbas et al., 2017). The details of associated groups and compounds in different wavenumbers of the spectra is also shown in Table 5.

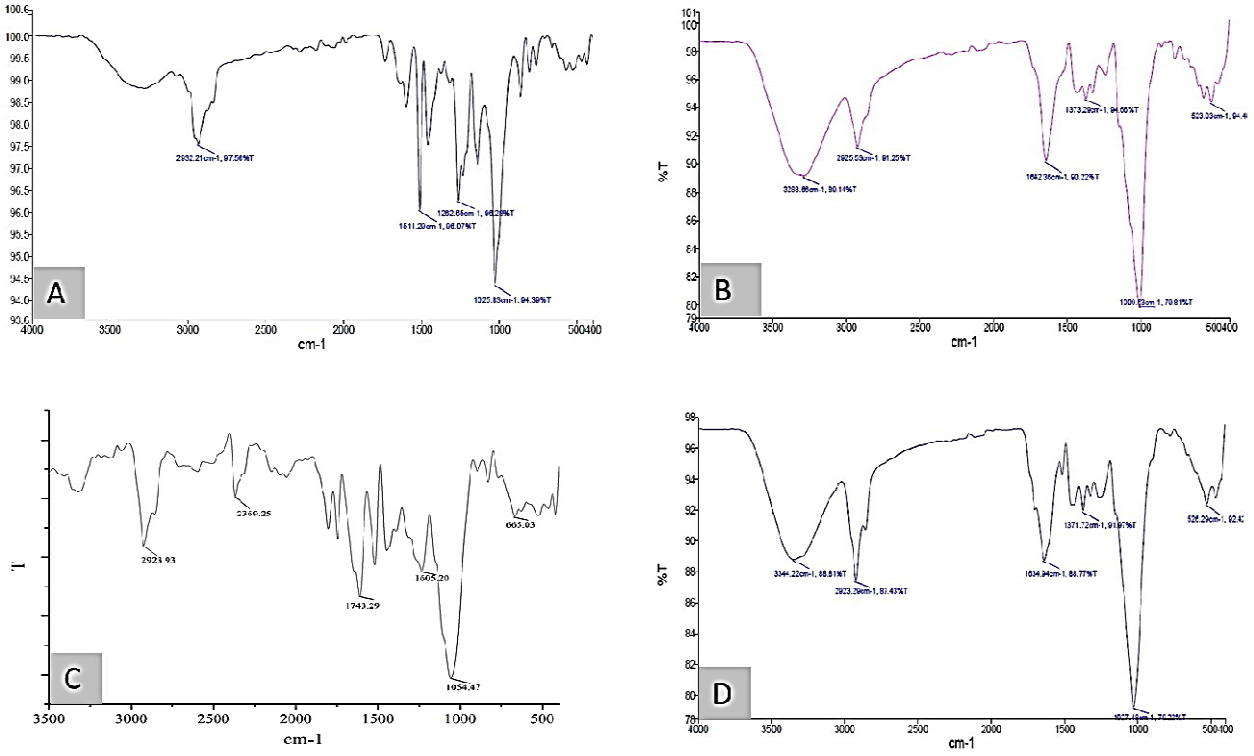


Fig. 11. FTIR spectra of selected species (A) C*. angustifolia (B) C. caesia (C) I. griffithii (D) Z. zerumbet*

Table 5. Main functional groups of the major plant biomass

Wavenumbers (cm^{-1})	**Functional group**	**Compounds**
3500-3000	O-H (stretch)	Phenolic, alcoholic, carboxylic
3000-2800	C-H (stretch)	Aliphatic compound
1730	C=O (stretch)	Carbonyl
1510-1650	C=C (stretch)	Aromatic ring
1440-1400	O-H (ben)	Alcoholic, carboxylic
1235	COOH (stretch)	Carboxylic, acetic acid ester
1246-950	C-O-C, C-O, C-OH (Stretch)	Lignin, polysaccharides
850-750	C-H (bend)	Aromatic compounds

A total of 9 major bioactive compounds viz. Gallic acid, Catechin, chlorogenic acid, vanillic acid, p-coumaric acid, m-coumaric acid, o-coumaric, rutin and T-cinnamic acids were detected (Table 6) in HPLC analysis of the methanolic extracts of the plants. Chlorogenic acids were highest in both the *Curcuma* species, while catechin was higher in Zingiber species. Further, gallic acid was highest in *I. grifithii,* among others. O-coumaric and Rutin was not detected in both the *Curcuma* species, while m-coumaric was not detected in *I. griffithii and* Z. zerumbet Further, o-coumaric acid was detected in only Z. zerumbet. Similarly, T-cinnamic acid and rutin was only detected in *C. angustifolia* and *I. griffithii* respectively as shown in Table 6.

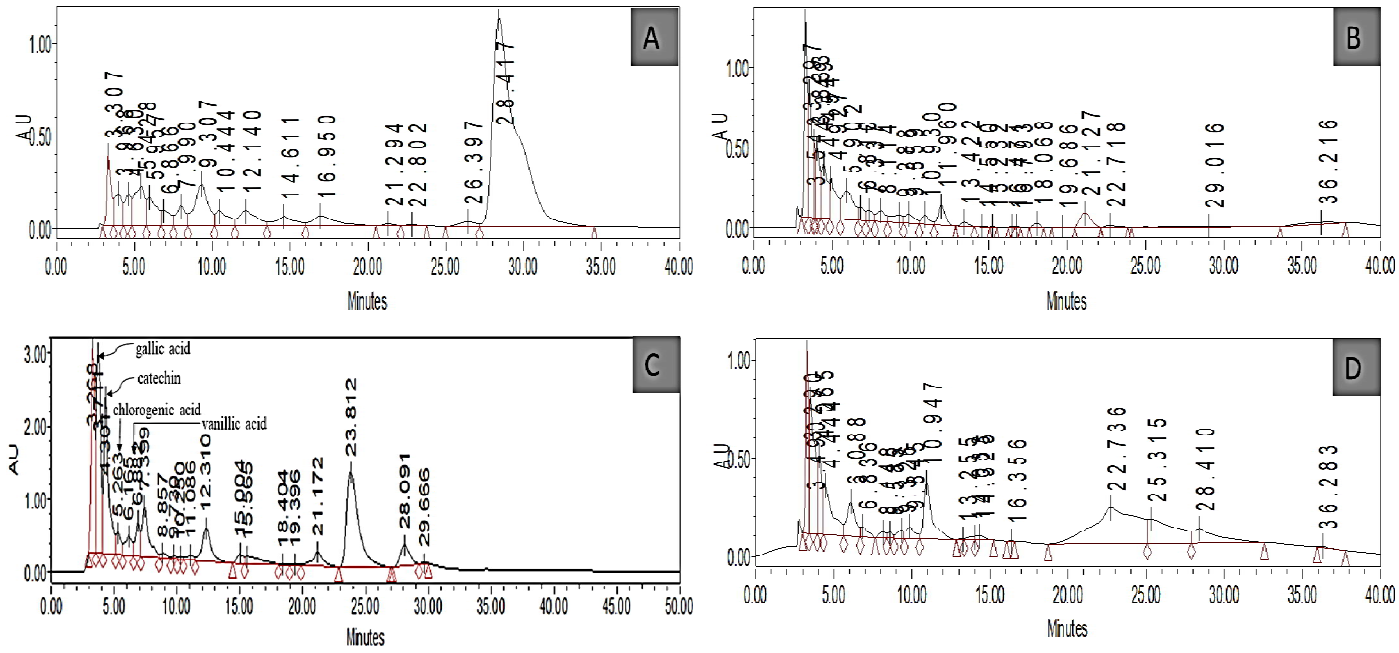


Fig.12. Chromatogram of methanolic extracts of *C. angustifolia(A), C. caesia (B), I. griffithii (C), Z. zerumbet (D)*

Table 6. Compound identified in the different plant species

Compound	**Concentration (mg/100g)**			
	C. angustifolia	*C. caesia*	*I. griffithii*	*Z. zerumbet*
Gallic acid	18.70±0.40	14.43±0.74	358.28±0.99	25.40±1.84
Catechin	20.58±0.18	41.34±2.38	237.23±0.61	57.08±4.80
Chlorogenic acid	185.27±4.07	165.00±5.51	278.03±5.42	nd
Vanillic acid	22.90±0.25	21.73±2.69	98.60±0.62	29.94±6.76
p-coumaric acid	35.79±0.74	31.46±5.56	39.14±0.09	32.22±7.70
m-coumaric acid	51.22±1.76	28.31±4.57	nd	nd
o-coumaric acid	nd	nd	nd	29.81±19.31
Rutin	nd	nd	62.21±2.97	nd
T-cinnamic acid	19.74±0.10	nd	nd	nd

All the three targeted species except *Illicium griffithii* was grown well in the cultivated area at Itanagar and Ziro. This shows that *Illicium griffithii* needs similar climatic conditions for growth. Or similar climatic conditions may be needed to provide for the healthy growth of the plant species. The other species i.e., *Curcuma caesia, Zingiber Zerumbet*, and *Curcuma aungustifolia* can grow in diverse climatic conditions. The three selected species are being cultivated every year at GBPNIHE-NERC, RTC Itanagar for knowledge dissemination and demonstration to local and students.

Fig. Growth of the targeted species (*Curcuma aungustifolia,* Zingiber *zerumbet, Curcuma caesia*) at GBPNIHE-NERC, Rural Technology Centre at Itanagar, Arunachal Pradesh

3.2 Key Results (max. 1000 words in bullets covering all activities)

- **HJRF02:** The mean concentration of particles below 10 μ (PM_{10}) was observed to be 43.4 ± 1.85 μg m^{-3} from January 2017 to December 2017 at Mohal, while at Kothi it was observed 22.2 ± 2.63 μg m^{-3} (April, May, June), respectively.
- The monthly mean concentration (January 2017 to December 2017) of TSP at Mohal observed as 76.5± 3.14 and for Kothi it was 47.4 ± 4.19 μg m^{-3} (for three months) respectively. The maximum concentration was 187.2 μg m^{-3} at Mohal and 93.3 μg m^{-3} at Kothi on 31th December and 11th April 2017 respectively. While the minimum concentration at Mohal and Kothi were 7.2 μg m^{-3} on 31th August 2017 and 24.7 μg m^{-3} on 17th May 2017 respectively.
- The daily maximum concentration of TSP at Mohal from April 2018 to December 2018 was 186 μg $^{m-3}$ on November 15, 2018, while the minimum concentration was 29.2 μg $^{m-3}$ on September 25, 2018. The monthly mean concentration of TSP was 86.2 ± 5.54 μg $^{m-3}$ during observation days at Mohal
- During winter season the highest ever concentration of PM_{10} (162.6 μg m^{-3}) was observed on January 16, 2019. This value of PM_{10} was recorded minimum 25.7 μg m^{-3} on February 25, 2019. The average concentration of PM_{10} was observed 56.6±5.8 μg m^{-3}. While the status of PM_{10} during spring season was observed 106.3 μg m^{-3} as maximum on April 10, 2019 and 37.2 μg m^{-3} minimum on April 20, 2019. The average concentration of PM_{10} was observed 60.4±6.9 μg m^{-3}. On the other hand, during summer season the highest concentration of PM_{10} (110.6 μg m^{-3}) was observed on June 05, 2019. This value of PM_{10} was recorded minimum 34.7 μg m^{-3} on June 03, 2019
- The $PM_{2.5}$ concentration ranged between 10.3 μg m^{-3} to 40.6 μg m^{-3} with the mean value of 21.6±1.9 μg m^{-3} at Raison. Highest concentration of PM_{25} (40.6 μg m^{-3}) was observed on June 20, 2019. On the other hand, at the Beasar (Control) site PM_{10} concentration ranged between 3.1 μg m^{-3} to 17.2 μg m^{-3} with the mean value of 10±0.9 μg m^{-3}. The AQI study reveals that air quality of Mohal falls under good to moderate category.

- The seven days back trajectories were drawn using Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) from National Oceanographic and Atmospheric Administration to indicate long range transport source during pollution episodes. Most of the air masses reach Kullu valley from western regions and some are from Indo-Gangetic regions
- The maximum rainfall was recorded 1304.4 mm during 1988 and minimum was recorded 647.8 mm during 2009. While the mean rainfall was 927.4± 28 mm). Rainfall is decreasing at the rate of 4.3 mm / year.
- Temperature data of 35 years was analyzed from 1985-2019. Temperature is continuously increasing in the study area. The maximum temperature was recorded 29.5^0C during 2019. On the basis of temperature data analysis, the temperature has been increasing at the rate of 0.07^0 C per year
- Chilling hour's data were calculated during 2009-10 to 2019-20. It is found that chilling hours has continuously decreasing in the study area. Chilling hours is decreasing at the rate of 22.7 hours / year. There was a positive correlation between chilling hours and apple production
- Apple production and area's data were collected from horticulture department Himachal Pradesh during 1990-91 to 2016-17 and the yearwise percentage increase rate of the data was calculated. It was found that there is variation between area and production. Despite increasing the area every year, production has not increased in the Kullu valley. The reason attributed to this may be the many other factors affecting apple production of which the main factor is climate. In 1991-92 about 7% apple sown area has increased while -9.5% productions have decreased. Similarly, in 2016-17, the area grew by 2.9% while production decreased by -45%

3.3 Conclusion of the study undertaken (maximum 500 words in bullets)

HRA01:

- High dependence on divine NTFPs that help poorly marginal people to fulfil their domestic needs.
- Unfortunately no strike conservation protocol is being implemented.
- Selected market demanding species can be multiplied and popularized in traditional agroforestry system.
- The occurrence of threatened species indicates high anthropogenic pressure and that the area has high conservation value
- In spite of the present shift towards NTFPs, the situation has not been changed much in favour of poor communities who are engaged in the collection and processing of NTFPs.
- More concerted efforts are needed to improve the market structure, as well as creating enabling conditions for the sustainable harvesting and management of NTFPs.
- Lack of good practices by the primary collectors leading to destruction of forest and absence of data to determine sustainable harvest levels.
- Primary collectors still receive very low returns from NTFPs. Because of these constraints, official policy changes cannot deliver adequate benefits for poor people.
- More & more crops should be brought under cultivation to ease the pressure on the wild source
- Most of the forest resources policies in the State has focus on sustainable timber exploitation.
- Announced a four-year closure policy, helped in providing adequate strength to the cause of conservation and sustainable

An appropriate policy framework for the sustainable promotion of NTFPs is necessary to help to ensure an effective development, promotion and sustainable harvesting of NTFPs in the Himachal Pradesh. Such a policy will also encourage right holders to domesticate these products on sustainable basis and thus reduce pressure on the forest resources.

HJRF002: The AAQM study carried out under the present selected sites showed the Particulate pollution is high at Mohal and raison as compared to Beasar control site. Because the Mohal and Raison are nearby National Highway (NH_3); so here the pollutants level is higher compared to the Control site.

- The concentration of PM_{10} at Mohal and Raison has crossed the permissible limit (100 μg m^{-3}) prescribed by NAAQS which might not be so good from a viewpoint of human's health and plant life. However, it is noted that except for the winter season at Mohal the concentration of $PM_{2.5}$ at study sites were well within the permissible limit set by NAAQS.
- The gaseous pollutants such as SO2, NO2 and NH3 were found far below the permissible limits.
- Rainfall is negatively correlated with $PM_{2.5,}$ SO_2 and NO_2 but positively correlated with $PM_{10,}$ TSP and NO_2. Humidity is negatively related with $PM_{10,}$ TSP and SO_2 and positively related with $PM_{2.5}$ and NO_2.Wind has shown negative correlation with all the pollutants except SO_2.
- TSP and PM10 concentrations were greatly influenced by both local and outside sources. The local sources such as vehicles and visitors' influx, burning of fuel wood, coal and solid waste, use of diesel generators, and dust blown from nearby un-metalled roads were the most important ones. The long-distance transport sources of air masses moving in from outside regions can also be considered to be contributing to the existing concentrations of these pollutants in the region.
- It is also made clear from HYSPLIT and CALIPSO analysis that the local source of pollutants are contribution in the air pollution of the Kullu valley.
- The AQI study reveals that air quality of Mohal falls under good to moderate category. However, PM_{10} was observed beyond its permissible limit during spring season when flowering in apple orchards are at peak, which might not be so good from viewpoint of apple orchards.
- The maximum precipitation was recorded during 1988 and minimum was during 2009. Precipitation is decreasing at the rate of 4.3 mm / year. The maximum temperature has been increasing at the rate of 0.07^0 C per year, which is pointing towards climate change.
- Chilling hours are also decreasing every year which has direct impacts on apple production and diseases have also increased in apple orchards. Therefore, the apple orchard has been shifting from lower region to higher regions in the Kullu valley.
- Environmental and health impacts of the air borne particles require that authorities urgently step up control of the ever-increasing level of air pollution not only in large cities but also in the towns/villages under study in this ecologically very sensitive and topographically fragile part of the Himalaya.

HJRF006:

The present study indicates the colonization of *T. wallichiana* roots by a variety of endophytic fungi. Fungal endophytes that comprise a diverse group of species and vary in symbiotic and ecological functions can influence the survival and fitness of plants in all the natural ecosystems. Isolation of the culturable fungi, species of *Penicillium* and *Aspergillus*, will be helpful in studying their contribution in the growth of *T. wallichiana* under low temperature environment. The endophytic fungi isolated from *T. wallichiana* roots growing in colder regions of IHR showed different ability to solubilize insoluble calcium, aluminum and iron phosphates through various mechanisms. Present study also highlighted that *Taxus wallichina* roots harbours culturable endophytes belongs to the *Burkholderia* and *Enterobacter* species. Both the psychrotolerant endophytes can grow at wide range of temperature, salt and pH. These psychrophilic endophytes exhibit remarkable plant growth promoting activity (Phosphate solubilization). The study indicated that *Burkholderia contaminans* and *Enterobacter asburiae* in particular possesses the PGP activities and they have ability to enhance growth of *Oryza sativa,* and *Glycine max* under net house condition. Thus, for plant growth enhancement these isolates can potentially use as plant biofertilizers and bioenhancers, because endophytes are environmentally friendly alternate to chemical pesticides and fertilizers. Five endophytic fungi were recovered and identified to the species level based on morphological and molecular trait 3 endophytic fungi belongs to the *Penicillium*sp. And 2 endohytic fungi belongs to the *Aspergillus* sp. Two isolates GBPITWR_F1 and GBPITWR_F2 were determined as a potent taxol producer based on the HPLC and molecular biomarker for taxol synthesis. From the study it was revealed that optimization of physico-chemical property for the secondary metabolite production

(specific reference to taxol production) is an important and crucial step. Both the endophytes produce good amount of taxol GBPI_TWR F1, 44.67±0.68 mg pt/L and GBPI_TWR F5 75.74±0.94 mg pt/L. Thus, both the endophytes used as an alternate source for the taxol production for pharmaceutical industries.

- All plant parts possess antimicrobial potential, being higher in bark and needle. Antimicrobial activity higher in maceration whereas antifungal activity higher in soxhlet method.
- Antimicrobial activity tested against 3 group of microorganism, bacteria, actinobacteria and fungi. The most affected group among the three categories was bacteria which is probably due to their prokaryotic organization. This was also supported by the low MIC values.
- The fungi against which the plant extracts showed antifungal activity are known as plant pathogens. However, the extracts did not show inhibition of the fungi such as *Trichoderma* indicate towards the mutualistic endophytic symbiotic relation. This shows the possibility of its use as biopesticide.
- Needles are renewable part of plant, and shows a good antimicrobial activity. Therefore, utilization of needles instead of bark and stem is recommended for harnessing their antimicrobial potential. For further isolation of the antibacterial and antifungal compounds, maceration and soxhlet are recommended respectively.
- Chloroform: E. acetate: methanol in ratio of 25:20:5 was good for separation during thin layer chromatography (TLC).
- With the help of LC-MS, GC-MS, FTIR and NMR total 10 compounds were identified with antimicrobial activity.
- Volatile compounds which are responsible for the antimicrobial activity are palmitic acid, stearic acid, arachidic acid, behenic acid, myoinositol and hexadecane. These compounds belong to saturated fatty acid, alkane hydrocarbon and carboxylic sugar.
- Non-volatile compounds which are responsible for the antimicrobial activity are cinchonine, procainamide, nicotinamide and timolol. These compounds belong to alkaloids, vitamins and flavanols group.

HJRF007: There is a lot of opportunities available with slight modification in the Traditional practices through the use of quality seeds suitable for hill agriculture and multi-cropping systems combined with animal husbandry through cattle rearing, poultry, fishing, bee-keeping, etc. Some other sectors also identified like Organic farming and agri-based employment opportunities which contain a lot of potential for the development of economy in the rural areas that need to be encouraged. The gardening and processing of fruits and vegetables, training for youths, and banking and insurance in the service sector can provide livelihood security and support. Development of all these areas along with infrastructure development and better education and medical facilities will be a great breakthrough for better life of rural people and for sustainable development of the hill regions. Possibly these steps will be very effective to strengthening the livelihood of rural areas and it will helpful to solving the problem of out migration from villages.

HJRF008: The study area (four village clusters) located in different parts of higher Himalayan region of the District Chamoli with altitudes ranging from 1500 masl to 2840 masl inhibited by 2934 householdswith total population of 13841 (Table 1). It is one of the most biologically diverse areas of the Central Himalaya. Vegetation varies according to both altitude and climatic conditions; from temperate broad leaf forest at middle altitudes, coniferous, subalpine and alpine forest at higher attitudes, giving way to alpine grasslands and high altitude meadows, and finally scrublands lead up to the permanent snowline. It was observed that about 80-85% of the households in all the four village clusters are directly dependent on forest, particularlyon wild bio-resources in terms of provisioning services for their livelihoods and income.The people living in the area are the traditional communities and have their own culture and community life. The rainfed agricultural terraces adjoining the villages; farming communities are predominant rural, despite decades of modernization. Even today, every aspect of the economy and day-to-day lives and livelihood of the majority of the population are governed by the agriculture, animal

husbandry and forest resources. The other occupations include allied activities, trade, business, unskilled and semi-skilled labour and government service. Whereas the crops are grown as a source of subsistence, wild bio-resources are collected from forest to generate village economy. In this scenario, local communities are highly dependent on the surrounding forest ecosystem. Therefore, understanding the linkages between forest ecosystem and human wellbeing and poverty alleviation is hence important (Semwal and Maikhuri 1996). This is especially true in rural landscapes of high altitude in central Himalayan region, where human dependency on natural resources is comparatively higher (Negi *et. al.* 2011, Chaudhary *et. al.,* 2016).The wild bio-resources had a huge contribution in balancing the economy as they are the ameliorative source of income of the local inhabitants, which have otherwise few other choices. These high value plants species had huge economic potential and also provide important sources of family income for those with few other choices, as well as for those with access to capital or land and the initiative to future market or commercialize a particular plant species. Although local people in the study area depend on forest ecosystems which provide several tangible (wild edibles, firewood, fodder and timberand intangible services or goods in the form of provisioning services. Additionally, it supplies medicinal plants, wild edible vegetables and fruits, and mushrooms. In the present case the total monetary values provided by the wild bio-resources in terms of provisioning services was estimated about Rs34.44crore/yr in all these four village clusters. Among the ecosystems, forest and alpine ecosystems are critical for sources of provisioning services. Interestingly, it was observed that the unique communities in higher elevations depend more on wild bio-resources as they live near forests and alpine pastures.The village community in the area are also aware that forest ecosystem has greater value, importance and significance in terms of regulating, supporting and cultural services. The results also revealed that the community is beginning to recognize the value of the services they use if they are valued in monetary terms as is the case of Keeda Jadi (Yarsagumba), Morchella, and high value medicinal plants, lichen and wild edibles, as also reported by others (Maikhuri *et. al.,* 2013, Negi*et. al.* 2011). In addition, people also acknowledge that the surrounding ecosystems provide them goods and services necessary for their livelihood and cultural survival. In contrast, local people perceive the contribution of the provisioning services from forests they obtained for the functioning of the rural landscape is enormous in terms of quantity and quality. . This suggests the forest ecosystem, is under pressure and delivery of its embedded services is gradually deteriorating. Nevertheless, despite the multi-dimensional (ecological, socio-cultural and economic) importance of ecosystems to human society, there have been no serious efforts to assess the ecosystem contribution in terms of primary services of the central Himalayan region (CHR) in totality (Maikhuri *et. al.,* 2015). Benefits provided by ecosystems are inadequately recognized and resource users do not take into account the cost of degradation of these services in their resource management decisions. Also, there is very limited understanding of ecosystem dynamics and the values that are being lost through overexploitation of the resources or degradation of the forest ecosystem. Some ways of reinforcing conservation and development simultaneously required major step such as is uppression of economic exploitation of hill farmers by middlemen in the marketing channel, iienhancing local knowledge of market dynamics and current discoveries, e.g. local people use *Taxus wallichiana* for medicinal use but are not aware of its value as a source of an anti-carcinogenic drug. Indigenous knowledge is a significant starting point for bio-prospecting and local communities must realize the economic benefits from it (Posey 1990), and providing policy incentives for cultivation of crops with fewer risks of damage by wildlife. The vast variability in ecological, socio-cultural and economic attributes and in the history of forest conservation as practiced by the traditional communities in many parts of the Himalaya demands more studies to develop strategies for reinforcing conservation to the benefit of local people as well as that of the wider global community.

4 OVERALL ACHIEVEMENTS

4.1 Achievements on Objectives [Defining contribution of deliverables in overall Mission (max. 1000 words)]

HRA01: About 61% of the flora of the study region had medicinal value.137 NTFPs are under diverse level of threat falls under various threat categories of IUCN, 2019 while 105 are under threat as per stakeholders due to excessive exploitation.

HRA02: The achievement with the proposed project has one way helped to rejuvenate the springs of Almora. The sampling last conducted was in 1991 and this helped to compare the parametric feature from then to now in 2017/18.This would help to compare the population of 1991 to 2017 along with the urbanisation around the springs. The surface water quality of the river Kosi which is a spring fed river will helped to see the surface water quality of the river in the monsoon and post monsoon season. This would help to estimate the water quality of the region of the entire region so that the sustainable use of the water would be encouraged and also the proper measures would be taken to estimate the planned urbanisation of the town.

HRA03: Bibliographic review on biodiversity and climate change

- Detailed literature collection, analysis and synthesis on biodiversity and climate change in IHR.

- The Himalayan Biodiversity and Climate Change- Knowledge Network (HBCC-KN) web portal has been developed and tested on different platform for its functioning. This knowledge network web portal can now be shared and popularize among different stakeholders of IHR for knowledge flow and sustainability.
- Book on lichen diversity of Western Himalaya

HJRF001:

- Water Evaluation and planning modelling system was effectively used to demonstrate implication of changing hydrological, climatological and land resources in selected watersheds of Kullu district of Himachal Pradesh and Almora district in Uttarakhand state.

- The societal implications were studied using available datasets from primary and secondary sources, future climate data (2015-2030) of GCM GFDL-ESM2M under RCP 4.5 and some model based scientific assumptions; and evaluated and analysed the existing and future water demands and supply in the watersheds and generated the trends of water demand and supply as well as the scenarios for water resources management till year 2030 to see the possible implications on society or on their needs.

- The present and future analysed datasets for respective study sites has been created for duration of 2015 to 2030 which includes datasets or status of rainfall, flow to groundwater from different land use/land cover, surface runoff from the watershed, population and livestock water demands, agriculture water demand, unmet water demand of population, livestock and agriculture, water supply to population, livestock and agriculture; and crop yield status in both the watersheds.

- The societal implications in terms of water demands (demands of population, livestock and agriculture) and to meet out the unmet water demand from available sources with-in-year and years to come, was examined and water allocation strategy using WEAP has been framed and demonstrated here for both of the watersheds under study.

HJRF02: The monthly mean concentration (January 2017 to December 2017) of TSP at Mohal observed as 76.5± 3.14 and for Kothi it was 47.4 ± 4.19 μg m^{-3} (for three months) respectively. The maximum concentration was 187.2 μg m^{-3} at Mohal and 93.3 μg m^{-3} at Kothi on 31th December and 11th April 2017 respectively. While the minimum concentration at Mohal and Kothi were 7.2 μg m^{-3} on 31th August 2017 and 24.7 μg m^{-3} on 17th May 2017 respectively. The daily maximum concentration of TSP at Mohal from April 2018 to December 2018 was 186 μg $^{m-3}$ on November 15, 2018, while the minimum concentration was 29.2 μg $^{m-3}$ on September 25, 2018. The monthly mean concentration of TSP was 86.2 ± 5.54 μg $^{m-3}$

during observation days at Mohal. PM_{10} concentration at Raison and Beasar sites were observed only in summer season, ranged between 9.6 µg m^{-3} to 31.8 µg m^{-3} with the mean value of 20.9±1.7 µg m^{-3} at Beasar. Highest ever concentration of PM_{10} (31.8 µg m^{-3}) was observed on June 28, 2019. On the other hand, at the Raison site PM_{10} concentration ranged between 34.7 µg m^{-3} to 112.3 µg m^{-3} with the mean value of 64.9±6.2 µg $m^{-3.}$ Temperature has negative correlation with $PM_{2.5,}$ $PM_{10,}$ ammonia but positive correlation with TSP and $SO_{2.}$ Rainfall is negatively correlated with $PM_{2.5,}$ SO_2 and NO_2 but positively correlated with $PM_{10,}$ TSP and NO_2. Humidity is negatively related with $PM_{10,}$ TSP and SO_2 and positively related with $PM_{2.5}$ and NO_2.Wind has shown negative correlation with all the pollutants except SO_2. The long-term meteorological data, apple production, cultivated area and chilling hours data were analyzed. Temperature data of 35 years (1985-2019) were also analysed. Temperature is continuously increasing in the study area. The maximum temperature was recorded 29.5^0C during 2019. On the basis of temperature data analysis, the temperature has been increasing at the rate of 0.07^0 C per year and the rainfall is decreasing at the rate of 4.3 mm/year. Chilling hours is decreasing at the rate of 22.7 hours / year. Which has direct impacts on apple production and apple tree and diseases have also increased in apple orchards over the period of time. In 1991-92 about 7% apple sown area has increased while -9.5% productions have decreased. Similarly, in 2016-17, the area grew by 2.9% while production decreased by -45%. The movement of apple orchards to higher altitudes were observed due to climate change. People at Bajaura and nearby areas felt significant decrease in apples with almost no orchard left productive upto commercial level. At the study site, there were some local coping and adaptation strategies adopted in response to observed risks and hazards related to climate and non-climatic factors.

- Shift towards new varieties (low chill and high yield varieties):- orchardists found traditional varieties (royal, red delicious, commercial, laldevi, kalidevi, jonathan, rich a red etc.) not suitable for cultivation in lower altitudes and hence, shifted their choice to low chill varieties (gala, vance, vance delicious, spur red, Oregon spur etc.). These varieties required less chill and early maturing.
- Change of choice of crops (vegetables and fruits):- to compensate the loss from the low productivity of apples, farmers have also introduced alternate crops (pears, kiwis, pomegranates, persimmon, cabbage and other vegetables) along with apples. This was found more in case of small and marginal orchards.
- Irrigation methods: - people at lower altitudes (Bajaura) were no more dependent on the rainfall as the source of water to the orchard. They have adopted various irrigation methods like lift irrigation, tank irrigation, usage of own wells (but the water table has also lowered down as per people's perception).
- Shift of orchards to higher altitudes: - orchardists felt higher altitudes were getting more suitable for apple cultivation and hence shifted their orchards toward upper valley. People at Bajaura and nearby areas felt significant decrease in apples with almost no orchard left productive upto commercial level.
- Bee keeping: - many farmers felt decrease in number of pollinators. To combat this change, many farmers had their own source of pollinators. Some farmers at the time of pollination hired bee colonies for successful pollination.
- More spray of chemicals: - many farmers felt an increase in pest infestation. To eradicate them chemicals were sprayed in the orchard. However, the no. of sprays had increased from 3-4sprays to 10-12 sprays per year.
- Usage of composts: - some people were also using organic composts (vermin composts) in place of chemical ones.
- Polyhouses and floriculture: - as people were facing threats of low productivity, they also switched over to alternate sources of income, such as setting up of polyhouses and floriculture (carnations).

HJRF004:

There are no state level policies which are primarily focused upon solar photo-voltaic technology despite the huge solar potential in the Indian Himalayan Region.

- If the focus of the state and national policies is compared, the national policies tend to have more weightage in terms of various solar energy policy formulations.
- If the focus of the policies of central and state governments is compared, it is observed that the central government is more focused towards the generation of solar energy through various technologies, while the state government is more focused upon the generation of hydro power.
- Meghalaya, Manipur, Mizoram and Tripura do not have any policies specific to just one renewable energy production technology, but there exists one single policy in each state which is common for all production technologies.
- An increase in the number of renewable energy policies by one unit will increase the amount of installed capacity by approximately 3.24%. (Annex V).

HJRF005: Primary Data Survey- Major Parameters taken into consideration for primary data survey are: Population, Education, Literacy, ICT Literacy, Landholding size, Livestock, Occupation, Infrastructure, Social Composition, Income group, etc. Design of the Conceptual Framework for the development of Village Information System (VIS). Designing the basic architecture for the Information System, i.e., Village Information System (VIS), this was developed using System Requirement Specification (SRS) and Software Development Life Cycle (SDLC).

HJRF006: Himalayan yew (*Taxus wallichiana* Zucc.; Family Taxaceae) is a highly valued medicinal conifer of Indian Himalayan region (IHR). It is well recognized in the world of medicine due to its anticancer property. As mentioned in IUCN red list, the species is important for its propagation and conservation. In this background, an insight on the root microbiome, with particular reference to the association of plant growth promoting microorganisms, will be essential. In present study, the plant is being studied for two major aspects (1) the root associated endophytic microbial diversity with respect to their structural and functional aspects, and (2) the antimicrobial potential of various plant parts including needle, stem and bark. Two bacteria and five fungi were isolated from the roots of *T. wallichiana*. The phenotypic and genotypic characters designated these bacteria and fungi to the species of *Burkholderia, Enterobacter* and *Penicillium, Aspergillus*, respectively. All the endophytes showed phosphate solubilization with production of phosphatases in aluminum, calcium and iron phosphate based medium and phytases in calcium and sodium phytate based medium. Burkholderia sp also produced yellow pigment with antagonistic or antimicrobial activity. In view of the very limited regeneration potential of *T. wallichiana*, knowledge on this symbiotic association and bio formulation of the promising endophytes is likely to have implications in enhancing propagation potential of this conifer. In antimicrobial activity section, according to GC-MS, LC-MS, FTIR and NMR analysis of fraction having antimicrobial activity, compound responsible for antimicrobial activity may belong to the group of compounds such as alkaloids, vitamins amino acids, fatty acids, carboxylic sugars.

HJRF007: A total of 674 household has been surveyed in 12 villages from the nine hill districts of the Uttarakhand. Questionnaire based livelihood survey was conducted and Perception of farmers regarding changes in the village in previous 50 years has been recorded. Literature review has been done on historical aspect with the current situation and the impact of changing socio-economic scenario on traditional livelihood practices. Primary data from household survey and secondary data from line departments and various published material like district census handbook, statistical diaries, Reports etc. on demography and economy structure, livelihood practices, land use changes and resource utilization, migration etc. was collected. Collected data has been tabulated and analyzed and on the basis of analysis a list of such issues which are responsible for the weakening of traditional livelihood has been prepared. It has been found that more than 60% People preferring the nuclear families now days so the landholdings division is increases, which leads to minimize the average landholding size per household and it is directly decreasing the production. People are looking for other options for the livelihood generation and they are getting psychologically prepared for the out migration. Focusing the issues of weakening traditional livelihood practices a one day training

program has been organized on the title “Awareness and capacity building on livelihood enhancement in rural areas”. Annual Progress report and work plan has been Prepared and submitted for 2nd Himalayan Researchers Consortium (HRC) during 26-27 November 2018. Submitted manuscripts for publication during 2nd Himalayan Researchers Consortium (HRC) during 26-27 November 2018 (Annex-VIII).

4.2 Establishing New Database/Appending new data over the Baseline Data (max. 1500 words, in bullet points)

HJRF02: For the accomplishment of objectives, both primary and secondary data were collected, analyzed, synthesized and documented. To identify the salient characteristics of the study area complete profile of the baseline environmental characteristics has been collected and compiled.

- The database on ambient quality was generated at Mohal at the Altitude of 1146 m (2016-2019) , Kothi (2500m) (2017-2018), Beasar (control site) at the Altitude of 2181 m and Raison at the Altitude of 1359 m (2019) during the tenure of study. In the available data, the ambient air quality monitoring parameters like total suspended particulate matter (TSP), particulate matter (PM10, PM 2.5), Sulphur dioxide (SO2), Nitrogen dioxide (NO2) and Ammonia (NH_3) have been covered largely for above mentioned locations.
- Meteorological data were collected and analyzed from Automatic Weather Tower (AWS) (2016-2019) installed in the institutes campus and the data on long term rainfall, temperature (1985-2019) and apple production & area (1990-91 to 2016-17), chilling hours (2009-10 to 2019-20) were collected from Krishi Vigyan Kender (KVK) Bajura, Himachal Pradesh Horticulture Department.

4.3 Generating Model Predictions for different variables (if any) (max 1000 words in bullets)

HJRF001: Water Evaluation and Planning modelling framework based datasets of rainfall, flow to groundwater from different land use/land cover, surface runoff from the watershed, population and livestock water demands, agriculture water demand, unmet water demand of population, livestock and agriculture, water supply to population, livestock and agriculture; and crop yield status in both the watersheds for the year 2015-2030.

4.4 Technological Intervention (max. 1000 words)
4.5 On-field Demonstration and Value-addition of Products (max. 1000 words, in bullet points)
4.6 Developing Green Skills in IHR

HJF002: Current study had revealed that, impacts of air pollution and climate change are significant in the region and their present livelihoods are being affected by these changes. Since in order to strengthen their livelihood and increasing their resilience against climate change, green skills are the best suited alternative especially in the Himalayan regions. In order to develop livelihoods which cannot get affected due to climate change easily will give reliability and confidence in people. In this context, locals were made aware about the consequences of these problems through different capacity building workshops, training programmes, consultative meeting, etc.

4.7 Addressing Cross-cutting Issues (max. 500 words, in bullet points)

- Future adaptation plans need to include measures that seek to address these adaptation-related gaps and barriers alongside measures that directly address and reduce current and future vulnerabilities to climate change impacts.
- Monitoring Air pollutants, climate change and their impacts on Apple orchards where local populations are largely dependent on for their livelihood.
- Informed decision making about long-range pollution transport requires sophisticated abilities to identify and quantify specific pollution sources.
- Increasing awareness level and enhancing capacity building of the stakeholders (project proponents, local communities, etc.
- Plantation along roads, streets, open places, and around the towns under a green belt concept as a sustainable option to bring ambient air pollution under control.
- The management of ambient air pollution in a coordinated manner, with active cooperation between local residents, management authorities, research institutions, and local government.

5 IMPACTS OF FELLOWSHIP IN IHR

5.1 Socio-Economic Development (max. 500 words, in bullet points)

HRA02: The fellowships are small little initiatives to see the region could be taken into sustainable form of livelihood. These small initiatives would help to understand regions and their problems for taking precautionary measures for protection of fragile IHR. These scholarships can act as pilot projects for taking mitigation measures in the large scale. These scholarships can also help in recognizing the problem and can be a stepping stone.

HRA03: A detailed literature search with appropriate keywords has been conducted. The preliminary database on various components of Himalayan Biodiversity and Climate Change have been collected and analyses in terms of objectives, methodology adopted, key findings etc. For developing mechanism for knowledge sharing and its flow among stakeholder groups, Himalayan Biodiversity and Climate Change-Knowledge Network (HBCC-KN) web portal has been developed, which can work on SQL and PHP database language as dynamic web portal.

HJRF002: From project finding, it was observed that the air pollution has been existing in the study area mainly from tourism activities in transport sector and household chulhas in residential sector but the concentration of pollutants has increased in the past few decades due to growth in the developmental activities like road construction, hydropower development and urbanization. Although control measures have been introduced in the state from time to time to combat the pollution levels but the pace at which the emission levels have increased is very high compared to that of control measures. The current developmental process fails to address the different environmental implications and loss of biodiversity. Instead, the lack of a comprehensive approach exacerbates these issues. Developmental intervention through community participation in the decision making, modern innovation in the farming systems, cultivating cash generating crops according to the agroclimatic conditions, establishment of small-scale village level industries, optimum use of timber and non-timber forest products, sustainable solid waste management, development of eco-tourism and installation of hydropower projects for generating electricity will augment employment, generate income, enhance livelihood options and will check outmigration. The project outcome contributes to an enhanced understanding of present climatic conditions, observed climate trends, status of air pollution and regional climate vulnerability of the study area. Kullu valley with complex, often high-altitude terrain and the severe impact of the summer monsoon leads to a strong exposure of the regions key economic sectors (agriculture, forestry, hydro-power generation and tourism) to climatic changes. Climate Change also threatens its vast biodiversity and

increases the likelihood of natural hazards (e.g., glacier lake outburst floods, flash floods, droughts and forest fires). A better understanding of the air pollution and its sources, climate and its variability, as well as observed and possible climate impacts, will help improving the handling of regional social, economic and ecologic challenges not limited to the area.

5.2 Scientific Management of Natural Resources In IHR (max. 500 words, in bullet points)

HJRF002: Himachal Pradesh is categorized under one of the most fragile ecosystems among India's hill states. Hill communities face dual challenges of food and energy shortages and have become more vulnerable to weather variabilities and susceptible to natural disasters, attributed to climate change. The biggest casualty of climate change would be the natural resources. A change in the climate could change the resource capacity as well as the pattern by which the resource is used by the adjacent population. The impact on natural resources, if not controlled by mitigating measures, could lead to extreme situations. Air pollution from tourist transportation has impacts on the global level, and it can contribute to severe local air pollution. The study showed increase in concentration of air pollutants during peak tourist activity. Tourist inflow, vehicular density, roadside dust, and burning of coal and fuel wood on a large scale are main sources of air pollution in the area. The rise in the number of vehicles, mismanaged traffic and deforestation has all contributed to the deterioration in air quality in the region. From project finding, it was observed that the increase in vehicular emission, temperature,large amounts of the glacier and ice that contribute to sustaining the water resources in the Western Himalaya are being lost annually as result of climate change Incidences of reduced discharges and drying up of springs (the traditional sources of drinking water supply) have been found increased during the past few decades. It was revealed from the current study that the study area has abundance of natural resources in the forms of land, water and forest, panoramic landscape of touristic importance. In spite of abundance of natural resources and its high potential for the socio-economic development, the whole region is socially backward and economically underdeveloped. Per capita income of the people is also low. Optimum/sustainable utilization of natural resources can enhance the economic development of the region. This can be achieved through sectoral development and through identifying the areas of potentials and fixation of priorities. Connecting remote rural areas by ropeways and road transportation, keeping landscape fragility/suitability in mind, can bring them in the main stream of development.

5.3 Conservation of Biodiversity in IHR (max. 500 words, in bullet points)

HJRF002: The great Himalayan region has peculiar identity in the perspective of its unique biogeography. It supports a large number of glaciers, lakes, rivers, flora and fauna due to its variable climate. It has a profound effect on the climate of the subcontinent. But due to anthropogenic activities there is increase in the concentration of air pollution since last few decades. The climate of the subcontinent has also adversely affected the biological resources of the country along with that of the Himalayan region. The project findings discuss the various causes responsible for increasing pollutant level in the study area. It also talks about the control measures and various management steps which can be taken, with special reference to the Himalayan region. The major point came out in this study are Habitat destruction, land-use/cover change, land degradation, forest fire, variation in the aquatic faunal communities has adversely affected biological resources of the sub-region induced by climatic change. The various altitudinal zones of the regions are witnessing major biodiversity, ecological and geophysical changes. The increasing unpredictability of weather and the natural catastrophes in the region are clear-cut indicators of marked shift in weather patterns in the region. Various control measures and management steps in the form of afforestation, reforestation, landscape management, tourism management, reducing energy consumption, increasing energy efficiency, promoting renewable energy technologies, control on greenhouse emission, prediction model, regular monitoring and more research

on related aspects of climate and biodiversity are needed in order to save the Himalayan region from decline of its wealth present in the forms of natural sources.

5.4 Protection of Environment (max. 500 words, in bullet points)

HJRF002: Though the whole world is suffering from the consequences of climate change but the severity is more in the Himalayan regions as the agricultural economy of the region greatly depends on climate. With the shift in Environment the extreme climatic conditions are giving rise to more geohydrological hazards. The present study tells about the significant change in the cropping pattern and forest land due to climate change impacts, such as change in rainfall pattern which is becoming more erratic and furious due to the dynamic nature of Environment. Environmental hazards like cloudburst, torrential rains, flash floods, etc. are becoming more frequent and divesting especially in the region for the last few decades. Field observations had shown that diversity in grain crops cultivated has been decreased with time. In order to maintain the ratio of green cover in a stable ecosystem, these studies are crucial to identify these changes and making policies which will minimize these effects. Tectonically active IHR is highly rugged and has inherent weak geology and structural features that causes natural hazards. Such disaster becomes mightier, whenever and wherever anthropogenic activities are not in harmony with nature.

5.5 Developing Mountain Infrastructures (max. 500 words, in bullet points)
5.6 Strengthening Networking in IHR (max. 700 words, in bullet points)

6 EXIT STRATEGY AND SUSTAINABILITY

6.1 How effectively the fellowship findings could be utilized for the sustainable development of IHR (max. 1000 words)

HRA02: The sustainability of the project intends for the survival of life on the mountainous region. Where most of the mountainous regions are suffering the deficiency and scarcity of water, Almora is gifted with sufficient amount of springs. The project intends to help sustain the serenity of water and as follows:

- To understand the impact of urbanisation and increase in population on to the springs of the region.
- To generate awareness among people to help them understand the water quality deteoriation due to dumping of waste in local boundaries of the springs.
- To also understand the necessity of sewer treatment plant for the town so that nitrate contamination could be restricted in the town.
- To extension of the project/project suggests to could develop more with designing the sewer treatment plant with zone wise division of the town.
- To ensure more and proper treatment of the sewer treatment discharge which at present carries just 10-12percent of the waste water generated in the town. This would help to conserve the water quality of the river Kosi as well.
- The remedy for water quality sustenance is major part of the project.

HRA03: Impact of different ecological variables is still under-explored condition. • Diversity of lower group organisms still under-explored condition. • It was hypothesized that it can be useful for further studies but only few studies have been found with ground level conclusion. • Indicator species analysis. • Climate change studies: points for mitigation have been given by many researchers but testing in ground level is still missing • Invasive species: maximum studies shows the impact of invasion on bio-diversity, however only few attempts have been made focusing on their sustainable use. Studies on development of control mechanism for their fast growth and development is still underexplored condition (e.g. Himalayan Tahr, which is near threatened in Himalaya but in NZ it is an invasive species and for their control, hunting is a single option in front of NZ government). Environmental assessment.

HJRF001: Present study or modelling framework may be used in the future studies to carry out site specific and demand driven or Purpose Driven Studies (PDS) in the other Himalayan river basins for the best water management in the context of changing hydrological, climatological and land resources regime for its possible implications.

HJRF002: Air pollution or aerosols studies have been a recent attempt from a multidisciplinary point of view. Air pollutants have numerous effects on physical, biological and social components on our surrounding environment. The recent development has posed a great pressure on our natural resources, as a result our environment is degraded drastically and there is a challenge to the carrying capacity of the Earth. The present work on air pollution is conducted in topographically fragile and ecologically delicate environment of the mountainous topography of the Himalaya. This work can create awareness among the local community as well as strengthen the knowledge of worldwide community. The present work has also much concern for the researchers who are dealing with the alike studies. Moreover, this work may also be used by the state and central governments as the guidelines for the framework and development of policies and plans. The policy implications may have long-term benefits in mitigating environmental pollutions and continuing sustainable development process in the mountain ecosystem.

HJRF006: All results are very encouraging and are very helpful in future investigation of *Taxus wallichiana* medicinal values. Based on the results of detailed investigation and interpretation, this study recommends following suggestion for future work:

- Endophytic fungi having potential of taxol production can be used as an alternate source for the taxol production for pharmaceutical industries.
- Bioformulation of these endophytes should be used in developing the environmentally friendly technology supporting the growth and development of Himalayan Yew.
- Optimization of media and growth conditions for isolation of more endophytic microbes from the host should be emphasized in future studies.
- It was observed that the maceration method was most efficient extraction method for isolation of antimicrobial compounds and also for obtaining the higher antimicrobial activity. In future optimization by using different extraction methods, can be further studied.
- The studies based on optimization of extraction of bioactive compounds and their synergistic effects can significantly contribute towards herbal medicine based healthcare sector across the globe.
- Isolation of bioactive components in the extracts would ascertain the individual potency of the compounds which could be further exploited in food and pharmaceutical industries.
- Further optimization for getting higher concentration of identified antimicrobial compounds can be further studied.
- In future further studied on identified antimicrobial compounds can be done, by testing their potential separately against different disease causing microorganism, so that we can know which antimicrobial compounds can be beneficial for treating the different diseases in plants and human.

HJRF007: As the traditional livelihood is concern the major population were involve in agriculture and livestock rearing practices but in present day the occupational structure is very much differ from the past few decades. The analysis shows that if we look on the occupational structure of the state we can easily understand that percentage of cultivators is decreasing and they are pursuing for the other works for their livelihood. Main reasons for these changes are that the resources of the traditional practices are compressed day by day, size of landholdings are decreasing and population is continuously increasing, people are feel unable to fulfill the requirements of their families by doing the agriculture so that they are losing interest to continuing the practice, so they are going for the other option for earnings. All over the IHR is facing these challenges. The findings suggested that there is a need of urgent steps to be taken for the solution of this situation.
Major recommendations for sustaining the outcomes of the fellowship in future (500 words in bullets)

- With the state's limitations in land and water resources, yields need to be improved through scientific transformation and modernization of agriculture through technological interventions.
- The development policies for the agriculture sector of the state in particular have to be oriented towards marginal and small landholders, due to their large share in totality for land holdings.
- To overcome the loss due to wild animals attacks on the crops in the villages: It is an alarming situation where the farmers are not interested in farming because their hard work is not fruitful for them, the wild animals are destroying their crops in the agriculture fields. And the farmers are helpless to protect their fields from wild animals. Thus there is a need of such a policy by the government either there is some compensation for the loss of production or the techniques should be provided to prevent their farms from the wild animals.
- To improve the productivity of the traditional subsistence crops: It is required that crop production should be market oriented so that the farmers can sold out their production and make money, it will attractive for the remaining people who are out migrated for the searching of their livelihood. This has tremendous potential for not only improving farm productivity but also for creating more employment opportunities in the agriculture sector (Badhani, 1998; Mamgain, 2004). The area under market oriented crops is very low about 15% during the year 2001 (Mamgain and Mehta, 2006). However, it has been slowly increasing over 2% points per annum (Mamgain, et al., 2005).
- To improve the skills of the farmers: The farmers are still using their traditional ways to cultivate in the remote areas. The present agriculture extension services are very weak, particularly in the hill districts in terms of their approach and outreach to farmers living in remote areas (Mamgain and Mehta, 2006). It is required that there must be some programs and workshop should organized in remote areas to enhance the technical knowledge and capacity of the farmers to improve their production and maximize the profit.

6.2 Efficient ways to replicate the outcomes of the fellowship in other parts of IHR (max. 1000 words)
6.3 Identify other important areas not covered under this study, but needs further attention (max. 1000 words)
6.4 Major recommendations for sustaining the outcomes of the fellowship in future (500 words in bullets)

HJFR002:

- There is a need to inform the local communities regarding the future consequences of polluted air among them and to adopt pollution free technologies.
- Burning and open dumping of solid waste should strictly be prohibited in the towns to free the environment from toxic air. To manage solid waste in towns, the authorities should be scientifically informed to dispose of the waste properly.

- The local communities and managing authorities should be aware of the practice of energy driven technologies, the use of quality fuel in the vehicles, and the practice of non-conventional energy sources which need to be supplemented with solar energy.
- Plantation along roads, streets, open places, and around the towns under a green belt concept should be encouraged as a sustainable option to bring ambient air pollution under control.
- The management of ambient air pollution needs to be done in a coordinated manner, with active cooperation between local residents, management authorities, research institutions, and local government.
- Government should conduct programs at community level to sensitize the public about the growing levels of the pollution due to vehicles and promote public transport systems.
- Tourism activities should be managed properly to control the vehicular movement.
- Old vehicles should be banned in the state as they cause more pollution.
- The sustainable development measures can deliver a wide range of co-benefits.

HJRF010: The finding of the fellowship study may be utilized for further detailed study on chemical profiling, advanced extraction methodology for higher yield of value-added chemicals for industrial purposes of these plants. The plants species possess important bioactive compounds, for multifaceted Industrial uses. The cultivation of the species at larger scale would help in conservation of the species as well as income generation. The large cultivation of three species of Zingiberaceae family and value addition with the help of Self-Help group may play an important role sustainable development of communities in IHR.

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