Template/Pro forma for Submission

NMHS-Himalayan Institutional Project Grant

NMHS-FINAL TECHNICAL REPORT (FTR)

Demand-Driven Action Research and Demonstrations

NMHS Reference No.:	GBPNI/NMHS-2017-18/SG 23

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

PROJECT TITLE (IN CAPITAL)

UNDERSTANDING THE NATURE OF ALPINE TIMBERLINES OF HIMALAYA: INTEGRATING ECOLOGICAL AND SCENARIO STUDIES FOR ASSESSING THE IMPACT OF CLIMATE CHANGE

Project Duration: *from* **01.04.2018** *to* **31.12.2021**

***Submitted to*:**
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***Submitted by*:**
[*Sh. Satpal Dhiman, HPFS*]
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GENERAL INSTRUCTIONS:

1. The Final Technical Report (FTR) has to commence from the date of start of the Project (as per the Sanction Order issued at the start of the project) 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 details contents of training programme technical details and techniques involved) or any such display material related to project activities along with slides, charts, photographs should be brought at the venue of the Annual Monitoring & Evaluation (M&E) Workshop and 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 proponent and verified by the Head of the Lead Implementing Organization/ Institution/ University.
5. Five (5) bound hard copies of the Project Final Technical Report (FTR) and a soft copy should be submitted to the **Nodal Officer, NMHS-PMU, GBP NIHE HQs, Kosi-Katarmal, Almora, Uttarakhand**.

The FTR is to be submitted into following two parts:

Part A – Project Summary Report

Part B – Project Detailed Report

Following Financial and other necessary documents/certificates need to be submitted 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 Assets Certificate** showing the cost of the equipment in Foreign and Indian currency, Date of Purchase, etc. (with break-up as per the NMHS Sanction Order and year wise).
Annexure IV	**List of all the equipment, assets and peripherals** purchased through the NMHS grant with current status of use including location of deployment.
Annexure V	Letter of Head of Institution/Department confirming Transfer of Equipment Purchased under the Project to the Institution/Department
Annexure VI	**Details, Declaration and Refund of any Unspent Balance transferred through Real-Time Gross System (RTGS) in favor of NMHS GIA General**

DSL: Date of Sanction Letter

2	8	0	3	**2**	**0**	**1**	**8**
d	d	m	m	y	y	y	y

DPC: Date of Project Completion

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

Part A: Project Summary Report

1. Project Description

i.	Project Reference No.	GBPNI/NMHS-2017-18/SG 23							
ii.	Type of Project	Small Grant	√	Medium Grant		Large Grant			
iii.	Project Title	**Understanding the Nature of Alpine Timberlines of Himalayan: Integrating Ecological and Scenario Studies for Assessing the Impact of Climate Change**							
iv.	State under which Project is Sanctioned	**Himachal Pradesh**							
v.	Project Sites (IHR States covered) (Maps to be attached)	Himachal Pradesh							
vi.	Scale of Project Operation	Local		Regional	√	Pan-Himalayan			
vii.	Total Budget/ Outlay of the Project	Rs. 0.4845220 (in Cr)							
viii.	Lead Agency	SCCC, HIMCOSTE							
	Principal Investigator (PI)	Dr. S.S. Randhawa Project Staff : Sh. Harish Bharti, Scientific Professional ; Ms. Aditi Panatu, Scientific Professional							
	Co-Principal Investigator (Co-PI)	Dr. Amit Chawla, Project Staff: Mr. Lakhbeer Singh, Ms. Nandita Mehta							
ix.	Project Implementing Partners	HIMCOSTE Shimla & CSIR-IHBT Palampur							
	Key Persons / Point of Contacts with Contact Details, Ph. No, E-mail								

2. Project Outcomes

2.1. Abstract (not more than 500 words) [it should include background of the study, aim, objectives, methodology, approach, results, conclusion and recommendations).

Background*:** The Himalaya, which are located in tropical region with vegetation reaching substantially higher altitudes, is a distinctive biome, where the functional responses may be different even in different parts, and in this region, the recent research primarily focusing on timberlines is still limited. Further, the traditional ecological knowledge and wisdom is seldom taken into account in the predictions of future impacts and the changes projected are not always practical in the local or landscape context. ***Aim: To understand the nature of alpine timberlines and study of likely impacts of climate change on these ecosystems, taking into account the socio-ecological aspects. ***Methodology:*** The timberline zone in Himachal Pradesh was mapped and 04 LTER sites were identified (in Chamba, Lahaul and Spiti and Kinnaur Districts). Further, high resolution satellite datasets (Sentinel 2A) were utilized with land and vegetation cover classification in the watersheds, treelines were mapped using NDVI, and patterns of snow cover extent were studied. Vegetation structure, composition and functional characteristics were studied in 1ha permanent monitoring plots and 0.1 ha Modified Whittaker Plots covering the treelines, with $1m^2$ quadrats marked for studying species recruitment rates. Temperature data loggers were installed to record at 1hr intervals and a time-lapse camera was installed to study the phenophases of *Betula utilis*. Further, the biomass, productivity and nutrient cycling process (litter fall, litter decomposition and nutrient resorption) and eco-physiological parameters of dominant tree species were studied. These field derived parameters were utilized to train the ecosystem models for simulating (current and future) Net Primary Productivity, Water Use Efficiency and standing biomass Carbon allocation in different components. Besides, awareness programmes and surveys were undertaken in the watersheds for collecting information on perception of local people to changing local climate. ***Approach:*** An integrated approach utilizing ecosystem models for parameterizing, using field derived and laboratory analysed datasets, was followed to simulate key ecosystem processes and predict changes in future. Besides, socio-economic modelling was used (with peoples' perception dataset) to depict changes in the landuse/landcover of watersheds *i.e*., at local level. ***Results*:** The timberline zone of Himachal Pradesh was delineated, Watershed maps of study sites prepared and average elevation of treelines (Chitkul (4215.25±252.84m), Mooling (3578.96±228.35m), Khanjar (3653.31±49.63m) and Sural (3953.88±131.71m)) were deciphered. The main dominant tree species at the study sites were *Betula utilis* (mean DBH = 7.92cm; mean height = 4.4m) and *Pinus wallichiana*, whereas the mean richness of under-canopy species was 44 across all the sites. The Specific Leaf Area (SLA) of trees varied between 137.08 to 161.62 cm^2/g and for under-canopy SLA from 199.00 to 239.31 cm^2/g, and height from 17.03cm to 25.91cm. The annual snow-cover for time-period between October and June from 2014-20, showed an average of 71%, 44%, 80% and 67% for Chitkul, Mooling, Khanjar and Sural respectively, with tree species recruitment being highest at Sural (924 saplings/ha). The mean annual and growing season temperatures recorded at the study sites were 5.5 ºC and 9.9 ºC, with growing season to be of 149 days. The mean litter-fall was 860 per ha/year, mass loss and decay rates were found to be greater for up to 34 weeks (19.03±4.55% and 0.35±0.06 yr^{-1} respectively). The BIOME BGC model simulated mean values of NPP ranging from 14.46 to 30.4 $gC/m^2/yr$ and Water Use Efficiency (WUE), ranging from 0.033 to 0.075 g $m^{-2}mm^{-1}$. The DayCent Model suggested a total biomass ranging from 135.73 to 266.73 g C m^{-2}. Besides, 09 awareness Programmes were conducted and 04 workshops organised, and based on the workshops, future scenarios of the watersheds were constructed for changes in land cover/land use classes**.** ***Conclusion:*** Studying nutrient cycling and eco-physiology revealed key insights on ecosystem processes in the LTER sites, which in turn were utilized to train models to get fairly accurate estimates of simulated NPP and WUE which correlated well with the field derived data. The future predictions showed a decreasing trend in various RCP scenarios for the year 2050. ***Recommendations:*** The study in LTERs should be continued in future with validation of the results from model predictions of simulated values of NPP and WUE, as well as the future scenarios generated from socio-economic models.

2.2. Objective-wise Major Achievements

S. No.	Objectives	Major achievements (in bullets points)
1.	To map timberline zone in Himachal Pradesh region of western Himalaya	• By mapping the timberline zone, 04 LTER sites were identified and studied for ecosystem processes • The watersheds were delineated, classified in to various LULC categories and treeline was depicted in these watersheds using NDVI datasets.
2.	To study plant populations, community structure and functional ecology in the LTER sites	• All the baseline data pertaining to phytosociological aspects and community structure was generated by laying out Permanent Monitoring Plots (1 ha and 0.1 ha). Further, the species recruitment was also studied in quadrats which were fixed in the treeline zone. • The functional traits (leaf traits, plant height and LAI) were estimated and suggested important features of timberlines
3.	To study effect of changing snow-cover extent on species diversity and recruitment patterns	• The annual snow-cover for time-period between October and June from 2014-20, showed an average of 71%, 44%, 80% and 67% for Chitkul, Mooling, Khanjar and Sural respectively (04 LTER sites).
4.	To study phenology of key species, net primary productivity, nutrient dynamics and ecophysiology in the LTER sites	• The temperature loggers revealed mean annual temperature to be 5.5 ºC and with growing season to be of 149 days, when the mean temperature was found to be 9.9 ºC. • The mean Litter-fall of 860 per ha/year, mass loss and decay rate were found to be greater for up to 34 weeks ($19.03 \pm 4.55\%$ and 0.35 ± 0.06 yr^{-1} respectively). • The photosynthesis net rate is from 3.4 to 8 µmol CO_2 m^{-2} s^{-1} and water potential from -1.19 to -1.12 MPa, the nutrient resorption in leaves of *Betula utilis* for N, P, K is approximately 48%, 55 % and 35% respectively, at the end of growing season.
5	To undertake predictive modelling for projecting future changes in vegetation	• The DayCent Model suggested a total biomass ranging from 135.73 to 266.73 g C m^{-2}. • The BIOME BGC model revealed mean values of simulated NPP ranging from 14.46 to 30.4 $gC/m^2/yr$ and simulated Water Use Efficiency (WUE), ranging from 0.033 to 0.075 g $m^{-2}mm^{-1}$. • The future predictions showed a decreasing trend in various RCP scenarios for the year 2050.
6	To integrate with modelled projections, the scenario studies by involving local stakeholders for understanding the future of their landscape	• A total of 09 awareness programmes were conducted and 04 workshops organised for knowing people's perceptions on climate change, and based on the workshops, future scenarios of the watersheds were constructed for changes in land cover/land use classes.

2.3. Outputs in terms of Quantifiable Deliverables*

S. No.	Quantifiable Deliverables*	Monitoring Indicators*	Quantified Output/ Outcome achieved	Deviations made, if any, & Reason thereof:

	More and updated socio-ecological information on alpine timberline ecosystems of western Himalaya (HP) for understanding drivers of change	No. of New Database/ Datasets/ generated on the identified dynamics and indices	No. of New Database/ Datasets/ generated on the identified dynamics and indices **Datasets: (08 nos.)** 1. Thematic map for sub-alpine & alpine vegetation 2. Set of plant species occurring in the timberline & treeline ecotonal zones 3. Population data of representative plants species 4. Key functional traits of plant species 5. Watershed maps of study sites 6. Snowline maps of these watersheds 7. Annual temperature records 8. Litter decomposition rate for *Betula utilis*, a key treeline forming species 9. Eco-physiological data	Nil
	Knowledge bank on likely impacts of climate change in the future at landscape levels;	No. of region-specific models/ techniques developed/ implemented *viz*., field-specific technology; conservation practices; etc.	**Models: (03 nos.)** 1. Training of CENTURY model 2. Training of BIOME BGC Model 3. Predictive Models based on scenario studies	Nil
	Strategy inputs for managers and policy makers for conservation of timberlines	Policy/ strategic framework/ drafts (No.) for conservation of timber line Other Publications and Knowledge Products (Nos.), among others an assessment.	**Research Papers**: (01nos., published; 03 nos. (in Preparation))	Nil
	Awareness among various stakeholders in 5 tribal districts.	No. of Awareness Raising/ Capacity Building (Total No. of Beneficiaries) involving participations of communities;	**Awareness Programmes/Workshops: 13 nos.**	Nil

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

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

S. No.	Particulars	Number/ Brief Details	Remarks/ Attachment
1.	New Methodology developed	05	
2.	New Models/ Process/ Strategy developed	03	
3.	New Species identified	--	
4.	New Database established	03	
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 -NA-

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	Status of Existing Baseline	Additionality and Utilisation New data
1.	Temperature Dataset of four years (2018-2021)	Temperature dataset of 02 years (2016, 2017)	Temperature datasets are recorded in continuity for the LTER sites.
2.	Phytosociological, functional and eco-physiological datasets	Species diversity dataset	The plots and quadrats are permanently marked.
3.	Litter decomposition of all the litterfall components in the timberline forests	Leaf litter decomposition process, studied for 05 years	The new experiment includes other components of litterfall such as twigs *etc*. other than the leaves.

5. Demonstrative Skill Development and Capacity Building/ Manpower Trained

S. No.	Type of Activities	Details with number	Activity Intended for	Participants/Trained			
				SC	**ST**	**Woman**	**Total**
1.	Workshops	**04**	**Local tribal people**				
2.	On Field Trainings	--					
3.	Skill Development	--					
4.	Academic Supports	--					

	Others (if any)	**09 Awareness programmes**					

6. Linkages with Regional & National Priorities (SDGs, INDC, etc)/ Collaborations -NA-

S. No.	Linkages /collaborations	Details	No. of Publications/ Events Held	Beneficiaries
1.	Sustainable Development Goal (SDG)			
2.	Climate Change/INDC targets			
3.	International Commitments			
4.	Bilateral engagements			
5.	National Policies			
6.	Others collaborations			

7. Project Stakeholders/ Beneficiaries and Impacts -NA-

S. No.	Stakeholders	Support Activities	Impacts
1.	Gram Panchayats		
2.	Govt Departments (Agriculture/ Forest)		
3.	Villagers		
4.	SC Community		
5.	ST Community		
6.	Women Group		
	Others (if any)		

8. Financial Summary (Cumulative)

S. No.	Financial Position/Budget Head	Funds Received	Expenditure/ Utilized	% of Total cost
I.	Salaries/Manpower cost	13,85,970/-	13,92,673/-	100.4%
II.	Travel	13,07,608/-	11,40,099/-	87.2%
III.	Expendables & Consumables	11,19,049/-	9,11,384/-	81.4%
IV.	Contingencies	2,08,977/-	1,40,586/-	67.3%
V.	Activities & Other Project cost	-	59,000/-*	100%
VI.	Institutional Charges	1,80,133/-	2,06,893/-	114.8%
VII.	Equipments	3,00,000/-	3,00,000/-	100%
	Total	**45,01,737/-**	**41,50,635/-**	93.03%
	Interest earned	1,04,360/-**		
	Grand Total	**46,06,097/-**		

*During extended period new sanction was given. Since, no particular funds were released, the carry forward was used in new sanctioned heads.

**The interest earned was adjusted in the Expendables & consumable and Institutional Head during different F.Y.

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

9. Major Equipment/ Peripherals Procured under the Project (if any)**

S. No.	Name of Equipments	Cost (INR)	Utilisation of the Equipment after project
1.	Time Lapse Camera	Rs.2,75,000.00	Phenology of *Betula utilis* species in the timberlines
2.	Video Camera	Rs.25,000.00	Videography of LTER sites

Details should be provided in details (*ref* **Annexure III &IV).

10. Quantification of Overall Project Progress

S. No.	Parameters	Total (Numeric)	Remarks/ Attachments/ Soft copies of documents
1.	IHR States Covered	*01*	
2.	Project Site/ Field Stations Developed	*04*	
3.	New Methods/ Modeling Developed	*03 nos.*	
4.	No. of Trainings arranged	--	
5.	No of beneficiaries attended trainings	--	
6.	Scientific Manpower Developed (Phd/M.Sc./JRF/SRF/ RA):	*Ph.D.-01; M. Sc-01;*	
7.	SC stakeholders benefited		
8.	ST stakeholders benefited		
9.	Women Empowered		
10.	No of Workshops Arranged along with level of participation	*13 nos.*	
11.	On field Demonstration Models initiated	.... (Attach maps about location & photos)	
12.	Livelihood Options promoted	--	
13.	Technical/ Training Manuals prepared	*05 (Posters and Pamphlets)*	
14.	Processing Units established	.... (Attach photos)	
15.	No of Species Collected	*194*	
16.	New Species identified	--	
17.	New Database generated (Types):		
	Others (if any)		

11. Knowledge Products and Publications:

S. No.	Publication/ Knowledge Products	*Number*		*Total Impact Factor*	*Remarks/* Enclosures
		National	International		
1.	Journal Research Articles/ Special Issue:		01	1.5	
2.	Book Chapter(s)/ Books:				
3.	Technical Reports				
4.	Training Manual (Skill Development/ Capacity Building)				

S. No.	Publication/ Knowledge Products	*Number*		*Total Impact Factor*	*Remarks/* Enclosures
		National	International		
5.	Papers presented in Conferences/Seminars				
6.	Policy Drafts/Papers				
7.	Others:	03 Research Papers are in preparation			

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

12. Recommendation on Utility of Project Findings, Replicability and Exit Strategy

Particulars	Recommendations
Utility of the Project Findings	• The project findings deal with the generation of biodiversity and habitat characterization of the LTER sites, and essentially this gives the habitat baselines of timberlines forests, which form important habitats of Brown Bear and other important animals dwelling in the upper region of these mountains. With these baselines, other studies on the faunal distribution could be initiated for their conservation. • The projections from different models which suggest expansion of the timberlines (in the form of upward shifts) could result in loss of snow leopard habitats in the region. • The results of ecosystem level processes and the outputs from bio-geo-chemical models have been proposed specific to *Betula utilis*, which has a wide range of occurrence across the IHR and therefore, the results would also hold true for other regions in IHR as well. • The future impacts on timberlines have been predicted, from the models utilized in the study. The reduction in Net Primary Productivity as projected in different future scenarios, is a cause of concern and such results will be an important factor in formulating any management practices in the sub-alpine and timberlines forests.
Replicability of Project	• The outcomes of the project should also be applicable in other sites with different climates across the IHR. However, the variability could be studied by undertaking similar studies in LTER sites across different parts of IHR.
Exit Strategy	• The research work initiated in this project could be continued and sustained with requesting funding from different agencies, and with Research Fellows with their fellowship from CSIR/UGC could investigate the LTER sites with further questions. • The results and data analyses, especially the model outputs require to be published in the literature. • Ph.D. thesis have to be submitted by the project staff. • The stakeholders (especially the youth and the school children) could be made aware of the probable local impacts of climate change in future awareness programmes, utilizing existing and ongoing programmes such as CSIR Jigyasa *etc*.

(PROJECT PROPONENT/ COORDINATOR)

(Signed and stamped)

Joint Member Secretary
State Council for Science, Tech. &
Environment, Shimla-171009

(HEAD OF THE INSTITUTION)

(Signed and stamped)

Joint Member Secretary
State Council for Science, Tech
Environment, Shimla-171009

Place: .....
Date: .... /...../.....

PART B: PROJECT DETAILED REPORT

The Detailed report should include an Executive Summary and it should have separate chapters on (i) Introduction (ii) Methodologies, Strategy and Approach (iii) Key Findings and Results (iv) Overall Achievements (v) Project's Impacts in IHR (vi) Exit Strategy and Sustainability (vii) References and (viii) Acknowledgement (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 project, Manual of Standard Operating Procedures (SOPs) developed, Technology developed/Transferred etc should be enclosed as Appendix.

1 EXECUTIVE SUMMARY

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

Background:

Alpine timberlines, which are the upper limits to tree survival, are vulnerable in mountain environments and are reported to be severely affected by changing climate. Globally much research has been undertaken to understand the nature of treelines and the Himalaya, which are located in tropical region with vegetation reaching substantially higher altitudes, is a distinctive biome, where the functional responses may be different even in different parts of the region, the recent research primarily focusing on timberlines is still limited. Further, the traditional ecological knowledge and wisdom is never taken in to account in the predictions of future impacts. As a result, there is not only a wide gap between scientific hypothesis and societal aspirations, but also, the changes projected are not always practical in the local or landscape context.

Aim:

To understand the nature of alpine timberlines and study of likely impacts of climate change on these ecosystems, taking into account the socio-ecological aspects.

Objectives:

(1) To map timberline zone in Himachal Pradesh region of western Himalaya; (2) To study plant populations, community structure and functional ecology in the LTER sites; (3) To study effect of changing snow cover extent on species diversity and recruitment patterns; (4) To study phenology of key species, net primary productivity, nutrient dynamics and ecophysiology in the LTER sites; (5) To undertake predictive modeling for projecting future changes in vegetation; (6) To integrate with modelled projections, the scenario studies by involving local stakeholders for understanding the future of their landscape.

Methodology:

(1) To map timberline zone in Himachal Pradesh region of western Himalaya

The timberline zone in Himachal Pradesh was mapped and 04 LTER sites were identified (in Chamba, Lahaul and Spiti and Kinnaur Districts), At these sites, watersheds were delineated, high resolution satellite datasets (Sentinel 2A) were utilized for land and vegetation cover classification, and the treelines were mapped using NDVI.

(2) To study plant populations, community structure and functional ecology in the LTER sites

Vegetation structure, composition and functional characteristics were studied in the 04 LTER sites, in a 1ha permanent monitoring plot and 0.1 ha Modified Whittaker Plots covering the treelines,

(3) To study effect of changing snow cover extent on species diversity and recruitment patterns

Further, the patterns of snow cover extent were also studied in the 04 watersheds. with $1m^2$ quadrats marked for studying the species recruitment rates.

(4) To study phenology of key species, net primary productivity, nutrient dynamics and ecophysiology in the LTER sites

Temperature data loggers were installed to record at 1hr intervals throughout the year. A time-lapse camera was installed to study the phenophases of *Betula utilis*. Further, the biomass, productivity and nutrient cycling process (Litter fall, litter decomposition and nutrient resorption) was also studied in the LTER sites. Besides, the eco-physiological parameters of dominant tree species such as Net Photosynthetic Rate, Stomatal Conductance, Transpiration Rate, Water Potential were also estimated at multiple times during the growing season.

(5) To undertake predictive modeling for projecting future changes in vegetation

All field parameters recorded and estimated from field observations and laboratory analyses were utilized to train the ecosystem models for simulating (current and future) Net Primary Productivity, Water Use Efficiency and standing biomass Carbon allocation in different components.

(6) To integrate with modelled projections, the scenario studies by involving local stakeholders for understanding the future of their landscape

Besides, awareness programmes and surveys were undertaken in the watersheds for collecting information on perception of local people to changing local climate. Based on the latter information, scenario studies were undertaken to visually depict future changes in the watershed.

***Results*:**

(1) To map timberline zone in Himachal Pradesh region of western Himalaya

The timberline zone of Himachal Pradesh was delineated using a 30m SRTM DEM and the Watershed maps of the study sites were prepared. Further, the watersheds with LTER sites were classified into various land and vegetation classes (accuracy >91% for all the sites), and the treeline was depicted. The average elevation of treelines was found to be greater than 3500 m amsl at all the sites (Chhitkul (4215.25 ± 252.84 m), Mooling (3578.96 ± 228.35m), Khanjar (3653.31 ± 49.63m) and Sural (3953.88 ± 131.71 m)).

(2) To study plant populations, community structure and functional ecology in the LTER sites

The main dominant tree species at the study sites were *Betula utilis* (mean DBH = 7.92 cm; mean height = 4.4 m) and *Pinus wallichiana* (mean DBH = 16.35 cm; mean height = 5.4 m), whereas the mean richness of under-canopy species was 44 across all the sites. The Specific Leaf Area (SLA) of trees varied between 137.08 to 161.62 cm^2/g across the 04 sites and height ranged from 5.36 to 8.21 m for *Betula utilis* and from 5.64 to 10.31 for *Pinus wallichiana*. For under-canopy life forms, the SLA and height ranged from 199.00 to 239.31 cm^2/g and from 17.03 to 25.91 cm respectively.

(3) To study effect of changing snow cover extent on species diversity and recruitment patterns

The annual snow cover for time-period between October and June from 2014-20, showed an average of 71%, 44%, 80% and 67% for Chhitkul, Mooling, Khanjar and Sural respectively. The tree species recruitment of *Betula utilis* recorded at the study sites was highest at Sural (924 saplings/ha). Similarly, the species recruitment of *Pinus wallichiana* was found to be highest at Khanjar (113 saplings/ha).

(4) To study phenology of key species, net primary productivity, nutrient dynamics and ecophysiology in the LTER sites

The phenocam revealed the time-period of growing season to be 149 days. The other pheno-phases (leaf buds emergence at 135th day, reproductive parts development at 147th day, leaf maturation at 162th day *etc*.) were also determined. The mean annual temperature recorded at the study sites was 5.5 ºC and the growing season mean temperature was found to be 9.9 ºC.

With mean litter-fall as approximately 860 per ha/year, mass loss and decay rate were found to be greater for up to 34 weeks (19.03 ± 4.55% and 0.35 ± 0.06 yr^{-1} respectively. The nutrient resorption in leaves of *Betula utilis* for N, P, K was found to be approximately 48%, 55 % and 35% respectively at the end of season. Further, among the eco-physiological parameters of the dominant tree species, *Betula utilis*, the photosynthesis net rate was found to range from 3.4 to 8 µmol CO_2 m^{-2} s^{-1} across all the sites, and water potential from -1.19 to -1.12 MPa.

(5) To undertake predictive modeling for projecting future changes in vegetation

The BIOME BGC model revealed mean values of simulated NPP ranging from 14.46 to 30.4 $gC/m^2/yr$ and simulated Water Use Efficiency (WUE), ranging from 0.033 to 0.075 g $m^{-2}mm^{-1}$. Further the DayCent Model

suggested a total biomass ranging from 135.73 to 266.73 g C m^{-2}. Besides, the allocation of carbon in different pools of forest ecosystem such as large wood biomass (82.91 to 143.58 g C m-2), leaves (0.18-0.24 g C m^{-2}), coarse roots (18.80 to 36.01 g C m^{-2}) *etc*. was also estimated.

(6) To integrate with modelled projections, the scenario studies by involving local stakeholders for understanding the future of their landscape

Besides, the knowledge generated on ecosystem basis in the LTER sites, 09 awareness Programmes were conducted and 04 workshops organised, and based on the workshops, future scenarios of the watersheds were constructed for changes in land cover/land use classes. The scenarios were based on perceptions of people living in the watershed and in the vicinity, as to how the changes will take place in the watersheds in which these people are dwelling.

Conclusion: Studying nutrient cycling and eco-physiology revealed key insights on ecosystem processes in the LTER sites, which in turn were utilized to train models to get fairly accurate estimates of simulated NPP and WUE which correlated well with the field derived data. The future predictions showed a decreasing trend in various RCP scenarios for the year 2050.

Outcomes:

- 12 datasets were prepared which form the baselines of the alpine timberline ecosystems representing environmental conditions of western Himalaya.
- 04 LTER sites have been marked for continuation and comparative studies to be undertaken in future.
- 03 models were parameterized for simulating current and future predictions of biomass allocation, Net primary productivity and water-use efficiency. All of them are replicable models which have been trained on field derived phytosociological, ecological, eco-physiological and climate datasets determined over the period of duration of the project.
- 13 awareness/workshops were organized in the region (in 05 districts of Himachal Pradesh) for understanding the perceptions of people and spreading awareness on changing climate.
- 04 research papers (01 published and 03 in process) have been envisaged till now on different aspects of ecosystem processes and predicting future changes in the alpine timberline zone.
- 04 project fellows have been trained on different aspects of the study, with one of them also submitting a Ph.D. thesis.

Significance of study and future strategy:

- The setting up of LTER sites would be utilized for collaborative research with different institutions and organizations across Himalaya.
- The outcomes of the project should also be applicable in other sites with different climates across the IHR. However, the variability could be studied by undertaking similar studies in LTER sites across different parts of IHR.
- The project findings deal with the generation of biodiversity and habitat characterization of the LTER sites, and essentially this gives the habitat baselines of timberlines forests, which form important habitats of Brown Bear and other important animals dwelling in the upper region of these mountains. With these baselines, other studies on the faunal distribution could be initiated for their conservation.
- The results of ecosystem level processes and the outputs from bio-geo-chemical models have been proposed specific to *Betula utilis*, which has a wide range of occurrence across the IHR and therefore, the results would also hold true for other regions in IHR as well.

Recommendations:

Continuation of ecosystem monitoring in the timberlines with recording of temperature and phenocam data and long-term monitoring of ecological processes such litterfall and litter decomposition would result in obtaining

important insights on the ecosystem processes in the region. The study in LTERs should thus be continued in future with validation of the results from model predictions of simulated values of NPP and WUE, as well as the future scenarios generated from socio-economic models.

2 INTRODUCTION

2.1 Background of the Project (max. 500 words)

Long term ecological studies not only enhance our understanding of the relationships of vegetation and environment but are also pre-requisite for documenting impacts of global climate change. The present project utilizes two approaches to holistically understand the impact of climate change on the alpine timberlines: ecological studies in LTER sites and scenario studies based on knowledge of local people.

Here, it is proposed that Long Term Ecological Research (LTER) plots be established at a number of sites in the timberline zone in Himachal Pradesh in western Himalaya. The sites will be selected based on probabilistic sampling among representative timberline forming species. Both biotic and abiotic parameters will be recorded for further monitoring of species in these LTER plots. Further, at these LTER plots, ecosystem functions *viz*., key species phenology, net primary productivity and nutrient dynamics will be studied. The biotic and abiotic parameters generated through LTER and climate simulation studies will be utilized to train ecological models. In addition, 'Scenario Studies' by involving local communities and other stakeholders will be undertaken. Scenario studies provide useful context for addressing questions of future climate change based on local ethno-ecological, traditional knowledge and wisdom. Unlike, predictive modelling based on theoretical emission scenarios, such scenario studies help understand future change, given a range of possible societal dynamics (e.g., population growth, shifting demographics, land use change and possible environmental dynamics (e.g. climate, disturbance etc.) by also involving local stakeholders to directly contribute to the study outcomes.

2.2 Overview of the Major Issues to be Addressed (max. 1000 words)

Predictive models for assessing impacts on ecosystems based on theoretical emission scenarios does not take into account socio-economic aspects including the disturbances and other factors which act at local scales. The tribal communities dwelling in high altitudes of Himalaya are dependent on sub-alpine forests including timberlines for their livelihoods and meeting their requirements of timber, forage, medicinal plants etc. In general, local communities are either unaware or could not understand the outcomes emanating from ecological modelling and other hard core science studies in these ecosystems. Hence, it is perceived that there is an urgent need to include participation of stakeholders in projecting for their future, for integrating the best available ecological science with myriad of uncertainties that are inherent in changing climate including local anthropogenic influences. Further, the predictive models for assessing impacts of climate change are based on regional scales utilizing coarse datasets. 'Scenario Studies' provide an important and powerful tool for synthesizing the results of LTER science in participation with stakeholders. Scenario studies are strategies for describing plausible future conditions while explicitly incorporating relevant science, societal expectations, and internally consistent assumptions about major drivers, relationships and constraints. Hence, by integrating scenario studies with ecological modelling, we can efficiently take into consideration the sociological aspects.

2.3 Baseline Data and Project Scope (max. 1000 words)

Some preliminary work has been conducted on nutrient dynamics, besides collecting baseline data on species populations, community structure and diversity.

2.4 Project Objectives and Target Deliverables (as per the NMHS Sanction Order)

Objectives

1. To map timberline zone in Himachal Pradesh region of western Himalaya
2. To study plant populations, community structure and functional ecology in the LTER sites

3. To study effect of changing snow cover extent on species diversity and recruitment patterns.
4. To study phenology of key species, net primary productivity, nutrient dynamics and ecophysiology in the LTER sites.
5. To undertake predictive modelling for projecting future changes in vegetation.
6. To integrate with modelled projections, the scenario studies by involving local stakeholders for understanding the future of their landscape

Deliverables

1. More and updated socio-ecological information on alpine timberline ecosystems of western Himalaya (HP) for understanding drivers of change;
2. Knowledge bank on likely impacts of climate change in the future at landscape levels;
3. Strategy inputs for managers and policy makers for conservation of timberlines;
4. Awareness among various stakeholders in 5 tribal districts.

3 METHODOLOGIES, STARTEGY AND APPROACH

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

Objective 1: To map timberline zone in Himachal Pradesh region of western Himalaya

Delineation of timberlines in Himachal Pradesh

The treeline zone has been delineated with the help of Digital Elevation Model (DEM) and Sentinel 2A Satellite Imagery. The prominent treeline zone has been observed between 3500-4000m from the mean sea level. Maps have been prepared for the treeline zone in Himachal Pradesh and probable occurrence of treelines has been delineated in the 3500-4000m range of elevation. Finding from these treeline maps revealed that treeline zone falls in Kinnaur, Lahaul & Spiti, Pangi region of Chamba district and upper reaches of Kangra, Kullu and Shimla. For mapping the timberline zones of Himachal Pradesh, shape files from H.P. Forest Department were also consulted and validated with the practical treeline zone.

Study Sites Watershed Delineation:

For mapping the timberline at the study sites, watershed areas were delineated. A satellite derived high-resolution DEM (12.5m) was utilized for delineation of watershed. The watersheds were delineated for all of the 04 study sites using ArcGIS Toolbox (Spatial Analyst Tool feature). These 04 watersheds are henceforth called as Sural, Khanjar, Mooling, and Chhitkul.

Satellite image classification:

The high-resolution satellite, Sentinel-2A dataset, with 13 spectral bands, ranging from the visible and the near-infrared to the shortwave infrared at different spatial resolutions of 10 m was utilized (bands G, R and NIR). The image classification was performed using a combination of (1) Cluster bursting/unsupervised image classification, and (2) Supervised image classification and the classification accuracy assessment performed using an error matrix using 100 samples points representing different LULC classes.

Treelines Delineation in the Watersheds:

For every watershed, the NDVI data was used to classify the vegetation and categorize them as forest and other vegetation, using a thresholding approach. The threshold NDVI values were arrived and fine-tuned taking signatures from the known dense forest patches of sub-alpine forests, and that of alpine meadows, which resulted in unambiguous identification of the “treeline ecotone” patches (Mohapatra et al., 2019, Singh et al., 2012).

Objective 2: To study plant populations, community structure and functional ecology in the LTER sites

Monitoring Plant Densities and Estimation of Taxonomic Diversity

For estimating the vegetation structure, composition and functional characteristics in the timberline zones, 01 ha permanent monitoring plots (PMPs) were established at all the study sites. The species diversity and other phytosociological studies were undertaken as suggested in Chawla et al., (2012). In sub-quadrat of 20m x 20m, three quadrats, each of 5m x 5m size were diagonally marked for estimation of shrubs species density, further in each of these 5m x 5m sub-quadrats, three quadrats each of size 0.5m x 2m were laid down for estimation of herbs density.
Further, transects of 0.1 ha Modified Whittaker plots (MWPs) were laid in the treeline ecotone zone. A transect of MWPs was established in the treeline ecotone region in all the study sites. The plot measures 20x50 m (1,000 m^2) as total area and contains nested subplots of three different sizes (Chawla et al., 2012).
All the trees, ≥ 10 cm in DBH, were enumerated, tagged and marked. In the subplots, all shrubs were identified and counted. The individual plants of herbaceous species (including graminoids) were identified and counted in the 1 m^2 plots. Their ground cover estimated according to Braun–Blaunquet scale. Temperature loggers (M-log 5W Geo Precision) were installed in the plots (01 temperature logger 2m above the ground and one at 10cm depth under soil).

Objective 3: To study effect of changing snow cover extent on species diversity and recruitment patterns

Delineation of patterns of snow cover in the watersheds

A SRTM-DEM of resolution 30 m was utilized. The lowest altitude of snow cover was calculated using the contours at 30 m interval. The snow cover area of different LTER sites was then calculated using Normalised Difference Snow Index (NDSI) model run in ERDAS software.

Normalized Difference Snow Index (NDSI)

The NDSI was calculated using the ratio of green wavelength (band 2) and SWIR (band 5) of AWiFS sensor from IRS satellite (Resourcesat-2): Normalised Differential Snow Index (NDSI) = (band2-band5) / (band2+band5)

To estimate NDSI, DN numbers were converted into reflectance. This involves conversion of digital numbers into the radiance values, known as sensor calibration, and then estimation of reflectance from these radiance values and the final product after running algorithm model. Various parameters needed for estimating spectral reflectance are maximum and minimum radiances and mean solar exo-atmospheric spectral irradiances in the satellite sensor bands, satellite data acquisition time, solar declination, solar zenith and solar azimuth angles, mean Earth- Sun distance etc. (Markham and Barker, 1987; Srinivasulu and Kulkarni, 2004).

Snow Cover Monitoring Algorithm

An algorithm was developed to provide changes in the areal extent of snow (Kulkarni et. al., 2006). Snow extent is estimated depending upon availabilities of AWiFS data. If any pixel is identified as snow on any specific date, then this pixel would be classified as snow on final product. Therefore, this product is generated watershed-wise. However, the NDSI model was in Raster format which was converted into Vector data format. Then the model was reclassified in ArcGIS to compute area from AWiFS, RESOURCESAT-2 high resolution satellite data. The snow-cover and altitude data were also analysed in the Microsoft Excel to generate the bar graphs and trendlines for particular years.

Species Recruitment Patterns

The 1sq.m quadrats were permanently marked for knowing the changes in species recruitment utilizing repeated sampling.

Objective 4: To study phenology of key species, net primary productivity, nutrient dynamics and eco-physiology in the LTER sites

For estimating the phenophases of key treeline species, *Betula utilis:*

A time-lapse camera was installed at the Sural site to observe the timberline patch under study, and the images were utilized to study the different pheno-phases and to estimate the growth period of the study species.

For estimating the Nutrient Resorption status of timberline forest:

To assess the nutrient status of *B. utilis* in the study sites, we randomly selected and marked 05 trees at each site. These trees were selected from the main LTER Plot (100m x 100m) i.e., in timberline zone. We sampled 60-80 leaves from each tree during the growing season period, when it is in peak growing biomass and fully expanded in August month i.e. mature leaves and when fully senesced period (n the month October).

For estimating the Biomass and productivity status of timberline forest:

We utilized litter-fall trap method and at each site, 10 litter-fall traps (1.0 m^2), made with iron sides fitted with the nylon mesh (1 mm mesh size) was installed in the timberline forest (Anderson and Ingram, 1994). Traps position was randomly selected, and each trap was placed approximately 0.30 m above the soil level to intercept litter fall. Litter contents were manually sorted into the following categories: leaves, reproductive structures (flowers, fruits, and seeds), twigs or branches (<2 cm in diameter), and miscellaneous residues (unidentified, fine plant tissue such as bark, pieces of insect bodies *etc*). Samples were oven dried to a constant weight at 70°C for 72 h and then weighed again. For standing floor litter estimation in the permanent plots, total of five quadrats 0.5m X 0.5m were laid down randomly in the plots. The present surface standing litter was collected from the ground till soil surface is clearly visible. Leaves, woods, barks, reproductive parts, etc along with degrading litter biomass was also collected. Samples was oven dried to a constant weight at 70°C for 72 h and weighed.

For estimating the litter decomposition in the timberline forest:

For studying the litter decomposition in the timberline zones of Himalayas, we used standard litter bag method. At the period of Senescence, during the month, October-2014, freshly fallen senescent leaves of *B. utilis* were collected from the study sites in the same week and transported to laboratory and then oven dried at 70˚C. Litter bags of size 20cm x 20cm made up of nylon mesh, with mesh size of 0.25 mm^2 on lower side and 1.0 mm^2 on the upper side was made, 10 g of oven dried leaves was packed in these bags. Three sub-samples of leaf litter were retained for determination of initial nutrient concentrations and ligno-cellulose contents. A total of 48 litter bags were packed with litter from each site and then placed randomly in 3 rows (16 in each row) in the same forest patch in the study site from where the leaves were collected. Litter bags were placed in the forest in the month of October 2014. Three bags from each site were randomly retrieved at various time intervals (May to October) in the following years (up to October 2020) and transported in sealed bags to the laboratory. Collected samples were oven-dried at 70°C to get a constant weight, for the determination of remaining weight and were then grinded and stored for the analysis of N, P, and K concentrations, and estimating ligno-cellulose content.

Eco-physiological Studies:

Estimation of key parameters related to photosynthesis in *Betula utilis* was undertaken. The gas-exchange measurements were taken on healthy fully grown leaves. Gas exchange measurements (net photosynthetic rate and stomatal conductance) were taken with an open-system portable photosynthesis meter (Li-Cor 6400-XT, Li-Cor Inc., Lincoln, NE, USA) equipped with the standard leaf chamber (encloses 6 cm^2 of leaf area). The saturating light intensity for all measurements was maintained by a red-blue light source (model 6400–02, Li-Cor Inc., Lincoln, NE, USA) and given after preparing light response curves on the same leaf. Ambient relative humidity and block temperature were maintained in the chamber. Water potential of leaves was measured using pressure chamber (PMS instruments Model 1505D). Water potential was measured on three leaves for each of the three selected trees per plot.

Objective 5: To undertake predictive modelling for projecting future changes in vegetation

Predictive Modelling

- BiomeBGC

BIOME-BGC estimates NPP on the basis of GPP and respiration. The BIOME-BGC version 4.1.1 was utilized as the model is used for this study along with MT-CLIM (Mountain Microclimate Simulator) (Running et al., 1993; Thornton et al., 2000).
Biome-BGC uses meteorological data, site-specific data (soil texture, effective soil depth, annual mean nitrogen deposition and biological nitrogen fixation, site elevation and latitude), and eco-physiological data (e.g., maximum stomatal conductance, canopy specific leaf area, etc. to simulate the biogeochemical processes of the given biome.
The model was input and parameterized with Site specific parameters, Eco-physiological parameters and meterological variables. These parameters were estimated from field data, and wherever these could not be measured or estimated, the default values were utilized. Thereafter, a sensitivity analysis of the model was also performed.

- CENTURY Biogeochemical Model

This model simulates fluxes of C and N between the atmosphere, vegetation, and soil. The DAYCENT model (Del Grosso et al., 2001) was parameterized with LTER site details, weather data and with the estimated parameters for timberline forest. Using these parameters, model was run which simulates SOC, ANPP and N_2O fluxes. The model was calibrated using field observations to produce outputs.

Objective 6: To integrate with modelled projections, the scenario studies by involving local stakeholders for understanding the future of their landscape

3.1 Climate Change Awareness Programmes

Awareness programmes were conducted in 04 districts: Kangra, Mandi, Kinnaur and Lahaul and Spiti. The surveys were conducted during October-November in the years 2019 and 2021. Cross-sectional survey was done among households of around 20 rural villages located in these 04 districts

We reviewed literature on climate change for developing the questionnaires and health knowledge, perception, attitude and behaviour measures in relation to climate change. Information regarding perception of climate change was collected from residents of villages using a structured questionnaire. As a part of the questionnaire, we also collected information on sociodemographic variables of the respondents. The respondents were chosen >30 years of age. We tried to interview as many as members of age ≥60 to evaluate climate change and its effects. We also prepared posters for the detailed explanation about climate change and its impact on the environment and human health. We focussed on forest and wild life conservation, utilization of natural resources and to reduced use of non-renewable resources that could contribute to climate change. We demonstrated the impact of climate change and efforts to prevent global environment change to each household utilizing posters and local language discussions. Finally, each filled-up questionnaire was checked to ensure that no information was missing; any error detected was corrected immediately at the field, sometimes by revisiting the household, before it was entered into the computer.

Scenario Studies

Invest Software was utilized to prepare various scenario-based maps. In order to show the transitions in the Land Use Land Cover (LULC) for the selected LTER sites of Himachal Pradesh, Scenario Generator: Proximity Based Tool of InVEST (Integrated Valuation of Ecosystem Services and Trade-offs) model (ver. 3.9.2) were used. The proximity-based scenario generator (InVEST) creates a set of contrasting land use change maps that convert habitat in different spatial patterns.

3.2 Preparatory Actions and Agencies Involved (max. 1000 words)

- Discussions were undertaken between the two implementing partners and a programme was chalked out taking in consideration the timelines of the approved project. Reconnaissance surveys were also conducted in the region for preparing a joint action plan.
- Study sites in Himachal Pradesh State were randomly determined by generating random points between the elevation zone of 3000 m to 4000 m and based on the accessibility of generated points we selected 04 sites (More details in Thakur and Chawla (2019)).

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

S. No.	Activity	Objective(s)	Equipment utilized
1.	Mapping of timberlines and Modelling of ecosystem processes	**Objectives 1,3**	High End Workstations
2.	Estimation of phytosociological parameters, recording of geo-coordinates and digital photographs	**Objective 2**	DBH Caliper (Haglof Inc.) Clinometer (Haglof) GPS Receiver (Garmin Montera) Nikon DSLR 7500D Increment borers (Haglof Inc.)
3.	Estimation of Specific Leaf Area in the different study sites	**Objective 2**	Portable Leaf Area Meter with Belt Conveyor (Licor LI3000A)
4.	Analysis of C, N and C: N Ratios	**Objective 4,5**	CHNS Analyzer (varioMICRO CUBE Elementar)
5.	Estimation of K in soil, litter and leaf samples	**Objective 4,5**	Flame Photometer (XP, BWB, UK)
6.	Estimation of Photosynthesis parameters in the targeted timberline species	**Objective 4,5**	Photosynthesis system (Licor 6400 XT)
7.	Annual temperature profile in the different study sites	**Objective 4,5**	Temperature Data loggers (Geoprecision M-Log5W-SIMPLE) Rainfall Data Logger
8.	Estimation of Water Potential of targeted timberline species	**Objective 4,5**	Water Potential System (PMS, 1505D)
9.	Storage and transportation of samples	**Objective 4**	Freezer Minus 20 (Thermoscientific) Liquid Nitrogen Cylinders
10.	For phenological observations and taking video clips of the study sites	**Objective 4,5**	Time Lapse Camera 4K Video Camera

3.4 Primary Data Collected (max 500 words)

The primary data collected was on the following sub-themes: -

- The biodiversity and phytosociology of the timberline forests was studied in the proposed 1 ha and the Modified Whittaker Plots (MWP) in the targeted LTER sites.
- The functional ecology was studied using easily measurable traits of different species belonging to Trees, Shrubs and Herbs found in the timberline zone.
- The biomass and growing stock were estimated for the tree growth-form.

- The species recruitment of tree species was studied using quadrats which are permanently marked in the zone.
- The temperature profiles were obtained using temperature loggers installed in the LTER sites.
- The phenology was studied using Time Lapse Camera installed at one of the LTER sites.
- The ecosystem processes such as Litter fall and litter decomposition were studied in the field for a period of 05 years
- The eco-physiological measurements (such as photosynthetic rate, water potential etc.) were made in the LTER sites at multiple times.
- Besides, all the parameters were estimated which are required for execution of the bio-geo-chemical models (viz., BIOME BGC and CENTURY).

3.5 Details of Field Survey arranged (max 500 words)

S.no.	Field Surveys (Dates)	Days	Location Sites
YEAR 2018			
1	24/05/18 to 02/06/18	08	(i) Sural, Pangi, District Chamba (ii) Mooling, Teh. Lahaul District Lahaul & Spiti (iii) Khanjar, Teh. Udaipur, District Lahaul & Spiti
2	15/06/18 to 18/06/18	02	(i) Chhitkul, Kinnaur
3	22/06/18 to 02/07/18	09	(i) Junda, Teh. Lahaul District Lahaul & Spiti (ii) Stingri, Teh. Lahaul District Lahaul & Spiti
4	19/07/18 to 22/07/18	02	Chhitkul, Kinnaur
5	13/08/18 to 23/08/18	09	(i) Khanjar, Lahaul & Spiti (ii) Mulling, Lahaul & Spiti
6	29/08/18 to 03/09/18	04	(i) Khanjar, Lahaul & Spiti (ii) Triloknath, Lahaul & Spiti
7	07/09/18 to 10/09/18	02	(i) Chhitkul, Kinnaur
8	29Aug-03Sep/2018	04	Khanjar and Triloknath (L&S)
9	07-10 Sep/2018	02	Chhitkul (Kinnaur)
10	06-16 Oct/2018	09	Sural (Pangi), Mooling and Khanjar (L&S)
11	25Oct-01 Nov/2018	06	Sural (Pangi)
12	12-15 Nov/2018	02	Chhitkul (Kinnaur)
13	04-06 Dec/2018	01	CeHAB-Ribling (L&S)
YEAR 2019			
14	27-29 Mar 2019	01	Barot, Badagram, Rulling and Kothikohad
15	25-29 May/2019	03	(i) Chhitkul, Kinnaur
16	30 May-09 Jun/2019	09	(i) Mooling, Teh. Lahaul District Lahaul& Spiti (ii) Khanjar, Teh. Udaipur, District Lahaul & Spiti (iii) Sural, Pangi, District Chamba
17	17-22 Jun/2019	04	Khanjar
18	25-29 Jun/2019	03	(i) Chhitkul, Kinnaur

19	05-18 Jul/2019	12	(i) Mooling, Teh. Lahaul District Lahaul& Spiti (ii) Khanjar, Teh. Udaipur, District Lahaul & Spiti (iii) Sural, Pangi, District Chamba
20	24 Aug-02 Sep/2019	08	(i) Mooling, Teh. Lahaul District Lahaul& Spiti (ii) Khanjar, Teh. Udaipur, District Lahaul & Spiti (iii) Rohtang, Teh. Lahaul District Lahaul& Spiti
21	08-12 Sep/2019	03	(i) Chhitkul, Kinnaur
22	14-25 Sep/2019	10	(i) Mooling, Teh. Lahaul District Lahaul& Spiti (ii) Khanjar, Teh. Udaipur, District Lahaul & Spiti (iii) Sural, Pangi, District Chamba
23	02-07 Oct/2019	04	(i) Chhitkul, Kinnaur
24	15-22 Oct/2019	06	(i) Mooling, Teh. Lahaul District Lahaul& Spiti (ii) Khanjar, Teh. Udaipur, District Lahaul & Spiti (iii) Sural, Pangi, District Chamba
YEAR 2020			
25	24-Aug-2020 to 29-Sep-2020	36	Chhitkul, Mooling, Khanjar, Sural
26	05-13 Oct-2020	07	Chhitkul
27	21-30 Oct-2020	08	Mooling, Khanjar, Sural
YEAR 2021			
28	19-Jun-2021 to 02-Jul-2021	12	Mooling, Sural, Khanjar
29	15-19 Jul-2021	03	Chhitkul
30	23-27 Jul-2021	03	Khanjar
31	07-10 Sep-2021	02	Chhitkul
32	23-30 Sep-2021	06	Mooling, Khanjar, Sural
33	4-10 Oct-2021	05	Khanjar
34	24-27 Oct-2021	02	Chhitkul

3.6 Strategic Planning for each Activities (max. 1000 words)

- For setting up of the LTER sites, we mapped the timberline zone of Himachal Pradesh using a DEM, assuming the normal elevation range of treeline and utilized this zone for selecting of the sites based on random occurrences of sites. For this sufficient number of random points were generated in GIS environment, these numbers were narrowed down to 11 points based on the criteria of accessibility and baseline surveys were performed (details in Chawla and Thakur, 2019) and 04 sites were selected randomly out of this set and further studies were conducted in the timberline zone at these sites.
- In the selected 04 sites, watershed areas were defined, treelines were mapped and these were utilized for plots establishment.
- Appropriate sites were also chosen on the opposite location of the LTER sites, where phenocams could be installed, the places where the cameras could be safely installed and gives a synoptic view of the timberline patch under study.
- The species diversity and other ecosystem processes were studied at appropriate times during the growth cycle of dominant and other associated species.
- The litterfall was estimated on a monthly basis from June-Sep every year. For nutrient resorption and litter decomposition studies, samples were taken at 03 times, every year.

- The quadrats were permanently marked for estimating the tree species recruitment.
- The awareness programmes were only conducted during the autumn season before the snowfall. Further, requisite information was collected in the form of questionnaires to estimate the future LULC scenarios of the landcover of watersheds.

3.7 Activity wise Time frame followed [using Gantt/ PERT Chart (max. 1000 words)]

S.N.	Activities	Months							
		6	12	18	24	30	36	42	45
1	Mapping of the timberline zone								
2	Setting up of LTER plots in the timberline zone of Himachal Pradesh								
3	Recording of phenology of key tree species and annual temperature								
4	Studying species distribution, ecology and ecophysiology of the timberline zone								
5	Snowline estimation and its effect on timberline ecosystems								
6	Estimation of NPP, nutrient conservation and nutrient recycling studies								
7	Model development for future predictions of likely impacts of climate change								
8	Participation of stakeholders in research and scenario planning studies								
9	Creating awareness among stakeholders and general public								
10	Compilation of project reports								

4 KEY FINDINGS AND RESULTS

4.1 Major Research Findings (max. 1000 words)

- The study resulted in valuable temperature datasets recorded over 05 years
- The study also resulted in generating the baseline datasets on species diversity, functional traits and eco-physiology of the timberlines
- The ecosystem processes such as litter decomposition and nutrient resorption efficiency was studied, which are important in estimating the Net Primary Productivity and form important inputs in future prediction of these variables.
- Our simulations of ecosystem processes in the forest ecosystem demonstrated that the model Biome-BGC may be used to calculate NPP and WUE of various forest species and CENTURY Model could be used to partition allocation of biomass in the various components.

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

Objective 1: To map timberline zone in Himachal Pradesh region of western Himalaya

- Timberline zone for the State of Himachal Pradesh was delineated using a high-resolution DEM (30m spatial resolution).
- Watershed maps of the study sites (Chhitkul, Mooling, Khanjar and Sural) were delineated with monitoring areas located on it.
- Each watershed was classified into different land and vegetation types (Supervised Classification) utilizing Sentinel 2A datasets of September 2020.

- Treeline was delineated in the watershed areas of the study sites. These were at a mean elevation of 4215m, 3579m, 3653m, and 3954m for Chhitkul, Mooling, Khanjar and Sural respectively.

Objective 2: To study plant populations, community structure and functional ecology in the LTER sites

- The main dominant tree species at the study sites were *Betula utilis* (mean DBH = 7.92 cm; mean height = 4.4 m) and *Pinus wallichiana* (mean DBH = 16.4 cm; mean height = 5.4 m).
- All the study sites harboured a mean richness of 44 under-canopy species.
- The Specific Leaf Area (SLA) of trees varied between 137.08 to 161.62 cm^2/g across the 04 sites and height ranged from 5.36 to 8.21 m for *Betula utilis* and from 5.64 to 10.31 for *Pinus wallichiana*. Further, the SLA and Height for shrubaceous life forms ranged from 169.83 to 242.96 cm^2/g and from 93.39 to 112.37 cm respectively. For Herbaceous life forms, the SLA and height ranged from 199.00 to 239.31 cm^2/g and from 17.03 to 25.91 cm respectively.

Objective 3: To study effect of changing snow cover extent on species diversity and recruitment patterns

- Snow cover was analysed for the different watersheds for time-period between October and June from 2014-20.
- The yearly average snow cover was found to be 71%, 44%, 80% and 67% for Chhitkul, Mooling, Khanjar and Sural respectively.
- The tree species recruitment of *Betula utilis* recorded at the study sites was highest at Sural (924 saplings/ha), followed by Mooling, Chhitkul and Khanjar.

Objective 4: To study phenology of key species, net primary productivity, nutrient dynamics and eco-physiology in the LTER sites

- The mean annual temperature recorded at the study sites was 5.5 ºC and the growing season mean temperature was found to be 9.9 ºC.
- The phenocam installed to take pictures of forest patch revealed the date of start of different phenophases and suggested a growing season of 149 days.
- Nutrient Resorption in *Betula utilis* for N, P, K is approximately 48%, 55 %and 35% respectively.
- Mean Litter-fall in the LTER sites is approximately 860 per ha/year.
- Leaf litter decomposition for *Betula utilis* suggested that the magnitude of mass loss and decay rate was found to be greater for up to 34 weeks (19.03 ± 4.55% and 0.35 ± 0.06 yr-1 respectively). There was an increase in N and decrease in C: N and lignin: N ratios with incubation time.
- The photosynthesis net rate is from 3.4 to 8 µmol CO_2 m^{-2} s^{-1} and water potential -1.19 to -1.12 MPa.

Objective 5: To undertake predictive modelling for projecting future changes in vegetation

- The DayCent CENTURY Model was parameterized and it was found that the *Betula utilis* species in timberline forests had a total biomass ranging from 135.73 to 266.73 g C m^{-2} whereas, the total soil carbon ranged from 2505.76 to 4242.98 g C m^{-2}. Besides, the allocation of carbon in different pools of forest ecosystem such as large wood biomass (82.91 to 143.58 g C m^{-2}), leaves (0.18-0.24 g C m^{-2}), coarse roots (18.80 to 36.01 g C m^{-2}) *etc*. was also estimated.
- The BIOME BGC model was also parameterized which revealed that mean values of simulated NPP ranged from 14.46 to 30.4 $gC/m^2/yr$ and for simulated Water Use Efficiency (WUE), these ranged from 0.033 to 0.075 g $m^{-2}mm^{-1}$.

Objective 6: To integrate with modelled projections, the scenario studies by involving local stakeholders for understanding the future of their landscape

- 03 probable future scenarios were modelled using InVest model: Forests encroaching into alpine Grasslands, Agricultural land expansion in to forest edges, and decrease in snow cover
- The above-mentioned scenarios were based on perceptions of people living in the watershed and in the vicinity.
- Besides, 09 Awareness Programmes were conducted and 04 workshops organised.

4.3 Conclusion of the study (maximum 500 words in bullets)

- With the available spatial resolution of satellite datasets, the treelines can be delineated at watershed and landscape levels with fairly good accuracy and utilizing historical datasets, the rate of upward movement can be studied.

- The community structure and phytosociological aspects were revealed for the alpine timberlines at the LTER sites, which form important baseline data for studies to be undertaken in future.

- Studying nutrient cycling and eco-physiology revealed key insights on ecosystem processes in the LTER sites, which in turn were utilized to train models to get fairly accurate estimates of simulated NPP and WUE which correlated well with the field derived data.

- The future predictions showed a decreasing trend in various RCP scenarios for the year 2050.

5 OVERALL ACHIEVEMENTS

5.1 Achievement on Project Objectives [Defining contribution of deliverables in overall Mission (max. 1000 words)]

The overall achievements for the Project Objectives are described under the Deliverables sub-heads, which are given as follows: -

(I) More and updated socio-ecological information on alpine timberline ecosystems of western Himalaya (HP) for understanding drivers of change

The project started with selection of 04 sites already established in the timberline zone of Himachal Pradesh, which was delineated using a high-resolution DEM. A preliminary experiment on leaf litter decomposition had also been initiated. Besides, a set of temperature data loggers have been placed in the air and soil at all these sites.

With this background, under various objectives of the Project, specific activities were initiated for generating the baseline datasets on the timberlines. An accurate timberline zone map of Himachal Pradesh State was prepared using a high-resolution DEM, and for the 04 sites, watershed maps were prepared. These 04 watersheds were later classified into land and vegetation classes (supervised classification) utilizing latest SENTINEL satellite datasets, and the treelines were delineated in these watersheds using NDVI data. The snow cover extent patterns were also analyzed for a period of 06 years from 2014-2020 (as per data available for all the sites). The temperature datasets (recorded for a period of 05 years), suggested mean annual temperature recorded at the study sites was 5.5 ºC, and the growing season mean temperature was found to be 9.9 ºC.

In the watersheds, which represented the LTER sites, phytosociological and species diversity studies were undertaken in 01 ha plot in the timberline zone, which were permanently marked along with a set of 03 0.1 ha rectangular Modified Whittaker Plots (Chawla et al., 2012). The main dominant species were *Betula utilis* (mean density of /sq.ha) and *Pinus wallichiana* (mean density of /sq.ha). Since, *Betula utilis*, a deciduous tree species, formed the most dominant species, this was targeted for subsequent studies on nutrient cycling and other ecosystem processes. The tree species recruitment of *Betula utilis* recorded at the study sites was up to 924 saplings/ha), which would be utilized for future comparisons. The recent installation of phenocam at one of the study sites, revealed data on growing season, which suggested this period to be of 149 days.

Similarly, other climatic, phytosociological and eco-physiological variables were estimated which are used to parameterize the bio-geochemical models for predictions about different ecosystem processes in the timberline zone. One of the key parameters determined are Nutrient Resorption Efficiency (NRE) of *B. utilis* for macro-nutrients (N, P and K), water potential and photosynthesis parameters. This study revealed high NRE for N and P (48% and 55% respectively).

The experiment on litter decomposition was carried out for almost 5 years, and suggested that the initial nutrient concentration and lignin content of litter was significantly different for the sites. Further, magnitude of mass loss and decay rate was found to be greater for up to 34 weeks (19.03 ± 4.55% and 0.35 ± 0.06 yr^{-1} respectively). There was an increase in N and decrease in C: N and lignin: N ratios with incubation time.

Snow cover

In order to estimate the area under snow cover in the study area, the snow cover products were generated using the NDSI method. The snow cover products were generated for the period 2014-2020 from October to June each year. Based on the analysis carried out, it is observed that all the four sites, i.e., Chhitkul (Kinnaur), Mooling (Lahaul & Spiti), Khanjar (Lahaul & Spiti) and Sural Bhaturi (Chamba) of Himachal Pradesh showed different trends. The early winter trend for all the sites was the same, i.e., a positive trend was observed during the period 2014-20. Likewise, the peak winter trends also showed a positive correlation, i.e., the snow cover has increased every year, showing an increasing trend, whereas in the late winter, i.e., from April to June, almost all except Mooling LTER site, the basin showed a decreased area under seasonal snow cover, which is mainly due to the fact that the temperature effect is more pronounced after March onwards, resulting in the vacation of the snow cover area. As far as the seasonal snow line variation is concerned, it is observed that the average snow line over six years, i.e., 2014-2020, for Chhitkul, Mooling, Khanjar, and Sural Bhaturi was 3626m, 3242m, 3847m, and 2917m amsl respectively.

(II) Knowledge bank on likely impacts of climate change in the future at landscape levels;

In order to study probable impacts of climate change on the timberline forests, three modelling approaches were utilized: BIOME BGC Model, CENTURY Model and the InVEST Model. The output from Biome BGC Model revealed information on Net Primary Productivity, which showed comparative values for the 05 years of study period (from 2017-2021) and ranged from 14.46±0.14 gC/m2/yr to 30.40±3.86 $gC/m^2/yr$. With the help of CENTURY model, the carbon pool was partitioned in different components of the timberline forests (such as leaf biomass, fine root, coarse root, fine branches, large wood, above ground and belowground biomass) and it was found that the total biomass ranged from 135.73 gC/m^2 to 266.73 gC/m^2. The InVEST model was utilized to map the changes in landcover types in the watershed based upon people's perceptions, and were able to visualize the changes that would occur in future in different land cover types.

(III) Strategy inputs for managers and policy makers for conservation of timberlines;

The baseline data on biodiversity status could form the basis of declaring biodiversity heritage sites (BHS) and sanctuaries. The future projections about the carbon sequestration potential is another dataset which will help the forest managers to present a strong case for the protection and conservation.

(IV) Awareness among various stakeholders in 5 tribal districts.

A total of 13 awareness programmes/workshops were conducted in 5 tribal districts of Kangra, Chamba, Lahaul and Spiti, Kinnaur and Mandi

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

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

- 03 models (BIOME BGC, CENTURY, InVEST) were trained using more than 40 variables most of which were derived from field measurements
- Meteorological, site specific and eco-physiological variables were utilized to train the model.
- The output from Biome BGC Model revealed information on Net Primary Productivity, which showed comparative values for the 05 years of study period (from 2017-2021) and ranged from 14.46±0.14 gC/m2/yr to 30.40±3.86 gC/m2/yr. With the help of CENTURY model, the carbon pool was partitioned in different components of the timberline forests (such as leaf biomass, fine root, coarse root, fine branches, large wood, above ground and belowground biomass) and it was found that the total biomass ranged from 135.73 gC/m^2 to 192.01 gC/m^2.
- The InVEST model was trained based on perceptions of people living in the vicinity as to how they perceive the land use/landcover changes which has happened in the past decades.

5.4 Technological Intervention (max 1000 words)

- Use of latest high resolution satellite images (Sentinel 2A and MODIS) and high-resolution DEM for mapping and delineation of treelines
- Use of Biogeochemical Models (BIOME BGC and CENTURY)
- Use of phenocams for monitoring phenology of forest patches
- Use of temperature loggers for measurement of annual temperatures

5.5 On field Demonstration and Value-addition of Products (max. 1000 words, in bullet points)

Not Applicable

5.6 Promoting Entrepreneurship in IHR

Not Applicable

5.7 Developing Green Skills in IHR

Not Applicable

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

During the project we tried to address NMHS cross-cutting issues including climate proofing, gender equality and communication.

- In this project we studied impacts of climate change on ecosystems on a scale at which it influences the livelihoods of local communities.
- The studies were carried out in a participatory mode, where all the stakeholders have an active role. In all the village surveys and deliberations, there were adequate representation of women and equal weightage was given to their views, thus abiding by gender equality principles.
- Communication with all the stakeholders (local communities, forest and local administration officials, school children, youth etc.) was undertaken wherever and whenever possible.

6 PROJECT'S IMPACTS IN IHR

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

Not applicable

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

- Baselines on biodiversity of the alpine timberlines were generated at 04 sites in Himachal Pradesh State with species richness ranging from 37-51 species.
- The knowledge and dataset on growing stock of forests helps not only in conservation but also effective management of timberline forests.
- The activities undertaken on the project resulted in knowledge on key ecosystem processes such as litter dynamics, nutrient resorption and estimation of net primary productivity, through long term monitoring. Besides the temperature data-loggers installed in the sites have generated crucial annual temperature datasets.
- The ecological modelling undertaken on the field datasets generated in the project indicates changes in productivity of forests, that might take place in future.
- The future monitoring of these forests would result in validating the predictions as well as yielding important information on essential biodiversity variables and thus important insights on key ecosystem processes.

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

- The baselines on biodiversity of the alpine timberlines were generated at 04 sites in the timberline forests of Himachal Pradesh.
- Previously, the biodiversity and species turn-over were described from sub-alpine to treeline zone for these locations (Thakur and Chawla, 2019).
- Species recruitment is being monitored in these sites with permanently marked quadrats.

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

- 02 (Sural and Khanjar along with adjacent valleys), were considered for being designated as Biodiversity Heritage Sites by H.P. State Biodiversity Board, and if designated would be a milestone long way in protecting the pristine environment.

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

- The LTER sites (with Phenocam, dataloggers installed) studied in the project would continue to be utilized for further studies and long-term monitoring, and would form an important component of mountain infrastructure.

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

- The setting up of LTER sites would be utilized for collaborative research with different institutions and organizations across Himalaya.

7 EXIT STRATEGY AND SUSTAINABILITY

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

The project findings deal with the generation of biodiversity and habitat characterization of the LTER sites, and essentially this gives the habitat baselines of timberlines forests, which form important habitats of Brown Bear and other important animals dwelling in the upper region of these mountains. With these baselines, other studies on the faunal distribution could be initiated for their conservation.

The projections from different models which suggest expansion of the timberlines (in the form of upward shifts) could result in loss of snow leopard habitats in the region.

The results of ecosystem level processes and the outputs from bio-geo-chemical models have been proposed specific to *Betula utilis*, which has a wide range of occurrence across the IHR and therefore, the results would also hold true for other regions in IHR as well.

The future impacts on timberlines have been predicted, from the models utilized in the study. The reduction in Net Primary Productivity as projected in different future scenarios, is a cause of concern and such results will be an important factor in formulating any management practices in the sub-alpine and timberlines forests.

7.2 Efficient ways to replicate the outcomes of the project in other parts of IHR (Max 1000 words)

Other species and ecosystems

The outcomes of the project should also be applicable in other sites with different climates across the IHR. However, the variability could be studied by undertaking similar studies in LTER sites across different parts of IHR.

7.3 Identify other important areas not covered under this study needs further attention (max 1000 words)

- Downscaling of climate datasets (derived from GCMs, present and future) for better prediction of ecosystem models at landscape or regional scales
- Targeting more treeline forming species for long-term studies
- Drone based remote sensing of alpine timberlines for extracting ecosystem level biophysical and eco-physiological attributes

7.4 Major recommendations for sustaining the outcome of the projects in future (500 words in bullets)

- Continuation of ecosystem monitoring in the timberlines with recording of temperature and phenocam data and long-term monitoring of ecosystem processes such litterfall and litter decomposition
- Validation of model results (BIOME BGC and CENTURY) by recording required variables in the LTER sites.
- Future surveys for knowing the changes in species recruitment rates.

8 REFERENCES/BIBLIOGRAPHY

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9 ACKNOWLEDGEMENT

- State Forest Department, Government of Himachal Pradesh

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 filled
Appendix 7 – Any other (specify)

******

Annexure-I

Consolidated and Audited
Utilization Certificate (UC) and Statement of Expenditure (SE)

For the Period: 01/04/2018 to 31/12/2021

1.	Title of the project/Scheme/Programme:	Understanding the Nature of Alpine timberlines of Himalaya: Integrating Ecological and Scenario Studies for assessing the Impact of Climate Change
2.	Name of the Principal Investigator & Organization:	**Sh. Satpal Dhiman, Joint Member Secretary** Himachal Pradesh Council for Science, Technology & Environment (HIMCOSTE), Shimla
3.	NMHS-PMU, G.B. Pant National Institute of Himalayan Environment, Kosi-Katarmal, Almora, Uttarakhand Letter No. and Sanction Date of the Project:	GBPNI/NMHS-2017-2018/SG23/621, 28-03-2018
4.	Amount received from NMHS-PMU, G.B. Pant National Institute of Himalayan Environment, Kosi-Katarmal, Almora, Uttarakhand during the project period (Please give number and dates of Sanction Letter showing the amount paid):	**Total = Rs. 45,01,737/-** Sanction letter & Date **1st Installment: 16,69,740/-** GBPNI/NMHS-2017-18/SG23/621 Dated 28/03/2018 **2nd Installment: 15,60,980/-** GBPNI/NMHS-2017-18/SG23/621/151/334 Dated 07/11/2019 **3rd Installment: 12,71,017/-** GBPNI/NMHS-2017-18/SG23/621/151/334/16/310 Dated 05/02/2021
5.	Total amount that was available for expenditure (Including commitments) incurred during the project period:	**Rs. 46,06,096/-** (Including Interest earned for four years **i.e.,** Rs. 1,04,359/-)
6.	Actual expenditure (excluding commitments) incurred during the project period:	**Rs. 41,50,635/-**
7.	Unspent Balance amount refunded, if any	**Rs. 1,16,977/- vide Cheque no. 551010**

	(Please give details of Cheque no. etc.):	**Dated 16/08/2021**
8.	Balance amount available at the end of the project:	**Rs. 3,38,484/-**
9.	Balance Amount:	**Rs. 3,38,484/-**
10.	Accrued bank Interest:	Rs. 1,04,359/-

Certified that the expenditure of **Rs. 41,50,635/- (Rupees Forty-one lakh fifty thousand six hundred thirty five only)** mentioned against Sr. No. 6 was actually incurred on the project/scheme for the purpose it was sanctioned.

Date:

(Signature of Principal Investigator)

Joint Member Secretary
State Council for Science, Tech. &
Environment, Shimla-171009

(Signature of Registrar/ Finance Officer)

Assistant Controller (F&A)
State Council for Science, Tech. &
Environment, Shimla-171009

(Signature of Head of the Institution)

Joint Member Secretary
State Council for Science, Tech. &
Environment, Shimla-171009

OUR REF. No.

ACCEPTED AND COUNTERSIGNED

Date:

COMPETENT AUTHORITY
NATIONAL MISSION ON HIMALAYAN STUDIES (GBP NIHE)

Statement of Consolidated Expenditure

[Institution Name here]

Statement showing the expenditure of the period from (01/04/2018 to 31/12/2021)
Sanction No. and Date : GBPNI/NMHS-2017-18/SG23/621 Dated 28/03/2018

1. Total outlay of the project : Rs. 48,45,220/-

2. Date of Start of the Project : 01/04/2018

3. Duration : 3 Years 9 Months

4. Date of Completion : 31/12/2021

a) Amount received during the project period : Rs. 45,01,737/-

b) Total amount available for Expenditure :**Rs. 46,06,096/- (Including Interest earned for four years i.e., Rs. 1,04,39/-)**

S. No.	Budget head	Amount received	Expenditure	Amount Balance/ excess expenditure
1	Salaries	13,85,970/-	13,92,673/-	-6,703/-
2	Permanent Equipment Purchased (Item-wise	3,00,000/-	3,00,000/-	0/-
3	Consumables	11,19,049/-	9,11,384/-	2,07,665/-
4	Contingencies	2,08,977/-	1,40,586/-	68,391/-
5	Travel	13,07,608/-	11,40,099/-	1,67,509/-
6	Other Cost	-	59,000/-	-59,000/-
7				
8				
9				
10	Institutional charges	1,80,133/-	206893/-	-26,760/-
11	Accrued bank Interest	1,04,359/-*	-	1,04,359/-
12	**Total**	46,06,096/-	41,50,635/-	4,55,461/-

***Rs. 1,16,977/-** has been refunded to NMHS GIA General vide Cheque no. 551040 dated 16/08/2021

***Rs. 1,04,359/-** consolidated interest earned during project

(Interest for 3 F.Y. was adjusted against institutional charges and consumables heads). The interest for 4th year, the extension period is included in the balance of Rs. 3,38,484/-

Certified that the expenditure of **Rs. 41,50,635/- (Rupees: Forty-one lakh fifty thousand six hundred thirty-five only)** mentioned against Sr. No.12 was actually incurred on the project/ scheme for the purpose it was sanctioned.

Date:

(Signature of Principal Investigator)

Joint Member Secretary
State Council for Science, Tech. & Environment, Shimla-171009

(Signature of Registrar/ Finance Officer)

Assistant Controller (F&A)
State Council for Science, Tech. & Environment, Shimla-171009

(Signature of Head of the Institution)

Joint Member Secretary
State Council for Science, Tech. & Environment, Shimla-171009

OUR REF. No.

ACCEPTED AND COUNTERSIGNED

Date:

COMPETENT AUTHORITY
NATIONAL MISSION ON HIMALYAN STUDIES (GBP NIHE)

Annexure-II

Consolidated Interest Earned Certificate

Please provide the detailed interest earned certificate on the letterhead of the grantee/ Institution and duly signed.

H.P. COUNCIL FOR SCIENCE, TECHNOLOGY & ENVIRONMENT (HIMCOSTE),
Vigyan Bhawan, Nr. Udyog Bhawan, Bemloe, Shimla-1
Tel Number: 0177-2656489, Fax Number: 0177-2814923
www.himcoste.hp.gov.in

CONSOLIDATED INTEREST EARNED CERTIFICATE

An amount of **Rs. 1,04,359/- (Rs. One lakh four thousand three hundred fifty-nine only)** is the interest earned during the project period **(01/04/2018 to 31/12/2021).** The year wise interest earned given in the table:

Year	Amount
2018-19	26,760/-
2019-20	41701/-
2020-21	23782/-
2021-22 (01/04/2021-31/12/2021)	12,116/-
Total	**1,04,359/-**

(Signature of Principal Investigator)

(Signature of Registrar/ Finance Officer)

(Signature of Head of the Institution)

Joint Member Secretary
State Council for Science, Tech. & Environment, Shimla-171009

Annexure-III

Consolidated Assets Certificate

Assets Acquired Wholly/ Substantially out of Government Grants

(Register to be maintained by Grantee Institution)

Name of the Sanctioning Authority: NMHS

1. Sl. No. _____
2. Name of Grantee Institution: CSIR-IHBT PALAMPUR
3. No. & Date of sanction order: GBPNI/NMHS-2017-18/SG123 Dated 28.03.2018
4. Amount of the Sanctioned Grant: ₹ 48,45,220.00 (3,00,000.00) for Equipment
5. Brief Purpose of the Grant: Understanding the Nature of Alpine Timberlines of Himalayan: Integrating Ecological and Scenario Studies for Assessing the Impact of Climate Change.
6. Whether any condition regarding the right of ownership of Govt. in the property or other assets acquired out of the grant was incorporated in the grant-in-aid Sanction Order: _____
7. Particulars of assets actually credited 1) Time Lapse Camera 2). Gopro Hero 5 Black or acquired _____
8. Value of the assets as on 1.) ₹ 2,75,000.00 2.) ₹ 25,000.00
9. Purpose for which utilised at present For recording of Phenology of study species and for Vidio recording of study site.
10. Encumbered or not _____
11. Reasons, if encumbered _____
12. Disposed of or not N/A
13. Reasons and authority, if any, for disposal N/A
14. Amount realised on disposal N/A

Any Other Remarks: _____

08/02/2023

(PROJECT INVESTIGATOR)
(Signed and stamped)

7/2/2023

(FINANCE OFFICER)
(Signed and Stamped)

7/2/2023

(HEAD OF THE INSTITUTION)

(Signed and stamped)

निदेशक
सी.एस.आई.आर–हिमालय जैवसंपदा प्रौद्योगिकी संस्थान
पालमपुर– 176061 (हि.प्र.)

Annexure-IV

List or Inventory of Assets/ Equipment/ Peripherals

S. No.	Name of Equipment	Quantity	Sanctioned Cost	Actual Purchased Cost	Purchase Details
1.	Time Lapse Camera System Complete	01.	2,75000.00	2,75,000.00	
2.	Gopro Hero5 Black Action Cameras	01.	25,000.00	25,000.00	

08/02/2023

(PROJECT INVESTIGATOR)

(Signed and stamped)

7/4/2023

(FINANCE OFFICER)

(Signed and Stamped)

11.2.23

(HEAD OF THE INSTITUTION)

(Signed and stamped)

निदेशक
सी.एस.आई.आर–हिमालय जैवसंपदा प्रौद्योगिकी संस्थान
पालमपुर– 176061 (हि.प्र.)

Annexure-V

Letter of Head of Institution/Department confirming Transfer of Equipment Purchased under the Project to the Institution/Department

To,

The Convener, Mountain Division
Ministry of Environment, Forest & Climate Change (MoEF&CC)
Indira Paryavaran Bhawan
Jor Bagh, New Delhi-110003

Sub.: Transfer of Permanent Equipment purchased under Research Project titled "...." funded under the NMHS Scheme of MoEF&CC – reg.

Sir/ Madam,

This is hereby certified that the following permanent equipment purchased under the aforesaid project have been transferred to the Implementing Organization/ Nodal Institute after completion of the project:

1. Time Lapse Camera System complete
2. Gopro Hero5 Black Action Cameras
3. .....
4. .....
5. .....
6. .....
7. .....

Head of Implementing Organization:
Name of the Implementing Organization:
Stamp/ Seal:
Date: 11/02/2023

निदेशक
सी.एस.आई.आर–हिमालय जैवसंपदा प्रौद्योगिकी संस्थान
पालमपुर– 176061 (हि.प्र.)

Copy to:

1. The Nodal Officer, NMHS-PMU, National Mission on Himalayan Studies (NMHS), G.B. Pant National Institute of Himalayan Environment (NIHE), Kosi-Katarmal, Almora, Uttarakhand-263643

Annexure-VI

Details, Declaration and Refund of any Unspent Balance

Please provide the details of refund of any unspent balance and transfer the balance amount through 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

*Rs. 1,16,977/- has been refunded in favor of NMHS GIA General vide Cheque no. 551040 Dated 16/08/2021

*Rs. 3,38,484/- has been refunded in favour of NMHS GIA General vide Cheque no. 991969 Dated 22/03/2023