Template/Proforma for Submission

NMHS-Himalayan Institutional Fellowship Grant

FINAL TECHNICAL REPORT (FTR)

NMHS Reference No.:	GBPI/NMHS/HF/RA/2015-16	**Date of Submission:**	2	5	1	1	2	0	2	2
			d	**d**	**m**	**m**	**y**	**y**	**y**	**y**

FELLOWSHIP TITLE (IN CAPITAL)

NATIONAL MISSION ON HIMALAYAN STUDIES (NMHS)

HIMALAYAN RESEARCH FELLOWSHIP

Sanctioned Fellowship Duration: *from* (**30.03.2016**) *to* (**29.03.2019**).

Extended Fellowship Duration (if applicable): *from* (30-03-2019) *to* (31.03.2020)

***Submitted to*:**

Er. Kireet Kumar

Scientist ‘G’ and Nodal Officer, NMHS-PMU

National Mission on Himalayan Studies, GBP NIHE HQs

Ministry of Environment, Forest & Climate Change (MoEF&CC), New Delhi

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

***Submitted by*:**

Dr. Sanjay Kr. Uniyal

Senior Principal Scientist

[*CSIR-Institute of Himalayan Bioresource Technology (IHBT), Palampur, (H.P.)*]

[*Contact No.:* 9418070321]

[*E-mail:* suniyal@ihbt.res.in]

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.

NMHS-Final Technical Report (FTR) *template*

NMHS- Institutional Himalayan Fellowship Grant

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
Name of the Institution/ University:	CSIR- Institute of Himalayan Bioresource Technology, Palampur -176061, Himachal Pradesh
Name of the Coordinating PI:	Dr. Sanjay Kr. Uniyal
Point of Contacts (Contact Details, Ph. No., E-mail):	9418070321, suniyal@ihbt.res.in

1.2 Research Title and Area Details

i.	Institutional Fellowship Title:	National Mission on Himalaya Studies (NMHS) Himalayan Research Fellowship					
ii.	IHR State(s) in which Fellowship was implemented:	Himachal Pradesh					
iv.	Scale of Fellowship Operation	Local:		Regional:	✓	Pan-Himalayan:	

iii.	Study Sites covered (*site/location maps to be attached*)	251 (*Appendix 7)*
v.	Total Budget Outlay (Crore):	INR 1,02,00,960/-

1.3 Details Himalayan Research /Project Associates/Fellows inducted

Type of Fellowship	Nos.	Work Duration	
		From	To
Research Associates	2	25 May 2016	31 March 2020
Sr. Research Fellow	-	-	-
Jr. Research Fellows	2	27 May 2016	29 March 2019
Project Fellows	8	25 May 2016	31 March 2020

2. Research Outcomes

2.1. Abstract

Background: The Himalaya with its wide altitudinal gradation, species richness, and diverse resident population is the best natural laboratory for long-term ecological monitoring and studying human nature and relationships. Despite this, Himalaya is known as the "white spot" (meaning data deficient). The lack of primary field data necessitates initiatives to monitor vegetation and document its rich legacy. In addition to the changing climatic conditions, the spread of invasive alien species in the bio-diverse Himalayan region is a major concern. They have not only threatened native species' survival, but have also disrupted ecosystem functioning on which depends the livelihood of the population. These communities hold traditional knowledge of high ecological and economic importance. Unfortunately, with changing lifestyles, this knowledge is dwindling, and the younger generation is abstaining from it. Unless this knowledge is systematically documented, it will vanish, along with many undocumented leads. All these call for raising awareness and building capacity. It is with this that proposal targeted the following objectives:

Objectives/Aim:

- Identification of bio-indicators for documenting environmental health.
- Establishment of LTEM sites and robust data-sets generation
- Indigenous knowledge documentation and strengthening through scientific evidence base

- Study the Invasive Alien Species (IAS)
- Analyze the extent of capacity built of the traditional institutions
- Capacity building on biodiversity conservation through field-based trainings/ awareness programs

Methodology(ies):

Standard methodologies were used, field surveys were conducted, monitoring plots were marked and established, stratified sampling was carried out, phenological patterns were recorded, image recordings were done, plant and samples were collected, physico-chemical characteristics were assessed, bioindicator assessment and Air Pollution Tolerance Index (APTI) of plants was performed. At the same time, interactions were held with the local communities and questionnaire recordings were done.

Results:

- Bioindicator assessment and Air Pollution Tolerance Index (APTI) of the commonly occurring 26 woody species were evaluated. Based on the results, *Grevillea robusta, Quercus floribunda, Toona ciliata* and *Ficus carica* were evaluated as best performers. These plants can be integrated into plantation programs.
- Ecological risk, geo-indicator analyses and spatial distribution of toxic elements have been assessed. The results showed that highest geo accumulation value (Igeo) for Cd (3.5), Cr (7.2), Mn (5.1), and Ni (3.0) were reported in the urban land-use soils followed by peri-urban land-use.
- A total of 255 plant species representing 47 families were identified across an altitudinal gradient of 2000 to 4000 m in the Dhauladhar mountain. Asteraceae had the largest proportion of plants (16%) followed by Lamiaceae (7%), Polygonaceae and Rosaceae (6% each), and Apiaceae, Ranunculaceae, Gentianaceae and Saxifragaceae (4% each).
- In Dhauladhar the α-diversity ranged from 21 to 114 (species richness index), 0.85–0.96 (Simpson index), 2.63–3.79 (Shannon index), and 0.24–0.81 (evenness index) across the elevation. Across the altitudinal gradient, β-diversity was calculated using the indices of Whittaker (3.95 ± 0.06). βw showed a unimodal hump shaped pattern across the altitudinal gradient. It was the minimum at 2000 m, then increased gradually, reached the maximum across 2500–2900 m, and thereafter declined gradually.
- An inverted hump-shaped pattern for evenness index (E), a unimodal hump-shaped pattern for Shannon index (H′), Margalef's richness index, and β-Whittaker(βw) diversity, and mild-hump-shaped pattern for Simpson index (λ) was revealed across the elevational gradient. Turnover(βsim) and the nestedness-resultant component of β-diversity (βsne) significantly

differed across the elevational gradient. The observed β-diversity patterns revealed that the species replacement rate was less in the mid altitude.

- The onset (OFD), the peak (PFD), and the end of the flowering day (EFD) of the year (DOY) were recorded at 20%, 55%, and 90% floral abundance, respectively, from 1st of January. Upon analyses, the Linear-mixed effects model depicted significant differences in the flowering phenological events with elevation and soil temperature. The onset of flowering DOY and peak of the flowering DOY varied significantly with soil temperature gradient, while the end of flowering DOY showed non-significant interaction.
- The linear model of ANOVA demonstrated that OFD, PFD, EFD and flower duration (FD) varied significantly with elevation at $p < 0.001$. FD increased with elevation for most of the species, whereas two species, *Aquilegia pubiflora* and *Primula denticulata*, showed early incidences of flowering compared to other species. Recurving in *Taraxacum officinale* was found to be an effective strategy for pollination.
- Altitudinal distribution of alien species richness in the Himalayan state of Himachal Pradesh was documented. Alien species richness was higher at lower altitudes and significantly varied along the altitudinal gradient. The maximum richness of alien species (317) was observed in the 1000–1100 m altitudinal band. After this, a gradual decline in their richness was observed. It declined to 254 in the 1500–1600 m band and was below 50 in the 3000–3100 m band. Alien species distribution patterns are in contrast to the native species distribution whose maximum richness is reported at mid-altitudes (2000–2500 m).
- Of the total alien species, maximum are herbs (n=323), followed by trees (n=49), shrubs (n=40), and climbers (n=13). Life form analyses revealed the absence of alien climbers above 2500 m. Members of Asteraceae, Fabaceae, and Poaceae dominated the alien flora along the entire altitudinal gradient.
- Different phenophases of *Betula utilis* were photo documented in the treeline in Pangi valley where its density was 490 individuals/ha. Digital images (n=653) of two growing seasons (2017 and 2018) captured through the camera set-up were used for the same. Images hold information in red, green, and blue channels (RGB) and relative changes in RGB indicate canopy coloration. We categorized the phenophases into Greenup, leaf maturity, senescence, and dormancy. The RGB analyses revealed that during both the years greenup in *B. utilis* started during early May [128 and 124 days of the year (DOY) in 2017 and 2018, respectively] and continued till mid-June when the canopy attained maturity. On the other hand, senescence started in early September and by mid-October, the trees became leafless (288 and 289 DOY in 2017 and 2018, respectively). A four-day earlier greenup and one-day delayed dormancy were noted in 2018 when compared to 2017. Thus, the length of the growing season was five-days longer in 2018. The snow cover ratio

revealed that snowmelt occurred 8 days earlier in 2018 than in 2017.

- Declining population of medicinal plants in the wild is a major conservation issue. Researchers across the globe have advocated assessments of their populations for effective management prioritization. We, therefore, assessed populations of 15 high valued medicinal plant species of the Himalaya and carried out their rapid vulnerability assessment (RVA). Seven different habitats viz., gentle slopes (GS), moist areas (MA), rocky areas (RA), scree slopes (SS), shrub gaps (SG), under canopy (UC) and undulating meadows (UM) identified based on their physiognomy and landform were surveyed and sampled across six alpine sites in the state of Himachal Pradesh using quadrats. We found that distribution and population of different species varied significantly across habitats. Overall, *Trillium govanianum* reported the highest density (3.83 individuals/m^2) and frequency (58.33%) while the lowest frequency (11.86%) was noted for *Picrorhiza kurrooa*. Amongst the 7 habitats, the highest species richness (13) and diversity ('H'=2.118) were recorded in the GS and UM, respectively. As opposed to other species which occurred in multiple habitats, *T. govanianum* was restricted to UC only. The RVA score of the species ranged between 20 (reported by *Heracleum candicans*) to 33 (observed for *Aconitum heterophyllum* and *Fritillaria roylei*, each). Based on the conservation status, habitats of occurrence and RVA, *A. heterophyllum*, *Dactylorhiza hatagirea, F. roylei, P. kurrooa, Sinopodophyllum hexandrum* and *T. govanianum* have been identified as the reddest of the red. Since medicinal plants are habitat specific, thus heterogeneous landscape are key to *in-situ* medicinal plant conservation.
- Traditional knowledge and climate change perception patterns of the local communities (n=240 respondents) were studied. It was revealed that they perceived 11 indicators of changing climate, of which decrease in snowfall was the most prominent (reported by ~97% of the respondents). The perceptions varied between the two genders with males having significantly higher proportion of responses for all the 11 indicators. Similarly, differences in perception amongst the age groups were also observed, elderly people reported higher proportion of climate change indicators as compared to respondents of lower age. Notably, their patterns of temperature and rainfall perceptions agreed with the trends of meteorological data. This highlights the importance of the study in documenting knowledge of ethnic communities especially from areas that lack monitoring stations. It argues for involving them in climate change programs.
- Plant derived utility products (PDPs) play an important role in sustaining humans, especially tribal communities. Despite this, knowledge on PDPs is declining. Therefore, in addition to taxonomic richness, frequency of species used; Use Value (UV), Use Diversity (UD), and Cultural Importance Index (CI) with regards to PDPs were analyzed. A total of 55 PDPs

under five use categories namely tools (34), artefacts (7), construction and storage (6 each), and miscellaneous (2) were noted to be used. For making these PDPs, 20 plant species representing 12 families were used. *Picea smithiana* (16.54%), *Cedrus deodara* (14.96%), *Cotoneaster bacillaris* (12.60%) and *Quercus semecarpifolia* (11.02%) reported the highest use frequency. On an average 15.13±0.25 PDPs per respondent was noted. Similarly, *Picea smithiana* (UV=0.088) and *Cedrus deodara* (UV= 0.079) reported the highest UV when compared to other species. Amongst all the species, maximum UD was revealed for *Juglans regia* in the tool category (0.91). On the other hand, maximum CI was also recorded for *Picea smithiana* (CI_{Total}=2.91).

- Documentation and use of Wild Edible Plants (WEP) was done. Their use was categorized into six categories (vegetables, fruits, chutney, flavoring food, raw food, and local brew) and trends of use (continuing, decreasing, increasing, and not used), and motivations (environmental, economic, sociocultural, agriculture & landuse practices, and human-wildlife conflict) behind their use were analyzed.
- Fifty plant species were used by the local people for edible purposes under six WEP categories. Mean and median of WEP used per respondent was 22.3 and 21, respectively. Maximum of these were used as vegetable (mean 8.9) while minimum were used as brew (mean 0.4). It was revealed that though plant use is still maintained in the area, changes are evident. While ~50% of the respondents presented views that they still continue to use WEP, 36% reported trends of declining use as compared to 5-10 years back. Close to 10% respondents do not consume WEP now, while ~3% reported that WEP use is now increasing. Taste and aroma were the major sociocultural reasons behind using WEP while modernization and changing lifestyle were the main reasons behind declining use of WEP.
- People residing in interior areas of the Himalaya are highly dependent on natural resources and thus have evolved their own beliefs and customs for conserving resources. Taboos form an important component of tribal lifestyle and guide sustainable utilization and management of natural resources. The results revealed a prevalence of 22 taboos that were mainly related to forest, water, farmland, and food resources. Of the total taboos, the maximum belonged to the segment and method category taboos (32% each) while the minimum (5%) were species-specific taboos. Adherence to taboos is high and breaking them is believed to bring the wrath of God. They, thus, are important for resource management.
- Awareness programme carried out and popular lecture delivered in villages and Government schools, which revealed that people are aware of the resources in their surroundings. Nature relatedness revealed people appreciation and bonding with it.

Conclusion(s):

Sampling across the monitoring plots established in the Dhauladhar Mountain revealed altitudinal distribution pattern of species with unique assemblage of taxa at the higher altitudes (3500 m asl). Also, temporal plant phenological recordings showed annual variations in growing season length. Digital images for phenological recordings are prime output of the program and possibly the first of its kind in the Himalaya. Also, patterns of alien species distribution showed their prominence at lower altitudes and probable uphill trends. Relation between habitat types and medicinal plant diversity has been elucidated with s correlation between habitats and high value medicinal plants. Gentle slopes harbor a higher number of high value medicinal plants. The resident communities hold immense traditional knowledge on the plant species and surrounding environment. Validation of their climate perception through meteorological data showed its importance and reliability. This knowledge, however, varies in relation to age and gender of the respondents. Ironically, the traditional knowledge of the people was noted to be declining. Still, many conservation practices are prevalent that have ecological and sociological ramifications and must be preserved. Thus, through the studies, primary field data has been generated from interior areas of Himalayan.

Recommendations:

Monitoring plots established through the study may be repeatedly visited and documented for any floristic changes. Based upon the ecology and environment, plants such as *Grevillea robusta, Quercus floribunda, Toona ciliata* and *Ficus carica* can be integrated into plantation programs. Landscapes with high habitat diversity provide ideal grounds for conservation of high value medicinal plants. Information on their trade and extraction is desired vis-à-vis developing good collection practices from wild also become important. Mapping of invasive species spread especially in higher altitude regions is suggested. Involvement of local communities in any conservation and management exercise in the Himalaya is a must. Quantitative ethnobotany and cross-cultural comparisons need prioritization. The importance of involving local communities in scientific documentation cannot be undermined especially in areas that lack monitoring stations.

2.2. Objective-wise Major Achievements

S. No.	Cumulative Objectives	Major achievements (in bullets points)
1.	Identification of bio-indicators for documenting environmental health	• Twenty-nine sites identified along a vehicular pollution gradient (NH-21). • Twenty-six dominant plant species sampled and their Air pollution tolerance and anticipated performance index have been worked out. • Anticipated performance of 23 plant species have been assessed in varied air pollution scenarios. • Tolerant and sensitive plant species identified. Based on the results, *Grevillea robusta*, *Quercus floribunda*, *Toona ciliata*, *Ficus carica*, were evaluated as best performers. These plants can be integrated into plantation programmes. *Acer caesium*, *Betula utilis*, *Morus alba*. that had low scores were predicted as poor performers. • Soil samples analyzed for physicochemical properties and heavy metal analysis. • Ecological risk, geo-indicator, and spatial distribution of toxic elements has been assessed. **Publications**: -Kashyap, R., Sharma, R. & Uniyal, S.K. (2018). Bioindicator responses and performance of plant species along a vehicular pollution gradient in western Himalaya. *Environmental Monitoring and Assessment* 190: 302 - Kashyap, R., Verma, K. S., Uniyal, S. K. & Bhardwaj, S. K. (2018). Geospatial distribution of metal (loid) s and human health risk assessment due to intake of contaminated groundwater around an industrial hub of northern India. *Environmental Monitoring and Assessment*, *190*(3): 1-18 - Greening with pollution-gobbling trees doubles benefits. https://india.mongabay.com/2018/11/world-environment-day-greening-with-pollution-gobbling-trees-doubles-benefits/ -Kashyap, R., Sharma, R. &Uniyal, S.K. (2019) Distribution

		of heavy metals in habitation land-use soils with high ecological risk in urban and peri-urban areas. *International Journal of Environmental Science and Technology*. https://doi.org/10.1007/s13762-018-02203- - Kashyap, R., Ahmad, M., Uniyal, S.K. & Verma, K.S. (2019). Dietary consumption of metal (loid) s-contaminated rice grown in croplands around industrial sectors: a human health risk perspective. *International Journal of Environmental Science and Technology*, *16*(12): 8505-8516
2.	Establishment of LTEM sites and robust data-sets generation	• Twenty-one LTEMs with automated loggers have been established. • Vegetation and soil sample analysis done. The soils were found to be acidic in nature (pH ranging between 4.36 to 5.506). Total potassium (%) ranged from 0.24 to 2.41, total phosphorus (%) from 0.04 to 0.18, and total nitrogen (%) from 0.19 to 0.82. • A total of 255 plant species representing 47 families were identified across 2000 to 4000 m in the Dhauladhar study area. Asteraceae had the largest proportion of plants (16%) followed by Lamiaceae (7%), Polygonaceae and Rosaceae (6% each), and Apiaceae, Ranunculaceae, Gentianaceae and Saxifragaceae (4% each). • The α-diversity ranged from 21 to 114 (species richness index), 0.85–0.96 (Simpson index), 2.63–3.79 (Shannon index), and 0.24–0.81 (evenness index) across the elevation. • An inverted hump-shaped pattern for evenness index (E), a unimodal hump-shaped pattern for Shannon index (H′), Margalef's richness index, and β-Whittaker(βw) diversity, and mild-hump-shaped pattern for Simpson index (λ) across the elevational gradient. Turnover(βsim) and the nestedness-resultant component of β-diversity (βsne) significantly

		differed across the elevational gradient. • Flowering phenology of 25 plant species done. Onset of flowering, Peak Flowering, End of flowering and Flowering duration varied significantly with elevation at $p < 0.001$. FD increased with elevation for most of the species, whereas two species, *Aquilegia pubiflora* and *Primula denticulata*, showed early incidences of flowering compared to other species. **Publications:** - Ahmad, M., Kashyap, R. & Uniyal, S.K. (2018). Pattern of Plant Functional Traits (PFTs) Variation between Two Populations of Morina longifolia Wall. at Western Himalaya. *Proceedings of Himalayan Researchers Consortium* Vol. 1(1). - Ahmad, M., Uniyal, S.K., Batish, D.R., Singh, H.P., Jaryan, V., Rathee, S., ... & Kohli, R.K. (2020). Patterns of plant communities along vertical gradient in Dhauladhar Mountains in Lesser Himalayas in North-Western India. *Science of The Total Environment*, *716*, 136919. - Ahmad, M., Uniyal, S.K., Batish, D.R., Rathee, S., Sharma, P. & Singh, H.P. (2021). Flower phenological events and duration pattern is influenced by temperature and elevation in Dhauladhar mountain range of Lesser Himalaya. *Ecological Indicators*, *129*, 107902 - Sharma, R., Kaur, S. & Uniyal, S.K. (2021). Tracking the seasonal dynamics of Himalayan birch using a time-lapse camera. *Folia Geobotanica*, *56*(2), 125-138. - Sharma, R., Kaur, S. & Uniyal, S.K. (2022). Population and vulnerability assessment of high value medicinal plants in the Alpine regions of western Himalaya. *Journal of Applied Research on Medicinal and Aromatic Plants*, *26*, 100353.
3.	Indigenous knowledge documentation and strengthening through scientific evidence base	• Indigenous knowledge on the use of 156 medicinal plants documented. • The importance of fifty wild edible plants (WEPs) in

		the livelihood of the communities presented. Mean and median of WEP used per respondent was 22.3 and 21, respectively. Maximum of these were used as vegetable (mean 8.9) while minimum were used as brew (mean 0.4). • It was revealed that though plant use is still maintained in the area, changes are evident. While ~50% of the respondents presented views that they still continue to use WEP, 36% reported trends of declining use as compared to 5-10 years back. • A total of 55 Plant Derived Utility Products (PDPs) under five use categories namely tools (34), artefacts (7), construction and storage (6 each), and miscellaneous (2) were noted to be used. For making these PDPs, 20 plant species representing 12 families were used. *Picea smithiana* (16.54%), *Cedrus deodara* (14.96%), *Cotoneaster bacillaris* (12.60%) and *Quercus semecarpifolia* (11.02%) reported the highest use frequency. On an average 15.13±0.25 PDPs per respondent was noted. • Use and knowledge on fuelwood species (n=29) showed a significant difference in the mean number of species known (10.02±0.2) and those used by the community (4.99±0.1). The highest Informant Consensus Factor was recorded for *Picea smithiana* (0.88) followed by *Cedrus deodara* (0.85). Of the total fuelwood that is annually collected by a community (*Bhangalis)*, forty-three percent is collected during the winter season while 30% is collected during the summer season. Minimum fuelwood is collected during the rainy season (26.17% of the total collection). Significant differences were observed for fuelwood consumed during summer and winter seasons ($p< 0.05$). As expected, higher fuelwood was consumed during winter months (23.24± 2.3 kg/household) while the least was consumed during

		summers (15.76±1.8 kg/household) • Eleven indicators of changing climatic conditions identified. "Decrease in snowfall" was the most prominent indicator as it was reported by the maximum number of respondents (~97%). It was followed by "increase in crop disease /pest attacks" (~82%), "decrease in monsoon rainfall" (~76%), and "decrease in water level" (~76%) that refers to reduced water in streams and also drying up of water sources. Sixty-nine percent of the respondents reported trends of "increasing temperatures". An "increase in dry period" was reported by ~65% of the people while ~47% noted a "decrease in winter rainfall". People also mentioned that moisture level in the soils has now reduced. The percentage of people who perceived "decrease in soil moisture" was ~45% and almost a similar proportion of respondents (45%) reported "range shift of plants". "Changes in phenology" and "early crop maturity" were reported by ~34% and ~11 % of the respondents, respectively. • Validation of the peoples' perception climate change indicators using the meteorological data shows their reliability. **Publications:** - Thakur, D., Sharma, A., & Uniyal, S. K. (2017). Why they eat, what they eat: patterns of wild edible plants consumption in a tribal area of Western Himalaya. *Journal of ethnobiology and ethnomedicine*, 13(1), 1-12 -Sharma, A. & Uniyal, S.K. (2018). Weaving warmth: From sheep to shawl. *Science reporter* 55(4): 30-32. -Sharma, A. & Uniyal, S.K. (2019). Mulling over mills: The Gharat. *Dream* 2047 21(5): 31-32. - Sharma, A., Thakur, D., & Uniyal, S. K. (2019). Plant-derived utility products: knowledge comparison across gender, age and education from a tribal landscape of

		western Himalaya. *Journal of ethnobiology and ethnomedicine*, *15*(1), 1-14. -Sharma, A., Batish, D.R. & Uniyal, S.K. (2020). Documentation and validation of climate change perception of an ethnic community of the western Himalaya. *Environmental Monitoring and Assessment*, *192*(8): 1-22. - Uniyal, S.K. (2021). Prioritizing Traditional Knowledge for Managing Bio-cultural Landscapes. IRALE. - Sharma, A., Parkash, O. & Uniyal, S.K. (2022). Moving away from transhumance: The case of Gaddis. *Trees, Forests and People*, *7*, 100193. -Sharma, A., Uniyal, S.K., Batish, D.R. & Singh, H.P. (2022). Utilization of fuelwood species by the Bhangalis community of western Himalaya, India. *Environment, Development and Sustainability*, 1-23.
4.	Study the Invasive Alien Species (IAS)	• Information on alien species compiled and categorized. • Alien species richness was maximum at lower altitudes. Their maximum richness (n=317) was observed in the 1000–1100 m altitudinal band. After this, a gradual decline in their richness was observed. It declined to 254 in the 1500–1600 m band and was below 50 in the 3000–3100 m band. • Of the total alien species, maximum are herbs (n=323), followed by trees (n=49), shrubs (n=40), and climbers (n=13). Life form analyses revealed the absence of alien climbers above 2500 m. Alien species distribution patterns are in contrast to the native species distribution whose maximum richness is reported at mid-altitudes (2000–2500 m). • Members of Asteraceae, Fabaceae, and Poaceae dominate the alien flora. **Publications:** -Ahmad, M., Uniyal, S.K. & Singh, R.D. (2018). Patterns of

		alien plant species richness across gradients of altitude: analyses from the Himalayan state of Himachal Pradesh. *Tropical Ecology* 59(1): 35-43. - Sharma, R.& Uniyal, S.K. (2018). Vegetation Patterns of Treeline Ecotone in the Pangi Valley, Western Himalaya. *Proceedings of Himalayan Researchers Consortium*, Vol. 1(1).
5.	Analyze the extent of capacity built of the traditional institutions	• Traditional practices pertaining for use and conservation of forest (dev bans, ghasnis), soil (bunds, grass sowing), and water (bawdi, nawns, chhrodu, kuhls, chhapris, mangru, panihars) were identified and documented. • Traditional Institutions (mahila mangal dal, yuv manch, van panchayat, rakhas, sanjhi van yojna) working in the field identified • Vegetation characteristics of a formally managed forest vis-à-vis traditionally managed sacred groves were compared. • Prevalence of twenty-two taboos highlighted. Most of these taboos (n=6) pertain to the management of the forests and were mainly associated with sacred forests of deities. A similar number of taboos (n= 6) were associated with water and were primarily related to sacred ponds. These were followed by food (n=3) and farmland (n=1) taboos. Food taboos are related to the consumption of food while the farmland taboos related to tillage and other farmland activities. • The maximum number of taboos were segment and method (32% each) followed by habitat taboos (14%). Temporal and life history taboos accounted for 9% of the total taboos, each, while the minimum (5%) were species-specific taboos. • Ponds such as *Panchali Narayan*, *Falyani Narayan* at Lug Valley, and *Devnala Ajaypal* at Chhota Bhangal

		with footwear is not permitted. So the method for approaching these sacred sites is barefoot. Similarly, for the collection of some of the medicinal plants, special techniques and methods are followed. For example, *Astragalus multiceps* is collected during dawn hours on Thursday mornings only. At the same time, no metal tools are used for the collection of *Staphylea emodi*. These method taboos help in the sustainable utilization of plant resources and their use. These methods result in a minimum collection of plants hence play a pivotal role in conservation. • Segment taboo includes prayers to be performed by members of only one clan/family such as during *Kahika* fair (Lug valley) and *Kaanabeerusaaja* festival (Chhota Bhangal). While people from far off villages come to witness these fairs and festivals, rituals. • Extraction of any kind of resources including fuel and fodder are not allowed from sacred forests such as *Falyani Narayan*, *Panchali Naryan*, *Bhalthi Narayan* at Lug Valley, and *Devnala Ajaypal* in Chhota Bhangal. Also, from the sacred ponds (*Mathasar* and *Badasar*) at lug valley and *Dansar* (Chhota Bhangal), no resource extraction is permitted. According to the taboo, the lake is home to the Goddess Parvati who visits the lake during Bhadrapada (August or September) of the Hindu calendar. Similarly, fishing is prohibited from sacred water bodies for example *Machhyal* and trees around sacred ponds are also not allowed to be cut. • Temporal taboos were identified in the study. These includes suspension of farmland activities including tillage during festivals of deity such as on Vishwakarma day which is a resting day for all farmers. At the same time, a family where a woman has recently delivered a baby refrain from agricultural activities.

		• The evolution of taboos and their integration into policies is now what is desired. **Publications:** - Thakur, D., Sharma A, Uniyal S. K. (2019). Mushroom-growing Elm trees can empower Barot village communities. *Down To Earth*. https://www.downtoearth.org.in/blog/agriculture/mushroom-growing-elm-trees-can-empower-barot-village-communities-62787. -Sharma, A., Thakur, D. & Uniyal, S.K. (2019). Taboos: Traditional beliefs and customs for resource management in the western Himalaya. *Indian Journal of Traditional Knowledge,* 20(2): 575–581.
6.	Capacity building on biodiversity conservation through field-based trainings/ awareness programs	• Identified villages at Low and high-altitude for awareness programme and group interaction. • Interacted with 10 village communities • Awareness programme carried out and popular lecture delivered in villages and Government schools each in Lahaul, Kinnaur and Kangra. • Community surveys conducted in villages • Initiation of plantation drives • Evaluated nature relatedness of students and villagers

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:
1.	Bio-indicators of environmental health for western Himalaya	Number of sites, tree species analysed	Vegetation sampled in 29 sites, where, 261 soil samples, 246 plant samples and 246 dust samples collect ed	

	A Monitoring protocol		Air Pollution Tolerance Index (APTI) of the commonly occurring 26 woody species evaluated. Tolerant and sensitive plant species identified. Based on the results, *Grevillea robusta*, *Quercus floribunda*, *Toona ciliata*, *Ficus carica*, were evaluated as best performers. These plants can be integrated into plantation programmes. *Acer caesium*, *Betula utilis*, *Morus alba*. that had low scores were predicted as poor performers. Compilation of heavy metal assessment in dust samples. Distribution of metal(loid)s in soils of three habitation land uses (Urban, peri-urban and rural) completed. Biochemical estimations of 23 dominant plant species completed near (polluted) and far away (unpolluted) from ACC cement plant. Anticipated performance of 23 plant species has been assessed in varied air pollution scenarios. Soil samples analysed for physicochemical properties and heavy metal analysis. Ecological risk, geo-indicator plant species accumulation and spatial distribution of toxic elements have been assessed. **Publications**: **04**	
2.	Identification of	Established	Twenty-one permanent plots with	

	sites for long-term environmental monitoring. Mainstreaming of long-term monitoring and building scientific evidence base across key sectors achieved	LTEMs, number of species documented, phenological records images	automated loggers established. Vegetation and soil sample analysis were carried out. The soils were found to be acidic in nature (pH ranging between 4.36 to 5.506). Total potassium (%) ranged from 0.24 to 2.41, total phosphorus (%) from 0.04 to 0.18, and total nitrogen (%) from 0.19 to 0.82. Documented flowering phenology of 25 plant species and alpha and beta diversity across altitudinal gradient. **Publications: 04**	
3.	Indigenous Knowledge and Practices (IKP) systematically documented and linked to scientific evidence base	Respondents and interviews conducted	Recordings from more than 800 respondents 11 indicators of climate change perception of the local communities identified. Fifty wild edible plants of use noted. WEP categorized into six categories (vegetables, fruits, chutney, flavoring food, raw food, and local brew) and trends of use (continuing, decreasing, increasing, and not used), and motivations (environmental, economic, sociocultural, agriculture & land use practices, and human wild life conflict) presented. 263 plants of medicinal importance, their use and dosage documented. Collection and consumption patterns of fuelwood and fodder recorded. Local indicators of changing climatic conditions identified (n=11) two of	

			which validated. **Publications**: **07**	
4.	Threat of proliferation of invasive alien species reduced and adversely impacted areas/ landscapes restored	Alien species categorized	Categorization of alien species (n=497). Distribution patterns of alien species revealed. Gradients of high alien species richness identified. **Publications: 04**	
5.	Key traditional institutions of IHR states identified. Their role, norms and practices concerning environment protection & socio-economic development documented. Identify their capacity building needs in present day context	Traditional conservation practices identified and documented.	Traditional practices pertaining to forest (dev bans, ghasnis), soil (bunds, grass sowing), and water (bawdi, nawns, chhrodu, kuhls, chhapris, mangru, panihars) and identified. Traditional Institutions (mahila mangal dal, yuv manch, van panchayat, rakhas, sanjhi van yojna) working in the field identified Sacred groves (deobans) and community protected forests identified in the area. Presence of sacred ponds (deotaals) and traditional baudies recorded. Terraces and stone bunds commonly followed for soil conservation. Fairs and festivals recorded. **Publications: 02**	
6.	Scientific evidences and databases	Community groups trained.	Low and high-altitude villages for awareness programme and group interaction identified	

	developed/ augmented/disseminated. All traditional Information and Communications Technologies (ICT) and innovative methods effectively used, etc.	Awareness Camps/Programmes organised.	Interacted with 10 village communities Awareness programme carried out and popular lecture delivered in villages and Government schools each in Lahaul, Kinnaur and Kangra. Community surveys conducted in villages Initiation of plantation drives Evaluated nature relatedness of students and villagers	

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

S. No.	Particulars	Number/ Brief Details	Remarks/ Enclosures
1.	New Methodology developed:	29 sites identified and marked along a vehicular pollution gradient (NH-21). Established 21 Long Term Environment monitoring sites. 04 Treeline sites have been established for long term monitoring. Established 01 Phenological monitoring station at Pangi, Chamba, HP.	Appendix 07
2.	New Models/ Process/ Strategy developed:	-	-
3.	New Species identified:	-	-

S. No.	Particulars	Number/ Brief Details	Remarks/ Enclosures
4.	New Database established:	-	-
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.	Baseline vegetation information of the established plots.	Several of the studied sites were explored for vegetation data on ecological perspectives for the first time.	This baseline information will provide a base for further long-term monitoring of those ecosystems and for accessing the impact of climate change.
2.	Density, height and dust capturing potential of plant species along pollution gradients		Appendix 7

3.	Population and vulnerability assessment of high value medicinal plants in the Alpine region	No such data was available from this region.	Appendix 7
4.	List of wild edible plants used by locals of Chhota Bhangal, region of Western Himalaya.	No such data was available from this region.	Appendix 7
5.	Traditional conservation practices Traditional practices pertaining for use and conservation of forest and water were identified and documented.	No such data was available in this region	Appendix 7

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)	Resource collection and use (fuelwood)	05 publications	Global community
2.	Climate Change/INDC targets	-Community perception revealed 11 indicators of climate change. -Digital images for plant phenological recordings	02 publications	Global community
3.	International Commitments			

4.	National Policies	-Conservation and management of traditional knowledge. -Conservation of and vulnerability assessment of high value medicinal plants.	02 publications	Global community
5.	Others collaborations			

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 I.**

7. Quantification of Overall Research Progress

S. No.	Parameters	Total (Numeric)	Attachments* with remarks
1.	IHR State(s) Covered:	*1*	
2.	Fellowship Site/ LTEM Plots developed:	*251*	*Appendix 7*
3.	New Methods/ Model Developed:		
4.	New Database/ Dataset generated:	*182278*	*Appendix 7*
5.	Types of Databases generated:		
6.	No. of Species Collected:		
7.	New Species identified:		
8.	Scientific Manpower Developed (PhDs awarded/ JRFs/ SRFs/ RAs):	*2(Ph.D.)/1 (JRF)/1 (RA)*	
9.	No. of SC Himalayan Researchers benefited:		
10.	No. of ST Himalayan Researchers benefited:	*2*	
11.	No. of Women Himalayan Researchers empowered:	*6*	

12.	No. of Knowledge Products developed:		
13.	No. of Workshops/ conferences participated:	*14*	*Appendix 03*
14.	No. of Trainings participated:	*3*	*Appendix 03*
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)	2	11	42.511	Appendix 2
2.	Book Chapter(s)/ Books:	-	-	-	-
3.	Technical Reports/ Popular Articles	4	-	NA	Appendix 2
4.	Training Manual (Skill Development/ Capacity Building)	-	-	-	-
5.	Papers presented in Conferences/ Seminars	2	-	NA	Appendix 2
6.	Policy Drafts (if any)	-	-	-	-
7.	Others (specify)	1	-	NA	Appendix 7

*Please append the list of KPs/ publications (with impact factor and URL link details) with due Acknowledgement to NMHS.

**Please provide supporting copies of the published documents.

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.	Do different plant species respond differently to air pollution	Commonly occurring plant species (n=26) have been assessed for this. These species responded differently. Some species were

		observed to be tolerant while others were sensitive.
2.	Which plant species should be recommended for green belt development	Based on APTI and API, it was revealed that tolerant and good performer tree species such as *Grevillea robusta, Juglans regia, Quercus floribunda*, and *Toona ciliata* should be planted in air polluted enviro(n)s in Himalaya
3.	Do biochemical characteristics of plant species vary along vehicular pollution gradient	Biochemical characteristics of plant species varied with pollution loads
4.	How different are forest soils in comparison to habitation soils in the same landscape	Soils differ along gradients of human pressure. Heavy metals concentration is maximum in human dominated landscape as compared to pristine forest soil.
5.	What impacts will be changing climate have on species range shifts	For addressing this, long term plots have been marked along an altitudinal gradient.
6.	Do native and alien species show similar distribution patterns	As opposed to native species that have high richness around 2500 m asl, highest species richness of alien species is observed at lower altitudes (1000 m asl)
7.	Do vegetation characteristics of treeline vary along an east-west gradient in HP	Yes, vegetation types changes across the east-west gradient
8.	Do tribal communities perceive changing climate and what are its major implications	The tribal communities reported 11 indicators of changing climatic conditions. Trends of decreasing snowfall and declining monsoon rainfall were their major observations across temporal scale. Increasing temperature was the other characteristic that was reported by the respondents. Interestingly, some of the respondents reported increased incidences of crop disease. All these are affecting their crop

		productivity and lifestyle. They are now more dependent on market forces.
9.	Does perception of climate change vary between the two genders	Males were found to be better perceivers.
10.	How upcoming of market forces influence folk knowledge	Changing socio-economy and alternatives available in the market negatively affects and lead to decline in folk knowledge
11.	Can plant phenophases be identified based on digital numbers.	Red, Green and blue band information stored in the digital photographs provide clues to this.
12.	Are traditional conservation practices prevalent in the area.	Traditional conservation practices for plant, soil and water are still followed.
13.	Do traditional conservation practices help in maintaining biodiversity	Our observations reveal that, sacred groves, protected in the name of deity, have dense canopy and higher species density as compared to adjoining forests.

9.2 Recommendations on Replicability and Exit Strategy:

Particulars	Recommendations
Replicability of Fellowship, if any	-The methods adopted and analyses carried out is easily replicable in the mountain areas including other parts of Himalaya. -For permanent plot marking, plot markings should have geo-coordinates of all corners and also of the centroid. -Repeat observations and recordings from marked sites would provide data of time scale changes. -All time human presence for field phenological recording is not possible in the Himalaya and also it has observer bias. It would, therefore, be of help to have automated phenological monitoring stations. Large temporal datasets are of utmost importance. -For knowledge documentation studies, confidence building with the local communities is a must. -Genuine respect for local customs and traditions add to data generation.

Exit Strategy:	*Please describe the Exit Strategy of the fellowship, self-sustaining and benefitting the stakeholders and target communities:* The individual fellowship provided a valuable experience and knowledge to the budding manpower. Each of them has benefitted and is excelling in their respective field. Three fellowship holders benefitted with PhD (two have been awarded).

(NMHS FELLOWSHIP COORDINATOR)

(Signed and Stamped)

डॉ. संजय कुमार
वरिष्ठ प्रधान वैज्ञानिक
पालमपुर-176061 (हि.प्र.)

(HEAD OF THE INSTITUTION)

(Signed and Stamped)

निदेशक
सी.एस.आई.आर.-हिमालय जैवसंपदा प्रौद्योगिकी संस्थान
पालमपुर- 176061

Place: Palampur

Date: 14/XII/2022

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.:	***01 of 06*** *(H-RA 001)*

Researchers Details

Type of Fellowship (HRA/HJRF/HJPF)	Name of Himalayan Researcher	Date of Joining	Date of Resignation**	Research Title	Name of the PI & Designation
HRA	Dr Rachit Raghava Kashyap	26-05-2016	28-02-2019	Identification of bio-indicators for documenting environmental health	Dr. Sanjay Kr. Uniyal Senior Principal Scientist
HRA	Dr. Anchal Rana	12-07-2019	31-03-2020	Identification of bio-indicators for documenting environmental health	Dr. Sanjay Kr. Uniyal Senior Principal Scientist

*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.

1 INTRODUCTION

Loss of forest cover and increasing air pollution are contemporary global problems having far reaching implications on health, ecology, and economy (Pandey et al. 2015; Dwivedi and Tripathi, 2007; Mondal et al. 2011). This not only calls for reducing emissions but also greening of landscape. In Himalaya, developmental activities that include expansion of roads and growth in automobiles are prime reasons for increasing air pollution and decreasing greenery. Green cover along roadsides not only acts as a bio-indicator of environmental conditions but also helps in minimizing the effects of pollutants (Radhapriya et al. 2012). Being static, plants are continuously exposed and thereby accumulate dust, particulate, and pollutants (Pandey et al. 2015; Wagh et al. 2006). Different plant species respond differently to pollution, while some can tolerate high levels of pollution others are sensitive (Nadgórska-Socha et al. 2016). This is guided by biochemical characteristics such as leaf chlorophyll, ascorbic acid, leaf extract pH, and relative water content (RWC) of the species (Rai and Panda, 2014). Studying these parameters is therefore important for understanding bio-indicator responses of species. Till late, Air Pollution Tolerance Index (APTI) of plants was advocated to identify tolerance levels of different species (Dwivedi and Tripathi, 2007). However, recently, Anticipated Performance Index (API), which in addition to biochemical characteristics also uses socio-economic and biological characteristics of plant species has been recommended (Ogunkunle et al. 2015). This ultimately helps in identifying bio-indicator species, guiding greening programs and ameliorating environmental health. It is with this background that the present study is being done.

1.1. Literature review

Studies perused reveal that bio-indicator analyses using vegetation is not only important for social reasons but also for managing air quality. Singh and Rao (1983) laid the methodological foundation for monitoring impacts of air pollutants on vegetation and emphasized assessment of biochemical parameters of plant leaves. Later, researchers worked on the responses of plants to air pollution where sensitive species were identified to act as bio-indicators while the tolerant species were recommended for greening and mitigating pollution (Singh et al 1991; Nadgórska-Socha et al. 2016; Pathak et al. 2011). Adverse effects of pollution on ecology motivated workers to study APTI of plants growing in polluted environments. Use of biological and socio-economic characteristics of plants such as tree type, canopy, leaf size, texture and economic uses, along with their biochemical characteristics led to coming up of API for evaluating overall performance of plant species (Govindaraju et al. 2012). It was an improvement over the APTI (Prajapati et al. 2006). Based on these indices, species were prioritized for green belt development and recommended for long term air pollution mitigation across the globe. Recent work of Prajapati et al. (2006); Prajapati and Tripathi (2008); Rai and Panda (2014) on bio-indicator responses represents an important contribution to science and knowledge.

Background studies for designing the present work are presented below:

S.No.	Reference	Year	Major Objectives	Methodology adopted	Findings
1.	Achakzai et al. (Journal of Env. Man. 190, 252-258)	2017	Assessment of APTI of plants around brick kilns	Biochemical parameters integrated into APTI	*C. procera* and *A. pungens* recommended to mitigate air pollution around brick kilns

2.	Dwivedi and Tripathi (Journal of Envir. Biology 28(2), 257–263)	2007	Assessing tolerance of plants growing around coal fired industries	Bio-indicator responses through biochemical parameters of plants	*R. communis* was found to be most resistant to air pollution
3.	Govindaraju et al. (Environmental Science and Pollution Research, 19(4), 1210–1223)	2012	Identification of species for development of green belt around thermal power plant	Screening of species for pollution tolerance based on their responses to polluted environment	*M. indica* identified excellent plant species for green belt development
4.	Mondal et al. (Plant Science, 2(4), 99–106)	2011	Green belt development in West Bengal	API of tree species for green belt development	*Ficus sp.* & *M. Indica* identified for green belt development
5.	Nadgorska-Socha et al. (Int. J. of Env. Sci. Tech., 13(7), 1741–1752)	2016	Bio monitoring of air pollution using plants	Changes induced by air pollution and soil pollution index	Plants in contaminated stands had lower APTI values
6.	Ogunkunle et al. (Agro. Sys., 89(3), 447–454)	2015	Biomonitoring of environmental health using green plants	APTI and API index used to study environmental health	*V. paradoxa* was best performer and suitable for planting
7.	Pandey et al. (Urban Forestry and Urban Greening, 14(4), 866–871)	2015	Development of vertical greenery systems in polluted city	APTI and Regression analysis	Three climbers viz., *I. palmata*, *A. leptopus* and *T. grandiflora* were recommended
8.	Pathak et al. (Urban Forestry and Urban Greening, 10(1), 61–66)	2011	Evaluation of APTI of tree species for green belt development	Urban health monitoring and modelling	*M. indica* & *F. religiosa* were classified as excellent performers
9.	Prajapati and Tripathi (J. of Env. Management, 88(4), 1343–1349)	2008	Biochemical estimation of tree leaves and evaluation of APTI index	Chemical analysis of leaves and development of API index	API index is most suitable method for assigning performance of tree species

10.	Radhapriya et al. (Journal of E. Biology, 33(3), 635–641)	2012	Air pollution tolerance of plants around cement industry	Bioindicator response assessment by air pollution assessment	*Bougainvillea sp.* showed higher APTI values and proved their tolerant nature
11.	Rai and Panda (Air Quality, Atmosphere and Health, 7(1), 93–101)	2014	Dust capturing potential and APTI of road side trees	Screening of road side tree vegetation by APTI and API index	*F. bengalensis*, *M. indica* and *F. religiousa* were best suited for plantations along roadside
12.	Wagh et al. (Journal of Environmental Biology, 27(2): 419–421)	2006	Biological monitoring of road side plants exposed to air pollution	Biochemical analysis of plants for assessing environmental heath	Plantations along road side should include *A. indica* and *F. religiosa*

1.2. Research question/s

- Do roadside tree species respond differently to air pollutants
- Does dust accumulation vary among different tree species
- How do different plant species perform along a vehicular pollution gradient
- What species should be recommended for green belt development

1.3. Objective/s of the study

Along a vehicular air pollution gradient:

- to study dust accumulation patterns on leaves of plant species
- to carry out physico-chemical analysis of leaves
- to study air pollution tolerance and anticipated performance of plant species

2 METHODOLOGIES, STARTEGY AND APPROACH

The study was carried out in Kullu district and adjoining areas of Himachal Pradesh along the 243 km stretch of NH-21. The area was chosen as heavy influx of tourists, annually ~60 million people visit areas around Kullu (HPTDC, 2012), and associated vehicular pollution has resulted in degradation of the environment. Taking a serious note of this, the National Green Tribunal (NGT), India has imposed stringent regulations on movement of vehicles in the region and widening of NH-21 has started. Additionally, the Government is now focusing on use of hybrid vehicles and initiating plantations using scientifically prioritized species in the area.

Twenty-nine locations between 31°24’40.85’’-71°51’38.81’’ to 32°21’8.34’’-77°13’32.63” were selected for sampling along NH-21. Each location lies at successive 100 m rise in altitude (500-3300 m asl). At each location, three sampling sites starting from the fringe of the road were identified. These have been named as Highly Polluted (HP) i.e., area within 0-15 m distance from the road boundary, Moderately Polluted (MP) represents area 15-30 m away from the road boundary, while Least Polluted (LP) represents area > 45 m away from the road. Quadrat sampling (10 × 10 m) was carried in each of these sites (Mueller Dombois and Ellenberg, 1974) and based on abundance 26 six commonly occurring plant species were selected for bio-indicator analyses (Table 1). Fully mature leaf samples of these species were collected in triplicates for biochemical analyses. The ascorbic acid (mg/g dry weight) was determined using the modified calorimetric 2, 6-dichlorophenol indophenol method (Keller and Schwager, 1977). Total chlorophyll (mg/g dry weight) was estimated following Maclachlan and Zalik (1963). Leaf extract pH was measured using a digital pH meter while RWC was determined following Weatherley (1965). APTI of the species was assessed using Singh and Rao (1983). API was evaluated following Prajapati and Tripathi (2008).

3 KEY FINDINGS AND RESULTS

3.1. Bio-indicator responses and performance of plant species along a vehicular pollution gradient in western Himalaya

Identification of study area

A 243 km stretch of national highway (NH-21, Bilaspur to Rohtang) in Himachal Pradesh (India) was identified for the present study. Twenty-nine locations between 31°24’40.85’’-71°51’38.81’’ to 32°21’8.34’’-77°13’32.63” with altitude ranging from 500 m to 3300 m amsl were selected for plant sampling (Table 1).

At all the sampling sites, starting from the fringe of the road, three pollution gradients were identified. These have been named as Highly Polluted (HP) i.e., area within 0-15 m distance from the road boundary, Moderately Polluted (MP) represents area 15-30 m away from the road boundary, while Least Polluted (LP) represents area > 45 m away from the road. A schematic representation is provided in Figure 1.

Evaluation of Density, height, and dust capturing potential of plant species

Tree density, and height of the studied plant species ranged from 1 to 6 (individuals/10m^2), and 2 to 31 meters, respectively. Dust accumulation loads varied amongst the species. In HP site, maximum dust load was noticed on leaves of *F. carica* (1.191 mg/m^2) followed by *T. ciliata* (0.820 mg/m^2), *P. cornuta* (0.308 mg/m^2), *J. regia* (0.249 mg/m^2), and *B. ceiba* (0.116 mg/m^2) (Table 2).

Negligible dust accumulation was noted on the leaves of *C. citrinus*, *D. sissoo,* and *C. deodara* (0.001 mg/m^2 each). Similar trends were noticed in MP, where dust load ranged from 0.001 mg/m^2 to 0.099

mg/m^2. Leaves of plants in LP sites accumulated minimal dust when compared to leaves of plants in the MP, and HP sites.

Collection of leaf samples

In each of the three sites (HP, MP, and LP), a plot of 10 × 10 m was marked with red paint. Twenty-six commonly occurring plant species namely *Abies pindrow*, *Acacia catechu*, *Acer caesium*, *Betula utilis*, *Bombax ceiba*, *Callistemon citrinus*, *Cedrus deodara*, *Dalbergia sissoo*, *Ficus carica*, *Grevillea robusta*, *Grewia optiva*, *Juglans regia*, *Mallotus philippensis*, *Melia azedarach*, *Morus alba*, *Murraya koenigii*, *Picea smithiana*, *Pinus roxburghii*, *Populus deltoides*, *Prunus cornuta*, *Punica granatum*, *Quercus floribunda*, *Robinia pseudoacacia*, *Salix alba*, *Toona ciliata*, *Zanthoxylum alatum* were selected on the basis of their abundance in quadrats. The height of trees occurring in the quadrats was measured using a digital clinometer (Nikon make). Fully mature 12 to 14 leaf samples were collected from commonly occurring plants in each plot.

After field sampling, leaf, and dust samples were brought to the laboratory for analytical investigations. Vials containing leaf samples were transferred to CRYO-CUBE F570 (Eppendorf, India make) ultra-low temperature freezer (-80°C) in ice boxes, and dust sample were kept in a desiccator (SECADOR™, USA make).

Biochemical analysis of plant leaves

In all the three sites, *B. ceiba* reported highest leaf extract pH i.e. 6.35±0.006, 7.57±0.017, 7.72±0.012 in HP, MP, and LP sites, respectively. On the other hand, minimum pH in all the three sites was recorded for *C. deodara* i.e. 3.05±0.002, 3.12±0.005, and 3.16±0.008 in HP, MP, and LP sites, respectively. For other species also, similar trends were noted. With respect to RWC, in comparison to other species, *F. carica* reported the highest RWC values in all the three sites i.e 117.63±0.141%, 109.61±0.202 %, and 96.57±0.095 % in LP, MP, and HP sites, respectively. The needles of *A. pindrow* retained less water when compared to all other species, and therefore reported significantly lower ($P<0.05$) RWC values in LP (17.16±0.227 %), MP (12.82±0.441), and HP sites (8.64±0.084 %). It was revealed that, in all the targeted plant species, total chlorophyll increased with decreasing pollution. In LP site, maximum total chlorophyll (7.87±0.011 mg/g) was recorded in *P. smithiana*, followed by *P. cornuta* (7.30±0.005 mg/g), and *Q. floribunda* (7.26±0.020 mg/g). Minimum total chlorophyll content in HP sites was recorded in *P. cornuta* (1.32±0.004 mg/g) followed by *R. pseudoacacia* (1.72±0.010 mg/g), *G. optiva* (1.85±0.079 mg/g), and *Z. alatum* (1.94±0.029 mg/g). When compared to total chlorophyll, a reverse trend was noticed for ascorbic acid. Ascorbic acid increased with increasing air pollution. In each of the three sites, *G. robusta,* and *S. alba* reported higher values of ascorbic acid. In HP, *G. robusta,* and *S. alba* had 9.66±0.008 mg/g, and 6.86±0.006 mg/g of ascorbic acid, respectively.

Evaluation of Bio-indicator responses and APTI of plant species

Bio-indicator response of the studied species, and its interpretation based on economic value, morphological traits along with APTI values showed that *G. robusta* had significantly (P<0.05) higher values i.e., 21.06, 21.19, 19.61 in LP, MP, and HP sites, respectively. The bioindicator response of *G. robusta* (>17) indicated that it was tolerant to air pollution in each of the sites. With low APTI values (<11), bio-indicator response of *P. deltoides*, *P. roxburghii*, *J. regia*, *A. caesium*, *A. pindrow*, *P. smithiana*, and *B. utilis* puts them under sensitive category in each of the sites. *G. optiva*, *F. carica,* and *S. alba* showed an intermediate response, with APTI values lying between 12 to 16. On the other hand, *D. sissoo,* and *Q. floribunda*, gave mixed responses i.e., they were sensitive in HP sites, and intermediate in LP sites.

Anticipated performance index of plant species

Anticipated performance index (API) is an advancement over APTI. Here socioeconomic, and biological characters of the targeted plant species along with their APTI values revealed that *G. robusta* (68.75 %), *J. regia* (68.75%), *Q. floribunda* (68.75 %), and *T. ciliata* (62.50 %) were good performers in HP sites along the national highway. Performance of *P. smithiana*, *C. deodara*, and *P. deltoides* was moderate in each of the sites. *A. pindrow* (50.00 %), *A. caesium* (43.75 %), *B. utilis* (43.75 %), *G. optiva* (43.75 %), *M. philippensis* (50.00 %), *M. alba,* (43.75 %), and *M. koenigii* (43.75 %) having low API scores were poor performers in their respective sites.

3.2. Spatial distribution of heavy metals in soils of different habitation land-uses and their associated ecological risks in a Himalayan state of India

The ecological risk posed by soil degradation varies along multiple gradients of which habitation land-use gradient is prime. Presence of toxic heavy metals in soil can pose ecological risks with multifarious ramifications. Heavy metals like Cd, Cr, Pb, Mn, Ni, and Zn are inorganic toxic pollutants having synergistic effects. They are known to effect soil fertility, reduce crop productivity, and influence human and ecological health.

Identification of habitation land-uses

Four habitation land-use types i.e., urban (n=4), peri-urban (n=4) and rural (n=4) were identified based on anthropogenic disturbances in Kullu and Mandi districts of Himachal Pradesh. Forest land-use that had minimal anthropogenic disturbance was taken as a control and used as a reference for comparison amongst the identified habitation land-uses. These habitation land-uses lie between co-ordinates 32°14’46” to 31°25’41’’ N and 77°11’30” to 76°50’35” E and altitude 500 - 2200 m amsl (Figure 2).

Soil sampling and processing

Soil samples were collected from each of the habitation land-use and control site. To ensure homogeneity in sampling; 8-10 discrete cores (sub-samples) were collected from 0 to 15 cm depth (plow layer) with a conical hand auger and mixed to make one composite soil sample at each site. Each composite soil sample weighed around one kilogram and was packed in a two kilogram polyethylene thermoplastic bag to provide insulation and proper packaging. Sampling was done only on dry days and a total of 72 composite soil samples (3 habitation land-use were collected. Samples were labeled and brought to the laboratory for further processing and analyses. They were kept for air drying before mixing and sieving (Figure 3).

Heavy metal analyses

After weighing 2 gram soil samples in digital balance, the same were digested with addition of 10 ml HNO_3 (1:1) at 95°C for 15 minutes in digestion tubes (specifications of tubes: FOSS make; material: glass; walls: straight; type: closed with a condenser at top; size: 40×300 mm; capacity: 250 ml volume) on an electric digester (KEL PLUS automatic 20 sample loader) (Figure 4A). After tri-acid digestion of samples, volume of aliquots was made to the volume of 50 ml by addition of double distilled water (Figure 4B).

Statistical analysis

Analytical data sets were checked for outliers and normal distribution. Test statistics of Kolmogorov-Smirnov (p>0.05) and Shapiro-Wilk test (p>0.05) proved statistical validity of the data. Visual inspection of Q-Q plots and histograms also suggested that data were normally distributed and bell shaped, respectively.

Parametric multivariate analysis of variance (MANOVA) was then applied to identify overall significant differences amongst the studied heavy metals. For multiple comparisons of habitation land-uses and the metal contents, Post Hoc test was used. Pearson’s correlation was applied for correlating concentrations of the heavy metals in soils with each other. Further, discriminant function analysis was carried out to differentiate the four-habitation land-uses based on their heavy metal content. Least significant difference (LSD) and Wilk’s lambda tests were employed to decipher significant changes among and within group means. All statistical analyses have been carried out using SPSS (version 20.0).

Spatial Distribution of heavy metals in soils

The results revealed significant variations in heavy metal contents around the habitation land-uses (Table 3).

Maximum significant Cd content (4.956±0.031 mg/kg, p<0.05) was found in urban followed by peri-urban (3.200±0.019 mg/kg), rural (1.132±0.003 mg/kg) and forest land-use (control) soils (0.030±0.003 mg/kg).

Chromium (Cr) and manganese (Mn) had trends similar to that of Cd. Their highest concentration was in the urban land-use soils (Cr=17.299±0.567 mg/kg, $p<0.05$ and Mn=76.473±3.342 mg/kg, $p<0.05$). Nickel reported highest concentration (82.225±7.342 mg/kg) in urban soils which was significantly higher in comparison to peri-urban and rural land-use soils. Significantly higher value of Pb was reported in peri-urban soils (13.453±0.615 mg/kg), while Zn (192.613±3.418 mg/kg, $p<0.05$) reported higher values in rural soils.

Assessment of geo-accumulation and ecological risk factors

Further, data of metals was incorporated into various indices and results are represented in table 4 and table 5. Highest Igeo value for Cd (3.5), Cr (7.2), Mn (5.1), and Ni (3.0) were reported in the urban land-use soils followed by peri-urban land-use. On the other hand, highest Igeo values for Pb (6.5) and Zn (1.0) were observed in peri-urban and rural land-use soils, respectively. Contamination factor (Cf) measures were high for Zn in rural (2.028) and urban (1.057) land-use. Lead reported highest Cf (0.673) in peri-urban land-use soils. Cf values of Cd varied from 3.772 in rural to 16.519 in urban soils (Table 5). Estimates of Cf with reference to nickel was high in urban (1.209), peri-urban (1.109) and lowest in control forest soils (0.001).

To study ecological risk imposed by heavy metals around habitation land-uses

The ecological risk index was higher in urban soils followed by peri-urban, rural, and control soils. Ecological risk index is represented in figure 5.

3.3. To study distribution of metal(loid)s and human health risk associated with consumption of contaminated apples

Soil and apple samples were collected from 11 places (Table 6, Figure 6). Samples of apple have been digested for metal(loid)s analysis (Figure 7).

3.4. Assessing air pollution tolerance index of plant species around a coal-based cement industry for green belt development

Twenty-three plant species commonly growing around Gagal cement factory (Figure 8) were identified (Table 7).

4 OVERALL ACHIEVEMENTS

- Air Pollution Tolerance Index (APTI) of the commonly occurring 26 woody species evaluated
- Tolerant and sensitive plant species identified. Based on the results, *Grevillea robusta, Quercus floribunda, Toona ciliata, Ficus carica* were evaluated as best performers. These plants can be

integrated into plantation programmes. *Acer caesium, Betula utilis, Morus alba* that had low scores were predicted as poor performers.

- Twenty-nine sites identified and marked along a vehicular pollution gradient (NH-21).
- Twenty-six dominant plant species sampled and their Air pollution tolerance and anticipated performance index have been worked out.
- Anticipated performance of 23 plant species have been assessed in varied air pollution scenarios.
- Laboratory analysis of eleven apple orchard soils, bark, fruit and leaf samples has been completed.
- Soil samples analysed for physicochemical properties and heavy metal analysis.
- Ecological risk, geo-indicator plant species accumulation and spatial distribution of toxic elements have been assessed.

Publications:

- Kashyap R, Sharma R, Uniyal SK (2018). Bioindicator responses and performance of plant species along a vehicular pollution gradient in western Himalaya. Environmental Monitoring and Assessment 190:302
- Kashyap, R., Verma, K. S., Uniyal, S. K., & Bhardwaj, S. K. (2018). Geospatial distribution of metal (loid) s and human health risk assessment due to intake of contaminated groundwater around an industrial hub of northern India. *Environmental monitoring and assessment*, *190*(3), 1-18
- Greening with pollution-gobbling trees doubles benefits. https://india.mongabay.com/2018/11/world-environment-day-greening-with-pollution-gobbling-trees-doubles-benefits/
- Kashyap, R., Sharma, R., Uniyal, S.K. (2019) Distribution of heavy metals in habitation land-use soils with high ecological risk in urban and peri-urban areas. *International Journal of Environmental Science and Technology*. https://doi.org/10.1007/s13762-018-02203-
- Kashyap, R., Ahmad, M., Uniyal, S. K., & Verma, K. S. (2019). Dietary consumption of metal (loid) s-contaminated rice grown in croplands around industrial sectors: a human health risk perspective. *International Journal of Environmental Science and Technology*, *16*(12), 8505-8516

5. IMPACTS OF FELLOWSHIP IN IHR

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

- The results of the study will help in guiding plantation of air pollutant tolerant plant multipurpose species in the air polluted areas (along the national highways, industries etc.) which ultimately reduce the human and environment health risks.

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

- Air Pollution Tolerance Index (APTI) value analysis showed that *Grevillea robusta* is highly tolerant and *Betula utilis* is highly sensitive to air pollution.
- Protection and plantation of *G. robusta* in the air polluted sensitive area to overcome the problem.
- Sustainable use of natural resources like forest with *B. utilis*, bioindicator of air pollution.

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

- Air pollution tolerant and sensitive plant species were identified in the studied area.
- Protection of these plant species is important as it ensure the health of the environment.
- Creating awareness regarding conservation of these plant species and their sustainable use.

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

- The identified species cater to pollution abatement

5.5. Developing Mountain Infrastructures (max. 500 words, in bullet points):

- Tolerant species may be incorporated in green belt development

5.6. Strengthening Networking in IHR (max. 700 words, in bullet points)

- Fellowship and Himalayan Researchers consortium provided an opportunity to know and forge possible future linkages

6. EXIT STRATEGY AND SUSTAINABILITY

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

- Categorization of bio indicator potential of the studied species has implications in sustainable development.

6.2. Efficient ways to replicate the outcomes of the fellowship in other parts of IHR (max. 1000 words)

- The methodology used is easily replicable in the Himalaya

6.3. Identify other important areas not covered under this study, but needs further attention (max. 1000 words)

- Pathankot Mandi highway

6.4. Major recommendations for sustaining the outcomes of the fellowship in future (500 words in bullets)

- Training college students

7. REFERENCES/BIBLIOGRAPHY

Achakzai, K., Khalid, S., Adrees, M., Bibi, A., Ali, S., Nawaz, R., & Rizwan, M. (2017). Air pollution tolerance index of plants around brick kilns in Rawalpindi, Pakistan. *Journal of Environmental Management*, 190, 252-258.

Mueller-Dombois, D., & Ellenberg, H. (1974). Aims and methods of Vegetation Ecology. *John Wiley and Sons*. London.

Dwivedi, A. K., & Tripathi, B. D. (2007). Pollution tolerance and distribution pattern of plants in surrounding area of coal-fired industries. *Journal of Environmental Biology*, 28(2), 257–263.

Govindaraju, M., Ganeshkumar, R. S., Muthukumaran, V. R., & Visvanathan, P. (2012). Identification and evaluation of air-pollution-tolerant plants around lignite-based thermal power station for greenbelt development. *Environmental Science and Pollution Research*, 19(4), 1210–1223.

H.P.T.D.C. (2012). Tourism Survey for the State Of Himachal Pradesh (April 2011 – March 2012) Final Report.http://tourism.gov.in/sites%20Final%20Report_%20new.pdf. Accessed on 28 July 2017.

Keller, T. (1986). The electrical conductivity of Norway spruce needle diffusate as affected by air pollutants.*Tree Physiology* 1, 85-94.

Maclachlan, S., & Zalik, S. (1963). Plastid structure, chlorophyll concentration, and free amino acid composition of a chlorophyll mutant barley. *Canadian Journal of Botany* 14, 1053-1062.

Mondal, D., Gupta, S., & Kumar, J. (2011). Anticipated performance index of some tree species considered for green belt development in an urban area. *Int. R. J. of Plant Science*, 2(4), 99–106.

Nadgórska-Socha, A., Kandziora-Ciupa, M., Ciepał, R., & Barczyk, G. (2016). Robinia pseudoacacia and Melandrium album in trace elements biomonitoring and air pollution tolerance index study. *International Journal of Environmental Science and Technology*, 13(7), 1741–1752.

Ogunkunle, C. O., Suleiman, L. B., Oyedeji, S., Awotoye, O. O., & Fatoba, P. O. (2015). Assessing the air pollution tolerance index and anticipated performance index of some tree species for biomonitoring environmental health. *Agroforestry Systems*, 89(3), 447–454.

Pandey, A. K., Pandey, M., Mishra, A., Tiwary, S. M., & Tripathi, B. D. (2015). Air pollution tolerance index and anticipated performance index of some plant species for development of urban forest. *Urban Forestry & Urban Greening*, 14(4), 866–871.

Pathak, V., Tripathi, B. D., & Mishra, V. K. (2011). Evaluation of Anticipated Performance Index of some tree species for green belt development to mitigate traffic generated noise. *Urban Forestry and Urban Greening*, 10(1), 61–66.

Prajapati, S. K., & Tripathi, B. D. (2008). Anticipated Performance Index of some tree species considered for green belt development in and around an urban area: A case study of Varanasi city, India. *Journal of Environmental Management*, 88(4), 1343–1349.

Radhapriya, P., Navaneetha, A., Malini, P., & Ramachandran, A. (2012). Assessment of air pollution tolerance levels of selected plants around cement industry, Coimbatore, India. *Journal of Environmental Biology*, 33(3), 635–641.

Rai, P. K., & Panda, L. L. S. (2014). Dust capturing potential and air pollution tolerance index (APTI) of some road side tree vegetation in Aizawl, Mizoram, India: An Indo-Burma hot spot region. *Air Quality, Atmosphere and Health*, 7(1), 93–101. doi:10.1007/s11869-013-0217-8.

Singh, S. K., & Rao, D. N. (1983). Evaluation of plants for their tolerance to air pollution.In: Proceedings symposium on air pollution control held at New Delhi. 218-224.

Wagh, N. D., Shukla, P. V., Tambe, S. B., & Ingle, S. T. (2006). Biological monitoring of roadside plants exposed to vehicular pollution in Jalgaon city. *Jour. Environ. Biology*, 27(2), 419–421.

Weatherley, P. E. (1965). The state and movement of water in the leaf. Symposium of the Society of Experimental Biology, 19, 157-184.

Singh, S. K., Rao, D. N., Agrawal, M. Pandey, J., & Narayan, D. (1991). Air pollution tolerance index of plants. *Journal of Environmental Management,* 32, 45-55.

Prajapati, S. K., Pandey, S. K., & Tripathi, B. D. (2006). Monitoring of vehicles derived particulates using magnetic properties of leaves. *Enivronment Monitoring Assessment,* 120 (1-3), 169-175.

8. ACKNOWLEDGEMENTS

We thank the Ministry of Environment, Forests and Climate Change; Government of India for financial support and GBPNIHE Almora (Uttarakhand) via National Mission on Himalayan Studies, through project GAP-0199. We also thank CSIR-IHBT Palampur HP, and State Forest Department for their support.

Fellowship Report No.: ***02 of 06 (n = H-JPF 001)***

Researchers Details

Type of Fellowship (HRA/HJRF/HJPF)	Name of Himalayan Researcher	Date of Joining	Date of Resignation**	Research Title	Name of the PI & Designation
H-JPF001	Mustaqeem Ahmad	14-06-2016		Diversity and species composition in Long Term Ecological Monitoring plots in western Himalaya	Dr. Sanjay Kr. Uniyal Senior Principal Scientist
H-JPF 001	Rishabh Sharma	08-07- 2019	27-02-2020	Diversity and species composition in Long Term Ecological Monitoring plots in western Himalaya	Dr. Sanjay Kr. Uniyal Senior Principal Scientist

1. INTRODUCTION

Mountains are amongst the rugged yet most fragile bio-rich regions of the world. They occupy 24% of the global landmass and support about half of the biological diversity occurring on this earth (Shrestha, 2014). A fundamental characteristic of mountain ecosystems is the drastic change in vegetation along altitudinal gradients. With change in altitude, variables such as temperature, precipitation, soil, and gases also change. These have a direct bearing on species composition, growth, diversity, and ecosystem (Whittaker, 1978). Generally, with a few exceptions, a mid-altitude species richness peak has been reported for the mountains (Bhattarai, 2004). With reference to taxa, a reduction in plant size but an increasing flower size is an important characteristic reported along altitudes (Körner et al. 1989). This has been attributed to attracting insects for pollination (Fabbro and Körner, 2004). Flowering time, bud-burst, leaf-expansion, flowering, abscission, vary spatially and temporally along this gradient (Körner et al. 1989; Li, 2004). Thus, variations in flower morphology and their traits (Fabbro and Körner, 2004) are now key parameters of global ecological studies. While unimodal distribution patterns of species richness have been documented from the Himalaya (Bhattarai, 2004), functional characteristics of Himalayan species have not been much studied. At the same time, changing climatic conditions are expected to influence species optima thereby bringing changes in their distribution, phenology and traits (Bhattarai, 2004; Shrestha, 2014). This needs to be documented and analysed from the Himalaya which at present is referred to as the *White Spot*.

1.1. Literature review

Gradients studies in mountains formed the basis of research with respect to ecology and evolution including niche theory, life zones, community assembly, environmental pressure (McCain and Grytnes, 2010). Species diversity along altitude has been the subject of numerous studies across the globe (Lomolino, 2001). These studies have investigated species richness, diversity, and composition along elevation, habitats, and taxa (McCain and Grytnes, 2010; Bhattarai, 2004). Körner (2007) highlighted understanding large-scale trends in species diversity and conservation. A humped shaped distribution pattern of species has been reported for diversity of taxa in the Alps, Andes, Rocky Mountains, and Himalaya (Bhattarai, 2004; Körner, 2007; Chawla et al. 2008; Acharya, 2011). Over the last three decades, trait-based studies are gaining prominence (Li, 2004; Fabbro and Körner, 2004; Flynn, 2011). These studies have focussed on leaf, stem, root (Cadotte, 2009), and reproductive traits (Fabbro and Körner, 2004). Recent studies are focusing on flower colour (Shrestha, 2014), flower display area (Fabbro and Körner, 2004), flower phenology (Lessaard-Therrien, 2013), flower longevity (Trunschke, 2017), and seed characteristics (Wang et al. 2014). Though not from Indian Himalaya, flower colour patterns have been studied by Shrestha (2014) while seed traits have been analyzed by Wang et al. (2014) for the Himalayan species. Such studies, though much desired, are meagre from the Indian Himalayan region.

Background studies for designing the present work are presented below:

S. No.	Reference	Year	Major objective	Methodology adopted	Findings
1	Bhattarai et al. (Journal of Biogeography, 31, 389-400)	2004	Species richness along altitude	Secondary data compilation	Unimodal relationship between richness and elevation
2	Fabbro and Körner (Flora, 199, 70-80)	2004	Study variations in flower area in alpine versus low altitude species	Measurement using calipers and dry biomass estimation	Reproductive allocation prioritized over maximization of growth in alpine species

3	Flynn et al. (Ecology, 92, 1573-1581)	2011	Functional & phylogenetic diversity	29 experiments with 1721 poly-cultures and 174 species from 11 publications	Phylogenetic and functional diversity can be predictors of the effect of biodiversity on ecosystem functioning
4	Harguindeguy et al. (Australian Journal of Botany, 61, 167-234)	2013	Traits measurement	Scientific methods for analyses	Handbook of standardized method for traits
5	Körner et al. (Flora, 182, 353-383)	1989	Functional traits with changing altitude	Survey and measurements	Plants at high altitudes are physiologically adapted
6	Körner (Trends in Ecology and Evolution, 22, 569-574)	2007	How altitude governs patterns of biodiversity	Modelling and extrapolation	Physiological, and evolutionary trends govern biodiversity in mountains
7	Li et al. (Trees-Structure Function, 18, 277-283)	2004	Structural and physiological responses of two *Picea* spp.	Functional traits recordings	Despite greater water availability, trees at higher altitudes have apparent acclimations to drought
8	Lomolino (Global Ecology and Biogeography,10, 3-13)	2001	How species diversity changes with elevations	Combination of ecological and evolutionary processes	Hump shaped pattern of species richness along elevation is most common
9	Shrestha et al. (Journal of Ecology, 102, 126-135)	2014	Flower colour variations along elevation	Measured light reflectance from 300 to 700 nm	Floral colors were diverse at higher elevation
10	Trunschke et al. (Botany, 127(1),41-51)	2017	Flower longevity in low altitude & alpine plants	Pollination intensity treatments	Flower longevity increased in high altitude populations
11	Wang et al. (Ecology and Evolution, 4, 1913-	2014	Study relationship between	Taxonomic characterization and seed analyses	Seed characteristics were significantly correlated with altitude and plant height

	1923)		elevation, plant height & seeds		

1.2. Research question/s

- How do species richness and functional traits change with altitude
- What traits characterize the high and low altitude species
- What are the patterns of plant growth and duration

1.3. Objective/s of the study

- To establish LTEM sites along an altitudinal gradient in Western Himalaya
- To study floral diversity and composition along altitudinal gradient
- To study plant functional traits along this gradient
- To study physico-chemical properties of soil along altitudinal gradient

2. METHODOLOGIES, STARTEGY AND APPROACH

The study was conducted in Dhauladhar mountain range of Himachal Pradesh between co-ordinates 32°08'19.813" and 76°33'47.856" to 32°11'33.975"and 76°35'55.237”. Himalayan temperate forests comprising of oak and conifers dominate the area. Annual rainfall in the area is close to 2500mm. The area was chosen as it is relatively undisturbed, highly diverse, and has gradients from wet to arid regions. Further, the selected sites offered accessibility, repeatability, and the desired altitudinal gradient for conducting temporal studies.

An altitudinal transect from hill base (2000 m) to hill top (4000 m asl) was established. Permanent plots of 20 × 20 m dimensions were marked at every 100m rise in altitude (n=21, Fig 1). These plots were further divided into 5 × 5 m and 1 × 1 m sub-plots for shrubs and herbaceous layer documentation. Habitat and vegetation were noted in pre-designed datasheets. Composite soil samples(n=66) were collected for physico-chemical analyses, while plants were analysed for functional traits (Lessaard-Therrien et al. 2014). Data loggers have been installed at each site for automated temperature recording throughout the study duration. Data collected from the plots has been analysed in excel and statistically compared using “R” language (R Core team, 2017).

3. KEY FINDINGS AND RESULTS

A fundamental characteristic of mountain ecosystems is drastic change in vegetation along altitudinal gradients. How plant functional traits vary across this gradient and how species will respond to the changing climatic conditions is key research area of global significance. This calls for establishing long term ecological monitoring plots such that temporal patterns can be recorded for future comparisons. 20

field surveys were carried out during the reporting period and at every 100 m rise in altitude 21 permanent plots of dimension 20 × 20 m with automated temperature loggers were marked in Kangra district of Himachal Pradesh. Sampling was carried out and plant samples were collected for functional traits analyses (Fig 2,3). Soil samples were collected for physico-chemical analyses using standard methods and protocols.

The soils were acidic in nature with pH ranging between 4.36 to 5.506. Generally, with increasing altitude, soil pH decreased. Total potassium (%) ranged from 0.24 to 2.41, toal phosphorus (%) from 0.04 to 0.18, and total nitrogen (%) from 0.19 to 0.82 (Table 1.). Based on the preliminary results, though, the blossom area and leaf area varied amongst the studied species and sites (Table 2,3,4), no clear cut patterns were observed. (Figure 4 a,b).

Further, nested plots were established within each plot and automated temperature loggers were installed (Fig.5.). A total of 295 plant species were recorded from these marked plots. A hump shaped pattern of species richness was recorded (Fig.6.). Maximum plant species richness was found between 2600 to 3100 m altitude ranges. Of the total species, 53 commonly occurring plant species were identified and 10-20 individuals of each of these were collected for functional traits analyses (Table 5). Besides, physico-chemical analyses of collected soil samples were assayed using standard methods (Table 6, Fig.8.). Flowering duration of *Taraxacum officinale* was also recorded and analysed across altitude. In the species, seed traits were associated with flower traits, where flower area and flower mass were of prime importance (Fig.7.). The maximum flowering duration was found at 2000 m and minimum was noticed at 4000 m. Increased flower visibility seems to ensure pollination whereas larger seed size in populations of high-altitude species provides them a chance to survive in harsh environments. Thus, flower traits and variations in flowering duration along altitude appear to be advantageous for reproductive success of plants. With respect to temperature data from loggers, maximum temperature was recorded in plots marked at 2300 m (21°C) while minimum was found at 4000 m (-4°C). Analyses of soil nutrients revealed declining nutrient status along altitude.

Tree, shrub, and herb were quantified in respective plots. While total count was done for trees, 1 × 1m quadrats were used for herbs and 5 × 5m quadrats for shrubs. Soil samples have been collected from these sites.

A hump shaped distribution of species richness was revealed while functional trait of species (n=40) varied with altitude (Fig 9,10). Reproductive traits were positively co-related with altitude, except for specific flower area. Vegetative traits, except Specific leaf area (SLA), were negatively correlated with altitude (Fig11,12). All below ground traits were negatively correlated with altitude. The maximum negative association was found between root height and altitude. Flower duration decreased with increasing altitude.

4. OVERALL ACHIEVEMENTS

- Twenty-one permanent plots and Twenty-one LTEMs with automated loggers established.
- Vegetation and soil sample analysis were carried out.
- Plant Functional Traits of five species, Above and belowground traits for 40 species were recorded.
- Documented flowering phenology of 25 plant species and alpha and beta diversity across altitudinal gradient.
- The soils were found to be acidic in nature (pH ranging between 4.36 to 5.506). Total potassium (%) ranged from 0.24 to 2.41, toal phosphorus (%) from 0.04 to 0.18, and total nitrogen (%) from 0.19 to 0.82.
- High altitudinal range species were mostly unique compared with low altitudes ones.
- Species richness highest at mid altitude compared to low or high altitudes
- α-diversity pattern and nestedness related processes or turnover (β-diversity) causes dissimilarity in plant communities' composition along the vertical gradient.
- The observed β-diversity patterns revealed that the species replacement rate was less in the mid altitude communities as compared to lower and higher altitude communities. It was largely attributed to the ecotonic nature of mid-altitudes, which benefited mid-elevational communities rather than low or high-altitude communities.
- Analysed altitudinal distribution of alien species richness in the Himalayan state of Himachal Pradesh and tested the null hypothesis that- alien species richness in Himalaya is independent of altitude.
- Members of Asteraceae, Fabaceae, and Poaceae dominated the alien flora along the entire altitudinal gradient

Publications:

-Ahmad, M., Uniyal, S.K., & Singh, R.D. (2018). Patterns of alien plant species richness across gradients of altitude: analyses from the Himalayan state of Himachal Pradesh. *Tropical Ecology* 59(1): 35-43.

- Ahmad, M., Kashyap, R. & Uniyal, S.K. (2018). Pattern of Plant Functional Traits (PFTs) Variation between Two Populations of Morina longifolia Wall. at Western Himalaya. *Proceedings of Himalayan Researchers Consortium* Vol. 1(1).

- Ahmad, M., Uniyal, S. K., Batish, D. R., Singh, H. P., Jaryan, V., Rathee, S., ... & Kohli, R. K. (2020). Patterns of plant communities along vertical gradient in Dhauladhar Mountains in Lesser Himalayas in North-Western India. *Science of The Total Environment*, *716*, 136919.

- Ahmad, M., Uniyal, S. K., Batish, D. R., Rathee, S., Sharma, P., & Singh, H. P. (2021). Flower phenological events and duration pattern is influenced by temperature and elevation in Dhauladhar mountain range of Lesser Himalaya. *Ecological Indicators*, *129*, 107902

Poster Presentation

- Mr. Mustaqeem Ahmad won the best poster presentation award (2nd prize) during the National Conference titled “Climate change, Environmental Pollution and Biodiversity Conservation” held at National Botanical Research Institute, Lucknow during 24-25 February 2018 (Appendix 7)

5. IMPACTS OF FELLOWSHIP IN IHR

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

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

- Plots for repeat monitoring established.
- Current status of bioresources documented.
- Patterns of species distribution revealed.
- Traits based ecology to be focused upon.
- Phenological records and images

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

- Mid elevational forests (~2500 m asl) are species rich.
- High elevation forests (~3200 m asl) harbor more unique taxa.
- Areas with high habitat diversity important for high value medicinal plants.

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

- Temporal patterns of phenology
- Snow cover recordings
- Soil temperature patterns

5.5. Developing Mountain Infrastructures (max. 500 words, in bullet points)

- Automated camera set-up
- Plots for repeat observations

5.6. Strengthening Networking in IHR (max. 700 words, in bullet points)

- Fellowship and Himalayan Researchers consortium provided an opportunity to know and forge possible future linkages

6. EXIT STRATEGY AND SUSTAINABILITY

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

- Himalaya is known as a white spot, the primary data generated will form the basis for future comparisons.
- Temporal patterns will provide information on species turnover and changes

1.2. Efficient ways to replicate the outcomes of the fellowship in other parts of IHR (max. 1000 words)

- The methodological approach has been published in the journals of repute and is replicable in the Himalaya

1.3. Identify other important areas not covered under this study, but needs further attention (max. 1000 words)

- Cold deserts of the Himalaya

1.4. Major recommendations for sustaining the outcomes of the fellowship in future (500 words in bullets)

- Long term monitoring plots established during the study may form a part of the global monitoring programs.

7. REFERENCES/BIBLIOGRAPHY

Acharya, B.K., Sanders, N.J., Vijayan, L., & Chettri, B. (2011). Elevational gradients in bird diversity in the eastern Himalaya: an evaluation of distribution patterns and their underlying mechanisms. *PloS ONE*, doi: 10.1371/journal.pone.0029097.

Bhattarai, K.R., Vetaas, O.R., & Grytnes, J.A. (2004). Fern species richness along a central Himalayan elevational gradient, Nepal. *Journal of Biogeography*, 31, 389-400.

Cadotte, M.W., Cavender-Bares, J., Tilman, D., & Oakley, T.H. (2009). Using phylogenetic, functional and trait diversity to understand patterns of plant community productivity. *PloS ONE*, 5, 56-95.

Chawla, A., Rajkumar, S., Singh, K.N., Brij Lal, Singh, R.D., & Thukral A.K. (2008). Plant species diversity along an altitudinal gradient of Bhabha Valley in western Himalaya. *Journal of Mountain Science*, 5, 157-177.

Fabbro, T., & Körner, C. (2004). Altitudinal differences in flower and reproductive allocation. *Flora*, 199, 70-80.

Flynn, D.F.B., Mirotchnich, N., Jain, M., Palmer, M.I., & Naeem, S. (2011). Functional and phylogenetic diversity as predictors of biodiversity-ecosystem-function relationships. *Ecology*, 92, 1573-1581.

Harguindeguy, N.P., Garnier, E., Lavorel, S., Poorter, H., Jaureguiberry, P., Cornwell, W.K., & Cornelissen, J.H.C. (2013). New handbook for standardised measurement of plant functional traits worldwide. *Australian Journal of Botany*, 61, 167-234.

Körner, C. (2007). The use of 'altitude' in ecological research. *Trends in Ecology and Evolution*, 22, 569-574.

Körner, C., Neumayer M., Menendez-Riedl, S.P., & Smeets-Scheel, A. (1989). Functional morphology of mountain plants. *Flora*, 182, 353-383.

Lessard-Therrien, M., Bolmgren, K., & Davies, T.J. (2014). Predicting flowering phenology in a subarctic plant community. *Botany*, 92, 749-756.

Li, C.Y., Liu, S.R., & Berninger, F. (2004). *Picea* seedlings show apparent acclimation to drought with increasing altitude in the eastern Himalaya. *Trees-Structure Function*, 18, 277-283.

Lomolino, M.V. (2001). Elevation gradients of species–density: historical and prospective views. *Global Ecology and Biogeography*, 10, 3-13.

McCain, C.M., & Grytnes, J. (2010). Elevational Gradients in Species Richness. *Encyclopedia of Life Sciences.* John Wiley & Sons Ltd. doi:10.1002/9780470015902.a0022548.

R Core Team. (2017). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

Shrestha, M., Dyer, A.G., Bhattarai, P., & Burd, M. (2014). Flower colour and phylogeny along an altitudinal gradient in the Himalayas of Nepal. *Journal of Ecology*, 102, 126-135.

Trunschke, J., & Stöcklin, J. (2017). Plasticity of flower longevity in alpine plants is increased in populations from high elevation compared to low elevation populations. *Alpine Botany*, 127(1), 41-51.

Wang, Y., Wang, J., Lai, L., Jiang, L., Zhuang, P., Zhang, L., Zheng, Y., Baskin, J.M., & Baskin. C.C. (2014). Geographic variation in seed traits within and among forty-two species of *Rhododendron*

(Ericaceae) on the Tibetan plateau: relationships with altitude, habitat, plant height, and phylogeny. *Ecology and Evolution*, 4, 1913-1923.

Whittaker, R. (1978). Ordination of plant communities, 287-321. In: Whittaker, R. (Ed.) *Handbook of vegetation science*. No 5. Junk, The Hague, 2nd ed., pp. 737.

8. ACKNOWLEDGEMENTS

We thank the Ministry of Environment, Forests and Climate Change; Government of India for financial support and GBPNIHE Almora (Uttarakhand) via National Mission on Himalayan Studies, through project GAP-0199. We also thank CSIR-IHBT Palampur HP, and State Forest Department for their support.

Fellowship Report No.: **03 of 06: (H-JPF 002)**

Researchers Details

Type of Fellowship (HRA/HJRF/HJPF)	Name of Himalayan Researcher	Date of Joining	Date of Resignation**	Research Title	Name of the PI & Designation
H-JPF002	Alpy Sharma	27-05-2016	06-11-2018	Extent of IKP documentation and strengthened through scientific evidence base	Dr. Sanjay Kr. Uniyal Senior Principal Scientist
H-JPF 002	Aradhna Bharti	09-07- 2019	27-02-2020	Extent of IKP documentation and strengthened through scientific evidence base	Dr. Sanjay Kr. Uniyal Senior Principal Scientist

1. INTRODUCTION

Historically, the basic requirements of humans were fulfilled by forests (Pei, 2001). Many of the tribal communities residing in the interior areas still depend on them and have immense folk knowledge on the utilization of plants (Uniyal et al. 2006). Exploring this knowledge that has evolved through ages becomes important for bio-prospecting. Unfortunately, folk knowledge is fast eroding (Pardo-de-Santayana and Macia, 2015; Kodirekkala, 2017). It is feared that loss of this knowledge will have far reaching implications on lead identification (Reyes-Garcia et al. 2007). Therefore, documentation and preservation of folk knowledge becomes important (Pardo-de-Santayana and Macia, 2015). Communities residing in interior areas such as the Himalaya are more dependent and knowledgeable in context of natural resource use (Samant and Dhar, 2013; Uniyal et al. 2011). Rich biodiversity and high tribal populations has resulted in unique assemblage of folk knowledge in the Himalaya (Thakur et al. 2016). Rapid transformations across the globe, to which Himalaya is no exception, has resulted in vanishing of folk knowledge (Uniyal et al. 2003; Reyes- Garcia, 2007). At the same time, cross-cultural comparisons of folk knowledge among different communities of Himalaya has also been emphasized (Mustafa et al. 2015). Thus, the present study has been initiated to plug in this gap.

1.1. Literature review

John William Harshberger coined the term ethnobotany (Harshberger, 1896) and Richard Evans Schultes brought about a revolution in studies with a shift from compilation of raw data to a greater methodological approach. Martin (1995); Pei (2001); Pieroni (2004) provided quantitative concepts in folk knowledge documentation. In India, folk knowledge and resource use documentation was started by Janaki Ammal (Janaki Ammal, 1956). Later, Jain (1963), father of Indian Ethnobotany, worked and devised methodology for documenting resource use. Pushpangadan et al. (1988) and Rao et al. (1989) worked extensively on the subject in India. Key workers in the Himalaya include Sundriyal et al. (1998); Sood et al. (2001); Negi and Chauhan (2009); Uniyal et al. (2011); Samant and Dhar (2013); Chauhan et al. (2016). Recent studies on folk knowledge focus on statistical applications and modelling (Reyes- Garcia, 2005; 2007; Kodirekkala, 2017).

Background studies for designing the present work are presented below:

S. No	Reference	Year	Major objective	Methodology adopted	Findings
1	Chaudhary and Bawa (Biology	2011	Perception of the local people towards	Study area: West Bengal. Villages categorized based	People perceived climate change and its impact. People at high altitude are more

2	Kodirekkala (Journal of Anthropolog	2017	Factors affecting traditional	Study area- Andhra Pradesh. Anthropological	Socioeconomic and environmental conditions govern use of resources.
3	Mustafa et al. (Journal of Ethnobiolog	2015	Documentation of traditional knowledge on local plants	Study area- Ksovo. Snowball sampling method, structured questionnaire	Overall 114 species were used for medicinal purposes, 29 for food and 20 in handicraft activities. Albanian and Turkish
4	Pandey et al. (Ecological	2018	Traditional knowledge and strategies to	Study area– Uttarakhand. Random household	Respondents perceive impacts of climate change. They have developed strategies to cope
5	Pardo- De-Santayana and Macia	2015	Study of traditional knowledge	Study area- Balkans. Selection of ethnic groups, information	Major variations in use of plant species amongst communities. Quantitative techniques may
6	Pushpangadan et al. (Ancient	1988	Folk knowledge of Kani tribe	Study area –Kerala. Interactions, plant collections, ayurvedic	*Trichopus zeylanicus* is a health food for getting instant stamina and is comparable to
7	Reyes-Garcia et al. (Human	2007	Study the effect of market economy on	Study area- Bolivian Amazon. Village and households selection,	Local knowledge would be lost if people shift away from the economic activities related to
8	Soares et al. (Economic	2017	Study of species knowledge	Study area- Brazil. Random household selection, questionnaire	Elder know and use more species. Men know more species than
9	Uniyal et al. (Environmentalist, 23, 307-312)	2003	Study of developmental activities, changing	Study area – Uttrakhand. Direct observation, structured interview	Developmental processes increases the availability of market products and modernization results in
10	Uniyal et al. (Journal of Ethnobiology and	2006	Documentation of traditional medicinal plants	Study area-Chhota Bhangal. Household selection, questionnaire recording	New medicinal uses of *Ranunculus hirtellus* and *Anemone rupicola*.
11	Uniyal et al. (Human Ecology, 39-	2011	To study the folk medicines practices	Study area- Kangra. Identification of key informants,	Unique treatment for curing the joint paints and gout was documented. Young generation

1.2. Research question/s

- Do tribal communities residing in different areas use same/similar plant resources
- How tribal people perceive and interpret climate change

- How developmental activities affect traditional knowledge

1.3. Objective/s of the study

- To document the folk knowledge of tribal communities residing in the interior areas of H.P.
- To compare spatio-temporal variations in folk knowledge
- To document people perception of climate change

2. METHODOLOGIES, STARTEGY AND APPROACH

Tribal dominated high altitude regions of Himachal Pradesh form the study area. *Bhangalis*, *Kinners*, and *Lahulas* residing in Lahaul, Kinnaur and Chhota Bhangal, respectively were selected so as to ensure spatial representation of HP. Further, these tribes are primarily dependent on natural resources and therefore possess folk knowledge generated over time. Recent developmental activities in these areas is limiting their folk knowledge. This, therefore, needs to be documented and preserved.

Based on literature search and reconnaissance surveys, tribal communities and study sites were identified for in-depth documentation and collection of primary information. Structured and open ended questionnaires were used to document socio-economic information (Martin, 1995; Uniyal et al. 2011). For detailed folk knowledge and resource use documentation, questionnaires, focus group discussions, Participatory Rural Appraisal and scan observations at household level were carried out (Martin, 1995). Perceptions of the tribal communities towards changing climatic conditions were documented following Chaudhary and Bawa (2011) and Pandey et al. (2018).

3. KEY FINDINGS AND RESULTS

Recognizing the importance of folk knowledge of tribal communities and the impacts of market forces on it, the present study was carried out. Based on literature review, tribal communities namely *Bhangalis* (Kangra), *Lahulas* (Lahaul & Spiti), *Gaddis* (Chamba) and *Kinners* (Kinnaur) were identified for folk knowledge documentation. Intensive field surveys were conducted, where structured questionnaires were developed, field tested, and finalized. Later, climate change perception and adaptation strategies of the *Bhangalis* residing in Tarmehr, Polling, Bhujling, Judhar, Andarli malahn, Napotha, Swad, villages of Chhota Bhangal were documented using PRA, questionnaires, and focused group interactions (Fig.1). After complete socio-economic profile documentation, 184 respondents were selected for detailed documentation (Fig.2). Though, only 70.11% of the people were aware of the term climate change, they reported trends of increasing temperature, shortfall in winter rains, delayed onset of monsoon, erratic rainfall patterns, decreasing and late snowfall, increase in dry period, loss of soil moisture, and decreasing water level in streams. Majority of the people perceived and reported trends of decreasing snowfall (97.28%) and declining monsoon rainfall (95.65%). Increasing temperature was the other characteristics that was reported by ~86% of the respondents (Table.1). Interestingly, some of the respondents (18%) reported increased incidences of crop disease as a result of changing climate. All these are affecting their crop productivity and lifestyle. As a result, some adaptive strategies are being followed (Table.2). These include changes in crops and varieties, increased used of fertilizers and pesticides, and irrigation through pipelines. People, are now more dependent on market forces and a few of them now work as daily wagers to earn hard cash.

Tribal communities residing in the interior areas are highly dependent on natural resources and hence possess practical knowledge on utilization of plants. However, due to the developmental activities and market influence, the knowledge is fast declining. Recognizing the importance of folk knowledge of tribal communities, the impacts of developmental activities and market influence, the present study was carried out. During the reporting period, five field surveys were conducted and information on plant derived products used by the *Bhangalis* (Table 3), their use and species used for making these products were recorded (Fig.3). We found use of 55 plant derived products that fall under five major categories namely tools, storage structures, construction use, artefacts & handicrafts, and miscellaneous. Of these, 34 were used as tool for carrying out specific activities. Six were used as storage structures for storing grains and household items. Six products were found to be used for building structures (construction) while seven products were used for preparing handicrafts (artefacts). The remaining 2 products fall under the miscellaneous category. A total of twenty plant species were used for making these products (Table 4). *Picea smithiana, Cedrus deodara,* and *Quercus semecarpifolia* were the most commonly used species. It was further revealed that while the *Bhangalis* are rich in folk knowledge, this knowledge is declining fast due to the upcoming of market forces (Fig.4)

Rapid decline of folk knowledge is a serious issue that has multiple ramifications. Documentation of folk knowledge is not only important for lead identification but also for fulfilling India's commitment to the Convention on Biological Diversity.

The main focus was on the communities residing in Lahaul & Spiti, Kinnaur, Kangra, and Bharmour. A total of 18 villages were surveyed and door-to-surveys were conducted (Table 5,6). Prevalence of 22 taboos that were mainly related to forest, water, farmland, and food resources was also recorded in the area. Of these, maximum belonged to the segment and method category (32% each) while the minimum (5%) were species- specific taboos. Adherence to taboos is high and breaking it is believed to bring wrath of the God. They are important for resource management (Table7, Fig.8).

4. OVERALL ACHIEVEMENTS

- IKP of local communities documented
- Knowledge on medicinal, wild edible plants, fuel, fodder, digitized.

- Species with high use value and fidelity level prioritized
- Local indicators of changing climatic conditions recorded.
- Indigenous technologies recorded.
- Taboos classified and analysed.

Publications:

Sharma, A., & Uniyal, S.K. (2018). Weaving warmth: From sheep to shawl. *Science reporter* 55(4): 30-32.

Sharma, A., & Uniyal, S.K. (2019). Mulling over mills: The Gharat. *Dream* 2047 21(5): 31-32.

Sharma, A., Thakur, D., & Uniyal, S. K. (2019). Plant-derived utility products: knowledge comparison across gender, age and education from a tribal landscape of western Himalaya. *Journal of ethnobiology and ethnomedicine*, *15*(1), 1-14.

Sharma, A., Thakur, D., & Uniyal, S. K. (2021). Taboos: Traditional beliefs and customs for resource management in the western Himalaya. *Indian Journal of Traditional Knowledge (IJTK)*, *20*(2), 575-581.

Sharma, A., Batish, D. R., & Uniyal, S. K. (2020). Documentation and validation of climate change perception of an ethnic community of the western Himalaya. *Environmental Monitoring and Assessment*, *192*(8), 1-22.

Uniyal, S.K., 2021. Prioritizing Traditional Knowledge for Managing Bio-cultural Landscapes. IRALE.

Sharma, A., Parkash, O., & Uniyal, S. K. (2022). Moving away from transhumance: The case of Gaddis. *Trees, Forests and People*, *7*, 100193.

Sharma, A., Uniyal, S. K., Batish, D. R., & Singh, H. P. (2022). Utilization of fuelwood species by the Bhangalis community of western Himalaya, India. *Environment, Development and Sustainability*, 1-23.

5. IMPACTS OF FELLOWSHIP IN IHR

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

- Tribal communities residing in the interior areas are highly dependent on natural resources and hence possess practical knowledge on utilization of plants.
- Rich biodiversity and high tribal populations have resulted in unique assemblage of folk knowledge in the Himalaya

- Documentation of various resource use patterns with reference to, fodder, and edible plants and medicines and utilization of fuelwood species by local inhabitants reveals the dependence of the locals on nature

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

- Biodiversity conservation and management is interwoven with traditional beliefs and customs.
- Traditional beliefs and customs for resource management has been documented by interacting with the resident communities of the Himalayan region.
- Taboos symbolize key cultural values with a high level of adherence that have deep rooted social ethics. Taboos have a story associated with them. They exist in all traditional cultures and have global prevalence. Being self-imposed, locals strictly adhered to it.

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

- Different taboos cater to different themes that ultimately help manage resources such as Temporal taboos that ban access to resources during certain time period, and species-specific taboos ban the killing and use of specific species in time and space
- Worshipping *Cedrus deodara*, commonly known as deodar (tree of Gods) and maintenance of traditional conservation practices reflect their views towards conservation and sustainable use of resources

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

- Climate change perception of the local communities documented. Local indicators of changing climatic conditions identified.
- Only 70.11% of the people were aware of the term climate change, they reported trends of increasing temperature, shortfall in winter rains, delayed onset of monsoon, erratic rainfall patterns, decreasing and late snowfall, increase in dry period, loss of soil moisture, and decreasing water level in streams

5.5. Developing Mountain Infrastructures (max. 500 words, in bullet points)

- Local trust with local communities

5.6. Strengthening Networking in IHR (max. 700 words, in bullet points)

- Fellowship and Himalayan Researchers consortium provided an opportunity to know and forge possible future linkages

6. EXIT STRATEGY AND SUSTAINABILITY

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

- Multiple utility resources and their importance in the livelihood

6.2 . Efficient ways to replicate the outcomes of the fellowship in other parts of IHR (max. 1000 words)

- Building trust with the communities
- Field validation of information

6.3 . Identify other important areas not covered under this study, but needs further attention (max. 1000 words)

- Areas such as Dodra, Kwar (Rohru)

6.4 . Major recommendations for sustaining the outcomes of the fellowship in future (500 words in bullets)

- Local knowledge of the communities should be factored in policy framing

7. REFERENCES/BIBLIOGRAPHY

Chaudhary, P., & Bawa, K.S. (2011). Local perceptions of climate change validated by scientific evidence in the Himalayas. *Biology* Letters, 7, 767- 770.

Chauhan, P.P., Nigam, A., & Santavan, K.V. (2016). Ethnobotanical study of wild fruits in Pabbar valley, district Shimla, Himachal Pradesh. *Journal of medicinal plant studies*, 4, 216-220.Harshberger, J.W. (1896). The purposes of ethno-botany. *Botanical Gazette*, 21, 146- 154.

Jain, S.K. (1963). The origin and utility of some vernacular plant names. Proc. *National Acad. Sci. India, Section B*, 33, 525- 530.

Janaki Ammal, E.K. (1956). Introduction to the subsistence economy of India. In: Man's role in changing face of the earth (Ed. William LT Jr) University of Chicago Press, Chicago, 324 – 335.

Kodirekkala, K.R. (2017). Internal and external factors affecting loss of traditional knowledge: Evidences from a horticultural society in South India. *Journal of Anthropological* Research, DOI: 10.1086/690524.

Martin, G. J. (1995). Ethnobotany: A methods manual. WWF International, UNESCO, Royal Botanic Gardens Kew, Chapman and Hall, London.

Mustafa, B., Hajdari, A., Pieroni, A., Pulaj, B., Koro, X., & Quave, C. L. (2015). A cross-cultural comparison of folk plant uses among Albanians, Bosniaks, Gorani and Turks living in south Kosovo. *Journal of ethnobiology and ethnomedicine*, 11(1), 39.

Negi, V.M., & Chauhan, N.S. (2009). Medicinal and aromatic plant wealth of tribal district Kinnaur in Himachal Himalaya. *Indian Forester*, 135, 838- 852.

Pandey, R., Kumar, P., Archie, K. M., Gupta, A. K., Joshi, P. K., Valente, D., & Petrosillo, I. (2018). Climate change adaptation in the western-Himalayas: Household level perspectives on impacts and barriers. *Ecological Indicators*, 84, 27-37.

Pardo-de-Santayana, M., & Marcia, M.J. (2015). The benefits of traditional knowledge. *Nature*, 518, 487-488.

Pei, S.J. (2001). Ethnobotanical approaches of the traditional medicines study: Some experiences from Asia. *Pharma.* Bio., 39, 74- 79.

Pieroni, A., Quave, C. L., & Santoro, R. F. (2004). Folk pharmaceutical knowledge in the territory of the Dolomiti Lucane, inland southern Italy. *Journal of Ethnopharmacology*, 95 (2-3), 373-384.

Pushpagandan, P., Rajasekharan, S., Ratheshkumar, P.K., Jawahar, C.R., Veleyudhan Nair V., Lakshmi, N., & Sarada Amma, L. (1988). Arogyappacha (*Trichopus zeylanicus* Gaerin), The 'Ginseng' of Kani tribes of Agashyar Hills (Kerala) for ever green health and vitality. *Anc. Sci. Life,* 8, 13-16.

Rao, R.R., Neogi, B., & Prasad, M.N.V. (1989). Ethnobotany of some weeds of some Khasi and Garo hills of Meghalaya and north- east India. *Economic Botany*, 43, 471.

Reyes-García, V., Vadez, V., Huanca, T., Leonard, W., & Wilkie, D. (2005). Knowledge and consumption of wild plants: a comparative study in two Tsimane villages in the Bolivian Amazon. *Ethnobotany Research and Application*, 3, 201- 207.

Reyes-Garcia, V., Vadez, V., Huanca, T., Leonard, W.R., & McDade, T. (2007). Economic development and local ecological knowledge: A Deadlock? Quantitative research from a native Amazonian Society. *Human Ecology*, 35, 371-377.

Samant, S.S., & Dhar, U. (2013). Diversity, endemism and economic potential of wild edible plants of Indian Himalaya. *International journal of sustainable development and world ecology*, 4, 179-181.

Soares, D. T. N., Sfair, J. C., Reyes-García, V., & Baldauf, C. (2017). Plant Knowledge and current uses of woody flora in three cultural groups of the Brazilian semiarid region: Does culture matter? *Economic Botany*, 1-16.

Sood, S.K., Nath, R., & Kalia, D.C. (2001). Ethnobotany of cold desert tribes of Lahaul- Spiti (North West Himalaya). India. Deep Publications. New Delhi, India. Sundriyal, M., Sundriyal, R.C., Sharma, E., & Purohit, A.N. (1998). Wild edibles and other useful plants from the Sikkim Himalaya. *Oecologia Montana*, 7, 43- 54.

Thakur, M., Asrani, R.K., Thakur, S., Sharma, P.K., Patil, R.D., Brij Lal., & Om Prakash. (2016). Observations on traditional usage of ethnomedicinal plants in humans and animals of Kangra and

Chamba districts of Himachal Pradesh in North-Western Himalaya India. *Journal of* Ethnopharmacology, 191, 280- 300.

Uniyal, S. K., Singh, K. N., Jamwal, P., & Lal, B. (2006). Traditional use of medicinal plants among the tribal communities of Chhota Bhangal, Western Himalaya. *Journal of ethnobiology and ethnomedicine*, 2(1), 14.

Uniyal, S.K., Awasthi, A., & Rawat, G.S. (2003). Developmental processes, changing lifestyle and traditional wisdom: Analyses from western Himalaya. *Environmentalist*, 23, 307-312.

Uniyal, S.K., Sharma, V., & Jamwal, P. (2011). Folk medicinal practices in Kangra district of Himachal Pradesh, western Himalaya. *Human Ecology*, 39, 479- 488.

8. ACKNOWLEDGEMENTS

We thank the Ministry of Environment, Forests and Climate Change; Government of India for financial support and GBPNIHE Almora (Uttarakhand) via National Mission on Himalayan Studies, through project GAP-0199. We also thank CSIR-IHBT Palampur HP, and State Forest Department for their support.

Fellowship Report No.: **04 of 06 (n = H-JRF 003)**

Researchers Details

Type of Fellowship (HRA/HJRF/HJPF)	Name of Himalayan Researcher	Date of Joining	Date of Resignation**	Research Title	Name of the PI & Designation
H-JRF 003	Rohit	27-05-2016	01-06-2018	Status of alien	Dr. Sanjay Kr.

				species	Uniyal Senior Principal Scientist
H-JRF 003	Ankush Dehlia	06-08-2018	29-03-2019	Status of alien species	Dr. Sanjay Kr. Uniyal Senior Principal Scientist
H-JPF 003	Deepak Verma	08- 07-2019	31-03-2020	Status of alien species	Dr. Sanjay Kr. Uniyal Senior Principal Scientist

1. INTRODUCTION

Climate change and plant invasion are two major threats to biodiversity (Walther et al. 2009). Impacts of both of these are argued to be more pronounced in the mountain timberline ecosystems (Walther, 2009; Korner, 2012). Timberline is a vegetation ecotone that separates closed canopy forests from the herbaceous alpine meadows (Holtmeier, 2009) and plays an important role in sustaining the socio-economic of migratory indigenous people (Holtmeier, 2009). Timberlines are widely viewed as early indicators of climatic change (Holtmeier, 2009; Korner, 2003) and shifts in species distribution have been studied in this ecotone, worldwide (Grabherr et al. 2010; Pauli et al. 2012; Walther, 2009). Up-hill movement of low land plants, including alien species, has also been reported from the Himalaya (Rawat, 2010). Introduction of alien species (Khuroo et al. 2007; Lambdon et al. 2008) poses threat to native flora by altering the structure and function of ecosystems. Timberline ecotones being fragile are particularly vulnerable to this (Korner, 2012). Monitoring their status is therefore desired. Phenology is an important tool for monitoring plant responses (Julitta et al. 2014; Fitter and Fitter, 2002; Nijland et al. 2014). Phenological events such as bud initiation, leafing, flowering and fruiting are climate driven and highly sensitive to it (Jaryan et al. 2014) and globally studied (Walther et al. 2009; Nijland et al. 2014). To avoid individual observer biases, automated digital cameras have been recommended to record such events (Jaryan et al. 2014; Crimmins and Crimmins, 2008). The present study, therefore, targets timberline phytosociology, alien species composition, and documentation of phenology.

1.1. Literature review

Many studies have noted an increase in the richness of alien species (non-native species that have been intentionally or accidentally introduced outside their range) in mountains (Dietz *et al.* 2006; McDougall *et al.* 2011; Marini *et al.* 2013; Lembrechts *et al.* 2014). Few studies have prepared checklist of alien floras

(Nagar *et al.* 2004; Negi & Hajra 2007; Sekar 2012; Reddy *et al.* 2008; Bhatt *et al.* 2012), analysed their floristics, nativity, and categorized them into various alien categories(Khuroo *et al.* 2007; Khuroo *et al.* 2009; Jaryan *et al.* 2013).Patterns of alien species distribution along roadsides have also been attempted (Sharma and Raghubanshi 2009; Pickering and Hill 2007; Kosaka *et al.* 2010)while others have discussed the distribution of woody alien species across altitude (Haider *et al.* 2011; Khuroo *et al.* 2011). McDoughall *et al.* (2011) has compared alien species composition in different mountain ranges whereas a comparative account of native and invasive species distribution in Nepal Himalaya has been presented by Bhattarai *et al.* (2014).

At the same time, owing to changing climatic conditions, timberline characteristics have been the focus of recent studies (Holtmeier, 2009), and theories and concept for the same have been proposed (Korner, 2012; Holtmeier, 2009). Various reasons for their existence and formation are hypothesized (Korner, 2003), and their preliminary status has also been presented from the Himalaya (Sundriyal and Bisht, 1988; Rawal et al. 1991; Bharti et al. 2012). Phenological monitoring of vegetation has also been carried out across the globe (Julitta et al. 2014; Nijland et al. 2014). Literature perused revealed that use of cameras and indices for recording phenology is an upcoming area of research (Jaryan et al. 2014; Nijland et al. 2014). At the same time, national and regional checklists of alien species have also started to come up (Preston et al. 2002; Weber et al. 2008). In India, work on invasive alien species started in the latter part of 20th century. Various workers like Jaryan et al. (2013); Khuroo et al. (2007); Sekar et al. (2012) have documented and categorised the alien flora of the country including that of the Himalaya.

Background studies for designing the present work are presented below:

S. No	**Reference**	**Year**	**Major objective**	**Methodology adopted**	**Findings**
1	Crimmins and Crimmins (Env. Man. ,41(6), 949-958	2008	Test the efficiency of repeat photography for monitoring phenology	Nikon D70 DSLR camera was used for photography	Photographs provide reliable & consistent measurements of phenophases
2	Holtmeier (Spring Sci.)	2009	Mountain timberline ecology and dynamics	Field data for ecology and dynamics of timberlines	Anthropogenic factors influence timberline
3	Hejda et al. (Journal of Ecology,	2009	Impact of invasive species on plant	Experimental plot were setup and cover percentage was	Species diversity and richness reduced in

	97 (3), 393-403		communities	recorded	invaded plots
4	Jaryan et al. (Env. Mon. Ass., 185(7), 6129-6153.	2013	Alien flora categorization & documentation in HP	Primary surveys and secondary information	A total of 497 species were enumerated from the state
5	Jaryan et al. (Env. Mon. Ass., 186 (7), 4423-4429.)	2014	Preparation of phenological calendar of Sapium *sebiferum*	Temporal photograph recording throughout the year	Phenophase documentation is important in invasion ecology
6	Khuroo et al. (Biol. Inv.,9(3),269-292)	2007	Studied the alien flora of Kashmir Himalaya	Plant species records were analysed	A total 571 alien species occur in Kashmir Himalaya
7	Korner (Springer Sci.)	2012	Studied the treeline ecology	Field surveys and sampling	Treelines are sensitive to climate change
8	Kuhn et al. (Biol. Inv., 19(12), 3505-3513.)	2017	Study the effect of urbanisation on alien species distribution	Floral data was obtained from FlorKart and BiolFlor databases	Neophyte richness vary along urbanisation gradient and environmental variables
9	Nijland et al. (Agri. & Fore. Met.,184,98-106)	2014	Phenology assessment using infrared sensitive digital camera	IR and RGB camera were installed for phenological documentation.	Digital cameras are promising tool for capturing plant phenology
10	Petr Pysek (Oikos, 282-294)	1998	Taxonomic pattern in plant invasion	Secondary data of 26 regions was recorded	164 families globally contribute to alien species
11	Richardson et al. (Div. & Dist., 6(2),93-107)	2000	Naturalization & invasion concept	Use of published data	Term invasive should be used without inference to economic or environmental impact

12	Sekar et al. PNAS-India, 82(3),375-383)	2012	Documentation of alien flora of Uttrakhand	Surveys and sample collection	A total of 163 alien species were recorded
13	Simberloff et al. (Trd. Eco. & Evol, 28 (1),58-66.)	2013	Discussed invasion impacts & challenges in invasion ecology	Published database & past record analyses	Need to focus on awareness programmes
14	Uniyal et al. (Nat. Acd. Sci. Let., 40(2), 135-139.)	2017	Digital documentation of plant phenology	RGB analyses through photographs	Digital documentation provides ideal tool for phenology documentation

1.2. Research question/s

- Do native and alien species richness differ along gradient of altitude
- Do vegetation characteristics of timberline vary along an east-west gradient in HP
- How are phenological patterns related to ambient environmental conditions in timberline

1.3. Objective/s of the study

- To categorise alien species occurring in the timberline
- To document community composition of timberlines in HP
- To document phenological patterns of timberline communities

2. METHODOLOGIES, STARTEGY AND APPROACH

Timberline sites in Pangi, Kullu, and Shimla districts have been identified and marked for the study. The sites have been chosen as they present an east west span and also a human use gradient occurs along these sites. Timberlines in Pangi are least disturbed while those in Kullu are highly disturbed. The co-ordinates of the timberline sites are given in table 1.

Consequent to field surveys, three timberline sites have been identified. The site at Pangi has been permanently marked (100 x 100m, plot) with total tree count records. Representative nested quadrat sampling has been carried out at the other sites (Mueller-Dombois and Ellenberg, 1974). For shrubs, 5 x 5 m quadrats were used while for herbaceous layer documentation quadrats of 1x1 m were laid. A total of 10 quadrats each were laid for trees and shrubs while 20 quadrats were laid for herb species documentation. Species presence and absence was noted, and girth and height of trees was recorded

(Shrestha et al. 2015). Invasive alien species were categorized using published literature (Khuroo et al. 2007; Jaryan et al. 1013). For phenological documentation an automated camera has been installed in the *Betula* timberline forest along with automated temperature logger. Soil samples from this site have been collected for physico-chemical analyses (Muller et al. 2017).

3. KEY FINDINGS AND RESULTS

Tree lines in the Himalaya represent the uppermost elevational limit of upright tree growth (3-5 m height). After this, the Krumholtz and alpine vegetation dominate the landscape. Tree lines are ecologically sensitive and key to climate change studies. Expansion of alien species into this ecotone is now a serious problem. Consequently, the present study was initiated to document the vegetation characteristics of Himalayan treelines, categorize alien species occurring in the treeline, and document phenological patterns of tree line communities. During the reporting period, four field surveys were conducted to the tree line areas (Dhauladhar, Chansal, Rohtang, and Pangi) in Himachal Pradesh (Table 2.). Vegetation sampling, revealed dominance of *Quercus semecarpifolia* and *Betula utilis* in the tree line areas. Herbaceous formations dominated the ground flora with *Rhododendron campanulatum* dominating the krumholtz vegetation. *Taraxaxum officinale*-a native of Europe reported high frequency of distribution. *Verbascum thapsus*-another alien species of south American origin was found to occur in the open area along border of tree lines. *Poa annua*, an European element was the most common alien grass. Repeat observations and categorization of these will be carried out. In a one of its kind initiative, an automated time lapse camera (Harbortronic DigiSnap 2000 series) has been installed in Pangi for documenting phenological patterns in Betula forest (Fig.1). The forest lies at 33°04’57.401” N and 76°27’42.817” E at an altitude of 3100 m asl. The camera has been programmed for taking photographs at an interval of every two hours. A data logger for automated temperature recording at a resolution on one hour has also been set up (Fig.2). Tree lines being open only for six months in a year, all effort during the reporting period were put in identifying sites across HP, marking the sites, and setting up of automated monitoring facility.

Treelines are climatically sensitive indicators of environmental change and thus of global importance. Alongside, invasion by alien species in these sensitive areas can cause serious threat to native flora (Table 4, Fig.3.). Thus, the present study focused on vegetation characteristics of Himalayan treelines. During the reporting period, different phenophases of Betula utilis were photo documented and categorization of alien species was carried out (Fig.5). Betula utilis dominated the treelines in Pangi valley with a density of 490 individuals/ha. Thirty-four herb species were recorded in the sampling plots with Anaphalis triplinervis, Astragalus spp., Cortusa spp., Gentiana argentea, Pedicularis spp., Picrorhiza kurroa, Polygonum effine, being the common ones. Highest species density was reported by Cortusa (6.6/m2) and Picrorhiza kurrooa (4.9/m2). Alien species namely *Achillea milifolium*, Polygonum aviculare, Rumex nepalensis, Rumex hastatus, Taraxacum officinale and Thymus linearis were noted occurring in the treeline ecotone (Table 3). Overall, species composition varied sharply across the ecotone. Betula forest phenophase documentation revealed that leafing in the species starts in May while leaf fall starts during the month of October. Phenological monitoring through cameras was found to be a reliable approach for documenting the forest canopy patterns. Temperature retrieved from data loggers revealed that mean soil temperature varied from 19.21°C during the growing season to -2.82°C during the winter season (Fig.5).

Being sensitive to global changes, treeline are amongst the best indicators of the same. At the same time up-hill migration and proliferation of alien species in this sensitive zone is a major conservation issue. Field surveys were carried out to Holi pass (Kangra), Rohtang pass (Kullu), Pangi valley (Chamba), Chhitkul (Kinnaur), Chanshal pass (Shimla) (Fig.8,9,10). The species richness in Pangi treeline sampling plots ranged from 5 to 18 while the diversity ranged from 0.70 to 2.63. The highest diversity (H′) was observed in the sampling plots above the treeline while the lowest was recorded in the downslope plots under the tree canopy. Overall, diversity increased from the forest canopy to open landscape. On the other hand, evenness (E) values ranged between 0.44-0.95. Highest evenness was also recorded in the plot located in open areas. The height and girth of the individuals decreased with altitude and along the treeline ecotone. Along the treeline ecotone, demographic traits like height and girth are highly governed by the altitude of the landscape and severity of climate. Further, spatial pattern analysis revealed a large number of young individuals above the treeline. It indicates recruitment of tree saplings during the recent times (Fig.7). The presence of saplings above the treeline also indicates reproductive potential of birch tree. The seeds of Betula utilis are light and mostly wind dispersed. Tree individuals were found to form clusters and the young individuals were found to be distributed in the vicinity of larger trees.

Phenophase documentation through photographs continued during this period also. RGB channel information was analysed and the same were useful in the interpretation of phenophases.

4. OVERALL ACHIEVEMENTS

- Categorization of alien species
- Facility for automated temporal phenological documentation set up at a timberline site
- Field surveys carried out at Holi pass (Kangra), Rohtang pass (Kullu), Pangi valley (Chamba), Chhitkul (Kinnaur), Chanshal pass (Shimla).
- Vegetation and soil characteristics of the timberline sites recorded.
- Annual cycle of phenological documentation of Betula utilis completed.
- Biennial data on phenophases of Betula utilis photo-recorded.
- Temporal recording of soil temperature for a complete year

Publications:

-Sharma R and Uniyal SK (2018). Vegetation Patterns of Treeline Ecotone in the Pangi Valley, Western Himalaya. Proceedings of Himalayan Researchers Consortium Vol. 1(1).

- Sharma, R., Kaur, S., & Uniyal, S. K. (2021). Tracking the seasonal dynamics of Himalayan birch using a time-lapse camera. *Folia Geobotanica*, *56*(2), 125-138.

- Sharma, R., Kaur, S., & Uniyal, S. K. (2022). Population and vulnerability assessment of high value medicinal plants in the Alpine regions of western Himalaya. *Journal of Applied Research on Medicinal and Aromatic Plants*, *26*, 100353

5. IMPACTS OF FELLOWSHIP IN IHR

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

- Trained manpower

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

- Lower altitudes hold more alien species.

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

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

- Baseline information on alien invasive species generated that are a major threat to ecology and environment.

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)

- Controlling alien species al lower altitudes, their spread leads to degradation of resources

6.2. Efficient ways to replicate the outcomes of the fellowship in other parts of IHR (max. 1000 words)

- Dissemination and popularization

6.3. Identify other important areas not covered under this study, but needs further attention (max. 1000 words)

- Wetlands and mesic areas

6.4. Major recommendations for sustaining the outcomes of the fellowship in future (500 words in bullets)

- Continued monitoring and sampling

7. REFERENCES/BIBLIOGRAPHY

Crimmins, M. A., & Crimmins, T. M. (2008). Monitoring plant phenology using digital repeat photography. Environmental Management, 41(6), 949-958.

Ellenberg, D., & Mueller-Dombois, D. (1974). Aims & methods of vegetation ecology. NY, Wiley.

Grabherr, G., Gottfried, M., & Pauli, H. (2010). Climate change impacts in alpine environments. Geography Compass, 4(8), 1133-1153.

Hejda, M., Pyšek, P., & Jarošík, V. (2009). Impact of invasive plants on the species richness, diversity and composition of invaded communities. Journal of Ecology, 97(3), 393-403.

Holtmeier, F. K. (2009). Mountain timberlines: ecology, patchiness, and dynamics (Vol. 36). Springer Science & Business Media.

Jaryan, V., Uniyal, S. K., Gupta, R. C., & Singh, R. D. (2013). Alien Flora of Indian Himalayan State of Himachal Pradesh. Environ. Monit. Assess., 185 (7): 6129-6153.

Jaryan, V., Uniyal, S. K., Gupta, R. C., & Singh, R. D. (2014). Phenological documentation of an invasive species, Sapium sebiferum (L.) Roxb. Environ. Monit. Assess., 186(7), 4423-4429.

Julitta, T., Cremonese, E., Migliavacca, M., Colombo, R., Galvagno, M., Siniscalco, C., & Menzel, A. (2014). Using digital camera images to analyse snowmelt and phenology of a subalpine grassland. Agricultural and Forest meteorology, 198, 116-125.

Khuroo, A. A., Rashid, I., Reshi, Z., Dar, G. H., & Wafai, B. A. (2007). The alien flora of Kashmir Himalaya. Biological Invasions, 9(3), 269-292.

Körner, C. (2003). Alpine plant life: functional plant ecology of high mountain ecosystems. Springer Science & Business Media.

Körner, C. (2012). Alpine treelines: functional ecology of the global high elevation tree limits. Springer Science & Business Media.

Kühn, I., Wolf, J., & Schneider, A. (2017). Is there an urban effect in alien plant invasions? Biological Invasions, 19(12), 3505-3513.

Lambdon, P. W., Pyšek, P., Basnou, C., Hejda, M., Arianoutsou, M., Essl, F., ...& Andriopoulos, P. (2008). Alien flora of Europe: species diversity, temporal trends, geographical patterns and research needs. Preslia, 80(2), 101-149.

Müller, M., Oelmann, Y., Schickhoff, U., Böhner, J., & Scholten, T. (2017). Himalayan treeline soil and foliar C: N: P stoichiometry indicate nutrient shortage with elevation. Geoderma, 291, 21-32.

Nijland, W., De Jong, R., De Jong, S. M., Wulder, M. A., Bater, C. W., & Coops, N. C. (2014). Monitoring plant condition and phenology using infrared sensitive consumer grade digital cameras. Agricultural and Forest Meteorology, 184, 98-106.

Pauli, H., Gottfried, M., Dullinger, S., Abdaladze, O., Akhalkatsi, M., Alonso, J. L. B., ...&Ghosn, D. (2012). Recent plant diversity changes on Europe's Mountain summits. Science, 336(6079), 353-355.

Preston, C. D., Pearman, D., & Dines, T. D. (2002). New atlas of the British & Irish flora. Oxford University Press.

Pyšek, P. (1998). Is there a taxonomic pattern to plant invasions? Oikos, 282-294.

Rawal, R. S., Bankoti, N. S., Samant, S. S., & Pangtey, Y. P. S. (1991). Phenology of tree layer species from the timber line around Kumaun in Central Himalaya, India. Vegetatio, 93(2), 108 118.

Rawat, D. S. (2010). Uphill journey of plants in the Himalaya. Current Science, 99(12), 1644-1645.

Richardson, D. M., Pyšek, P., Rejmánek, M., Barbour, M. G., Panetta, F. D., & West, C. J. (2000). Naturalization and invasion of alien plants: concepts and definitions. Diversity and Distributions, 6(2), 93-107.

Sekar, K. C., Manikandan, R., & Srivastava, S. K. (2012). Invasive alien plants of Uttarakhand Himalaya. Proceedings of the National Academy of Sciences, India Section B: Biological Sciences, 82(3), 375-383.

Simberloff, D., Martin, J. L., Genovesi, P., Maris, V., Wardle, D. A., Aronson, J., ...&Pyšek, P. (2013). Impacts of biological invasions: what's what and the way forward. Trends in Ecology & Evolution, 28(1), 58-66.

Sonnentag, O., Hufkens, K., Teshera-Sterne, C., Young, A. M., Friedl, M., Braswell, B. H., ...& Richardson, A. D. (2012). Digital repeat photography for phenological research in forest ecosystems. Agricultural and Forest Meteorology, 152, 159-177.

Sundriyal, R. C., & Bisht, N. S. (1988). Tree structure, regeneration and survival of seedlings and sprouts in high montane forests of the Garhwal Himalayas, India. Vegetatio, 75(1-2), 87-90.

Uniyal, S. K., Jaryan, V., & Singh, R. D. (2017). Digital Images for Plant Phenology Documentation. National Academy Science Letters, 40(2), 135-139.

Walther, G. R., Roques, A., Hulme, P. E., Sykes, M. T., Pyšek, P., Kühn, I., ... & Czucz, B. (2009). Alien species in a warmer world: risks and opportunities. Trends in Ecology & Evolution, 24(12), 686-693.

Weber, E., Sun, S. G., & Li, B. (2008). Invasive alien plants in China: diversity and ecological insights. Biological Invasions, 10(8), 1411-1429.

Fitter, A. H., & Fitter, R. S. R. (2002). Rapid changes in flowering time in British plants. Science, 296(5573), 1689-1691.

8. ACKNOWLEDGEMENTS

We thank the Ministry of Environment, Forests and Climate Change; Government of India for financial support and GBPNIHE Almora (Uttarakhand) via National Mission on Himalayan Studies, through project GAP-0199. We also thank CSIR-IHBT Palampur HP, and State Forest Department for their support.

Fellowship Report No.: **05 of 06 (n = H-JPF 004)**

Researchers Details

Type of Fellowship (HRA/HJRF/HJPF)	Name of Himalayan Researcher	Date of Joining	Date of Resignation**	Research Title	Name of the PI & Designation
H-JPF004	Deepika Devi	26-05-2016	29-03-2019	Assessment of level and diversity of engagement of traditional institutions facilitated. Analyze the extent of capacity built of the traditional institutions	Dr. Sanjay Kr. Uniyal Senior Principal Scientist
H-JPF 004	Meghna Thakur	11-07- 2019	31-03-2020	Assessment of level and diversity of engagement of traditional institutions	Dr. Sanjay Kr. Uniyal Senior Principal Scientist

				facilitated. Analyze the extent of capacity built of the traditional institutions	

1. INTRODUCTION

People residing in the Himalayan hinterlands have high dependency on natural resources and have, therefore, devised practices that support its use and conservation (Uniyal et al. 2006; Sharma and Choudhry 1997; Singh et al. 1984). Consequently, traditional beliefs and customs have played an important role in biodiversity conservation (Negi 2010; Gadgil et al. 1993). Sacred groves are amongst the best examples of this. They represent areas of spiritual significance that are devoted to local village deities and rarely used for extractive purposes (Dash 2005). No doubt, they are rightfully highlighted as natural museums of giant trees, threatened species, medicinal plants, economic species and regulators of water shed (Manikandan et al. 2011; Bhagwat 2009). Traditional conservation practices also play an important role in soil and water conservation (Dabral and Subbo Rao 1969). Many scientific studies have revealed that these indigenous practices not only support and conserve flora and fauna (Singh et al. 2010; Khan and Tripathi 2004) but also help in soil and water conservation (Malhotra et al. 2007). Unfortunately, these practices seem to be now breaking. Rampant extraction of resources and an inclination towards market have been highlighted as the main reasons for this (Serrasolses et al. 2016; Siva and Eswarappa 2007). Therefore, the present study was initiated to document the traditional conservation practices and use patterns of natural resources in the hill state of Himachal Pradesh.

1.1. Literature review

Documentation of conservation practices has been an important area of research. Many workers reported that indigenous people and small-scale societies are often conservers of biodiversity (Smith and Wishnie 2000). Walker et al. (1997) and Martin (1985) provided detailed methodological information on acquisition of local ecological knowledge. Few studies have revealed that natural resource management is guided by religious beliefs and behaviours of human communities (Anthwal et al. 2010; Rist et al. 2003). On the other hand, many workers have reported that sacred forests have higher biodiversity values and richness (Jaryan et al. 2010; Bernbaum 2006; Gadgil et al. 1993). Their role in ecosystem services has brought them in the forefront of conservation research.

Background studies for designing the present work are presented below:

S.No.	Reference	Year	Major Objectives	Methodology adopted	Findings
1.	Alcorn (Conservation Biology, 7(2),424-426)	1993	What interests do indigenous people and conservationist have in common?	Literature review and comments.	Indigenous people offer the best options for achieving ground conservation
2.	Anthwal et al. (Journal of Resources Conservation and Recycling, 54(11), 962-971)	2010	Conserving biodiversity through traditional beliefs in sacred groves of Uttarakhand.	Literature survey.	Linkages between cultural attributes of community and its conservation.
3.	Jaryan et al. (The Environmentalist, 30(2), 101-110)	2010	Floristics of Shivbari sacred grove.	Systematic field surveys and vegetation sampling.	Despite occupying a miniscule area, it supports 2 % of the flora of HP.
4.	Kandari et al. (Environmental System Research, 3(1), 16)	2014	Conservation and management of sacred groves, myths and beliefs of tribes.	Questionnaire method.	Degradation of ancient heritage takes place due to changes in social belief and modernization.
5.	Luo et al. (Forest Ecology and Management, 257(10), 1995-2001)	2009	Traditional beliefs of Baima Tibetan community in biodiversity conservation.	Quantitative checklist questionnaire, and semi structured questionnaire method.	It was find out that there is balance between traditional beliefs of Baima Tibetan and nature and ecosystem in which they live.
6.	Mir and Upadhaya (Journal of Mountain Science, 14(8), 1500-1512)	2017	Effect of traditional management practices on woody species	Belt transect method for vegetation sampling.	The study revealed that management system of local people helped in conserving the plant

			structure and composition.		diversity and its sustainable use.
7.	Reyes – Garcia et al. (Ecological Economics, 120, 303-311)	2015	Study the trends in the use of natural resources.	Making inventory and systematic survey for recording information.	Cultural factors are responsible for decrease in consumption of natural resources.
8.	Sen (Assessment, 3(3), 33-42)	2018	Assessment of diversity, regeneration and conservation status of sacred grove.	Field visits and quadrat method.	Regeneration status of tree species was good in the forest.
9.	Sharma et al. (Society and Natural Resources, 12(6), 599-612)	1999	Conservation of natural resources through religion.	Making inventory, field survey and interview methods.	Religion helps in protecting the natural resources in Himalaya.
10.	Uniyal et al. (Journal of Ethnobiology and Ethnomedicine, 2(1), 14)	2006	Documentation of traditional knowledge.	Questionnaire method.	Tribal people still depend on natural resources.

1.2. Research question/s

- Are traditional conservation practices still followed by the residents of Himachal Pradesh?
- Do traditional conservation practices help in management of natural resources?
- What are the recent trends related to utilization of natural resources?

1.3. Objective/s of the study

- To document the traditional conservation practices prevalent in HP.
- To document wild resource used for edible purposes

2. METHODOLOGIES, STARTEGY AND APPROACH

The study was carried out in the Chhota Bhangal and Lug valley of Himachal Pradesh. Chhota Bhangal lies at co-ordinates 32°04’32.83’’ N and 76°51’30.45’’ E while Lug valley is located at 31°58’00.45’’ N and 77°04’56.93’’ E. Both the sites are representative of the temperate Himalayan ecosystem with forests dominated by oak and conifers (Uniyal et al. 2006). The areas receive heavy rainfall between July to September while January is the coldest month with temperature plummeting to sub-zero.

The study involved intensive field surveys, interaction with local people, recording and interpretation of collected information. Personal interviews and focus group discussions were conducted using structured questionnaire (Martin 1995) while for analyses Serrasolses et al. (2016); Uprety et al. (2012) and Tardio et al. (2005) have been followed. During the reporting period fifteen field surveys were conducted to a total of 31 villages (11 in Chhota Bhangal and 20 in Lug valley) and information recorded from 250 respondents.

3. KEY FINDINGS AND RESULTS

Breaking of traditional practices has been cited as one of the important resaons for loss of biodiversity and ecosystem services. People in the hinterlands of Himalaya have been following many conservation practices that were in symbiosis with the nature. Developmental activities and economic changes have led to breaking up of these bonds and thereby led to degradation of resources. The present study was, therefore initiated to identify traditional conservation practices and institutions in Himachal Pradesh. It also aimed at looking into reasons behind the loss of these practices. Concept of *devbans* and *ghasnis* with respect to conservation of forests and grasslands, respectively still exist in the region. *Devbans* represent sacred groves from where no resources are extracted while *ghasnis* represent grasslands that are only harvested during lean periods of fodder availability (Fig 4).

Prevalence of twenty-two taboos was noted. Most of these taboos (n=6) pertain to the management of the forests and were mainly associated with sacred forests of deities. A similar number of taboos (n= 6) were associated with water and were primarily related to sacred ponds. These were followed by food (n=3) and farmland (n=1) taboos. Food taboos are related to the consumption of food while the farmland taboos related to tillage and other farmland activities.

For water conservation and management people used bawdi, nawns, chhrodu, kuhls, chhapris, mangru, and panihars. Some of the high-altitude lakes such as Dyansurar are considered as abode of local deities and hence conserved. Even plants growing in its surroundings are not extracted. While no specific practices for soil conservation was observed, using forest leaf litter for maintaining soil fertility in agricultural fields was noted (Fig. 3). Bund formations and sowing of grasses targeted checking soil erosion. Traditional institutions working towards conservation of resources, that were identified include, mahila mangal dal, yuv manch, rakhas, van panchayat, community forestry and sanjhi van yojna.

It was noticed that sacred groves (*Deobans)* and protected forests are the two ways of conserving forests traditionally in Lug valley. Kasturi Narayan, Falyani Narayan, Panchali Narayan, Bhalthi Narayan at Bhalyani; Fallan; Rujag; Bhalta sacred areas were identified. Two protected areas were also identified (one at Rujag and other at Bhalta) within sampled villages. Rules of community for extraction of fuel wood and conservation of grasslands (locally called Phaat) were followed by local people in villages. For water conservation sacred ponds (two at Bhalyani and one at Jindi), traditional ponds (at Tiun) and traditional baudies (at Tiun, Rujag, Telang, Dughilag, Bhutti) were reported in the areas (Table 5, Fig. 6). Sacred ponds are the residing places of local deities. Cutting of trees, extraction of fuel wood from around the sacred ponds and traditional water ponds is strictly prohibited. For conservation of fertile soil, terraces, bunds are formed by people. Organic manure and leaf litter of trees (*Rhododendron, Picea, Deodar* and *Quercus)* are used for maintaining the soil fertility. Traditionally a process “Malaan daani” was documented in which herd of sheep and goat is allowed to settle in the fields for manuring which increases the soil fertility.

Thus, conservation of natural resources is important for survival of mankind. Local communities of Himalaya have developed their own conservation and management practices that may guide recent conservation initiatives. These practices were noted to occur for plant, soil and water. Scared groves (Revered forests); Sacred ponds (Holy Ponds), Machyals (sites for fish conservation), and Baudis (traditional water sources) form an important component of these.

4. OVERALL ACHIEVEMENTS

- Traditional practices pertaining for use and conservation of forest (dev bans, ghasnis), soil (bunds, grass sowing), and water (bawdi, nawns, chhrodu, kuhls, chhapris, mangru, panihars) were identified and documented.
- Traditional Institutions (mahila mangal dal, yuv manch, van panchayat, rakhas, sanjhi van yojna) working in the field identified.
- Twenty-two taboos identified and categorized.
- Vegetation characteristics of a formally managed forest vis-à-vis traditionally managed sacred groves compared.

Publications:

-Sharma, A., Thakur, D. & Uniyal, S.K. (2019). Taboos: Traditional beliefs and customs for resource management in the western Himalaya. *Indian Journal of Traditional Knowledge,* 20(2): 575–581.

- Thakur D, Alpy and Uniyal SK (2017). Why they eat what they eat: patterns of wild edible plants consumption in a tribal area of western Himalaya. *Journal of Ethnobiology and Ethnomedicines* 13(1):70

-Thakur D, Sharma A, Uniyal SK (2019). Mushroom-growing Elm trees can empower Barot village communities. Down To Earth. https://www.downtoearth.org.in/blog/agriculture/mushroom-growing-elm-trees-can-empower-barot-village-communities-62787

5. IMPACTS OF FELLOWSHIP IN IHR

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

- Status and prevalence of traditional practices documented through the work are of help in guiding local development.

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

- The importance of traditional institutions (mahila mangal dal, yuv manch, rakhas, van panchayat, community forestry and sanjhi van yojna) emphasized.

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

- Sociocultural factors found to play an important role in bioresource use and conservation. The comparison of vegetation characteristics of a formally managed forest vis-à-vis traditionally managed sacred groves revealed higher species diversity and density in traditionally managed areas. Some of the high-altitude lakes such as Dyansurar are considered as abode of local deities and hence conserved. Even plants growing in its surroundings are not extracted

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

- Various practices were noted to occur for the conservation of plant, soil and water. Scared groves (Revered forests); Sacred ponds (Holy Ponds), Machyals (sites for fish conservation), and Baudis (traditional water sources) form an important component of these.

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)

- Recognition of the traditional conservation practices will add to their involvement in sustainable development.

6.2. Efficient ways to replicate the outcomes of the fellowship in other parts of IHR (max. 1000 words)

- Popularization and awareness

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)

- Involving communities and mutual learning

7. REFERENCES/BIBLIOGRAPHY

Alcorn, J., B. (1993). Indigenous people and conservation. Conservation Biology, 7(2), 424-426.

Anthwal, A., Gupta, N., Sharma, A., Anthwal, S., & Kim, K. H. (2010). Conserving biodiversity through traditional beliefs in sacred groves in Uttarakhand Himalaya, India. Resources, Conservation and Recycling, 54(11), 962-971.

Bernbaum, E. (2006). Sacred mountains: Themes and teachings. Mountain Research and Development, 26(4), 304-309.

Bhagwat, S. A. (2009). Ecosystem services and sacred natural sites: reconciling material and non-material values in nature conservation. Environmental Values, 417-427.

Dabral, B. G., & Rao, B. S. (1969). Interception studies in sal (Shorea robusta) and khair (Acacia catechu) plantations-New Forest. Indian Forester, 95(5), 314-323.

Dash, S.S. (2005). Kabi sacred grove of north Sikkim. Current Science, 89(30), 427–428.

Gadgil, M., Berkes, F., & Folke, C. (1993). Indigenous knowledge for biodiversity conservation. Ambio, 151-156.

Jaryan, V., Uniyal, S. K., Singh, R. D., Lal, B., Kumar, A., & Sharma, V. (2010). Role of traditional conservation practice: highlighting the importance of Shivbari sacred grove in biodiversity conservation. The Environmentalist, 30(2), 101-110.

Kandari, L. S., Bisht, V. K., Bhardwaj, M., & Thakur, A. K. (2014). Conservation and management of sacred groves, myths and beliefs of tribal communities: a case study from north-India. Environmental Systems Research, 3(1), 16.

Khan, M. L., & Tripathi, R. S. (2004). Sacred groves of Manipur–ideal centres for biodiversity conservation. Current Science, 87(4), 430-433.

Luo, Y., Liu, J., & Zhang, D. (2009). Role of traditional beliefs of Baima Tibetans in biodiversity conservation in China. Forest ecology and management, 257(10), 1995-2001.

Malhotra, K. C., Gokhale, Y., Chatterjee, S., & Srivastava, S. (2007). Sacred groves in India: An overview. Aryan Books International.

Manikandan, P., Venkatesh, D. R., & Muthuchelian, K. (2011). Conservation and management of sacred groves in theni district, Tamil Nadu, India. Journal of Biosciences Research, 2(2), 76-80.

Martin, G.J. (1995). Ethnobotany: a method manual. London: Chapman and Hall. pp 268.

Mir, A. H., & Upadhaya, K. (2017). Effect of traditional management practices on woody species composition and structure in montane subtropical forests of Meghalaya, Northeast India. Journal of Mountain Science, 14(8), 1500-1512.

Negi, C. S. (2010). Traditional culture and biodiversity conservation: Examples from Uttarakhand, Central Himalaya. Mountain Research and Development, 30(3), 259-265.

Reyes-García, V., Menendez-Baceta, G., Aceituno-Mata, L., Acosta-Naranjo, R., Calvet-Mir, L., Domínguez, P., & Rodríguez-Franco, R. (2015). From famine foods to delicatessen: Interpreting trends in the use of wild edible plants through cultural ecosystem services. Ecological Economics, 120, 303-311.

Rist, S., Burgoa, F. D., & Wiesmann, U. (2003). The role of social learning processes in the emergence and development of Aymara land use systems. Mountain Research and Development, 23(3), 263-270.

Sen, U. K. (2018). Assessment of diversity, population structure, regeneration and conservation status of tree species in a sacred grove of west Midnapore district, West Bengal, India. Assessment, 3(3).33-42.

Serrasolses G, Calvet-Mir L, Carrio E, Ambrosio UD, Garnatje T, Parada M, Reyes-Garcia V. A matter of taste: local explanations for the consumption of wild food plants in the Catalan Pyrenees and the Balearic Islands. Economic Botany, 2016;70(2):176–89.

Sharma, S., & Chaudhry, S. (1996). Forestry, Agriculture, and People's Participation in the Central Himalaya. Journal of Sustainable Forestry, 4(1-2), 63-73.

Sharma, S., Rikhari, H. C., & Palni, L. M. S. (1999). Conservation of natural resources through religion: a case study from central Himalaya. Society & Natural Resources, 12(6), 599-612.

Singh, H., Husain, T., & Agnihotri, P. (2010). Haat Kali sacred grove, Central Himalaya, Uttarakhand. Current Science, 98(3), 290.

Singh, J. S., Pandey, U., & Tiwari, A. K. (1984). Man and forests: a Central Himalayan case study. Ambio, 13(2), 80-87.

Siva Prasad, R., & Eswarappa, K. (2007). Tribal livelihood in a limbo: Changing tribe-nature relationship in south Asia. At the crossroads: South Asia Research, Policy and Development in Global World, 69-78.

Smith, E. A., & Wishnie, M. (2000). Conservation and subsistence in small-scale societies. Annual Review of Anthropology, 29(1), 493-524.

Tardío, J., Pascual, H., & Morales, R. (2005). Wild food plants traditionally used in the province of Madrid, Central Spain. Economic Botany, 59(2), 122-136.

Uniyal, S. K., Singh, K. N., Jamwal, P., & Lal, B. (2006). Traditional use of medicinal plants among the tribal communities of ChhotaBhangal, Western Himalaya. Journal of Ethnobiology and Ethnomedicine, 2(1), 14.

Uprety, Y., Poudel, R. C., Shrestha, K. K., Rajbhandary, S., Tiwari, N. N., Shrestha, U. B., & Asselin, H. (2012). Diversity of use and local knowledge of wild edible plant resources in Nepal. Journal of Ethnobiology and Ethnomedicine, 8(1), 16.

Walker, D. H., Sinclair, F. L., Joshi, L., & Ambrose, B. (1997). Prospects for the use of corporate knowledge bases in the generation, management and communication of knowledge at a frontline agricultural research centre. Agricultural Systems, 54(3), 291-312.

8. ACKNOWLEDGEMENTS

We thank the Ministry of Environment, Forests and Climate Change; Government of India for financial support and GBPNIHE Almora (Uttarakhand) via National Mission on Himalayan Studies, through project GAP-0199. We also thank CSIR-IHBT Palampur HP, and State Forest Department for their support.

Fellowship Report No.: **06 of 06 (H-JPF 005)**

Researchers Details

Type of Fellowship (HRA/HJRF/HJPF)	Name of Himalayan Researcher	Date of Joining	Date of Resignation**	Research Title	Name of the PI & Designation
H-JPF005	Manju Bala	07-07-2017	06-11-2018	Capacity building on biodiversity conservation	Dr. Sanjay Kr. Uniyal Senior Principal

				through field based trainings/ awareness programs	Scientist
H-JPF 005	Priya Dhiman	12-07-2019	31-03-2020	Capacity building on biodiversity conservation through field based trainings/ awareness programs	Dr. Sanjay Kr. Uniyal Senior Principal Scientist

1. INTRODUCTION

Biodiversity that includes variety of life on the earth ensures our well-being and existence (Eblen and Eblen, 1994). Overexploitation of biodiversity and its serious implications on life and livelihood has led to coming up of many important initiatives such as the Convention on Biological Diversity. The convention highlights the importance of sustainable development and biodiversity conservation through awareness creation and capacity building (Navarro-Perez and Tidball, 2012; www.cbd.int). It is realized that a programme can only be successful if it has participation of local communities. Highlighting actions and measures that are contemporary, adapted to local communities and conveyed in local dialect have been found to be more successful (Slattery, 2003; Slattery and Rapp, 2003). Further, awareness programmes at school level are known to enhance the knowledge and responsibility of budding individuals in relation to conservation of biodiversity (Kahn, 1997; Hinds and Sparks, 2008; Kellert, 2002). Keeping this in view, the present work focussed on awareness creation amongst the rural communities and school children in Himachal Pradesh.

1.1. Literature review

Biodiversity conservation and management is interwoven in our traditional beliefs and customs (Hongmao et al. 2002). Chipko Andolan, wherein villagers of Uttarakhand hugged trees to protect them from saws and axes, represents a perfect example of this (Berremen, 1987). “Our Common future” paved the way for global discourse and united action (Navarro-Perez and Tidball, 2012). Researchers started to work on tools and techniques in awareness creation and capacity building (Eade, 1997). It was highlighted that while audio and visual presentations do motivate society (Pearson et al. 2011), practical demonstration and field visits have a far reaching impact (Padua, 1994). Designing posters and brochures in local language were also found to be helpful (Getz and Sailor, 1994).

S. No	Reference	Year	Major objective	Methodology adopted	Findings
1	Christoph et al. (Reports and Research,	2005	To evaluate the amphibian conservation programme for	Programme was conducted in indoor & outdoor classroom.	Students who participated in a conservation programme performed better in achievement test.
2	Fikret et al. (Ecological Application,	2000	Role of local communities in managing	Literature survey.	A diversity of traditional practices existed for ecosystem management.
3	Genovart et al. (Biological Conservation	2013	To test the hypothesis that exotic species	Selection of high school children and species.	Children's poor knowledge on local fauna in relation to exotic species was
4	Marc et al. (Reports and Research, 39, 4)	2008	Influence of residential environmental education	Survey. Awareness programme.	Significant positive, effects was recorded.
5	Nisbet and Zelenski (Frontiers in Psychology,	2013	Scale measurement of relatedness to nature	Scale development. Validation.	This will guide future awareness programmes.
6	Prakash et al. (Journal of Asia-Pacific Biodiversity, 9, 39-46)	2016	Promote medicinal and aromatic plants cultivation for conservation.	Perception analysis. Participatory action research framework approach.	The approach provided opportunities for farmers to build skills, knowledge, and self confidence, and ensure conservation of plants.
7	Philipp et al. (Urban Science, 1, 24)	2017	The perception and evaluation of landscape sceneries.	Photograph-based survey. Questionnaire method.	People perceived nature in a self referential way. Their appreciation of nature is closely linked to practical and aesthetic value.

8	Seely et al. (Journal of Arid Environment,	2003	To support the conservation of biodiversity.	Education for problem solving. Establishment of basis for decision	Analytical and management skills are necessary for effective biodiversity conservation.
9	Wakar et al.(International Journal of Sociology	2013	To create awareness among the rural population	Stratified random sampling followed by interview.	Education and gender play an important role in generating awareness.

1.2. Research question/s

- Are people aware of issues related to biodiversity and its loss?
- Do awareness programmes enhance the knowledge of the people regarding conservation?

1.3. Objective/s of the study

-To organize popular lectures for school children on biodiversity conservation.

-To generate awareness amongst village folk and rural communities.

-To develop material on biodiversity awareness and capacity building for wider dissemination.

2. METHODOLOGIES, STARTEGY AND APPROACH

The awareness programs were conducted in Palampur and Barot regions of district Kangra, Himachal Pradesh. The district lies between 75°39' E & 31°41'N to 76°56' E & 32°25' N and covers an area of 5739 sq Km (Kumar et al. 2007). Of which, ~35% is under forest. It receives a maximum rainfall of about 3000 mm and has an average temperature of 20–24°C. The soil around Kangra is slightly acidic in nature and light to dark brown in colour. It is loamy to sandy loam and is rich in iron and carbon, although it lacks mineral constituents (Pandey and Palni, 1996).

Based on the literature and reconnaissance surveys, schools and villagers were identified in the district (Fig. 1). A total of seven field surveys were conducted to achieve the predefined objectives and 7 villages were surveyed. Nature oriented days namely "Earth day" and "Environment day" were prioritized for awareness programmes. Lectures were prepared and delivered in local dialect (Moli, 2011; Waker et al. 2013). A plantation drive was also carried out (Navarro- Perez and Tidwall, 2012).

3. KEY FINDINGS AND RESULTS

Two awareness programmes, a plantation drive and village surveys revealed that people are aware of the resources in their surroundings and could easily relate to its uses. They are worried over the pace of natural resource degradation that is affecting that livelihood. Nature relatedness revealed people appreciation and bonding with it. Active participation of villagers and school children is a positive sign.

Awareness creation is one of the leading strategies for biodiversity conservation and management (Fig.2) Consequently, awareness creation amongst village folk and rural communities, and popular lectures amongst the school children were targeted.

A popular lecture on desertification and human wellbeing was delivered in Government Senior Secondary School, Khalet (HP). In addition to the school children and teachers, family members of the students also attended the same.

Further, four surveys were conducted to ten villages and group discussions and interaction were held (Table 1). The interactions were held in Pahari dialect and were mutually beneficial (Fig.3). Spread of *Lantana camara*, *Eupatorium adenophorum* and *Parthenium hysterophorous* were cited as the major environmental problems by the villagers. Crop raids by wild pig and monkeys was an agricultural problem of immediate concern.

Conservation of nature is much desired for sustainable development of society. For this, awareness creation, capacity building, and motivating people are desired. Recognizing natural and environmental values, the present study was carried out. A total of seven field surveys were conducted to achieve the predefined objectives. Three field surveys were conducted to Chhota Bhangal where programmes were carried out in five villages and a school. Nature relatedness was documented using pre-tested questionnaire (n=90). Results revealed that people are concerned about the degrading resources with students being more proactive. In addition, a lecture on biodiversity conservation and management was delivered at the Govt. senior secondary school Lohardi to create awareness among students (Fig. 4,5). A plantation drive was also carried out wherein seedlings of *Cedrus deodara* were planted in the school premises. Three surveys were organized in lug valley, Kullu district. Here 60 respondents were randomly selected to test the validity of nature relatedness. Further, a popular lecture was delivered to local inhabitants on current issues of desertification and human wellbeing. Another lecture was organized at the Govt. middle school, Bohal, Palampur (H.P) on the theme “Beat Plastic Pollution” (Fig.6).

Awareness creation and motivating people for conservation now form a part of multi-pronged conservation strategy. Targeting this, awareness programs were carried out in 12 villages that involved villages communities. In order to reach to the school children, two popular lectures and know your environment programs were conducted (Fig.7,8).

4. OVERALL ACHIEVEMENTS

- Confidence build with 10 village communities
- Community surveys conducted in villages
- Initiation of plantation drives (02)
- Awareness programme carried out and popular lecture delivered in villages and Government schools each in Lahaul, Kinnaur and Kangra.
- Evaluate nature relatedness of students and villagers

5. IMPACTS OF FELLOWSHIP IN IHR

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

- Awareness programmes, plantation drive, and village surveys revealed people easily relate to resources; this relationship has implications for socio-economic development.
- Nature relatedness was documented using pre-tested questionnaire (n=90).

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

- Communities are concerned about the degrading resources with students being more proactive. Involving school children in management programs would reap much benefits.

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

- Awareness creation and motivating people for conservation forms a part of multipronged conservation strategy. Targeting this, awareness programs were carried out in several villages.

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

- “Know your environment” and “Beat Plastic Pollution” initiatives impacted the society

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)

- The nature relatedness and willingness of the people especially school children could be great help.

6.2. Efficient ways to replicate the outcomes of the fellowship in other parts of IHR (max. 1000 words)

- The use of standard methodology and involvement of communities make it replicable in the IHR.

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)

- Student/ school may adopt trees/ forest for recordings and documentation.

7. REFERENCES/BIBLIOGRAPHY

Berreman, G. (1987). The Chipko movement in the Indian Himalayas. Dimensions of Social Life. Essays in Honour of David G. Mandelbaum, 345-368.

Christoph, R., Angelika, I., & Janina, K. (2005). Cognitive and Emotional evaluation of an amphibian conservation program for elementary school students. Journal of Environment Education, 37, 1.

Eade, D. (1997). Capacity-building: An approach to people-centred development. Oxfam.

Eblen, R., & Eblen, R. (1994). Economic, social, and environmental sustainability in development theory and urban planning practice The Encyclopedia of the Environment. New York: Houghton Mifflin Company, 432-433.

Getz, D., & Sailor, L. (1994). Design of destination and attraction-specific brochures. Journal of Travel & Tourism Marketing, 2(2-3), 111-131.

Haila, Y., & Kouki, J. (1994). The phenomenon of biodiversity in conservation biology. Annales of Zoologici Fennici (Finish Zoological Publishing Board), 31, 5-18.

Hinds, J., & Sparks, P. (2008). Engaging with the natural environment. Journal of Environmental Psychology, 28, 109-120.

Hongmao, L., Zaifu, X., Youkai, X., & Jinxiu, W. (2002). Practice of conserving plant diversity through traditional beliefs: a case study in Xishuangbanna, southwest China. Biodiversity & Conservation, 11(4), 705-713.

Hooper, D. U., Chapin, F. S., Ewel, J. J., Hector, A., Inchausti, P., Lavorel, S., Lawton, J. H., Lodge, D. M., Loreau, M., Naeem, S., Schmid, B., Setala, H., Symstad, A. J., Vandermeer, J., & Wardle, D. A. (2005). Effects of biodiversity on ecosystem functioning. Ecological Monographs, 75: 3–35.

Kahn, P. (1997). Developmental psychology and the biophilia hypothesis: Children’s affiliation with nature. Developmental Review, 17, 1-61.

Kellert, S. (2002). Experiencing nature: Affective, cognitive and evaluative development in children. In; Kahn & S. Kellert (Eds.), Children and Nature, (pp.117-151). Cambridge, MA: MIT Press.

Kumar, A., Uniyal, S.K., BrijLal (2007). Stratification of forest density and its validation by NDVI analysis in a part of Western Himalayas, India using Remote Sensing & GIS Techniques. International Journal of Remote Sensing, 28 (11): 2485-2495.

MEA. (2005). Millennium Ecosystem Assessment, Ecosystems and Human Well-being: Synthesis Washington (DC) Island Press.

Meritxell, G., Giacomo, Tavecchia., Juan- José, E., & Paola, L. (2013). Biological Conservation 159 Pandey A, & Palni LMS. The rhizosphere effect of tea on soil microbes in a Himalayan monsoonal location. Biology and Fertility of Soils, 21, 131, 484–489.

Moli, G. P. (2011). Community based eco cultural heritage tourism for sustainable development in the Asian region: A conceptual framework. International Journal of Social Ecology and Sustainable Development (IJSESD), 2(2), 66-80.

Navarro, P., & Tidwall, T. (2012). Challenges of biodiversity education: A Review of education strategies for biodiversity education. International Electronic Journal of Environmental Education, 1(2).

Nisbet, E.K., Zelenski, J.M. (2013). TheNR-6: a new brief measure of nature relatedness. Frontiers in Psychology, 4 (813):1-11.

Padua, S. M. (1994). Conservation awareness through an environmental education programme in the Atlantic forest of Brazil. Environmental Conservation, 21(2), 145-151.

Pandey, A., & Palni, L. M. S. (1996). The rhizosphere effect of tea on soil microbes in a Himalayan monsoonal location. Biology and fertility of soils, 21(3), 131-137.

Pearson, E., Dorrian, J., & Litchfield, C. (2011). Harnessing visual media in environmental education: increasing knowledge of orangutan conservation issues and facilitating sustainable behaviour through video presentations. Environmental Education Research, 17(6), 751-767.

Philipp, A., Unterweger, I D., Nicolas, Schrode. & Oliver, B. (2017). Urban nature: perception and acceptance of alternative green space management and the change of awareness after provision of environment information. A change for biodiversity protection. Urban Science, 2(3).

Ramadoss, A., & Poly, G. (2011). Biodiversity Conservation through environmental education for sustainable development - A Case Study from Puducherry, India. International Electronic Journal of Environment Education, Vol.1.

Sah M.P., & R.K. Mazari. (2007), An Overview of the Geo Environmental Status of the Kullu Valley, Himachal Pradesh, India. Journal of Mountain Science, 4(1), 3- 2.

Seely, M. K., Zeidler, J. J., Henschel, R., & Barnard, P. (2003). Creative problem solving in support of biodiversity conservation. Journal of Arid Environments, 54, 155–164.

Siddhartha, B., & Khadga, B. (2007) Community Forestry: Conserving Forests, Sustaining Livelihoods and Strengthening Democracy. Journal of Forest and Livelihood, 6(2).

Slattery, C. A. (2003). The impact of a computer-based training system on strengthening phonemic awareness and increasing reading ability level. 3234.

Slattery, P., & Rapp, D. (2003). Ethics and the foundations of education: Teaching convictions in a postmodern world. A and B.

Trombulak, S. C., Omland, K. S., Robinson, J. A., Lusk, J. J., Fleischner, T. L., & Domroese, M. (2004). Principles of conservation biology: Recommended guidelines for conservation literacy from the education committee of the society for conservation biology. Conservation Biology, 18, 1180–1190.

Wakar, A., & Mudasir, R. (2013). An assessment of environmental awareness among the residents of Tehsil Mendhar, District Poonch J&K, 185211, India. International Journal of Sociology and Anthropology, 5(3),78-83.

www.cbd.int

8. ACKNOWLEDGEMENTS

We thank the Ministry of Environment, Forests and Climate Change; Government of India for financial support and GBPNIHE Almora (Uttarakhand) via National Mission on Himalayan Studies, through project GAP-0199. We also thank CSIR-IHBT Palampur HP, and State Forest Department for their support.

APPENDICES

Appendix 1 – Details of Technical Activities

Appendix 2 – Copies of Publications duly Acknowledging the Grant/ Fund Support of NMHS

Appendix 3 – List of Trainings/ Workshops/ Seminars with details of trained resources and dissemination material and Proceedings

Appendix 4 – List of New Products (utilizing the local produce like NTFPs, wild edibles, bamboo, etc.)

Appendix 5 – Copies of the Manual of Standard Operating Procedures (SOPs) developed

Appendix 6 – Details of Technology Developed/ Patents filed

Appendix 7 – Any other (specify)

******

(Signature of HRA/HJRF/HPF)

14/XII/22

(NMHS FELLOWSHIP COORDINATOR)

वरिष्ठ प्रधान

(Signed and Stamped)

संपदा प्रौद्योगिकी संस्थान

पालमपुर-176061 (हि.प्र.)

DIRECT BENEFIT TRANSFER (DBT) DETAILS

Scheme Name:	**National Mission on Himalayan Studies (NMHS)**
Scheme Type:	**Central Sector (CS) Grant-in-Aid Scheme**
Scheme Code:	**NMHS**
Category:	**Fellowship Grant**
Month-Year:	

PRO FORMA FOR DBT DETAILS

University/Institution Name: CSIR-Institute of Himalayan Bioresource Technology, Palampur (HP)

S#	Position (H-RA, H-JRF/ H-JPF)	Name	DoB*	DoI*	PI	Research title	Objectives	Study Area, IHR State	Contact details (Complete corresponding address), Mobile No., E-mail ID	Bank details (Account number, IFSC Code)	Emoluments /Fellowship	Aadhaar No.

1.	H-RA-001	Dr Rachit Raghava Kashyap	01-01-1989	26-05-2016	Dr Sanjay Kr. Uniyal	Identification of bio-indicators for documenting environmental health	1. To assess air pollution tolerance index (APTI) of plants for identifying bio-indicator plant species. 2. To document species richness. 3. To study dust accumulation patterns on the foliage of plant species.	Kullu, Mandi (Himachal Pradesh)	Dev-Raghav Niwas, S/O Banshi Lal Sharma, Village-Pasta, Post office-Troh, Tehsil-Sadar, District-Mandi, Himachal Pradesh 175008 +919418426263 rachit198@gmail.com	Acc. No. - 20144699833 IFSC code- SBIN0011883	36000/- +3600 (HRA)	901108837848

6.	H-JPF 001	Mustaqeem Ahmad	14/05/1990	14-06-2016	Dr. Sanjay Kr. Uniyal	Diversity and species composition in Long Term Ecological Monitoring plots in western Himalaya	-To establish LTEM sites along an altitudinal gradient in Western Himalaya -To study floral diversity and composition along altitudinal gradient -To study Plant Functional Traits along this gradient -To study physico-chemical properties of soil along altitudinal gradient	Kangra, Himachal Pradesh	High Altitude Biology Division, CSIR-IHBT, Palampur, 176061 (HP) +919882503286 mustaqeem.env@gmail.com	Bank Account No.: 00000032981878516 IFSC Code: SBIN0003632	Rs.16000/- PM	846254062028

7.	H-JPF002	Alpy Sharma	02-02-1989	27-05-2016	Dr.Sanjay Kumar Uniyal	Extent of IKP documentation and strengthened through scientific evidence base.	1. To document the folk knowledge of selected tribal communities 2. To document the spatio temporal variation in folk knowledge and resource use of selected tribal communities 3. To study the factor influencing the status of the folk knowledge of selected tribal communities	Kangra, Kinnaur, and Lahaul Spiti (Himachal Pradesh)	High altitude biology division, CSIR- IHBT Palampur +918988120582 sharmaalpy@gmail.com	Acc. No. - 31733645356 IFSC code- SBIN0011848	16000/- +1600 (HRA)	209872358393

8.	H-JRF 003	Rohit	15/06 / 1990	27 May 2016	Dr. Sanjay Kr. Uniyal	Ecological characteristics of Himalayan timberlines and status of alien species	-To document community composition of timberline in HP -To categorize alien species occurring in the timberline -To document status of invasive alien species in timberline ecosystem -To study phenological patterns of timberline line communities	Timberline areas in Chamba, Kullu, Kinnaur; Himachal Pradesh	High Altitude Biology Division, CSIR-IHBT, Palampur, 176061 (HP) +919418101892 rohit.sharma2613@gmail.com	Bank Account No.: 32499267935 IFSC Code: SBIN0002490	Rs.25000/- PM + 10% HRA	860400412350

9.	H-JPF004	Deepika Devi	22-04-1991	26-05-2016	Dr. Sanjay Kr. Uniyal	Assessment of level and diversity of engagement of traditional institutions facilitated. Analyze the extent of capacity built of the traditional institutions	1. To identify traditional institution in HP. 2. To document traditional conservation practices in HP.	Chhota Bhangal (Kangra) Lug Valley (Kullu), (Himachal Pradesh)	High altitude biology division CSIR- institute of Himalayan bioresource technology Palampur (H.P.) +919459738797 thakurdeepika424@gmail.com	Acc. No. - 20172509793 IFSC code- SBIN0011848	16000/- +1600 (HRA)	237265375648

10.	H-JPF005	Manju Bala	05-10-1992	07-07-2017	Dr. Sanjay Kr. Uniyal	Capacity building on biodiversity conservation through field based trainings/ awareness programs	-To organize popular lectures for school children on biodiversity conservation -To generate awareness amongst village folk and rural communities -To develop material on biodiversity awareness and capacity building for wider dissemination	High altitude areas of Himachal Pradesh	V.P.O Rajiana (53-miles) Teh – Nagota Bagwan Distt- Kangra (HP) +918351831815 manjukundal225@gmail.com	Bank Account No.: 00000035294032005 IFSC Code: SBIN0010117	Rs.16000/-PM	798124871518

11.	H-JRF003	Ankush Dehlia	22-09-1993	16-08-2018	Dr. Sanjay Kr. Uniyal	Ecological characteristics of Himalayan timberlines and status of alien species	1. To document community composition of timberlines in HP 2. To categories alien species occurring in the timberline 3. To document the phenological patterns of timberline communities	Pangi Valley (Chamba), Holi Pass (Kangra), Rohtang Pass (Kullu), Chhitkul (Kinnaur), and Chanshal Pass (Shimla), (Himachal Pradesh)	943, Friends colony, model town, Ambala city, Haryana-134003 +91-9034863825 ankushdehlia@gmail.com	Acc. No.- 65204387914 IFSC code-SBIN0050316	25000/-	882446097114

6.	H-RA 001	Dr. Anchal Rana	08.04.1989	12 July 2019	Dr. Sanjay Kumar Uniyal	Identification of bio-indicators for documenting environmental health	-To document species richness in sites located along a vehicular air pollution gradient. -To study dust accumulation on the foliage of plant species -To carry out physico-chemical analyses of leaves -To assess air pollution tolerance index (APTI) and anticipated performance indices (API) of plant species for	Himachal Pradesh	Anchal Rana C/O Dr. Sanjay Uniyal Research Associate, High Altitude Biology, Biodiversity Division, CSIR-IHBT Palampur, HP-176061 **Mob No**: +91-9805156692 **Email**: anchal.rana89@gmail.com	33247647157 IFSC: SBIN0010505	36,000/PM	556542215907

7.	H-JPF 001	Rishabh Sharma	02.01.1996	08 July 2019	Dr. Sanjay Kumar Uniyal	LTEM sites established/investigated/ robust data sets generated. Extent of scientific evidences generated across key sectors	-To establish LTEM sites along an altitudinal gradient in Western Himalaya -To study floral diversity and composition along altitudinal gradient -To study Plant Functional Traits along this gradient -To study physico-chemical properties of soil along altitudinal gradient	Himachal Pradesh	Rishabh Sharma C/O Dr. Sanjay Uniyal Junior Project Fellow (JPF), High Altitude Biology, Biodiversity Division, CSIR-IHBT Palampur, HP-176061 **Mob No**: +91-9459262062 **Email:** rishabhsharma249@gmail.com	32974853158 IFSC: SBIN0000692	16,000/PM	563635546208

8.	H-JPF 002	Aradhna Bharti	01.11.1995	09 July 2019	Dr. Sanjay Kumar Uniyal	Extent of IKP documentation and strengthened through scientific evidence base	**-**To document the folk knowledge of selected tribal communities -The spatio temporal variation in folk knowledge and resource use of selected tribal communities -To study the factor influencing the status of the folk knowledge of selected tribal communities	Himachal Pradesh	Aradhna Bharti C/O Dr. Sanjay Uniyal Junior Project Fellow (JPF), High Altitude Biology, Biodiversity Division, CSIR-IHBT Palampur, HP-176061 **Mob No**: +91-9459783834 **Email**: aradhnabharti0116@gmail.com	38599017023 IFSC: SBIN0050126	16,000/PM	684366254547

9.	H-JPF 003	Deepak Verma	07.06.1996	08 July 2019	Dr. Sanjay Kumar Uniyal	Study the Invasive Alien Species (IAS): Effectiveness of approaches developed for reduction of IAS/ innovative use of biomass/ extent of areas/ landscapes restored	-Community compositions of timberline in HP -Categorization of alien species occurring in the timberline -Documentation of status of invasive alien species in timberline ecosystem -Documenting phenological patterns of tree line community	Himachal Pradesh	Deepak Verma C/O Dr. Sanjay Uniyal Junior Project Fellow (JPF), High Altitude Biology, Biodiversity Division, CSIR-IHBT Palampur, HP-176061 Mob No: +91-9882971438 Email: dpkvrma355@gmail.com	20463276723 IFSC: SBIN0011955	16,000/PM	418244901632

10.	H-JPF 004	Meghna Thakur	02.05.1995	11 July 2019	Dr. Sanjay Kumar Uniyal	Capacity building on biodiversity conservation through field based trainings/ awareness programs	**-**To organize popular lectures for school children on biodiversity conservation -To generate awareness amongst village folk and rural communities	Himachal Pradesh	Meghna Thakur C/O Dr. Sanjay Uniyal Junior Project Fellow (JPF), High Altitude Biology, Biodiversity Division, CSIR-IHBT Palampur, HP-176061 **Mob No**: +91-9805137205 **Email**: thakurmeghna1993@gmail.com	20321886878 IFSC: SBIN0003632	16,000/PM	801632393600

11.	H-JPF 005	Priya Dhiman	15-01-1995	12 July 2019	Dr. Sanjay Kumar Uniyal	Assessment of level and diversity of engagement of traditional institutions facilitated. Analyze the extent of capacity built of the traditional institutions	-To identify traditional institution in HP -To document traditional conservation practices in HP	Himachal Pradesh	Priya C/O Dr. Sanjay Uniyal Junior Project Fellow (JPF), High Altitude Biology, Biodiversity Division, CSIR-IHBT Palampur, HP-176061 **Mob No**: +91-7718453686 **Email**: priyadhiman.paru@gmail.com	38617509074 IFSC: SBIN0000692	16,000/PM	909328115010

Note: For each month, the DBT Details Pro forma dully filled and signed for each Himalayan Fellowship Grant under NMHS must be submitted at finance.nmhspmu2017@gmail.com; nmhspmu2016@gmail.com. *DoB (Date of Birth); DoJ (Date of Joining).

(Authorized Signatory)

Month **2019 – Latest Updated List of Himalayan Researchers or Fellows** *(working in the current time)*

S#	Name	Fellowship (RA/JRF/JPF)
1.	Dr. Anchal Rana	H-RA001
2.	Rishabh Sharma	H-JPF001
3.	Aradhna Bharti	H-JPF002
4.	Deepak Verma	H-JPF003
5.	Meghna Thakur	H-JPF004
12.	Priya Dhiman	H-JPF005

Annexure-IV

Details and Declaration of Refund of Any Unspent Balance

Please provide the details of refund of any unspent balance as RTGS (Real-Time Gross System) in favor of **NMHS GIA General** and declaration on the official letterhead duly signed by the Head of the Institution.

Kindly note the further Bank A/c Details as follows:

Name of NMHS A/c: NMHS GIA General

Bank Name & Branch: Central Bank of India (CBI), Kosi Bazar, Almora, Uttarakhand 263643

IFSC Code: CBIN0281528

Account No.: 3530505520 (Saving A/c)

In case of any queries/ clarifications, please contact the NMHS-PMU at e-mail: nmhspmu2016@gmail.com

Annexure-V

Technology Transfer and/ or Intellectual Property Rights Certificate

With a view to encourage the institutions to file patent applications on their innovations, motivate them to transfer their technologies for commercialization, and facilitate them to reward their inventions, the following instructions are issued.

1. In these instructions:

(a) **"Institution"** means any technical, scientific or academic establishment where research work is carried out through funding by the Central / State Government.

(b) **"Intellectual Property Rights"** include patents, registered designs, copyrights and layout design of integrated circuits.

(c) **"Inventor"** means an employee of the institution whose duties involve carrying out of scientific or technical research.

2. Scope: These instructions apply to those institutions receiving funds for research projects/ fellowships from NMHS, the Ministry of Environment, Forest and Climate Change (MoEF&CC).

3. Inventions by institutions: Institutions shall be encouraged to seek protection of Intellectual Property Rights (IPR) to the results of research through R&D projects/ fellowships. While the patent may be taken in the name(s) of inventor(s), the institutions shall ensure that the patent is assigned to it & DBT, GOI. The institution shall take necessary steps for commercial exploitation of the patent on non-exclusive basis. The institution is permitted to retain the benefits and earnings arising out of the IPR. However, the institution may determine the share of the inventor(s) and other persons from such actual earnings. Such share(s) shall be limited to 1/3rd of the actual earnings.

4. Inventions by institutions and industrial concerns: IPR generated through joint research by institution(s) and industrial concern(s) through joint efforts can be owned jointly by them as may be mutually agreed to by them and accepted by the Department through a written agreement. The institution and industrial concern may transfer the technology to a third party for commercialization on exclusive/non-exclusive basis. The third party, exclusively licensed to market the innovation in India, must manufacture the product in India. The joint owners may share the benefits and earnings arising out of commercial exploitation of the IPR. The institution may determine the share of the inventor(s) and other persons from such actual earnings. Such share(s) shall not exceed 1/3rd of the actual earnings.

5. **Patent Facilitating Fund:** The institution shall set apart not less than 25 per cent of such earnings for crediting into a fund called Patent Facilitating Fund. This Fund shall be utilized by the institution for updating the innovation, for filing new patent applications, protecting their rights against infringements, for creating awareness and building competency on IPR and related issues.

6. **Information:** The institutions shall submit information relating to the details of the patents obtained, the benefits and earnings arising out of IPR and the turnover of the products periodically to the Department/Ministry, which has provided funds.

7. **Royalty-free license:** The Government shall have a royalty-free license for the use of the intellectual property for the purposes of the Government of India.

(Signed and Stamped)

वरिष्ठ प्रधान

संपदा प्रौद्योगिकी संस्थान

पालमपुर-176061 (हि.प्र.)