Timberline and Altitudinal Gradient Ecology of Himalayas and Human Use Sustenance in a Warming Climate

Under

National Mission of Himalayan Studies (NMHS)
Ministry of Environment, Forest &Climate Change
Govt. of India, New Delhi

Annual Progress Report: FY-2017-2018

Submitted to

G.B.Pant National Institute of Himalayan Environment & Sustainable Development
Kosi-Katarmal, Almora

From

Central Himalayan Environment Association
Naiital (Uttarakhand), India

National Mission of Himalayan Studies
Annual Progress Report
(Period *from* April 2017 *to* March 2018)

1. Project Information

Project ID:	NMHS/LG-2016/009	**Sanction Date:**	31-03-2016

Project Title:	Timberline and Altitudinal Gradient Ecology of Himalaya and Human use Sustenance in a warming climate
BTG:	Conservation and Sustainable Use of Biodiversity

PI and Affiliation (Institution):	Prof. S. P. Singh Central Himalayan Environment Association (CHEA)
Name & Address of the Co-PI, if any:	NA
Structured Abstract - detailing the current year progress [Word Limit 250 words]:	The year 02 was the year of intensive data collection involving 21 research scholars and 10 PIs. As far as possible field visits were synchronized to strengthen collaboration. The coordinator was in continuous touch with individual PIs, engaging them in discussions, monitoring of raw data and data interpretation. The book entitled "Manuals of field methods" for timberline studies was published, which involved "a team research approach". The data collected was shared through poster presentations of each component under IHTRP in a workshop, Dehradun organized by CHEA in collaboration with IHCAP. Honorable CM of the state took interest and appreciated the importance of timberline. The concept and importance of timberline and the research achievements under this project were disseminated among youngsters, academicians, researchers and politicians. Several presentations were made by coordinator at different platforms e.g. International Seminar on Biodiversity Conservation and Cllimate Change held at IIT, Khadakpur A special issue of *Tropical Ecology* is being devoted to the studies conducted under this project and 14 research papers are being communicated to *Tropical Ecology* research journal. In most of the components the targets have not only been achieved, but exceeded. One of the major limitations of this project is that the field work time is very short though we tried to prolong it by trying to sample in early spring and autumn in difficult situations. It showed that normally such studies should be of long term at least of 05 years, which is the case with the original proposal.

Here is a summary of summaries provided by PIs and a preliminary synthesis of them.

1. **Timberline Mapping** (Subrat Sharma and his team, GBPNIHESD, Kosi- Katarmal, Almora. **Regional Timberline in Uttarakhand State:** For the first time a regional timberline (UK) was mapped revealing some facts unknown earlier. For this remote sensing techniques were applied. The total length of timberline is about 2,750.47 km in the entire state of Uttarakhand, which is several times longer than the width of the state. The timberline takes a zig-zag course between 2600 and 4366m elevation. It shows that timberline above 4000m elevation may be common in Himalayas not confined to Tibet or some other such sites. More than half (57.6%) of the total timberline of the state occurs between 3400m and 3800m altitude. Timberline can be both continuous type (>90%) and island or dot types.
2. **Temperature Lapse Rate (TLR) and Precipitation Gradient** (Rajesh Joshi and his team, GBPNIHESD, Kosi-Katarmal, Almora). This is the first TLR estimate from Indian Himalayas based on observed data along an elevation transect. The mean annual TLR in CT transect is found less steep (-0.53^0C/100m) than the commonly used global value (-0.65^0C/100m). It varied considerably from one season to other and between the aspects. The low TLR may indicate the impact of climate change as temperature increase is elevation dependent.
3. **Vegetation and species diversity along elevational gradient in three study region** (Zafar A. Reshi, Kashmir University; R.S Rawal, GBPNIHESD, Kosi-Katarmal, Almora; Devendra Kumar, GBPNIHESD, Sikkim Unit).

   The species richness data measured continuously in 100 m elevation bands were as following: In Kashmir site between 2200 and 3800 m 425 plant species of 268 genera and 170 families. Of these 194 were angiosperms, 4 gymnosperms, 33 pteridophytes, 39 bryophytes and 159 lichens. The tree species number was 8. The species richness curve along the elevation gradient varied, trees showing declining trend with altitude, shrubs with mid-elevation hump and herbs a plateau. At Uttarakhand site between 2000 and 3500 m (05 transects) the values were as following: total species number 1471 with 106 trees, 233 shrubs, and 1132 herbs. The values were highest between 2000-2500 m elevation. In Sikkim between 3000 and 4000 m, 101 species were recorded belonging to 80 genera and 46 families.

   The main timberline species were *Betula utilis*, *Abies spectabilis*, and *Pinus wallichiana* in Kashmir: *A. spectabilis* and *A. pindrow* were the main timberline species along with *B. utilis* and *Sorbus* in Uttarakhand; in Sikkim *A. densa* was the main timberline species. However, there were several species of rhododendrons in Sikkim. In Kashmir and Uttarakhand. *R. campanulatum* was common krummholz species.

3. **Phenology** (G.C.S Negi and his team, GBPNIHESD). Tungnath is characterized by a markedly higher mean growing season and temperature higher than the climatic treelines of the world (11.2°C vs. 6.7°C) and mean soil temperatures (6.4°C at 10 cm depth vs. 9.8°C at 30 cm depth at Tungnath). The tree species occupying timberline varied considerably in leaf size, leaf mass loss and N resorption during senescence. The leaf size was smallest for the tallest species and largest for the krummholz forming *R. campanulatum.*

4. **Tree water relations** (Ashish Tewari and his team, Kumaun University). During in year 02, all the studied species were measured for water potential; osmotic adjustment and leaf conductance at moist Tungnath site in Uttarakhand and dry Chitkul site in Himachal Pradesh. At Tungnath, trees were seldom water stressed, the most negative water potential being -1.2 m Pa ± 0.027. Interestingly, the daily change in water potential was highest during rainy season (always more than 1 m Pa), which is not the case in trees of low altitudes. Even at dry Himachal site trees were not water stressed. Osmotic adjustments were relatively small compared to lower altitude trees. Soil moisture was adequate at 60cm depth in all seasons. Leaf conductance values at Tungnath site for birch reached up to 304.6±5.23 m mol $m^{-2}sec^{-1}$. Interestingly, leaf conductance values are much higher at the drier site in the morning hours (up to 1323.3±100.4 m mol $m^{-2}sec^{-1}$). However, the conductance dropped rapidly as day progressed. Seed germination and water content behavior differed significantly in large seeded *Quercus semecarpifolia* and very small seeded *R. campanulatum*.

5. **Livelihood interventions** (Pankaj Tewari and his team, CHEA). After investigating socio-ecological background of the study area following interventions with regard to livelihood were carried out : off-season vegetable cultivation, mushroom cultivation etc. Approximately 5.5 ha area have been covered under high value crops for enhancing the income among 170 families. Vegetable were produced by beneficiaries (both from poly house and open farm) worth Rs. 15,12,500.00 including income of Rs. 4,50,000.00. A total of 160 Kg of mushroom was produced in two consecutive seasons, worth Rs. 90,000 in the nearby markets including direct income of Rs. 40,000. The fodder demonstration was made in 1.5 ha area in terraces by 70 individuals. In all, 56 quintal (190 head loads) of fodder has been harvested.

   Refresher on "Carbon Sequestration Measurement" was conducted during second year to strengthen the skills of youths and to popularize the citizen science. Tourism which is a major activity in the area, was also taken up for promotion. An introductory training on bird watching along with several awareness camps and meetings were organized in both the villages to promote responsible tourism, citizen science, biodiversity conservation, and solid waste management in the zone. Attempts such as

establishment of dustbins and degradable bags in Tungnath trek, management of horse/ponies waste on Tungath trek, etc. were made to reduce waste in CTS, in collaboration with temple committee, horse union and local villagers. Floriculture, another livelihood intervention demonstrated in the initial phase of the project and continued. To address the main concern i.e. Solid Waste Management in the tourism zone (Chopta-Tungnath), several meetings were organized with temple committee, horse union, village representative, Van Panchayat committee and district magistrate.

6. **Tree ring chronologies** (P. S. Ranhotra and his team, BSIP). Trees within the altitudinal transect of ~2780-3364 m amsl at Tungnath site were dated and calculated for Age and Diameter at breast height (DBH), and correlation models are developed between Age-DBH, DBH-Altitude and Age-Altitude for analyzing the age stand structure and tree line dynamics of Himalayan fir. Developed mean chronology of ~ 317 years for *A.spectabilis* which extends back to 1699 AD. Correlation between tree ring width and climate (temperature and precipitation) has also been established using the gridded climate data (CRU-TS.422) for the Tungnath region. Carried out field works in May and September 2017 to Daksum (~2400 m amsl) and Sinthan top (~3800 m amsl), south Kashmir, J&K.
7. **Snow removal experiment** (B.S.Adhikari and his team, WII Dehradun). In year 02, snowfall was measured and pattern analysed. The study is being carried out at Tungnath region, which is in the upper catchment of Alaknanda river in Chamoli District, Uttarakhand. The elevation ranged from 2900 m to 3680 m a.s.l. (subalpine to alpine). Five major communities viz. *Trachydium*, Mixed herbaceous, *Polygonum*, mixed *Danthonia* and *Danthonia* were selected as permanent sites to monitor structure, composition and phonological changes at spatio-temporal scale. Overall plant density decreased from May to June, and remained stable until September. The species richness across communities roughly ranged between 25 and 30 species during the stable phase of vegetation from July to September. The peak period for the studied phenophases were as following:
   - Vegetative phase- May to June
   - Productive phase- August to September
   - Senescence- October

The snowfall was measured for an area between Chopta and Tungnath for the year 2016-17 (year 01) and 2017-18(year 02). The first and last snowfall dates for the year 01 were 25 December, 2016 and 12 April, 2017. It was 12 December, 2017 and 15 March, 2018 for year 02. The snowfall days (37 days) were more than double for the year 01 than year 02. A comparison of early and late snowmelt site showed that early snow melt generally increases plant density. However, such a difference was missing at higher altitudes (3400-3600 m).

Project Partner Name	Affiliations	Role & Responsibilities
Partner 1	University of Kashmir, Department of Botany, Srinagar, J&K	**Role:** Plant diversity along the three principal elevation transects; Community structure/regeneration and seedling age structure/endemism; tree diameter changes; anthropogenic/ Natural disturbance on trees due to storm/snow/fire; Invasive & alien species **Responsibility:** Trends of floral diversity and vegetation change in timberline ecosystem assemblage (TEA) and strategies for conservation and sustainable management
Partner 2	Kumaun University, Nainital	**Role:** Soil & tree water potential, leaf conductance and photosynthesis rate; seed maturity indices and seedling dynamics in timberline **Responsibility:** Projection of future changes in plant water relations and adaptations due to changes in precipitation and soil moisture regimes.
Partner 3	Wildlife Institute of India (WII), Chandrabani, Dehradun	**Role:** Influence of micro-climate variations on herbaceous plant communities through snow removal experiment; grazing; selected structural and functional characteristics of Alpine meadows. **Responsibility:** Dynamics of alpine vegetation and contribution of diversity to stability of plant communities.
Partner 4	G.B. Pant National Institute of Himalayan Environment & Sustainable Development, HQs-Kosi-Katarmal, Almora and Regional Unit-Sikkim	**Role:** Collection & analysis of data on temperature lapse rate, precipitation and its components along elevational transects in IHR Plant diversity along two altitudinal transects-Uttarakhand & Sikkim Phenology of important timberline trees; N-resorption & nutrient conservation strategy Mapping and a larger picture of Himalayan timberline based on ground truthing; trends of changes **Responsibility:** Statistically sound data base on (i) temperature (ii) precipitation (iii) Temperature lapse rate (TLR) determination Trends of diversity and vegetation change and strategies for conservation Identification of effective climate change indicators based on phenology. Development of software for phone/tablet based application location etc.

Partner 5	Birbal Sahni Institute of Palaeobotany , Lucknow	**Role:** Tree ring studies of selected timberline species (*Abies pindrow, Birch, Oak* and Krummholz sp. *Rhododendron*) across IHR to relate past climate variability and tree ring growth; Palyonological studies of surface soil. **Responsibility:** Empirical relationship between tree ring growth and past climate; characterization of the influence of inter-annual climate variability on treering increment across IHR; reconstruction of past vegetation diversity.
Partner 6	Central Himalayan Environment Association (CHEA), Nainital	**Role:** Timberline resources (e.g., ringal and wild edibles) based cottage industries promotion and technology- transfer; training and capacity building of women for livelihood enhancement. **Responsibility:** Strengthening livelihoods based on timberlines based on timberlines and employment of local people, particularly women on Citizen Science Concept.

2. Project Site Details

Project Site	Indian Himalayan Region
IHR States Covered	Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Sikkim and Arunachal Pradesh
Long. & Lat.	
Site Maps	
Site Photographs	

3. Project Activities Chart w.r.t. Timeframe [Gantt or PERT]

PROJECT ACTIVITIES	WORK UNDERTAKEN				OUTPUT
	Year 2017-2018				
	Qtr 1	Qtr 2	Qtr 3	Qtr 4	
Project Activity 1 To characterize and map timberline zone in the IHR using satellite and ground based observations including smart phone applications.					
Project Activity 2 To determine the temperature lapse rate (TLR) and pattern of precipitation along altitudinal gradients in different precipitation regimes across the IHR.	• Data collection for Pre- monsoon season for CT transect (UK). • Installation of data loggers in selected sites along DS transect (J&K).	• Data collection for monsoon season for CT transect (UK). • Data collection for monsoon season for YD transect (Sikkim). • Data collection for monsoon season for DS transect (J&K).	• Data collection for post-monsoon season for CT transect (UK). • Data collection for post-monsoon season for YD transect . • Data collection for post-monsoon season DS transect (J&K).	• Data collection for winter season for CT transect (UK). • Data collection for winter season for YD transect. • Data collection for winter season for DS transect (J&K).	• Annual and seasonal TLR for CT transect is calculated. • TLR for monsoon season for YD transect in Sikkim is calculated. • 4 Long term monitoring sites in J&K are established.

		• Establishment of experimental plots (10mx5 m) for study of hydrological response of different vegetation types along treeline zone in CT transect. • Data for rainfall interception (gross rainfall, through fall, stem flow) and surface runoff is collected.			• Rainfall partitioning (gross rainfall, throughfall, stemflow) and surface runoff behaviour for Abies spectabilis, Rhododendron campanulatum, Quercus semecarpifolia, and Grassland is being studied. This field based study will also be continued in next year of the project.
				• Collection of data from study sites in J&K, UK, and Sikkim	• Daily data for temperature, relative humidity and rainfall is collected. • Quality control and processing of collected data is ongoing.

				• Preparation of project progress reports.	• Half yearly and Annual Progress Report of the project submitted to PMU of the project.
		• Developed a chapter on TLR estimation for field manual of IHTP project		• Based on one year data, a manuscript on TLR for treeline environment of CT transect is prepared	• Book chapter published in "Field Manual for IHTP project". • Research paper, titled "Near surface temperature lapse rates for treeline environment in western Himalaya and possible impacts on ecotone vegetation "submitted to the Journal of Tropical Ecology for publication.

Project Activity 3 To study plant diversity, community structure, tree diameter changes and natural recruitment pattern along the three principal sites in the IHR					
Project Activity 4 Plant diversity and community structure along altitudinal gradient in three sites of Indian Himalayan Region	• Field visit for the flora collection	• Field visit for the Disturbance assessment	• Data analysis disturbance and phytosociology	• Herbarium preparation	• Data set generated regarding disturbance intensities along the altitude gradient. • Document prepared for reported occurrence of floral species in west Himalayan forested high altitude area (i.e., 2000-3500 m asl) • More than 200 specimen of plant species collected and herbarium prepared.

	• Field visit for the soil sample collection transect-A	• Flora collection and herbarium preparation	• Soil analysis	• Soil analysis • Field visit of the vegetation assessment (trees) (transect-c) (2700-3200 m)	• Detailed analysis of soil properties (physic-chemical-pH, moisture, water holding capacity, soil organic carbon and soil organic matter) conducted for each elevation belt • Quantitative data sets regarding vegetation diversity and dominance (Trees) were collected for 2nd altitude transect in Tungnath Area
		• Field visit for the assessment of fern flora		• Soil sample collection(Transect-2) • Disturbance intensity assessment in each elevation belt (transect-2)	• Quantitative data sets generated regarding the fern flora of the study site • Soil samples from the transect-2 were collected for each study plots.

					• Disturbance intensity in each elevation belt were studied and all data sets were generated
				• Herbarium specimen preparation and vegetation assessment training	• Capacity building of 26 researchers (including 03 IHTP researchers)
		• Finalization of Research Manual		• Herbarium specimen preparation and vegetation assessment training	• Manual of Field Methods prepared in collaboration with CHEA • Capacity building of 30 researchers (including 02 IHTP researchers) in collaboration with CBCM

	• Vegetation survey	• Vegetation survey			• Yuksam-Dzongri transect was surveyed between 3000-4000m (timberline)
Project Activity 5 To study plant diversity, community structure, tree diameter changes and natural recruitment pattern along the three principal sites in the IHR.	• Species identification/ confirmation	• Species identification/ confirmation			• With the help of photographs, different experts were approached for the identification of plant species (especially the herb species) and confirmation of the plant identity. A total of 23 tree species along with 22 shrub and 56 herb species were identified from the surveyed area.

		• Data entry and analysis	• Data entry and analysis		• The information collected in the data sheets was entered and analysed to understand the patterns of plant diversity, community structure, and stand density along the studied elevation gradient.
				• Manuscript/ report preparation	• Based on the study so far, a manuscript draft has been prepared for the Special issue in Tropical Ecology

	• Site revisit		• Site revisit		• Data from temperature/humidity loggers collected, as team work
Project Activity 6 To understand tree phenological responses, nutrient conservation strategies and tree-water relations in response to warming climate	• Marking of trees of selected species for phenological studies				• Established stands and marked 100 mature individuals of tree species (viz., Abies spectabilis, Betula utilis, Quercus semecarpifolia, Rhododendron arboreum and R. campanulatum) for detailed studies (Fig. 1).
	• Micro-climatic data collection under the stands of each of the five tree species	• Micro-climatic data collection under the stands of each of the five tree species	• Micro-climatic data collection under the stands of each of the five tree species	• Micro-climatic data collection under the stands of each of the five tree species	• Data (May 2017- December 2017) of atm. temp., atm. humidity, soil

					moisture and soil temp. collected (Fig. 2). A markedly high growing season temperature than the climatic treelines of the world (11.2 ^{o}C vs. 6.7^{o}C) and mean soil temperatures (9.8^{o}C at 30 cm depth) was reported.
	• Data collection on tree phenophases and leaf characters of selected species	• Data collection on tree phenophases and leaf characters of selected species	• Data collection on tree phenophases and leaf characters of selected species	• Data collection on tree phenophases and leaf characters of selected species	• A pheno-calendar of the five selected tree species was prepared and data on leaf area, leaf mass, leaf number per shoot of these species from May 2017-

					December 2017 was collected (Fig. 3).
	• Collection of tree leaves for nitrogen analysis	• Collection of tree leaves for nitrogen analysis	• Collection of tree leaves for nitrogen analysis	• Collection of tree leaves for nitrogen analysis	• Dataset on N concentration (mature and senescent leaf) and N-retranslocation of the five tree species calculated (Fig. 4).
	• Collection of soil for physico-chemical characteristics	• Collection of soil for physico-chemical characteristic	• Collection of soil for physico-chemical characteristic	• Collection of soil for physico-chemical characteristics	• Dataset on soil organic carbon and nitrogen of the five forest sites was generated.
		• Data collection on recruitment rate of seedlings of *R. campanulatum* and expansion of its population.	• Data collection on recruitment rate of seedlings of R. campanulatum and expansion of its population.		• Data synthesis revealed that the population of *R. campanulatum* is expanding @ 1.4 m/yr. which is comparable to other reports from this region.

	• Data compilation and syntheses	• Data compilation and syntheses	• Data compilation and syntheses	• Data compilation and syntheses	• Half Yearly Report prepared. Data was also presented in the Review Workshop at INSA, New Delhi. Two papers are communicated to Tropical Ecology Journal.
Project Activity 7 Tree Water Relation: Another perspective determining altitudinal limits of timberlines in the Himalayan region.					
Project Activity 8 Tree growth response of selected tree species of timber line to climate variability across the Indian Himalayan Region.	• (Since May 2017) Field work to Daksum-Sinthan, Kashmir J&K for the collection of tree ring samples.	• Continued analysis of Tungnath samples with the collection and addition of more *Abies* samples by GBPNIHESD	• Field work to Daksum-Sinthan, Kashmir J&K for more collection of tree ring samples. Continued processing of	• (Till March 2018) The data generated for the Tungnath region region has been analysed for stand dynamics, shift rate and growth-climate	• Processing, data generation and analyses of *Abies* from Tungnath is completed. The data analysis of Kashmir samples is under

		Almora group. Processing of Kashmir samples.	samples with data generation and analysis.	relationship for Himalayan fir species and the manuscript is under preparation for its publication.	process. • Previous JPF left in October 2017 and new JPF appointed in December 2017.
Project Activity 9 To understand the impact of depletion of snow-melt water on growth on grassland species composition and selected functional processes.					
Project Activity 10 Demonstration of appropriate livelihoods options and strengthening capacities of local communities in assessing carbon accumulation potential in an around timberline areas.	• Evaluation/ assessment of the demonstrations done in Ist year were done.				• 60 kg mushroom was produced worth Rs. 42,000 by community members /beneficiaries in 03 months. • Around 1600 kg vegetable were produced under poly-houses (*Tomato, Brinjal, Chilly,*

					Cabbage, Cucumber, Green vegetables and Capsicum) and beside self consumption income of Rs. 15,000 generated by 120 families in both villages. • Approx. 4 ha area covered under vegetable cultivation benefitting 120 families.
	• Meetings with Temple committee and horse union were conducted for trek management with the help of shopkeepers in Tungnath track (Chanis) under waste management to ban the use of				• A positive response with full support was committed by temple committee for using natural flowers (marigold) and baskets of Ringal as Prasad.

	poly bags in timberline area.				• Members of horse union agreed to clean the track twice a week and for that 04 brooms were provided to them. • Degradable bags were distributed to Chanis along with awareness campaigns among horse/ponies owners and local porters to keep trek clean.
		• Technology and input support for high value vegetable crop and nutritious fodder among beneficiaries.			• 4 ha area covered under vegetable cultivation benefitting 120 families. 1.5 ha area covered under improved fodder grasses in the terraces by seed sowing to ensure fodder availability in the vicinity of

					house and to reduce women drudgery.
		• Meeting with government officials, market stakeholders and other organizations working in the region for extensive services and resource mobilization.			• Project activities initiated and progress was shared with District Magistrate, senior officers of line departments. • Village level meetings with line department representatives including Village Development Officer, Veterinary department, Horticulture department, BAIF, District Industry, etc. were organized, in which several social issues and problems were discussed.

					• "Swachhata Pakhwara" was celebrated at village level in the presence government representative, Gram Pradhan, Head of Tungnath Temple Committee.
		• Promotion of Citizen Science Concept among local communities to develop RRPs in different sectors.			• Beneficiaries skill developed by organizing training on ringal based handicrafts, vegetable nursery preparation, bird watching, measurement of carbon sequestration rate, etc. • Community members initiated to make several

					showpieces made up of Ringal such as dustbins, flower pots, pen stand etc. • Training programs were organized under the supervision of the experts and within the involvement of government agencies.
			• Expansion of appropriate low cost technologies.		• 10 polyhouses were replicated for vegetable cultivation. • 100kg mushroom spawns were provided to project beneficiaries. • Continuation of floriculture in project areas.

				• Technology and input support for high value vegetable and nutritious fodder among beneficiaries.	• Over all, approximately 5.5 ha area has been covered under high value crops based on needs and technical inputs provided by experts for enhancing the income among 170 families. • Vegetable were produced by beneficiaries (both from poly house and open farm) worth Rs. 15,12,500.00 including income of Rs. 4,50,000.00. • In all, a total of 160 Kg of mushroom was produced in two consecutive seasons worth Rs. 90,000 in

					the nearby markets including direct income of Rs. 40,000. • In all, 56 quintal (190 head loads) of fodder has been harvested.
			• Promotion of Citizen Science Concept among local communities to develop RRPs in different sectors.		• In all 28 Rural Resource Persons (RRPs) were developed (03 in poly house construction; 15 in nursery development; 03 in making ringal handicrafts; 04 in mushroom cultivation; 02 in carbon measurement; 01 in responsible tourism and allied activities) having expertise in demonstrated

					activities. • Refresher on "Carbon Sequestration Measurement" was conducted during second year to strengthen the skills of youths and to popularize the citizen science.
				• Meeting with government officials, market stakeholders and other organizations working in the region for extensive services and resource mobilization temple committee, horse union, village representative, Van Panchayat	• For resource mobilization and ensuring convergence with line department the project concept, learnings were shared. • In continuation, project theme along with the progress and results achieved was communicated through poster

				committee.	presentations, slide presentation in national and international seminars/ conferences/workshops i.e. a workshop funded by IHCAP-HDC, international seminar organized by Doon University, 105th Indian Science Congress 2018 etc. • 02 research articles are being submitted in renowned journals i.e. Tropical Ecology and ENVIS for further dissemination of learnings.

					• Technical support and monitoring on regular basis was made by the experts from horticulture department. • To resolve the main concern i.e. Solid Waste Management in the tourism zone (Chopta-Tungnath), several meetings were organized with temple committee, horse union members.

4. Financial and Resource Information

Note: A separate bank account is expected to be opened for NMHS Project as per the provision of Direct Beneficiary Account (DBA) as laid out by the Govt. of India and also facilitate the audit of accounts. The interest earned out of the NMHS project funds should be reported clearly in the utilization certificate.

Total Grant:		**Grant Received Date:**	

Project Partner(s)	**Affiliations/ Institution**	**Budget Allocated to**	**Work Done**
Partner 1	University of Kashmir, Department of Botany, Srinagar (J&K)	Prof. Zafar A Reshi	
Partner 2	Kumaun University, Nainital	Dr. Ashish Tewari	
Partner 3	Wildlife Institute of India (WII), Chandrabani, Dehradun	Dr. B.S. Adhikari	
Partner 4	G.B. Pant National Institute of Himalayan Environment & Sustainable Development, HQs-Kosi-Katarmal, Almora and Regional Unit- Sikkim	Dr. Subrat Sharma; Dr. Rajesh Joshi; Dr. R.S.Rawal; Dr. G.C.S Negi; Dr. Devendra Kumar	
Partner 5	Birbal Sahni Institute of Palaeobotany, Lucknow	Dr. Parminder Singh Ranhotra	
Partner 6	Central Himalayan Environment Association (CHEA), Nainital	Dr. Pankaj Tewari	

Project Staff Information:

S. No.	Name	Qualification	Designation	Fellowship/ Wages paid	Remarks
1.	Priyanka Sah	M.Sc. Remote Sensing & GIS	JPF	16000+HRA	
2.	Avantika Latwal	M.Sc Remote Sensing & GIS	JPF	16000+HRA	
3.	Mr. Kumar Sambhav	M.Sc. Mathematics	JPF	16,000 pm (+10% HRA)	
4.	Mr. Balam Singh Bisht	B.A	F.A	8,000 pm	
5.	Mr.Mohit Fulara	M.Sc. Geology	JPF	16,000 pm (+10% HRA)	
6.	Sabzar Nanda	M.Sc (NET)	JPF	Rs. 16000/- + HRA	
7.	Nafeesa Farooq	M.Sc	JPF	Rs. 16000/- + HRA	Resigned
8.	Bilal A. Lone	M.Sc	JPF	Rs. 16000/- + HRA	Resigned
9.	Sunil Chandra Joshi	M.Sc – Botany	JPF	16000 + 10% HRA /PM	
10.	Renu Rawal	M.Sc. Botany	JPF	16000/month	
11.	Aseesh Pandey	Ph. D. Botany	Research Associate	38,000.00+ 10% HRA	
12.	Sandhya Rai	MSc. Forestry UGC Net Qualified	Junior Project fellow	14,000.00+ 10% HRA	
13.	Mr. Pradeep Singh	M.Sc. Forestry	SPF	Rs. 18000+10%HRA	
14.	Dr. Shruti Shah	Ph.D. (Forestry)	Research Associate	36000+3600 (HRA)= 39600.00	
15.	Mr. Nandan Singh Mehra	M.Sc. Forestry	Project Assistant	8000=00	
16.	Ms. Utsa Singh	M.Sc in Geology	Junior Project Fellow (JPF)	Rs. 19200/ per month	

17.	Ms. Bency David	M.Sc. in Ecology and Environmental Science	JPF	Rs. 19200 per month	
18.	Mr. Krishna Kumar Tamta	M.Sc. (Forestry)	JPF	16000 + 10%HRA	
19.	Mr. Amit Mittal	M.Sc. (Forestry)	JPF	16000 + 10%HRA	
20.	Mr. Ripu Daman Singh	M.Sc. (Forestry)	SPF	19000 + 10%HRA	
21.	Dr. Pratap Dhaila	Ph.D Forestry	SPF	19000+10% HRA	

5. Equipment and Asset Information (Already given in previous year Annual Report)

S. No.	Equipment Name (Qty)	Details (Make/ Model)	Cost	Date of Installation	Photographs of Equipment	Lowest Quotation, IF NOT purchased

6. Expenditure Statement and Utilization Certificate

Please update the annual Expenditure Statement and Utilization Certificate (UC) periodically.

Expenditure Information: UC Being sent separately

S. No.	Financial Position/Budget Head	Funds Sanctioned	Expenditure	% of Total cost
	Interest earned			
	Grand Total			

7. Project Beneficiary Groups

Beneficiary Groups [Capacity Building]	Target	Achieved
No. of Beneficiaries with income generation:	**NIL**	**175**
No. of stakeholders trained, particularly women:		**24 Researchers (Including 10 female)**
No. of capacity building Workshops/ trainings:		**11**
No. of Awareness & outreach programmes:	**Nil**	**18**
No. of Research/ Manpower developed:		**33 (Continuing)**

8. Project Progress Summary (as applicable to the project): Already given in previous year annual report.

Description	Total (Numeric)	Description
IHR States Covered	**05**	Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, Arunachal Pradesh
Project Site/ Field Stations Developed:	**.... (attach photos) ... (attach maps)**	•
No. of Patents filed (Description):		•
Article/ Review/ Research Paper/ Publication:	**15**	•
New Methods/ Modellings Developed (description in 250 words):	**10**	•
No. of Trainings (No. of Beneficiaries):	**11 trainings (No. of beneficiaries - 150) (28 RRPs)**	•
Workshop:		•
Demonstration Models (Site):	**.... (attach maps about location & photos)**	•
Livelihood Options:	Polyhouse for protected cultivation, LDPE tanks for conservation and sustainable use of water, vermicomposting for production of quality organic manure,	•

	floriculture, promotion of cash crops e.g. citrus fruit,walnut, onion, garlic.	
Training Manuals:		•
Processing Units:	**.... (attach photos)**	•
Species Collection:		•
Species identified:		•
Database/ Images/ GIS Maps:		•

Note: Photos/ maps should be attached in high quality in compatible formats viz., JPEG, .JPG, .PNG, .SHP, etc. along with a suitable figure legend/ caption.

9. Project Linkages (with nearby Institutions/ State Agencies)

S. No.	Institute/ Organization	Type of Linkages	Brief Description
1.	Forest Department, Government of Uttarakhand	Cooperation	For establishment of sites and installation of sensors
2.	HAPPRC, HNB Garhwal University , Srinagar Garhwal	Cooperation	For installation of AWS
3.	Botanical Survey of India, Dehradun	Technical assistance	Herbarium consultation for identification of seasonal floristic specimens
4.	Kumaun University Nainital, Doon University, Dehradun; G.B. Pant Univ of Agri & Tech, Pant Nagar; HNB Garhwal Univ; LSMPG College Pithoragarh, BGSB J&K	Capacity Building	Participation of researchers from these organizations was in hands on training.
5.	SS J campus Kumaun University Almora	Technical assistance	Consultation for study design and identification of lichen specimens, etc.
6.	Forest Environment and Wildlife Management Department, Govt of Sikkim	Cooperation	Permission for work in Khangchendzonga Biosphere Reserve

7.	Temple committee, Tungnath	Cooperation	For waste management in Tungnath track and control on use of artificial plastic flowers and garlands.
8.	Horticulture department, Ukhimath	Backward and Forward Linkages	
9.	Garhwal Mandal Vikas Nigam (GMVN)	Backward and Forward Linkages	
10.	Village level institutions (Van Panchayat, Nav Yuvak Mangal Dal, Mahila Mangal Dal etc.)	Cooperation and capacity building	For strengthening their capacities and enhancing their livelihood status with local community participation.
11.	GBPNIHED, Almora	Academic	Study on alpine meadows in the identified sites Support for meteorological data from the area
12.	District Administration, Rudraprayag	Cooperation	

10. Additional (publication, recommendations, etc.)

Time Period	**Publications** (Research Papers, Information Material, Policy drafts, Patents, etc.)
Annual [Year .....]	

11. Project Concluding Remark

Kindly update the following Progress Parameters for the Reporting Period:

Project Objectives	Project Output against each objective	Progress made against Monitoring Indicators (specified in Sanction Letter)	Remarks
1. To characterize and map timberline zone in the Indian Himalayan Region (IHR) using satellite	• Characterization of geo-spatial attributes. • Mapping of timberline.		
2. To determine the temperature lapse rate (TLR) and precipitation gradient (PG) along altitudinal gradients in different precipitation regimes across the IHR	• Daily data on maximum- minimum and average temperature and relative humidity is collected from (i) 10 sites at different altitude (1500-3900 m) in Chopta-Tungnath transect for December 2016-March 2018, (ii) 4 sites at different altitude (1900- 3000 m) in Daksum-Sintahan transect (J & K) for June 2017-March 2018, and (iii) 6 sites at different altitude (1700-4000 m) in Yuksam-Dzongri transect (Sikkim for December 2016-March 2018.	• Established 10 monitoring sites in Uttarakhand, 6 monitoring sites in Sikkim and 4 monitoring sites in J & K to record temperature and relative humidity from different altitudes in timberline area of three climatically different regimes in Indian Himalayan region. • Annual (December 2016 – November 2017) and seasonal temperature lapse rates for two different aspects of Tungnath-Chopta transect is determined. • Winter season lapse rate for Yuksam-Dzongri transect in Sikkim is determined.	• Annual and seasonal TLR for CT transect is calculated. Data generation, compilation and synthesis are under process. • Data will be collected in 2018-19 as well to establish TLR for different seasons and precipitation gradient along different climate regimes of IHR. The generated data will also be used to study micro climatic variations in the study area.

3. Plant diversity and community structure along altitudinal gradient in three sites of Indian Himalayan region	• During the 2nd year, more vegetation sampling in seventeen (17) elevational bands (100m apart) along the altitudinal gradient of 2200 to 3800 m asl in the Daksum-Sinthan Top area was carried out which resulted in the documentation of 425 species belonging to 117 families and 268 genera. Among these, dicotyledons included 175 species belonging to 44 families and 131 genera, monocotyledons were represented by 19 species belonging to 10 families and 16 genera, gymnosperms were represented by 4 species belonging to 2 families and 4 genera. Thirty three species of pteridophytes belonging to 9 families and 16 genera were also recorded during the present survey. Bryophytes included 39 species belonging to 22 families and 33 genera. Significant number of lichen species was identified during this year and now we report 155 species of lichens belonging to 30 families and 68 genera	• In comparison to documentation of 173 plant species belonging to 134 genera and 75 families during the 1st year, currently we report 425 species belonging to 117 families and 268 genera. Thus, it is indicative of satisfactory performance during the period under review. • For the first time a detailed vegetational analysis along the entire elevational gradient was carried out which has yielded interesting trends vis-à-vis timberline and treeline ecotone, and treeline in Kashmir Himalaya. • Seedling recruitment of tree species and stem diameter of adult tree species vis-à-vis altitude was also studied. • The forest profile has been built based on the detailed analysis of different bands of elevational transect & understanding of how species	• We plan to undertake surveys in two more transects during the 3rd year in order to discern unambiguous elevational patterns of species diversity in the Himalaya. • We would analyze the elevation species richness data for mid-domain effect employing Range Model. • Whether or not alien species are moving upwards into mountains would also be worked out. Similarly, elevational pattern in endemic species will be studied.

	from the study area. • Functional diversity quantified in terms of growth form of species revealed that herbs predominate with 202 species followed by shrubs represented by 18 species, trees by 8 species and sub-shrubs by 2 species. • In terms of life span, most of the species are perennial including 142 species when annuals and biennials were represented by 34 and 3 species respectively. Life span in 15 species was variable. • Pattern of species richness and diversity in each of the seventeen elevational bands along the gradient was also documented which has revealed interesting trends in relation to altitude. In all, four patterns of species richness in relation to elevation were observed during the present study: low-elevation plateau with a mid-peak in bryophytes, mid-peak pattern in pteridophytes and lichens, and inverted hump-shaped pattern in	respond to timberline, treeline & alpine elevation zone has been assessed.	

	monocots. • South and North facing slopes revealed peculiar differences in community structure which have been presented diagrammatically • Finally a manuscript based on the work has been prepared and submitted to *'Tropical Ecology'* for publication.		
4.To study the plant diversity and community structure along the altitudinal gradient in the selected study site	• Identification of two transects and establishment of one long term forest study transact along altitude gradient • Data-sets on forest vegetation (density, frequency, TBA, IVI, diversity, regeneration and population structure) along altitude gradient in one transact (Transact-A). • Seasonal collection and documentation of floristic diversity (collection of herbarium specimen) • Lichen diversity assessment along altitude range	• Baseline data-sets on vegetation compositional attributes along 2nd altitude transect generated and analyzed. These data-sets would add to the data base on vegetation science generated from first transect. (Nos - 02 transect.) • Systematic floristic studies initiated to generate seasonal datasets on taxonomic diversity to quantify species richness and rarity at species, generic and family levels. (Nos - 200	• Data-sets generated from 2 altitude transects would form part of envisaged vegetation diversity database (studies continuing) • This information forms the part of detailed floristic inventories (all groups, including pteridophytes, bryophytes, lichens, fungi) as part of biodiversity database. • The manual

		specimens.) • Following the available literature (floras), floristic diversity of 1471 plant species [106 (7.2%) trees, 233 (15.8%) shrubs and 1132 (77.0%) herbs] for high altitude forested zone of west Himalaya prepared. • Manual of field methods on various work components of IHTP published/printed (Nos - 01). • Awareness and capacity building event on Herbarium Methods and Vegetation Assessment organized for researchers of the region. (Nos - 01.)	will act as the base for undertaking studies for monitoring changes over temporal scale in IHTPR project site as well as in other areas in the Himalaya. • Such capacity building events will help in developing a cader of well trained researchers in plant diversity studies in higher Himalaya.
5.To study the plant diversity and community structure along the altitudinal gradient in the selected study site	• Vegetation assessment across the vertical transect along the timberline of study area has been done. • Considering the diverse physio-geography of Sikkim Himalaya, a modified methodology was used to assess the vegetation along the timberline.	• Identification of potential Lichen species, along the elevation gradient, as climate change indicator is under process	• Field visits are scheduled for next quarters to fulfil remaining project activities

	• The subalpine conifer forest across the identified transect was surveyed using quadrat method and sampling was done at every 100 m steps between 3000 m and 4000 m gradients. • A total of 109 species were recorded (identified spp. 101) belonging to 80 genera and 46 families. The species richness demonstrated a decreasing pattern along the gradients and peaked at 3100 m; corresponding to transition zones between temperate-subalpine forests.		
6.To understand timberline tree phenological responses, nutrient conservation strategies, tree water relations, seed ecology and regeneration in response to warming climate	• Data-set on micro-climate, phenology of leafing, flowering, leaf population dynamics, leaf life span, shoot growth of major timberline trees species of Chopta-Tungnath (Uttarakhand) from May 2017 - December 2017. • Data set on leaf and soil nitrogen dynamics and soil organic carbon of the above five forests.	• Data-set generated as proposed in the project activity and data was synthesized and two papers were communicated to Tropical Ecology Journal.	• Data on these parameters will be collected again in 2018-19 to see the annual changes in relation to climate change.
7. Tree Water Relation: Another perspective determining altitudinal limits of timberlines in the Himalayan region.			

8.Tree growth response of selected tree species of timber line to climate variability across the Indian Himalayan Region	• The samples collected from both the area of IHR were processed and analyses for one species (*Abies*) have been finished with the data generation. • The data generated has been analyzed for the age stand structure, Temporal tree line dynamics, shift rate and climate growth relationship of the *Abies* for the Tungnath area (Uttarakhand). • The samples of *Abies* and *Pinus* collected from Kashmir region have been processed and measured for further analyses. • Future sampling will be carried out from the Himachal and Sikkim regions of IHR in 2018-19 and their analyses.		
9.To understand the impact of depletion of snow-melt water on growth on grassland species composition and selected functional processes			
10. Demonstration of appropriate livelihoods options and strengthening capacities of local communities in assessing carbon accumulation potential in an	• 60 kg mushroom was produced worth Rs. 42,000 by community members /beneficiaries in 03 months. • Around 1600 kg vegetable were produced under poly-houses (*Tomato,*	• Village level meetings with line department representatives including Village Development Officer, Veterinary department,	

around timberline areas.	*Brinjal, Chilly, Cabbage, Cucumber, Green vegetables and Capsicum)* and beside self consumption income of Rs. 15,000 generated by 120 families in both villages. • Approx. 4 ha area covered under vegetable cultivation benefitting 120 families. • A positive response with full support was committed by temple committee for using natural flowers (marigold) and baskets of Ringal as Prasad. • Members of horse union agreed to clean the track twice a week and for that 04 brooms were provided to them. • Degradable bags were distributed to Chanis along with awareness campaigns among horse/ponies owners and local porters to keep trek clean. • 4 ha area covered under vegetable cultivation benefitting 120 families. 1.5 ha area covered under improved fodder grasses in the terraces by seed sowing to ensure fodder availability in the vicinity of house and to reduce women drudgery. • 10 polyhouses were replicated for vegetable cultivation. • 100kg mushroom	Horticulture department, BAIF, District Industry, etc. were organized, in which several social issues and problems were discussed. • "Swachhata Pakhwara" was celebrated at village level in the presence government representative, Gram Pradhan, Head of Tungnath Temple Committee. • Beneficiaries skill developed by organizing training on ringal based handicrafts, vegetable nursery preparation, bird watching, measurement of carbon sequestration rate, etc. • Community members initiated to make several showpieces made up of Ringal such as dustbins, flower pots, pen stand etc. • Training programs were organized under the supervision of the experts and within the involvement of government agencies. • Project activities	

	spawns were provided to project beneficiaries. • Continuation of floriculture in project areas. • Over all, approximately 5.5 ha area has been covered under high value crops based on needs and technical inputs provided by experts for enhancing the income among 170 families. • Vegetable were produced by beneficiaries (both from poly house and open farm) worth Rs. 15,12,500.00 including income of Rs. 4,50,000.00. • In all, a total of 160 Kg of mushroom was produced in two consecutive seasons worth Rs. 90,000 in the nearby markets including direct income of Rs. 40,000. • In all, 56 quintal (190 head loads) of fodder has been harvested. • In all 28 Rural Resource Persons (RRPs) were developed (03 in poly house construction; 15 in nursery development; 03 in making ringal handicrafts; 04 in mushroom cultivation; 02 in carbon measurement; 01 in responsible tourism and allied activities) having expertise in	initiated and progress was shared with District Magistrate, senior officers of line departments. • Refresher on "Carbon Sequestration Measurement" was conducted during second year to strengthen the skills of youths and to popularize the citizen science. • For resource mobilization and ensuring convergence with line department the project concept, learnings were shared. • Refresher on "Carbon Sequestration Measurement" was conducted during second year to strengthen the skills of youths and to popularize the citizen science. • For resource mobilization and ensuring convergence with line department the project concept, learnings were shared. • To resolve the main concern i.e. Solid Waste Management in the tourism zone	

	demonstrated activities. • In continuation, project theme along with the progress and results achieved was communicated through poster presentations, slide presentation in national and international seminars/ conferences/workshops i.e. a workshop funded by IHCAP-HDC, international seminar organized by Doon University, 105th Indian Science Congress 2018 etc. • 02 research articles are being submitted in renowned journals i.e. Tropical Ecology and ENVIS for further dissemination of learnings. • Technical support and monitoring on regular basis was made by the experts from horticulture department.	(Chopta-Tungnath), several meetings were organized with temple committee, horse union members.	

Methodology (in brief):	
Major Research Achievements:	
Brief Conclusion - the current year progress – during the reporting period (point-wise):	
Progress Achieved (%):	
Remaining work to be done:	

Submitted to:
Nodal Officer, NMHS-PMU
National Mission on Himalayan Studies (NMHS)
G.B. Pant National Institute of Himalayan Environment and Sustainable Development, Kosi-Katarmal,
Almora 263643, Uttarakhand
E-mail: nmhspmu2016@gmail.com

Submitted by:
Project PI (Signature):
Institution (Seal):
Dated (dd/mm/yy):

Completion in the last one year in % (According to each Deliverables)-:

Sl. No	Quantifiable Deliverables (as per sanction letter)	Output/ achievements	Performance in terms of Monitoring indicators	Remarks
1.	Awareness and training material/ knowledge products for sustainable use of resources for improved livelihood	• A manual of methods for timberline and treeline study had been published. • The research achievements under IHTRP were presented through posters in a workshop at UCOST, Dehradun in collaboration with IHCAP for policy purposes.	• Timberline as a functional unit has been conceptualized and study approach developed	• Manual of methods developed and implemented in field for further studies
2.	Repository of global literature on the Himalayan timberline (treeline)	• 14 manuscripts on different studies conducted under this project on Himalayan timberline has been prepared.	• It is being communicated to *Tropical Ecology* for a special issue on timberline to be published very soon.	• Research article to be submitted by the mid of June, 2018.
3.	Workshops	• We organized two workshops, the first in June, 2017 in beginning of the second year of the project and the second at last of January, 2018. Among these two workshops, involvement of young researchers and PIs of the different study components showed "a team research approach". **I** • A one day workshop on Project Conceptualization of Timberline (IHTRP),	• Outlines of research papers concretized almost. However, they required continual improvement and modifications based on in the reviews and suggestions provided by project coordinator.	• The Dehradun conference enabled us to understand and convince politicians for Himalayan Research and how to apply community and ecosystem approaches to treelines as concept.

		the Workshop was organized (27 July 2017) for policy purposes • Academicians from different universities, institutes and organizations; young researchers/students from different universities/institutes and politicians participated along with PIs to develop an effective policies. **II** • A two-day workshop at the INSA, New Delhi was organized by the project Coordinator with the project partners for developing the research papers in a defined time schedule in January 2018. • The purpose of this field workshop was also to develop a coordinated plan for carrying out research and livelihood interventions. • Field experiences of research scholars were discussed and useful components incorporated.		
4.	Liaison with partners and NMHS-PMU	• Permission of HAPRC director was taken for logistic support for field work and kind permission to install Snow-Pack Analyzer at Tungnath. • IHTRP activities were shared at International Conference conducted at IIT Kharagpur, and at Shimla on October 6	• Familiarity with timberline as a unit of research, and management has increased at various levels	• All project partners were regularly in touch with regard field visits, data collection, methods, concerns and guidance through e-mails and phones.

		(H.P.) by the project coordinator and also at ICIMOD, with experts. • Discussion has been initiated with UCOST, and some other organizations in concern with developing an interpretation center; the knowledge developed through studies will be used. • Almost all research papers have been finally reviewed by project coordinator and communicated to the all the PIs; even some of them are communicated to *Tropical Ecology* too • Rounds of visits were made to GBPIHED Kosi-Katarmal, Almora and Dehradun for sharing the project concepts and achievements.		• A project which involves several sites and investigators and is carried out in Himalayas should be given two additional year i.e. it should be at least of 5 years instead of usual 3 years.

Annexure-II

Site maps

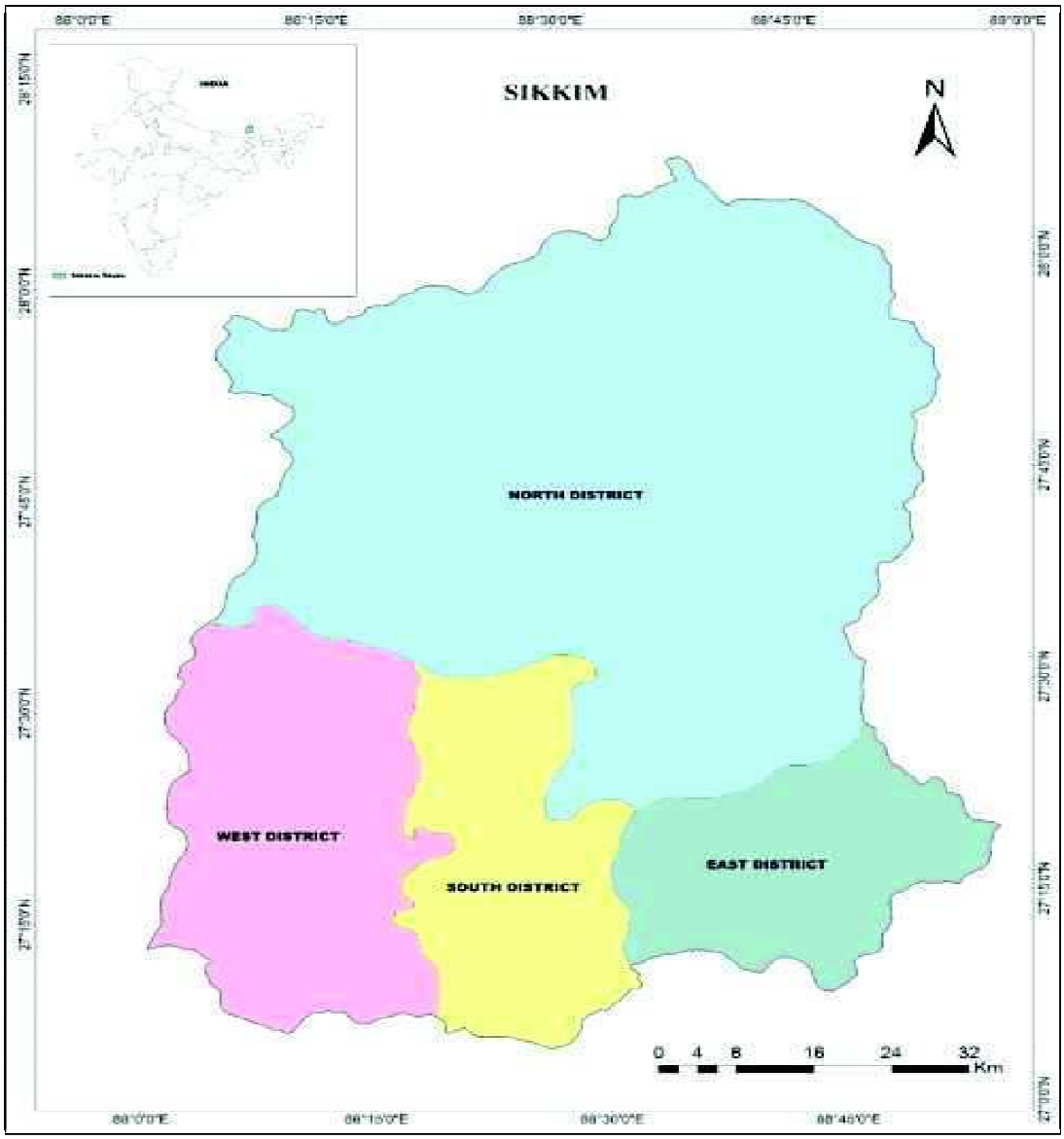


Fig. 1. Location map of Studied State – Sikkim

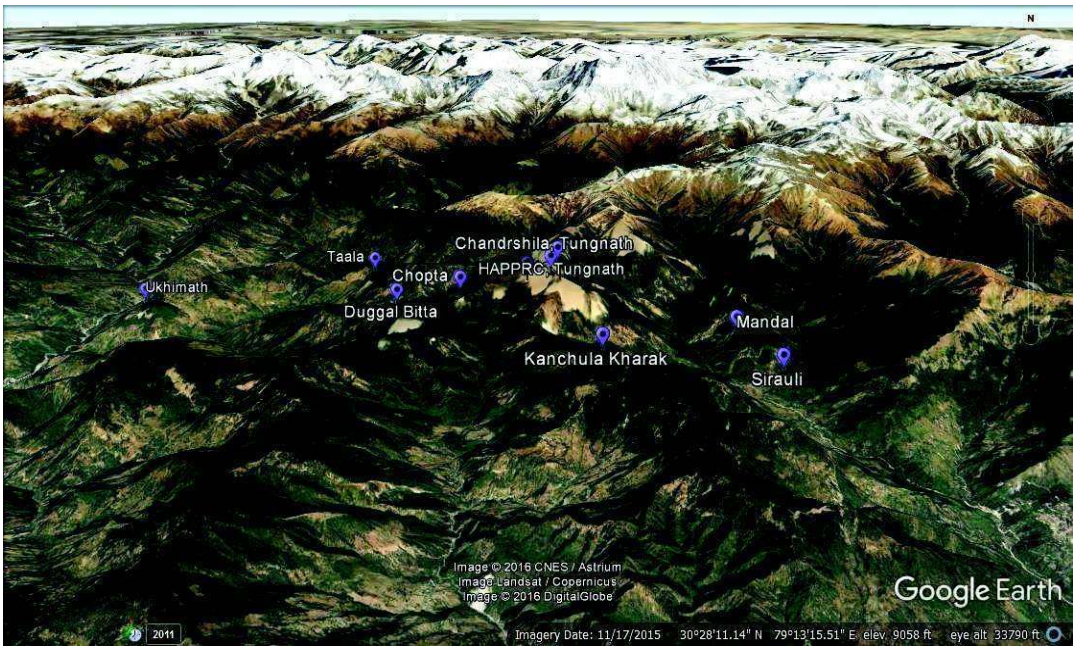


Fig .2. Google map of the sites identified for installation of meteorological instruments in Tungnath- Chopta transect (Uttarakhand)

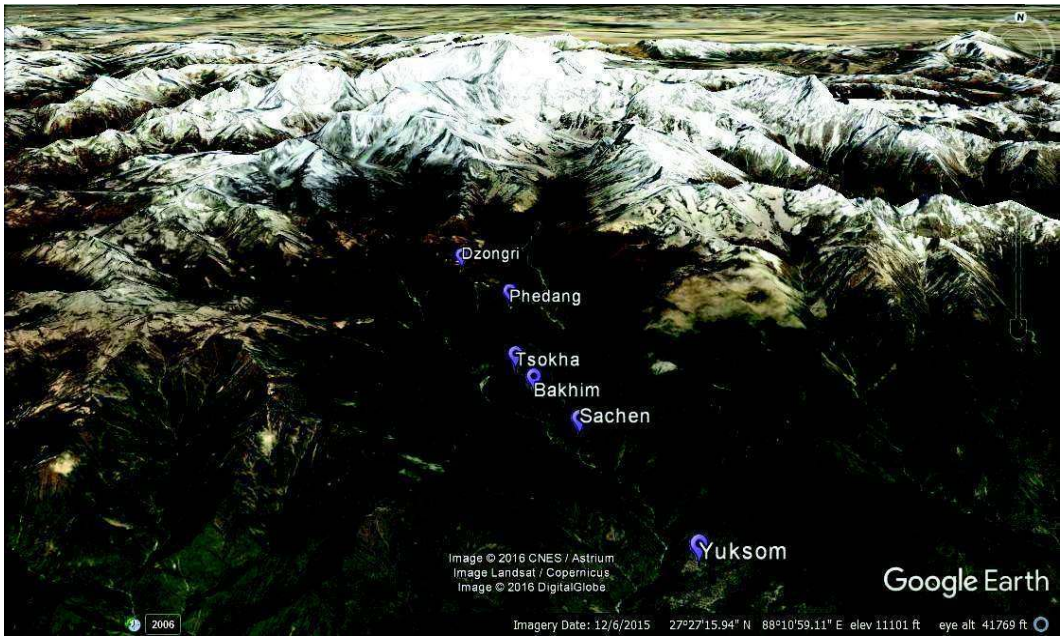


Fig .3. Google map of the sites identified for installation of meteorological instruments in Yuksam-Dzongri transect (Sikkim)

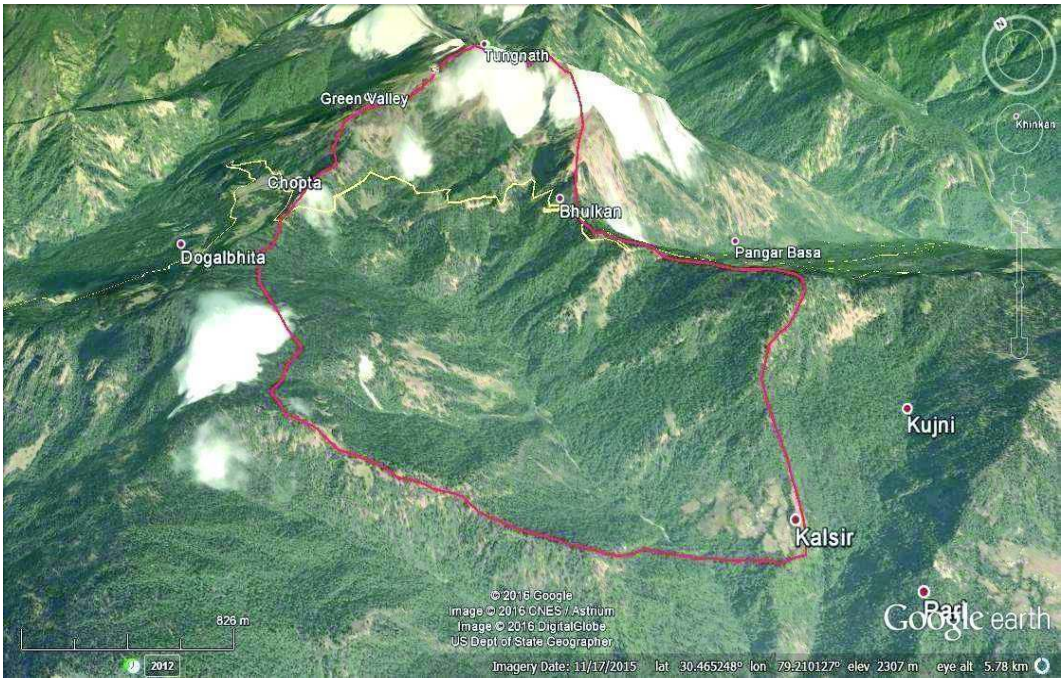


Fig .4. Map of study area Tungnath transect (Dist- Chamoli)

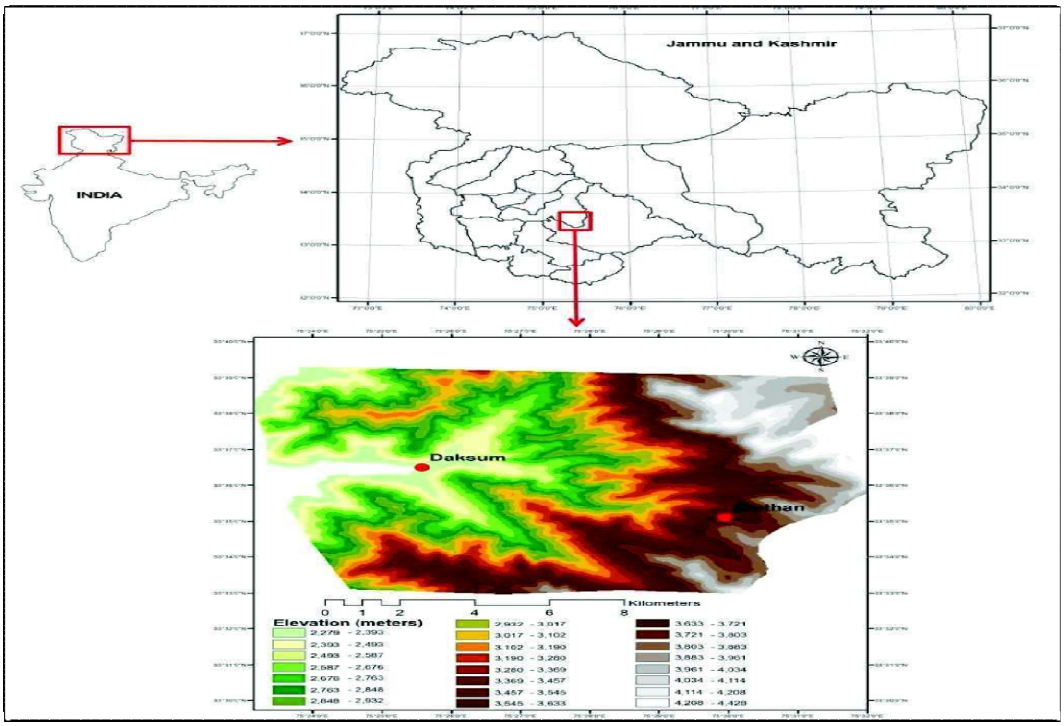


Fig. 5. Location map of the study site.

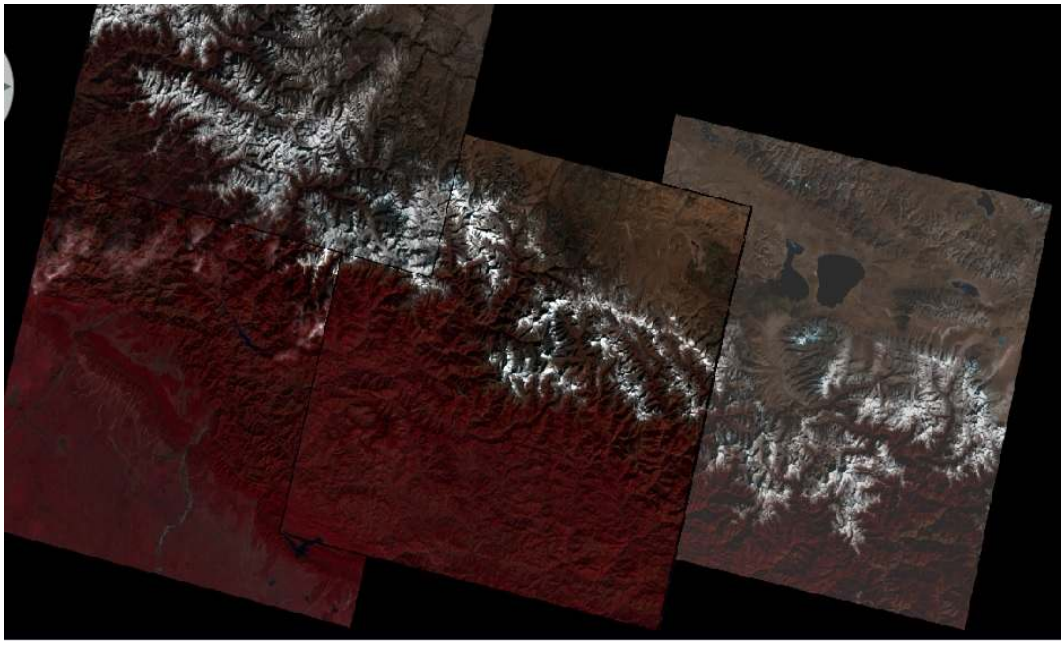


Fig.6. Landsat 8 satellite images

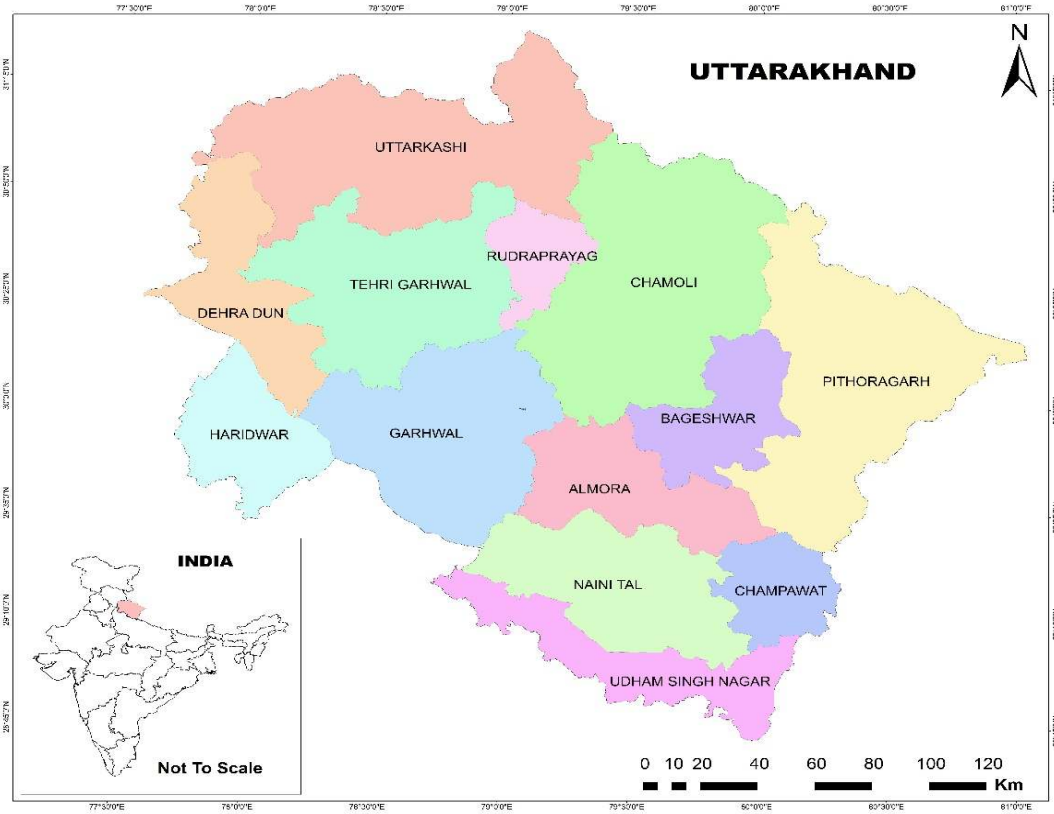


Fig. 7. Location map of Studied State - Uttarakhand

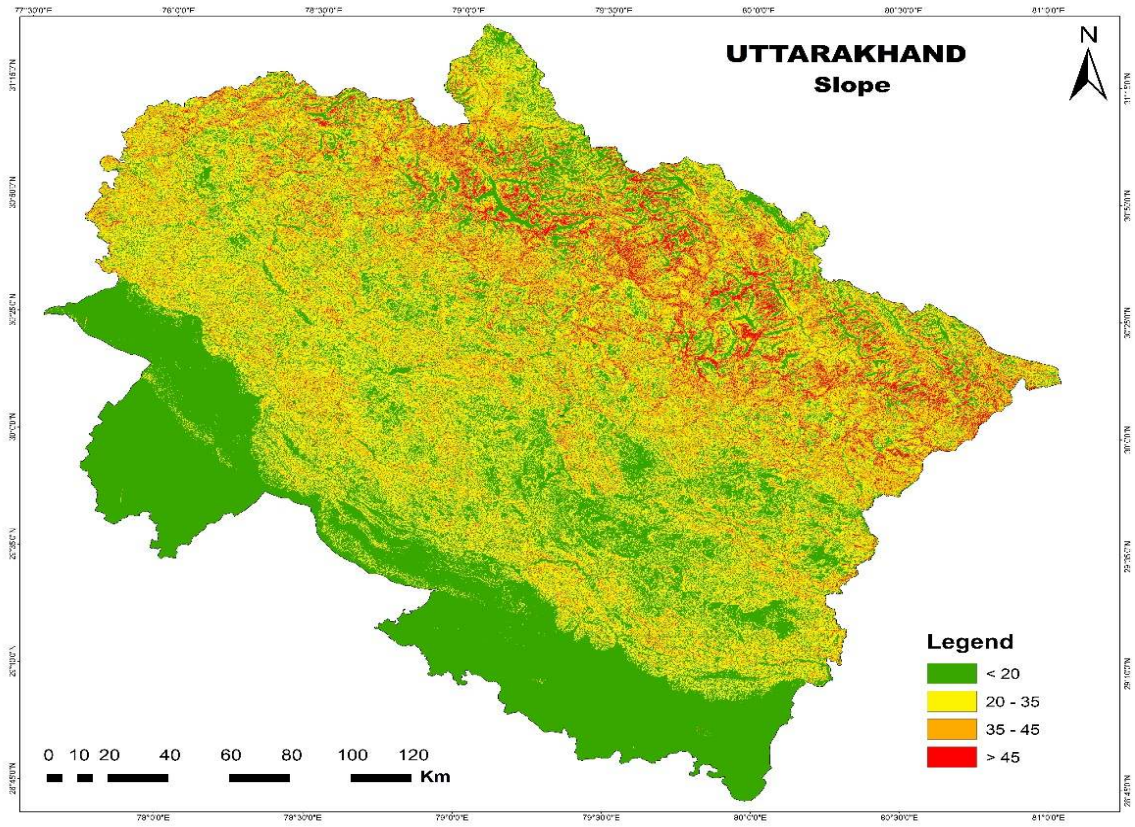


Fig. 8. Slope Map of Uttarakhand

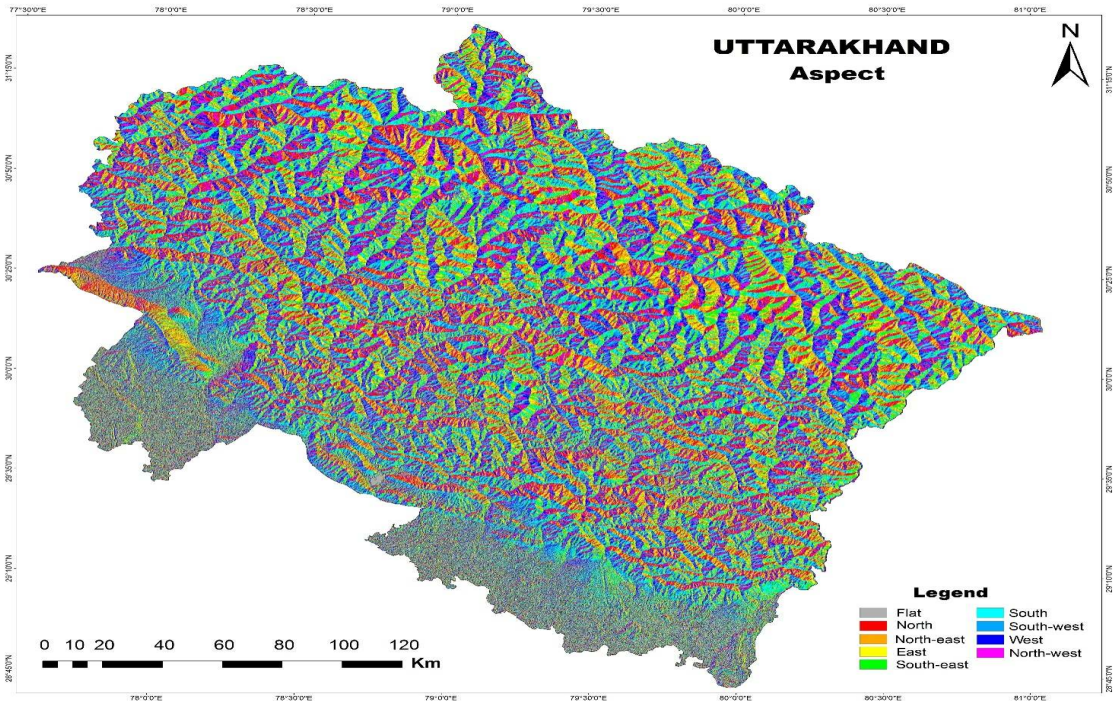


Fig. 9. Aspect map of Uttarakhand

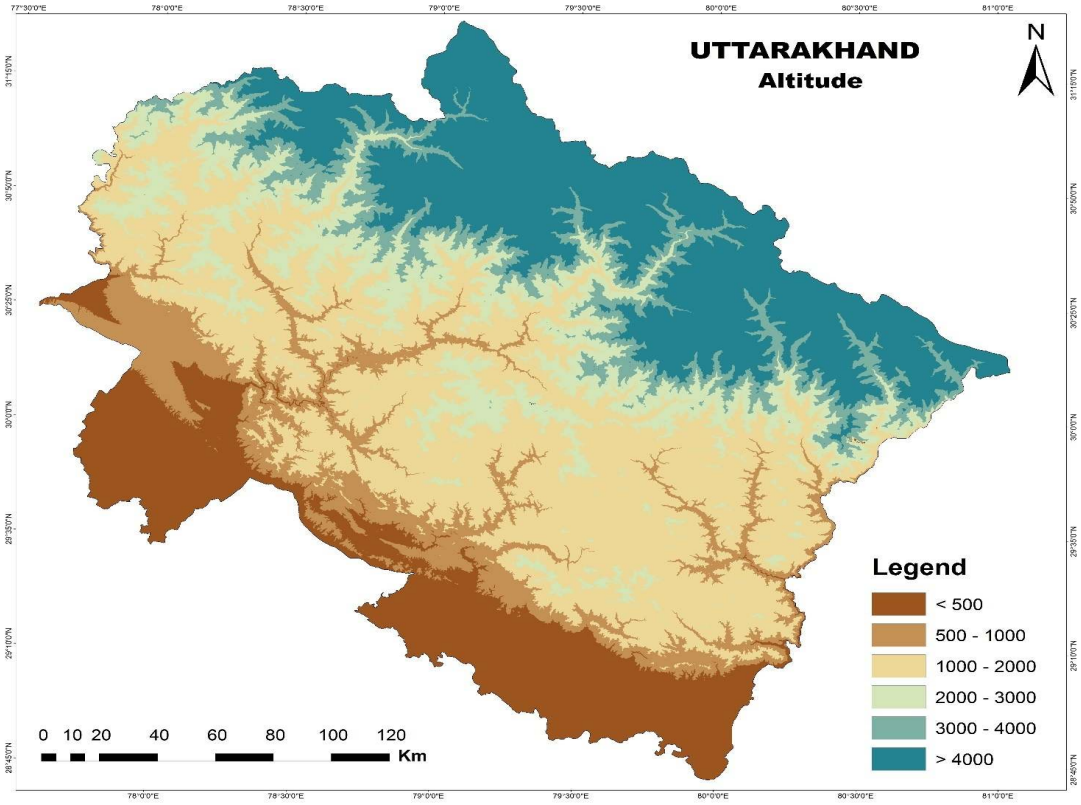


Fig.10. Altitudinal zone map of Uttarakhand

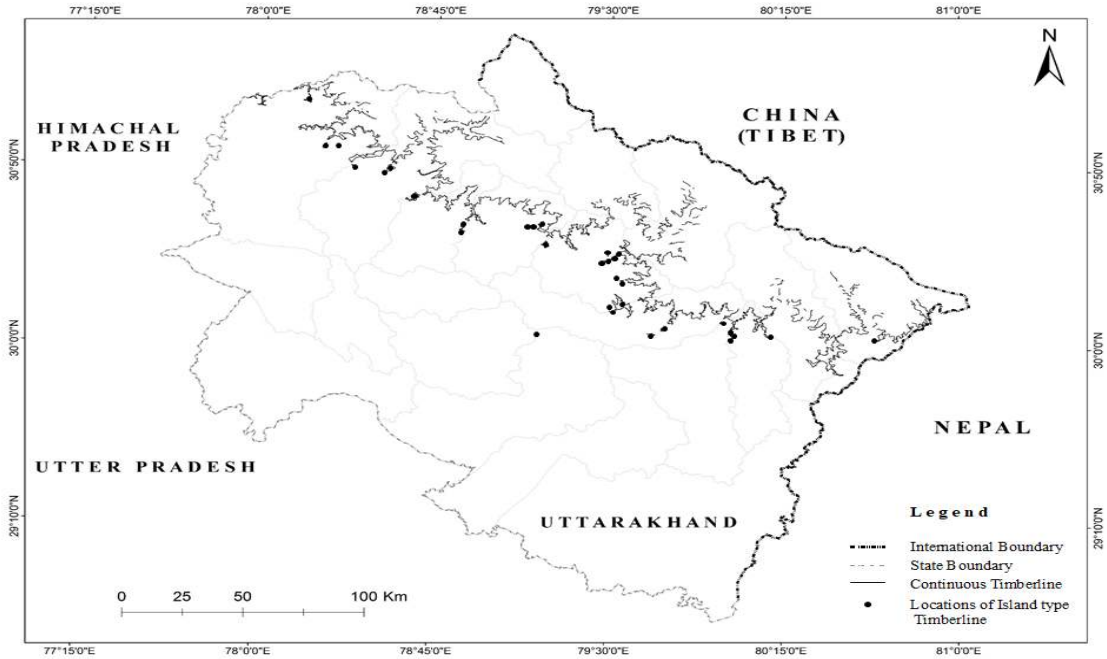


Fig .11. Timberline map of Uttarakhand derived from Landsat 8

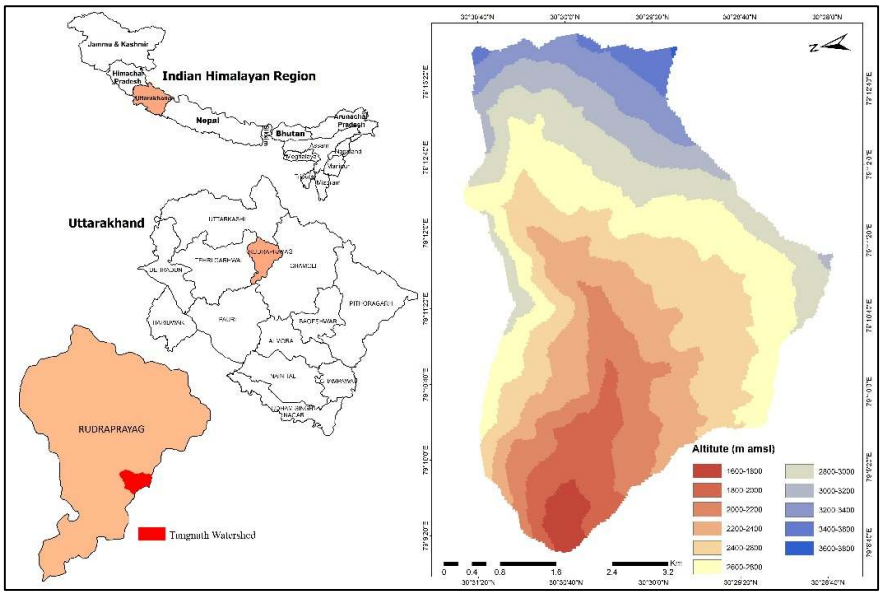


Fig.12. Location Map of Studied State – Tungnath

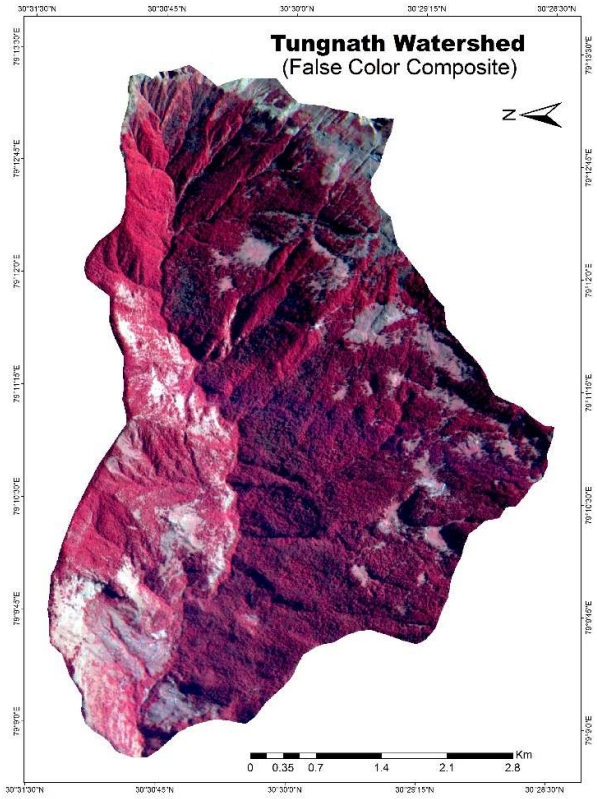


Fig.13. FCC of Tungnath Watershed

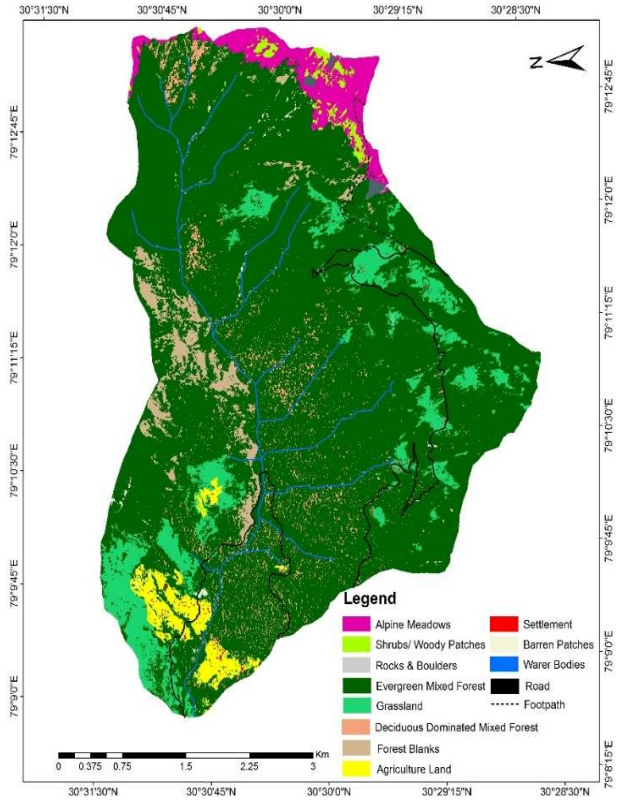


Fig.14.Landuse/Landcover Map of Tungnath Watershed

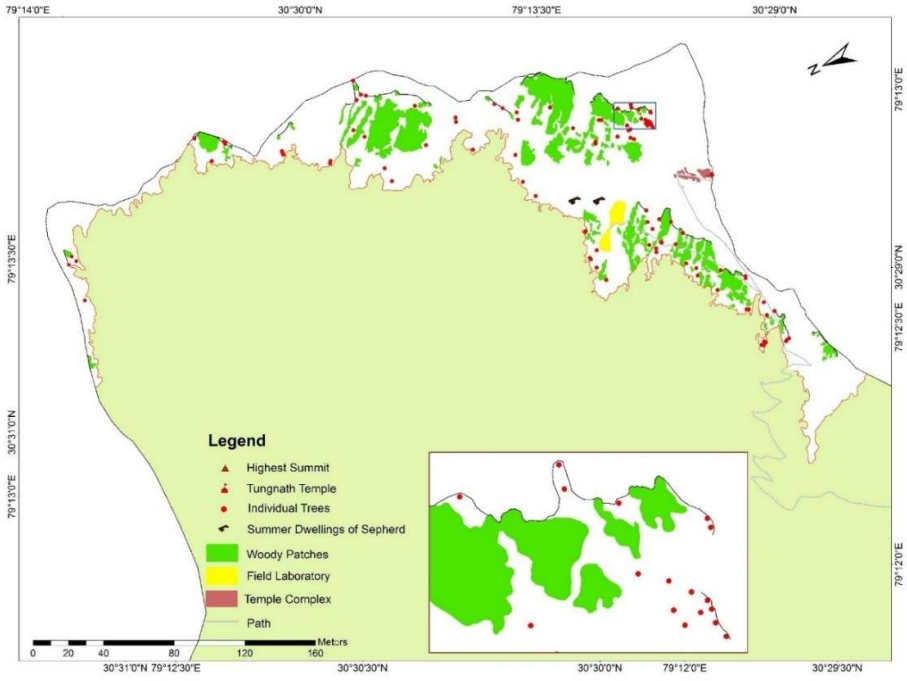


Fig.15. Mapping of Timberline, Treeline, Woody Patches & Individual Trees

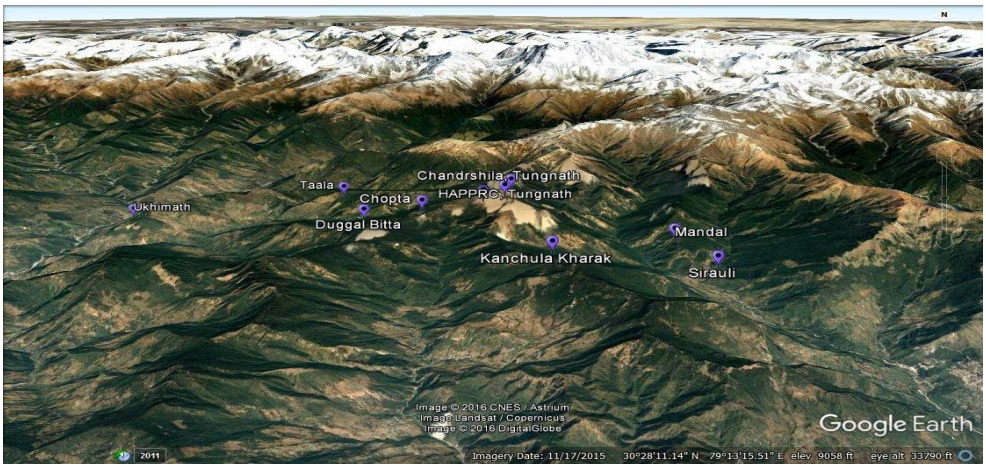


Fig. 16. Google map indicating installation of metreological instruments along Tungnath- Chopta transect (Uttarakhand)

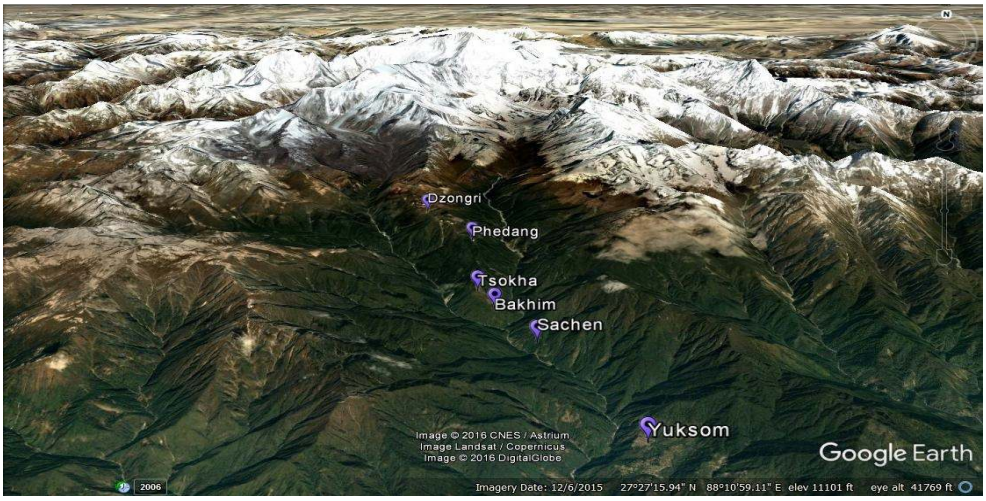


Fig.17. Google map indicating installation of metreological instruments along Yuksam-Dzongri transect (Sikkim)

Fig. 18. Google map indicating installation of metreological instruments along Daksum-Sinthan transect (J&K)

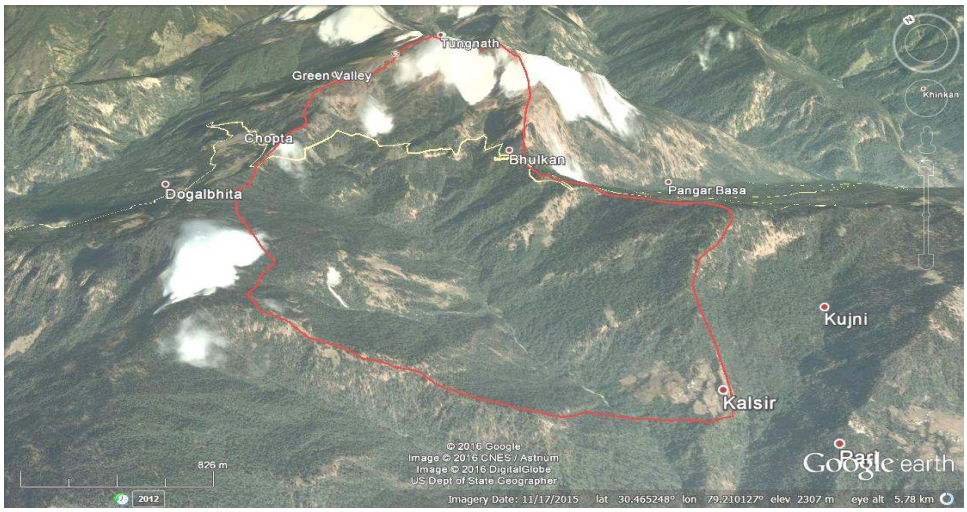


Fig. 19.Map of study area Tungnath transect-A & C (Dist- Chamoli-Rudraprayag

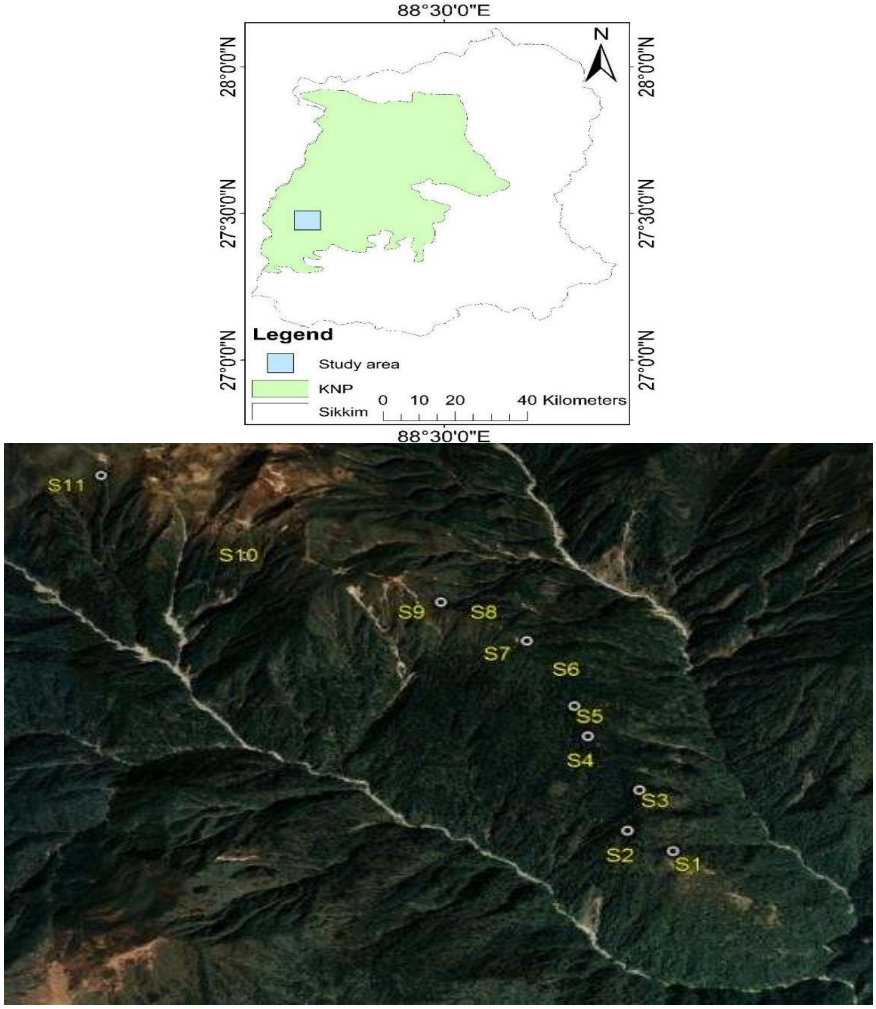


Figure .20. Study area map of subalpine conifer forest in Khangchendzonga National Park

Annexure-III

Seperate Reports

(Dr Subrat Sharma)

1. **OBJECTIVE:** To characterize and map timberline zone in the Indian Himalayan Region (IHR) using satellite and ground based observations including smart phone applications.
2. **STUDY AREA:** In the Indian Himalayan Region (IHR), Uttarakhand state has been selected for understanding the geographical influence on the state's timberline and its impact on the changing environment of the Himalayas. Regional scale mapping of timberline has been attempted in this state where high altitude timberline occurs. The geographical area of 53,483 km2. It lies on 30.0668° N latitude and 79.0193° E longitude (fig. 3). It borders Tibet to the north; the Mahakali Zone of the Far-Western Region, Nepal to the east; and the Indian states of Uttar Pradesh to the south and Himachal Pradesh to the west and north-west as well as Haryana on its south-western corner. The state is divided into two divisions, Garhwal and Kumaon, with a total of 13 districts.

3. CREATION OF GEO-SPATIAL DATABASE AND MAPPING OF TIMBERLINE

3.1. Characterization of Geo-spatial Attributes: To create geo-database for five states having timberline in IHR and timberline mapping in each of the statestandardized protocol has been developed. Topography controls the overall presence of timberline hence various attributes [slope - to measure the steepness of the terrain which may influence the occurrence of vegetation on a landscape; aspect - direction of various slopes and proxy for moisture and temperature gradient on a given altitude; elevation – proxy of air temperature along altitudinal gradient] were developed for entire state of Uttarakhand with the help of digital elevation model (DEM). During analysis it was realized that watershed has also influent in controlling vegetation (barriers and pathways) on a given landscape hence different watersheds were also derived from the DEM.

3.2. Mapping of Timberline: Tree vegetation towards the high elevation is not a continuous feature and is disrupted by slopes, rocks, landslides, snow, etc. Certain rules were framed to draw a continuous timberline - (i) Consideration of timberline – it was realized as termination of regular forested landscape (continuum of forest from lower elevation) towards high elevation, and (ii) Disruption in continuum of a line due to large scale geographical feature and natural process (landslides, eroding soils, rocks on higher slopes and their continuity towards permanent snow, etc.) which suddenly drops timberline at a much lower elevation then its normal occurrence were joined on upper side (where trees were present without disturbance) to continue the line. Hence timberline in the present case does not mean that at every spot of this line a tree is present but certainly the presence of upper limit of trees on this line is as high as 99% of the total length described for an area. Hence it can be fairly considered as upper timberline in the region.

4. METHODOLOGY: Timberline mapping of Uttarakhand state, which was carried out by using Landsat 8 satellite images 2015 having spatial resolution of 30m(Table 1).Watershed approach was adopted for timberline. Challenges of complex topography of mountains were addressed by applying human interpretation and local knowledge through visual interpretation, supported by ground truthing in different watersheds. Topography controls the overall presence of timberline hence various attribute i.e., slope, aspect and elevation were developed for entire state of Uttarakhand with the help of Digital Elevation model (DEM). DEM was used to assign the elevation of timberline, eight watershed's timberline was selected and their elevation and aspect were extracted from merging timberline with the DEM (Fig. 2).

Table 1. Characteristic of bands of Landsat 8

Band Name	Bandwidth(µm)	Resolution(m)
Band 2 Blue	0.45- 0.51	30
Band 3 Green	0.53- 0.59	30
Band 4 Red	0.64- 0.67	30
Band 5 NIR	0.85- 0.88	30
Band 6 SWIR 1	1.57- 1.65	30
Band 7 SWIR 2	2.11- 2.29	30

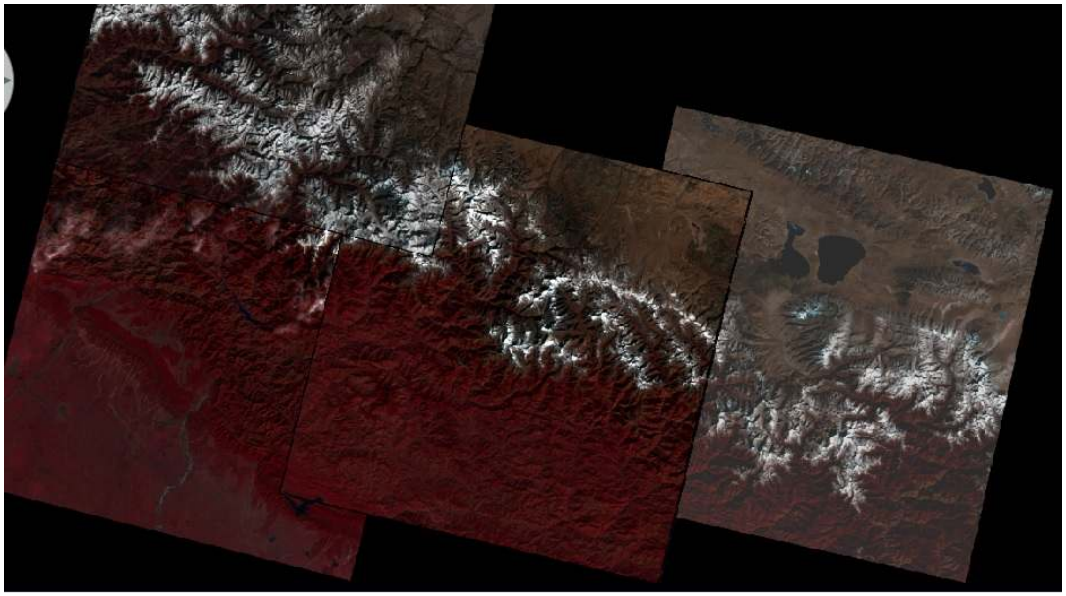


Fig.1. Landsat 8 satellite images

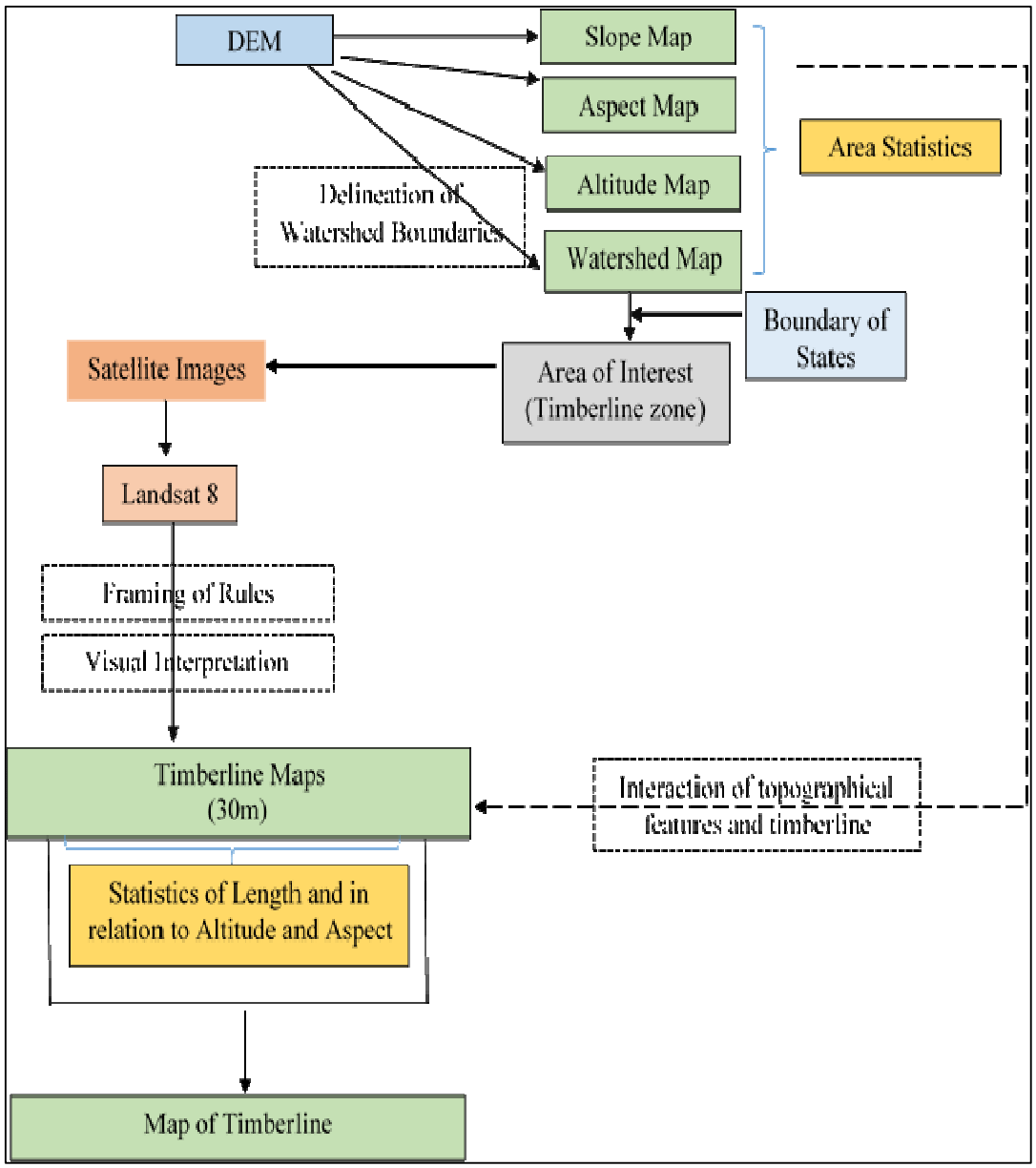


Fig. 2. Chart of methodology for timberline mapping and characterization of geo-spatial attributes

5. RESULTS:

5.1. Geo-Database of Uttarakhand:

Uttarakhand state hasthirteen districts (Fig. 3) - Almora, Bageshwar, Champawat, Nainital, Pithoragarh, Utham singh nagar, Chamoli, Dehradun, Haridwar, Pauri garhwal, Rurdeaprayag, Tehri garwal, Uttarakashi, respectively.

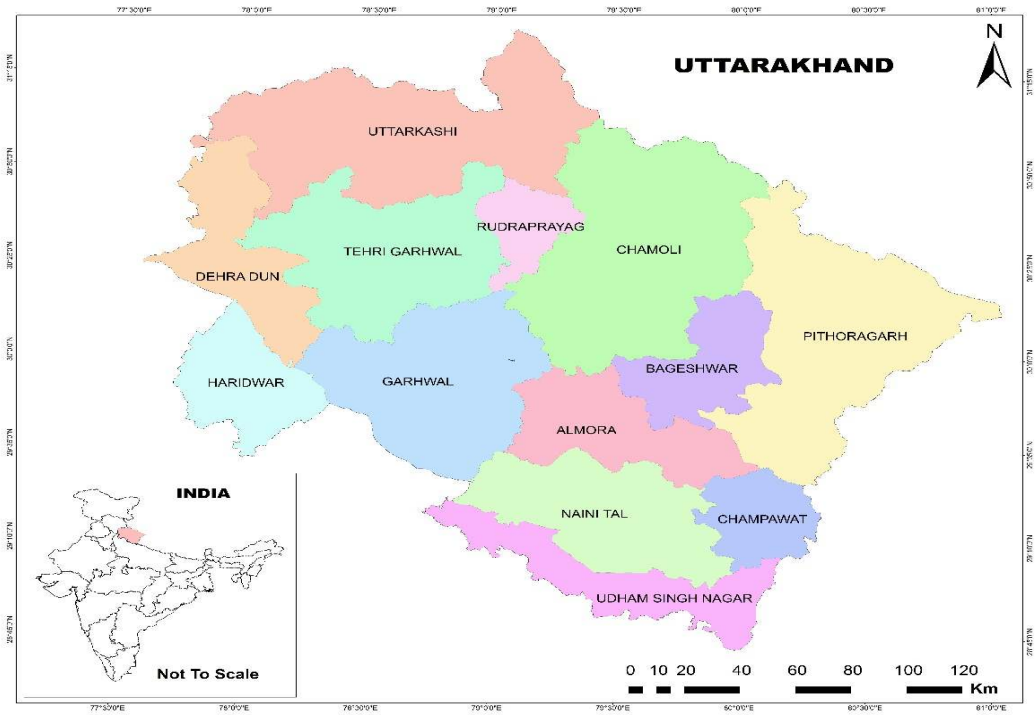


Fig. 3. Location map of Studied State - Uttarakhand

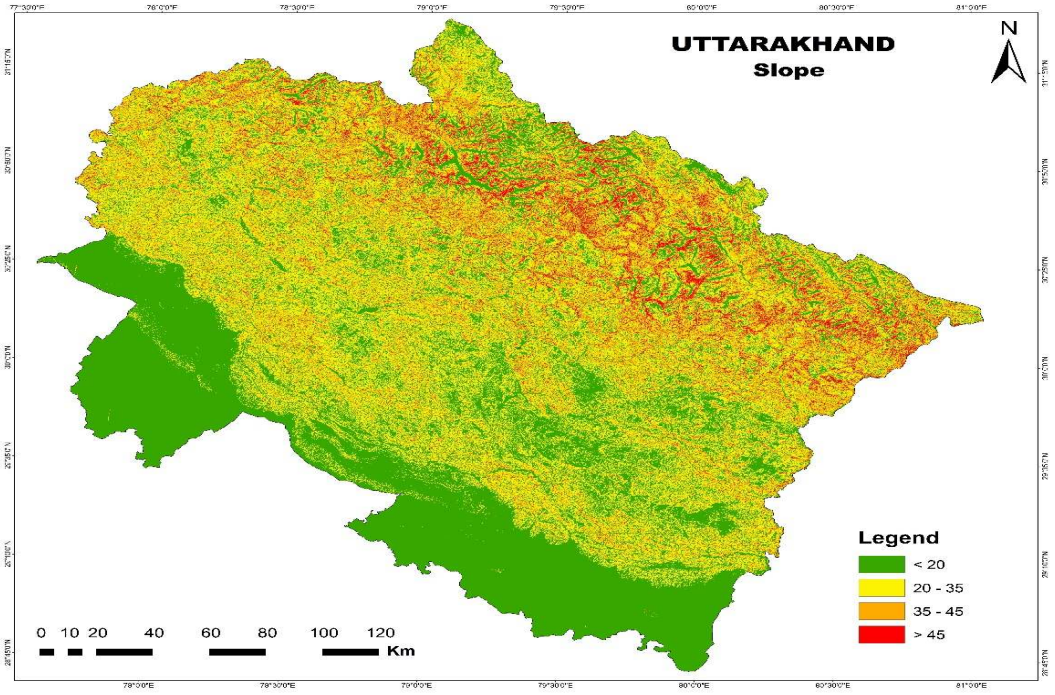


Fig. 4. Slope Map of Uttarakhand

Only (5.9%) of the state has gentle slopes (Table 2). Middle part of the state has more than 41.9% steepness than other parts. In nearly 52% areas slopes are steeper than 35^{o}.

Table 2. Uttarakhand State- Different Slope categories

(Values in parenthesis are per cent of total)

Slope Class	Area (km^2)
$< 20^{o}$	3134.92 (5.9%)
$20\text{-}35^{o}$	22394.92 (41.9%)
$35\text{-}45^{o}$	7419.86 (13.9%)
$>45^{o}$	20503.90 (38.4%)

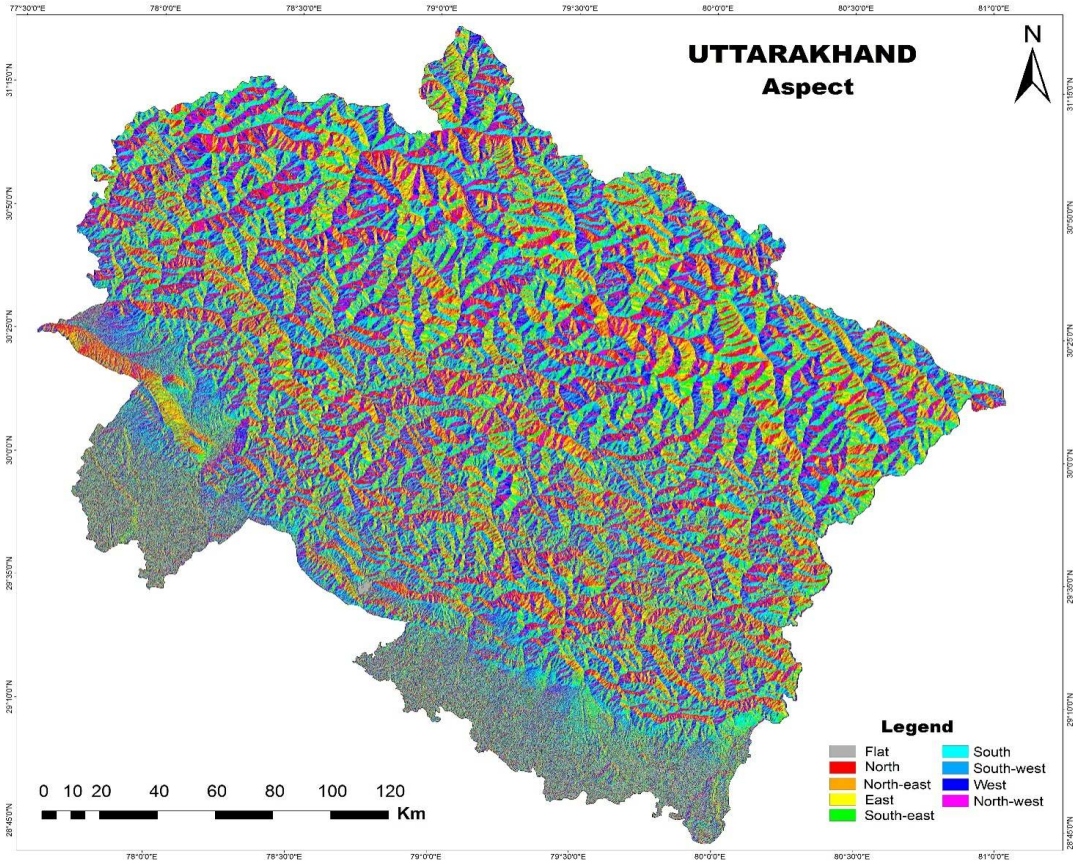


Fig. 5. Aspect map of Uttarakhand

A very small portion of the state can be considered as flat topography (0.04%). Distribution of mountainous topography in to different faces (Table 3) ranges between 11.8% (East) and 13.7% (South-west).

Table 3. Uttarakhand State - Aspect wise distribution of landscape

(Values in parenthesis are percent of total

Aspects	Area(km^2)
Flat	232.22 (0.4%)
North	6362.69 (11.9%)
North-east	6363.94 (11.9%)
East	6253.19 (11.7%)
South-east	6753.35 (12.6%)
South	7239.76 (13.5%)
South-west	7312.71 (13.7%)
West	6647 (12.4%)
North-West	6287.62 (11.8%)

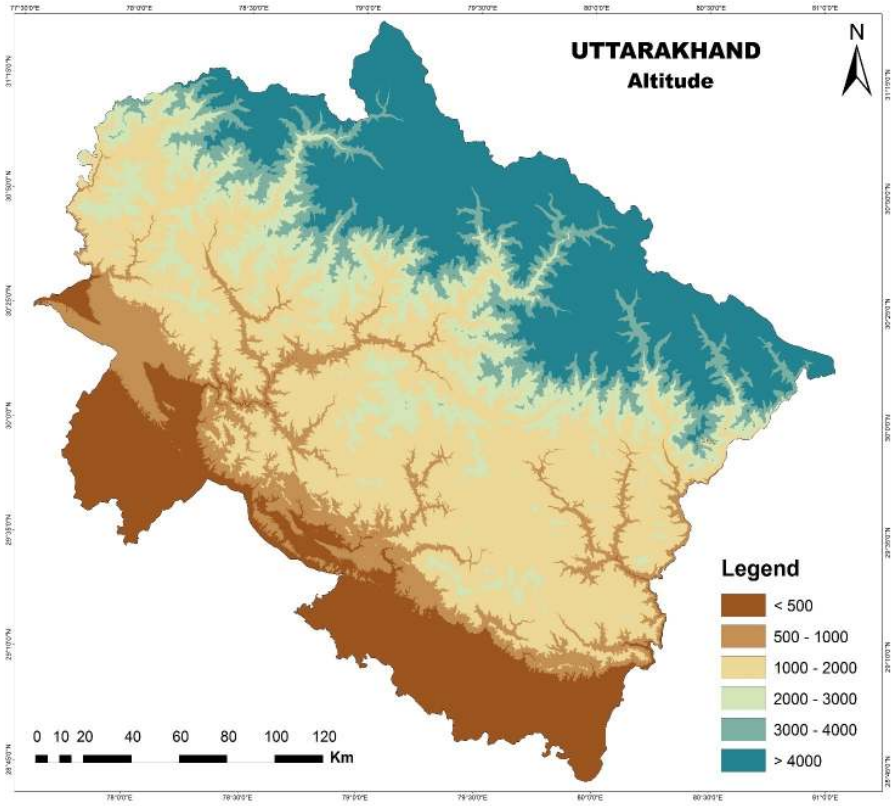


Fig.6. Altitudinal zone map of Uttarakhand

More than one fourth (20.73%) of the area of state lies above the permanent snow line (above 4000 m, Fig.6). As per the field studies conducted in eastern Himalayan region 38.4% of the state area may be considered as timberline zone (above 3000m and below 5000m).

Table 4. Uttarakhand State - Altitude wise distribution of landscape
(Values in parenthesis are percent of total)

S.No.	Altitude	Area	%
1	**<500**	8258.49	15.45
2	**500-1000**	5804.99	10.86
3	**1000-2000**	17447.06	32.64
4	**2000-3000**	6745.77	12.62
5	**3000-4000**	4121.22	7.71
6	**>4000**	11075.46	20.72

Area of Uttarakhand states can be segmented in 15 different watersheds in which Timberline exist and one non-Timberline watershed (table 5).

Table 5. Uttarakhand State –Sub-watersheds
(Values in parenthesis are percent of total)

S.No.	Sub-watershed	Area	%
1	Bhilangana	**1478.87**	2.8
2	Birahi	**1830.84**	3.4
3	Dharamganga	**2363.69**	4.4
4	Dhauliganga	**3032.60**	5.7
5	East-nayar	**2114.37**	4.0
6	Ganga	**4089.11**	7.6
7	Goriganga	**2234.22**	4.2
8	Kaliganga	**223.04**	0.4
9	Mandakini	**1635.73**	3.1
10	Pindari	**2184.07**	4.1
11	Ramganga	**1354.47**	2.5
12	Saraswati	**1543.72**	2.9
13	Saryu	**2446.85**	4.6
14	Yamuna	**4683.09**	8.8

15	West-ramganga	**3487.67**	6.5
16	Non- Timberline watershed	**18750.65**	35.1

5.2 Regional Timberline in Uttarakhand State:

The total length of timberline is 2,750.47 km in the entire state of Uttarakhand(Fig. 7.) but is broken at several places. In rare locations of the mountainous topography, timberline may descend to 2601m amsl altitude (negligible but present) and ascends upto 4,366 m amsl altitude.

Distribution of timberline in different altitudinal zones of a watershed is given in Fig.8. However, at few rare locations timberline elevation may descend close to 2600m asl (negligible in proportion) and may ascend up to 4,365 m asl, nearly one third of the total timberline in the region occurred between 3400m and 3600m asl altitude. It is apparent from uncommon pattern in the watersheds that mountainous topography has major role in occurrence of timberline at a particular watershed or area. Most of the timberline is between 3200m and 4400m while above this minimal portion of timberline occurs. More than half (57.6%) of the total timberline of the state occurs between 3400m and 3800m altitude.

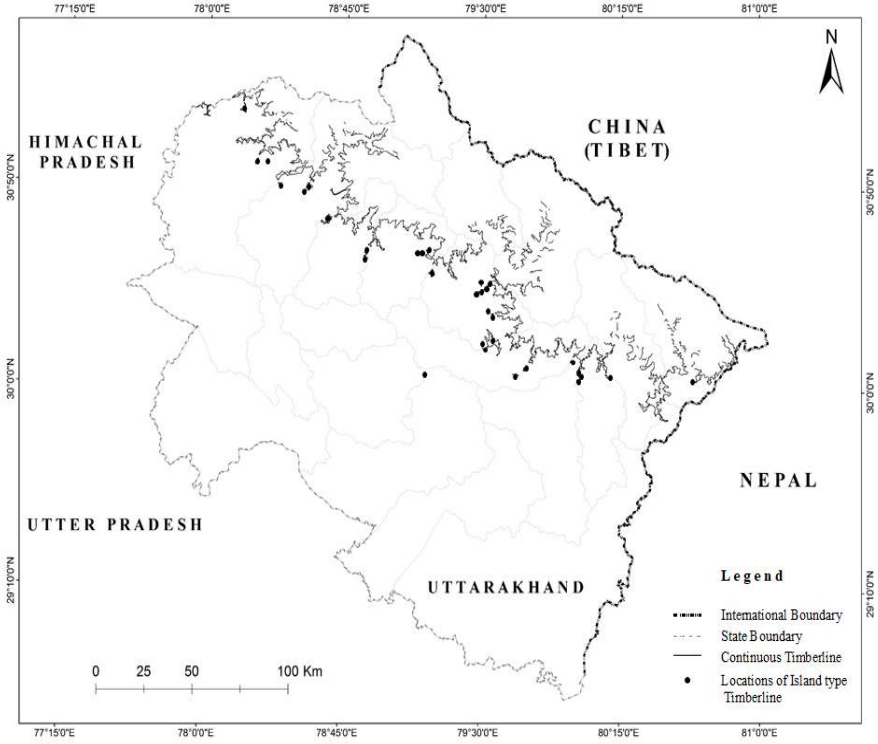


Fig 7. Timberline map of Uttarakhand derived from Landsat 8

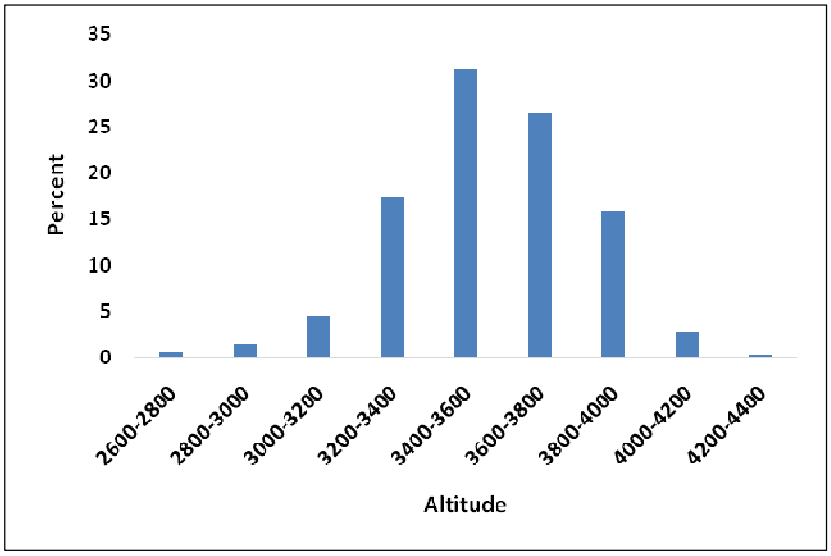


Fig.8. Distribution of total timberline in different altitudinal range

5.2.1.Type of timberline based on locations - continuous and island type,

Based on shape and characteristics of landscape, timberline can be categorized in to two types -

• **Continuous Timberline** –Continuous timberline on the Landscape having continuity to permanent snow line. This type of Timberline continuously travels between different watersheds but it is segmented in parts in different places due to physical or geographical features. Some watersheds having continuous timberline as well as islands type of timberline and some watersheds have only island type habitat (no continuous timberline, e.g. East-Nayar and West-Ramganga).

Depending upon the topographical limitations within a watershed variation in occurrence of timberline may range widely between 2600m to 4400mamsl. Most of the timberline occurs between 3200m and 4000m amsl and 60.9% continuous timberline occurs between 3400m and 3800m amsl.

• **Island timberline**- Island Timberlineis an area where abrupt rising summit occurs and having altitude more than 3000m but not leading to higher altitudes of permanent snowline (Isolated summit trap locations). These islands occur in different sizes and pattern. In this case most of them are summer dwellings of grazers and some have natural type of habitat, it may be anthropogenic and climatic timberline.

In distribution of continuous timberline upper and lower altitude ranges varies from 2600m to 4000m amsl. Most of the timberline part falls in range of 3200m and 3400m amsl and almost 48% part occurs between 3200m and 3400m amsl (peak occurrence between this zones).

5.2.2. Characters of different types of Timberline

(i) Continuous timberline- Distribution of continuous timberline in different watersheds is given in Table 6. It runs East to West continuously but have some fragments (105), 90.4% of

total timberline occurs in continuous timberline and rest in island type. Segmentation of total timberline into major watersheds of the state reveals that timberline also occur in the areas those do not culminate in the permanent snowline, e.g., Timberline in Saryu and Kaliganga watersheds where elevation is high and timberline forms an island type of habitat, particularly in the former. One more conclusion can be drawn that having largest area in high altitudes may reflects the maximum presence of timberline, e.g., Yamuna watershed is the largest (8.8% of total area)followed by Ganga watershed (7.6% of total area)in the state and this contributes 15.1% and 14.8% of the total timberline,respectively. Whereas kaliganga watershed is the smallest watershed, with Small portion of timberline (1.5%) in the state.

Table 6. Distribution of Continuous timberline in different altitudinal zones of Uttarakhand State (values in parenthesis are percent of total)

S. No.	Altitudinal Range	%
1	**2600-2800**	0.5
2	**2800-3000**	0.8
3	**3000-3200**	2.9
4	**3200-3400**	14.1
5	**3400-3600**	32.1
6	**3600-3800**	28.8
7	**3800-4000**	17.5
8	**4000-4200**	3.0
9	**4200-4400**	0.3

Majority of timberline in watersheds lies between altitudinal zone of 3200m and 4000m, highest occurrence of timberlinewas in four watersheds (4400min altitudinal zone), however maximum timberline (80%), there, lies between 3600m and 4400m amsl.

(ii) Island habitats- In the state of Uttarakhand timberline has a unique character known as Island type timberline. 32island types of summits occur, having an area of approximately 3000m amsl or above, in different parts of the Uttarakhand. Most of these islands are found in the Garhwal Region (5 in Kumaun).The total area in these isolated summit alpines (surrounded by island timberline) of the state is 65.27sqkm. and area ranges from 0.02 and 26.44 km2.Island timberline runs in the total length of 265.04 km (9.6% of the total timberline)length ranges from 0.55 to 59.9km. Minimum and maximum altitude of these summits are 2622m and 3866m amsl, respectively.

Table 7. Distribution of Island timberline in different altitudinal zones of Uttarakhand State (values in parenthesis are percent of total)

S. no.	Altitudinal ranges	%
1	**2600-2800**	1.0
2	**2800-3000**	5.8
3	**3000-3200**	18.7
4	**3200-3400**	47.8
5	**3400-3600**	22.5
6	**3600-3800**	4.0
7	**3800-4000**	0.2

Further, segmentation of total timberline into major watersheds of the state reveals that timberline also occur in the areas those do not culminate in the permanent snowline, e.g., Timberline in Saryu and Kaliganga watersheds where elevation is high and timberline forms an island type of habitat, particularly in the former. Distribution of timberline in different watersheds of the Uttarakhand state are given in Table 7. One more conclusion can be drawn that having largest area in high altitudes does not reflect the maximum presence of timberline, e.g., Ganga watershed is the largest watershed in the state and this contributes 16.2% of the total timberline while Kaliganga watershed is the smallest watershed, with Small portion of timberline (1.5%) in the state.

Table 7. Distribution of Timberline (% of total watershed) in different altitudinal bands of various watershed in Uttarakhand state.

Altitudinal Range	bhilangana	Birahi	dharamganga	Dhauliganga	East-Nayar	Ganga	Gorigang a	Kaligang a	Mandakini	Pindari	East-Ramganga	Saraswati	Saryu	Yamuna	West-ramganga
2600-2800	0.0	0.2	1.7	0.0	0.0	0.3	0.0	13.0	0.0	0.0	0.0	1.4	6.6	0.0	0.0
2800-3000	0.0	1.1	1.2	0.3	65.5	0.8	1.5	7.6	1.8	0.1	2.4	1.2	17.1	0.3	88.6
3000-3200	3.6	4.3	1.4	1.2	34.5	4.1	4.3	5.4	9.7	7.3	8.4	1.8	19.8	3.1	11.4
3200-3400	24.1	25.0	9.0	8.1	0.0	16.6	14.6	12.0	28.1	24.4	19.1	4.5	25.2	14.2	0.0
3400-3600	51.0	41.1	24.5	13.1	0.0	30.4	22.4	21.4	43.1	39.8	41.0	13.2	30.5	28.4	0.0
3600-3800	18.6	21.6	28.4	32.2	0.0	28.3	29.8	24.6	14.4	19.5	21.6	24.7	0.8	39.2	0.0
3800-4000	2.8	6.7	24.4	34.2	0.0	18.2	23.6	15.2	2.9	7.9	7.3	39.2	0.0	14.4	0.0
4000-4200	0.0	0.1	8.1	9.6	0.0	1.3	3.5	1.0	0.0	1.1	0.2	13.6	0.0	0.3	0.0
4200-4400	0.0	0.0	1.3	1.2	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0

ITL was absent in three watersheds and two of these (Sarswati and Dhauliganga) were in the Inner Himalayan ranges. The third watershed (Kaliganga) is a small watershed (223km^2) which was separated as a small watershed due to political divide between India and Nepal while total area of remaining 14 watersheds ranged from 1354km^2 to 4683km^2.

Contribution of a watershed, to the total CTL, may vary from 0.6% (a rainfed watershed adjacent to watershed having permanent snow cover) to 15%. For ITL such contribution of a watershed varied between 0.6% and 28.1% of the total ITL, and length from 1.6km to 74km.

The highest presence of IST was in a watershed where several geological faults were present, thus may have contributed to formation of abrupt summits and landscapes having elevations >3000m. Similarly, high segmentation of timberline (9 or more fragments in a watershed) was also observed in the watersheds those had some area in Inner Himalayan ranges or Trans Himalayan Belt. Such observations indicate that topography and geology has dominant role in developing forests in the high altitudes of the Himalaya and formation of timberline.

Distribution of entire timberline with respect to aspect indicated that most of the timberline occurred on warmer aspects (SW=14.3%, SE=14%, W=13.4%, E=13.1%, & S=12.6%) than cooler aspects (N=10.5%, NE=10.9%, & NW=11.2%).

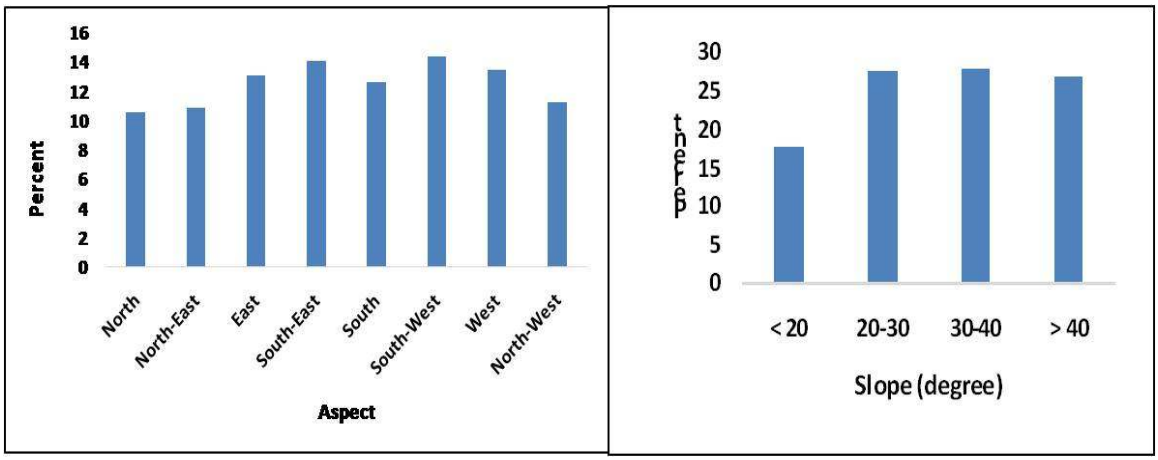


Fig. 9 Distribution of total timberline in different **(a)** aspects **(b)** Slopes

High Himalayan topography is very rugged and constituted by peaks and high steep walls of watersheds and moderate slopes of valley floor. High altitude forests either creeps in a valley floor towards glacier or climbs to slopes (low elevation than the highest summit) of a watershed wall towards areas having no permanent snow. Distribution of timberline in different slope categories indicates that trees have capabilities to reach on step gradients. 17.7% of total timberline occurred in gentle to moderate slopes (<20^{o}) while it was almost equally distributed (26.9%-27.7%) in moderately steep slopes (20-30^{o}), Steep (30^{o}-40^{o}), and very steep slopes (>40^{o}).

6. Discussion

At a regional scale climate is an important determinant of timberline, but at local scale topography is an obvious way to size up the landscape and influencing distribution of tree species. Elevation band of 3200-3600m where more than half of the timberline occurs can be considered as 'timberline zone' for the Indian Central Himalaya. Timberline elevation varies considerably in this region and sub-units (watersheds therein). Two watersheds (Ganga and Yamuna) of the river Ganga contribute nearly 30% of the total timberline in the Indian Himalayan region, however they occupy only 16% of the total area of the state.

This study is first description of presence of *islandtypetimberline* while summit trap phenomenon for a forest is known for a quiet long. Maximum of such island types timberline around a summit were in the Garhwal region (27 locations) of the state indicating more rugged terrain than the Kumaun region.It can be deducted that complexities of topographic features in the mountains positively influence the distribution of timberline which may react sensitively to climate warming and anthropogenic changes in different ways.

Structure and species composition of timberline are influenced by aspect (Danby and Hik, 2007). An influence of topography and geology of the region is apparent on elevation and spatial attributes of timberline. *Abies pindrow* makes timberline around two summits in the rainfed watersheds those were located in the outermost Himalayan ranges. This site represents a classic example of "*summit trap*" phenomenon in the Outer Himalayan ranges. Such sites are more vulnerable to impacts of climate change coupled with anthropogenic activities.

However, isolated summits are natural habitats for timberline zone and alpine vegetation, influence of human activities cannot be ignored, which lead to uncertainties in determining anthropogenic and climatic timberline in such areas. This study along with observations of anthropogenic activities can be used as bench mark for such locations to realize any shift (both wards) in future.

Detailed Mapping of Intense Sites

1. Study Area – Tungnath

One of the intense study sites in the Central Himalaya lies between 30.47 - 30.51dd N latitude and 79.15 - 79.22dd E longitude, covering an altitude between 1630m and 3625m amsl (Fig1.1). Tungnath Watershed is one of the micro watershed of Mandakini River. It is a small region of meadows and evergreen forest area which is a part of Kedarnath wildlife sanctuary located in Rudraprayag District of Uttarakhand state. The topography of the area is completely hilly with gradual slopes forming alpine meadows. Small streams are also quite common.

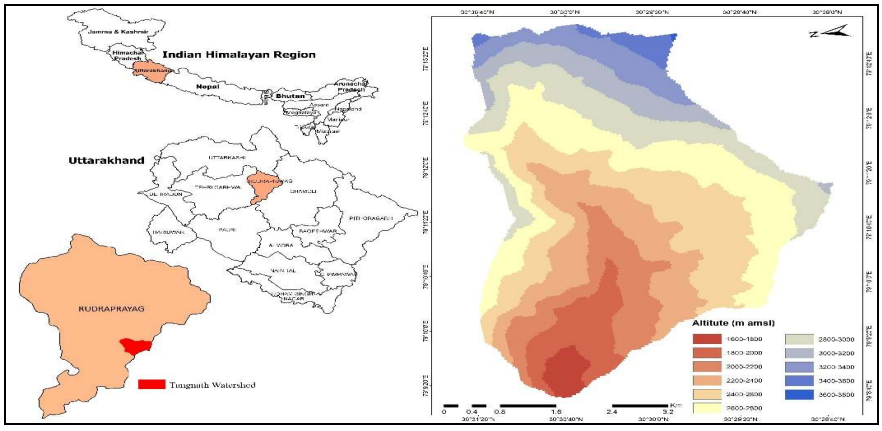


Fig.1.1. Location Map of Studied State – Tungnath

2. Methodology

In this study two high resolution satellite images were used, first LISS IV (21 December2015) multispectral image (False Color Composite) was used for mapping of landuse/landcover of Tungnath watershed (Fig. 1.2). Major classes were categorized from LISS IV satellite image of band 2, band 3, and band 4 having 5.8m resolution. These bands were layer stacked and was subject to supervised classification (employed in ERDAS IMAGINE 2016) to obtain following classes- (1) mixed Evergreen and Deciduous forests, (2) alpine meadows, (3) low altitude grasslands, (4) woody patches above timberline, (5) forest blanks, (6) cultivated land, (7) rocks and boulders, (8) barren, (9) water bodies, (10) settlement, and (11) road. Recoding of image was done using high resolution satellite image from Digital Globe (available through Google Earth) was done. Second, Digital Globe image (available through Google Earth with resolution 0.5 – 2 m) was used for mapping of timberline, treeline, woody patches and individual trees by visual interpretation technique. The digitized features (KML files) convert into shapefile, after that post processing of data (topology build) was done and final map was prepared in ArcGIS software. DEM (Digital Elevation Model, 30m) was also used to understand the distribution of timberline along an altitudinal gradient and aspect. To understand the distribution of treeline, woody patches and individual trees above timberline was done with the help of Digital Globe Image (available through Google Earth).

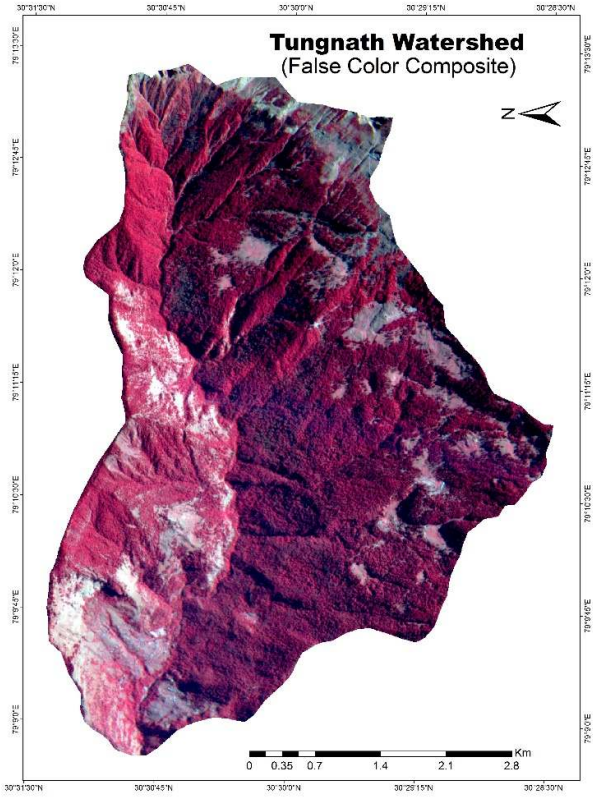


Fig.1.2. FCC of Tungnath Watershed

3. Results

3.1. Landuse- Landcover map and Area Statistics- Tungnath watershed is spread in an area of 24 km^2 (Fig.1.3). Worthwhile to note that the forest (evergreen mixed forest and deciduous dominated mixed forest) is dominated on the landscape covering an area of 80.31 % whereas 3.68%, 0.72%, 0.20, 8.28%, 3.37 and 2.33% area was covered by alpine meadows, shrubs (or woody patches above timberline), rocks &boulders, low altitude grassland, forest blanks within forest and agriculture classes respectively. Settlement, barren patches, road and water bodies covers an area of 1.11% (Table 1.1).

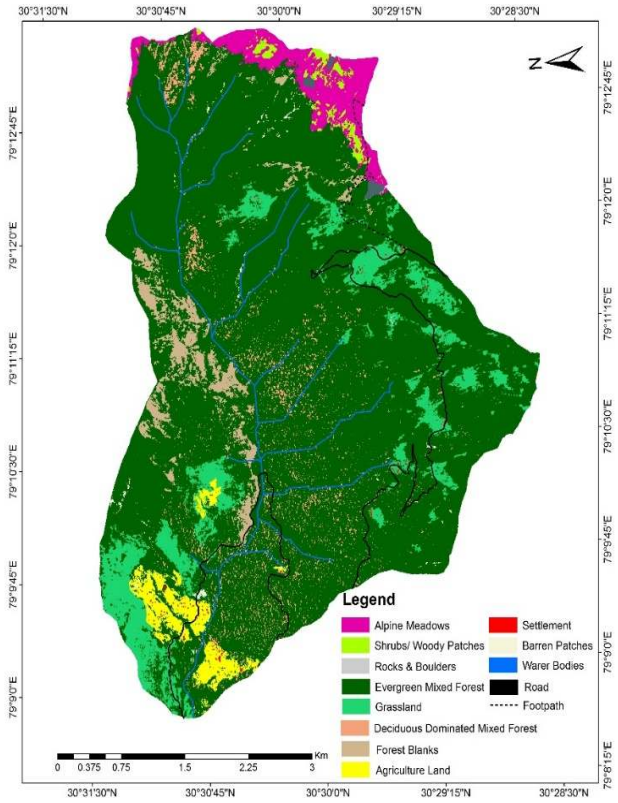


Fig.1.3. Landuse/Landcover Map of Tungnath Watershed

Table 1.1. Area under different classes of Landuse/Landcover of Tungnath Watershed

Sl. No	Classes	Area	
		(ha)	(%)
1	Evergreen Mixed Forest	1877.9	78.23
2	Deciduous Dominated Mixed Forest	49.8	2.08
3	Alpine Meadows	88.3	3.68
4	Low altitude Grassland	198.8	8.28

5	Shrubs/Woody patches	17.4	0.72
6	Forest Blanks	80.9	3.37
7	Agriculture land	56.0	2.33
8	Rocks and Boulders	4.9	0.20
9	Barren Patches	6.2	0.26
10	Water Bodies	10.4	0.43
11	Settlements	2.8	0.12
12	Roads	7.1	0.30

3.2. Distribution of Timberline, Treeline, Woody patches, and Individual Trees-

Mapping of timberline, treeline, woody patches and individual trees derived from Digital Globe Image (available through Google Earth) is presented in Fig. 1.4.

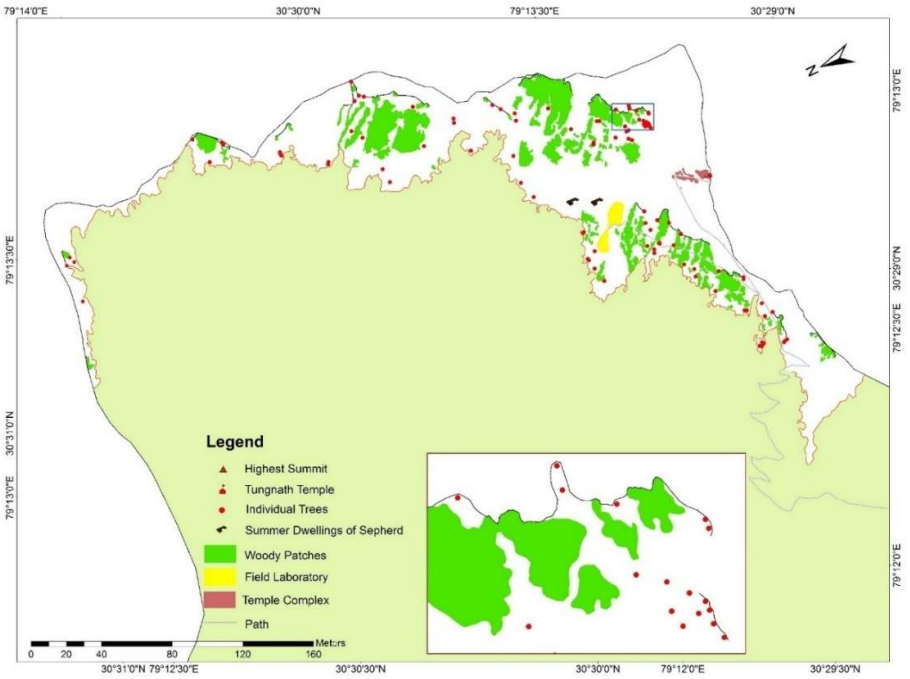


Fig.1.4. Mapping of Timberline, Treeline, Woody Patches & Individual Trees

3.2.1.Timberline attributes

Timberline in the year 2017 is presented in Fig.1.4. Total length of timberline is 9.67 km in the studied state.The result indicates that the minimum elevation is 3062m amsl and maximum timberline elevation of Tungnath watershed is 3453m amsl, whereas mean

elevation of timberline is 3289m amsl.The timberline in Tungnath watershed was found to be in two fragments instead of being continuous because of the presence of a path in between.

Distribution of timberline on the basis of different elevational zones starting from 3050m to 3500m with a class interval of 50m. It was found that the maximum distribution of timberline in the range 3250-3300m asl (37.11%) while the minimum was found in 3450-3500m (0.63%)Fig.1.5.

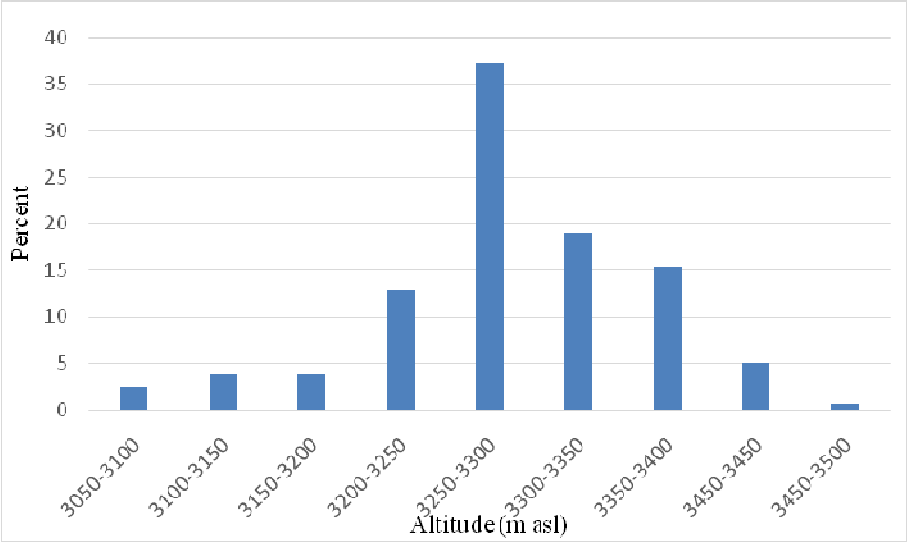


Fig.1.5. Percent distribution of total timberline along different elevational zones

Distribution of timberline in relation to aspects in Tungnath watershed indicated that timberline is distributed in North, North West, West, South and South West aspect. The maximum distribution is in the North West (49.69%) aspect whereas minimum in South (2.20%) aspect (Fig.1.6).

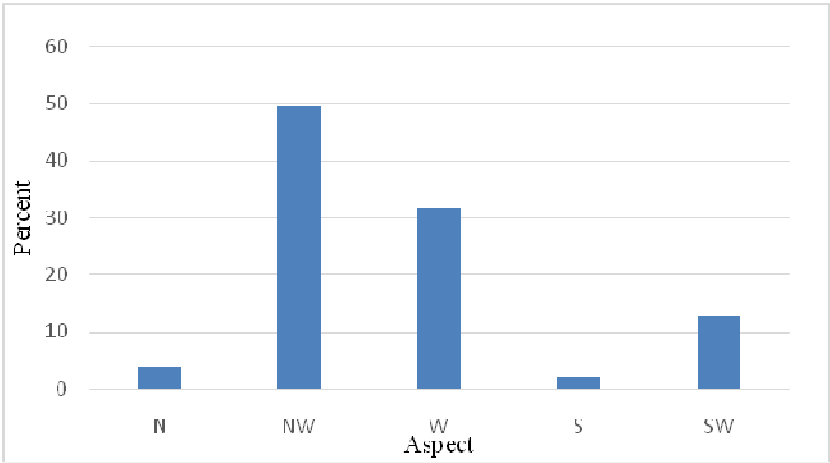


Fig.1.6. Percent distribution of total timberline along different Aspects

3.2.2. Treeline attributes

Treeline is an imaginary line joining top most trees present above timberline at various locations (Fig. 1.4.). Total length of treeline is 2.70 km with minimum elevation 3228m amsl and maximum elevation 3550m amsl. Mean elevation of treeline is 3383m amsl. Total Treeline segmented into 16 fragments presented in Table 1.2.

Table 1.2. Treeline fragments characteristics

Treeline Fragments	Minimum Elevation (m asl)	Maximum Elevation (m asl)	Average Elevation (m asl)	Length (km)
1	3292	3322	3305	0.19
2	3301	3318	3311	0.10
3	3343	3405	3383	0.53
4	3405	3406	3406	0.01
5	3426	3435	3429	0.12
6	3466	3532	3510	0.29
7	3505	3550	3522	0.43
8	3519	3527	3523	0.03
9	3376	3381	3378	0.05
10	3373	3399	3382	0.32
11	3332	3338	3335	0.16
12	3301	3318	3313	0.17
13	3278	3323	3303	0.17
14	3228	3254	3242	0.05
15	3365	3367	3366	0.01
16	3408	3433	3421	0.07

Spatial attributes of treeline reveals that there are some locations where treeline goes up to the upper watershed boundary at five locations (3295m, 3310m, 3380m, 3254m and 3525m asl), however, at other sites treeline was 15m to 625m below the upper boundary of watershed.

3.2.3 Woody Patches attributes

Total 80 woody patches of different size and area of total woody patches are 17.194 ha. Minimum elevation of woody patch is 3225 m asl while maximum elevation of woody patch is 3550 m asl. Based on the total area these woody patches were categorized into 5 classes. Most of the woody patches was below the size of 0.1 ha (65 %), second area class (0.1- 0.5

ha) containing 26.25% of total patches. 5 % patches have an area between 0.5 to 1ha and only 3.75 % patches have an area above 1 ha Table 1.3.

Table 1.3. Distribution of woody patches in different area classes

Classes (Area in hectare)	Number of Woody Patches	Percent
< 0.05	41	51.25
0.05- 0.1	11	13.75
0.1-0.5	21	26.25
0.5-1	4	5
>1	3	3.75

Distribution of woody patches along altitudinal gradient (mean elevation of centroide)indicates that maximum woody patches (43.75%, 35 in number)occur in a range of 3300-3350m amsl of the total woody patches, whereas only one woody patch was found in the range 3200-3250 m i.e. 1.25% (Table 1.4).Individual patch has a narrow range of elevational width (lowest and highest point of a patch), however this spread was observed 100m or more in five patches (Fig. 1.7).

Table 1.4. Distribution of woody patches along an altitudinal gradient (at central point of the patch)

Altitude Range (m)	Number of Woody Patches	Percentage
3200-3250	1	1.25
3250-3300	7	8.75
3300-3350	35	43.75
3350-3400	10	12.5
3400-3450	12	15
3450-3500	11	13.75
3500-3550	4	5

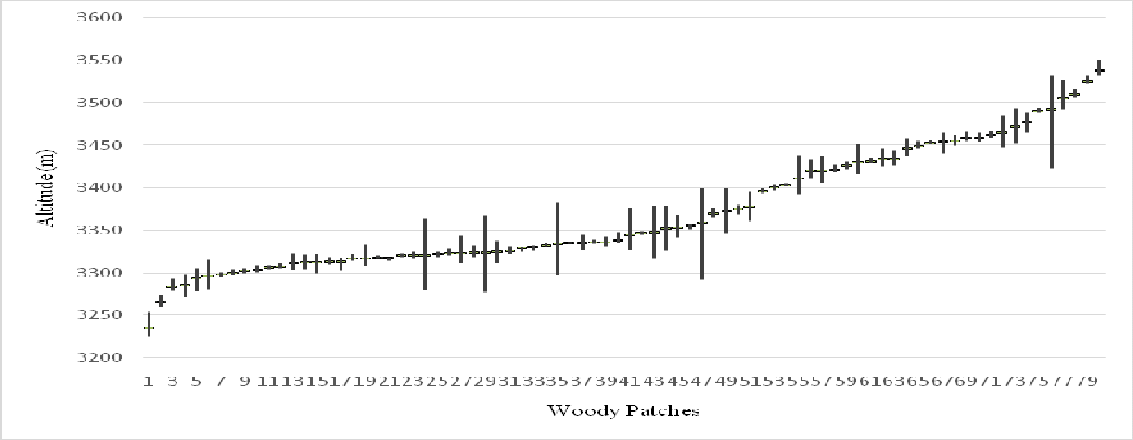


Fig. 1.7. Mean elevation of woody patches and spread (minimum and maximum). Patches are arranged in increasing mean elevation.

Distance of woody patches from timberline (from minimum elevation of a patch) may vary between adjacent to forest (in continuation to timberline) to more than 600m away.Half of the total woody patches (52.5%) is in the range between 0-100m and only 1.25% is in the range of 500-600m (Fig.1.8), which indicates more colonization near the forest habitat but also indicates capability of woody patches (e.g *Rhododendrom campanulatum*) to establish towards higher elevations if conditions are favourable.

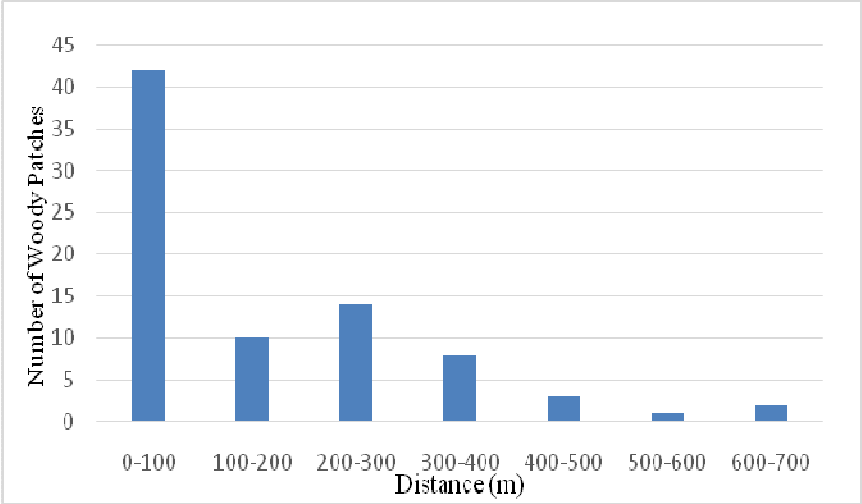


Fig. 1.8. Distribution of Woody Patches (minimum elevation) from timberline in relation to distance range

At places woody patch may reach to watershed boundary, however maximum distance of a patch is 825.77 m from boundary. Based on range of distance from watershed boundary, 30 % woody patches is in the range between 0-100m and only 1.25% (1 patch in number) is in the range of 800-900m (Fig1.9).

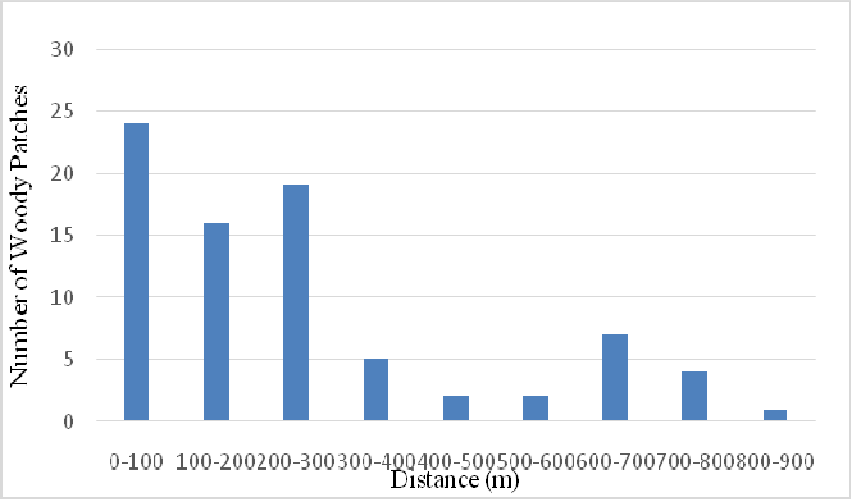


Fig.1.9. Distribution of Woody Patches in relation to distance range

3.2.4 Individual Trees attributes

Total 101 individual trees were identified on the image and were mapped (Fig. 1.4). Distribution of individual trees on the basis of different elevational zones starting from 3200m to 3550m with a class interval of 50m. It was found that the maximum (27.72%) distribution of individual trees in the range 3300-3350m while the minimum (0.99%). was found in 3200-3250m (Table 1.5).

Table 1.5. Distribution of Individual Trees along an elevational zone

Elevation Zone (m)	Number of Trees	Percent
3200-3250	1	0.99
3250-3300	19	18.81
3300-3350	28	27.72
3350-3400	18	17.82
3400-3450	7	6.93
3450-3500	12	11.88
3500-3550	16	15.84

Distance of individual trees from timberline was measured to realize advancement in tree establishment. The minimum distance is 4.32m having an elevation 3320 m amsl and maximum distance reaches 674.92m having an elevation 3547m amsl. Much of the explanation of distance is explained by the altitude (Fig.1.10), however, other factors also exists (pilgrims activities, grazing, etc.).Based on range of distance,the distribution of individual trees was divided into 7 classes. Half of the total trees (53.47%) is in the range between 0-100m and only 1.98% is in the range of 200-300m Table 1.6.

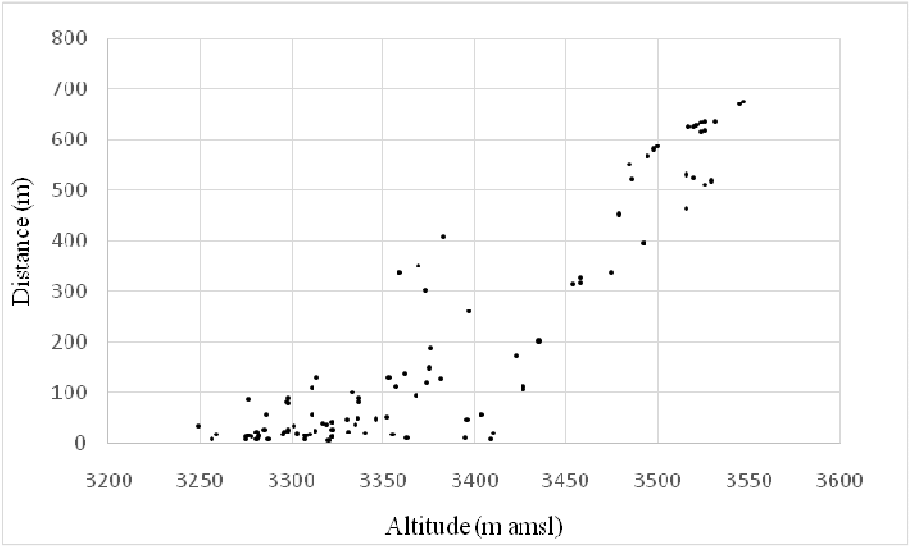


Fig.1.10. Distribution of individual trees along an altitudinal gradient and distance from timberline

Table 1.6. Distribution of Individual Trees in relation to distance range

Distance Range (m)	Number of Individual Trees	Percent
0-100	54	53.47
100-200	13	12.87
200-300	2	1.98
300-400	9	8.91
400-500	3	2.97
500-600	9	8.91
600-700	11	10.89

3.2.5. Space above Timberline/Treeline and Summit Syndrome

The mountain height has a conclusive effect on timberline and treeline elevation. The relationship was analyzed by linear regression with timberline and treeline elevation as a dependent variable. Present elevations of timberline (n=24) and treeline (n=17) were positively related with mountain heights (summit and nearest watershed boundary) of the Tungnath watershed. It was observed that an increase in mountain height will lead to an increase in timberline elevation($p = <0.001$), and treeline elevation ($p = <0.001$).

4. Discussion

The study demonstrates first time current positions of treeline/timberline in a Himalayan watershed and their various attributes. However, timberline crosses the boundary on lower slopes those are much below the summit of that watershed, current treeline in the watershed

attains much height to do so but towards highest elevation difference between maximum altitudes of both lines remains 160m only. Overlapping of timberline and treeline are due to topographic features and edge effect of watershed boundaries, thus sharp differences in a locality are not visible (end of one and start of another).

Area available for future expansion of forests and trees in the watershed is about 80% of the area above timberline (alpine vegetation) which also has an influence of human activities (grazing and pilgrims). In addition to biological attributes of a tree species and impacts of climate change, cultural influences are critical for understanding the response of timberline in the watershed. Landuse practices (current) in Tungnath may influence perceived shifts of timberline (upward movement) in the Himalaya due to climate change, however, being a historically grazing ground and visits of tourists/pilgrims may further influence the shape of current timberline/treeline in the watershed.

Further research is required (i) to know and quantify species association/vegetation assemblages of woody patches to realize role in ecosystem functioning, and (ii) in association with present data set to develop landscape level understanding on facilitation/expansion of tree species towards high altitude.

(Dr. Rajesh Joshi)

NMHS Progress Report
(Period *from* 01.04.2017 *to* 31.03.2018)

1. Project Information

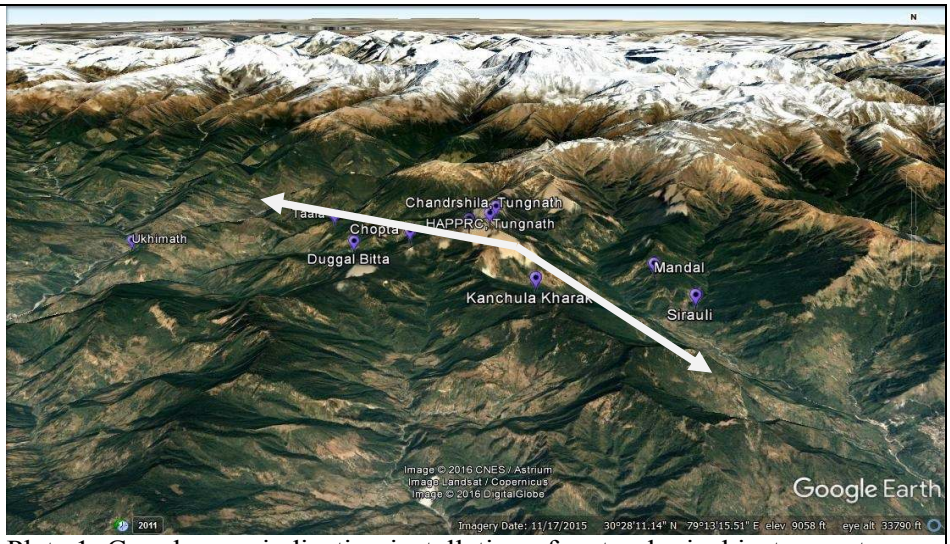
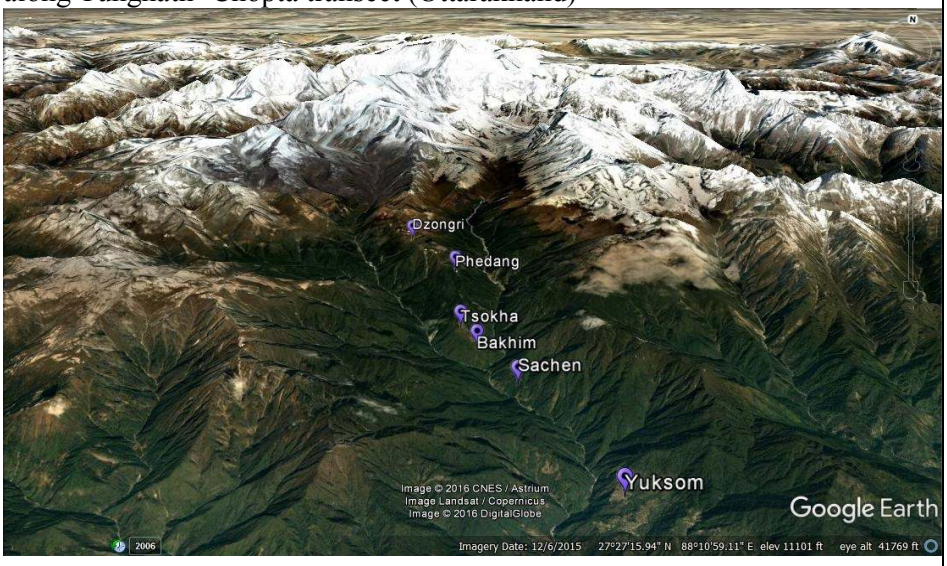
Project ID:		**Sanction Date:**	
Project Title:	Timberline and Altitudinal Gradient Ecology of Himalayas, and Human Use Sustenance in a Warming Climate **Sub project:** To determine the temperature lapse rate (TLR) and pattern of precipitation along altitudinal gradients in different precipitation regimes across the IHR		
BTG:			
PI and Affiliation (Institution):	**Dr. Rajesh Joshi, Scientist-D** G. B. Pant National Institute of Himalayan Environment and Sustainable Development, Kosi-Katarmal, Almora		
Name & Address of the Co-PI	--NA--		
Structured Abstract - detailing the current year progress [Word Limit 250 words]:	For Tungnath-Chopta (CT) transect in Uttarakhand, temperature lapse rate (TLR) is calculated for treeline environment based on ground observations along an elevation transect (1500-3680 m). The TLR is calculated for the four main climatic seasons, namely Winter (DJF), Pre-monsoon (MAM), Monsoon (JJAS), Post-monsoon (OC) and on annual scale for two different aspects of the transect. The mean annual TLR in CT transect is found less steep (-0.53^{0}C/100m) than the commonly used global value (-0.65^{0}C/100m). The highest mean TLR (-0.64^{0}C/100 m on NW aspect and -0.60^{0}C/100 m on SE aspect) is		

	observed for pre-monsoon season whereas the lowest (0.42^0C/100 m on NW aspect and -0.39^0C/100 m on SE aspect for the winter season. In case of Yuksam-Dzongri (YZ) transect in Sikkim, the winter season lapse rates of average temperature is estimated as -0.46^0C/100 whereas for maximum and minimum temperature it is estimated as -0.36^0C/100 and -0.56^0C/100 respectively. Further, temperature loggers are installed at 4 different stations along an elevation range (1900-3000 m) along Daksum-Sinthan (DS) transect in Jammu & Kashmir to record maximum, minimum and average temperature and relative humidity on daily scale. Additionally, 09 hydrological plots are established along treeline zone of the CT transect to study the hydrological response of four major vegetation types (*viz*. Conifer, Broadleaf deciduous, Krumholz, and grassland). Under this component, study on rainfall partitioning (gross rainfall, throughfall, stemflow), surface runoff and sediment loss analysis for different vegetation type as initiated during monsoon season of 2017.

Project Partner Name	Affiliations	Role & Responsibilities
Partner 1	--NA--	

2. Project Site Details

Project Site	Chopta –Tungnath (CT) transect (Uttarakhand) Yuksam-Dzongri (YZ) transect (Sikkim) Daksum-Sinthan (DS) transect (J&K)
IHR States Covered	Uttarakhand, Sikkim and Jammu & Kashmir
Long. & Lat.	N $30^0$29.57’; E $79^0$12.95’ (Uttarakhand) N 27^0 22’40.30”; E $88^0$13’18.21’’ (Sikkim) N $33^0$35.231’ ; E $075^0$28.554’ (J&K)

Site Maps	 Plate 1: Google map indicating installation of metreological instruments along Tungnath- Chopta transect (Uttarakhand)  Plate 2: Google map indicating installation of metreological instruments along Yuksam-Dzongri transect (Sikkim)

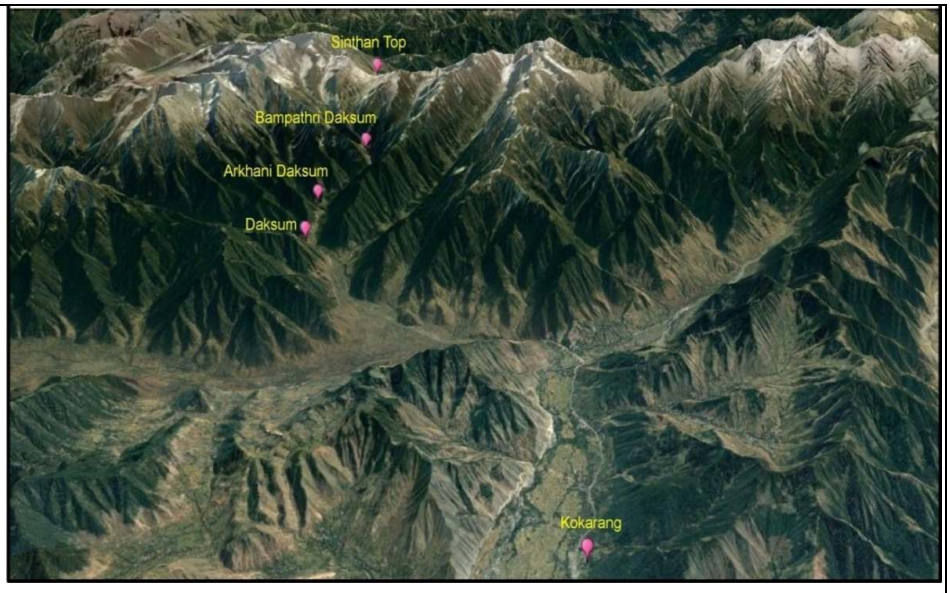


Plate 3: Google map indicating installation of metreological instruments along Daksum-Sinthan transect (J&K)

Site Photographs

Plate 3: Sampling plot established along tree line zone of CT transect for hydrological response of (A) *Abies spectabilis* (B) *Quercus semecarpifolia* (C) *Rhododendron campanulatum,* and (D) grass land

3. Project Activities Chart w.r.t. Timeframe [Gantt or PERT]

Project Activities	WORK UNDERTAKEN				OUTPUT
	Year 2017-2018				
	Qtr 1	Qtr 2	Qtr 3	Qtr 4	
Project Activity 1	Data collection for Pre-monsoon season for CT transect (UK) Installation of data loggers in selected sites along DS transect (J&K)	Data collection for monsoon season for CT transect (UK) Data collection for monsoon season for YD transect (Sikkim) Data collection for monsoon season for DS transect (J&K)	Data collection for post-monsoon season for CT transect (UK) Data collection for post-monsoon season for YD transect Data collection for post-monsoon season DS transect (J&K)	Data collection for winter season for CT transect (UK) Data collection for winter season for YD transect Data collection for winter season for DS transect (J&K)	Annual and seasonal TLR for CT transect is calculated. TLR for monsoon season for YD transect in Sikkim is calculated. 4 Long term monitoring sites in J&K are established.
Project Activity 2		Establishment of experimental plots (10mx5 m) for study of hydrological response of different vegetation types along treeline zone in CT transect Data for rainfall interception (gross rainfall, throughfall, stemflow) and surface runoff is collected			Rainfall partitioning (gross rainfall, throughfall, stemflow) and surface runoff behaviour for *Abies spectabilis, Rhododendron campanulatum, Quercus semecarpifolia,* and Grassland is being studied. This field based study will also be continued in next year of the project.

Project Activity 3				Collection of data from study sites in J&K, UK, and Sikkim	Daily data for temperature, relative humidity and rainfall is collected. Quality control and processing of collected data is ongoing.
Project Activity 4				Preparation of project progress reports	Half yearly and Annual Progress Report of the project submitted to PMU of the project.
Project Activity 5		Developed a chapter on TLR estimation for field manual of IHTP project		Based on one year data, a manuscript on TLR for treeline environment of CT transect is prepared	Book chapter published in "Field Manual for IHTP project". Research paper, titled "Near surface temperature lapse rates for treeline environment in western Himalaya and possible impacts on ecotone vegetation " submitted to the Journal of Tropical Ecology for publication.

4. Financial and Resource Information

Note: A separate bank account is expected to be opened for NMHS Project as per the provision of Direct Beneficiary Account (DBA) as laid out by the Govt. of India and also facilitate the audit of accounts. The interest earned out of the NMHS project funds should be reported clearly in the utilization certificate.

Total Grant:	49,15,000.00	Grant Received Date:	May, 2016
Project Partner(s)	**Affiliations/ Institution**	**Budget Allocated to**	**Work Done**
Partner 1	NA	NA	NA

Project Staff Information:

S. No.	Name	Qualification	Designation	Fellowship/ Wages paid	Remarks
1.	Mr. Kumar Sambhav	M.Sc. MATHEMATICS	JPF	16,000 pm (+10% HRA)	Appointed for objective no. 2
2.	Mr. Mohit Fulara	M.Sc. Geology	JPF	16,000pm (+10% HRA)	Appointed for objective no. 5
3.	Mr. Balam Singh Bisht	B.A	F.A.	8,000 pm	

5. Equipment and Asset Information

6. Expenditure Statement and Utilization Certificate

Please update the annual Expenditure Statement and Utilization Certificate (UC) periodically.

Expenditure Information:

S. No.	Financial Position/Budget Head	Funds Sanctioned	Expenditure	% of Total cost
I	Salaries/Manpower cost	5,18,400	To be sent soon	
II	Travel	2,50,000.00		
III	Expendables &Consumables	2,00,000.00		
IV	Contingencies	1,10,000.00		
V	Activities & Other Project cost	4,00,000.00		
VI	Institutional Charges	--NIL--		
VII	Equipments	--NIL--		
	Total	14,78,400.00		
	Interest earned			
	Grand Total			

Period	Expenditure Statement	Utilization Certificate (UC)
Annual (2016-17)	[**Attach**] To be sent soon	[**Attach**] To be sent soon

7. Project Beneficiary Groups

Beneficiary Groups [Capacity Building]	Target	Achieved
No. of Beneficiaries with income generation:	NA	NA
No. of stakeholders trained, particularly women:	1	1
No. of capacity building Workshops/ trainings:	NA	NA
No. of Awareness & outreach programmes:	NA	NA
No. of Research/ Manpower developed:	3	3

8. Project Progress Summary (as applicable to the project)

Description	Total (Numeric)	Description
IHR States Covered	3	Uttarakhand, Sikkim, and J&K
Project Site/ Field Stations Developed:	20	Uttarakhand (10); Sikkim (6); J & K (4)
No. of Patents filed (Description):	NIL	
Article/ Review/ Research Paper/ Publication:	1	Near surface temperature lapse rates for treeline environment in western Himalaya and possible impacts on ecotone vegetation.
New Methods/ Modellings Developed	NIL	
No. of Trainings (No. of Beneficiaries):	NIL	
Workshop:	NIL	
Demonstration Models (Site):	NIL	
Livelihood Options:	NIL	
Training Manuals:	1	One Chapter on TLR in a combined Manual of the IHTP project
Processing Units:	NIL	
Species Collection:	NIL	
Species identified:	NIL	
Database/ Images/ GIS Maps:	Meteorological data for the study transect in J&K, Uttarakhand, and Sikkim	For CT transect: December 2016-till date For CT transect: December 2016-till date For CT transect: June 2017-till date

	Rainfall interception data for monsoon season (July-September 2017)	For CT transect in Uttarakhand

Note: Photos/ maps should be attached in high quality in compatible formats *viz*., JPEG, .JPG, .PNG, .SHP, etc. along with a suitable figure legend/ caption.

9. Project Linkages (with nearby Institutions/ State Agencies)

S. No.	Institute/ Organization	Type of Linkages	Brief Description
1.	Forest Department, Government of Uttarakhand		**For establishment of sites and installation of sensors**
2.	HAPPRC, HNB Garhwal University , Srinagar Garhwal		**For installation of AWS**

10. Additional (publication, recommendations, etc.)

Time Period	Publications (Research Papers, Information Material, Policy drafts, Patents, etc.)
Annual [Year 2017-18]	Near surface temperature lapse rates for treeline environment in western Himalaya and possible impacts on ecotone vegetation"submitted to the Journal of Tropical Ecology for publication.

11. Project Concluding Remark

Kindly update the following Progress Parameters for the Reporting Period:

Project Objectives	Project Output against each objective	Progress made against Monitoring Indicators (specified in Sanction Letter)	Remarks
To determine the temperature lapse rate (TLR) and precipitation gradient (PG) along altitudinal gradients in different precipitation regimes across the IHR	• Daily data on maximum- minimum and average temperature and relative humidity is collected from (i) 10 sites at different altitude (1500-3900 m) in Chopta-Tungnath transect for December 2016-March 2018, (ii) 4	• Established 10 monitoring sites in Uttarakhand, 6 monitoring sites in Sikkim and 4 monitoring sites in J & K to record temperature and relative humidity from different altitudes in timberline area of three climatically different regimes in Indian Himalayan region.	Annual and seasonal TLR for CT transect is calculated. Data generation, compilation and synthesis are under process.

	sites at different altitude (1900- 3000 m) in Daksum-Sintahan transect (J & K) for June 2017-March 2018, and (iii) 6 sites at different altitude (1700-4000 m) in Yuksam-Dzongri transect (Sikki mfor December 2016-March 2018.	• Annual (December 2016 – November 2017) and seasonal temperature lapse rates for two different aspects of Tungnath-Chopta transect is determined. • Winter season lapse rate for Yuksam-Dzongri transect in Sikkim is determined.	Data will be collected in 2018-19 as well to establish TLR for different seasons and precipitation gradient along different climate regimes of IHR. The generated data will also be used to study micro climatic variations in the study area.

Methodology (in brief):	Initially field visit was carried out to identify suitable sites for installation of sensors along different altitudinal gradient in Tungnath-Chopta transect (Uttarakhand), Yuksam- Dzonrgi transect (Sikkim) and Daksum-Sinthan (J&K). ONSET HOBO temperature loggers were installed at 10 selected sites within CT transect to collect temperature and humidity data and estimate temperature lapse rate (TLR). Further, tipping bucket rangauge (6) were installed at identified sites for estimation of precipitation gradient. High temporal scale temperature data, collected at 15 minute sampling interval from different sites using HOBO loggers, was aggregated to hourly scale. The standard methodology for quality control and processing of the data was followed. Following the methodology proposed by Immerzeel et al. (2014) TLR was calculated. However, processing and analysis of rainfall data recorded since February 2017 for estimation of precipitation gradient for CT transect (Uttarakhand) is ongoing. Similarly, the data collected from Yuksam-Dzongri transect (Sikkim) and Daksum-Sinthan transect (J & K) is being analyzed to estimate annual and seasonal TLR for different climatic regime in IHR. Further, nine hydrological plots (10mx5m) were layed out in treeline zone of CT transect to study rainfall interception in different vegetation types. For this study 3 plot were layed in each of the three identified different vegetation type (i.e. *Abies spectabilis, Rhododendron campanulatum,* and Grassland) whereas for *Quercus semecarpifolia only rainfall particitioning is being studied*. The methodology followed in earlier studies published by various researchers was adopted for analysis of rainfall interception and rainfall-runoff analysis. Analyses of the data collected for monsoon season of 2017-18 is under process.

Major Research Achievements:	• Meteorological monitoring sites for treeline zone in three states of Indian Himalaya established. • The high temporal scale data on temperature and relative humidity collected along altitudinal gradient in two different aspects of treeline zone is first of its kind from Himalayan region. • Based on one year observed dataset, both and seasonal TLR for two different aspects is calculated for Tungnath-Chopta transect (Uttarakhand). Also the annual cycle of the TLR in treeline zone is analyzed.
Brief Conclusion - the current year progress – during the reporting period (point-wise):	Our estimate of TLR for CT transect based on observed data (-0.53^{0}C/100m) is distinctly lower than values of TLR used in the past for Himalayan region. Our study confirms the recent observations that TLR varies seasonally; it is generally lower during winters and monsoon periods whereas higher during pre-monsoon and post-monsoon periods. This study has shown for the first time that TLR varies from one aspect to another, which may partially explain the aspect-related difference in treeline elevation in Himalayas. The low TLR indicates that conditions in high Himalayas, for which data are not available, are warmer than perceived. The shallow TLR indicates elevation dependent warming (EDW) in Himalaya under the influence of climate change. Further, a bi-modal pattern of TLR (two maxima in pre- and post-monsoon season and two minima in winter and summer, respectively) is contrast to other mountain regions.
Progress Achieved (%):	50%
Remaining work to be done:	• Collection of meteorological data from different sites in Sikkim and J & K. • Estimation of seasonal and annual TLR for the study sites in Sikkim and J & K. • Estimation of precipitation gradient for CT transect (Uttarakhand), YD transect (Sikkim) and DS transect (Jammu & Kalshmir).

Submitted to:
Nodal Officer, NMHS-PMU
National Mission on Himalayan Studies (NMHS)
G.B. Pant National Institute of Himalayan Environment and Sustainable Development, Kosi-Katarmal, Almora 263643, Uttarakhand
E-mail: *nmhspmu2016@gmail.com*

Submitted by:
Dr. Rajesh Joshi
Scientist-D & PI (Sub-Project No 2) (Signature):
Institution (Seal):
Dated (dd/mm/yy):

Please fill the NMHS Progress Report pro forma as applicable with respect to time and other requirements and return *via* post/ e-mail. In case of any query, please contact at: nmhspmu2016@gmail.com

Table 1: Details of the long term meteorological observation sites established in Uttarakhand

SN	Monitoring sites	Altitude (masl)	Aspect	Sensors installed	Collaborating Department
1.	Siroli	1600	S-E	TL	UKFD
2.	Mandal	2100	S-E	TL, TBR	UKFD
3.	Kanchula Kharak	2675	S-E	TL, TBR	UKFD
4.	Sau Kharak	3100	S-E	TL, TBR, AWS	UKFD
5.	Chandrashila Top	3900	Summit	TL	UKFD
6.	Tungnath	3360	N-W	TL, TBR	HAPPRC, HNBGU
7.	Chopta	2870	N-W	TL	UKFD
8.	Dugal Bhitta	2500	N-W	TL, TBR	PWD Ukhimath
9.	Taala	1820	N-W	TL	UKFD
10	Ukhimath	1500	N-W	TL, TBR	PWD Ukhimath

S-E: South East; N-W: North-West; TL: Temperature Logger; TBR: Tipping Bucket Raingague; AWS: Automatic Weather Station; UKFD: Uttarakhand state Forest Department; PWD: Public Works Department; HNBGU: HNB Garhwal University, Srinagar Garhwal

Table 2: Details of the long term meteorological observation sites established in Sikkim

SN	Monitoring sites	Altitude (masl)	Aspect	Sensors installed	Collaborating Department
1	Yuksam	1760	S-E	TL	SKFD
2	Sachen	2225	S-E	TL	SKFD
3	Bakhim	2649	S-E	TL	SKFD
4	Tsokha	3002	S-E	TL	SKFD
5	Phedang	3690	S-E	TL	SKFD
6	Dzongri	4000	S-E	TL	SKFD

S-E: South East; Temperature Logger; SKFD: Sikkim state Forest Department

Table 3. Details of the sites along Daksum-Sinthan (DS)-Transect in Jammu & Kashmir

SN	Monitoring sites	Altitude (m asl)	Aspect	Sensors installed	Collaborating Department
1	Kokarnag	1919 m	S-E	TL	J&K tourism Dept.
2	Daksum	2400 m	S-E	TL	J&K tourism Dept.
3	Arkhani	2563m	S-E	TL	Local Community
4	Bampathri	2973 m	S-E	TL	Local Community

Table 4: TLR (in ^{0}C/100 m) for mean, minimum and maximum temperatures in relation to aspects and seasons in CT transect, Uttarakhand.

	N-W Aspect			S-E Aspect		
Season	**Mean TLR**	**Maximum TLR**	**Minimum TLR**	**Mean TLR**	**Maximum TLR**	**Minimum TLR**
Winter (DJF)	-0.42	-0.71	-0.35	-0.39	-0.36	-0.35
Pre-monsoon (MAM)	-0.64	-0.85	-0.49	-0.60	-0.81	-0.51
Monsoon (JJAS)	-0.57	-0.67	-0.55	-0.55	-0.63	-0.57
Post-monsoon (ON)	-0.44	-0.41	-0.38	-0.47	-0.42	-0.48

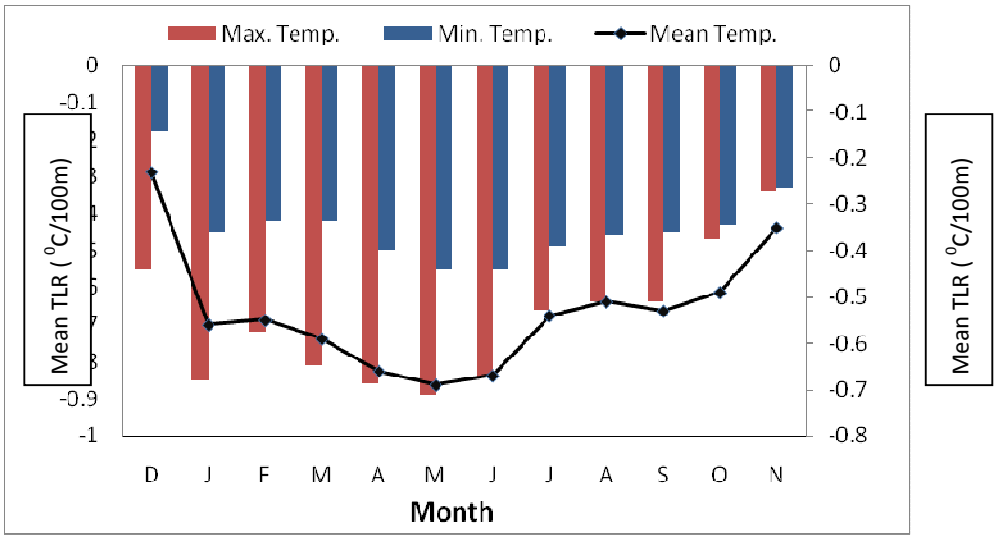


Figure 1: Variation in monthly temperature lapse rates along NW aspect of the study transect

(Prof. Zafar.A.Reshi)

NMHS Progress Report
(Period *from* 01.04.2017 *to* 31.03.2018)

Project Title -: **Timberline and altitudinal Gradient Ecology of Himalayas and Human Use sustenance in a Warming Climate**

Sanction No. and date -: NO. NMHS/LG-2016/009 dated 31-03- 2016
No. 1882/XII-86/2016 Dated 27-04-2016

Institution Name-: University of Kashmir, Srinagar

Personal Details -: Professor, Department of Botany
University of Kashmir

Name and Address of the PI-: **Prof. Zafar A Reshi**
Department of Botany
University of Kashmir
Srinagar-190 006, J&K, India

Name and Address of the Co PI-: None

Partner Details:

Sl No	Name/ Address	Work assigned to partners	Fund allocated to partners during the period
1	Dr. R.S. Rawal	To study plant diversity, community structure, tree diameter changes and natural recruitment pattern along the altitudinal gradient in Uttarakhand	
2	Dr. H.K. Badola/ Dr. Devendra Kumar	To study plant diversity, community structure, tree diameter changes and natural recruitment pattern along the altitudinal gradient in Sikkim.	

Project Objectives -: The approved objective is as under:

To study plant diversity, community structure, tree diameter changes and natural recruitment pattern along the three principal sites in the IHR.

Completion in the last six months in % (According to each Deliverables)-:

S. No	Quantifiable Deliverables (as per sanction letter)	Output/achievements	Performance in terms of Monitoring Indicators	Remarks
1.	*Plant diversity and community structure along altitudinal gradient in three sites of Indian Himalayan region*	**1.** During the 2nd year, more vegetation sampling in seventeen (17) elevational bands (100m apart) along the altitudinal gradient of 2200 to 3800 m asl in the Daksum-Sinthan Top area was carried out which resulted in the documentation of 425 species belonging to 117 families and 268 genera. Among these, dicotyledons included 175 species belonging to 44 families and 131 genera, monocotyledons were represented by 19 species belonging to 10 families and 16 genera, gymnosperms were represented by 4 species belonging to 2 families and 4 genera. Thirty three species of pteridophytes belonging to 9 families and 16 genera were also recorded during the present survey. Bryophytes included 39 species belonging to 22 families and 33 genera. Significant number of lichen species was identified during this year and now we report 155	**1.** In comparison to documentation of 173 plant species belonging to 134 genera and 75 families during the 1st year, currently we report 425 species belonging to 117 families and 268 genera. Thus, it is indicative of satisfactory performance during the period under review. **2.** For the first time a detailed vegetational analysis along the entire elevational gradient was carried out which has yielded interesting trends vis-à-vis timberline	We plan to undertake surveys in two more transects during the 3rd year in order to discern unambiguous elevational patterns of species diversity in the Himalaya. We would analyze the elevation species richness data for mid-domain effect employing Range Model. Whether or not alien species are moving upwards into mountains would also be worked out. Similarly,

		species of lichens belonging to 30 families and 68 genera from the study area.	and treeline ecotone, and treeline in Kashmir Himalaya.	elevational pattern in endemic species will be studied.
		2. Functional diversity quantified in terms of growth form of species revealed that herbs predominate with 202 species followed by shrubs represented by 18 species, trees by 8 species and sub-shrubs by 2 species. In terms of life span, most of the species are perennial including 142 species when annuals and biennials were represented by 34 and 3 species respectively. Life span in 15 species was variable. **3.** Pattern of species richness and diversity in each of the seventeen elevational bands along the gradient was also documented which has revealed interesting trends in relation to altitude. In all, four patterns of species richness in relation to elevation were observed during the present study: low-elevation plateau with a mid-peak in bryophytes, mid-peak pattern in pteridophytes	**3.** Seedling recruitment of tree species and stem diameter of adult tree species vis-à-vis altitude was also studied. **4.** The forest profile has been built based on the detailed analysis of different bands of elevational transect & understanding of how species respond to timberline, treeline & alpine elevation zone has been assessed.	

		and lichens, and inverted hump-shaped pattern in monocots. **4.** South and North facing slopes revealed peculiar differences in community structure which have been presented diagrammatically **5.** Finally a manuscript based on the work has been prepared and submitted to *'Tropical Ecology'* for publication.		

Summary of progress -: (with in 200 words)

Stratified vegetation sampling employing quadrat method in each of the seventeen (17) elevational bands (100m apart) along the altitudinal gradient of 2200 to 3800 m asl in the Daksum-Sinthan Top, Kashmir Himalaya area resulted in the identification of 425 species belonging to 268 genera and 117 families. Dicotyledons were predominant with 175 species belonging to 44 families and 131 genera. Monocotyledons were represented by 19 species belonging to 10 families and 16 genera. Four species of gymnosperms belonging to 2 families and 4 genera were also recorded from the area. Pteridophytes were represented by 33 species belonging to 9 families and 16 genera. Bryophytes included 39 species belonging to 22 families and 33 genera. Besides, 155 species of lichens belonging to 30 families and 68 genera were also collected from different habitats and substrates in the study area.

Species of vascular plants were categorized on the basis of growth form and life span. Herbs were predominant with 202 species followed by shrubs represented by 18 species, trees by 8 species and sub-shrubs by 2 species.

In terms of life span, most of the species were perennial including 142 species when annuals and biennials were represented by 34 and 3 species respectively. Life span in 15 species was variable.

Among the bryophytes, mosses (35 spp.) were more common than liverworts (4 spp.). Among the lichens, foliose (71 spp.), crustose (70 spp.) types were common in the study area compared to fruticose (7 spp.) and leprose (7 spp.) growth forms.

Elevational patterns of various taxonomic and functional plant groups did not show any consistent pattern. Angiosperms, including dicots and pteridophytes showed a wavy pattern distribution along increasing altitude with several peaks and troughs. Monocots showed a characteristic pattern of mid-elevational decline and subsequent increase in higher elevations while bryophytes kept on decreasing with increasing altitude. Lichen richness peaked in mid

elevations and declined in higher elevations with modest increase in alpine zone. In all, four patterns of species richness in relation to elevation were observed during the present study: low-elevation plateau with a mid-peak in bryophytes, mid-peak pattern in pteridophytes and lichens, and inverted hump-shaped pattern in monocots.

Recruitment pattern and changes in trunk diameter of several tree species vis-à-vis altitude was also recorded. Floristic surveys revealed differences in species composition not only at different altitudes but also showed variable patterns on south and north facing slopes. *Pinus wallichinana* was more dominant on South facing slopes than on North facing slopes not only at lower altitudes but at higher altitudes as well. Differences in tree line on north and south facing slopes were very distinct with *Betula utilis* representing the treeline on north facing slope and *Abies* sp. together with *Pinus wallichiana* constituting the treeline on south facing slopes. Based on the examination of type & number of species in each elevation band, a forest profile has been created for the site revealing the physical structure of the mountain (Fig.1).

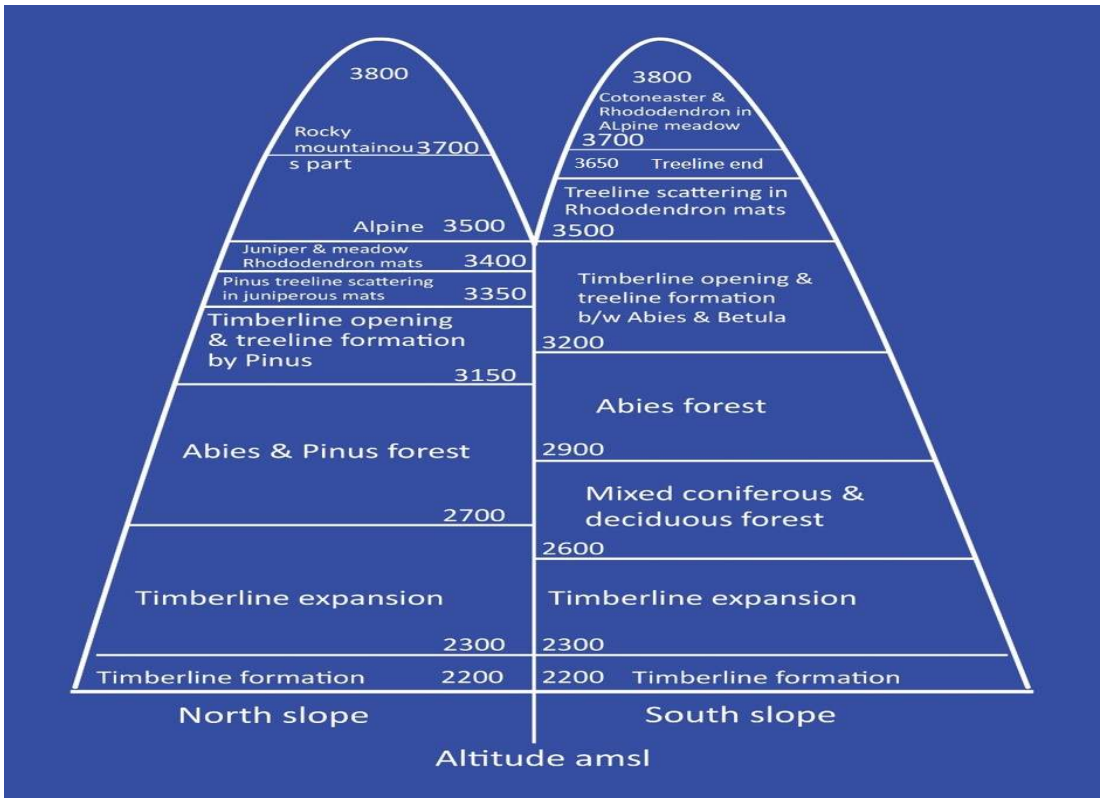


Fig. 1: Diagrammatic representation of the community structure on North (South facing) and South (North facing) slopes in the study area.

Name of the PI-: Prof. Zafar A Reshi

Signature -:

Date: 31-12-2017

VEGETATION SAMPLING

The altitudinal gradient of 2200 to 3800 m was divided into 17 100 m. altitudinal bands. Three plots of 50 × 50 m area were established in each of these altitudinal bands. In each each plot ten (10x10 m) quadrats for trees, 20 (5x5 m) for shrubsand 40 (1x1 m) for herbs were laidrandomly for sampling. 30 (10x10 m) quadrats for trees, 60 (5x5 m) for shrubsand 120 (1x1 m) quadrats for herbs were laidrandomly for vegetation sampling in each of the elevation bands. Thus, in all 510 quadrats were laid for sampling of trees, 1,020 for shrubs and 20,400 for herbs in the entire altitudinal gradient. Species richness of taxonomic groups, such as angiosperms (dicots, monocots), gymnosperms, pteridophytes, bryophytes and lichens was recorded in each altitudinal band. In addition, density of trees and shrubs was also recorded in the altitudinal bands. Growth form, habit, and life span of each species was recorded in the field.Data on recruitment of trees and tree diameter was also recorded in each altitudinal band.

Species accumulation curves to standardize sampling across altitudinal bands, to predict the species richness of sites and to estimate the minimum effort required for adequate completeness of inventories were also computed (Figs. 2-4). Species accumulation curves for trees, shrubs and herbs are given below which suggest that sampling effort for recording species during the present survey in different altitudinal bands was adequate.

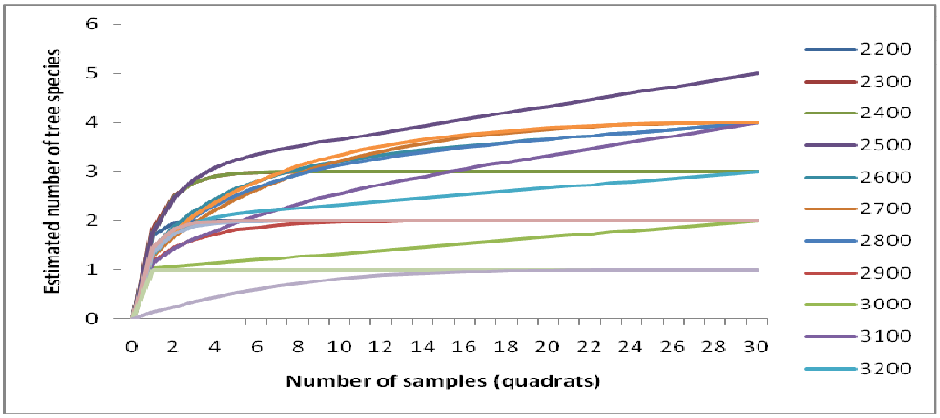


Fig.2. Species accumulation curves for trees in different elevational bands

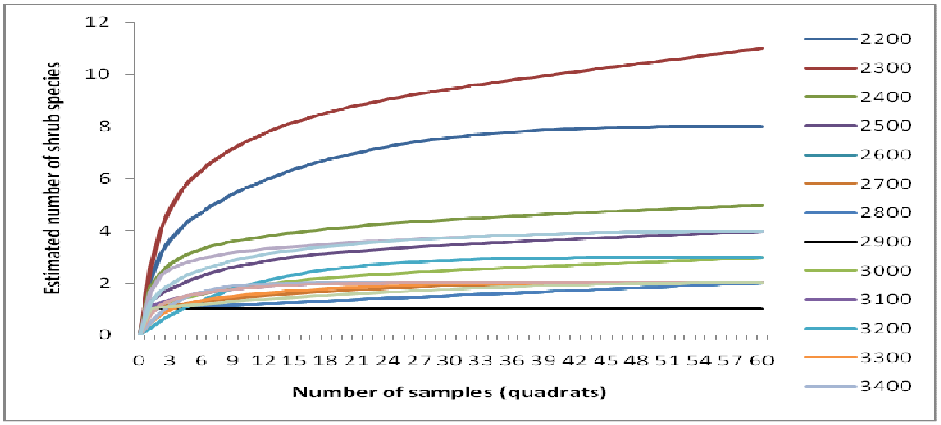


Fig.3. Species accumulation curves for shrubs in different elevational bands

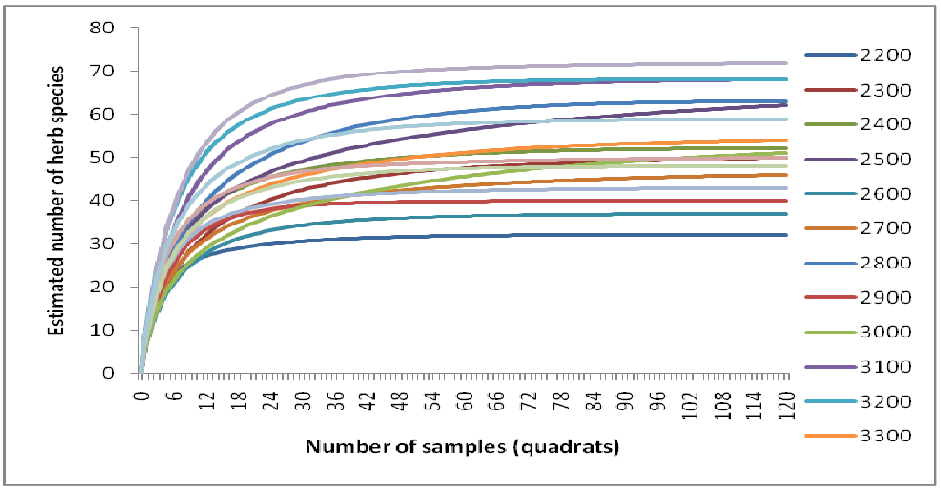


Fig.4. Species accumulation curves for herbs in different elevational bands.

Taxonomic diversity

Floristic surveys in the study site of Daksum-Sinthan Top in the Kashmir Himalaya resulted in collection and identification of 425 plant species belonging to 268 genera and 117 families (Table 1; Fig.5). Amongst these, the flowering plants were predominant, with dicots sharing 175 species in 131 genera and 44 families, and monocots only 19 species in 16 genera of 10 families. Gymnosperms were represented by 4 species belonging to 4 genera and 2 families. Besides, 33 species of Pteridophytes in16 genera and 9 families, 39 species of bryophytes in 33 genera and 22 families and 155 species of lichens in 68 genera and 30 families were also recorded from the area.

Table 1 Numerical analysis of plant taxa.

Plant Group	NO.OF SPECIES	GENERA	FAMILIES
ANGIOSPERMS	194	147	54
DICOTS	175	131	44
MONOCOTS	19	16	10
GYMNOSPERMS	4	4	2
PTERIDOPHYTES	33	16	9
BRYOPHYTES	39	33	22
LICHENS	155	68	30
Total	**425**	**268**	**117**

Dominant families (Table 2) in case of angiosperms were Asteraceae which included 24 species, followed by Ranunculaceae(15 spp.), Rosaceae(13), Lamiaceae (12), Caryophyllaceae (9) and Brassicaceae, Plantaginaceae, Polygonaceae and Poaceae each with8 species. In gymnosperms, single family Pinaceae represents the dominant conifers. In case of pteridophytes, Dryopteridaceae was the dominant family which included 10 species followed by Athyriaceae (6) and Pteridaceae (5) species. In bryophytes, Polytrichaceae was the dominant family with 5 species followed by Dicranaceae and Thuidiaceae each represented by 4 species. In case of lichens, Parmeliaceae and Physciaceae were the largest families.

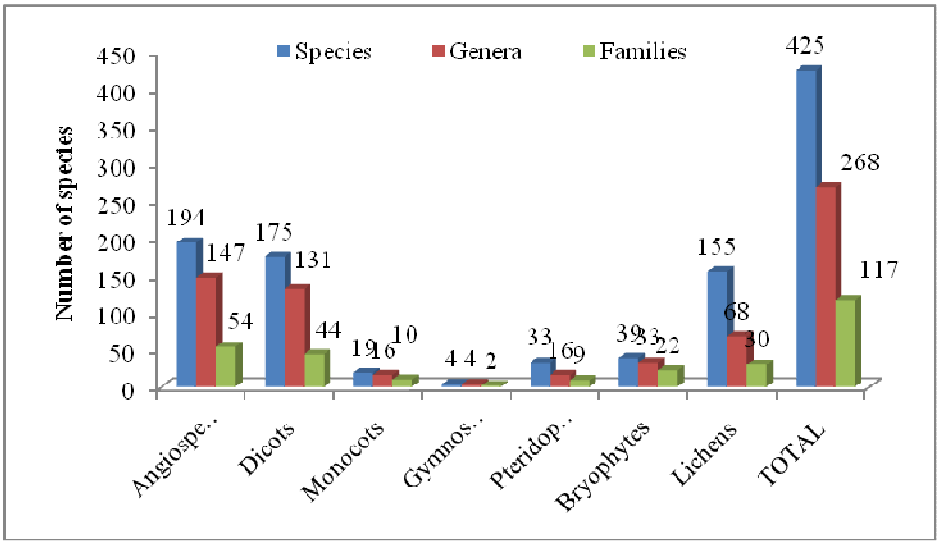


Fig. 5. Conspectus of the vascular plant species growing in the area.

Table 2. The largest families with their number of species in the area in different groups of plants.

S. No.	Group/Family	Number of species
Angiosperms		
1.	Asteraceae	24
2.	Ranunculaceae	15
3.	Rosaceae	13
4.	Lamiaceae	12
5.	Caryophyllaceae	9
6.	Brassicaceae	8
7.	Plantaginaceae	8
8.	Poaceae	8
9.	Polygonaceae	8
Gymnosperms		
1.	Pinaceae	3
2.	Cupressaceae	1
Pteridophytes		
1.	Dryopteridaceae	10
2.	Athyriaceae	6
3.	Pteridaceae	5

4.	Aspleniaceae	4
Bryophytes		
1.	Polytrichaceae	5
2.	Dicranaceae	4
3.	Thuidiaceae	4
4.	Brachythiaceae	3
5.	Pottiaceae	3

Functional diversity in vascular plants

a. Growth forms

In respect of growth forms of vascular plants (Fig. 6), herbs predominated with 202 species representing 88% species followed by shrubs (18 species; 8%) and trees (8 species; 3%). Complete conspectus of species of different growth forms is given in Table 6.

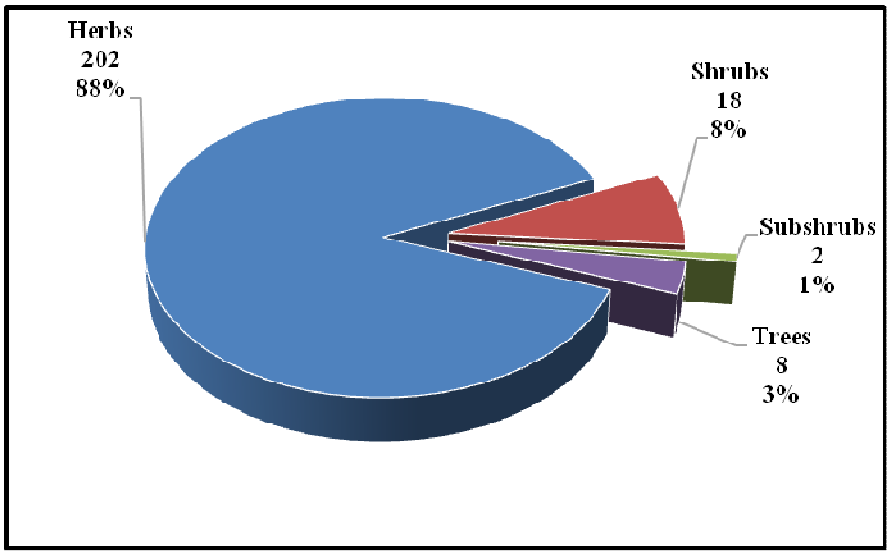


Fig. 6. Number and proportion of species of different growth forms.

b. Life span

In respect of life span of vascular plants (Fig. 7) majority of angiosperms were perennials (142 species; 73%) followed by annuals (34 species; 17%) and annual/ perennial (9 species; 5%) species. Complete conspectus of species with different life span is given in Table 3.

Table 3. Number of species belonging to different life span categories.

Life span	No. of species
Annuals	34
Biennials	3
Perennials	142
Annual/Biannual	2
Annual/Perennial	9
Biannual/Perennial	1
Annual/Biannual/Perennial	3

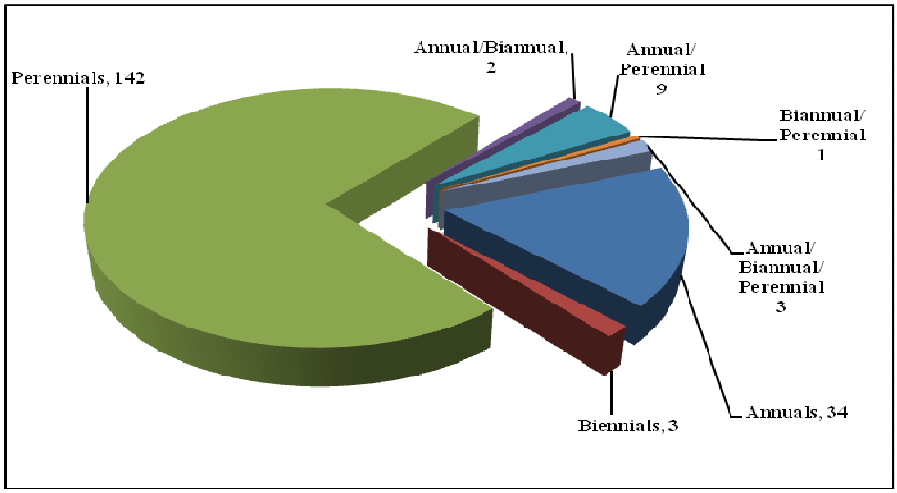


Fig. 7. Number of species belonging to different life span categories.

Functional diversity in bryophytes and lichens

Functional diversity computed in terms of growth habit of bryophytes and lichens in presented in Figs 8 and 9 and Tables 4 and 5.

Table 4. Number of bryophyte species belonging to different growth habits.

Growth habit	No. of Species
Liverworts	4
Mosses	35
Hornworts	0

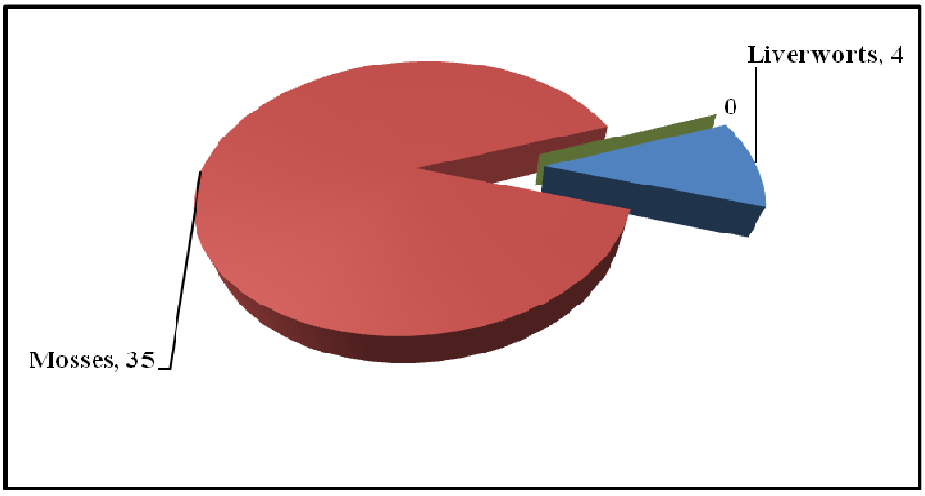


Fig. 8. Number of species of mosses and liverworts**.**

Table 5. Number of lichen species belonging to different growth habits.

Trees	
Species name	**Family**
Abies pindrow	Pinaceae
Acer sp.	Sapindaceae
Aesculus indica	Hippocastenaceae
Betulautilis	Betulaceae
Euonymus hamiltonianus	Celastraceae
Picea smithiana	Pinaceae
Pinus wallichiana	Pinaceae
Prunuscornuta	Rosaceae
Shrubs	
Berberis lycium	Berberidaceae
Clematis montana	Ranunculaceae
Cotoneaster sp	Rosaceae
Crataegus songarica	Rosaceae
Indigofera heterantha	Fabaceae
Jasminum officinale	Oleaceae
Juniperus wallichiana	Cupressaceae
Parrotiopsis jacquemontiana	Hamamelidaceae
Plectranthus rugosus	Lamiaceae
Rhododendron anthopogon	Ericaceae
Rhododendron campanulatum	Ericaceae
Robinia pseudoacacia	Fabaceae
Rosa brunonii	Rosaceae
Sambucus weightiana	Adoxaceae
Skimmia anquetilia	Rutaceae
Sorbaria tomentosa	Rosaceae
Spiraea canescens	Rosaceae
Viburnum foetans	Adoxaceae
Herbs	
Achillea nigrescens	Asteraceae
Achillea millefolium	Asteraceae
Aconitum sp	Ranunculaceae
Aconitum heterophyllum	Ranunculaceae
Adiantum venustum	Pteridaceae
Ainsliae aaptera	Asteraceae
Ajuga bracteosa	Lamiaceae
Alchemilla xanthochlora	Rosaceae
Anaphalis royleana	Asteraceae
Anaphalis margaritaceae	Asteraceae
Androcorys josephi	Orchidaceae
Androsace primuloides	Primulaceae
Anemone obtusiloba	Ranunculaceae

Anemone rivularis	Ranunculaceae
Aquilegia nivalis	Ranunculaceae
Arabidopsis thaliana	Brassicaceae
Arctium lappa	Asteraceae
Arenaria neelgheriense	Caryophyllaceae
Arisaema jacquemontii	Araceae
Artemisia annua	Asteraceae
Artemisia tournefortiana	Asteraceae
Artemisia roxburghiana	Asteraceae
Asplenium kukkonenii	Aspleniaceae
Asplenium septentrionale	Aspleniaceae
Asplenium trichomanes	Aspleniaceae
Asplenium variance	Aspleniaceae
Astragalus glycyphyllos	Fabaceae
Asyneuma thomsonii	Campanulaceae
Athyriu matkinnsonnii	Athyriaceae
Athyrium attenuatum	Athyriaceae
Athyrium mackinnoni	Athyriaceae
Athyrium wallichianum	Athyriaceae
Bellis perennis	Asteraceae
Bergenia ciliata	Saxifragaceae
Bromus sp	Poaceae
Bupleurum longicaule	Apiaceae
Caltha palustris var. alba	Ranunculaceae
Campanula pallida	Campanulaceae
Capsella bursa-pastoris	Brassicaceae
Cardamine macrophylla	Brassicaceae
Carpesium cernuum	Asteraceae
Cassiope fastigiata	Ericaceae
Cerastium cerastoides	Caryophyllaceae
Chaerophyllum villosum	Apiaceae
Chenopodium album	Amaranthaceae
Chorispora sabulosa	Brassicaceae
Chrysopogon fulvus	Poaceae
Circaea cordata	Onagraceae
Cirsium arvense	Asteraceae
Clinopodium vulgare	Lamiaceae
Clinopodium umbrosum	Lamiaceae
Codonopsis ovata	Campanulaceae
Comastoma pedunculatum	Gentianaceae
Coniogramme affinis	Pteridaceae
Corydalis rutifolia	Papavaraceae
Corydalis govaniana	Papavaraceae
Crucihimalaya himalaica	Brassicaceae
Cryptogramma brunoniana	Pteridaceae

Cryptogramma stelleri	Pteridaceae
Cucubalus baccifera	Caryophyllaceae
Cynodon dactylon	Poaceae
Cynoglossum glochidiatum	Boraginaceae
Cynoglossum lanceolatum	Boraginaceae
Cynoglossum sp.	Boraginaceae
Cyperu sp.	Cyperaceae
Cystopteris fragalis	Cystopteridaceae
Deparia acuta	Athyriaceae
Deparia allantodioides	Athyriaceae
Dioscorea deltoidea	Dioscoreaceae
Dipsacus inermis	Dipsacaceae
Draba affghanica	Brassicaceae
Dryopteris juxtaposita	Dryopteridaceae
Dryopteris nigropaleaceae	Dryopteridaceae
Dryopteris stewartii	Dryopteridaceae
Dryopteris barbigera	Dryopteridaceae
Dryopteris rosthornii	Dryopteridaceae
Dryopteris sp	Dryopteridaceae
Epilobium laxum	Onagraceae
Epilobium royleanum	Onagraceae
Epimedium sp.	Berberidaceae
Equisetum arvense	Equisetaceae
Erigeron multiradiatus	Asteraceae
Euphrasia officinalis	Orobanchaceae
Fragaria nubicola	Rosaceae
Gagea gageoides	Liliaceae
Galium aparine	Rubiaceae
Galium sp	Rubiaceae
Gaultheria trichophylla	Ericaceae
Gentiana capitata	Gentianaceae
Gentiana carinata	Gentianaceae
Gentiana phyllocalyx	Gentianaceae
Geranium pratense	Geraniaceae
Geranium pusillum	Geraniaceae
Gerbera nepalensis	Asteraceae
Geum montanum	Rosaceae
Gnaphalium supinum	Asteraceae
Goodyera repens	Orchidaceae
Gymnocarpium dryopteris	Cystopteridaceae
Gypsophila cerastoides	Caryophyllaceae
Hemerocallis fulva	Asphodelaceae
Heracleum candicans	Apiaceae
Herniaria hirsuta	Caryophyllaceae
Hordeum sp	Poaceae

Impatiens brachycentra	Balsaminaceae
Inula racemosa	Asteraceae
Juncus sp.	Juncaceae
Lactuca hastata	Asteraceae
Lactuca alpina	Asteraceae
Lagotis sp	Plantaginaceae
Lamium album	Lamiaceae
Lamium maculatum	Lamiaceae
Leontopodium leontopodinum	Asteraceae
Leontopodium alpinum	Asteraceae
Leontopodium jacotianum	Asteraceae
Leonurus cardiaca	Lamiaceae
Lepisorus stewartii	Polypodiaceae
Lepisorus clathratus	Polypodiaceae
Lepyrodiclis holosteoides	Caryophyllaceae
Lindelofia longifolia	Boraginaceae
Lomatogonium carinthiacum	Gentianaceae
Malva neglecta	Malvaceae
Mentha arvensis	Lamiaceae
Myosotis arvensis	Boraginaceae
Myosotis sylvatica	Boraginaceae
Myriactis nepalensis	Asteraceae
Nasturtium officinale	Brassicaceae
Nepeta cataria	Lamiaceae
Orobanche sp.	Orobanchaceae
Osmunda claytonia	Osmundaceae
Oxalis acetosella	Oxalidaceae
Oxalis corniculata	Oxalidaceae
Oxyria digyna	Polygonaceae
Pedicularis comosa	Orobanchaceae
Pedicularis pectinata	Orobanchaceae
Phegopteris connectilis	Thelypteridaceae
Phleum alpinum	Poaceae
Phytollaca acinosa	Phytolacaceae
Picrorhiza kurrooa	Plantaginaceae
Plantago lanceolata	Plantaginaceae
Plantago major	Plantaginaceae
Pleurospermum candollei	Apiaceae
Poa annua	Poaceae
Poa palustris	Poaceae
Poa pratensis	Poaceae
Podophyllum hexandrum	Podophyllaceae
Polygonatum multiflorum	Asparagaceae
Polygonatum verticillatum	Asparagaceae
Polygonum coccineum	Polygonaceae

Polygonum nepalense	Polygonaceae
Polygonum sp	Polygonaceae
Polygonum plebeium	Polygonaceae
Polystichum piceopaleaceum	Dryopteridaceae
Polystichum prescottianum	Dryopteridaceae
Polystichum sp	Dryopteridaceae
Polystichum lonchitis	Dryopteridaceae
Potentilla aurea	Rosaceae
Potentilla curviseta	Rosaceae
Primula denticulata	Primulaceae
Primula macrophylla	Primulaceae
Pseudomertensia nemorosa	Boraginaceae
Pseudophegopteris sp	Thelypteridaceae
Pteris cretica	Pteridaceae
Ranunculus laetus	Ranunculaceae
Ranunculus sp	Ranunculaceae
Ranunculus palmatifidus	Ranunculaceae
Ranunculus sceleratus	Ranunculaceae
Rubia cordifolia	Rubiaceae
Rubus clarkei	Rosaceae
Rumex hastatus	Polygonaceae
Rumex nepalanse	Polygonaceae
Salvia hains	Lamiaceae
Saxifraga cernua	Saxifragaceae
Scandix sp	Apiaceae
Scrophularia sp	Scrophulariaceae
Sedum ewersii	Crassulaceae
Sedum album	Crassulaceae
Sedum hispanicum	Crassulaceae
Sedum oreades	Crassulaceae
Senecio chrysanthemoides	Asteraceae
Sibbaldia cuneata	Rosaceae
Silene gonosperma	Caryophyllaceae
Spergularia media	Caryophyllaceae
Stachys tymphaea	Lamiaceae
Stellaria media	Caryophyllaceae
Swertia petiolata	Gentianaceae
Taraxacum officinalis	Asteraceae
Thalictrum cultratum	Ranunculaceae
Thalictrum minus	Ranunculaceae
Thalictrum alpinum	Ranunculaceae
Thalictrum foliolosum	Ranunculaceae
Thalspi cochleriformis	Brassicaceae
Trifolium repens	Fabaceae
Trillium govanianum	Melanthiaceae

Urtica dioca	Urticaceae
Valeriana hardwickii	Valerianaceae
Valeriana jatamansii	Valerianaceae
Verbascum thapsus	Scrophulariaceae
Veronica beccabunga	Plantaginaceae
Veronica biloba	Plantaginaceae
Veronica persica	Plantaginaceae
Veronica sp.	Plantaginaceae
Viola odorata	Violaceae

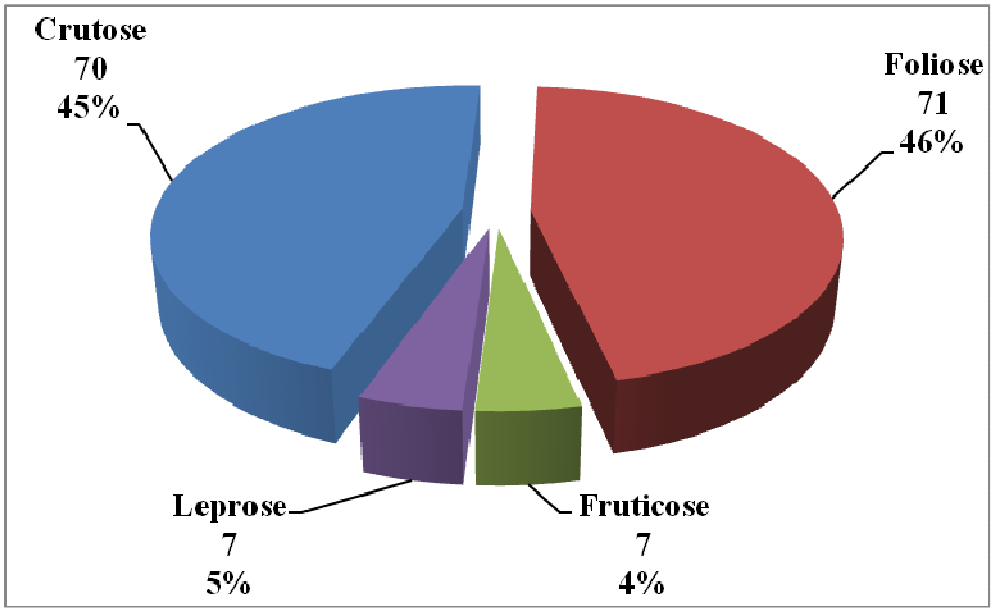


Fig. 9. Number of lichen species belonging to different growth habits.

Table 6. List of trees, shrubs and trees recorded from the study site.

Trees	
Species name	**Family**
Abies pindrow	Pinaceae
Acer sp.	Sapindaceae
Aesculus indica	Hippocastenaceae
Betula utilis	Betulaceae
Euonymus hamiltonianus	Celastraceae
Picea smithiana	Pinaceae
Pinus wallichiana	Pinaceae
Prunus cornuta	Rosaceae
Shrubs	
Berberis lycium	Berberidaceae
Clematis montana	Ranunculaceae
Cotoneaster sp	Rosaceae
Crataegus songarica	Rosaceae

Indigofera heterantha	Fabaceae
Jasminum officinale	Oleaceae
Juniperus wallichiana	Cupressaceae
Parrotiopsis jacquemontiana	Hamamelidaceae
Plectranthus rugosus	Lamiaceae
Rhododendron anthopogon	Ericaceae
Rhododendron campanulatum	Ericaceae
Robinia pseudoacacia	Fabaceae
Rosa brunonii	Rosaceae
Sambucus weightiana	Adoxaceae
Skimmia anquetilia	Rutaceae
Sorbaria tomentosa	Rosaceae
Spiraea canescens	Rosaceae
Viburnum foetans	Adoxaceae
Herbs	
Achille anigrescens	Asteraceae
Achillea millefolium	Asteraceae
Aconitum sp	Ranunculaceae
Aconitum heterophyllum	Ranunculaceae
Adiantumvenustum	Pteridaceae
Ainsliaea aptera	Asteraceae
Ajuga bracteosa	Lamiaceae
Alchemilla xanthochlora	Rosaceae
Anaphalis royleana	Asteraceae
Anaphalis margaritaceae	Asteraceae
Androcorys josephi	Orchidaceae
Androsace primuloides	Primulaceae
Anemone obtusiloba	Ranunculaceae
Anemone rivularis	Ranunculaceae
Aquilegia nivalis	Ranunculaceae
Arabidopsis thaliana	Brassicaceae
Arctium lappa	Asteraceae
Arenaria neelgheriense	Caryophyllaceae
Arisaema jacquemontii	Araceae
Artemisia annua	Asteraceae
Artemisia tournefortiana	Asteraceae
Artemisia roxburghiana	Asteraceae
Asplenium kukkonenii	Aspleniaceae
Asplenium septentrionale	Aspleniaceae
Asplenium trichomanes	Aspleniaceae
Asplenium variance	Aspleniaceae
Astragalus glycyphyllos	Fabaceae
Asyneumathomsonii	Campanulaceae

Athyriumatkinnsonnii	Athyriaceae
Athyriumattenuatum	Athyriaceae
Athyriummackinnoni	Athyriaceae
Athyrium wallichianum	Athyriaceae
Bellis perennis	Asteraceae
Bergeniaciliata	Saxifragaceae
*Bromus*sp	Poaceae
Bupleurum longicaule	Apiaceae
Caltha palustris var. alba	Ranunculaceae
Campanula pallida	Campanulaceae
Capsella bursa-pastoris	Brassicaceae
Cardaminemacrophylla	Brassicaceae
Carpesiumcernuum	Asteraceae
Cassiope fastigiata	Ericaceae
Cerastiumcerastoides	Caryophyllaceae
Chaerophyllum villosum	Apiaceae
Chenopodium album	Amaranthaceae
Chorispora sabulosa	Brassicaceae
Chrysopogonfulvus	Poaceae
Circaea cordata	Onagraceae
Cirsiumarvense	Asteraceae
Clinopodiumvulgare	Lamiaceae
Clinopodium umbrosum	Lamiaceae
Codonopsis ovata	Campanulaceae
Comastomapedunculatum	Gentianaceae
Coniogramme affinis	Pteridaceae
Corydalis rutifolia	Papavaraceae
Corydalis govaniana	Papavaraceae
Crucihimalaya himalaica	Brassicaceae
Cryptogramma brunoniana	Pteridaceae
Cryptogramma stelleri	Pteridaceae
Cucubalusbaccifera	Caryophyllaceae
Cynodondactylon	Poaceae
Cynoglossumglochidiatum	Boraginaceae
Cynoglossumlanceolatum	Boraginaceae
Cynoglossum sp.	Boraginaceae
*Cyperus*sp.	Cyperaceae
Cystopterisfragalis	Cystopteridaceae
Deparia acuta	Athyriaceae
Deparia allantodioides	Athyriaceae
Dioscoreadeltoidea	Dioscoreaceae
Dipsacus inermis	Dipsacaceae
Draba affghanica	Brassicaceae
Dryopterisjuxtaposita	Dryopteridaceae
Dryopter isnigropaleaceae	Dryopteridaceae

Dryopterisstewartii	Dryopteridaceae
Dryopteris barbigera	Dryopteridaceae
Dryopteris rosthornii	Dryopteridaceae
Dryopteris sp	Dryopteridaceae
Epilobium laxum	Onagraceae
Epilobium royleanum	Onagraceae
*Epimedium*sp.	Berberidaceae
Equisetum arvense	Equisetaceae
Erigeron multiradiatus	Asteraceae
Euphrasia officinalis	Orobanchaceae
Fragarianubicola	Rosaceae
Gageagageoides	Liliaceae
Galiumaparine	Rubiaceae
*Galium*sp	Rubiaceae
Gaultheria trichophylla	Ericaceae
Gentianacapitata	Gentianaceae
Gentianacarinata	Gentianaceae
Gentianaphyllocalyx	Gentianaceae
Geranium pratense	Geraniaceae
Geranium pusillum	Geraniaceae
Gerbera nepalensis	Asteraceae
Geum montanum	Rosaceae
Gnaphalium supinum	Asteraceae
Goodyera repens	Orchidaceae
Gymnocarpiumdryopteris	Cystopteridaceae
Gypsophila cerastoides	Caryophyllaceae
Hemerocallisfulva	Asphodelaceae
Heracleumcandicans	Apiaceae
Herniariahirsuta	Caryophyllaceae
*Hordeum*sp	Poaceae
Impatiens brachycentra	Balsaminaceae
Inula racemosa	Asteraceae
*Juncus*sp.	Juncaceae
Lactucahastata	Asteraceae
Lactuca alpina	Asteraceae
*Lagotis*sp	Plantaginaceae
Lamium album	Lamiaceae
Lamium maculatum	Lamiaceae
Leontopodiumleontopodinum	Asteraceae
Leontopodium alpinum	Asteraceae
Leontopodium jacotianum	Asteraceae
Leonurus cardiaca	Lamiaceae
Lepisorusstewartii	Polypodiaceae
Lepisorus clathratus	Polypodiaceae
Lepyrodiclisholosteoides	Caryophyllaceae

Lindelofia longifolia	Boraginaceae
Lomatogonium carinthiacum	Gentianaceae
Malvaneglecta	Malvaceae
Menthaarvensis	Lamiaceae
Myosotisarvensis	Boraginaceae
Myosotis sylvatica	Boraginaceae
Myriactis nepalensis	Asteraceae
Nasturtium officinale	Brassicaceae
Nepetacataria	Lamiaceae
*Orobanche*sp.	Orobanchaceae
Osmunda claytonia	Osmundaceae
Oxalis acetosella	Oxalidaceae
Oxalis corniculata	Oxalidaceae
Oxyriadigyna	Polygonaceae
Pedicularis comosa	Orobanchaceae
Pedicularis pectinata	Orobanchaceae
Phegopteris connectilis	Thelypteridaceae
Phleum alpinum	Poaceae
Phytollacaacinosa	Phytolacaceae
Picrorhiza kurrooa	Plantaginaceae
Plantagolanceolata	Plantaginaceae
Plantago major	Plantaginaceae
Pleurospermum candollei	Apiaceae
Poa annua	Poaceae
Poa palustris	Poaceae
Poa pratensis	Poaceae
Podophyllumhexandrum	Podophyllaceae
Polygonatummultiflorum	Asparagaceae
Polygonatumverticillatum	Asparagaceae
Polygonumcoccineum	Polygonaceae
Polygonumnepalense	Polygonaceae
*Polygonum*sp	Polygonaceae
Polygonum plebeium	Polygonaceae
Polystichumpiceopaleaceum	Dryopteridaceae
Polystichumprescottianum	Dryopteridaceae
*Polystichum*sp	Dryopteridaceae
Polystichum lonchitis	Dryopteridaceae
Potentilla aurea	Rosaceae
Potentilla curviseta	Rosaceae
Primuladenticulata	Primulaceae
Primula macrophylla	Primulaceae
Pseudomertensianemorosa	Boraginaceae
*Pseudophegopteris*sp	Thelypteridaceae
Pteriscretica	Pteridaceae
Ranunculus laetus	Ranunculaceae

Ranunculus sp	Ranunculaceae
Ranunculus palmatifidus	Ranunculaceae
Ranunculus sceleratus	Ranunculaceae
Rubiacordifolia	Rubiaceae
Rubusclarkei	Rosaceae
Rumexhastatus	Polygonaceae
Rumexnepalanse	Polygonaceae
Salvia hains	Lamiaceae
Saxifraga cernua	Saxifragaceae
*Scandix*sp	Apiaceae
*Scrophularia*sp	Scrophulariaceae
Sedum ewersii	Crassulaceae
Sedum album	Crassulaceae
Sedum hispanicum	Crassulaceae
Sedum oreades	Crassulaceae
Senecio chrysanthemoides	Asteraceae
Sibbaldia cuneata	Rosaceae
Silene gonosperma	Caryophyllaceae
Spergularia media	Caryophyllaceae
Stachys tymphaea	Lamiaceae
Stellaria media	Caryophyllaceae
Swertia petiolata	Gentianaceae
Taraxacumofficinalis	Asteraceae
Thalictrumcultratum	Ranunculaceae
Thalictrum minus	Ranunculaceae
Thalictrum alpinum	Ranunculaceae
Thalictrum foliolosum	Ranunculaceae
Thalspicochleriformis	Brassicaceae
Trifoliumrepens	Fabaceae
Trillium govanianum	Melanthiaceae
Urticadioca	Urticaceae
Valerianahardwickii	Valerianaceae
Valerianajatamansii	Valerianaceae
Verbascumthapsus	Scrophulariaceae
Veronica beccabunga	Plantaginaceae
Veronica biloba	Plantaginaceae
Veronica persica	Plantaginaceae
Veronica sp.	Plantaginaceae
Viola odorata	Violaceae

Elevational trend

Angiosperms including dicots and pteridophytes show hump like distribution along increasing altitude, bryophytes goes on decreasing along increasing altitude. However gymnosperms being dominant members show little variation along an elevational gradient, lichens first increase then show steady decrease along an altitudinal gradient.

Functional groups of vascular plants viz, trees, shrubs and herbs also responded differently to different altitudinal bands and exhibit patterns of change characteristic of each group with herbs showing hump like distribution pattern similar to that shown by angiosperms and pteridophytes, but in case of shrubs and trees little variation occurs in distribution pattern along an altitudinal gradient (Fig. 10).

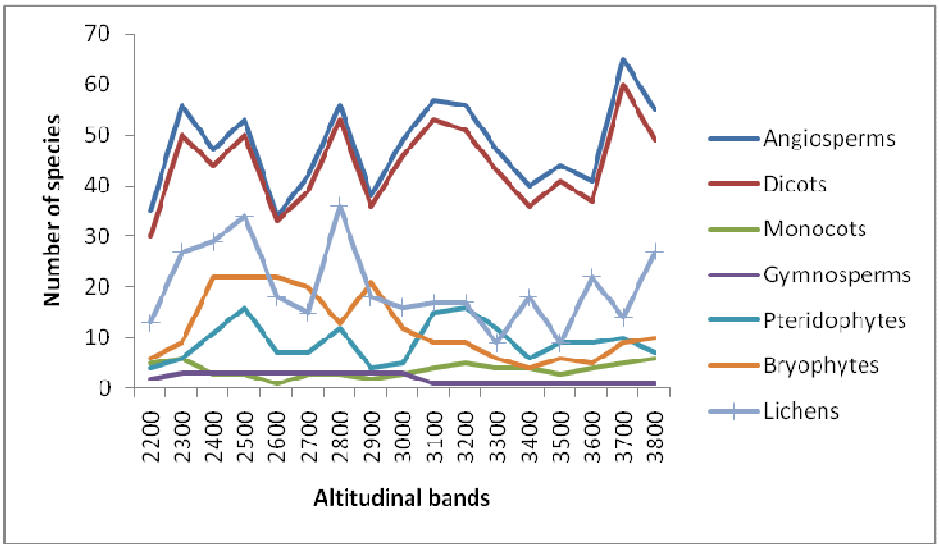


Fig.10. Species richness of different plant groups along the altitudinal gradient.

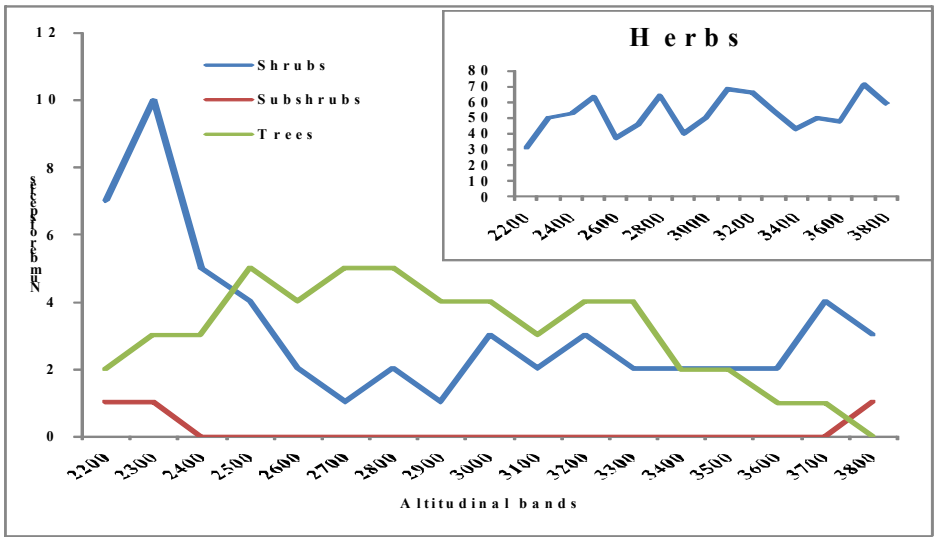


Fig.11. Number of species of different growth forms along the altitudinal gradient.

Similarity matrix prepared on the basis of shared species between the bands (Table 7) reveals that the number of species shared by altitudinal bands more or less decreases with increasing altitude. A detailed comparison of each community with all other communities is given in table 8.

Perusal of density data (Fig.11) reveals that *Abies pindrow* is the most dominant species in the coniferous forests and its density peaks around 32500 m amsl and thereafter declines. It grows interspersed with *Picea* spp. *Betula utilis* is the treeline species and appears from an altitude of 3200 m amsl. It shows peaks density at 3600 m amsl and thereafter declines. In respect of shrubs (Fig.12) *Vibernum foetans* is the dominant species in lower altitudes whereas *Cotoneaster* sp. and *Rhododendron* spp. are the predominant species in the higher altitudes.

Tree diameter changes in relation to altitude are presented in Fig. 13 and no distinct pattern is discernible.

Table.7. Species matrix table showing similarity above diagonal & dissimilarity below diagonal between communities

Communities	2200	2300	2400	2500	2600	2700	2800	2900	3000	3100	3200	3300	3400	3500	3600	3700	3800
2200	**100**	60	47	45	39	38	39	37	37	26	25	19	13	16	15	14	7
2300	0.492	**100**	76	67	52	51	56	51	51	39	38	30	25	27	22	21	13
2400	0.678	0.534	**100**	104	69	66	71	64	64	49	47	36	32	31	28	27	24
2500	0.72	0.638	0.362	**100**	72	74	78	70	68	51	49	38	31	35	30	27	22
2600	0.683	0.667	0.552	0.561	**100**	70	68	65	59	44	41	33	26	25	21	20	14
2700	0.703	0.683	0.59	0.554	0.444	**100**	72	66	63	45	44	39	29	30	24	20	14
2800	0.755	0.702	0.622	0.598	0.575	0.55	**100**	73	75	52	52	41	29	33	29	24	17
2900	0.702	0.673	0.595	0.576	0.484	0.488	0.526	**100**	76	46	42	37	26	29	24	20	11
3000	0.711	0.681	0.605	0.602	0.566	0.537	0.519	0.356	**100**	49	45	37	27	31	26	23	15
3100	0.821	0.781	0.732	0.737	0.72	0.719	0.719	0.701	0.684	**100**	83	68	47	52	36	38	20
3200	0.837	0.796	0.755	0.759	0.754	0.738	0.729	0.745	0.729	0.381	**100**	77	55	56	40	38	21
3300	0.86	0.825	0.8	0.801	0.783	0.74	0.772	0.748	0.755	0.46	0.379	**100**	58	57	41	37	20
3400	0.898	0.846	0.812	0.832	0.821	0.801	0.837	0.819	0.816	0.647	0.583	0.453	**100**	58	47	37	22
3500	0.876	0.835	0.823	0.81	0.833	0.799	0.815	0.8	0.789	0.606	0.585	0.486	0.396	**100**	52	42	26
3600	0.891	0.875	0.849	0.847	0.87	0.852	0.847	0.847	0.836	0.768	0.747	0.694	0.588	0.54	**100**	64	41

3700	0.919	0.9	0.877	0.884	0.898	0.9	0.895	0.897	0.883	0.797	0.804	0.785	0.766	0.732	0.549	**100**	75
3800	0.958	0.937	0.886	0.902	0.926	0.927	0.923	0.942	0.921	0.896	0.894	0.886	0.862	0.837	0.73	0.507	**100**

Table.8. Pairwise comparison between communities in respect of Similarity indices and β- diversity.

Site pairs	Shared Species Observed	Jaccard Classic	Sorensen Classic	Morisita-Horn	Bray-Curtis	β- diversity
2200-2300	60	0.508	0.674	0.674	0.674	0.492
2200-2400	47	0.322	0.487	0.487	0.487	0.678
2200-2500	45	0.28	0.437	0.437	0.437	0.72
2200-2600	39	0.317	0.481	0.481	0.481	0.683
2200-2700	38	0.297	0.458	0.458	0.458	0.703
2200-2800	39	0.245	0.394	0.394	0.394	0.755
2200-2900	37	0.298	0.46	0.46	0.46	0.702
2200-3000	37	0.289	0.448	0.448	0.448	0.711
2200-3100	26	0.179	0.304	0.304	0.304	0.821
2200-3200	25	0.163	0.281	0.281	0.281	0.837
2200-3300	19	0.14	0.245	0.245	0.245	0.86
2200-3400	13	0.102	0.184	0.184	0.184	0.898

2200-3500	16	0.124	0.221	0.221	0.221	0.876
2200-3600	15	0.109	0.197	0.197	0.197	0.891
2200-3700	14	0.081	0.151	0.151	0.151	0.919
2200-3800	7	0.042	0.081	0.081	0.081	0.958
2300-2400	76	0.466	0.636	0.636	0.636	0.534
2300-2500	67	0.362	0.532	0.532	0.532	0.638
2300-2600	52	0.333	0.5	0.5	0.5	0.667
2300-2700	51	0.317	0.481	0.481	0.481	0.683
2300-2800	56	0.298	0.459	0.459	0.459	0.702
2300-2900	51	0.327	0.493	0.493	0.493	0.673
2300-3000	51	0.319	0.483	0.483	0.483	0.681
2300-3100	39	0.219	0.359	0.359	0.359	0.781
2300-3200	38	0.204	0.339	0.339	0.339	0.796
2300-3300	30	0.175	0.299	0.299	0.299	0.825
2300-3400	25	0.154	0.267	0.267	0.267	0.846
2300-3500	27	0.165	0.283	0.283	0.283	0.835

2300-3600	22	0.125	0.222	0.222	0.222	0.875
2300-3700	21	0.1	0.181	0.181	0.181	0.9
2300-3800	13	0.063	0.119	0.119	0.119	0.937
2400-2500	104	0.638	0.779	0.779	0.779	0.362
2400-2600	69	0.448	0.619	0.619	0.619	0.552
2400-2700	66	0.41	0.581	0.581	0.581	0.59
2400-2800	71	0.378	0.548	0.548	0.548	0.622
2400-2900	64	0.405	0.577	0.577	0.577	0.595
2400-3000	64	0.395	0.566	0.566	0.566	0.605
2400-3100	49	0.268	0.422	0.422	0.422	0.732
2400-3200	47	0.245	0.393	0.393	0.393	0.755
2400-3300	36	0.2	0.333	0.333	0.333	0.8
2400-3400	32	0.188	0.317	0.317	0.317	0.812
2400-3500	31	0.177	0.301	0.301	0.301	0.823
2400-3600	28	0.151	0.263	0.263	0.263	0.849
2400-3700	27	0.123	0.219	0.219	0.219	0.877

2400-3800	24	0.114	0.205	0.205	0.205	0.886
2500-2600	72	0.439	0.61	0.61	0.61	0.561
2500-2700	74	0.446	0.617	0.617	0.617	0.554
2500-2800	78	0.402	0.574	0.574	0.574	0.598
2500-2900	70	0.424	0.596	0.596	0.596	0.576
2500-3000	68	0.398	0.569	0.569	0.569	0.602
2500-3100	51	0.263	0.416	0.416	0.416	0.737
2500-3200	49	0.241	0.389	0.389	0.389	0.759
2500-3300	38	0.199	0.332	0.332	0.332	0.801
2500-3400	31	0.168	0.288	0.288	0.288	0.832
2500-3500	35	0.19	0.32	0.32	0.32	0.81
2500-3600	30	0.153	0.265	0.265	0.265	0.847
2500-3700	27	0.116	0.208	0.208	0.208	0.884
2500-3800	22	0.098	0.178	0.178	0.178	0.902
2600-2700	70	0.556	0.714	0.714	0.714	0.444
2600-2800	68	0.425	0.596	0.596	0.596	0.575

2600-2900	65	0.516	0.681	0.681	0.681	0.484
2600-3000	59	0.434	0.605	0.605	0.605	0.566
2600-3100	44	0.28	0.438	0.438	0.438	0.72
2600-3200	41	0.246	0.394	0.394	0.394	0.754
2600-3300	33	0.217	0.357	0.357	0.357	0.783
2600-3400	26	0.179	0.304	0.304	0.304	0.821
2600-3500	25	0.167	0.286	0.286	0.286	0.833
2600-3600	21	0.13	0.231	0.231	0.231	0.87
2600-3700	20	0.102	0.185	0.185	0.185	0.898
2600-3800	14	0.074	0.138	0.138	0.138	0.926
2700-2800	72	0.45	0.621	0.621	0.621	0.55
2700-2900	66	0.512	0.677	0.677	0.677	0.488
2700-3000	63	0.463	0.633	0.633	0.633	0.537
2700-3100	45	0.281	0.439	0.439	0.439	0.719
2700-3200	44	0.262	0.415	0.415	0.415	0.738
2700-3300	39	0.26	0.413	0.413	0.413	0.74

2700-3400	29	0.199	0.331	0.331	0.331	0.801
2700-3500	30	0.201	0.335	0.335	0.335	0.799
2700-3600	24	0.148	0.258	0.258	0.258	0.852
2700-3700	20	0.1	0.182	0.182	0.182	0.9
2700-3800	14	0.073	0.135	0.135	0.135	0.927
2800-2900	73	0.474	0.643	0.643	0.643	0.526
2800-3000	75	0.481	0.649	0.649	0.649	0.519
2800-3100	52	0.281	0.439	0.439	0.439	0.719
2800-3200	52	0.271	0.426	0.426	0.426	0.729
2800-3300	41	0.228	0.371	0.371	0.371	0.772
2800-3400	29	0.163	0.28	0.28	0.28	0.837
2800-3500	33	0.185	0.313	0.313	0.313	0.815
2800-3600	29	0.153	0.266	0.266	0.266	0.847
2800-3700	24	0.105	0.19	0.19	0.19	0.895
2800-3800	17	0.077	0.142	0.142	0.142	0.923
2900-3000	76	0.644	0.784	0.784	0.784	0.356

2900-3100	46	0.299	0.46	0.46	0.46	0.701
2900-3200	42	0.255	0.406	0.406	0.406	0.745
2900-3300	37	0.252	0.402	0.402	0.402	0.748
2900-3400	26	0.181	0.306	0.306	0.306	0.819
2900-3500	29	0.2	0.333	0.333	0.333	0.8
2900-3600	24	0.153	0.265	0.265	0.265	0.847
2900-3700	20	0.103	0.186	0.186	0.186	0.897
2900-3800	11	0.058	0.109	0.109	0.109	0.942
3000-3100	49	0.316	0.48	0.48	0.48	0.684
3000-3200	45	0.271	0.427	0.427	0.427	0.729
3000-3300	37	0.245	0.394	0.394	0.394	0.755
3000-3400	27	0.184	0.31	0.31	0.31	0.816
3000-3500	31	0.211	0.348	0.348	0.348	0.789
3000-3600	26	0.164	0.281	0.281	0.281	0.836
3000-3700	23	0.117	0.21	0.21	0.21	0.883
3000-3800	15	0.079	0.146	0.146	0.146	0.921

3100-3200	83	0.619	0.765	0.765	0.765	0.381
3100-3300	68	0.54	0.701	0.701	0.701	0.46
3100-3400	47	0.353	0.522	0.522	0.522	0.647
3100-3500	52	0.394	0.565	0.565	0.565	0.606
3100-3600	36	0.232	0.377	0.377	0.377	0.768
3100-3700	38	0.203	0.338	0.338	0.338	0.797
3100-3800	20	0.104	0.189	0.189	0.189	0.896
3200-3300	77	0.621	0.766	0.766	0.766	0.379
3200-3400	55	0.417	0.588	0.588	0.588	0.583
3200-3500	56	0.415	0.586	0.586	0.586	0.585
3200-3600	40	0.253	0.404	0.404	0.404	0.747
3200-3700	38	0.196	0.328	0.328	0.328	0.804
3200-3800	21	0.106	0.192	0.192	0.192	0.894
3300-3400	58	0.547	0.707	0.707	0.707	0.453
3300-3500	57	0.514	0.679	0.679	0.679	0.486
3300-3600	41	0.306	0.469	0.469	0.469	0.694

3300-3700	37	0.215	0.354	0.354	0.354	0.785
3300-3800	20	0.114	0.204	0.204	0.204	0.886
3400-3500	58	0.604	0.753	0.753	0.753	0.396
3400-3600	47	0.412	0.584	0.584	0.584	0.588
3400-3700	37	0.234	0.379	0.379	0.379	0.766
3400-3800	22	0.138	0.242	0.242	0.242	0.862
3500-3600	52	0.46	0.63	0.63	0.63	0.54
3500-3700	42	0.268	0.422	0.422	0.422	0.732
3500-3800	26	0.163	0.28	0.28	0.28	0.837
3600-3700	64	0.451	0.621	0.621	0.621	0.549
3600-3800	41	0.27	0.425	0.425	0.425	0.73
3700-3800	75	0.493	0.661	0.661	0.661	0.507

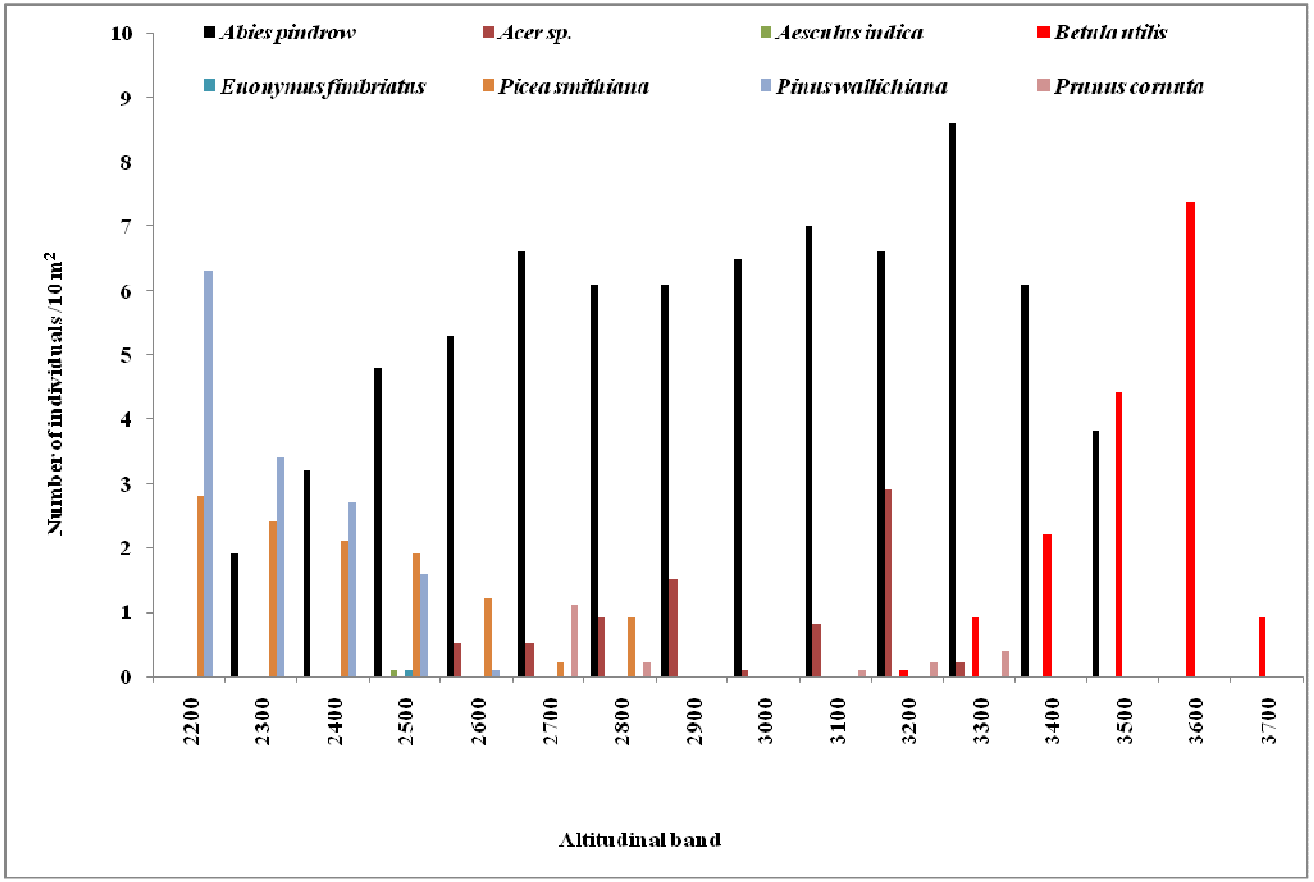


Fig.12. Density (number of individuals/10 m^2) of various tree species in different altitudinal bands.

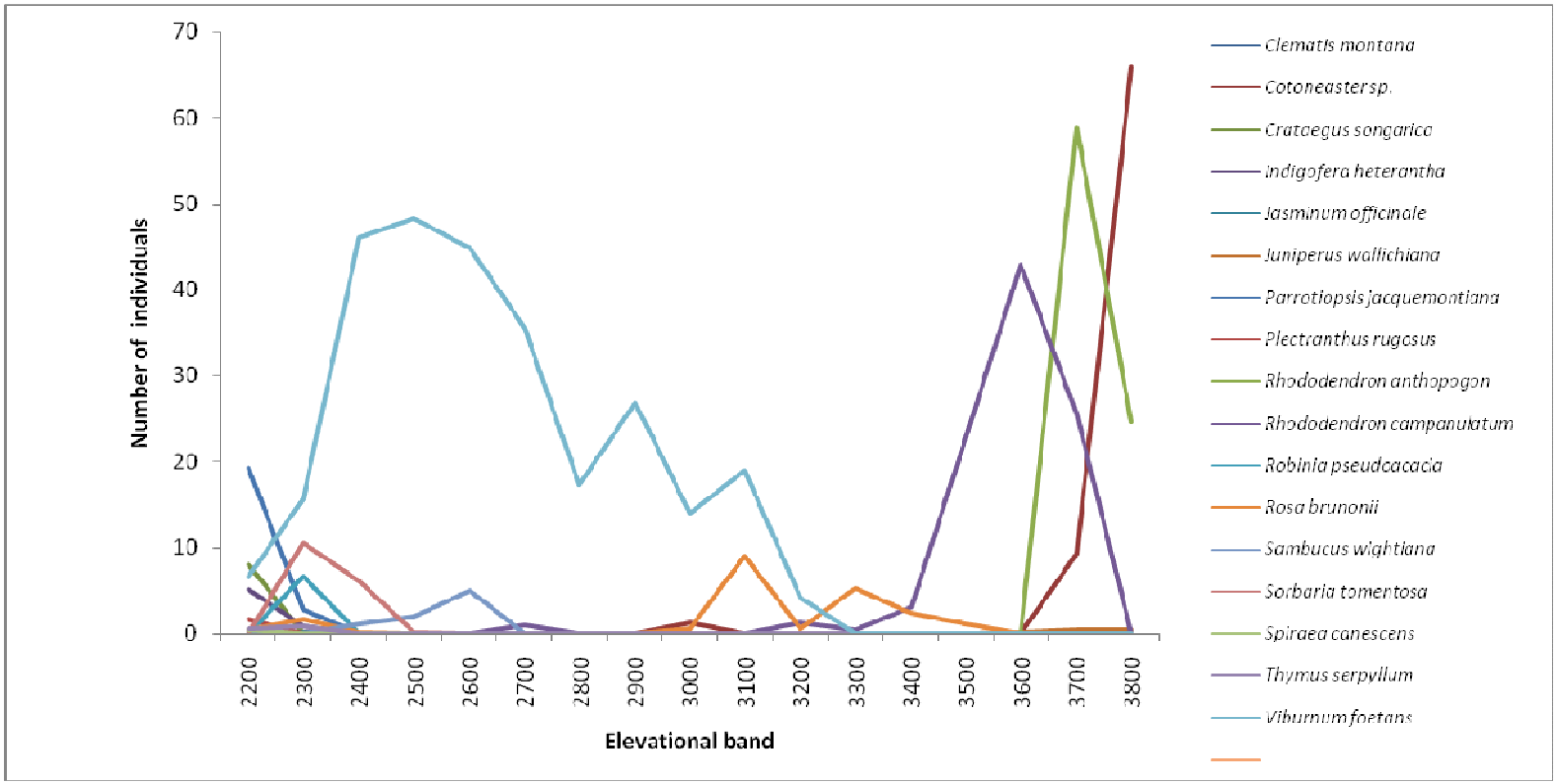


Fig.12. Density (number of individuals/5 m^2) of various shrub species in different altitudinal bands.

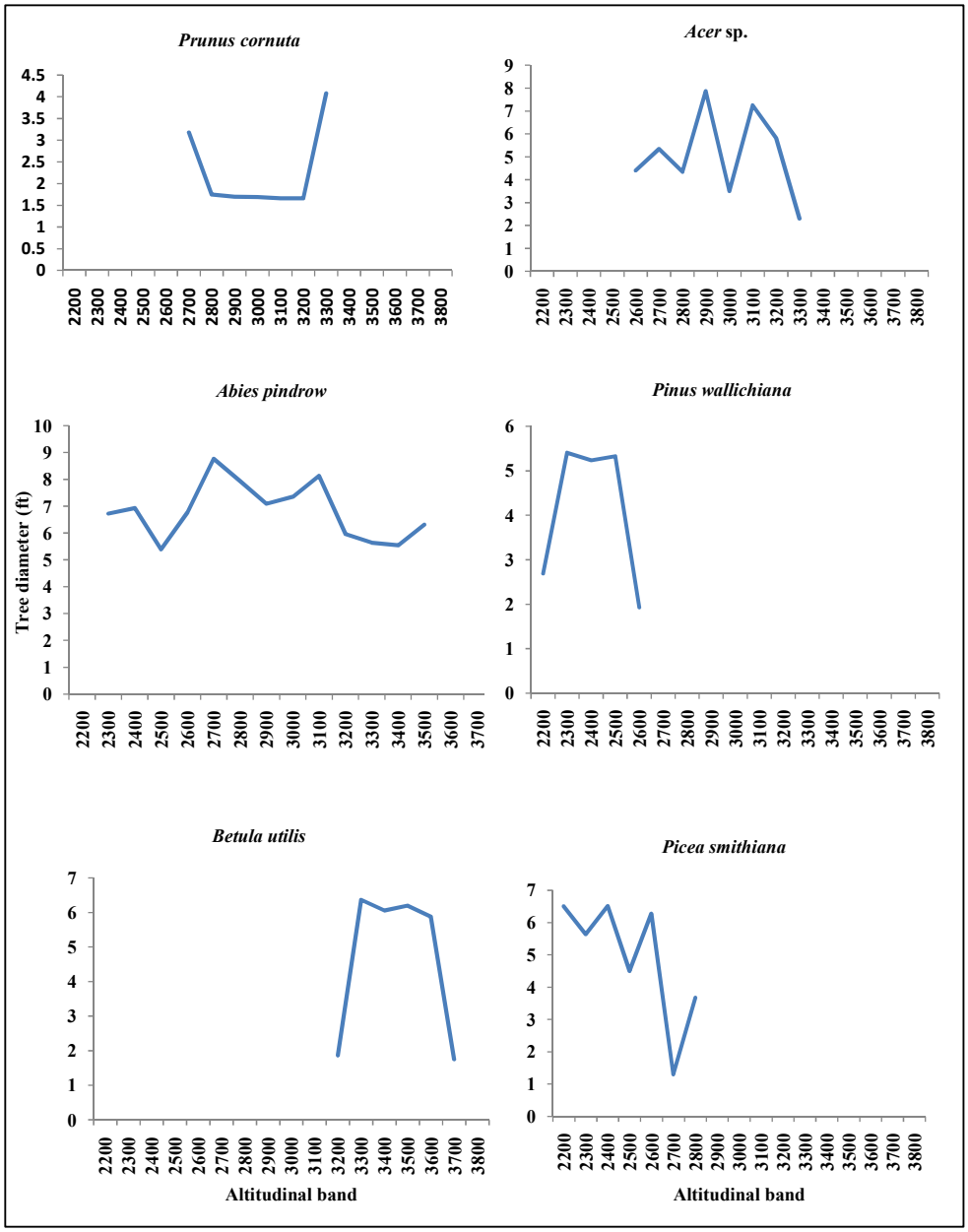


Fig.13. Changes in tree diameter in different altitudinal bands

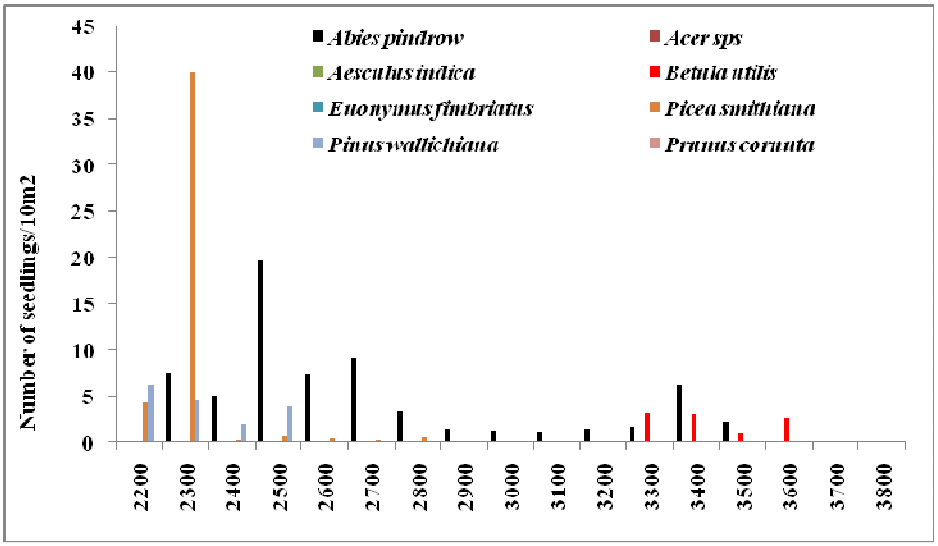


Fig.14. Seedling recruitment of various tree species in different altitudinal bands.

Seedling recruitment

Recruitment of seedling of different tree species in different altitudinal bands in presented in Fig. 14. Data reveal that *Picea smithiana* shows recruitment in lower altitudes while *Abies pindorw* shows recruit across several altitudinal bands and extends to an altitude of 3500 m amsl. *Betula* recruitment was recorded from altitudinal band of 3300 to 3600.

Patterns of species richness along the elevational gradient

Elevational patterns of various taxonomic and functional plant groups are presented in Figs. 15-19. Angiosperms including dicots and pteridophytes show a wavy pattern distribution along increasing altitude with several peaks and troughs. Monocots showed a characteristic pattern of mid-elevational decline and subsequent increase in higher elevations while bryophytes kept on decreasing with increasing altitude. Lichen richness peaked in mid elevations and declined in higher elevations with modest increase in alpine zone (Fig. 15). In all, four patterns of species richness in relation to elevation were observed during the present study: low-elevation plateau with a mid-peak in bryophytes, mid-peak pattern in pteridophytes and lichens, and inverted hump-shaped pattern in monocots.

Functional groups of spermatophytes viz, trees, shrubs and herbs also showed specific elevational patterns in species richness (Figs. 16-19). Trees showed a characteristic mid-elevational peak, but overall curve was wavy, with several rises and falls. Shrubs, on the contrary, showed highest richness at 2300 m and thereafter declined sharply up to 2700 m, whereafter it leveled off. Herbs, on the other hand presented a wavy pattern with many peaks and troughs but overall curve showed no tendency for species decline within the study elevational range. Patterns of species richness studied in terms of life span of species (Fig. 17) revealed that annuals and perennials show more or less similar patterns of increase and

decreases with increasing elevation. The overall trend was similar to that of herbs. Growth forms of bryophytes characterized in terms of liverworts and mosses more or less showed mid-elevation peaks and decline in higher elevations (Fig. 18). While mid-elevation peaks in species richness of lichens was observed in crustose, foliose and fruticose functional types (Fig. 19), leprose functional type showed highly irregular pattern in species richness in relation to elevation. Species richness peak occurred at 3700-3800 m for angiosperms as a whole, dicots and monocots and all herbs, at 3200 m for pteridophytes, at 2800 m for lichens, at 2500-2800 m for trees and 2400 m for bryophytes.

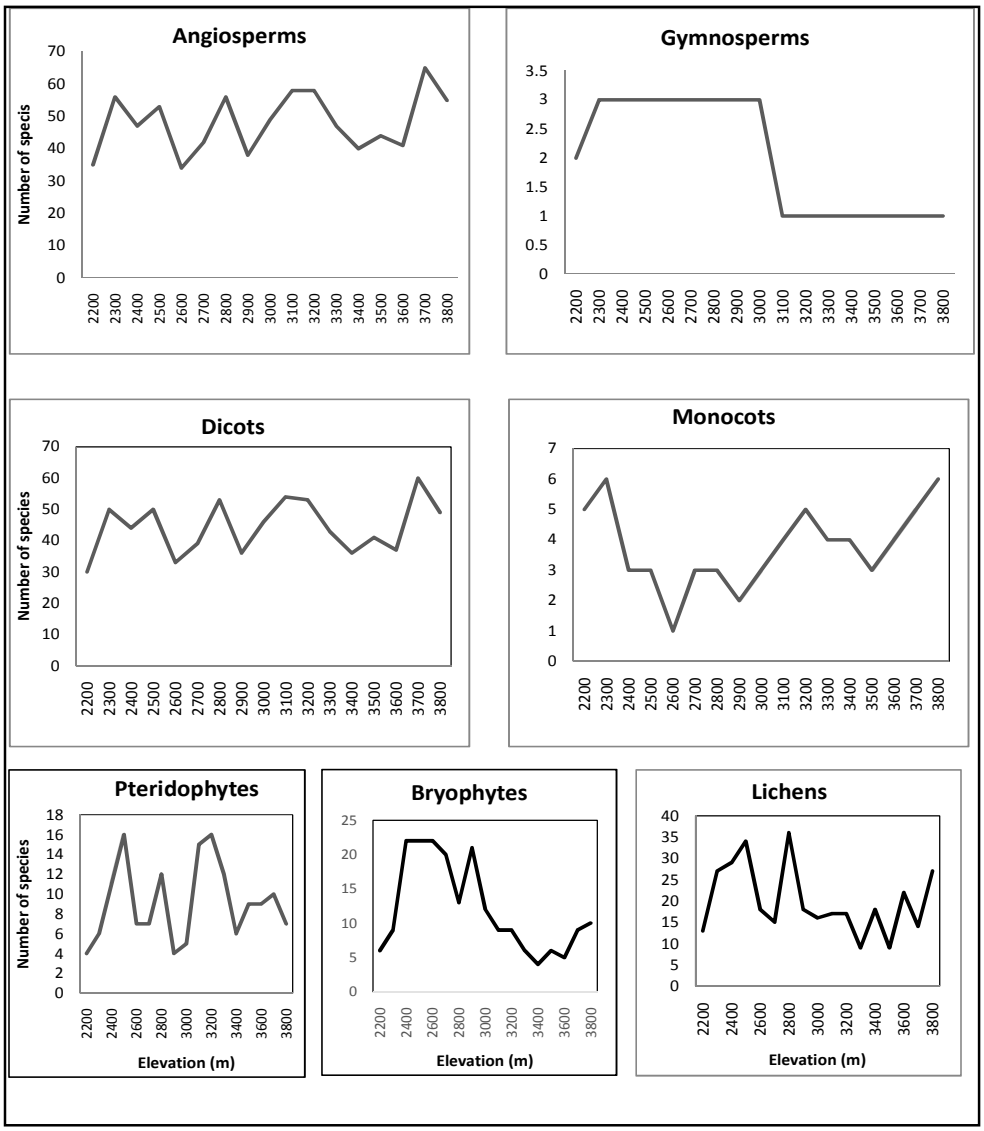


Fig.15. Elevational pattern in species richness of different plant groups.

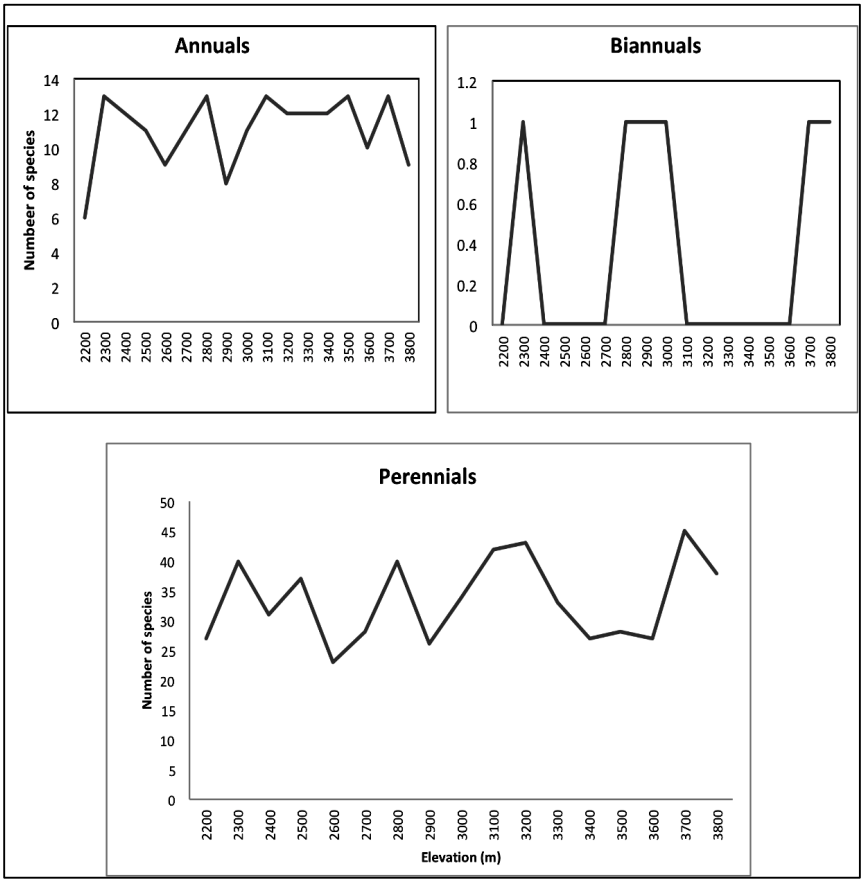


Fig. 17.Elevational pattern in species with different life spans in spermatophytes

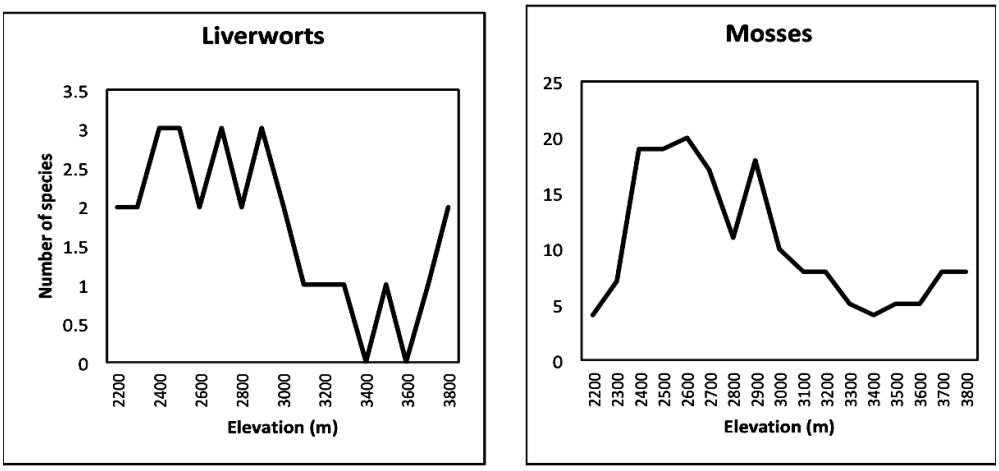


Fig. 18. Elevational pattern in growth forms of bryophytes

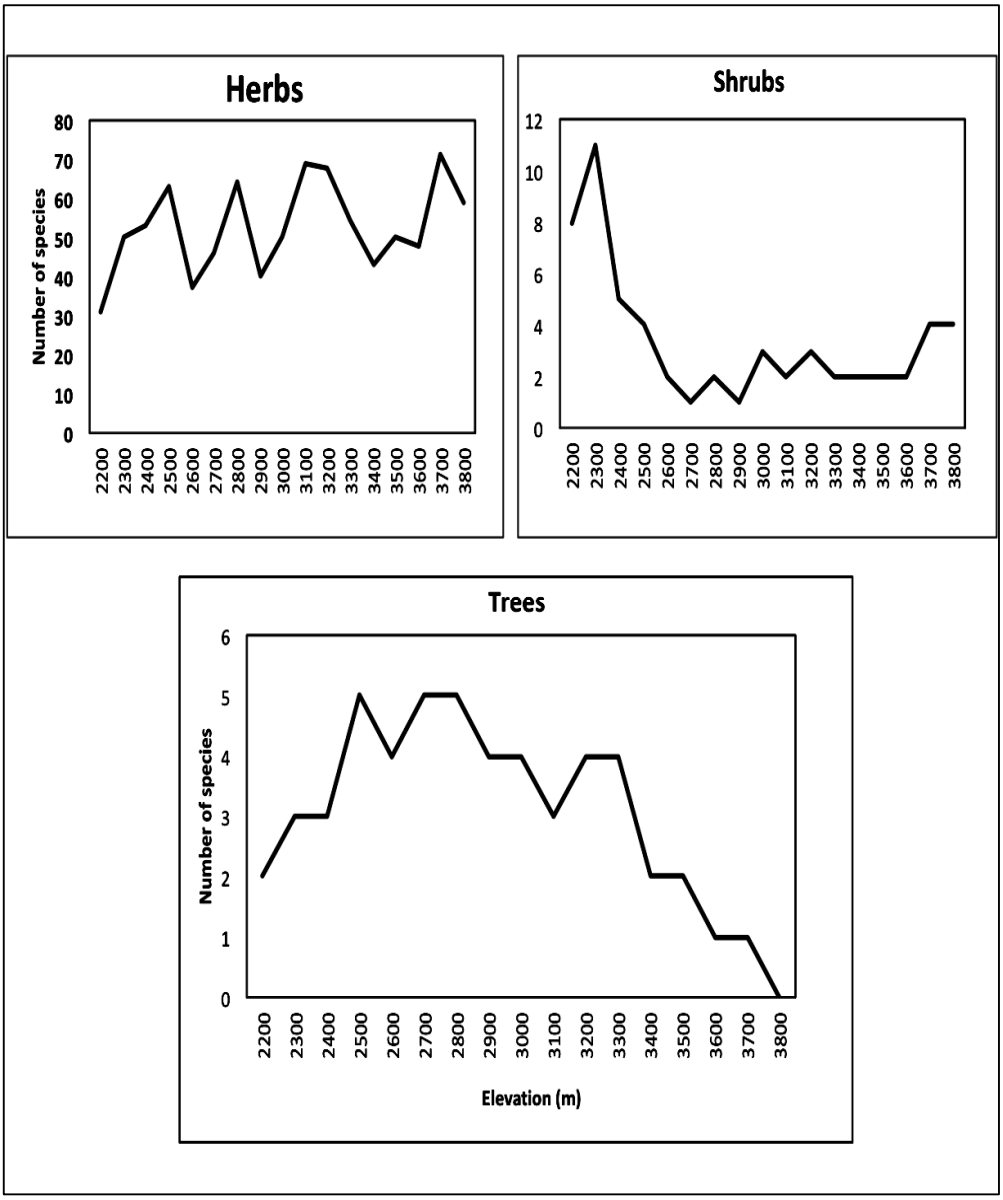


Fig. 16. Elevational pattern in growth forms of spermatophytes.

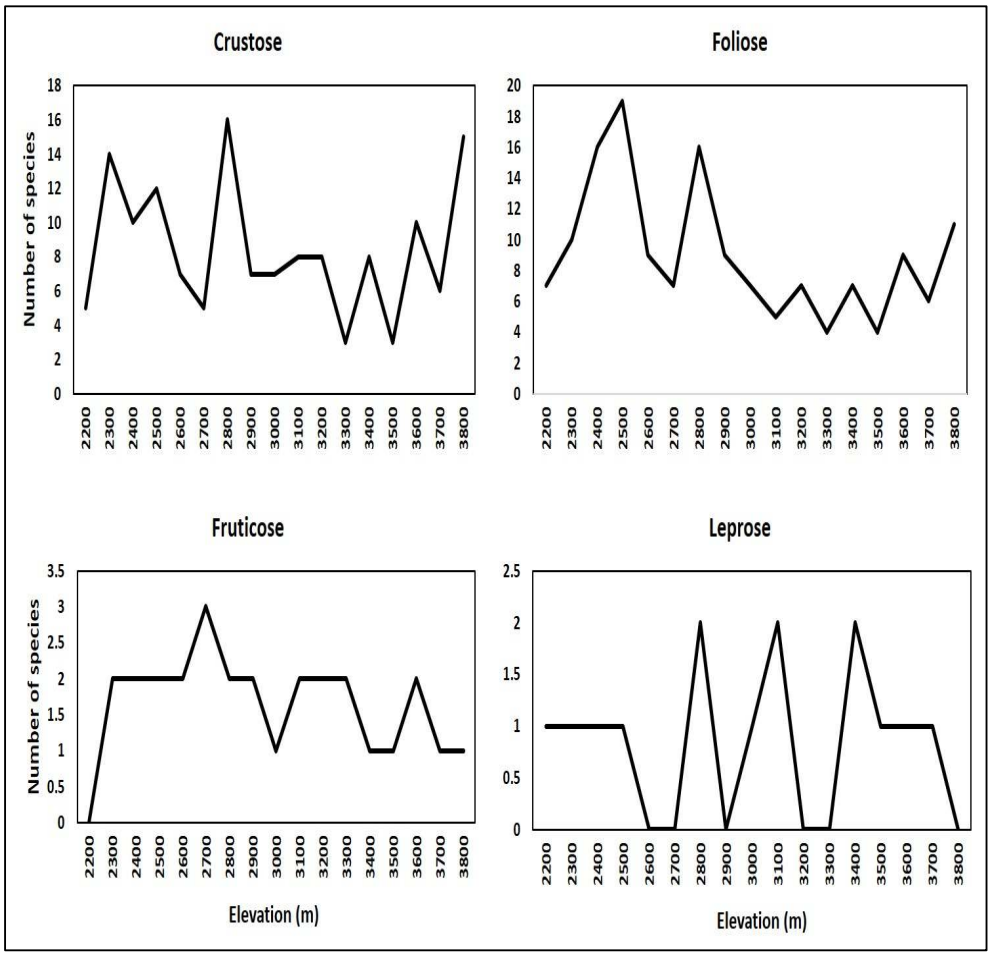


Fig. 19. Elevational pattern in growth forms of lichens.

The present study demonstrates that the elevational patterns of species richness are not consistent across taxonomic or functional groups of plants. Four patterns of species richness in relation to elevation were observed: low plateau pattern in gymnosperms, low-elevation plateau with a mid-peak in bryophytes, mid-peak pattern in pteridophytes and lichens, and inverted hump-shaped pattern in monocots (Figs. 22, 23).

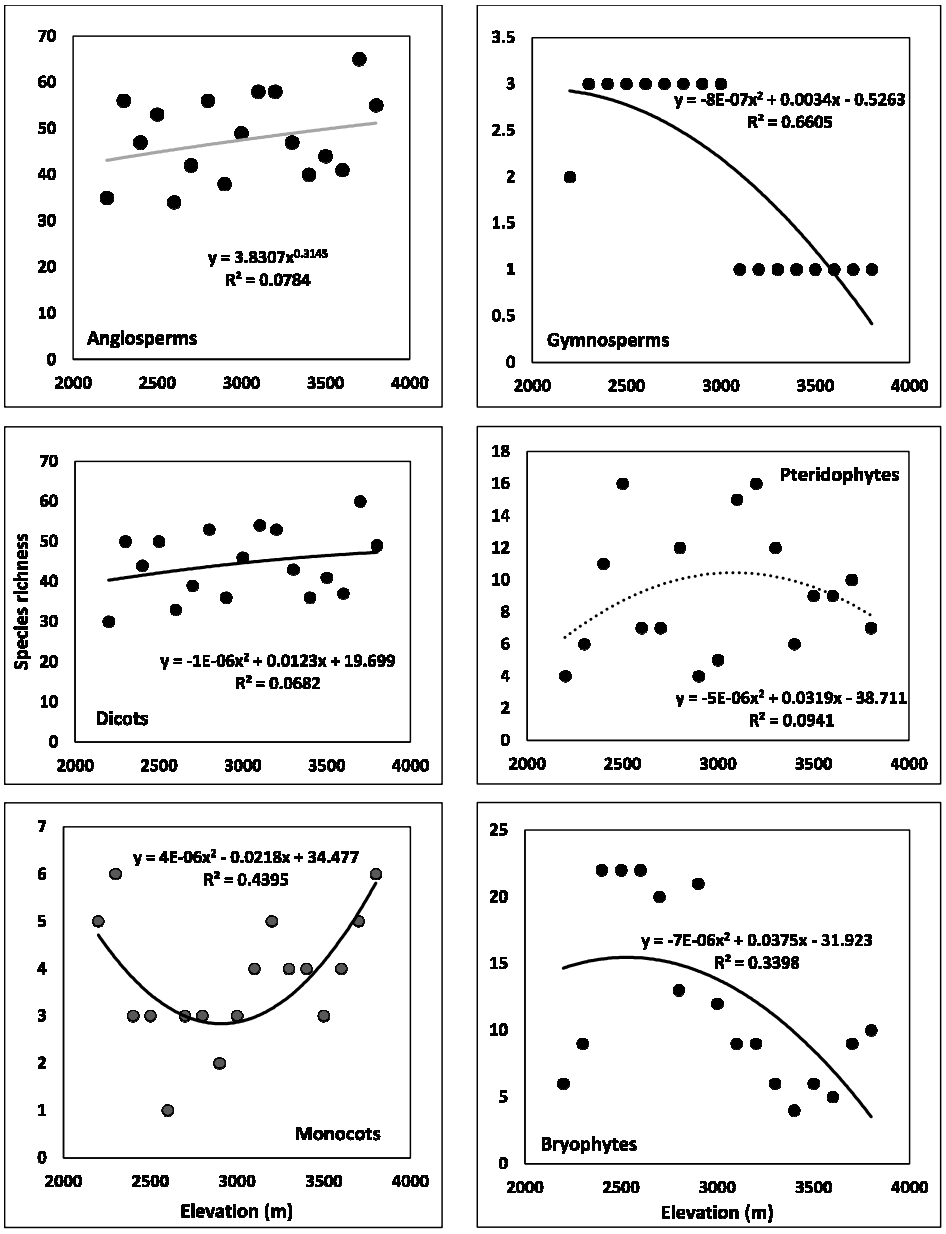


Fig. 22. Relationship between species richness of different plant groups and elevation.

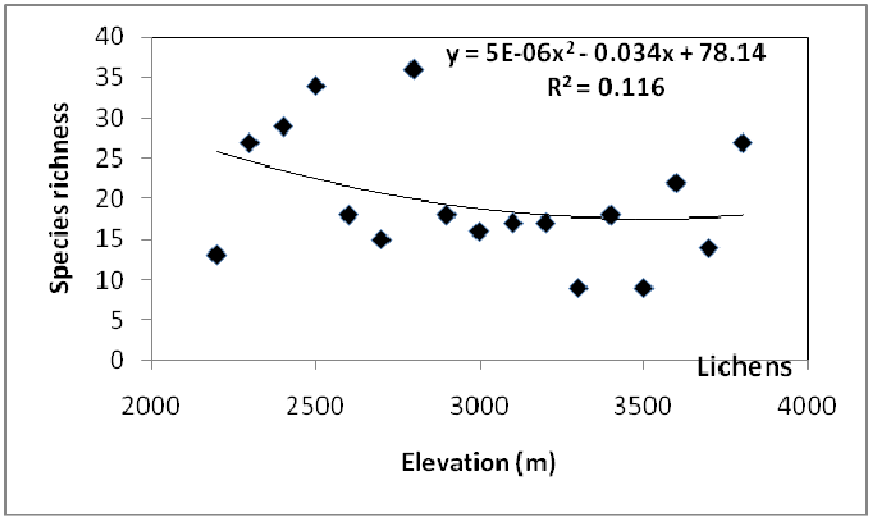


Fig. 23. Relationship between species richness of lichens and elevation

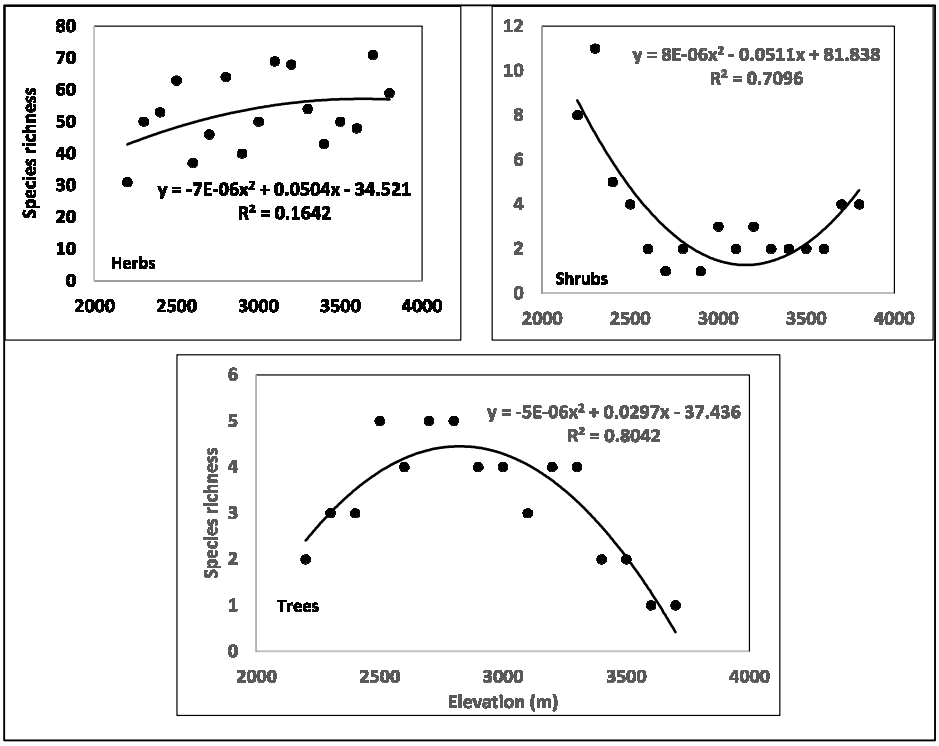


Fig. 24. Relationship between species richness of different plant functional groups and elevation.

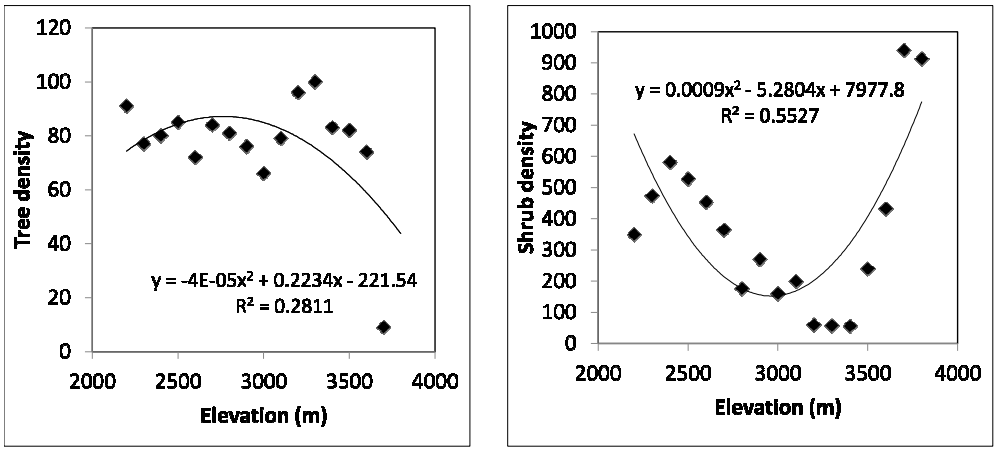


Fig. 25 . Relationship between tree and shrub density and elevation.

Treeline ecotone

Overall species richness and composition

The treeline ecotone of study area stretches from the timberline limit (3200 amsl) to the treeless alpine zone (>3700 amsl). The treeline ecotone is species rich comprising 225 species belonging to 157 genera and 81 families (Table 9).

Table. 9. Taxonomic conspectus of species in the treeline ecotone. Values in parentheses are the percentage of species recorded in the entire elevation transect.

Plant group	No. of species	No. of genera	No. of families
Angiosperms	111(57.2%)	92	37
Dicots	102 (58.3%)	85	32
Monocots	9 (47.3%)	7	5
Gymnosperms	2 (50%)	2	2
Pteridophytes	21 (63.6%)	12	8
Bryophytes	16 (41.0%)	14	10
Lichens	75 (48.3%)	37	24
Total	225 (52.9%)	157	81

Elevational trend in species richness

Trends in species richness along elevational gradient in the treeline ecotone (Fig. 20) reveals that the overall species richness is in the lowest elevation of treeline ecotone (3200 m) and thereafter it declines rapidly and shows modest increase beyond 3600 m and more or less similar pattern in evident in respect of angiosperms and gymnosperms and lichens. Other

groups of plants, such as monocots, gymnosperms, pteridophytes and bryophytes do not show any significant variation in relation to elevation in the treeline ecotone.

Relatively, treeline ecotone (ranging from 3200 to 3700 m and including six bands) is richer than the lower part of the elevation gradient (ranging from 2200 to 3200 and including twelve 100 m elevation bands). About 30% of the elevational transect that represented the treeline ecotone had about 53% of total species recorded in the transect (225 of 425 species). It contained almost 63% of pteridophytes, about half of lichens, but was relatively low in bryophytes.

Functional diversity of vascular plants characterized in terms of growth forms (Table 10) reveals that herbs predominate with 121 species (90%). Elevational pattern of herbs was more or less similar to overall species richness pattern with high species richness at 3200 m and some decline between 3000 to 3600 m and then again in increase in the elevation zone of 3700 m. Shrubs, though less in number, also show a more or less similar elevational pattern. Trees, on the other hand, showed relatively high species richness at 3200 m, thereafter declined with no tree species recorded beyond 3700 m (Fig. 20).

Perusal of data in Fig. 21 reveals that *Abies pindrow* is the dominant tree species upto 3400 m. In fact, it is the timberline species in the study area. However, *Betula utilis* which appears at an altitude of 3300 m increases in numbers relative to *Abies pindrow* and ultimately becomes the dominant tree species at 3600 m but decreases in abundance at 3700 m (Fig. 21).

Table 10: Number of species belonging to different growth forms in the treeline ecotone.

Growth form	**No. of species**
Herbs	121
Shrubs	9
Trees	4
Total	134

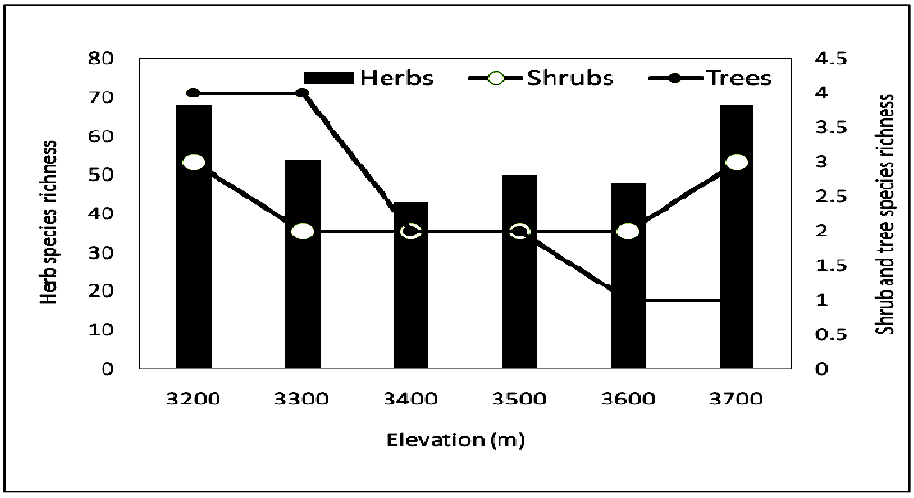


Fig. 20. Elevation pattern in species richness of tress, shrubs and herbs

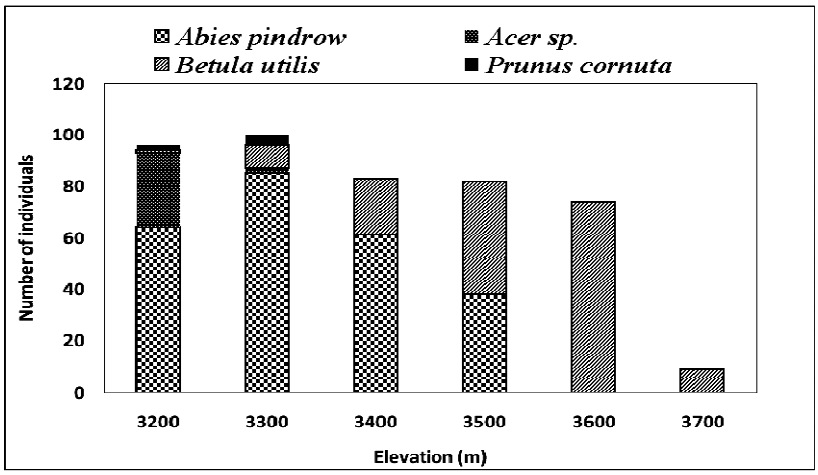
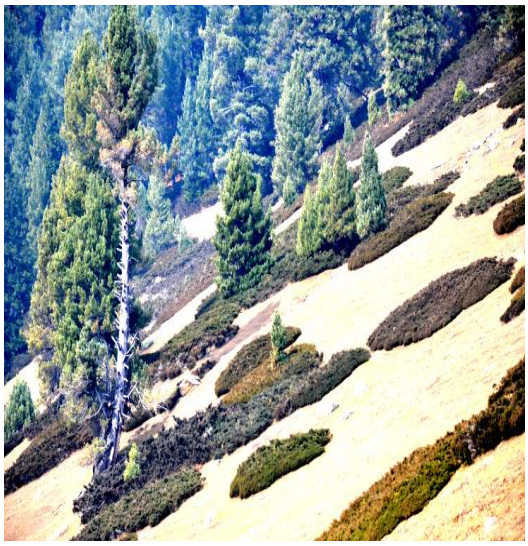


Fig. 21. Density of important tree species in the treeline ecotone.

North vs south slope of the study area

North vs south slope of the study area



Treeline in the Northern aspect

Treeline in the Southern aspect

Timberline area of the study site in Daksum-Sinthan Kashmir Himalaya

Research team during a field survey

(Dr. R.S. Rawal)

NMHS Progress Report
(Period from April 2017 to March 2018)

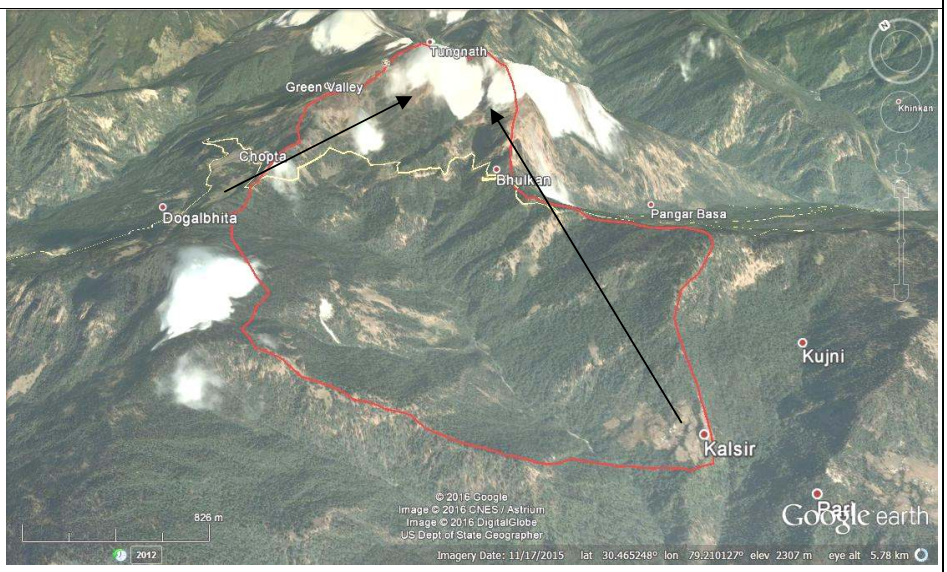
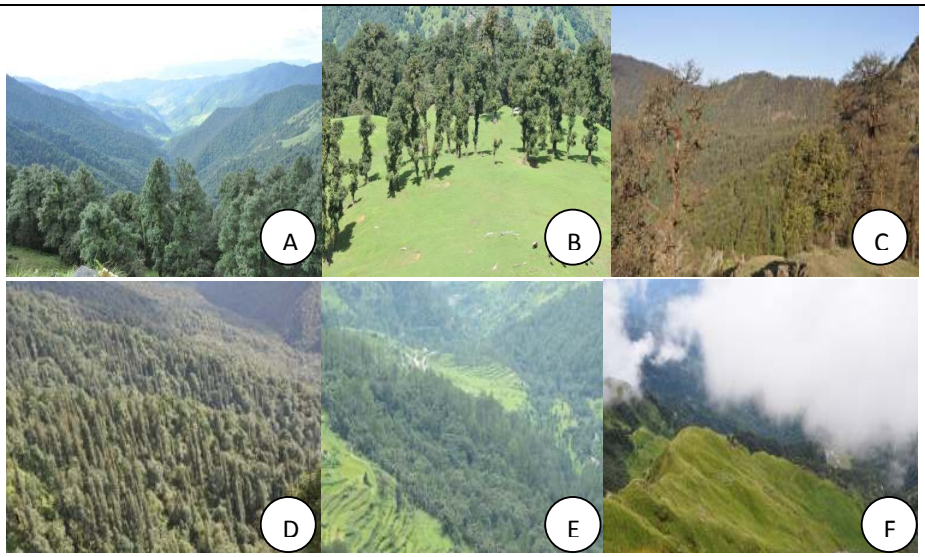
1. Project Information

Project ID:		**Sanction Date:**	31-03-2016
Project Title:	Timberline and Altitudinal Gradient Ecology of Himalaya and Human use Sustenance in a warming climate		
BTG:	Large Grant		
PI and Affiliation (Institution):	Dr. R.S. Rawal, Scientist-F, GBPNIHESD, Kosi-Katarmal , Almora		
Name & Address of the Co-PI, if any:			

Structured Abstract - detailing the current year progress [Word Limit 250 words]:	Second year study targeted: (i) developing detailed floristic inventory of forested high altitude zone (2000-3500 m asl) of west Himalaya, which resulted in documentation of 1471 plant species [106 (7.2%) trees, 233 (15.8%) shrubs and 1132 (77.0%) herbs]. The altitude zone between 2000-2500 m exhibited maximum floristic diversity (815 spp; 55.4%) and the zone between 3000-3500 minimum (619 spp; 42.1%); (ii) comparative assessment of diversity patterns of forests in three altitude transects of west Himalaya, which indicates heterogeneous patterns of vegetation diversity distribution in different transects; (iii) understanding the soil properties in relation with plant diversity across the altitude gradient in each 100 m altitude belt, and (iv) vegetation assessment across second altitude transect in Tungnath area in Chamoli, Uttarakhand. The results have been presented to: (i) describe the floristic diversity and forest compositional patterns along the altitude range, (ii) make comparison of vegetation parameters of Tungnath transect with the Pindari and Bhagirathi Transects, and (iii) describe soil properties across the altitude gradient in Tungnath area.

Project Partner Name	**Affiliations**	**Role & Responsibilities**
Partner 1	GBPNIHESD, Kosi-Katarmal, Almora, Uttrakhand	To undertake plant diversity studies along altitudinal transect of Uttrakhand .

2. Project Site Details

Project Site	Tungnath and nearby area, Uttarakhand
IHR States Covered	Uttarakhand
Long. & Lat.	30°27'04.44"N to 30°28'58.30"N 79°12'41.19"E to 79°12'53.62''E
Site Maps	 **Map of study area Tungnath transect-A & C (Dist- Chamoli-Rudraprayag)**
Site Photographs	 ***A: Overview of study transect, B: Q. Semecarpifolia degraded site, C: Mixed forest stand near tree line; D: Q. semecarpifolia and Abies mixed stands; E.Oak- Pine mixed forest stands at lower end of transect, F: Tree line and alpine pastures***

3. Project Activities Chart w.r.t. Timeframe [Gantt or PERT]

Project Activities	WORK UNDERTAKEN				OUTPUT
	Year 2017-2018				
	Qtr 1	Qtr 2	Qtr 3	Qtr 4	
Project Activity 1	Field visit for the flora collection	Field visit for the Disturbance assessment	Data analysis disturbance and phyto-sociology	Herbarium preparation	1)-Data set generated regarding disturbance intensities along the altitude gradient. 2). -Document prepared for reported occurrence of floral species in west Himalayan forested high altitude area (i.e., 2000-3500 m asl) 2)-More than 200 specimen of plant species collected and herbarium prepared
Project Activity 2	Field visit for the soil sample collection transect-A	Flora collection and herbarium preparation	Soil analysis	Soil analysis Field visit of the vegetation assessment (trees) (transect-c) (2700-3200 m)	1)-Detailed analysis of soil properties (physic-chemical-pH, moisture, water holding capacity, soil organic carbon and soil organic matter) conducted for each elevation belt 2)-Quantitative data sets regarding vegetation diversity and dominance

					(Trees) were collected for 2nd altitude transect in Tungnath Area
Project Activity 3		Field visit for the assessment of fern flora		Soil sample collection(Transect-2) Disturbance intensity assessment in each elevation belt (transect-2)	1)-Quantitative data sets generated regarding the fern flora of the study site 2)-Soil samples from the transect-2 were collected for each study plots. 3). Disturbance intensity in each elevation belt were studied and all data sets were generated
Project Activity 4				Herbarium specimen preparation and vegetation assessment training	• Capacity building of 26 researchers (including 03 IHTP researchers)
.....		Finalization of Research Manual		Herbarium specimen preparation and vegetation assessment training	• Manual of Field Methods prepared in collaboration with CHEA • Capacity building of 30 researchers (including 02 IHTP researchers) in collaboration with CBCM

4. Financial and Resource Information

Note: A separate bank account is expected to be opened for NMHS Project as per the provision of Direct Beneficiary Account (DBA) as laid out by the Govt. of India and also facilitate the audit of accounts. The interest earned out of the NMHS project funds should be reported clearly in the utilization certificate.

Total Grant:		**Grant Received Date:**	

Project Partner(s)	**Affiliations/ Institution**	**Budget Allocated to**	**Work Done**
Partner 1			
Partner 2			
Partner 3			
[**Add**]			

Project Staff Information:

S. No.	**Name**	**Qualification**	**Designation**	**Fellowship/ Wages paid**	**Remarks**
1.	Sunil Joshi	M.Sc. Botany	JPF	16000/month	Continuing
2.	Renu Rawal	M.Sc. Botany	JPF	16000/month	Continuing

5. Equipment and Asset Information (As in previous Report)

S. No.	**Equipment Name (Qty)**	**Details (Make/ Model)**	**Cost**	**Date of Installation**	**Photographs of Equipment**	**Lowest Quotation, IF NOT purchased**
1.	Equipment 1				**[Attach]**	
2.	Equipment 2				**[Attach]**	
3.	Equipment 3				**[Attach]**	

6. Expenditure Statement and Utilization Certificate

Please update the annual Expenditure Statement and Utilization Certificate (UC) periodically.

Expenditure Information: UC Being sent separately

S. No.	Financial Position/Budget Head	Funds Sanctioned	Expenditure	% of Total cost
	Interest earned			
	Grand Total			

7. Project Beneficiary Groups

Beneficiary Groups [Capacity Building]	Target	Achieved
No. of Beneficiaries with income generation:	**NIL**	**Nil**
No. of stakeholders trained, particularly women:	**20 researchers**	**23 Researchers (Including 10 female)**
No. of capacity building Workshops/ trainings:	**01***	**01**
No. of Awareness & outreach programmes:	**Nil**	**Nil**
No. of Research/ Manpower developed:	**02**	**02 (Continuing)**

** In collaboration with GBPNIHESD in-house project& lead BG project*

8. Project Progress Summary (as applicable to the project): As in previous year

Description	Total (Numeric)	Description
IHR States Covered		•
Project Site/ Field Stations Developed:	**.... (attach photos)** **... (attach maps)**	•
No. of Patents filed (Description):		•

Article/ Review/ Research Paper/ Publication:		•
New Methods/ Modellings Developed (description in 250 words):		•
No. of Trainings (No. of Beneficiaries):		•
Workshop:		•
Demonstration Models (Site):	**.... (attach maps about location & photos)**	•
Livelihood Options:		•
Training Manuals:		•
Processing Units:	**.... (attach photos)**	•
Species Collection:		•
Species identified:		•
Database/ Images/ GIS Maps:		•

Note: Photos/ maps should be attached in high quality in compatible formats *viz*., JPEG, .JPG, .PNG, .SHP, etc. along with a suitable figure legend/ caption.

9. Project Linkages (with nearby Institutions/ State Agencies)

S. No.	Institute/ Organization	Type of Linkages	Brief Description
1.	Botanical Survey of India, Dehradun	Technical assistance	Herbarium consultation for identification of seasonal floristic specimens.
2.	Kumaun University Nainital, Doon University, Dehradun; G.B. Pant Univ of Agri & Tech, Pant Nagar; HNB Garhwal Univ; LSMPG College Pithoragarh, BGSB J&K	Capacity Building	Participation of researchers from these organizations was in hands on training.
3.	SS J campus Kumaun University Almora	Technical assistance	Consultation for study design and identification of lichen specimens, etc.

10. Additional (publication, recommendations, etc.)

Time Period	Publications (Research Papers, Information Material, Policy drafts, Patents, etc.)
Annual [Year .....]	**Singh SP & Rawal, RS 2017: Manual of Field Methods - Indian Himalayan Timberline Project (IHTP). CHEA Nainital.**

11. Project Concluding Remark

Kindly update the following Progress Parameters for the Reporting Period:

Project Objectives	Project Output against each objective	Progress made against Monitoring Indicators (specified in Sanction Letter)	Remarks
1. To study the plant diversity and community structure along the altitudinal gradient in the selected study site	• Identification of two transects and establishment of one long term forest study transact along altitude gradient • Data-sets on forest vegetation (density, frequency, TBA, IVI, diversity, regeneration and population structure) along altitude gradient in one transact (Transact-A). • Seasonal collection and documentation of floristic diversity (collection of herbarium specimen) • Lichen diversity assessment along	1. Baseline data-sets on vegetation compositional attributes along 2nd altitude transect generated and analyzed. These data-sets would add to the data base on vegetation science generated from first transect. (Nos - 02 transect.) 2. Systematic floristic studies initiated to generate seasonal datasets on taxonomic diversity to quantify species richness and rarity at species, generic and family levels. (Nos - 200 specimens.) 3. Following the available literature (floras), floristic diversity of 1471 plant species [106 (7.2%) trees, 233 (15.8%) shrubs and 1132 (77.0%) herbs] for high altitude forested zone of west Himalaya prepared.	rData-sets generated from 2 altitude transects would form part of envisaged vegetation diversity database (studies continuing) • This information forms the part of detailed floristic inventories (all groups, including pteridophytes, bryophytes, lichens, fungi) as part of biodiversity database. • The manual

	altitude range	4. Manual of field methods on various work components of IHTP published/printed (Nos - 01). 5. Awareness and capacity building event on Herbarium Methods and Vegetation Assessment organized for researchers of the region. (Nos - 01.)	will act as the base for undertaking studies for monitoring changes over temporal scale in IHTPR project site as well as in other areas in the Himalaya. • Such capacity building events will help in developing a cader of well trained researchers in plant diversity studies in higher Himalaya.
Methodology (in brief):	**(i) Floristic diversity inventorization** • A detailed review of published floras w.r.t. west Himalaya was conducted for occurrence of plants across life forms (tree, shrub and herbs) in high altitude forested area (i.e., 2000-3500 m). The information was further analysed for distribution of plant species in different altitude zones (2000-2500 m; 2500-3000, and 3000 - 3500 masl). • During surveys/field studies, the herbarium specimens for plant species falling within the plots/quadrates and outside the quadrates were prepared for detailed assessment of floristic diversity along altitude range. This is being done on seasonal basis. **(ii) Altitude transects & vegetation sampling** • The vegetation sampling along altitude transects followed the methodology described in IPTP Manual (Singh and Rawal 2017). • Comparative assessment of species richness distribution for presently studied altitude transect (i.e., Tungnath transect) was made with comparable altitude transect (i.e., Pindari and Bhagirathi) in the region.		

Brief Conclusion - the current year progress – during the reporting period (point-wise):	• The high altitude forested zone of west Himalaya represents 1431 plant species of which 7.2% species are trees, 15.8% shrubs and 77.0% herbs. Among life forms, a sharp decline in tree species representation with increasing altitude is apparent from 88.7% (2000-2500 m zone) to 15.1% (3000-3500 m zone). For shrubs, representation declined from 66.5 to 27.4%. The herb species representation, however, remained more or less similar (50-47.6%) across altitude zones. • Tungnath transect shows considerable difference in patterns of vegetation attributes including species distribution. Modelled distribution for density and total basal area for this transect is not accetable ($F < F_{crit}$).
Progress Achieved (%):	55% of the envisaged progress in 3 years
Remaining work to be done:	• Assessment of forest structure and regeneration patterns of communities along altitude gradient (Transect 2) • Comparison of vegetation patterns of Uttarakhand transect with Sikkim and J&K transect. • Assessing advancement of species in their altitudinal range through study of recruitment at timberline ecotone. • Authentication of vegetation diversity database (diverse life forms and taxonomic groups) based on herbarium consultation • Development of knowledge products on vegetation studies

Submitted to:
Nodal Officer, NMHS-PMU
National Mission on Himalayan Studies (NMHS)
G.B. Pant National Institute of Himalayan Environment and Sustainable Development, Kosi-Katarmal,
Almora 263643, Uttarakhand
E-mail: nmhspmu2016@gmail.com

Submitted by:
Project PI (Signature):
Institution (Seal):
Dated (dd/mm/yy):

Please fill the NMHS Progress Report pro forma as applicable with respect to time and other requirements and return *via* post/ e-mail. In case of any query, please contact at: nmhspmu2016@gmail.com

Major Research Achievements:

(i) Floristic diversity patterns

Within the investigated altitude range (i.e., 2000-3500 m) in west Himalaya a total of 1471 plant species [106 (7.2%) trees, 233 (15.8%) shrubs and 1132 (77.0%) herbs] are known to occur. The altitude zone between 2000-2500 m exhibited maximum floristic diversity (815 spp; 55.4%) and the zone between 3000-3500 minimum (619 spp; 42.1%). Among life forms, a sharp decline in tree species representation with increasing altitude is apparent from 88.7% (2000-2500 m zone) to 15.1% (3000-3500 m zone). For shrubs, representation declined from 66.5 to 27.4%. The herb species representation, however, remained more or less similar (50-47.6%) across altitude zones (Table 1).

While considering diversity distribution of higher level of taxa (i.e., genera and family), more rapid decline with altitude is apparent as compared to the species (Table 2). The species to genera ratio (S/G) for the entire landscape was calculated as 1.63 for trees, 1.97 for shrubs and 2.21 for herbs. However, across low to high altitude zone, the S/G values showed a declining pattern for trees but increasing trend for both shrubs and herbs (Table 1).

Table 1. Floristic diversity pool in high altitude forest zone (2000-3500 m) of Uttarakhand

	Trees			Shrubs			Herbs		
Altitude range (m asl.)	**Species (%)**	**Genera (%)**	**Family (%)**	**Species (%)**	**Genera (%)**	**Family (%)**	**Species (%)**	**Genera (%)**	**Family (%)**
2000-2500	93 (87.7)	61 (93.8)	35 (94.5)	155 (66.5)	97 (82.2)	44 (89.7)	567 (50)	359 (70.2)	88 (88)
	S/G 1.52			***S/G 1.60***			***S/G 1.57***		
2500-3000	45 (42.5)	32 (49.2)	21 (56.7)	108 (46.3)	69 (58.4)	35 (71.4)	529 (46.7)	296 (57.92)	75 (75)
	S/G 1.40			***S/G 1.57***			***S/G 1.79***		
3000-3500	16 (15.1)	15 (23%)	11 (29.7)	64 (27.4)	31 (26.2)	16 (32.6)	539 (47.6)	245 (47.9)	62 (62)
	S/G 1.10			***S/G 2.06***			***S/G 2.20***		
Total	106	65	37	233	118	49	1132	511	100
	S/G 1.63			***S/G 1.97***			***S/G 2.21***		

(ii) Comparison of Forest Vegetation Composition

Comparative analysis of broad range compositional attributes of Tungnath altitude transect with Pindari and Bhagirathi transects in Uttarakhand are given (Table 2). While tree density and TBA range is comparable for the studied transects, comparatively high density of shrubs and herbs is revealing for Pindari transect. Both sapling and seedling density invariably remained low. Tungnath transect has comparatively low density of recruits. Species richness distribution patterns are exhibited (Figure 1).

Table 2. Compositional attributes of forests in three altitude transects

Transect	Density Range (individual ha^{-1})					TBA Range (m^{2}ha^{-1})
	Tree	Sapling	Seedling	Shrubs (x100)	Herbs (x1000)	
Pindari	210-800	100-410	670-9500	43.5-999.0	35.2-984.0	14.8-116.9
Tungnath	110-900	00-520	20-2280	4.6-57.6	44.5-351.3	3.9-99.1
Bhagirath	540-1120	140-2200	200-12720	7.6-21.4	67.0-132.0	10.3-111.2
Overall	110-1120	000-2200	20-12720	4.6-999.0	35.2-984.0	3.9-116.9

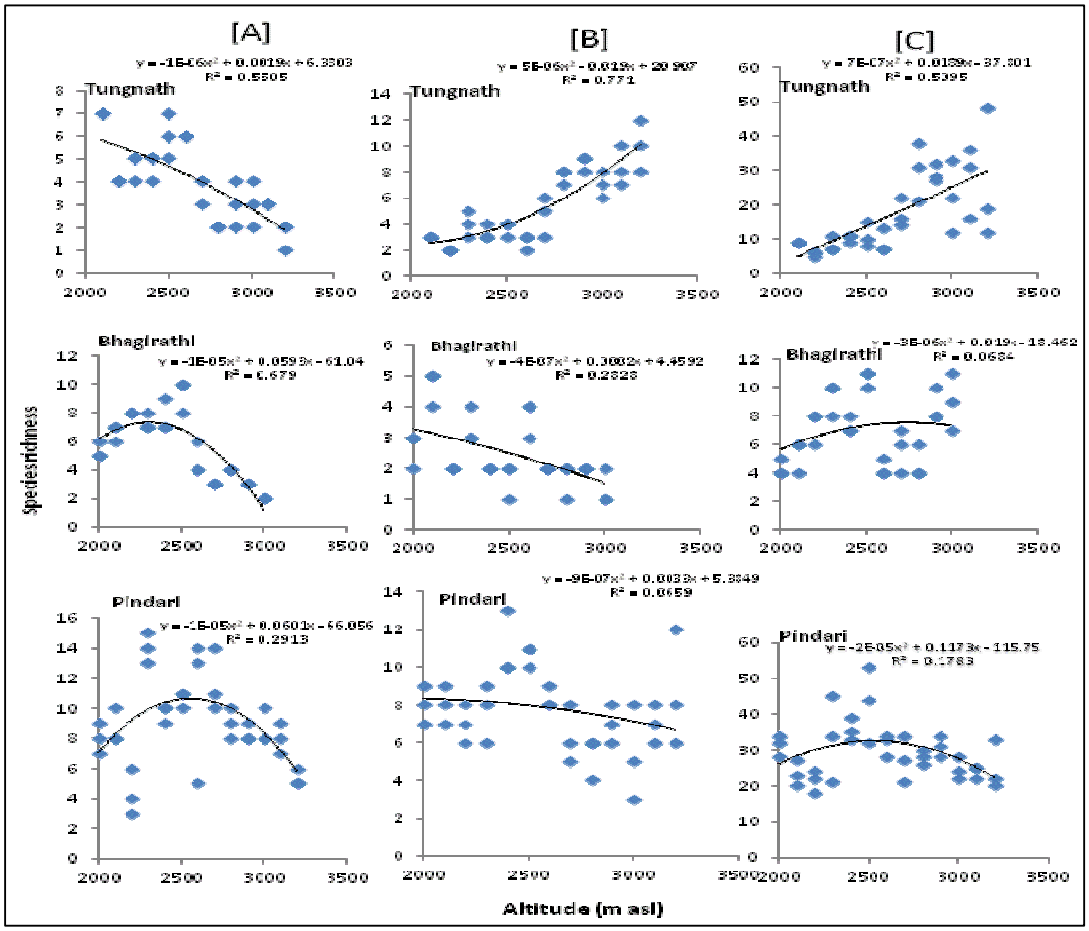


Figure 1: Species richness distribution in different life forms [A - trees, B - shrubs, C- Herbs] along altitude transects

(iii) Studies of Edaphic Features

Soil samples collected from the altitude transect were analysed for Soil moisture, pH, Water holding capacity and Organic carbon %. The results are summarized at Table 2.

Table:2. Details of analysed soil physical and chemical parameters across elevation belts.

Altitude (m)	Soil Moisture (%)		Soil pH		Water Holding Capacity (%)		Soil Org C (%)	
	(0-15)	(15-30)	(0-15)	(15-30)	(0-15)	(15-30)	(0-15)	(15-30)
2100	23.82	14.35	3.6	4.1	33.59	29.81	5.33	4.94
2200	26.68	24.95	4.7	4.2	34.22	31.66	7.8	4.94
2300	28.24	30.06	4.3	4.0	36.69	40.67	8.06	7.15
2400	30.17	29.83	4.3	3.9	37.26	36.97	6.63	4.81
2500	32.18	28.41	6.3	5.7	48.55	40.99	8.32	2.34
2600	31.83	27.93	5.1	4.8	49.65	38.01	5.85	3.51
2700	37.49	37.59	5.1	4.9	56.59	40.94	8.23	6.5
2800	37.89	40.05	5.2	5.3	54.62	42.67	8.06	5.2
2900	40.87	37.40	5.1	5.2	64.35	58.57	10.44	8.06
3000	36.63	30.37	5.3	5.5	64.87	53.16	7.28	3.9
3100	38.17	36.45	5.2	5.1	48.78	46.48	8.06	7.8
3200	36.35	33.02	5.0	5.2	51.41	34.91	6.89	7.28

(Dr. Devendra Kumar)

NMHS Progress Report
(Period *from* 1.04.2017 *to* 31.03.2018)

1. Project Information

Project ID:	1886/XII-86/2016	**Sanction Date:**	31/03/2016

Project Title:	Timberline and altitudinal gradient ecology of Himalayas and human use sustenance in warming climate
BTG:	

PI and Affiliation (Institution):	Dr. Devendra Kumar, Scientist "C", G.B. Pant National Institute of Himalayan Environment and Sustainable Development, Sikkim Regional Center, Pangthang, Gangtok 737103, Sikkim
Name & Address of the Co-PI, if any:	NA

Structured Abstract - detailing the current year progress [Word Limit 250 words]:	During the current project tenure, as per the assigned objectives, the Yuksam-Dzongri, transect located at West district of Sikkim was studied. The standard method with was used in this study and sampling was done at every 100 m steps between 3000 m and 4000 m gradients. The vegetation (herb, shrub, and tree) demonstrated a greater variation along the gradients (Fig. 1). A total of 101 species were recorded belonging to 80 genera and 46 families along with 8 unknown spp. Overall the studied area was dominated by *Rhododendron hodgsonii* (440 ind ha^{-1}) and *Abies densa* (167 ind ha^{-1}) in tree layer, and *Rubus* sp. (1452 ind ha^{-1}) and *Rosa sericea* (931 ind ha^{-1}) in shrub layer, and *Fragaria daltoniana* (17818 ind ha^{-1}) and *Polygonum runcinatum* (14697 ind ha^{-1}) in herb layer respectively. The species richness demonstrated a decreasing pattern along the gradients and peaked at 3100 m. The tree density was peaked at lower elevations (3300 m) and total basal area (TBA) peaked at middle elevation (3700m) (Fig. 2). The forest density in present study was observed significantly higher from its western Himalayan counterparts of Indian Himalayan region (IHR). The comprehensive list of all life forms is attached in Appendix 4.

Project Partner Name	Affiliations	Role & Responsibilities
Partner 1		

2. Project Site Details

Project Site	Yuksam-Dzongri transect, West Sikkim
IHR States Covered	Sikkim, Eastern Himalaya
Long. & Lat.	88˚08'58.69" E & 27˚29'04.79"N
Site Maps	Fig. 1
Site Photographs	Fig. 2

3. Project Activities Chart w.r.t. Timeframe [Gantt or PERT]

PROJECT ACTIVITIES	WORK UNDERTAKEN Year 2017-2018				Output
	Q1	Q2	Q3	Q4	
Vegetation survey					Yuksam-Dzongri transect was surveyed between 3000- 4000m (timberline)
Species Identification/ confirmation					With the help of photographs, different experts were approached for the identification of plant species (especially the herb species) and confirmation of the plant identity. A total of 23 tree species along with 22 shrub and 56 herb species were identified from the surveyed area.
Data entry and analysis					The information collected in the data sheets was entered and analysed to understand the patterns of plant diversity, community structure, and stand density along the studied elevation gradient.
Manuscript/ report preparation					Based on the study so far, a manuscript draft has been prepared for the Special issue in Tropical Ecology
Site revisit					Data from temperature/humidity loggers collected, as team work

4. Financial and Resource Information

A separate bank account is expected to be opened for NMHS Project as per the provision of Direct Beneficiary Account (DBA) as laid out by the Govt. of India and also facilitate the audit of accounts. The interest earned out of the NMHS project funds should be reported clearly in the utilization certificate.

Total Grant:	49, 24,800.00	**Grant Received Date:**	12/05/2016

Project Partner(s)	**Affiliations/ Institution**	**Budget Allocated to**	**Work Done**
Partner 1			
Partner 2			
[**Add**]			

5. Project Staff Information:

S. No.	**Name**	**Qualification**	**Designation**	**Fellowship/ Wages paid**	**Remarks**
1.	Aseesh Pandey	Ph.D. (Botany)	Research Associate	38,000.00+ 8% HRA	
2.	Sandhya Rai	M.Sc. (Forestry)	Junior Project fellow	14,000.00+ 10% HRA	

6. Equipment and Asset Information

S. No.	**Equipment Name (Qty)**	**Details (Make/ Model)**	**Cost**	**Date of Installation**	**Photographs of Equipment**	**Lowest Quotation, IF NOT purchased**
1.	GPS	(Garmin/ Oregon 650)	44426.00	4/11/2016	Fig. 3	NA
2.	GPS	(Garmin/GPSMAP 64s)	33205.00	4/11/2016	Fig. 4	NA

7. Expenditure Statement and Utilization Certificate

Please update the annual Expenditure Statement and Utilization Certificate (UC) periodically.

Expenditure Information*:

S. No.	Financial Position/Budget Head	Funds Sanctioned 2017-2018			Expenditure	% of Total cost
		Amount Carry Forwarded	Grant Sanctioned	Total fund available		
I	Salaries/Manpower cost	283375.00	712800.00	996175.00	707698.00	**71.04**
II	Travel	40316.00	300000.00	340316.00	93862.00	**27.58**
III	Expendables & Consumables	161634.00	250000.00	411634.00	21490.00	**5.22**
IV	Contingencies	48711.00	120000.00	168711.00	17577.00	**10.42**
V	Activities & Other Project cost	179664.00	400000.00	579664.00	35910.90	**6.20**
VI	Institutional Charges					
VII	Equipments					
	Total	**713700.00**	**1782800.00**	**2496500.00**	**713700.00**	**35.11**
	Interest earned			**11899.00**		
	Grand Total			**2508399.00**		

- **To be verified and certified by the institute headquarters at Kosi by the Finance Officer, separately**

Period	Expenditure Statement	Utilization Certificate (UC)
Annual	[**Appendix 1**]	[**Appendix 2**]

7. Project benefciary group:

Beneficiary Groups [Capacity Building]	Target	Achieved
No. of Beneficiaries with income generation:	**NA**	
No. of stakeholders trained, particularly women:	**NA**	
No. of capacity building Workshops/ trainings:	**NA**	
No. of Awareness & outreach programmes:	**NA**	
No. of Research/ Manpower developed:	**-**	RA (01) and JPF (01)

8. Project Progress Summary (as applicable to the project):

Description	Total (Numeric)	Description
IHR States Covered	**1**	**Eastern Himalaya (Sikkim)**
Project Site/ Field Stations Developed:	**1**	**Yuksam-Dzongri transect**
No. of Patents filed (Description):	**NA**	**NA**
Article/ Review/ Research Paper/ Publication:	**01**	**Under review (2)** **Under process (1)**
New Methods/ Modellings Developed (description in 250 words):		
No. of Trainings (No. of Beneficiaries):		
Workshop:	**02**	**Details provided in publication details**
Demonstration Models (Site):		
Livelihood Options:		
Training Manuals:		
Processing Units:		
Species Collection:	**52**	**Herbarium (under process)**
Species identified:	**101**	**Herb:56 Shrub:22 Tree:23** (list provided in appendix 4)
Database/ Images/ GIS Maps:	**1**	**A check list of identified transect with spatial database of species distribution (under process)**

Note: Photos/ maps should be attached in high quality in compatible formats *viz*., JPEG, .JPG, .PNG, .SHP, etc. along with a suitable figure legend/ caption.

9. Project Linkages (with nearby Institutions/ State Agencies)

S. No.	Institute/ Organization	Type of Linkages	Brief Description
1	Forest Environment and Wildlife Management Department, Govt of Sikkim	Cooperation and collaboration	Permission for work in Khangchendzonga National Park

10. Additional (publication, recommendations, etc.)

Time Period	Publications (Research Papers, Information Material, Policy drafts, Patents, etc.)
Annual [Year 2017-18]	**Abstracts** **1.** Pandey A, Rai S, Singh M, Kumar D. 2017. "Lichens: Indicator of Climate Change in Himalayan Region" in National Conference on *Current Development and Next Generation Lichenology*. pp.59. **2.** Pandey A. and Kumar D. 2018. "Assessment of Vegetation Patterns and Community Structure along the Elevation Gradient in the Sikkim, Eastern Himalaya, India" in 2nd International workshop on biodiversity and climate change, IIT Kharagpur. **Research papers** **3.** Rai, S., Pandey, A. and Badola, H.K. 2017. Biomass and Carbon Stock Estimation across the Timberline of Khangchendzonga National Park, Eastern Himalaya, India. *Taiwania* (In review) **4.** Pandey, A., Rai, S., Badola, H.K and Singh, S.P.2017. Timberlines structure and woody taxa regeneration towards tree lines along latitudes in Khangchendzonga National Park, Eastern Himalaya. *PLOS One* (In review) **5.** Pandey, A., Rai, S. and Kumar, D. (2018). Trends of vegetation structure, composition, and distribution patterns along the elevation gradient in Sikkim, East Himalaya. *Tropical Ecology* (Under process)

11. Project Concluding Remark

Kindly update the following Progress Parameters for the Reporting Period:

Project Objectives	Project Output against each objective	Progress made against Monitoring Indicators (specified in Sanction Letter)	Remarks
3.	• Vegetation assessment across the vertical transect along the timberline of study area has been done. • Considering the diverse physio- geography of Sikkim Himalaya, a modified methodology was used to assess the vegetation along the timberline.	• Identification of potential Lichen species, along the elevation gradient, as climate change indicator is under process	Field visits are scheduled for next quarters to fulfil remaining project activities

	• The subalpine conifer forest across the identified transect was surveyed using quadrat method and sampling was done at every 100 m steps between 3000 m and 4000 m gradients. • A total of 109 species were recorded (identified spp. 101) belonging to 80 genera and 46 families. The species richness demonstrated a decreasing pattern along the gradients and peaked at 3100 m; corresponding to transition zones between temperate-subalpine forests.		

Methodology (in brief):	Appendix 3
Major Research Achievements:	Assessment of patterns of forest structure, composition, and species richness along an elevation gradient in subalpine conifer forest of identified Yuksam-Dzongri transect
Brief Conclusion - the current year progress – during the reporting period (point-wise):	• Vertical transect (3000-4000 m) studied by laying a total of 33 (50 x 20 m) plots. • Among the angiosperms the highest tree density was recorded for *Rhododendron hodgsoni* (440 ind ha^{-1}), however, in gymnosperms it was recorded maximum for *Abies densa* (167 ind ha^{-1}). • In shrub species the highest density was recorded for *Rubus sp.* (1452 ind ha^{-1}). However, *Mahonia napaulensis, Rhododendron camelliiflorum* and *Viburnum cotinifolium* shared the minimum density (5 ind ha^{-1}) each. • In herb layer the maximum density value was recorded for
	Fragaria daltoniana (17818 ind ha^{-1}) • In shrub and tree layer Ericaceae emerged as the most dominant family however, Compositae dominated the herbaceous layer in terms of number of species. • The forest density in studied transect of in eastern Himalaya was observed significantly higher from its western Himalayan.
Progress Achieved (%):	45% of the entire project
Remaining work to be done:	Lower elevations of the vertical transect across the study site (Yuksam-Dzongri transect) needs to be completed

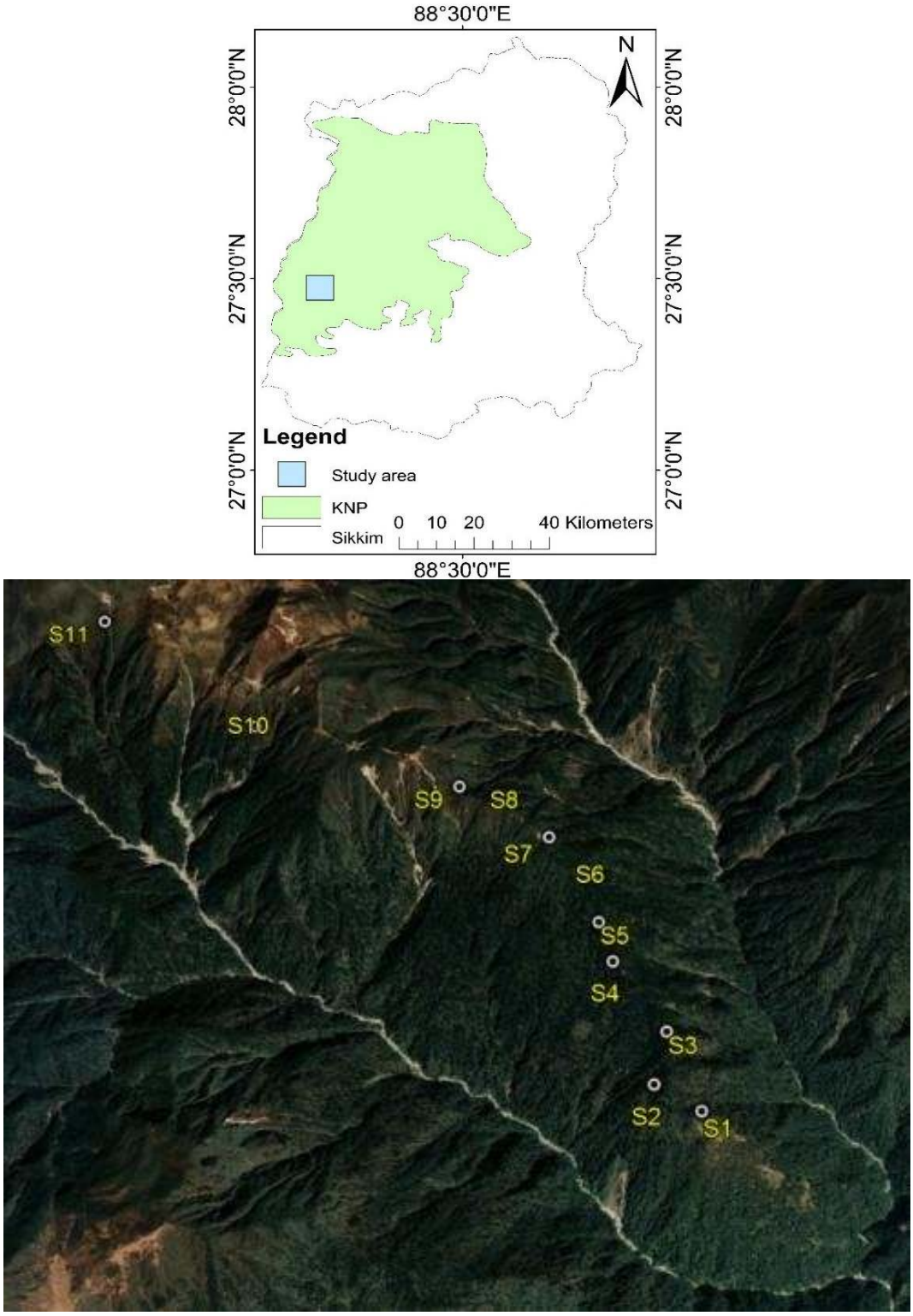


Figure 1. Study area map of subalpine conifer forest in Khangchendzonga National Park

Figure 2. Site Photographs pertaining different forest stands across Yuksam-Dzongri transect West Sikkim

Figure 3. Instrument 1; GPS (Garmin, Oregon 650)

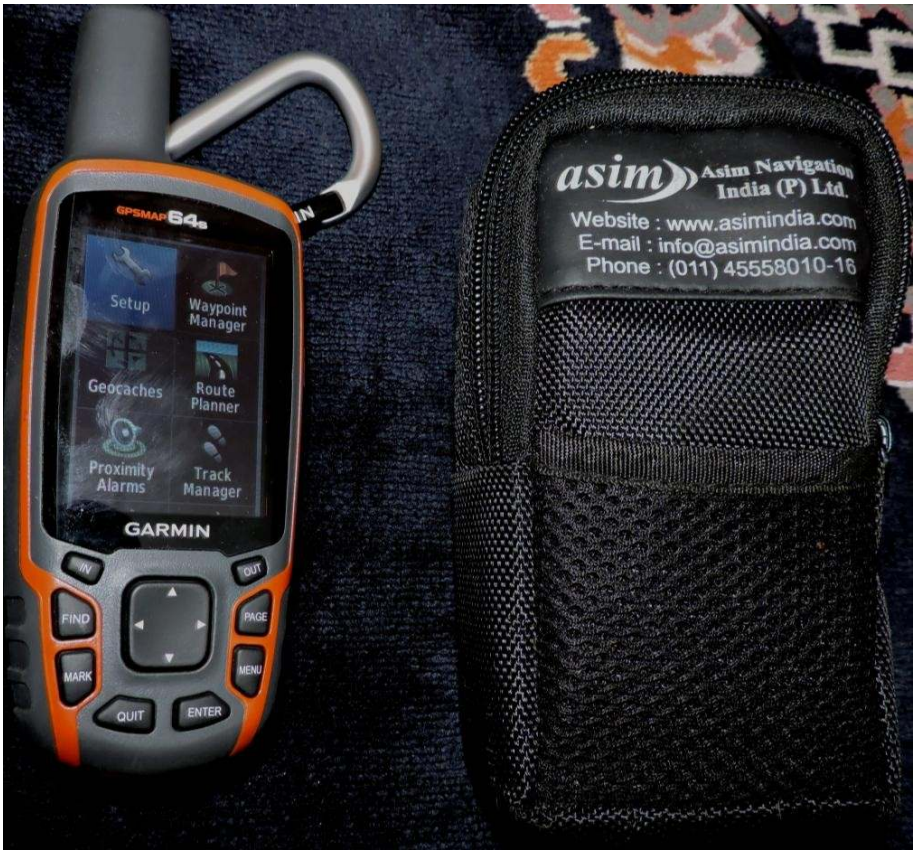


Figure 4. Instrument 2; GPS (Garmin, GPSMAP 64s)

Appendix 3

Methodology (in brief):

Three 0.1ha plots (dimensions: 50m × 20 m) were sampled in each 100m elevation difference across the subalpine forests (3000-4000 m) of KNP, West Sikkim. In each 0.1ha plot, five 10m × 10 m quadrats were laid randomly for enumerating trees and saplings; each 10m×10m quadrat was further subdivided into one 5m×5m sub-quadrat for enumerating shrub species/saplings, and two random 1m×1m sub-quadrats for seedlings/herbs respectively. All individuals present within the quadrats/sub- quadrats were enumerated. Woody stems were measured for size and the circumference at breast height (CBH, *i.e.* 1.37 m above the tree base) was measured for the determination of tree basal area, and in case of small-saplings and seedlings, it was taken at collar height and finally calculated as πr^2 (where r is the radius). Woody stems having ≥ 30cm CBH were considered as trees; individuals with 10.0 to 30 cm CBH as saplings; and those with CBH less than 10.0cm were considered as seedlings.

Appendix 4

Table: List of the species enumerated during the study in different layers

Sl.No.	Tree species	Family
1.	*Abies densa* Griff.	Pinaceae
2.	*Acer caudatum* Wall.	Sapindaceae
3.	*Betula alnoides* Buch.-Ham. ex D.Don	Betulaceae
4.	*Betula utilis* D.Don	Betulaceae
5.	*Litsea sericea* (Wall. ex Nees) Hook. f.	Lauraceae
6.	*Lyonia villosa* (Wall. ex C.B. Clarke) Hand.-Mazz.	Ericaceae
7.	*Magnolia campbelli* Hook.f. & Thomson	Magnoliaceae
8.	*Prunus bracteopadus* Koehne	Rosaceae
9.	*Prunus rufa* Wall. exHook.f.	Rosaceae
10.	*Rhododendron arboreum* Sm.	Ericaceae
11.	*Rhododendron barbatum* Wall.ex G.	Ericaceae
12.	*Rhododendron decipiens* Lacaita	Ericaceae
13.	*Rhododendron falconeri* Hook.f.	Ericaceae
14.	*Rhododendron fulgens* Hook.f.	Ericaceae
15.	*Rhododendron hodgsonii* Hook.f.	Ericaceae
16.	*Rhododendron lanatum* Hook.f.	Ericaceae
17.	*Rhododendron thomsonii* Hook.f.	Ericaceae
18.	*Rhododendron wightii* Hook.f.	Ericaceae
19.	*Sorbus microphylla* (Wall. ex Hook.f.) Wenz.	Rosaceae
20.	*Symplocos dryophila* C.B. Clarke	Symplocaceae
21.	*Tsuga dumosa* (D.Don) Eichler	Pinaceae
22.	*Viburnum nervosum* D. Don	Adoxaceae
23.	*Vitex quinata* (Lour.) F.N.Williams	Lamiaceae
	Shrub species	**Family**
24.	*Agapetes serpens* (Wight) Sleumer	Ericaceae
25.	*Berberis wallichiana* DC.	Berberidaceae
26.	*Clematis montana* Buch.-Ham. ex DC.	Ranunculaceae
27.	*Cotoneaster microphyllus* Wall. ex Lindl.	Rosaceae
28.	*Daphne papyracea* Wall. ex G. Don	Thymelaeaceae
29.	*Eurya* sp.	Pentaphylacaceae
30.	*Gaultheria pyroloides* Hook.f. & Thomson ex Miq.	Ericaceae
31.	*Gaultheria trichophylla* Royle	Ericaceae
32.	*Juniperus recurva* Buch.-Ham. ex D.Don	Cupressaceae
33.	*Mahonia napaulensis* DC.	Berberidaceae
34.	*Rhododendron anthopogon* D. Don	Ericaceae
35.	*Rhododendron camelliiflorum* Hook. f.	Ericaceae
36.	*Rhododendron campanulatum* D. Don	Ericaceae
37.	*Rhododendron campylocarpum* Hook. f.	Ericaceae
38.	*Rhododendron pendulum* Hook. f.	Ericaceae
39.	*Ribes glaciale* Wall.	Grossulariaceae
40.	*Rosa sericea* Wall. ex Lindl.	Rosaceae
41.	*Rubia* sp.	Rubiaceae

42.	*Rubus* sp.	Rosaceae
43.	*Vaccinium nummularia* Hook. f. & Thomson ex C.B. Clarke	Ericaceae
44.	*Viburnum cotinifolium* D. Don	Adoxaceae
45.	*Zanthoxylum nepalense* Babu	Rutaceae
	Herb species	**Family**
46.	*Ainsliaea latifolia* (D. Don) Sch. Bip.	Compositae
47.	*Anaphalis adnata* Wall. ex DC.	Compositae
48.	*Anaphalis busua* (Buch.-Ham.) DC.	Compositae
49.	*Anaphalis triplinervis* (Sims) Sims ex C.B.Clarke	Compositae
50.	*Androsace hookeriana* Klatt	Primulaceae
51.	*Arabis* sp.	Brassicaceae
52.	*Arisaema griffithii* Schott	Araceae
53.	*Bergenia stracheyi* (Hook.f. & Thomson) Engl.	Saxifragaceae
54.	*Bistorta vacciniifolia* (Wall. ex Meisn.) Greene	Polygonaceae
55.	*Capsella bursa-pastoris* (L.) Medik.	Brassicaceae
56.	*Carax* sp.	Cyperaceae
57.	*Clematis* sp.	Ranunculaceae
58.	*Clintonia udensis* Trautv. &C.A.Mey.	Liliaceae
59.	*Corydalis casimiriana* Duthie&Prain ex Prain	Papaveraceae
60.	*Cynoglossum glochidiatum*	Boraginaceae
61.	*Elatostema obtusum* Wedd.	Urticaceae
62.	*Fragaria daltoniana* J.Gay	Rosaceae
63.	*Gentiana phyllocalyx* C.B.Clarke	Gentianaceae
64.	*Geranium* sp.	Geraniaceae
65.	*Geranium wallichianum* D.Don ex Sweet	Geraniaceae
66.	*Hemiphragma heterophyllum* Wall.	Plantaginaceae
67.	*Heracleum nepalense* D. Don	Apiaceae
68.	*Hidra* sp.	Araliaceae
69.	*Holboellia latifolia* Wall.	Berberidaceae
70.	*Hypericum hookerianum* Wight &Arn.	Hypericaceae
71.	*Impatiens sulcata* Wall.	Balsaminaceae
72.	*Ipomea* sp.	Convolvulaceae
73.	*Kobresia curticeps* (C.B.Clarke) Kük.	Cyperaceae
74.	*Maianthemum oleraceum* (Baker) LaFrankie	Asparagaceae
75.	*Neopicrorhiza scrophulariiflora* (Pennell) D.Y.Hong	Plantaginaceae
76.	*Nepeta* sp.	Lamiaceae
77.	*Panax pseudoginseng* Wall.	Araliacea
78.	*Paris polyphylla* Sm.	Melanthiaceae
79.	*Pedicularis* sp.	Orobanchaceae
80.	*Picris* sp.	Compositae
81.	*Plantago*sp.	Plantaginaceae
82.	*Poa* sp.	Poaceae
83.	*Polygonum emodi* Meisn.	Polygonaceae
84.	*Polygonum molle* D. Don	Polygonaceae
85.	*Polygonum runcinatum* Buch.-Ham. ex D. Don	Polygonaceae

86.	*Potentilla* sp.	Rosaceae
87.	*Potentilla* sp.	Rosaceae
88.	*Potentilla microphylla* D.Don	Rosaceae
89.	*Primula atrodentata*W.W. Sm.	Primulaceae
90.	*Primula calderiana* Balf. f. & R.E. Cooper	Primulaceae
91.	*Primula denticulata* Sm.	Primulaceae
92.	*Primula glomerata* Pax	Primulaceae
93.	*Senesio* sp.	Compositae
94.	*Stellaria* sp.	Caryophyllaceae
95.	*Taraxacum campylodes* G.E.Haglund	Compositae
96.	*Thalictrum virgatum* Hook. f. & Thomson	Ranunculaceae
97.	*Thamnocalamus* sp.	Poaceae
98.	*Thamnocalamus spathiflorus* (Trin.) Munro	Poaceae
99.	*Valeriana* sp.	Caprifoliaceae
100.	*Viola biflora*	Violaceae
101.	*Xanthium strumarium* L.	Polygonaceae
102.	Unknown 1	Rosaceae
103.	Unknown 2	-
104.	Unknown 3	-
105.	Unknown 4	-
106.	Unknown 5	-
107.	Unknown 6	-
108.	Unknown 7	-
109.	Unknown 8	-

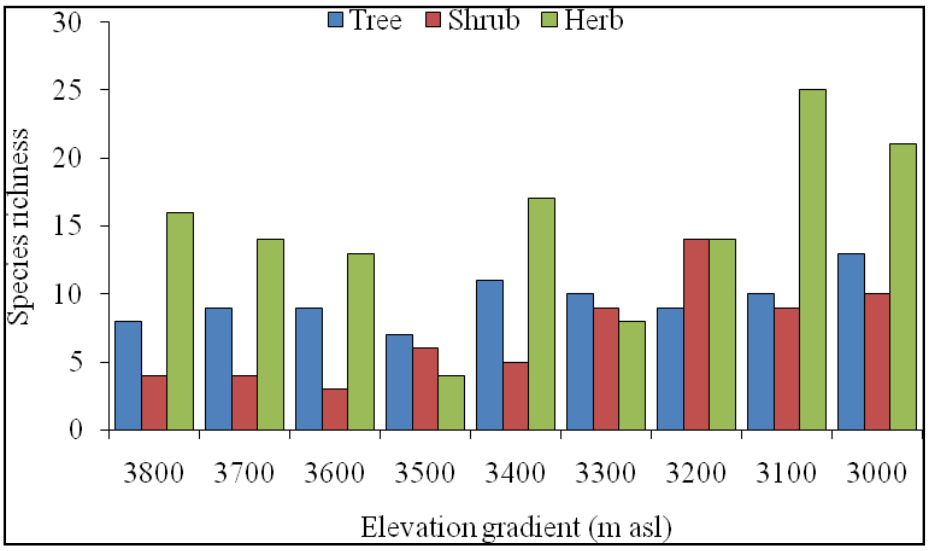


Figure 1. Species richness trends along elevation gradient in Eastern Himalaya

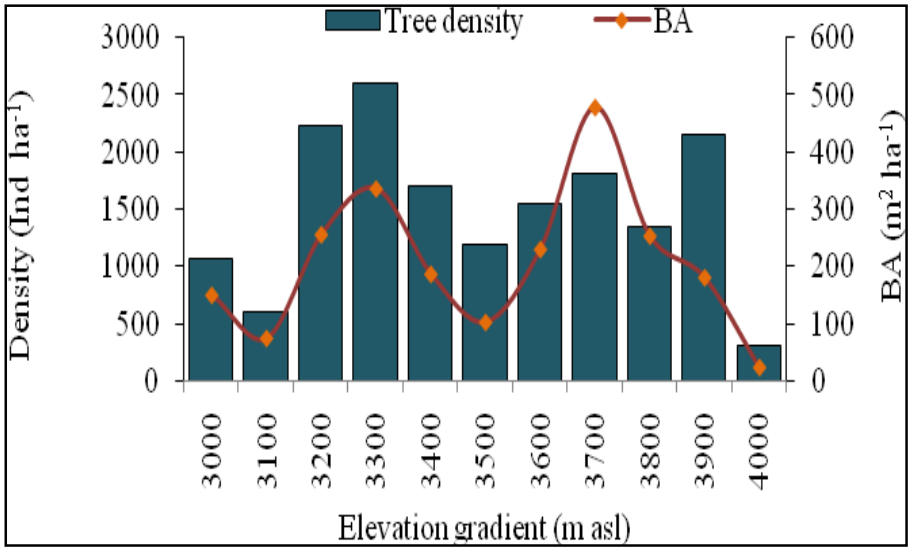


Figure 2. Trends of tree species density and basal area along the elevation gradient in Eastern Himalaya

(Dr. G.C.S. Negi)

NMHS Progress Report
(Period from April 2017 to March 2018)

1. Project Information

Project ID:	NMHS/LG-2016/009	**Sanction Date:**	31-03-2016
Project Title:	Timberline and Altitudinal Gradient Ecology of Himalayas, and Human Use Sustenance in a Warming Climate		
BTG:	To understand timberline tree phenological responses, nutrient conservation strategies, tree-water relations, seed ecology and regeneration in response to warming climate		

PI and Affiliation (Institution):	Dr. G.C.S. Negi, Scientist F, GBPNIHESD, Kosi - Katarmal, Almora
Name & Address of the Co-PI, if any:	NA
Structured Abstract - detailing the current year progress [Word Limit 250 words]:	In Chopta-Tungnath timberline ecotone (altitude, 2955-3700 masl) timing of major phenophases, leaf growth and leaf nitrogen dynamics were studied in five timberline tree species (viz., *Abies spectabilis, Betula utilis, Quercus semecarpifolia, Rhododendron arboreum* and *R. campanulatum*) (Plate 1-4). In addition micro-climatic data and soil physico-chemical analysis was undertaken. The atmospheric temperature and soil temperature were positively correlated (Fig. 1). The peak relative humidity was recorded in August and the peak soil moisture in July. Tungnath is characterized by a markedly higher mean growing season temperature than the climatic treelines of the world (11.2^{o}C vs. 6.7^{o}C) and mean soil temperatures (6.4 ^{o}C at 10 cm depth vs. 9.8^{o}C at 30 cm depth at Tungnath). Leaf area (cm^{2}leaf^{-1}) at mature leaf stage ranged from 0.29 cm^{2} (*A. spectabilis*; a conifer) to 64.8 cm^{2} (*R. campanulatum*). Similarly, at the mature leaf stage the leaf dry weight (g leaf^{-1}) was measured lowest

	for *A. spectabilis* (0.008 g) and highest for *R. campanulatum* (1.37 g), and the leaf mass loss ranged from 25.3% (*R. arboreum*) to 42.0% (*B. utilis*). Leaf N concentration gradually declines from leafing in May to mature leaf stage that varied from 1.53% (*R. campanulatum*) to 1.89% (*Q. semecarpifolia*) (Fig. 2). N mass resorption efficiency at the stage of leaf senescence was computed ranging from 34% in *A. spectabilis* to 63% in *R. arboreum*. Soil organic carbon across the forests was found minimum (4.3%) in *R. campanulatum* and maximum (7.4%) in *A. spectabilis*. The soil C:N ratio was recorded ranging from 9.8 (*R. campanulatum*) to 14.6 (*B. utilis*). Both soil organic C (r = 0.223) and N (r= 0.301) decreased with increasing altitude of the five forests and the was reverse true for C:N ratio. The treeline species were characterized by short growing period (2-4 months), lower period of steady-state in peak leaf mass and rapid leaf mass loss, low nitrogen concentration in leaves (1.7% vs. 2.5%), slow shoot growth, lower shoot length (5.6 cm vs. 9.5 cm) and shoot growth period, and higher leaf density in shoots (1.2 vs. 0.8 leaves/cm shoot length) than the mid-altitude forest trees. It is expected that with the increasing rate of warming in Tungnath the phenological behaviour of treeline species would change markedly in future leading to changes in ecosystem properties. The expansion rate of *R. campanulatum* population (seedlings and saplings) was found 1.4 m/yr (Plate 5).

Project Partner Name	Affiliations	Role & Responsibilities
Partner 1	NA	

2. Project Site Details

Project Site	Chopta-Tungnath
IHR States Covered	Uttrakhand
Long. & Lat.	30°27'04.44"N to 30°28'58.30"N 79°12'41.19"E to 79°12'53.62''E
Site Maps	NA
Site Photographs	  Plate 1: Overview of study site Plate 2: Measuring soil temperature   Plate 3-4: Trees of *A. spectabilis* and *B. utilis* numbered for phenological study

3. Project Activities Chart w.r.t. Timeframe [Gantt or PERT]

Project Activities	WORK UNDERTAKEN				OUTPUT
	Year- 2017- 2018				
	Qtr 1	Qtr 2	Qtr 3	Qtr 4	
Project Activity 1	Marking of trees of selected species for phenological studies			-	Established stands and marked 100 mature individuals of tree species (viz., *Abies spectabilis, Betula utilis, Quercus semecarpifolia, Rhododendron arboreum* and *R. campanulatum*)

					for detailed studies (Fig. 1).
Project Activity 2	Micro-climatic data collection under the stands of each of the five tree species	Micro-climatic data collection under the stands of each of the five tree species	Micro-climatic data collection under the stands of each of the five tree species	Micro-climatic data collection under the stands of each of the five tree species	Data (May 2017- December 2017) of atm. temp., atm. humidity, soil moisture and soil temp. collected (Fig. 2). A markedly high growing season temperature than the climatic treelines of the world (11.2 ^{o}C vs. 6.7^{o}C) and mean soil temperatures (9.8^{o}C at 30 cm depth) was reported.
Project Activity 3	Data collection on tree phenophases and leaf characters of selected species	Data collection on tree phenophases and leaf characters of selected species	Data collection on tree phenophases and leaf characters of selected species	Data collection on tree phenophases and leaf characters of selected species	A pheno-calendar of the five selected tree species was prepared and data on leaf area, leaf mass, leaf number per shoot of these species from May 2017-December 2017 was collected (Fig. 3).
Project Activity 4	Collection of tree leaves for nitrogen analysis	Collection of tree leaves for nitrogen analysis	Collection of tree leaves for nitrogen analysis	Collection of tree leaves for nitrogen analysis	Dataset on N concentration (mature and senescent leaf) and N-retranslocation of the five tree species calculated (Fig. 4).

Project Activity 5	Collection of soil for physico-chemical characteristics	Collection of soil for physico-chemical characteristics	Collection of soil for physico-chemical characteristics	Collection of soil for physico-chemical characteristics	Dataset on soil organic carbon and nitrogen of the five forest sites was generated.
Project Activity 6	-	Data collection on recruitment rate of seedlings of *R. campanulatum* and expansion of its population.	Data collection on recruitment rate of seedlings of *R. campanulatum* and expansion of its population.	-	Data synthesis revealed that the population of *R. campanulatum* is expanding @ 1.4 m/yr. which is comparable to other reports from this region.
Project Activity 7	Data compilation and syntheses	Data compilation and syntheses	Data compilation and syntheses	Data compilation and syntheses	Half Yearly Report prepared. Data was also presented in the Review Workshop at INSA, New Delhi. Two papers are communicated to Tropical Ecology Journal.

4. Financial and Resource Information

Note: A separate bank account is expected to be opened for NMHS Project as per the provision of Direct Beneficiary Account (DBA) as laid out by the Govt. of India and also facilitate the audit of accounts. The interest earned out of the NMHS project funds should be reported clearly in the utilization certificate.

Total Grant:	12,16,200.00	Grant Received Date:	April 2017

Project Partner(s)	Affiliations/ Institution	Budget Allocated to	Work Done
Partner 1	NA	NA	NA

Project Staff Information:

S. No.	Name	Qualification	Designation	Fellowship/ Wages paid	Remarks
1.	Pradeep Singh	M.Sc. Forestry	SPF	18000 + 10% HRA	Joined project on 3 May 2017

5. Equipment and Asset Information

S. No	Equipment Name (Qty)	Details (Make/ Model)	Cost	Date of Installation	Photographs of Equipment	Lowest Quotation, IF NOT purchased
1.	Portable Leaf Area Meter	Biovis Co.	Rs. 99,000	28.3.2018		-

6. Expenditure Statement and Utilization Certificate

Please update the annual Expenditure Statement and Utilization Certificate (UC) periodically.

Expenditure Information:

S. No.	Financial Position/Budget Head	Funds Sanctioned	Expenditure	% of Total cost
I	Salaries/Manpower cost	2,11,200.00	Will be sent soon	
II	Travel	2,50,000.00		
III	Expendables &Consumables	2,00,000.00		
IV	Contingencies	1,55,000.00		
V	Activities & Other Project cost	2,00,000.00		
VI	Institutional Charges	00		
VII	Equipments	2,00,000.00		
	Total	12,16,200.00		
	Interest earned			
	Grand Total			

Period	Expenditure Statement	Utilization Certificate (UC)
Annual (2016-17)	[Attach] To be sent soon	[Attach] To be sent soon

7. Project Beneficiary Groups

Beneficiary Groups [Capacity Building]	Target	Achieved
No. of Beneficiaries with income generation:	NA	NA
No. of stakeholders trained, particularly women:	NA	NA
No. of capacity building Workshops/ trainings:	NA	NA
No. of Awareness & outreach programmes:	NA	NA
No. of Research/ Manpower developed:	**One**	**One**

8. Project Progress Summary (as applicable to the project)

Description	Total (Numeric)	Description
IHR States Covered	*1*	• *Chopta-Tungnath timberline forests in Uttarakhand*
Project Site/ Field Stations Developed:	.... (attach photos) ... (attach maps)	• NA
No. of Patents filed (Description):	NA	• NA
Article/ Review/ Research Paper/ Publication:	*Two papers communicated to Tropical Ecology (special volume on Himalayan timberline)*	1. Treeline species phenology: shoot growth, leaf characteristics and nutrient dynamics 2. Expansion of *Rhododendron campanulatum* krummholz in the treeline ecotone in Tungnath, Garhwal Himalaya
New Methods/ Modellings Developed (description in 250 words):	NA	• NA
No. of Trainings (No. of Beneficiaries):	*NA*	• NA

Workshop:	*1 (No. of beneficiaries 30)*	• *A training workshop was organized in collaboration with CHEA, Nainital on the CC impact on timberline vegetation in a village in the vicinity of Tungnath (project field site) (Plate 6)*
Demonstration Models (Site):	.... (attach maps about location & photos)	• NA
Livelihood Options:	NA	• NA
Training Manuals:	*One Chapter in a Manual*	• *Negi, G.C.S. 2017. Tree phenological responses and nutrient conservation strategies at timberline. In: S.P. Singh & R.S. Rawal, 2017. Manual of Field Methods (Indian Himalayan Timberline Project), CHEA, Nainital. pp. 39-49.*
Processing Units:	NA.... (attach photos)	NA
Species Collection:	NA	NA
Species identified:	NA	NA
Database/ Images/ GIS Maps:	NA	NA

Note: Photos/ maps should be attached in high quality in compatible formats *viz*., JPEG, .JPG, .PNG, .SHP, etc. along with a suitable figure legend/ caption.

9. Project Linkages (with nearby Institutions/ State Agencies)

S. No.	Institute/ Organization	Type of Linkages	Brief Description
	NA	**NA**	**NA**

10. Additional (publication, recommendations, etc.)

Time Period	Publications (Research Papers, Information Material, Policy drafts, Patents, etc.)
Annual [2017-18]	Two papers entitled, (1. Treeline species phenology: shoot growth, leaf characteristics and nutrient dynamics) and (2. Expansion of *Rhododendron campanulatum* krummholz in the treeline ecotone in Tungnath, Garhwal Himalaya) based on the research work under the project were developed and submitted to Tropical Ecology Journal- Special Issue on Timberline.

11. Project Concluding Remark

Kindly update the following Progress Parameters for the Reporting Period:

Project Objectives	Project Output against each objective	Progress made against Monitoring Indicators (specified in Sanction Letter)	Remarks
To understand tree phenological responses, nutrient conservation strategies and tree-water relations in response to warming climate	• Data-set on micro-climate, phenology of leafing, flowering, leaf population dynamics, leaf life span, shoot growth of major timberline trees species of Chopta-Tungnath (Uttarakhand) from May 2017 - December 2017. • Data set on leaf and soil nitrogen dynamics and soil organic carbon of the above five forests.	• Data-set generated as proposed in the project activity and data was synthesized and two papers were communicated to Tropical Ecology Journal.	Data on these parameters will be collected again in 2018-19 to see the annual changes in relation to climate change.

Methodology (in brief):	Mirco-climatic data (atmospheric temperature, relative humidity and soil temperature) were recorded on each sampling visits using standard equipments (Pocket Weather Meter; Make- Kestrel 4000 NV) under the mature stands of forests of the five tree species. Phenological observations were made using a binocular at periodical intervals (May 2017-December 2017) on 100 marked mature trees of *A. spectabilis, B. utilis, Q. semecarpifolia, R. arboreum* and *R. campanulatum*. Leaf characters (leaf area and leaf dry mass was based on 100 randomly plucked current year leaves) was determined using a Leaf Area Meter (Make: Biovis Leaf Av) and oven drying leaves at 60^{o}C till constant weight. Total nitrogen concentration in leaves and soil, and soil organic carbon was determined at monthly interval in the laboratory using CHNS Analyzer (Make: Elementar Co).
Major Research Achievements:	Detailed data for two years (2016-17 and 2017-18) on micro-climatic parameters on five different forest types, changes in leaf area, leaf mass, leaf N concentration, leaf number per shoot, and leaf N retranslocation collected under the project are first of its kind from the timberline of this region. *R. arboreum* were characterized by a large amount of N resorption efficiency (63%) as a measure to cope up with the poor soil N status.
Brief Conclusion - the current year progress – during the	(i) The timberline species are characterized by a delayed bud-break and leafing, a slow leaf expansion, a short steady-state period in leaf mass, lower shoot growth, higher leaf density per

reporting period (point-wise):	shoot and lower leaf N concentration compared to the mid-altitude forest tree species of the western Himalayan region; (ii) Timberline of our study site is characterized by a longer growing season owing to markedly higher mean growing season temperature than the climatic treelines of the world (11.2 ^{o}C vs. 6.7 ^{o}C). Treeline ecotone vegetation of western Himalayan region may face several eco-physiological implications with the ongoing pace of global warming.
Progress Achieved (%):	90%
Remaining work to be done:	All the work elements described in this APR will be repeated in 2018-19.

Submitted to:
Nodal Officer, NMHS-PMU
National Mission on Himalayan Studies (NMHS)
G.B. Pant National Institute of Himalayan Environment and Sustainable Development, Kosi-Katarmal,
Almora 263643, Uttarakhand
E-mail: nmhspmu2016@gmail.com

Submitted by:
Project PI (Signature):
Institution (Seal):
Dated (dd/mm/yy):

Please fill the NMHS Progress Report pro forma as applicable with respect to time and other requirements and return *via* post/ e-mail. In case of any query, please contact at: nmhspmu2016@gmail.com

Fig. 1: Mean values of micro-climatic data observed at Tungnath forest sites (ST= Soil temperature; AT= Air temperature).

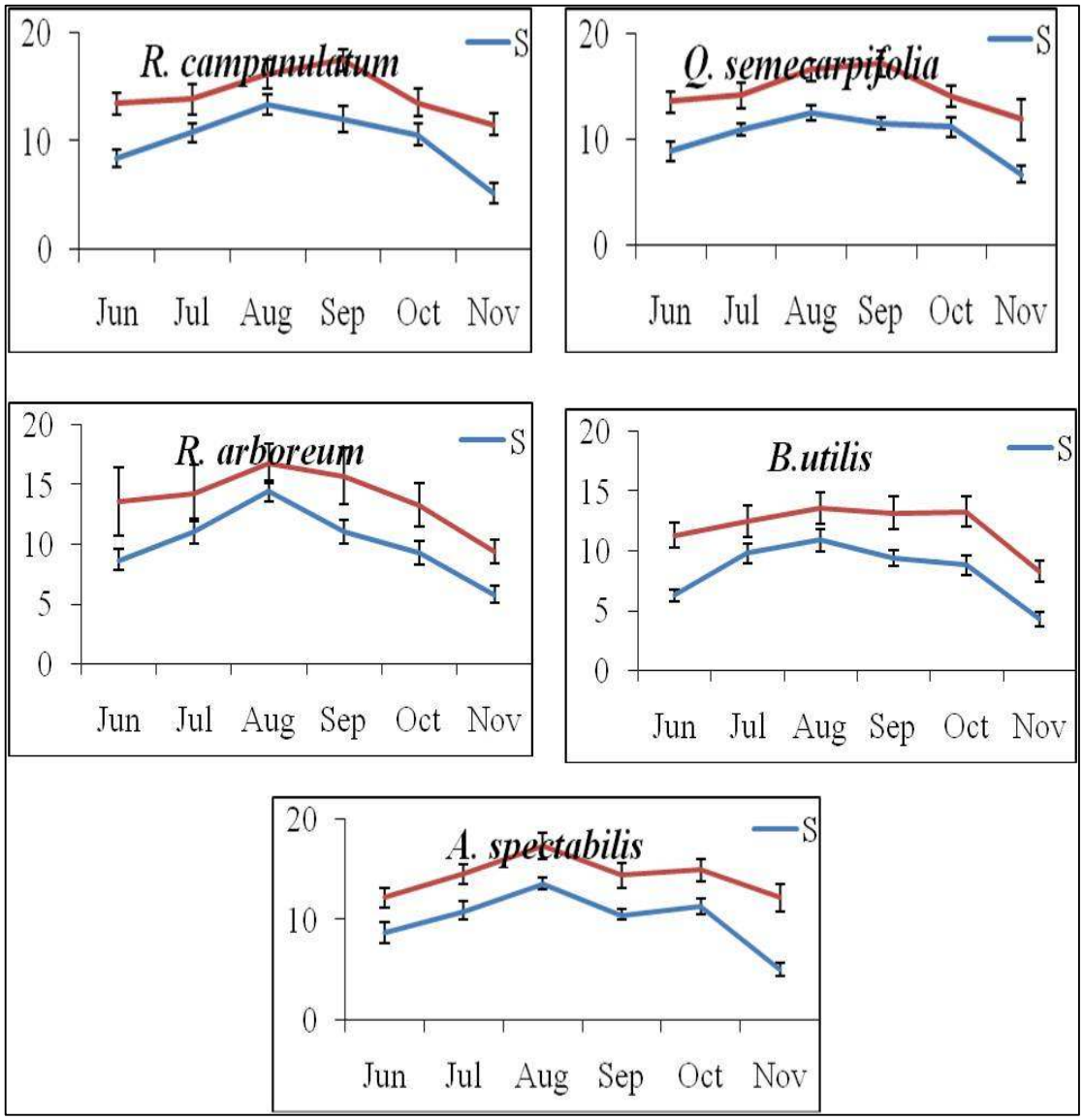


Fig. 2: Leaf nitrogen dynamics of different studied species

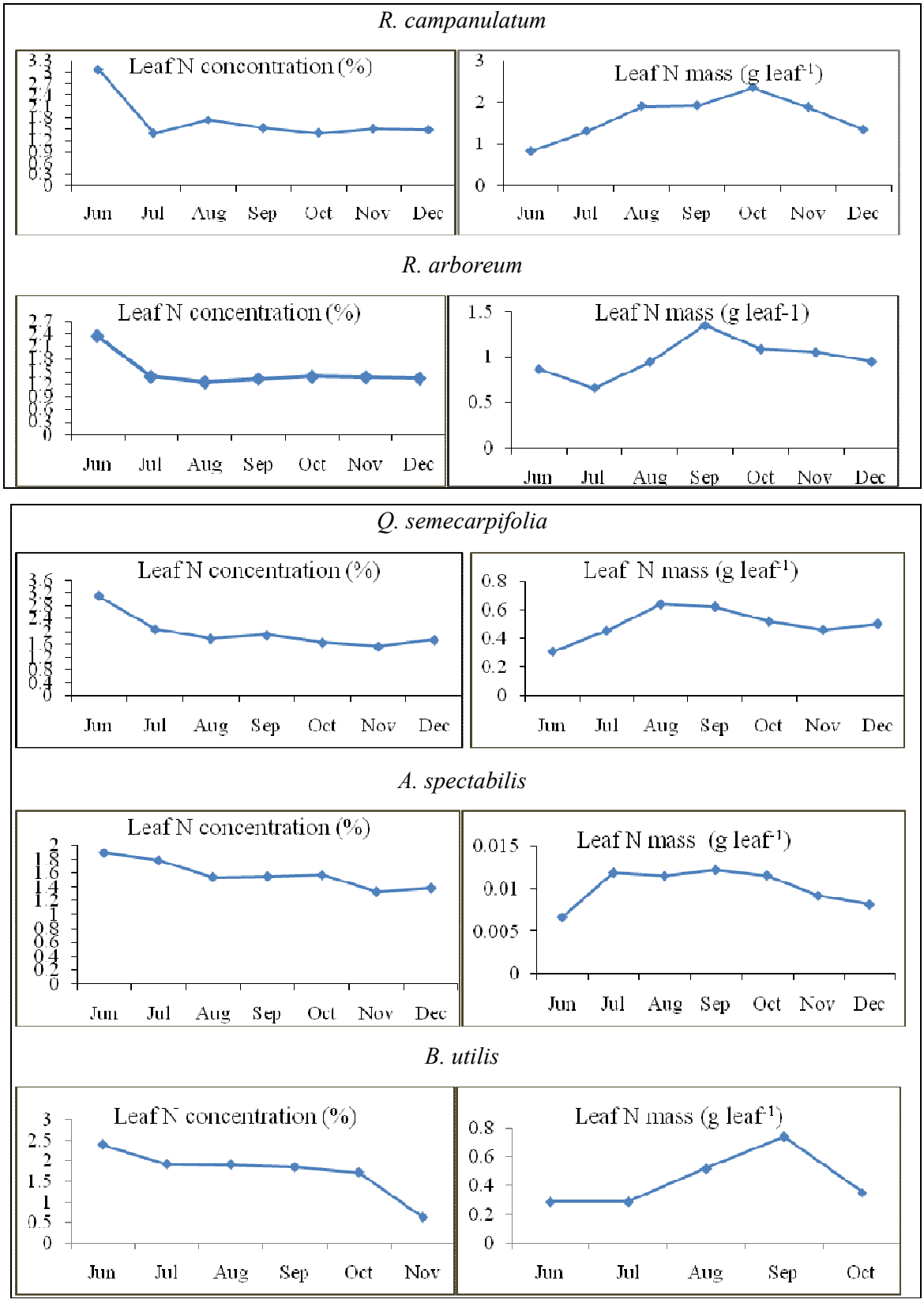


Plate 5: Seedling growth and internode measurements to determine the age of plants and rate of expansion of *R. campanulatum* krummholz in Tungnath treeline ecotone.

Plate 6: Training workshop on impact of climate change on timberline and determination of carbon stock in trees at Sari village (Chopta- Tungnath area).

(Dr. Ashish Tewari)

NMHS Progress Report
(Period from April 2017 to March 2018)

Project Title -: Tree Water Relation: Another perspective determining altitudinal limits of timberlines in the Himalayan region

Sanction No. and date -: **1882/XII-86/2016 Dated 27/04/16**

Institution Name-: **Department of Forestry & Environmental Science**
D.S.B. Campus,
Kumaun University,
Nainital- 263001

Name and Address of the PI-: **Dr. Ashish Tewari**
AssistantProfessor,
Department of Forestry & Environmental Science
D.S.B. Campus
Kumaun University, Nainital

Name and Address of the Co PI-: NA

Project Objectives -:

- To assess the sensitivity and response of the Himalayan tree line to water relation parameters.
- To determine the drought adaptation mechanisms of different species to assess their survival potential.
- To study the role of microsite facilitation in drought avoidance and growth.
- To assess the impact of water deficits and warming on seed maturation and seedling dynamics.
- To develop base line data on timberline tree water relations.

Completion in the last six months in % (According to each Deliverables)-:

Sl No	Quantifiable Deliverables (as per sanction letter)	Output/ achievements	Performance in terms of Monitoring indicators	Remarks

Summary of progress -:

Tree Water Potential

Tungnath Site:

Across all seasons the tree species were not severely stressed. During the summer season all the tree species encountered moderately stress and the pre dawn water potential values ranged between -7.1± 0.22 and -12.09± 0.27 bars. The mid day water potentials were marginally lower and the daily change between pre-dawn and mid day was less than 4.5 bars for all species (Table 1). During the rainy season the pre dawn water potential ranged between -1.61±0.16 and - 3.83± 0.14 bars however, the daily change was always more than10 bars for all the species (Table 1). During the autumn season the pre dawn water potential values ranged between -4.3± 0.1 and -6.9± 0.3 bars. The daily change in water potential was less than 9.7 bars for all species (Table 1). The daily change was maximum in *B. utils in autumn season*. All species had predawn water potentials above 12.0 bars in the winter season. The pre dawn water potential values ranged between *-3.0 ± 0.1*and *-11.8 ± 0.2bars*. The mid day water potential values ranged between *-6.0 ± 0.3* and -1*5.4 ± 0.3bars* (Table 1). The species appeared to be moderately stressed during the winter season. The daily change was maximum in *Q. semecarpifolia*.

Chitkul Site (H.P.):

The autumn tree water potential values of pre dawn in the month of September end (autumn) was similar to the values of the rainy season at Tungnath site and ranged between -1.57±0.13 and -2.6±0.19 bars. Even the seedlings were least stressed and values varied between -1.31±0.12 to -2.07±0.10 bars. The mid day water potential values for trees ranged between -9.62±0.36 and -12.7±0.43 bars and for seedlings -11.5± 0.49 to -14.4±0.31 bars (Table 5)

Water Potential Components (Tungnath site) The osmotic potential at zero and full turgor in *A. spectabilis* declined between summer to autumn season and in *Q. semecarpifolia* between summer and rainy season at full turgor and summer to winter at zero turgor. In *B. utilis* the decline was between autumn and winter season. Across all species and seasons the adjustment was small generally below 6.0bars at full turgor except in *Q. semecarpifolia* at zero turgor where it was close to 10 bars. The R.W.C. % was lowest in all species during the summer season and ranged between 52.18 ± 5.77% and 88.76 ± 2.6%.(Table2)

Soil water potential:

The soil water potential was estimated by Psypro water potential system. The soil were most moist during the rainy season and moderatelly stressed during the autumn season and winter season. During the winter season at 60cm soil depth the soil water potential ranged between -0.53±0.02 and -2.59±0.15 bars indicating sufficient moisture in the deeper soils which was higher even than the rainy season soil water potential at the same depth. During summers the soils were most stressed in top layer (10cm) and values ranged between 25.6±0.23 and 28.9±0.87 bars. The soil water potential at 60cm depth ranged from 15.3±0.13 to 16.6±0.32 bars (Table 3).

Leaf Conductance

Tungnath Site:

The morning leaf conductance during the summer season was low for *Quercus semecarpifolia* 13.3± 0.83 m mol $m^{-2}sec^{-1}$and *Rhododendron arboreum* 58.6±7.60 m mol $m^{-2}sec^{-1}$. *R. campanulatum* and *Betula utilis* had relatively higher conductance 232.9±3.01 and 279.9±27.3 m mol $m^{-2}sec^{-1}$. The afternoon leaf conductance ranged between 105.7± 3.92 and 249±24.9 m mol $m^{-2}sec^{-1}$. In the rainy season *B. utilis* had the highest morning leaf conductance 304.6±5.23 m mol $m^{-2}sec^{-1}$ followed by *Rhododendron* species and was lowest for *Q. semecarpifolia* 117.9± 7.95 m mol $m^{-2}sec^{-1}$. The afternoon conductance values were lower than the morning conductance values. The morning leaf conductance during the autumn season was *48.22 ±7.24* m mol $m^{-2}sec^{-1}$ for *Q. semecarpifolia, 30.83 ± 2.30* m mol $m^{-2}sec^{-1}$ for *R. campanulatum and 51.6 ± 4.60* m mol $m^{-2}sec^{-1}$ for *R. arboreum. Q. semecarpifolia* had relatively higher conductance in comparison to other two species. The afternoon leaf conductance ranged between *118.56 ±9.83*and *62.9 ± 3.96* m mol $m^{-2}sec^{-1}$. In the autumn season *Q. semecarpifolia* had the highest conductance followed by *R. campanulatum* and was lowest for *R. arboreum*. The morning leaf conductance during the winter season was *100.8 ±4.61*m mol $m^{-2}sec^{-1}$ for *Q. semecarpifolia, 29.1 ± 1.09* m mol $m^{-2}sec^{-1}$ for R. *campanulatum* and 216.0±3.79 m mol $m^{-2}sec^{-1}$ for *R. arboreum. Q. semecarpifolia* had relatively higher conductance in comparison to other two species. The afternoon leaf conductance ranged between *16.28 ± 2.34* and *166.7±8.05* m mol $m^{-2}sec^{-1}$. In the winter season *Q. semecarpifolia* had the highest morning conductance whereas *R. arboreum* had the highest afternoon conductance. (Table 4)

Chitkul Site (H.P.):

The morning conductance values for autumn season in *R. campanulatum* and *B. utilis* trees were 783.86± 105.4 and 667.06± 12.3.1 m mol m^2/sec which were much higher than the Tungnath site. The seedling leaf conductance for these species was exceptionally high 1147.7±59 and 1323.3± 100.4 m mol m^2/sec. However, the afternoon conductance values were much lower and declined by 80% approximately for both trees and seedlings (Table 6).

Seed Maturation:

Work on seed maturation indices of *Q. semecarpifolia* and *R. campanulatum* was continued. The physical seed parameters of both the species were measured. Total five collections were made for both the species on different collection dates from the time of appearance of acorns/ capsules till availability. The maximum germination in *Q. semecarifolia* was 63.5±1.58% when the acorn moisture content was 46.6± 0.83 % and had declined to 28.3±12% when the moisture content was 38.03± 0.79% (Table 8). In *R. campanulatum* no germination had occurred till March end but the moisture content of capsule had declined from 70.26±0.23% to 44.98± 0.29%. In *R. campanulatum* the number of seeds in one gram ranged between 5250 and 7619 (Table 7&8).

Name of the PI-: Dr. Ashish Tewari **Signature -:**

Date-:

Table 1. Mean Predawn and Mid day water potential of trees of selected species in summer and rainy season at Tungnath:

Species	Water Potential Pre-dawn (-Bars)	Water Potential Mid-day (-Bars)
Summer Season		
A. spectabilis	11.29 ± 0.42	12.52 ± 0.46
Q. semecarpifolia	12.09±0.27	10.4 ± 0.34
R. campanulatum	7.1 ± 0.22	11.47 ± 0.27
R. arboreum	9.91±0.24	10.29 ± 0.47
B.utilis	8.11± 0.19	8.58 ± 0.18
Rainy Season		
A. spectabilis	1.61±0.16	13.56± 0.51
Q. semecarpifolia	2.62±0.35	14.06± 0.43
R. campanulatum	2.19±0.16	14.36± 0.65
R. arboreum	3.83±0.14	15.2 ± 0.41
B. utilis	1.21± 0.11	11.9 ± 0.42
Autumn Season		
A. spectabilis	4.3 ±0.1	10.9±0.3
Q. semecarpifolia	6.9 ±0.3	11.4 ± 0.2
R. campanulatum	4.6 ± 0.1	13.1 ± 0.3
R. arboreum	5.0 ± 0.2	13.0 ± 0.4
B. utilis	5.1 ± 0.2	14.8 ± 0.3
Winter Season		
A. spectabilis	8.4 ±0.1	13.6±0.1
Q. semecarpifolia	6.5 ±0.1	14.2 ± 0.3
R. campanulatum	8.7± 0.2	15.4 ± 0.3
R. arboreum	11.8 ± 0.2	13.9 ± 0.1
B. utilis	3.0 ± 0.1	6.0 ± 0.3

Table 2. Components of water potential (Osmotic Potential at full and zero turgor, Relative water content and Pressure potential) across different seasons at Tungnath:

Species	***Osmotic Potential at full turgor (-MPa)***	***Osmotic Potential at zero turgor (MPa)***	***RWC (%)***
Summer Season			
A. spectabilis	-0.72±0.19	-1.54±0.42	52.18±5.77
Q. semecarpifolia	-1.04±0.20	-1.45±0.20	54.63±1.46
R. campanulatum	-0.74±0.02	-1.54±0.42	73.20±4.01
R. arboreum	-1.8±0.01	-2.36±0.02	74.34±0.84
B. utilis	-1.38±0.15	-2.07±0.14	88.76±2.6
Rainy Season			
A. spectabilis	-1.02±0.28	-1.54±0.42	92.14±3.03
Q. semecarpifolia	-1.21±0.21	-1.84±0.31	81.8±2.90
R. campanulatum	-1.29±0.25	-1.91±0.30	86.5±4.80
R. arboreum	-0.81±0.01	-1.34±0.21	85.6± 5.10
B. utilis	-0.91±0.16	-1.43±0.12	89.6±3.4
Autumn Season			
A. spectabilis	-1.29±0.62	-1.64± 0.62	85.41±1.09
Q. semecarpifolia	-0.92 ± 0.08	-2.08 ± 0.42	66.92 ± 4.12
R. campanulatum	-0.71 ± 0.29	-1.41 ± 0.58	74.83 ± 1.74
R. arboreum	-1.5 ± 0.01	-1.85 ± 0.02	93.26 ± 0.74
B. utilis	-0.98 ± 0.14	-1.63 ± 0.37	76.53 ± 1.90
Winter Season			
A. spectabilis	-1.19±0.22	-1.77±0.09	83.02±3.88
Q. semecarpifolia	-1.58±0.06	-2.50±0.07	73.84±5.75
R. campanulatum	-1.55±0.26	-2.54±0.07	90.7±1.02
R. arboreum	-1.33±0.07	-1.98±0.12	78.95±5.75
B. utilis	-1.45±0.13	-2.22±0.06	79.34±1.06

Table 3: Soil water potential (-bars) in two different seasons at Tunganath site along the transect at different depth

Site	Soil Depth (cm)	Soil water potential (-Bars)			
		Summer	Rainy	Autumn	Winter
Top	10 cm	28.9± 0.87	-8.7±0.32	-18.66±0.65	-15.35±0.61
	30 cm	20.8±0.56	-6.9±0.17	-12.66±0.45	-2.79±0.13
	60cm	16.6±0.32	-6.3±0.32	-10.53±0.78	-2.59±0.15
Mid	10 cm	-25.8±0.23	-6.7±0.12	-17.45±0.67	-3.40±0.15
	30 cm	-19.6±0.54	-6.76±0.34	-12.71±0.87	-2.45±0.22
	60cm	-15.5±0.23	-5.87±0.18	-12.68±1.32	-0.53±0.02
Base	10 cm	-26.7±0.42	-7.99±0.65	-22.5±1.23	-16.6±1.15
	30 cm	-19.6±0.21	-6.34±0.35	-14.1±0.54	-3.56±0.59
	60cm	-15.3±0.13	-5.23±0.87	-11.6±0.34	-1.09±0.08

Table 4. Leaf Conductance of trees of selected species at Tungnath:

Species	Leaf Conductance *(*m mol $m^{-2}sec^{-1}$*)*	
	Morning	Afternoon
Summer		
Q. semecarpifolia	13.3± 0.83	105.7± 3.92
R. campanulatum	232.9± 3.01	157.4± 5.23
R. arboreum	58.6 ± 7.60	163.4± 13.7
B.utilis	279.9±27.3	249±24.9
Rainy		
Q. semecarpifolia	117.9±7.95	89± 4.04
R. campanulatum	265.8 ± 15.1	120.7± 20.23
R. arboreum	245.8 ± 26.1	125± 13.0
B.utilis	304.6 ± 5.23	102.8 ± 9.09

Autumn		
Q. semecarpifolia	48.22 ±7.24	118.56 ±9.83
R. campanulatum	30.83 ± 2.30	75.11 ± 2.56
R. arboreum	51.6 ± 4.60	62.9 ± 3.96
B. utilis	leafless	leafless
Winter		
Q. semecarpifolia	100.8 ±4.61	49.5 ± 2.81
R. campanulatum	29.1 ± 1.09	16.28 ± 2.34
R. arboreum	216.0±3.79	166.7±8.05
B. utilis	leafless	leafless

Table 5. Mean Predawn and Mid day water potential of selected species in Autumn season at Chitkul (H.P.):

Species	**Water Potential Pre-dawn (-Bars)**		**Water Potential Mid-day (-Bars)**	
	Tree	**Seedling**	**Tree**	**Seedling**
A. spectabilis	2.6 ± 0.19	2.07 ± 0.10	10.6 ± 0.18	11.5 ± 0.49
R. campanulatum	1.57 ± 0.13	1.31 ± 0.12	12.7 ± 0.43	11.6 ± 0.24
B. utilis	1.91 ± 0.14	1.81 ± 0.01	9.62 ± 0.36	14.42 ± 0.31

Table 6. Leaf Conductance of *Rhododendron campanulatum* and *Betula utilis* in autumn season at Chitkul:

Species	**Leaf Conductance *(m mol m^2/sec)***			
	Tree		**Seedling**	
	Morning	**Afternoon**	**Morning**	**Afternoon**
R. campanulatum	783.86± 105.4	170.8± 66.7	1147.7±59	245.2± 27.7
B.utilis	667.06±123.1	210.06±36.5	1323.3±100.4	347.5±14.03

Table 7. Physical acorns attributes and germination percent of *Quercus semecarpifolia*

Date	Acorn size (mm^2)	Weight of 100 acorns (g)	No. of acorns/100g	Moisture Content %	Germination %
10 July 17	247.8± 23.1	202±13.6	52.6± 3.33	67.05 ± 2.26	0±0
18 July 17	256±11	225.3 ± 15.7	43.3±3.33	65.17 ± 1.19	13.16± 1.49
24 July 2017	346± 28.6	524.6± 23.2	20.3± 0.33	56.6 ± 1.51	52.8 ± 1.59
1 August 17	557± 37.7	756.6± 46.5	10.6 ± 0.33	46.6 ± 0.83	63.5 ± 1.58
8 August 17	583.7± 35.8	830 ±20	9.67± 0.33	38.03 ± 0.79	28.3 ± 12.0

Table 8. Physical attributes of capsules of *Rhododendron campanulatum*

Date	Capsule size (mm^2)	Weight of 100 capsule (g)	No. of capsule/100g	Moisture Content %
5 June 17	68.53±5.79	128.67±2.67	137.00±0.58	70.26±0.35
20 June 17	100.81±2.39	133.67±0.88	101.67±0.58	70.63±0.49
10 July 17	85.92±5.89	148.33±2.03	142.00±1.15	56.55±0.73
13 August 17	124.76±2.42	159.33±3.84	140.00±1.15	47.05±0.33
8 September 17	170.88±3.21	174.67±2.40	158.00±1.15	44.98±0.29

(Dr. Pankaj Tewari)

NMHS Progress Report
(Period from April 2017 to March 2018)

1. Project Information

Project ID:	NMHS/LG-2016/009	**Sanction Date:**	31/3/2016
Project Title:	Demonstration of appropriate livelihoods options and strengthening capacities of local communities in assessing carbon accumulation potential in an around timberline areas.		
BTG:	Conservation & Sustainable use of Biodiversity		
PI and Affiliation (Institution):	**Dr. Pankaj Tewari** Central Himalayan Environment Association (CHEA) 06 Weldorf Compound, Mallital, Nainital, Uttarakhand (263001)		
Name & Address of the Co-PI, if any:	-NA		
Structured Abstract - detailing the current year progress [Word Limit 250 words]:	Demonstrations of appropriate low cost technologies was made among the villages during first year and based on their feedback and evaluation (production and income) during second year the expansion was made along with effective convergence with line departments for exploring supply of surplus produce in local markets. In all 28 Rural Resource Persons (RRPs) were developed (03 in poly house construction; 15 in nursery development; 03 in making ringal handicrafts; 04 in mushroom cultivation; 02 in carbon measurement; 01 in responsible tourism and allied activities) having expertise in demonstrated activities. Approximately 5.5 ha area has been covered under high value crops based on needs and technical inputs provided by experts for enhancing the income among 170 families. Vegetable were produced by beneficiaries (both from poly house and open farm) worth Rs. 15,12,500.00 including income of Rs. 4,50,000.00. Satisfactory production and positive response from villagers was received on pilot demonstrations of mushroom (*Pleurotus.spp*). A total of 160 Kg of mushroom was produced in two consecutive seasons worth Rs. 90,000 in the nearby markets including direct income of Rs. 40,000. The fodder demonstration was made in 1.5 ha area in terraces by 70 individuals. In all, 56 quintal (190 head loads) of fodder has been harvested. Refresher on "Carbon Sequestration Measurement" was conducted during second year to strengthen the skills of youths and to popularize the citizen science. The whole studied region indicates itself as a high tourism zone as it contributes to 47.35 % of the total economy generated by all livelihood activities. An introductory training on bird watching along with several awareness camps and meetings were organized in both the villages to promote responsible tourism, citizen science, biodiversity conservation, and solid waste management in the zone. Attempts such as		

	establishment of dustbins and degradable bags in Tungnath trek, management of horse/ponies waste on Tungath trek, etc. were made to reduce waste in CTS, in collaboration with temple committee, horse union and local villagers. Floriculture, another livelihood intervention demonstrated in the initial phase of the project and continued. 0.5 ha area has been covered under *Tagetes erecta* (marigold) by 20 farmers. For resource mobilization and ensuring convergence with line department the project concept, learnings were shared. In continuation, project theme along with the progress and results achieved was communicated through poster presentations, slide presentation in national and international seminars/ conferences/workshops i.e. a workshop funded by IHCAP-HDC, international seminar organized by Doon University, 105th Indian Science Congress 2018 etc. 02 research articles are being submitted in renowned journals i.e. Tropical Ecology and ENVIS for further dissemination of learnings. Technical support and monitoring on regular basis was made by the experts from horticulture department. To resolve the main concern i.e. Solid Waste Management in the tourism zone (Chopta-Tungnath), several meetings were organized with temple committee, horse union, village representative, Van Panchayat committee and district magistrate. To promote the "Clean India Programme" launched by govt. of India "Swachhata-Pakhwada" were celebrated at village level along with several awareness campaigns. In continuation of replicating livelihood options in an around the studied villages; a working plan has been developed.

Project Partner name	**Affiliations**	**Role & Responsibilities**
Partner 1	Central Himalayan Environment Association (CHEA), Nainital	**Role:** Timberline resources (e.g., ringal and wild edibles) based cottage industries promotion an technology- transfer; training and capacity building of women for livelihood enhancement **Responsibility:** Strengthening livelihoods based on timberlines based on timberlines and employment of local people, particularly women on Citizen Science Concept

2. Project Site Details

Project Site	Indian Himalayan Region
IHR States Covered	Uttarakhand
Long. & Lat.	
Site Maps	[**Attach**]
Site Photographs	[**Attach**]

3. Project Activities Chart w.r.t. Timeframe [Gantt or PERT]

Project Activities	Work undertaken				Output
	Year 2017-2018				
	Qtr 1	Qtr 2	Qtr 3	Qtr 4	
Project Activities 1	• Evaluation/ assessment of the demonstrations done in Ist year were done.				• 60 kg mushroom was produced worth Rs. 42,000 by community members /beneficiaries in 03 months. • Around 1600 kg vegetable were produced under poly-houses (*Tomato, Brinjal, Chilly, Cabbage, Cucumber, Green vegetables and Capsicum)* and beside self consumption income of Rs. 15,000 generated by 120 families in both villages. • Approx. 4 ha area covered under vegetable cultivation benefitting 120 families.
Project Activity 2	• Meetings with Temple committee and horse union were conducted for trek management with the help of shopkeepers in Tungnath track (Chanis) under waste management to ban the use of poly bags in timberline area.				• A positive response with full support was committed by temple committee for using natural flowers (marigold) and baskets of Ringal as Prasad. • Members of horse union agreed to clean the track twice a week and for that 04 brooms were provided to them. • Degradable bags were

					distributed to Chanis along with awareness campaigns among horse/ponies owners and local porters to keep trek clean.
Project Activity 3		• Technology and input support for high value vegetable crop and nutritious fodder among beneficiaries.			• 4 ha area covered under vegetable cultivation benefitting 120 families. 1.5 ha area covered under improved fodder grasses in the terraces by seed sowing to ensure fodder availability in the vicinity of house and to reduce women drudgery.
Project Activity 4		• Meeting with government officials, market stakeholders and other organizations working in the region for extensive services and resource mobilization.			• Project activities initiated and progress was shared with District Magistrate, senior officers of line departments. • Village level meetings with line department representatives including Village Development Officer, Veterinary department, Horticulture department, BAIF, District Industry, etc. were organized, in which several social issues and problems were discussed. • "Swachhata Pakhwara" was celebrated at village level in the presence government

					representative, Gram Pradhan, Head of Tungnath Temple Committee.
Project Activity 5		• Promotion of Citizen Science Concept among local communities to develop RRPs in different sectors.			• Beneficiaries skill developed by organizing training on ringal based handicrafts, vegetable nursery preparation, bird watching, measurement of carbon sequestration rate, etc. • Community members initiated to make several showpieces made up of Ringal such as dustbins, flower pots, pen stand etc. • Training programs were organized under the supervision of the experts and within the involvement of government agencies.
Project Activity 6			• Expansion of appropriate low cost technologies.		• 10 polyhouses were replicated for vegetable cultivation. • 100kg mushroom spawns were provided to project beneficiaries. • Continuation of floriculture in project areas.
Project Activity				• Technology and	• Over all, approximately

7				input support for high value vegetable and nutritious fodder among beneficiaries.	5.5 ha area has been covered under high value crops based on needs and technical inputs provided by experts for enhancing the income among 170 families. • Vegetable were produced by beneficiaries (both from poly house and open farm) worth Rs. 15,12,500.00 including income of Rs. 4,50,000.00. • In all, a total of 160 Kg of mushroom was produced in two consecutive seasons worth Rs. 90,000 in the nearby markets including direct income of Rs. 40,000. • In all, 56 quintal (190 head loads) of fodder has been harvested.
Project Activity 8			• Promotion of Citizen Science Concept among local communities to develop RRPs in different sectors.		• In all 28 Rural Resource Persons (RRPs) were developed (03 in poly house construction; 15 in nursery development; 03 in making ringal handicrafts; 04 in mushroom cultivation; 02 in carbon measurement; 01 in responsible tourism and allied activities) having

					expertise in demonstrated activities. • Refresher on "Carbon Sequestration Measurement" was conducted during second year to strengthen the skills of youths and to popularize the citizen science.
Project Activity 9				• Meeting with government officials, market stakeholders and other organizations working in the region for extensive services and resource mobilization temple committee, horse union, village representative, Van Panchayat committee.	• For resource mobilization and ensuring convergence with line department the project concept, learnings were shared. • In continuation, project theme along with the progress and results achieved was communicated through poster presentations, slide presentation in national and international seminars/ conferences/workshops i.e. a workshop funded by IHCAP-HDC, international seminar organized by Doon University, 105th Indian Science Congress 2018 etc. • 02 research articles are being submitted in renowned journals i.e.

					Tropical Ecology and ENVIS for further dissemination of learnings. • Technical support and monitoring on regular basis was made by the experts from horticulture department. • To resolve the main concern i.e. Solid Waste Management in the tourism zone (Chopta-Tungnath), several meetings were organized with temple committee, horse union members.

4. Financial and Resource Information

Note: A separate bank account is expected to be opened for NMHS Project as per the provision of Direct Beneficiary Account (DBA) as laid out by the Govt. of India and also facilitate the audit of accounts. The interest earned out of the NMHS project funds should be reported clearly in the utilization certificate.

Total Grant:		**Grant Received Date:**	

Project Partner(s)	**Affiliations/ Institution**	**Budget Allocated to**	**Work Done**
Partner 1			
Partner 2			
Partner 3			
[**Add**]			

Project Staff Information:

S. No.	**Name**	**Qualification**	**Designation**	**Fellowship/ Wages paid**	**Remarks**
1.	Krishna Kumar Tamta	M.Sc. Forestry	JPF	16000 + (HRA 10%)	
2.	Amit Mittal	M.Sc. Forestry	JPF	16000 + (HRA 10%)	

5. Equipment and Asset Information

S. No.	**Equipment Name (Qty)**	**Details (Make/ Model)**	**Cost**	**Date of Installation**	**Photographs of Equipment**	**Lowest Quotation, IF NOT purchased**
1.	Equipment 1				**[Attach]**	
2.	Equipment 2				**[Attach]**	
3.	Equipment 3				**[Attach]**	
[**Add**]	[**Add**]				**[Attach]**	

6. Expenditure Statement and Utilization Certificate

Please update the annual Expenditure Statement and Utilization Certificate (UC) periodically.

Expenditure Information:

S. No.	Financial Position/Budget Head	Funds Sanctioned	Expenditure	% of Total cost
I	Salaries/Manpower cost			
II	Travel			
III	Expendables &Consumables			
IV	Contingencies			
V	Activities & Other Project cost			
VI	Institutional Charges			
VII	Equipments			
	Total			
	Interest earned			
	Grand Total			

Period	Expenditure Statement	Utilization Certificate (UC)
Annual	[**Attach**]	[**Attach**]

7. Project Beneficiary Groups

Beneficiary Groups [Capacity Building]	Target	Achieved
No. of Beneficiaries with income generation:	-	**175**
No. of stakeholders trained, particularly women:	-	
No. of capacity building Workshops/ trainings:	-	**10**
No. of Awareness & outreach programmes:	-	**18**
No. of Research/ Manpower developed:	-	**28 (03 in poly house construction; 15 in nursery development; 03 in making ringal handicrafts; 04 in mushroom cultivation; 02 in carbon measurement; 01 in responsible tourism and allied activities)**

8. Project Progress Summary (as applicable to the project)

Description	Total (Numeric)	Description
IHR States Covered	01	*Uttarakhand*
Project Site/ Field Stations Developed:	.... (attach photos) ... (attach maps)	*Makkumath Saari*
No. of Patents filed (Description):	*NA*	•
Article/ Review/ Research Paper/ Publication:	*One paper communicated to Tropical Ecology (Special Volume on Himalayan Timberline)* *One research article communicated to ENVIS news letter*	•
New Methods/ Modelling Developed (description in 250 words):	*NA*	•
No. of Trainings (No. of Beneficiaries):	*10 trainings (No. Of beneficiaries 150)* *(28 RRPs)*	•
Workshop:	*NA*	•
Demonstration Models (Site):	.... (attach maps about location & photos)	•
Livelihood Options:	*Off-season vegetable cultivation; Mushroom cultivation; Responsible tourism and its allied activities such as bird watching, porters/guides/trainers, home stay; Handicrafts made by Ringal*	•
Training Manuals:	*One chapter in Manual*	•
Processing Units:	*NA.... (attach photos)*	•
Species Collection:	*NA*	•
Species identified:	*NA*	•
Database/ Images/ GIS Maps:	*NA*	•

***Note*:** Photos/ maps should be attached in high quality in compatible formats *viz*., JPEG, .JPG, .PNG, .SHP, etc. along with a suitable figure legend/ caption.

9. Project Linkages (with nearby Institutions/ State Agencies)

S. No.	Institute/ Organization	Type of Linkages	Brief Description
1	District Administration	Cooperation	To resolve the main concern i.e. Solid Waste Management in the tourism zone (Chopta-Tungnath).
2	Temple Committee, Tungnath	Cooperation	To resolve the main concern i.e. Solid Waste Management in the tourism zone (Chopta-Tungnath).
3	Department of Horticulture	Technical Assistance	For technical support and monitoring on regular basis for enhancing the production of high value crops.
4	Village level institutions (Van Panchayat, Nav Yuvak Mangal Dal, Mahila Mangal Dal etc.)	Cooperation and capacity building	For strengthening capacities and enhancing livelihood status with local community participation and transparent beneficiary selection.

10. Additional (publication, recommendations, etc.)

Time Period	**Publications** (Research Papers, Information Material, Policy drafts, Patents, etc.)
Annual [Year .....]	**[Attach]**

11. Project Concluding Remark

Kindly update the following Progress Parameters for the Reporting Period:

Project Objectives	Project Output against each objective	Progress made against Monitoring Indicators (specified in Sanction Letter)	Remarks
1. Demonstration of appropriate livelihoods options and strengthening capacities of local communities in assessing carbon accumulation potential in an around timberline areas.	• 60 kg mushroom was produced worth Rs. 42,000 by community members /beneficiaries in 03 months. • Around 1600 kg vegetable were produced under poly-houses (*Tomato, Brinjal, Chilly, Cabbage, Cucumber, Green vegetables and Capsicum)* and beside self consumption income of Rs. 15,000 generated by 120 families in both villages. • Approx. 4 ha area covered under vegetable cultivation benefitting 120 families. • A positive response with full support was committed by temple committee for using natural flowers (marigold) and baskets of Ringal as Prasad. • Members of horse union agreed to clean the track twice a week and for that 04 brooms were provided to them. • Degradable bags were distributed to Chanis along with awareness campaigns among horse/ponies owners and local porters to keep trek clean.	• Village level meetings with line department representatives including Village Development Officer, Veterinary department, Horticulture department, BAIF, District Industry, etc. were organized, in which several social issues and problems were discussed. • "Swachhata Pakhwara" was celebrated at village level in the presence government representative, Gram Pradhan, Head of Tungnath Temple Committee. • Beneficiaries skill developed by organizing training on ringal based handicrafts, vegetable nursery preparation, bird watching, measurement of carbon sequestration rate, etc. • Community members initiated to make several showpieces made up of Ringal such as dustbins, flower pots, pen stand etc. • Training programs were organized under the supervision of the experts and within the involvement of government agencies.	

	• 4 ha area covered under vegetable cultivation benefitting 120 families. 1.5 ha area covered under improved fodder grasses in the terraces by seed sowing to ensure fodder availability in the vicinity of house and to reduce women drudgery. • 10 polyhouses were replicated for vegetable cultivation. • 100kg mushroom spawns were provided to project beneficiaries. • Continuation of floriculture in project areas. • Over all, approximately 5.5 ha area has been covered under high value crops based on needs and technical inputs provided by experts for enhancing the income among 170 families. • Vegetable were produced by beneficiaries (both from poly house and open farm) worth Rs. 15,12,500.00 including income of Rs. 4,50,000.00. • In all, a total of 160 Kg of mushroom was produced in two consecutive seasons worth Rs. 90,000 in the nearby markets including direct income of Rs. 40,000. • In all, 56 quintal (190 head loads) of fodder	• Project activities initiated and progress was shared with District Magistrate, senior officers of line departments. • Refresher on "Carbon Sequestration Measurement" was conducted during second year to strengthen the skills of youths and to popularize the citizen science. • For resource mobilization and ensuring convergence with line department the project concept, learnings were shared. • Refresher on "Carbon Sequestration Measurement" was conducted during second year to strengthen the skills of youths and to popularize the citizen science. • For resource mobilization and ensuring convergence with line department the project concept, learnings were shared. • To resolve the main concern i.e. Solid Waste Management in the tourism zone (Chopta-Tungnath), several meetings were organized with temple committee, horse union members.	

	has been harvested. • In all 28 Rural Resource Persons (RRPs) were developed (03 in poly house construction; 15 in nursery development; 03 in making ringal handicrafts; 04 in mushroom cultivation; 02 in carbon measurement; 01 in responsible tourism and allied activities) having expertise in demonstrated activities. • In continuation, project theme along with the progress and results achieved was communicated through poster presentations, slide presentation in national and international seminars/ conferences/workshops i.e. a workshop funded by IHCAP-HDC, international seminar organized by Doon University, 105th Indian Science Congress 2018 etc. • 02 research articles are being submitted in renowned journals i.e. Tropical Ecology and ENVIS for further dissemination of learnings. • Technical support and monitoring on regular basis was made by the experts from horticulture department.		

Methodology (in brief):	
Major Research Achievements:	
Brief Conclusion - the current year progress – during the reporting period (point-wise):	
Progress Achieved (%):	
Remaining work to be done:	

Submitted to:	***Submitted by:***
Nodal Officer, NMHS-PMU National Mission on Himalayan Studies (NMHS) G.B. Pant National Institute of Himalayan Environment and Sustainable Development, Kosi-Katarmal, Almora 263643, Uttarakhand	Project PI (Signature): Institution (Seal): Dated (dd/mm/yy):

E-mail: nmhspmu2016@gmail.com

Please fill the NMHS Progress Report pro forma as applicable with respect to time and other requirements and return *via* post/ e-mail. In case of any query, please contact at: nmhspmu2016@gmail.com

(Dr. P.S.Ranhotra)

NMHS Progress Report
(Period from April 2017 to March 2018)

1. Project Information

Project ID:	**1886/XII-86/2016**	**Sanction Date:**	12th May 2016
Project Title:	Tree growth response of selected tree species of timber line to climate variability across the Indian Himalayan Region.		
BTG:			
PI and Affiliation (Institution):	**DR. PARMINDER SINGH RANHOTRA** Birbal Sahni Institute of Palaeosciences, 53 University Road, Lucknow, (UP) - 226007		
Name & Address of the Co-PI, if any:	**DR. AMALAVA BHATTACHARYYA** Birbal Sahni Institute of Palaeosciences, 53 University Road, Lucknow (UP) - 226007 **DR. RAJESH JOSHI,** GBPNIHESD, Almora		
Structured Abstract - detailing the current year progress [Word Limit 250 words]:	Previously collected tree ring core samples of *Abies spectabilis* (Himalayan fir) from Tungnath area (Uttarakhand) were analyzed for tree line dynamics and climate-growth response of this species in the area. *Abies* forms the timber line limit at ~3355 m amsl along the Chopta-Tungnath temple transect. The sampled trees within the altitudinal transect of ~2780 to 3364 m amsl were dated and calculated for Age and Diameter at breast height (DBH), and correlation models are developed between Age-DBH, DBH-Altitude and Age-Altitude (Figs 1-abc) for analyzing the age stand structure and tree line dynamics of Himalayan fir. Also the temporal shift rate of this species at the area has been calculated. Developed mean chronology of ~317 years (Fig 2) extends back to 1699 AD. Correlation between tree ring width and climate (temperature and precipitation) has also been established using the gridded climate data (CRU-TS.422) for the Tungnath region. Carried out field works in May and September 2017 to Daksum (~2400 m amsl) and Sinthan top (~3800 m amsl), south Kashmir, J&K (Fig 3). *Abies spectabilis* grow densely on slopes till ~3500 m amsl (Fig 4), where as *Pinus wallichiana* has been reported till ~3600 m amsl. Stunted *Juniperus* reach above *Pinus* limit. In broadleaved trees *Acer* form patches till ~3300 m amsl (Fig. 5), overtopped by *Betula utilis* (Fig. 6). *Rhododendron* form dense patches on slopes reaching above ~3600 m amsl. The ground taxa are well covered by the elements of Poaceae, Asteraceae, Ranunculaceae, Polygonaceae, Rosaceae, Saxifragaceae etc. Collected 426 cores from 213 trees of *Abies spectabilis* from altitudinal range of 3200-3500 m amsl and ~2400 m amsl; 112 cores from 56 trees of *Betula utilis* between altitudes 3400 to 3620 m amsl; 50 cores from		

	~28 trees of *Pinus wallichiana* between altitudes 3380 to 3600 m amsl. 35 surface (moss) samples are collected from the altitudinal range of 2300 to 3800 m amsl. Core samples have been processed and measured for chronology development and further analyses.	
Project Partner name	**Affiliations**	**Role & Responsibilities**

1. Project Site Details

Project Site	The tree line areas of Jammu & Kashmir, Himachal Pradesh, Uttarakhand and Sikkim
IHR States Covered	Daksum and Sinthan area, (Kashmir, J & K)
Long. & Lat.	75^{O} 30' E and 33^{O} 35' N
Site Maps	Site map showing the sample collection points. (Fig 3 attached below)
Site Photographs	Site and sample collection photographs. (Figs. 4 to 7 Attached below)

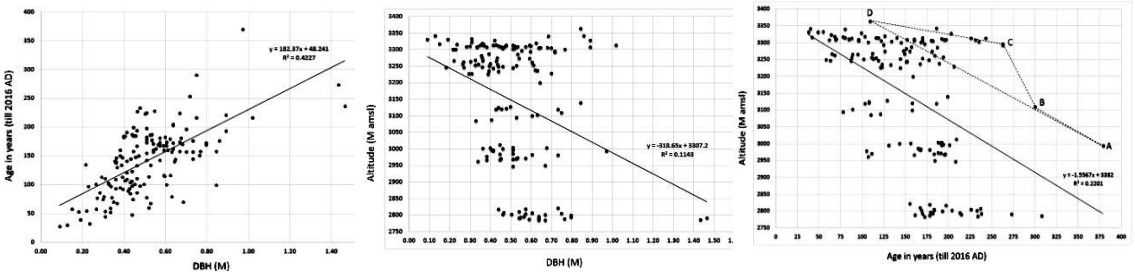


Fig 1 a. DBH-Age correlation b. DBH-Altitude correlation c. Age-Altitude correlation

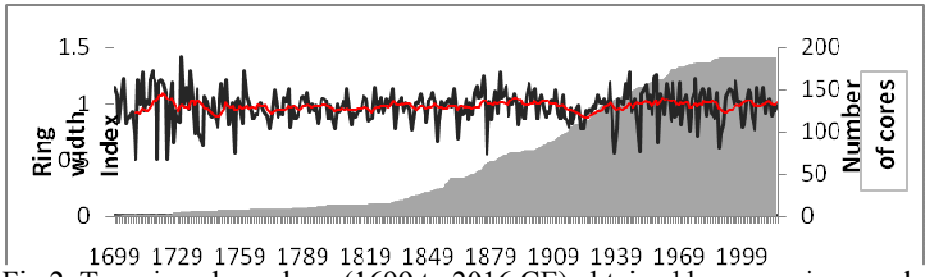


Fig 2. Tree ring chronology (1699 to 2016 CE) obtained by averaging yearly standardized indices for 110 trees and 189 cores of *Abies spectabilis* using ARSTAN (Auto Regression Standardization).

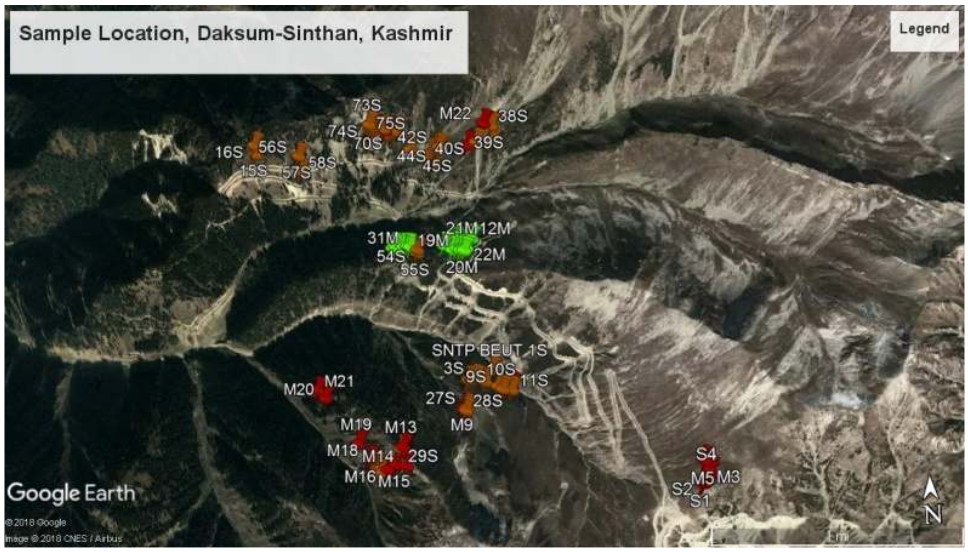


Fig. 3. Tree ring sampling points at Daksum-Sinthan, Kashmir


Fig 3. Regeneration of *A. spectabilis*, Sinthan


Fig 4. Growth of *Abies* and *Acer*


Fig 5. Betula utilis form tree line with *Abies*


Fig 6. Collection of *Morchella* fungi by locals

3. Project Activities Chart w.r.t. Timeframe [Gantt or PERT]

Project Activities	WORK UNDERTAKEN Year 2017-18				Output
	Qtr 1	Qtr 2	Qtr 3	Qtr 4	
Project Activity 1	(Since May 2017) Field work to Daksum-Sinthan, Kashmir J&K for the collection of tree ring samples.	Continued analysis of Tungnath samples with the collection and addition of more *Abies* samples by GBPNIHESD Almora group. Processing of Kashmir samples.	Field work to Daksum-Sinthan, Kashmir J&K for more collection of tree ring samples. Continued processing of samples with data generation and analysis.	(Till March 2018) The data generated for the Tungnath region region has been analysed for stand dynamics, shift rate and growth-climate relationship for Himalayan fir species and the manuscript is under preparation for its publication.	Processing, data generation and analyses of *Abies* from Tungnath is completed. The data analysis of Kashmir samples is under process. Previous JPF left in October 2017 and new JPF appointed in December 2017

4. Financial and Resource Information

***Note*:** A separate bank account is expected to be opened for NMHS Project as per the provision of Direct Beneficiary Account (DBA) as laid out by the Govt. of India and also facilitate the audit of accounts. The interest earned out of the NMHS project funds should be reported clearly in the utilization certificate.

Total Grant:	38,99,000/- Including instuments	Grant Received Date:	8th June 2016 (first instalment)
Project Partner (S)	Affiliations/ Institution	Budget Allocated to	Work Done

Project Staff Information:

Sl	Name	Qualification	Designation	Fellowship/ Wages paid	Remarks
1	Ms. Utsa Singh	M.Sc in Geology	Junior Project Fellow (JPF)	Rs. 19200/ pm	Resigned from post in October end 2017. Joined GSI as assistant geologist.
2	Ms. Bency David	MSc. in Ecology and Environment Science	JPF since 8th December 2017	Do	Continuing

5. Equipment and Asset Information

Sl	Equipment Name and Quantity	Details (Make/Model)	Cost	Date of Installation	Photographs of Equipment	Lowest Quotation, If Not Purchased
1	Tree ring measuring Machine	LINTAB 6 (TSAP win scientific) from Rinntech Germany	10080 Euro	18th April 2017		
2	Centrifuge machine	Remi with 8 sample rotar	Rs. 40,000/-	January 2017		
3	4 Tree ring corers	Hogloff, Sweden	Rs. ~2 Lakhs	procured		

6. Expenditure Statement and Utilization Certificate

Please update the annual Expenditure Statement and Utilization Certificate (UC) periodically.
Expenditure Information:

S. No.	Financial Position/Budget Head	Funds Sanctioned	Expenditure	% of Total cost
I	Salaries/Manpower cost			
II	Travel			
III	Expendables &Consumables			
IV	Contingencies			
V	Activities & Other Project cost			
VI	Institutional Charges			
VII	Equipments			
	Total			
	Interest earned			
	Grand Total			

Period	Expenditure Statement	Utilization Certificate (UC)
Annual	[Attach]	[Attach]

7. Project Beneficiary Groups

Beneficiary Groups [Capacity Building]	Target	Achieved
No. of Beneficiaries with income generation:		
No. of stakeholders trained, particularly women:		
No. of capacity building Workshops/ trainings:		
No. of Awareness & outreach programmes:		
No. of Research/ Manpower developed:		

8. Project Progress Summary (as applicable to the project)

Description	Total (Numeric)	Description
IHR States Covered	02	1. Chota-Tungnath, Uttarakhand in 2016. Daksum-Sinthan, Kashmir, J&K in 2017.
Project Site/ Field Stations Developed:	.... (attach photos) ... (attach maps)	
No. of Patents filed (Description):	NA	
Article/ Review/ Research Paper/ Publication:		
New Methods/ Modelling Developed (description in 250 words):	NA	DBH and Age model developed for *Abies* of Tungnath area. Using the tree ring cores, and measured girth at breast height for the trees, the correlation model (Fig 1a) has been developed between the Diameter at breast height (DBH) and Age of around 120 trees. The model [Y =182.37X+48.421; R^2=0.4227,

		Y-age, X_{-DBH}] is useful in calculating the age of uncored *Abies* trees with measured girth at breast height (GBH) growing at the Tungnath area (Uttarakhand).
No. of Trainings (No. of Beneficiaries):		
Workshop:	NA	
Demonstration Models (Site):	.... (attach maps about location & photos)	
Livelihood Options:		
Training Manuals:		
Processing Units:	(attach photos)	
Species Collection:	03	Tree ring sample collection of *Abies spectabilis, Betula utilis* and *Pinus wallichiana* species
Species identified:		
Database/ Images/ GIS Maps:		

Note: Photos/ maps should be attached in high quality in compatible formats *viz*., JPEG, .JPG, .PNG, .SHP, etc. along with a suitable figure legend/ caption.

9. Project Linkages (with nearby Institutions/ State Agencies)

S. No.	Institute/ Organization	Type of Linkages	Brief Description

10. Additional (publication, recommendations, etc.)

Time Period	Publications
	(Research Papers, Information Material, Policy drafts, Patents, etc.)
Annual [Year .....]	

11. Project Concluding Remark

Kindly update the following Progress Parameters for the Reporting Period:

Project Objectives	Project Output against each objective	Progress made against Monitoring Indicators (specified in Sanction Letter)	Remarks
To study sensitivity of tree ring growth of selected tree line species to climate change	The samples collected from both the area of IHR were processed and analyses for one species (*Abies*) have been finished with the data generation. The data generated has been analyzed for the age stand structure, Temporal tree line dynamics, shift rate and climate growth relationship of the *Abies* for the Tungnath area (Uttarakhand). The samples of *Abies* and *Pinus* collected from Kashmir region have been processed and measured for further analyses. Future sampling will be carried out from the Himachal and Sikkim regions of IHR in 2018-19 and their analyses.		
To study relationship between tree ring growth and climate change in different climate regime across IHR			
To reconstruct past spatio-temporal climatic variability in timberline in IHR			

Methodology (in brief):	Selection of suitable natural sites. Collection of the tree ring samples (using hoglof increment borer) from tree line limit and ecotone range. Processing of samples (mounting and polishing). Tree ring counting, measurement (using Lintab machine), cross dating of samples and development of ring-width chronology (using softwares COFECHA and ARSTAN). Establishing tree growth and climate relationship, analyzing stand structure and shift rate of tree line species. Correlation of ring-width chronology with the climatic parameters. Reconstruction of the climate using transverse function.
Major Research Achievements :	**<u>For Chopta-Tungnath temple transect (Uttarakhand):</u>** • *Abies spectabilis* forms the conifer limit at ~3355 m amsl overtopped by *Rhododendron companulatum* till ~3500 m amsl. • The oldest tree of *Abies* (~379 yrs) reported at altitude ~3000 m amsl. • The uppermost *Abies* tree reported at ~3364 m amsl is ~109 yrs old. • DBH-Altitude relationship (Fig 1b) show good number of high girth class trees of *Abies* along the ecotone limit. • The highest girth *Abies* trees (DBH 1.45 and 1.46 m) are at altitude ~2790 m amsl but younger in age (~310 yrs) than the oldest tree. • Average advancement of ~350 m (between 3000 to 3364 m amsl transect) since past 280 years (1647 to 1907 AD) with shift rate of ~9.8 m per decade is calculated for *Abies*.

	• Shift rate was highest (~36 m per decade) between 3100 to 3300 m amsl transect during 18th century AD (1720 to 1780 AD), when the ring growth trend was also recorded high. • The natural regeneration of *Abies* is not reported above the present fir limit, hence suggesting abrupt fir limit and mainly having control of human activities and herbivore grazing for present stand structure. • Climate-growth relationship shows positive correlation with temperature for winter months suggesting winter warming favours the tree growth by extending the growing period. • Correlation is negative for precipitation for June, July, September and October months indicate that the high precipitation during summer cause low tree growth in tree line areas. **For Daksum-Sinthan, Kashmir J&K** • The oldest *Abies spectabilis* tree of 463 years recorded from Daksum. More than 400 years chronology for *Abies* has been developed for further analysis. • *Pinus wallichiana* forms the highest conifer tree limit at 3584 m amsl altitude in association with *Juniperus* sp. on dry slopes. • Regeneration of *Rhododendron companulatum* observed along the slopes. • Regeneration of *Abies* along the slopes at lower altitudes within the valleys in association with *Rhododendron* (Fig 4). Also shows the topographic and biotic controlled regeneration.
Brief Conclusion - the current year progress – during the reporting period (point-wise): **Progress Achieved (%):** **Remaining work to be done:**	• Field work to second IHR site i.e. Kashmir (J&K). • New Staff recruitment. • For *Abies* samples of Tungnath DBH-Age model has been developed. Temporal Shift rate has been calculated. Ring width chronology has been established and relationship between growth and climate has been developed. • Manuscript is under progress for the results of Tungnath area. • For Kashmir, samples has been processed, counted for age and measured. Chronology development for further analyses is in progress. • Chronology development and data analysis for Kashmir samples. • Data generation for tree ring samples of *Betula utilis*. • Sample collection from Himachal and Sikkim regions to cover the entire Himalayan region and representation of different climate zones.

Sbmitted to:
Nodal Officer, NMHS-PMU
National Mission on Himalayan Studies (NMHS)
G.B. Pant National Institute of Himalayan Environment and

Submitted by:
Project PI (Signature): P.S. Ranhotra
Institution (Seal): BSIP, Lucknow
Dated (10/05/2018)

(Dr. B.S.Adhikari)

NMHS Progress Report
(Period from April 2017 to March 2018)

Title: Alpine plant communities and impact of snow-melt water on phenology at Tungnath, Western Himalaya

Aim: The present study is focusing on understanding spatio-temporal changes in herbaceous vegetation across different communities as well as across elevation gradient.

Location: The study is being carried out at Tungnath region, which is in the upper catchment of Alaknanda river in Chamoli District, Uttarakhand. The elevation ranged from 2900 m to 3680 m a.s.l. (subalpine to alpine). The local climate is influenced by the southwest monsoon (rainy season) in summer and westerly disturbances in winter. However, the precipitation largely occurs during the end of June until mid-September. The vegetation in the subalpine region mostly comprised broad-leaved sclerophyllous stands of *Quercus semecarpifolia, Rhododendron arboreum*, *R. campanulatum*, *Abies pindrow*, *A. spectabilis,* and *Sorbus* sp., whereas the alpine meadows in and around Tungnath were dominated by diverse grasses and Herbaceous plants.

Methods: Five major communities viz. *Trachydium*, Mixed herbaceous, *Polygonum*, Mixed *Danthonia* and *Danthonia* were selected as permanent sites to monitor structure, composition and phonological changes at spatio-temporal scale. During initial vegetation survey 25, 1x1m quadrats were laid randomly and the individuals of each species were counted, while tussock forming species cover and bunches were counted to understand the community structure. The phenological events has been recorded such as vegetative growth i.e. start of shoot elongation); reproductive stages i.e. flower buds swelling, flower open, flower senescence and fruit ripe) as per the "BiologischeBundesanstalt, Bundessortenamt und CHemischeIndustrie"(BBCH) scale (Hess et al., 1997) on a 20 days interval from May 2017 to October 2017. We have also identified four transects along elevation gradient starting from 3000m to 3600m and in each transect four altitudes (3200-3300 m, 3300-3400 m, 3400-3500 m and 3500-3600 m) were identified to study changes in species composition and phenological variation. At each altitude zone, 50x50m plot was selected and permanently marked. Within each such plot, 6 quadrats (3 in early snow melt area and 3 in late snow melt area) of 1x1m were laid. HOBO data loggers were installed at every 150m interval from 3000m to 3600m to record environmental variables such as ambient air and soil temperatures and relative humidity. Biomass and soil samples were also collected at regular intervals from all the plots to understand the nutrient dynamics.

Results:

A. **Spatio-temporal changes in herbaceous community and phenology:**

The density for *Trachydium*, Mixed herbaceous and *Polygonum* communities was highest as compared to following months, in Mixed *Danthonia* it was high and declined fast , may be

due to early growth cycle species and in *Danthonia* community it was initially low and further increased up to September and then declined (Fig. 1). The contribution to density across the months was 38-47% by *Trachydium* and 20-27% by *Oxygraphis* in *Trachydium* community, 30-37% by *Trachydium* and 16-20% by *Oxygraphis* in Mixed herbaceous community, 22-37% by *Ranunculus* and 10-12% by *Rumex* and 2-15% by *Poa* in *Polygonum* community, 34-40% by *Danthonia*, 12-26% by *Oxygraphis* and 9-14% by *Trachydium* in Mixed *Danthonia* community and 59-71% by *Danthonia*, 1-20% by *Fragaria* and 2-9% by *Anaphalis* in *Danthonia* community.

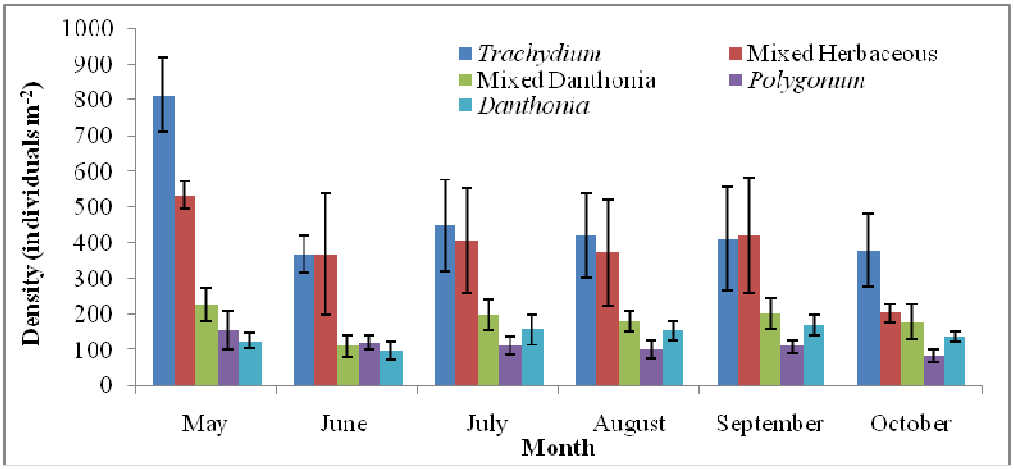


Fig. 1: Density (individuals m^{-2}) in different plant communities across months.

The species richness was highest in *Trachydium,* Mixed herbaceous and Mixed *Danthonia* community in the initial stage, while lowest in *Danthonia* community. Almost all communities showed high species richness during July, except Mixed *Danthonia* community, and continue till September and declined further. As a general trend, species richness attains two peaks during the month of July and September, could be due to early growth cycle and late growth cycle species (Fig 2).

Across the months the species diversity was highest for Mixed *Danthonia, Danthonia, Trachydium* and Mixed herbaceous communities in the month of July, while in August for *Polygonum* community. The communities like *Polygonum*, Mixed herbaceous, *Danthonia* and *Trachydium* the species diversity during July to September was similar (Fig. 2). The evenness values indicate that the species were unevenly distributed across the months in *Trachydium* community as compared to other communities, while in *Danthonia* it was initially even and later become uneven (Fig. 2). However, communities like Mixed *Danthonia*, *Polygonum* and Mixed herbaceous showed almost similar distribution across the months.

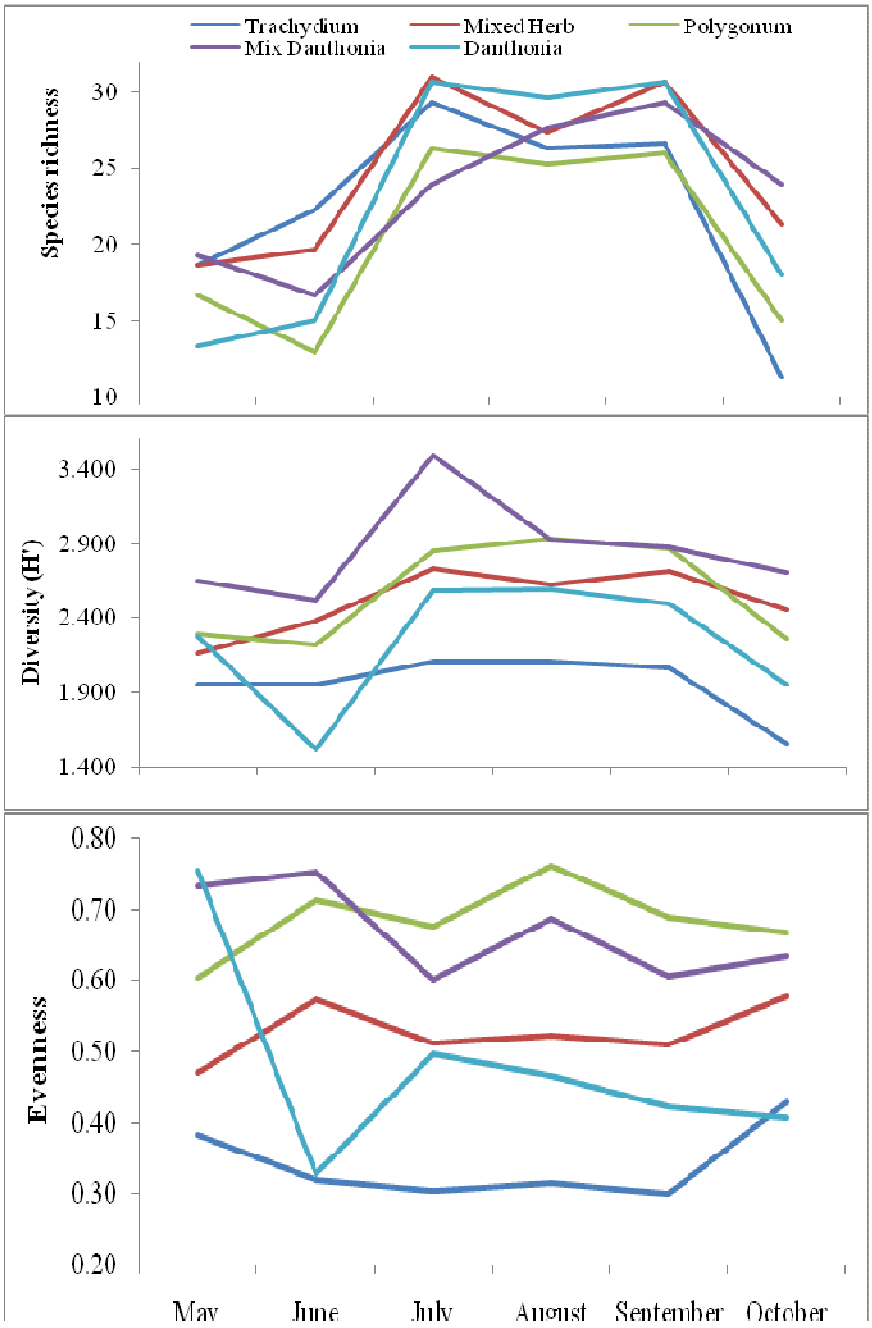


Fig. 2: Species richness (Top), Diversity (Middle) and Evenness (Bottom) of different plant communities across months.

Community phenology

The majority of species were in vegetative phase in May and June in *Trachydium* and Mixed herbaceous communities. In majority of species reproductive phenophase started from June and showed peak during August and September. Majority of species showed fruiting between

July to September, while most of species showed senescence during October in both the communities (Fig. 3).

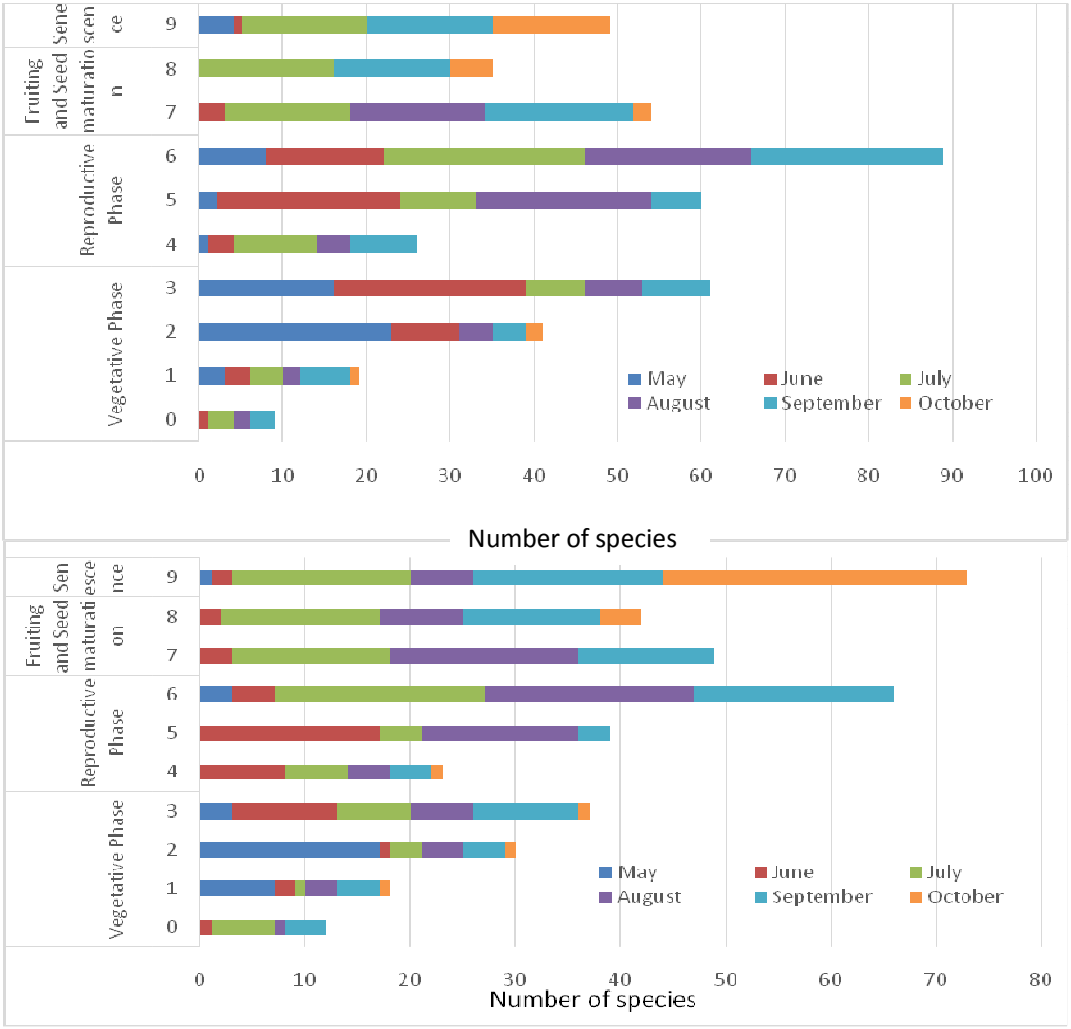


Fig. 3: Phenophases of different species across months for *Trachydium* (Top) and Mixed herbaceous (Bottom) communities as per BBCH scale.

The stages are: 0, Germination/sprouting/bud development; 1, Leaf development (main shoot); 2, Formation of side shoots/tillering; 3, Stem elongation/shoot development (Main shoot); 4, Vegetative propagation/ booting (Main shoot); 5, Inflorescence emergence (Main shoot)/heading, 6, flowering (Main shoot); 7, Development of fruit; 8, Ripening and maturity of fruit or seed and 9, Senescence or beginning of dormancy.

B. Spatio-temporal changes in herbaceous vegetation along elevation gradient:

As a general trend the species density across elevation gradient was highest in May and declined gradually for both early and late snow melt sites along elevation gradient. Species density was always higher in early snow melt sites, except Jhabra at 3300-3400m and 3400-3500m in Ravanshila. In early melt sites the density was comparatively much higher in lower elevation gradients (3200-3400m) than that of higher late snow melt sites, except Jhabra. The density was more or less similar in higher elevation gradients (3400-3600m) in early and late

snow melt sites. At each elevation, Chandrashila had highest species density as compared to other macrosites for early snow melt sites, while Ravanshila had highest species density for late snow melt sites.

Work going on:

1. The data for altitudinal phenology for the period of May 2017 to October 2017 is still being processed.
2. The data for community phenology is being processed for other communities (Mixed *Danthonia, Polygonum* and *Danthonia*).
3. The analysis of biomass and soil samples is under process.

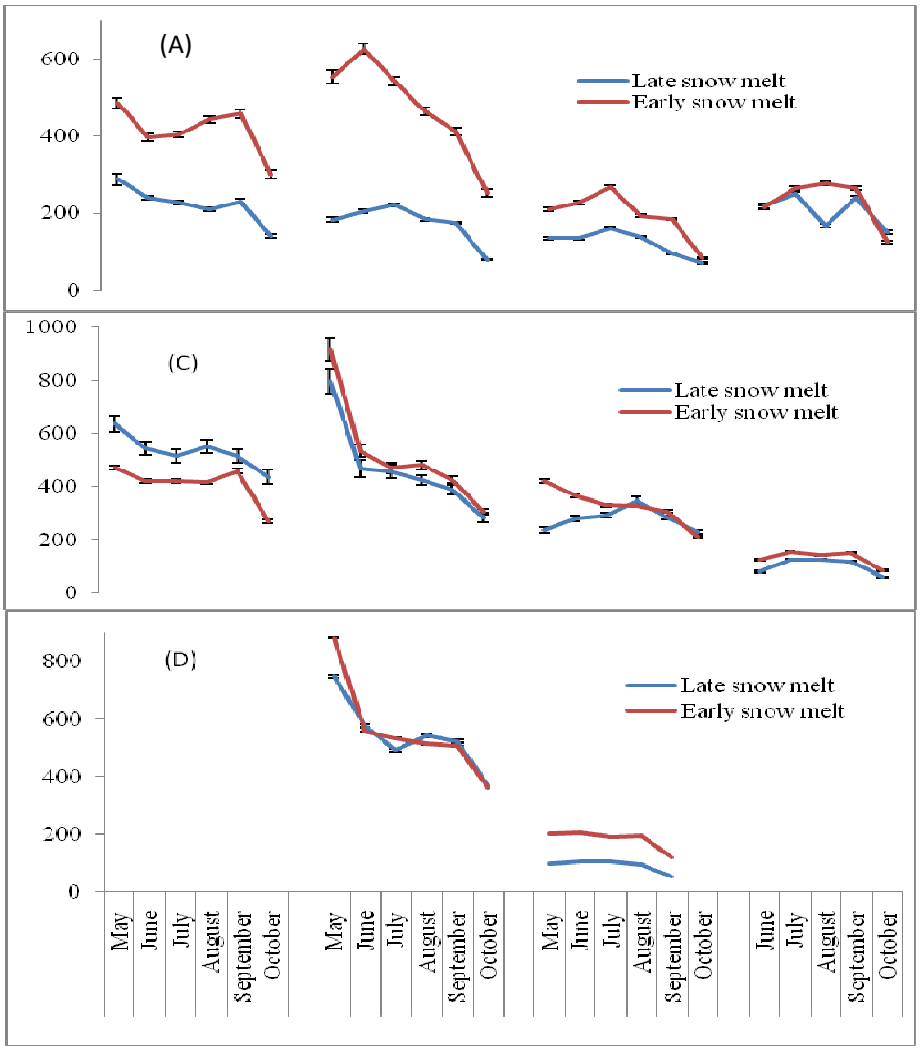


Fig. 4: Density (individuals m^{-2}) in early and late snow melt sites within each microsite at 3200-3300m (A), 3300-3400m (B), 3400-3500m (C) and 3500-3600m (D).