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

Under

National Mission on Himalayan Studies (NMHS)
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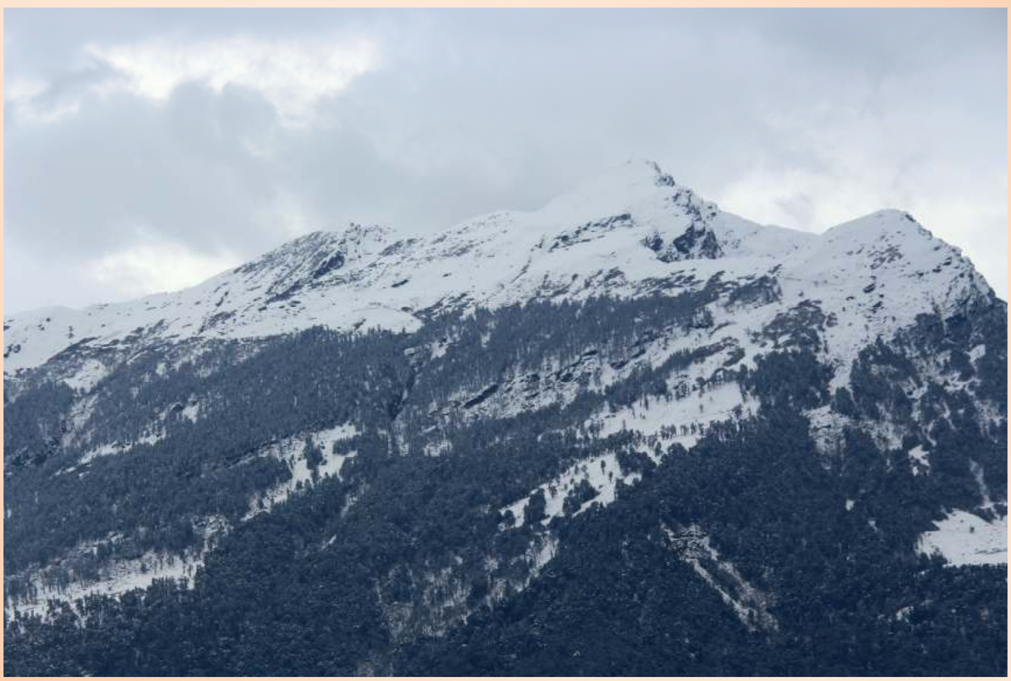
Six Month Progress Report: FY- 2017-18



Submitted to

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From

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Summary of progress -:

Soon after snow melt in Timberline sites, researchers began to visit study sites for data collection. Research programme of each study component was thoroughly analyzed and discussed to finalize data collection for year 2. Attention was particularly paid to snow melt study which needed some corrections and modifications. Several meetings with different groups were organized from time to time. Additional instruments were purchased and temperatures were measured at all the three sites. At Tunganth site, timberline forest hydrology was investigated. Visit to Kashmir enabled us to improve our understanding of heterogeneity in Himalayan timberlines and treelines. The need for ecosystem approach to describe treeline is being increasingly recognized. Below is the given a summary of various study components.

Creating geo-spatial data based and Timberline mapping: The detailed study on Uttarakhand showed the following: 52% of the slopes are steeper than 35º; and it has little area under flat surface (0.4%); the state is divisible roughly equally in 8 aspects; more area is between 1000-2000m (32.6%) than other elevation bands (7.71-20.7%); the total length of timberline is 2,543km in the state, and it is divided into 52 segments; more than half of the timberline length is between 3200-4000m; among the 13 watersheds, Ganga watershed accounts for the highest portion of timberline (16.2%); and LISS IV (5.8 m) is more effective in mapping timberline length in rugged topography of the state than Landsat (30 m), the former giving about 24% longer timberline than the later, while such refinement accounted less than 5% in moderate topography of Sikkim.

Temperature Lapse Rate: Because of additional efforts, now we have Temperature Lapse Rate (TLR) data for all the three sites. TLR is affected by aspect, season and location of the site. It was lower during wet, monsoon season than drier pre-monsoon, and across the sites it decreases with increasing wetness. The meaning and implications of these differences is being analyzed.

Plant diversity:

Kashmir- Plant species sampling continued along 2200m to 3800m elevation transect by sampling in 17,100m elevation bands and it yielded additional taxa: 326 species (173 species in year 1 sampling) of which 202 were herbs, 18 shrubs, 2 subshrubs and 8 trees. Among herbs 142 species were perennial, 3 biennial and 34 annual. Bryophytes consisted of 39 species (35 moss, and lichens 5-4 species). Data are being analyzed using appropriate statistics.

Uttarakhand- Vegetation studied continued in 100 m elevation bands along identified 2100-3200 m elevation transect. The broad outcome included: (i) collection of a total 176 new floral specimen representing 136 herbs, 32 - shrubs and 9- trees, (ii) detailed analysis of soil physico-chemical properties across altitude belts of studied transects, (iii) qualitative and quantitative assessment of fern flora (8 terrestrial, 3 epiphytes, 4 lithophytes), and (iv) collection of detailed information on anthropogenic disturbance intensities across studied plots.

Sikkim- Across the Yuksam-Dzongri transects, elevation gradient between 3000-3800 m asl was surveyed and a total of 27 plots were enumerated for plant diversity and community structure. Results revealed the presence of 25 tree species belonging to 12 families (Table1), a total of 10shrub species belonging to 5 families and a total of 29 herb species belonging to 25 families across the elevation gradient covered till date. Ericaceae emerged as the most dominant family in both tree and shrub layers, however, Asteraceae was the most dominant in herbaceous layer. The IVI indicates that the Abies densa dominates the plots between3800 and 3200 m asl with Sorbus microphylla is its prominent associate, however, the Tsuga dumosa was observed as the dominant species in lower altitudes (3100-3000 m asl) with different Rhododendron spp. as common associate.

Total nine major timberline sites were assessed for the estimation of total basal area, aboveground biomass, belowground biomass, total carbon, and stem density. The total basal area varied between 4.50(±2.41)-99.55(±1.90) m2ha-1. The total above ground biomass ranged between 15.35(±7.38)-279.25(±3.04) Mgha-1, while the total below ground biomass ranged between 9.85(±4.82)-144.76(±8.10) Mgha-1.

Phenology: Micro-environmental data are useful to understand plant phenology. In the forest stands soil temperature was conspicuously lower than air temperature for all the five species. Across all the species *B. utilis* stand recorded lowest values of soil temperature. As expected, compared to forests studied below 2500 m, leafing was delayed in timberline by about 1-2 months. Trees leaved out in May or June. However, leaf drop occurred earlier than the low altitude species. Leaf mass loss during senescence was relatively high, ranging from about 36% in *R. arboreum* to 45% in *Q. semecarpifolia*. Leaf nitrogen resorption from senescing leaves ranged from 41.5% to 66.8%. These values of leaf mass loss and leaf N retranslocation were greater than the low altitude species.

Tree water relations: At Tungnath (UK) site tree water potentials (from -0.71 to -1.2 MPa) indicated moderate stress, and during monsoon trees were always in moist conditions (>-0.16MPa).

At Chitkul site (HP) tree potentials in autumn from (-0.15 to -0.26 MPa) were similar to that of Tungnath trees in monsoon season.

Leaf conductance at Tungnath site was clearly higher for birch (304.6m mol m^2/sec) than for evergreen oak, *Q.semecarpifolia* (13.3-58.6m mol m^2/sec). Values were higher at Chitkul site.

Soil moisture pattern with soil depth varied between the two study sites. Soil was drier in top layer at Tungnath, while at Chitkul site during autumn upper layer was more moist, indicating that trees used more water from low soil layer.

Seeds of *Q.semecarpifolia* were highly desiccation sensitive, seed germination declining from 63.5% at 46.6% seed water content to 28.3% at 38.03% seed water content.

Tree ring width chronology: At Tungnath (UK) site correlation has been developed between tree ring width and climate (temperature and precipitation). Pre-monsoon (April-May) and early monsoon (June-July) temperatures were negatively correlated with tree ring width in silver fir, however, October-November temperatures were positively related to growth. Global warming might promote growth by prolonging growth period i.e., raising temperatures during autumn and winters. Sampling has been carried out at Kashmir where focus is on silver fir, blue pine, juniper, birch and rhododendron (*R. campanulatum*).

Snow melt water impact: In ridges snow melt occurs earlier than in depressions, but depressions have more moisture. So growth period is expected to be longer at ridges, but dry soil may limit plant growth. On the other hand in depressions plant growth would be delayed, but moisture will not be limiting. Often sunlight is more on ridges. The positive effect of early snow melt at ridges could be seen at some of the sites. However, patterns are a bit complex, and needs more analysis. Species richness across communities was low in May (21-27), then it picked up rapidly to peak in July (42-50 species), then it declined a bit in August (39-45 species) to rise again in September (41-47 species), and finally it dropped off in October (16-34 species), when temperatures were low. It seems that species composition changed July afterwards.

Snow melt and plant species relationships are not likely to be straight forward.

Livelihood: Following important livelihood activities were undertaken during the first 6 months of year 2: demonstration of off-season vegetable cultivation in 24 polyhouses; construction of poly line tanks for rain water harvesting; vermin-composting for organic manure and mushroom cultivation; imparting training for *Ringal* handicrafts; training for forest carbon measurement, bird watching session was organized to develop ecotourism. A considerable success has been achieved in establishing relationship with government departments while undertaking livelihood activities. Our experience in this has been quite encouraging and it has raised new hope.

The summary exceeded the limit of 200 words, as it covered several components undertaken by principal investigators.

Annexures

Annexure 1

Sub project: Timberline and Altitudinal Gradient Ecology of Himalayas, and Human Use Sustenance in a Warming Climate

(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:** From Indian Himalayan Region (IHR), five states have been selected for understanding timberline and altitudinal gradient ecology with human use sustenance in a warming climate. The selected states include Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Arunachal Pradesh, and Sikkim. Sikkim and Arunachal Pradesh represents north-eastern part and Uttarakhand, Himachal Pradesh, Jammu & Kashmir represents North-western part of IHR.

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 state standardized 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. RESULTS:

4.1. Geo-Database of Uttarakhand:

Uttarakhand state has thirteen districts (Fig. 1.) - Almora, Bageshwar, Champawat, Nainital, Pithoragarh, Utham singh nagar, Chamoli, Dehradun, Haridwar, Pauri garhwal, Rurdeaprayag, Tehri garwal, Uttarakashi, respectively.

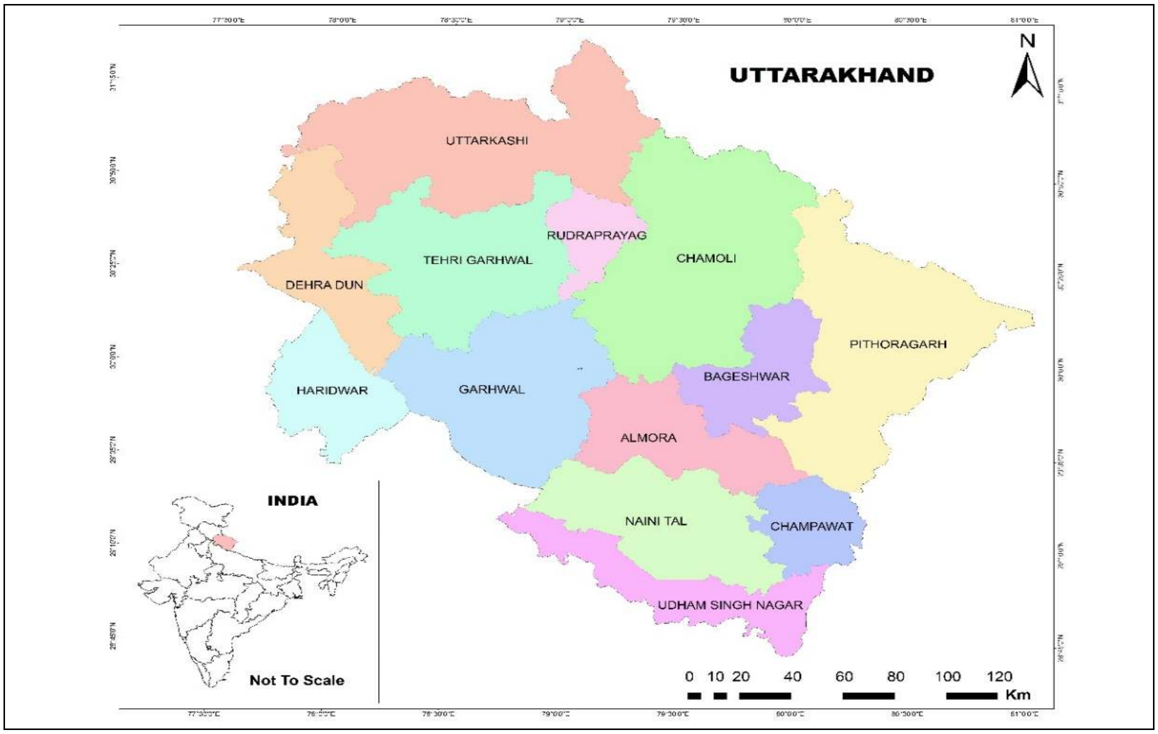


Fig. 1. Location map of Studied State – Uttarakhand

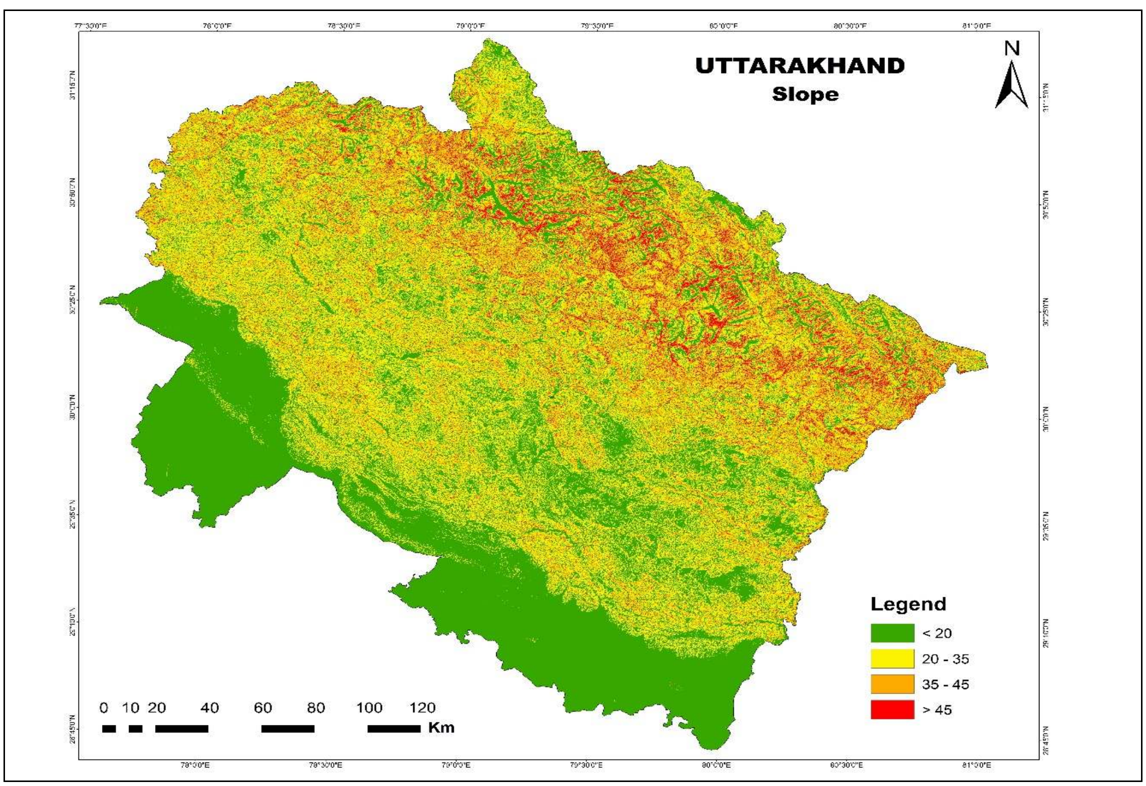


Fig. 2. Slope Map of Uttarakhand

Only (5.9%) of the state has gentle slopes (Table 1). 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 1. Uttarakhand State- Different Slope categories

(Values in parenthesis are per cent of total)

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

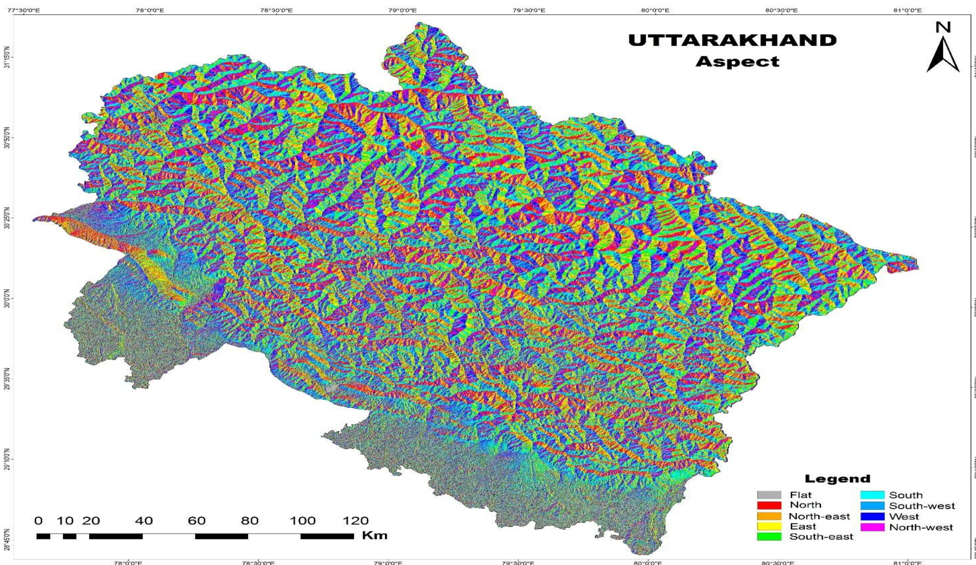


Fig. 6. Aspect map of Uttarakhand

A very small portion of the state can be considered as flat topography (0.04%). Distribution of mountainous topography in to different faces (Table 2) ranges between 11.8% (East) and 13.7% (South-west).

Table 2. 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%)

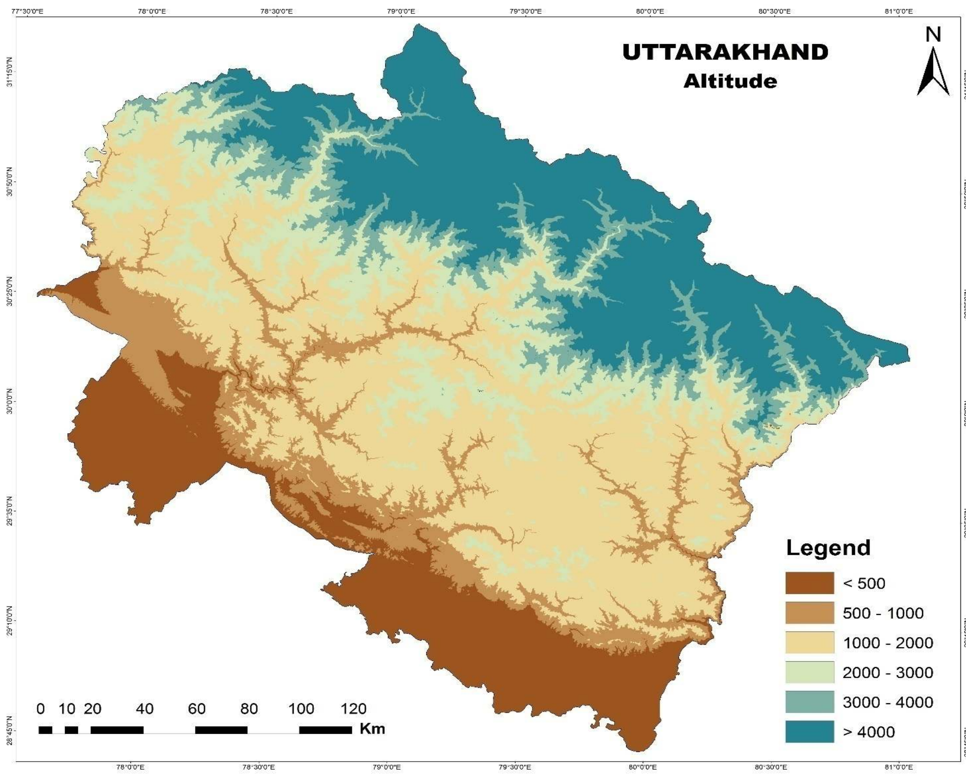


Fig 4. Altitudinal zone map of Uttarakhand

More than one fourth (20.73%) of the area of state lies above the permanent snow line (above 4000 m, Fig. 4). 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 3. 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 13 different watersheds in which Timberline exist and one non-Timberline watershed.

Table 4. Uttarakhand State – Sub-watersheds
(Values in parenthesis are percent of total)

S.No.	Sub-watersheds	Area	%
1	Bhilangana	1478.868	2.77
2	Birahi	1830.843	3.42
3	dharamganga	2363.689	4.42
4	Dhauliganga	3032.605	5.67
5	Ganga	4089.114	7.65
6	Goriganga	2234.22	4.18
7	Kaliganga	223.0434	0.42
8	Mandakini	1635.728	3.06
9	Pindari	2184.074	4.08
10	Ramganga	1354.466	2.54
11	Saraswati	1543.724	2.89
12	Saryu	2446.853	4.58
13	Yamuna	4683.086	8.76
14	Watersheds having no Timberline	24352.69	45.56

4.2 Regional Timberline in Uttarakhand State:

4.2.1 At Resolution of 30m:

Table 5. Characteristic of bands of Landset 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

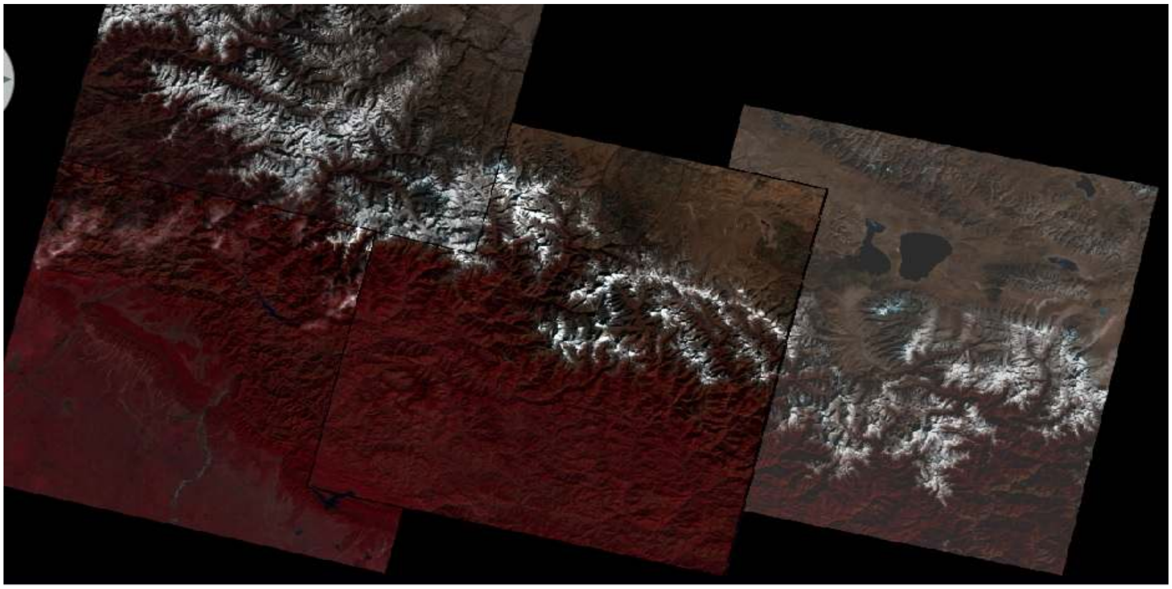


Fig 6. Landset 8

Timberline in the year 2015 (derived from 30m resolution of Landsat 8) is presented in Fig. 7. Total length of timberline is 2,543 km in the entire state but is broken at several places thus divided into 52 segments. In rare locations of the mountainous topography, timberline may descend to 2600m altitude (negligible but present). Most of the timberline is between 3200m and 4400m while above this minimal portion of timberline occurs. More than half of the total timberline of the state occurs between 3200m and 4000m altitude.

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 6. 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.

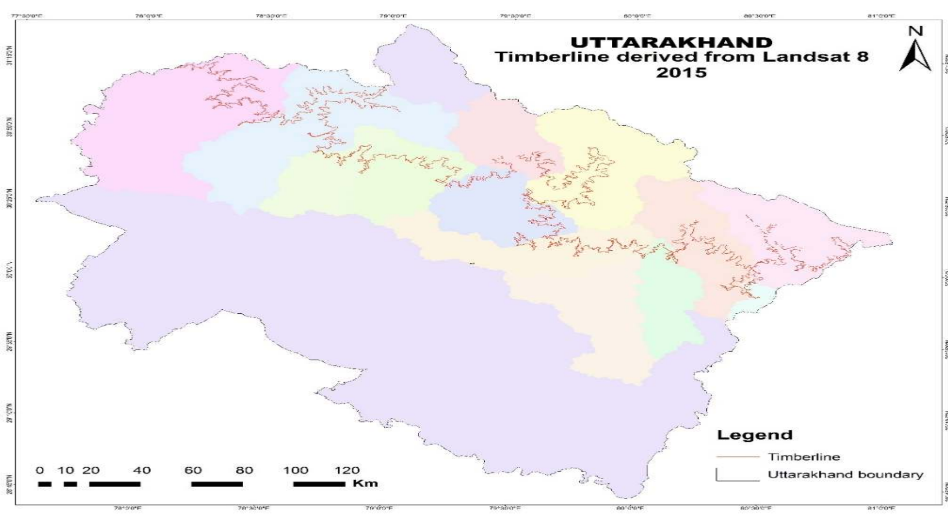


Fig 7. Timberline map of Uttarakhand derived from Landsat 8

Table 6. Distribution of Timberline (derived from Landsat 8) in different watersheds of Uttarakhand State (values in parenthesis are percent of total)

S.No.	Watershed	Length (Km^2)
1	Bhilangana	113.91 (4.5%)
2	Birahi	274.15 (10.8%)
3	dharamganga	277.42 (10.9%)
4	Dhauliganga	299.30 (11.8%)
5	Ganga	412.00 (16.2%)
6	Goriganga	254.70 (10.0%)
7	Kaliganga	37.77 (1.5%)
8	Mandakini	147.82 (5.8%)
9	Pindari	230.65 (9.1%)
10	Ramganga	62.23 (2.4%)
11	Saraswati	101.90 (4.0%)
12	Saryu	9.79 (0.4%)
13	Yamuna	322.22 (12.7%)

Distribution of timberline in different elevational zones of a watershed is given in Table 7. These attribute revel that a few rare locations presence of timberline may descend upto 2600m. 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. In Dhauliganga watershed elevation reaches to highest point but more than half timberline (52%) falls in between 3600m and 4400m.

Proportionate distribution of timberline in different watersheds of the state is depicted in Fig. 8. Peak occurrence of timberline in all the watersheds found between altitudinal zone of 3400m and 3800m, reflecting most favourable environment for timberline in this region.

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

Altitude	Bhilangana	Birahi	Dharamganga	Dhauliganga	Ganga	Goriganga	Kaliganga	Mandakini	Pindari	Ramganga	Saraswati	Saryu	Yamuna
2600-2800	0	0	1.62	0.46	0.37	0	12.96	0	0	0	1.36	0	0
2800-3000	0	0.45	1.11	1.86	0.99	0.79	7.60	0.48	0	0	1.19	0	0.38
3000-3200	0.06	2.58	1.32	2.19	2.28	2.22	5.36	3.80	2.47	0.86	1.75	0	1.93
3200-3400	14.43	18.98	9.55	7.88	12.11	10.90	11.97	28.20	23.13	9.20	4.50	15.63	6.20
3400-3600	60.30	41.99	24.32	12.26	33.80	19.87	21.36	46.47	43.10	42.86	13.21	81.94	28.24
3600-3800	21.96	25.69	28.30	27.92	30.95	28.17	24.58	17.29	21.45	34.19	24.66	2.43	43.97
3800-4000	3.25	9.38	23.99	24.58	16.07	26.88	15.19	3.77	8.68	12.89	39.23	0	18.45
4000-4200	0	0.93	8.49	11.68	2.85	8.32	0.98	0	1.18	0	13.57	0	0.67
4200-4400	0	0	1.29	7.79	0.59	2.24	0	0	0	0	0.53	0	0.16
4400-4600	0	0	0	2.54	0	0.61	0	0	0	0	0	0	0
4600-4800	0	0	0	0.84	0	0	0	0	0	0	0	0	0

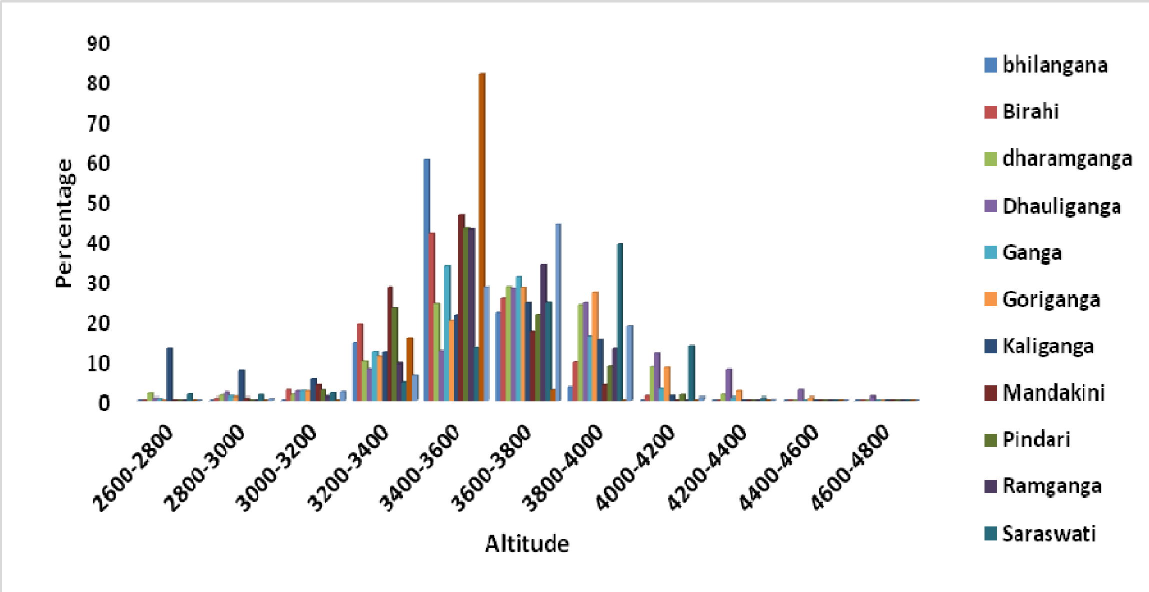


Fig 8. Distribution of Timberline (Landsat 8) in different Watershed of Uttarakhand

4.2.2 At Resolution of 5.8m:

Table 8. Characteristic of bands of LISS IV (Multispectral)

Band Name	Bandwidth(µm)	Resolution(m)
Band 2 Green	0.52- 0.59	5.8
Band 3 Red	0.62- 0.68	5.8
Band 4 NIR	0.77- 0.86	5.8

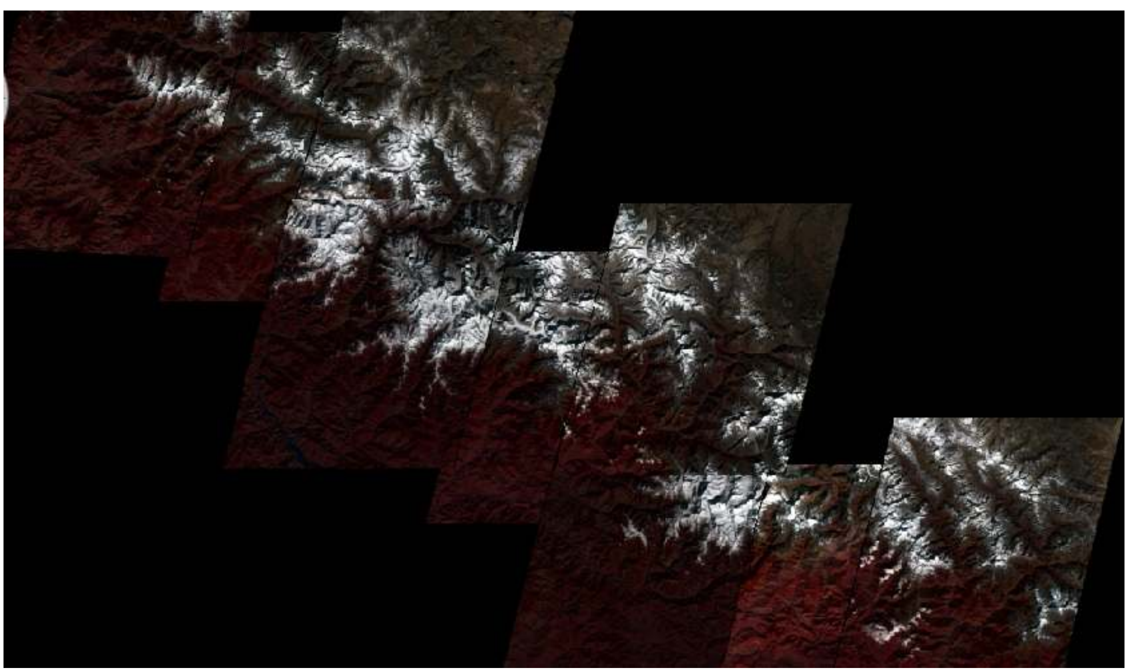


Fig 9. LISS IV

To refine the mapping and see the influence of satellite resolution, timberline was derived for the same year of 2015 by using LISS IV (5.8m resolution), and is presented in Fig. 10. Due to high resolution length of timberline increased by 614.4 km. Hence, high resolution image adds nearly one fifth (19.4%) to the mapping using 30m resolution.

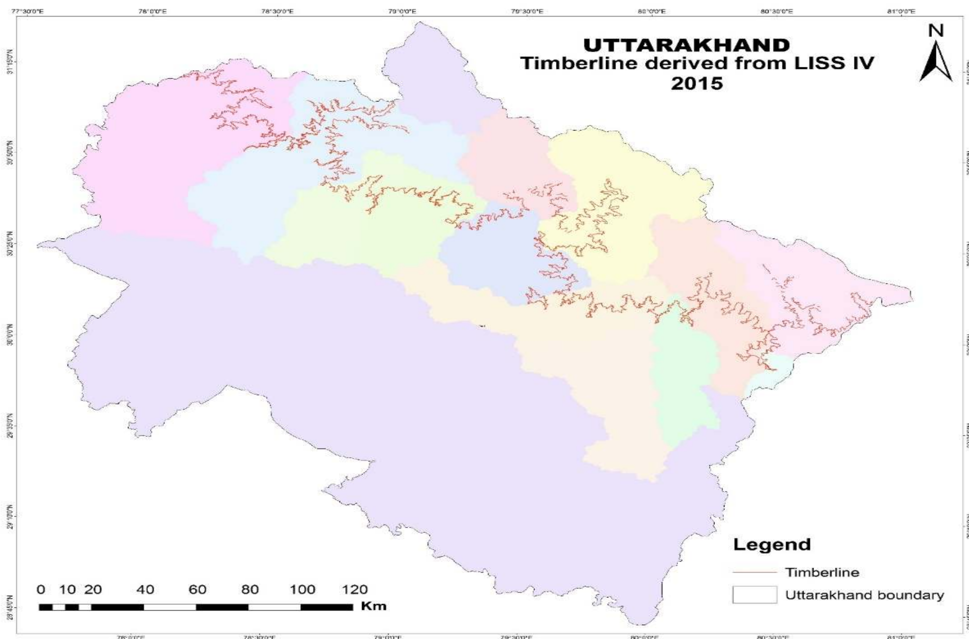


Fig 10. Timberline map of Uttarakhand derived from LISS IV

Table 8. Length of different watershed Timberline of Uttarakhand State derive from LISS IV (values in parenthesis are percent of total)

S.No.	Watershed	Length (Km^2)
1	Bhilangana	135.98 (4.3%)
2	Birahi	312.23 (9.9%)
3	Dharamganga	287.00 (9.1%)
4	Dhauliganga	322.35 (10.2%)
5	Ganga	689.71 (21.8%)
6	Goriganga	277.91 (8.8%)
7	Kaliganga	36.59 (1.2%)
8	Mandakini	246.46 (7.8%)
9	Pindari	240.73 (7.6%)
10	Ramganga	72.07 (2.3%)
11	Saraswati	107.54 (3.4%)
12	Saryu	14.76 (0.5%)
13	Yamuna	414.91 (13.1%)

Distribution of refined timberline of the Uttarakhand (i) in different watershed (Table 8) and (ii) in different altitudinal zones of a watershed (Table 9) is given. Ganga watersheds was gaining more length in the timberline due to higher resolution. Depending upon the topographical limitations within a watershed variation in occurrence of timberline may range widely between

2600m and 4600m in the state. However, full expression of timberline varies between the watersheds, maximum timberline occurs in an altitudinal zone of 3400-4000m altitudes.

Table 9. Percent distribution of Timberline in different altitudinal zones in different watersheds of Uttarakhand

Altitude	bhilangan	Birahi	dharamga	Dhauligan	Ganga	Goriganga	Kaliganga	Mandakin	Pindari	Ramganga	Saraswati	Saryu	Yamuna
2600-2800	0	0	1.67	0	0.11	0	3.75	0	0.00	0	1.11	0	0.00
2800-3000	0	0.35	0.65	1.45	0.97	0.60	8.34	0.00	0.00	0.00	1.07	0.00	0.29
3000-3200	0.15	3.38	1.85	2.37	2.39	3.00	5.65	1.99	1.57	1.16	1.39	0.00	1.68
3200-3400	13.17	19.70	10.97	8.22	12.55	11.03	12.72	19.37	22.78	7.76	3.48	43.35	5.96
3400-3600	57.43	38.00	26.21	16.30	24.28	19.20	29.47	46.72	44.53	45.34	9.11	54.13	26.02
3600-3800	26.50	24.61	27.55	29.72	34.20	30.64	25.80	24.73	21.78	34.94	20.80	2.52	44.64
3800-4000	2.75	12.28	25.69	29.97	21.31	28.63	13.43	7.19	8.59	10.80	50.96	0.00	20.92
4000-4200	0.00	1.68	4.88	9.58	3.94	6.17	0.85	0.00	0.74	0.00	12.08	0.00	0.50
4200-4400	0.00	0.00	0.53	2.22	0.25	0.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4400-4600	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Proportionate distribution of refined timberline in different watersheds of the state is depicted in Fig. 11. Similar to previous resolution of Landsat, peak occurrence of timberline in majority of the watersheds lies between altitudinal zone of 3400m and 4000m, further proving this zone most favourable environment for timberline in this region.

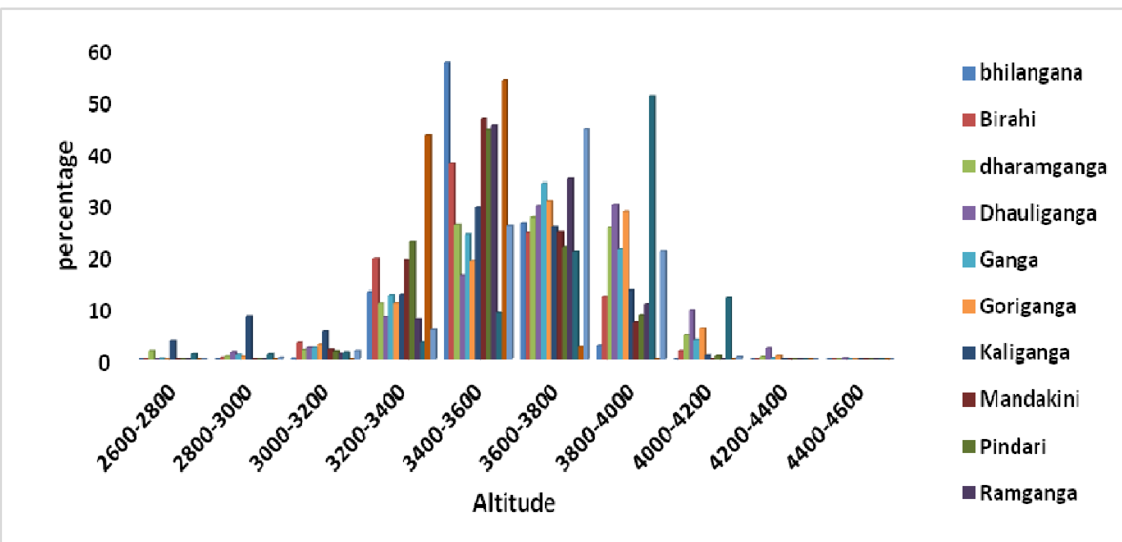


Fig 11. Distribution of Timberline (LISS IV) in different Watershed of Uttarakhand

5. Detailed Mapping of Intense Sites

1.1 Study Area - Tungnath

One of the intense study sites in the Central Himalaya lies between 30.47 - 30.51 N latitude and 79.15 - 79.22 E longitude, covering an altitude of ~1500 to ~3600m amsl in Chopta-Tungnath area. 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.

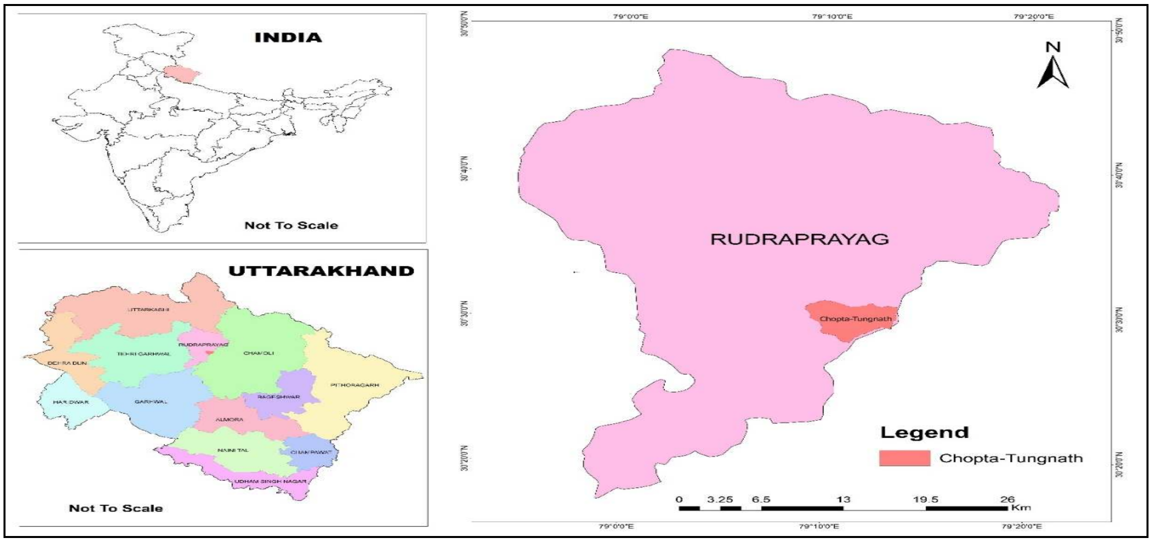


Fig1.1 Location Map of Chopta-Tungnath

2. Methodology

Major classes were categorized using recent (2015) LISS IV Multispectral imagery of Chopta-Tungnath. False Colour Composite of LISS IV Multispectral image was layer-stacked for the following bands (Table2.1).

Table 2.1. Characteristic of bands of LISS IV (Multispectral)

Band Name	Bandwidth(µm)	Resolution(m)
Band 2 Green	0.52- 0.59	5.8
Band 3 Red	0.62- 0.68	5.8
Band 4 NIR	0.77- 0.86	5.8

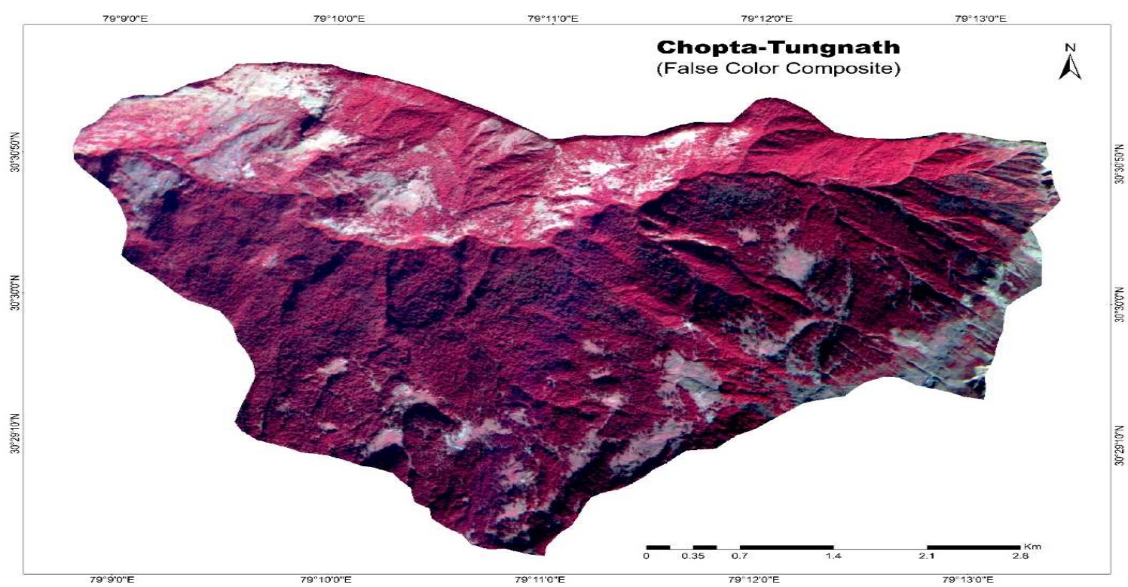


Fig. 2.1 FCC of Chopta-Tungnath

This image was subject to unsupervised classification (employed in ERDAS IMAGINE 2016), and ground truthing was done through high resolution satellite images.

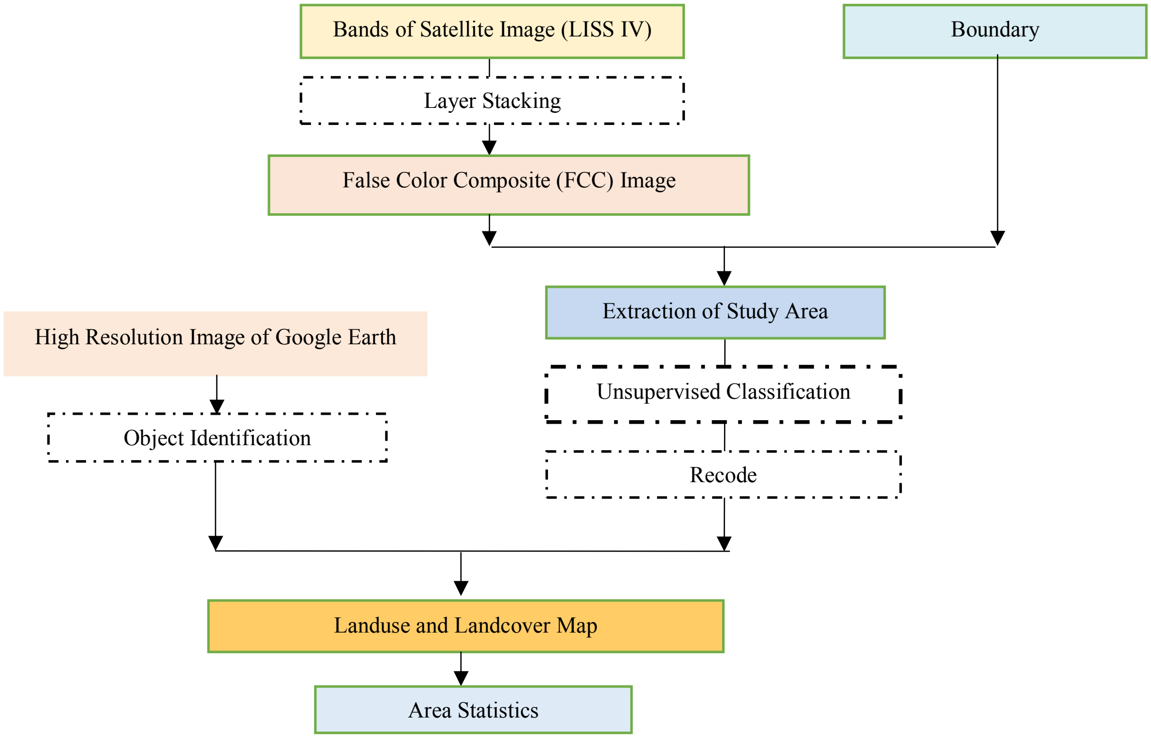


Fig. 2.2. Schematic Representation of methodology for Landuse/Landcover mapping of Chopta-Tungnath

3. Results

3.1. Landuse & Landcover of Chopta-Tungnath

Landuse/Landcover map of Chopta-Tungnath area has been classified (Fig. 3.1) into different classes (Alpine, Shrubs, Mixed Forest, Deciduous Dominated Mixed Forest, Grassland, Agriculture, Settlement, Barren, Water body and Road) using ERDAS IMAGINE 2016.

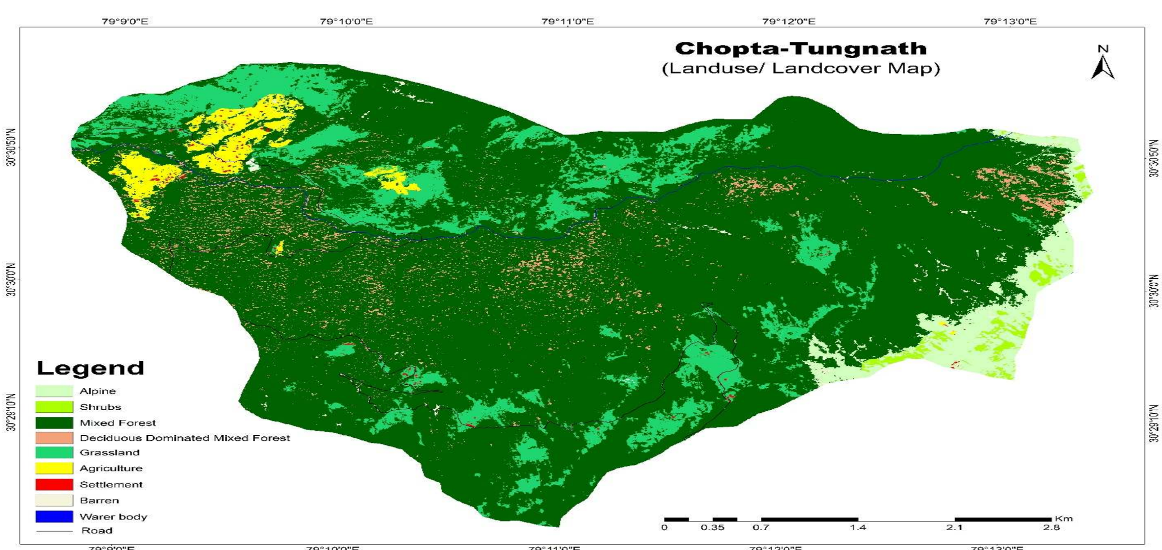


Fig.3.1 Landuse/Landcover Map of Chopta-Tungnath - Intense Field Study Area in the Central Himalayan Region

Detailed statistics for the Chopta-Tungnath is given in Table 3.1. Worthwhile to note that forest is dominating on the landscape covering an area of about 80 % of the total study area whereas 3.82%, 0.68%, 11.53% and 2.31% area was covered by Alpine, Shrubs, Grassland and Agriculture classes, respectively. Settlement, Barren and Water body covers an area of 0.6% of the total study area.

Table 3.1 Area under different Landuse/Landcover of Yuksom-Dzongri

Classes	Area (sq. km)	Area (%)
Alpine	0.92	3.82
Shrubs	0.16	0.68
Mixed Forest	18.79	78.31
Deciduous Dominated Mixed Forest	0.66	2.76
Grassland	2.77	11.53
Agriculture	0.55	2.31
Settlement	0.03	0.13
Barren	0.08	0.31
Water Body	0.04	0.16
Total	**24**	**100**

Annexure 2

Sub project-: To determine the temperature lapse rate (TLR) and pattern of precipitation along altitudinal gradients in different precipitation regimes across the IHR

(Dr. Rajesh Joshi)

Sanction No. and date -: NO. NMHS/LG-2016/009 dated 31-03- 2016

Institution Name-: G B Pant National Institute of Himalayan Environment and Sustainable Development, Kosi-Katarmal, Almora

Personal Details -:

Name & Address of the PI	**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--

Partner Details-: --NA—

Project Objective -: To determine the temperature lapse rate (TLR) and precipitation gradient (PG) along altitudinal gradients in different precipitation regimes across the IHR

Sub Objectives:

- To determine the TLR and establish the monthly, seasonal, and annual characteristics of TLR
- To determine the PG along altitudinal gradients in different precipitation regimes
- To analyse controlling factors on temperature lapse rate

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	Installation of temperature and Humidity loggers in selected sites along Daksum-Sinthan transect in Jammu & Kashmir completed.	Established 4 new climate monitoring stations in J&K. Hence, a total of 20 satiations for observation of meteorological parameters (i.e. temperature and relative humidity) have been established in three states (10 in UK, 6 in SK and 4 in J&K) of Indian Himalayan region	80%	Long term meteorological data generation, compilation and syntheses are under progress. Few stations in J&K are yet to be established depending upon suitability of sites.

		representing different climate regimes.		
2	Daily data on maximum, minimum and average temperature and relative humidity collected from 10 stations in Uttarakhand, 6 stations in Sikkim and 4 stations from J&K at different altitude for pre-monsoon and monsoon season.	Pre-monsoon (March-May) and monsoon (June-September) season TLR for two different aspects of Chopta-Tungnath transect (UK), pre-monsoon (March-May) season TLR for Yuksam-Dzongri transect (SK), monsoon season (June-September) TLR for Daksum-Sinthan transect (J&K) was determined.	60%	TLR for different sites were calculated depending upon availability of data. However, seasonal and annual TLR along different climatic regimes of IHR will be calculated after having relatively extended temporal data.
3	Nine (9) field based experiments for study of rainfall partitioning in tree line zone established.	Study of rainfall interception losses (i.e., through-fall and stem-flow) initiated for three different vegetation types; viz. Coniferous trees *species* (*Abies spectabilis),Broad leaf deciduous tree species (Qaercus semecurpifolia) and* Krumholz (*Rhododendron campanulatum)* initiated		Data compilation and analyses is under progress.
4	3 artificial runoff plots were established for each of 3 three different vegetation types (Conifers, Krumholz, and Grassland) for eco-hydrological studies in tree line ecotone of Chopta-Tungnath transect (UK)	Data on rainfall, runoff and soil loss from 9 artificial runoff plots was collected during monsoon season of 2017 for eco-hydrological studies of 3 three different vegetation types (represented by *Abies spectabilis, Rhododendron campanulatum , and* grass land) in treeline ecotone in CT transect (UK)		Data compilation and analyses is under progress. Rainfall, runoff and soil erosion modeling for different vegetation types initiated

Summary of progress -: (with in 200 words)

During April-September, loggers were installed in four different sites (1919- 2973 m asl) along Daksum-Sinthan transect in J&K (Table 1). Based on observed data, pre-monsoon (March-May) and monsoon (June-September) season TLR for Chopta-Tungnath transect (UK), pre-monsoon season TLR for Yuksam-Dzongri transect (SK), and monsoon season TLR for Daksum-Sinthan transect (J&K) was estimated.

For Chopta-Tungnath transect, along N-W aspect the mean, maximum and minimum values of pre monsoon season TLR are estimated as -0.0063 ^{0}C/m, -0.0081 ^{0}C/m, -0.0048 ^{0}C/m respectively. However, along S-E aspect the mean, maximum and minimum temperature are found to be decreasing at a rate of -0.0060 ^{0}C/m, -0.0073 ^{0}C/m, and -0.0049 ^{0}C/m respectively pre monsoon season (Table 2). Similarly, for monsoon season mean, maximum and minimum TLR values for N-W aspect are estimated as -0.0055 ^{0}C/m, -0.0067 ^{0}C/m, and -0.0054 ^{0}C/m respectively; whereas, for S-E aspect the mean, maximum and minimum TLR values are estimated as -0.0054 ^{0}C/m, -0.0058 ^{0}C/m, and -0.0052 ^{0}C/m respectively (Table 3).

For Yuksam-Dzongri transect, the mean, maximum and minimum values of pre monsoon season TLR are estimated as -0.0043^{0}C/m, -0.0014^{0}C/m, -0.0064^{0}C/m respectively (Table 4). For Daksum-Sinthan transect, the mean, maximum and minimum values of monsoon season TLR are estimated as -0.0071 ^{0}C/m, -0.015 ^{0}C/m, -0.0044 ^{0}C/m respectively (Table 5).

Supporting data files/ maps/ tables/ figures of the results

Table 1: Details of the long term meteorological observation sites established in Jammu & Kashmir

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

S-E: South East; TL: Temperature Logger

Table 2: Observed mean, maximum and minimum values of pre-monsoon season (March-May 2017) temperature lapse rate for two different aspects in Tungnath-Chopta transect (Uttarakhand)

TLR for North-West aspect (^{0}C/m)		TLR for South-East aspect (^{0}C/m)	
Mean	-0.0063	Mean	-0.0060
Maximum	-0.0081	Maximum	-0.0073
Minimum	-0.0048	Minimum	-0.0049

Table 3: Observed mean, maximum and minimum values of monsoon season (June-September 2017) temperature lapse rate for two different aspects in Tungnath-Chopta transect (Uttarakhand)

TLR for North-West aspect (^{0}C/m)		TLR for South-East aspect (^{0}C/m)	
Mean	-0.0055	Mean	-0.0054
Maximum	-0.0067	Maximum	-0.0058
Minimum	-0.0054	Minimum	-0.0052

Table 4: Observed mean, maximum and minimum values of monsoon (June-September 2017) temperature lapse rate for S-E aspects in Yuksam-Sinthan transect (Sikkim)

TLR for South-East aspect (^{0}C/m)	
Mean	-0.0043
Maximum	-0.0014
Minimum	-0.0064

Table 5: Observed mean, maximum and minimum values of monsoon (June-September 2017) temperature lapse rate for S-E aspects in Daksum-Sinthan transect (Jammu & Kashmir)

TLR for South-East aspect (^{0}C/m)	
Mean	-0.0071
Maximum	-0.0153
Minimum	-0.0044

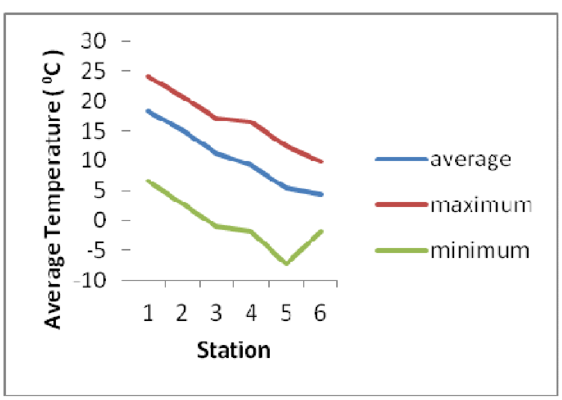


Figure 1: Temperature distribution along altitudinal gradient in North-West aspect of Tungnath-Chopta transect (Uttarakhand)

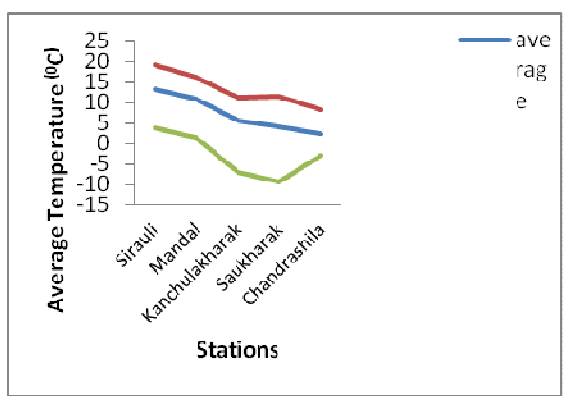


Figure 2: Temperature distribution along altitudinal gradient in South-East aspect of Tungnath-Chopta transect (Uttarakhand)

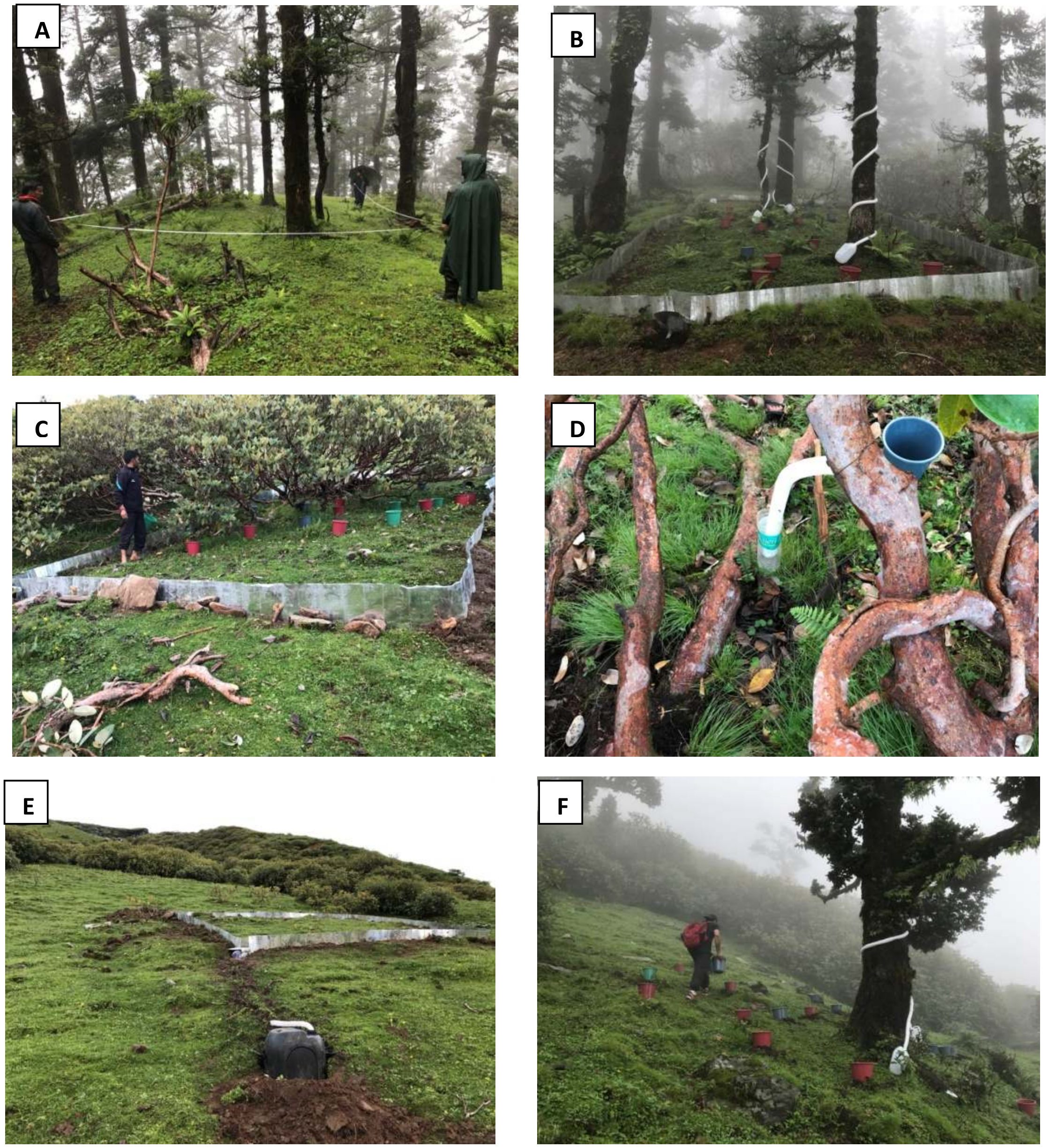


Plate 1: Representative photographs of selected sites for eco-hydtological studies of different vegetation types along treeline in Uttarakhand (A & B- Abies spectabilis, C & D- Rhododendron campanulatum, E- Grass-land, F-Quercus Semecurpifolia)

Sub-Project: Plant diversity and community structure along altitudinal gradient in three sites of Indian Himalayan region

(Prof. Zafar.A.Reshi)

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. Extensive 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 resulted in the documentation of 326 species belonging to 117 families and 229 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 and 56 species of lichens belonging to 30 families and 29 genera were also collected from the site.	1. In comparison to documentation of 173 plant species belonging to 134 genera and 75 families during the 1st year, currently we report 326 species belonging to 104 families and 230 genera from the study area. 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	Only one elevational gradient has been studied for exploring plant diversity and community structure in Kashmir Himalaya along the altitudinal gradient but we propose to undertake similar studies along two more

		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 addition to changes in seedling recruitment and diameter of several tree species in relation to altitude.	yielded interesting trends vis-à-vis timberline and treeline ecotone, and treeline in Kashmir Himalaya. 3. Seedling recruitment of tree species and stem diameter of adult tree species vis-à-vis altitude was also studied.	elevational gradients in Kashmir Himalaya in order to discern unambiguous elevational patterns of species diversity in the Himalaya.

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 326 species belonging to 229 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, 56 species of lichens belonging to 17 families and 30 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, crustose (27 spp.) and foliose (21 spp.) types were common in the study area compared to fruticose (6 spp.) and leprose (2 spp.) growth forms.

Pattern of species richness, abundance of tree and shrubs showed a characteristic pattern along the elevational gradient. Recruitment pattern and changes in trunk diameter of several tree species vis-à-vis altitude was also recorded during the present period.

Supporting data files/ maps/ tables/ figures of the results are attached

Name of the PI-: Prof. Zafar A Reshi

Signature -:

Date: 03-12-2017

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 shrubs and 40 (1x1 m) for herbs were laid randomly for sampling. 30 (10x10 m) quadrats for trees, 60 (5x5 m) for shrubs and 120 (1x1 m) quadrats for herbs were laid randomly 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 samples 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. 1-3). Species accumulation curves for trees, shrubs and herbs are given below which are suggest that sampling effort for recording species during the present survey in different altitudinal bands was adequate.

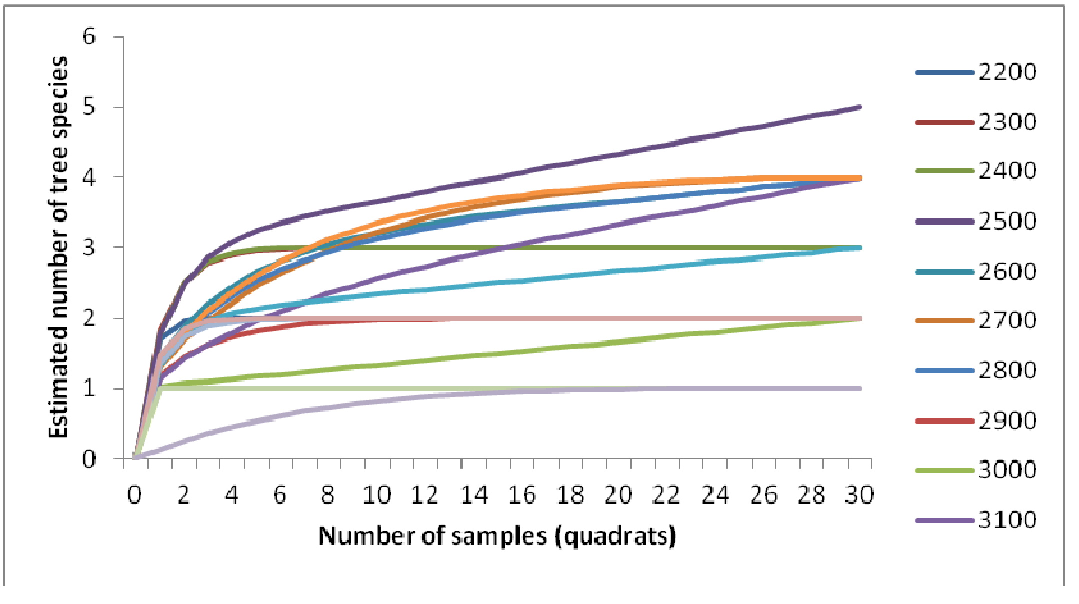


Fig.1. Species accumulation curves for trees in different elevational bands

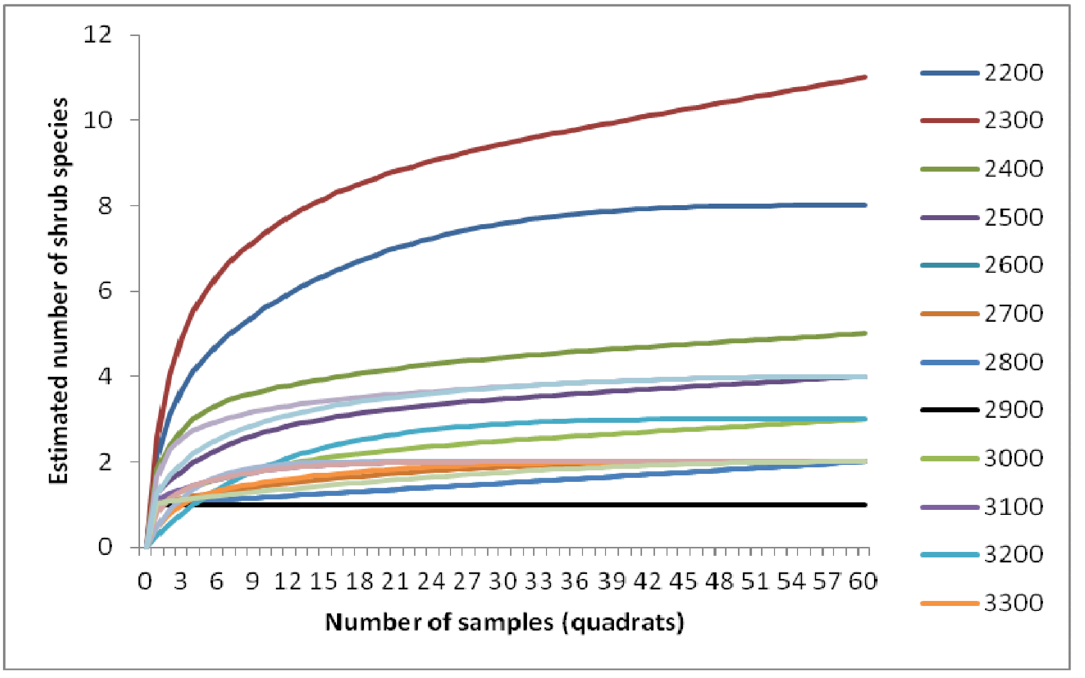


Fig.2. Species accumulation curves for shrubs in different elevational bands

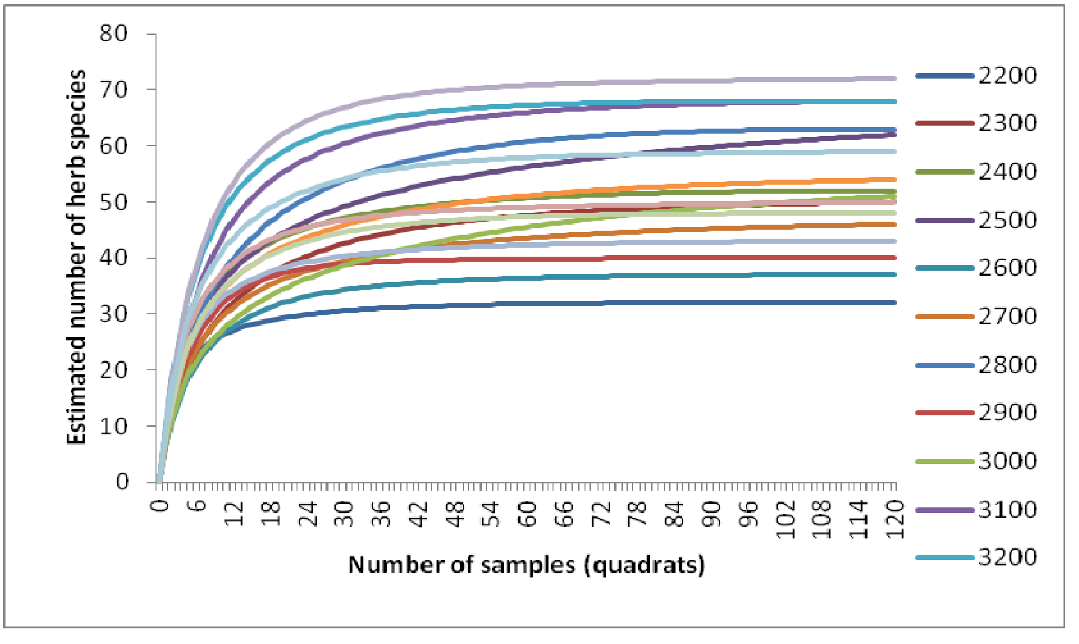


Fig.3. Species accumulation curves for herbs in different elevational bands.

Taxonomic diversity

Floristic surveys in the study site of Daksum-Sinthan Top in the Kashmir Himalaya resulted in collection and identification of 326 plant species belonging to 229 genera and 117 families (Table 1; Fig.4). 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 56 species of lichens in 29 genera and 30 families were also recorded from the area.

Table 1 Numerical analysis of plant taxa.

Plant group	No. of species	Genera	Families
Dicots	175	131	44
Monocots	19	16	10
Gymnosperms	4	4	2
Pteridophytes	33	16	9
Bryophytes	39	33	22
Lichens	56	29	30
Total	**326**	**229**	**117**

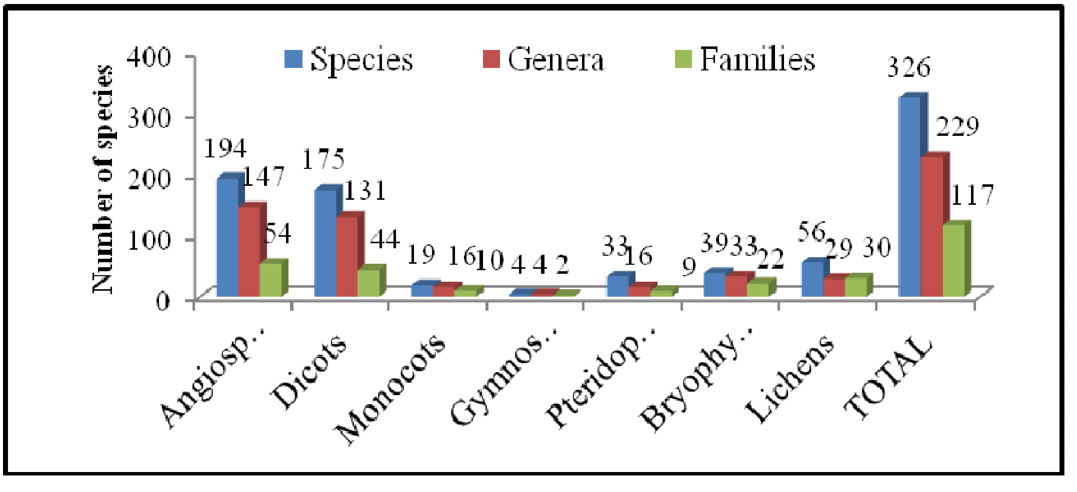


Fig. 4. Conspectus of the vascular plant species growing in the area.

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 with 8 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 represented by 8 species each, followed by Leconaraceae (7 spp.) and Telochistaceae (6 spp.).

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		
2.	Pinaceae	3
1.	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
Lichens		
1.	Parmeliaceae	8
2.	Physciaceae	8
3.	Lecanoraceae	7
4.	Telochistaceae	6
5.	Cladoniaceae	5
6.	Peltigeraceae	5

Functional diversity in vascular plants

a. Growth forms

In respect of growth forms of vascular plants (Fig. 5), 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.

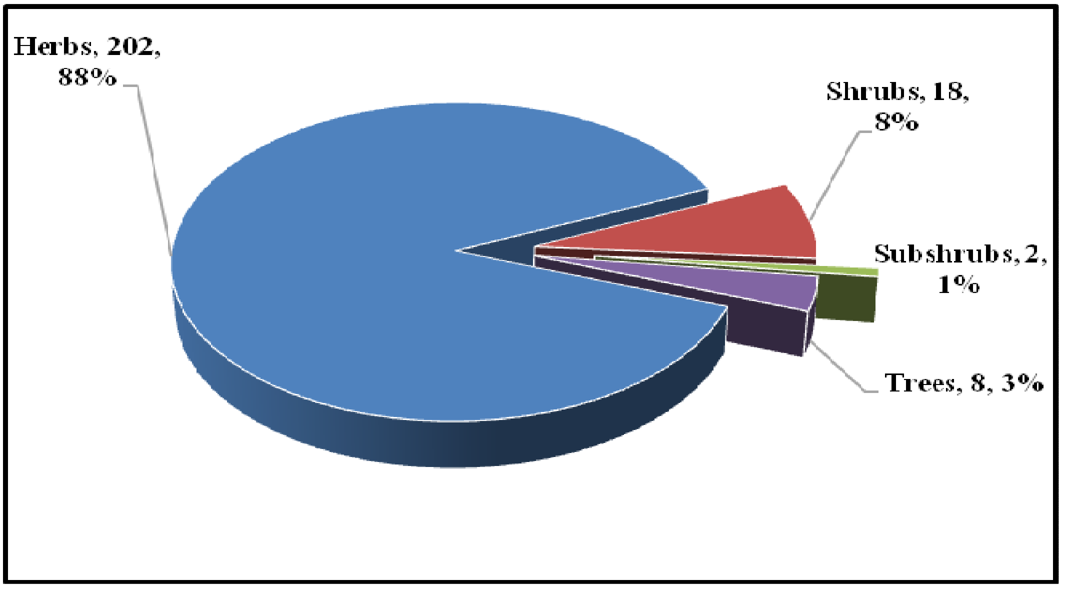


Fig. 2. Number and proportion of species of different growth forms.

b. Life span

In respect of life span of vascular plants (Fig. 6) 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

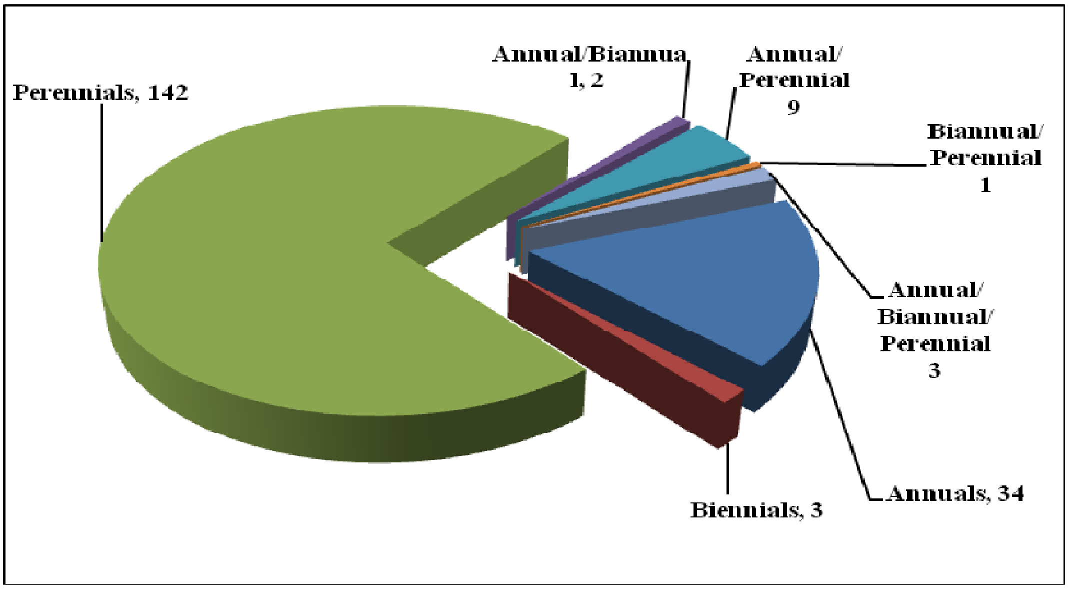


Fig. 6. Number of species belonging to different life span categories.

Functional diversity in bryophytes and lichens

Functional diversity computed in terms of growth habit of bryophytes and lichens in presented in Figs 7 and 8 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

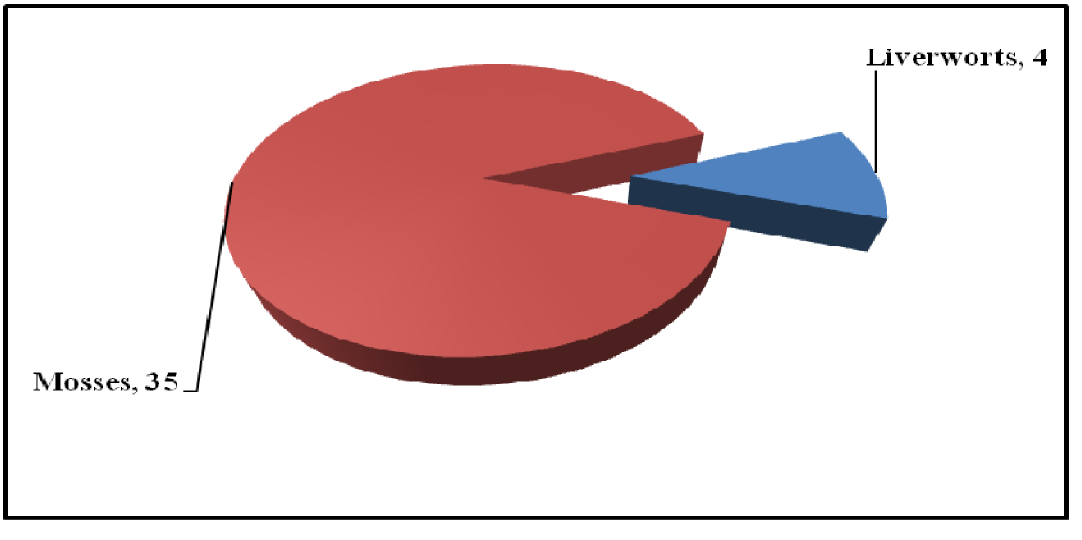


Fig. 7. Number of species of mosses and liverworts.

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

Growth habit	No. of species
Crutose	27
Foliose	21
Fruticose	6
Leprose	2

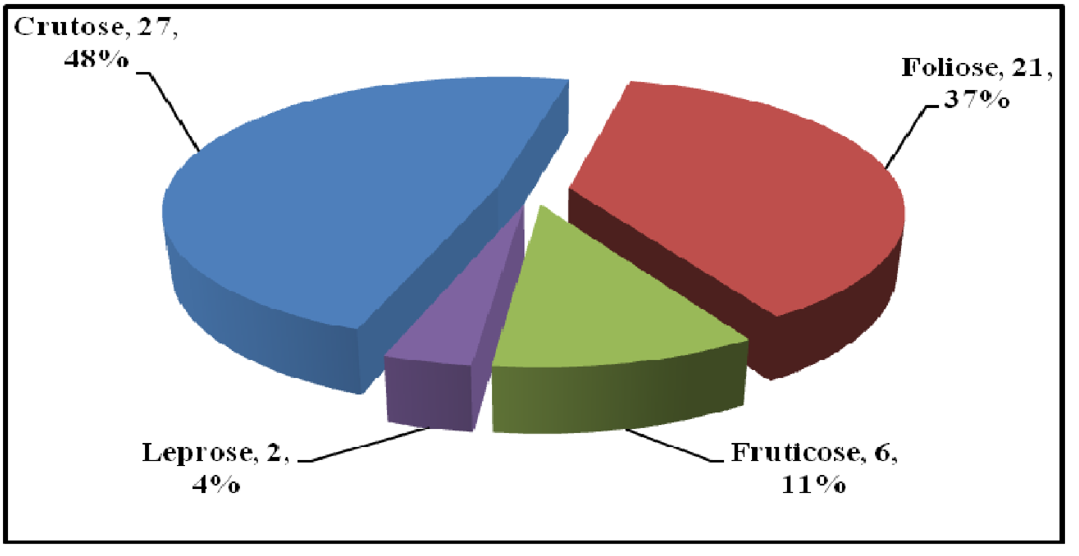


Fig. 8. Number of lichen species belonging to different growth habits.

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
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

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. 9).

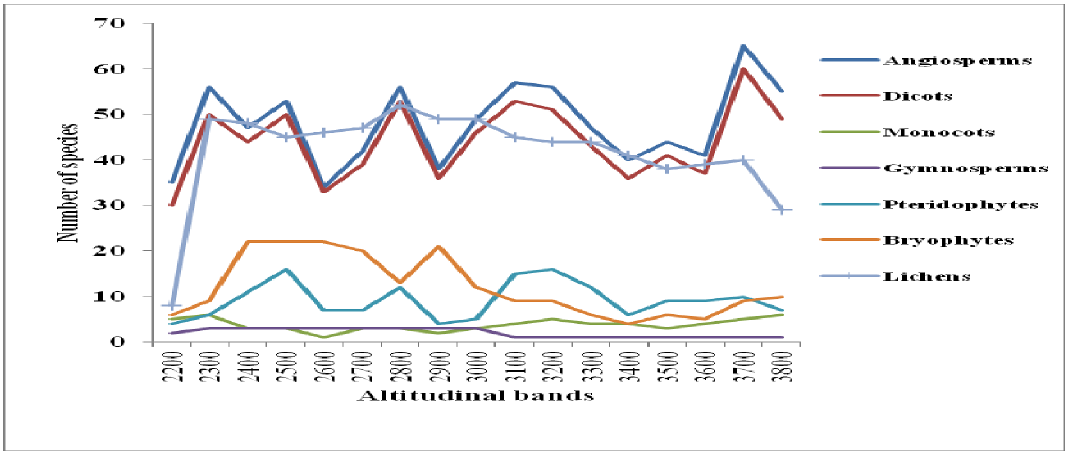


Fig.9. Species richness of different plant groups along the altitudinal gradient.

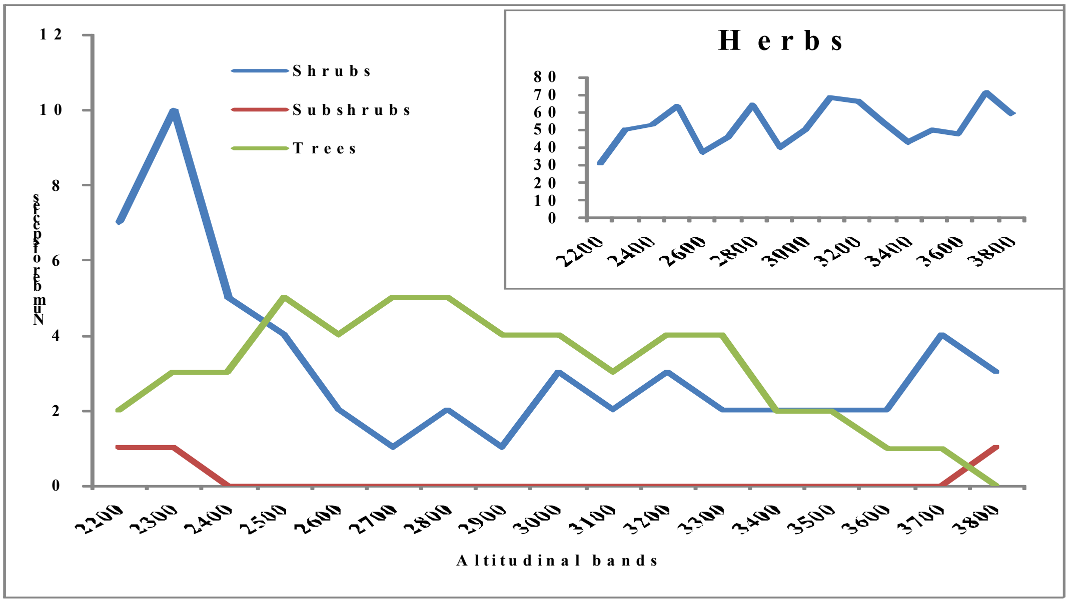


Fig.10. Number of species of different growth forms along the altitudinal gradient.

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.

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. Similarity index on the basis of shared species between altitudinal bands.

Altitudinal band	AB-2200	AB-2300	AB-2400	AB-2500	AB-2600	AB-2700	AB-2800	AB-2900	AB-3000	AB-3100	AB-3200	AB-3300	AB-3400	AB-3500	AB-3600	AB-3700
AB-2200	*	69.05	56.14	39.76	15.94	2.30	10.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AB-2300	*	*	85.34	66.65	42.93	26.09	35.43	24.83	26.56	24.35	21.96	21.46	23.74	23.89	0.00	0.00
AB-2400	*	*	*	81.21	59.21	41.48	50.94	41.04	43.85	40.26	36.37	35.57	39.28	39.51	0.00	0.00
AB-2500	*	*	*	*	77.71	59.19	68.69	59.65	63.59	58.55	53.05	51.91	57.16	45.53	0.00	0.00
AB-2600	*	*	*	*	*	78.22	88.90	79.75	79.70	78.16	70.25	65.13	69.69	49.36	0.00	0.00
AB-2700	*	*	*	*	*	*	84.86	82.49	87.98	88.33	78.89	78.25	73.04	45.78	0.00	0.00
AB-2800	*	*	*	*	*	*	*	89.16	84.33	87.49	81.36	71.84	74.39	46.63	0.00	0.00
AB-2900	*	*	*	*	*	*	*	*	87.30	89.04	88.37	71.60	76.73	48.11	0.00	0.00
AB-3000	*	*	*	*	*	*	*	*	*	91.04	80.22	79.52	81.88	51.36	0.00	0.00
AB-3100	*	*	*	*	*	*	*	*	*	*	83.42	81.56	75.31	47.21	0.00	0.00

AB-3200	*	*	*	*	*	*	*	*	*	*	*	70.41	69.26	43.82	1.16	1.89
AB-3300	*	*	*	*	*	*	*	*	*	*	*	*	76.50	51.66	10.34	16.52
AB-3400	*	*	*	*	*	*	*	*	*	*	*	*	*	72.73	28.01	19.57
AB-3500	*	*	*	*	*	*	*	*	*	*	*	*	*	*	56.41	19.78
AB-3600	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	21.68
AB-3700	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

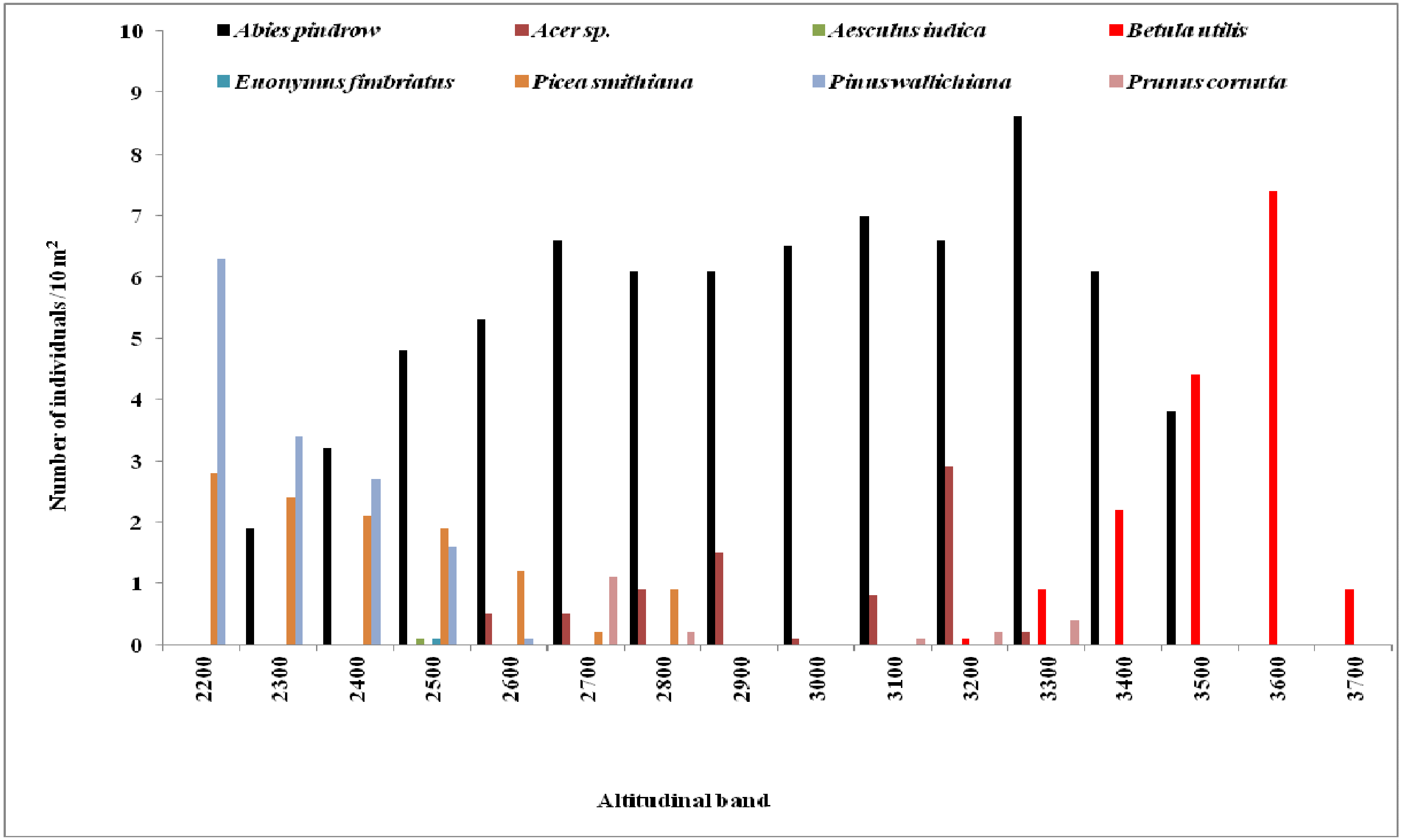

Abies pindrow
Acer sp.
Aesculus indica
Betula utilis
Euonymus fimbriatus
Picea smithiana
Pinus wallichiana
Prunus cornuta
Number of individuals/10 m2
0
1
2
3
4
5
6
7
8
9
10
2200
2300
2400
2500
2600
2700
2800
2900
3000
3100
3200
3300
3400
3500
3600
3700
Altitudinal band

Fig.11. Density (number of individuals/10 m^2) of various tree species in different altitudinal bands.

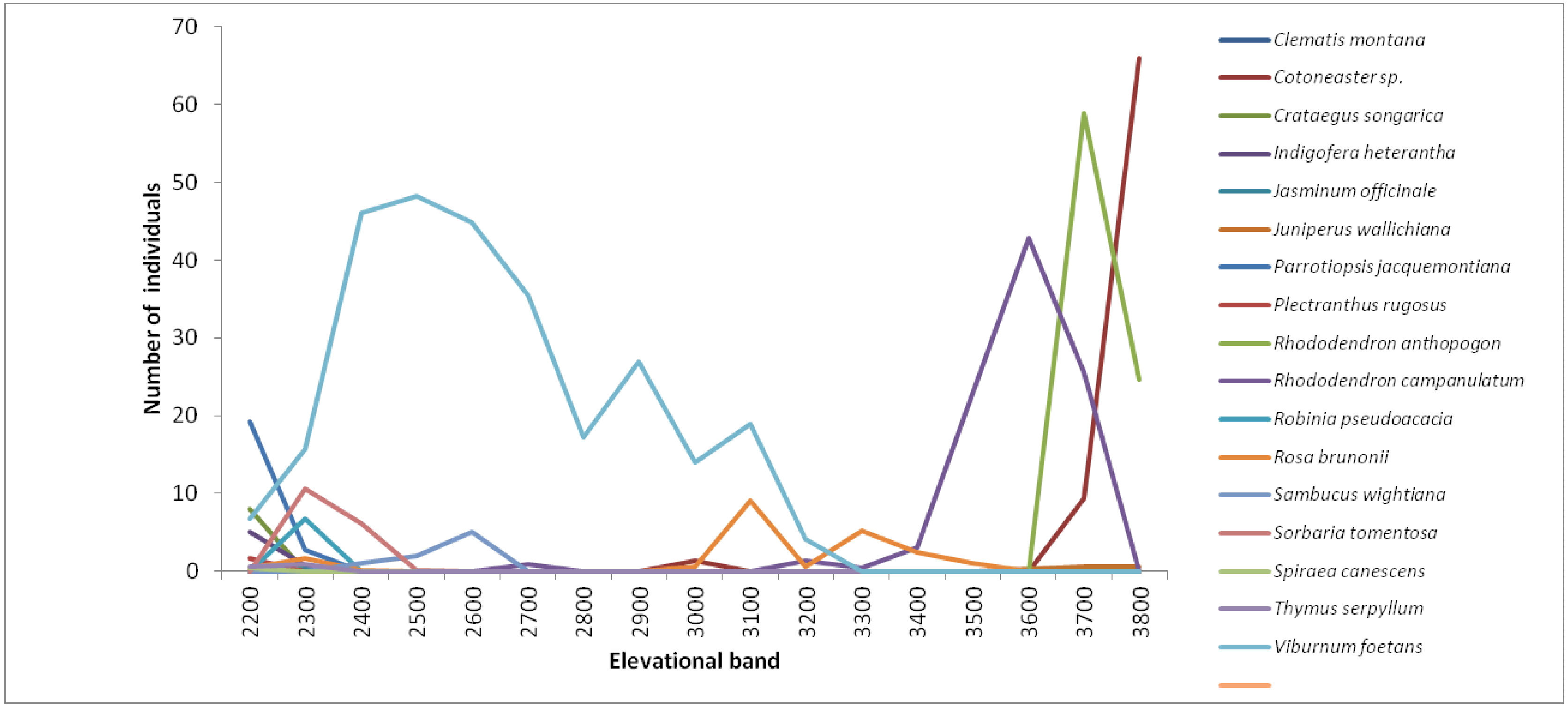


Fig.12. Density (number of individuals/5 m^2) of various shrub species in different altitudinal bands.

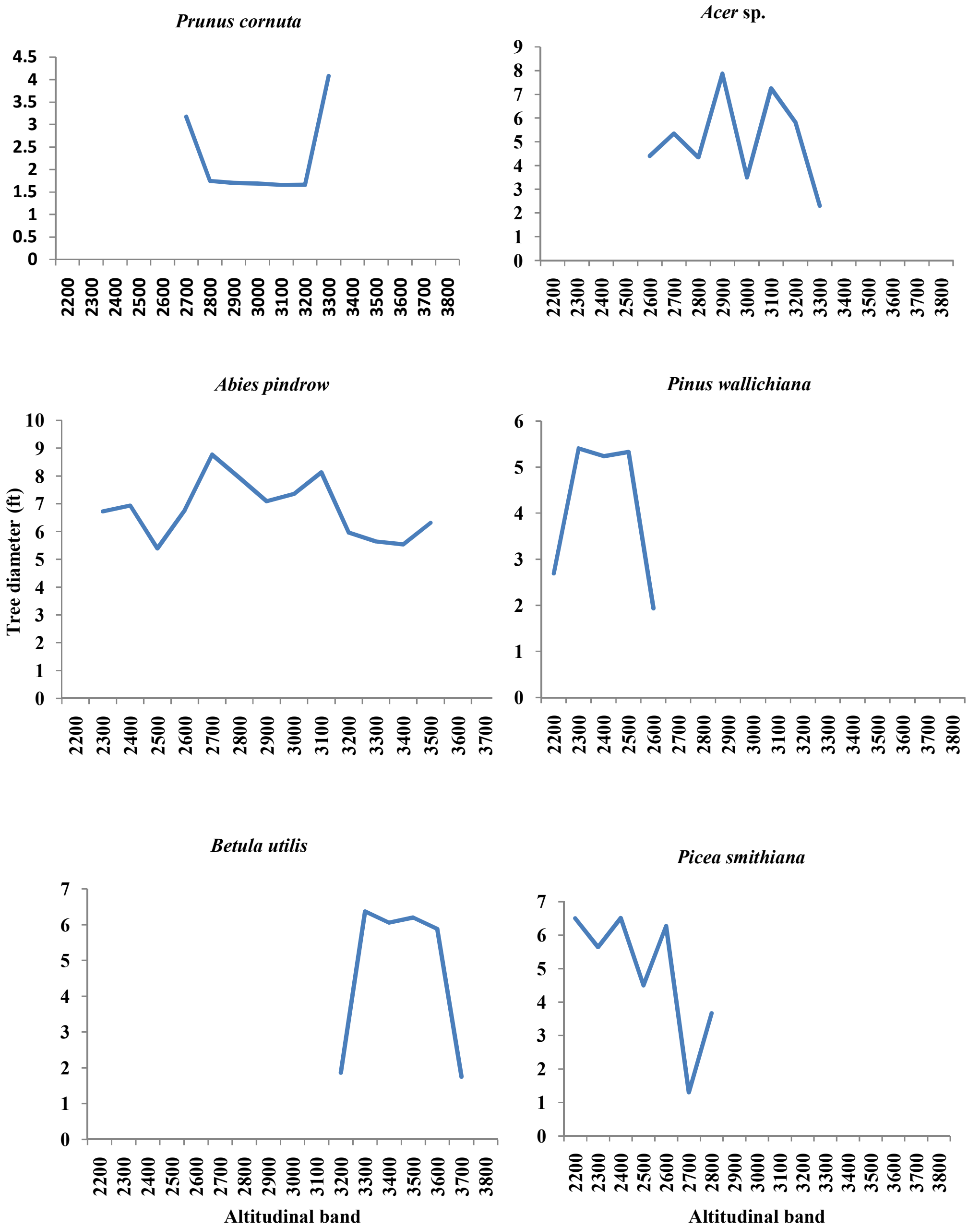


Fig.13. Changes in tree diameter in different altitudinal bands

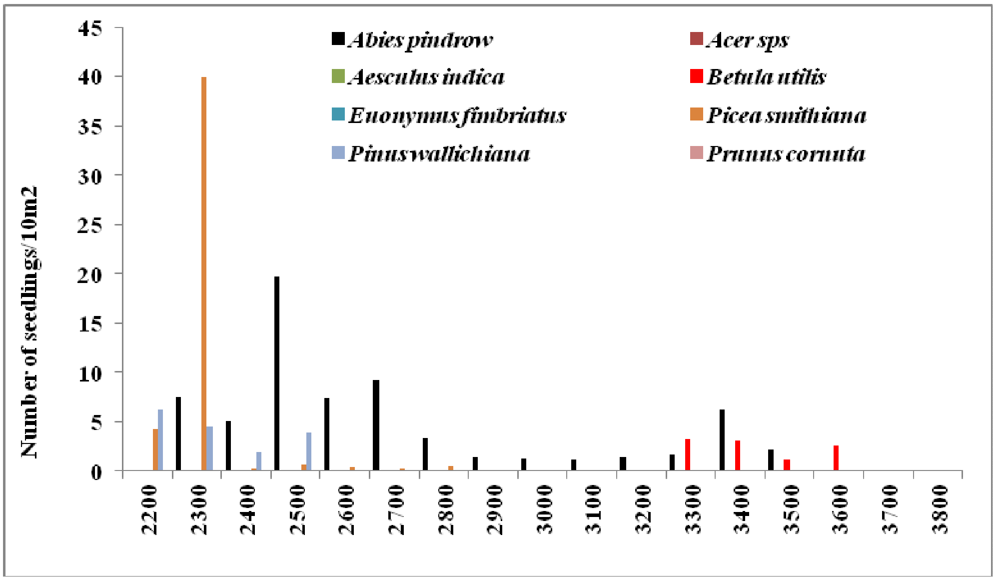


Fig.14. Seedling recruitment of various tree species in different altitudinal bands.

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.

Quadrat laying in alpine meadow **Tree diameter measurement at breast height**

Field survey team

Sub project: Plant diversity and community structure along altitudinal gradient in three sites of Indian Himalayan region

(Dr. R.S. Rawal)

Sanction No. and date: NO. NMHS/LG-2016/009 dated 31-03- 2016

Institution Name: G.B. Pant National Institute of Himalayan Environment & Sustainable Development

Personal Details:

Name & Address of PI	**Dr. R S. Rawal, Scientist F, GBPNIHESD, Kosi - Katarmal, Almora, PIN-263643**
Name & Address of the Co-PI, if any:	

Partner Details :

Sl No	Name/ Address	Work assigned to partners	Fund allocated to partners during the period
1.	GBPNIHESD, Kosi-Katarmal, Almora, Uttarakhand	Collection & analysis of data on Plant diversity along altitudinal transects of Uttarakhand	17,42,400.00

Project objective: 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 Deliverable):

S. No	Quantifiable Deliverables *(as per sanction letter)*	Output/ achievements	Performance in terms of Monitoring indicators	Remarks
1.	Creation of database and knowledge products on vegetation science and tree-soil water relations of timberline in3 principal sites (J&K, Sikkim and Uttarakhand) *(Plant diversity and community structure along altitudinal gradient in Uttarakhand site of Indian Himalayan region)*	• Collection of 176 plant specimens (136 herbs, 32 shrubs and 9 trees) for spring, summer and rainy season along identified altitude transect of 2100-3200 m asl. • Collection and analysis of soil samples for physico-chemical parameters (certain parameters yet to be studied) for each altitude belt. • Field vist for the data collection regarding phytosociological parameters and disturbance across the altitude gradient. • Collection and quantitative assessment of fern flora from the study site.	• Datasets along identified transect further strengthened w.r.t. soil parameters, floristic diversity, and disturbance intensity. • Installation of soil data loggers in the identified transect will provide data sets for soil temperature variations over the year.	• The plant specimens are under process of identification/ authentication. • Soil samples being analysed for remaining parameters

Summary of progress: (within 200 words)

- The information and data-sets from the studied altitude transect (in first year) were further strengthened w.r.t. (i) floristic diversity (specimen collection for different seasons) along the altitude range, (ii) understanding the disturbance intensity of various studied plots in each altitude belt, and (iii) variations in soil physico-chemical properties across the altitude range.
- The floristic diversity information was collected through repeat surveys and collection of plant specimens across diverse seasons (spring-rainy). Level of anthropogenic pressure on studied forest plots was assessed by counting the cut stumps and lopped trees in ten 10X10 m quadrats of each 50x50 m plot. For enumerating fern flora of the study transect (2500 to 3200 m), the terrestrial ferns were assessed using 40 (1x1 m) quadrats in each plot; and epiphytes by 20 (25x25 cm) qudrats on 20 randomly placed tree boles (up to 2 m height only).
- The broad outcome include: (i) collection of a total 176 floral specimen representing 136 herbs, 32 - shrubs and 9- trees, (ii) variations in soil physico- chemical properties across altitude belts of studied transects, (iii) qualitative and quantitative assessment of fern flora (8 terrestrial, 3 epiphytes, 4 lithophytes) ferns across altitude range 2500-3200 m, and (iv) collection of detailed information on anthropogenic disturbance intensities across studied plots.

Study Site:

The study was conducted in Tungnath area located between (30°27'04.44"N 30°28'58.30"N) to (79°12'41.19"E 79°12'53.62''E) in the border of Chamoli District of Uttarakhand in west Himalaya. The representative altitude transect (Site- A) covered the elevation range between 2100-3200 m asl. The details of studied altitude belts and site characteristics have been given in previous reports.

Major focus during reporting period (April to September 2017) :

i. Extensive field surveys and plant spcimen collection for collection of floristic diversity (spring to rainy) information.
ii. Collection and analysis of soil samples across altitude belts in studied transect.
iii. Assessment of disturbance intensities of studied plots/altitude belts.
iv. Qualitative and and quantitative assessment of fern flora across altitude belts.
v. Installation of soil data loggers in the study transect.

Methodology:

- **Floristic diversity assessment:**

  For the documentation of seasonal floristic diversity across study transect, extensive field survey were carried out (covering seasons spring to rainy). Following standard taxonomic approach, herbarium specimen were collected and prepared (fig.2: A & B)

- **Soil sampling and analysis**

  Field Sampling: soil samples were collected from the study transect (in pre-monsoon season; consecutively for 3 days), within an altitude range between 2100 to 3200 m asl. Composite soil samples were collected (soils of 5 points) from individual 50x50 m plots of each altitude band. plots were established and sampled. The soil samples were collected from the individual plots of vegetation assessment The samples were collected at two depths (0-15 cm and 15-30 cm). Therefore, a total of 72 (3x12x2) composite soil samples were collected from the transect for analysis (fig.3, 4.A & B)

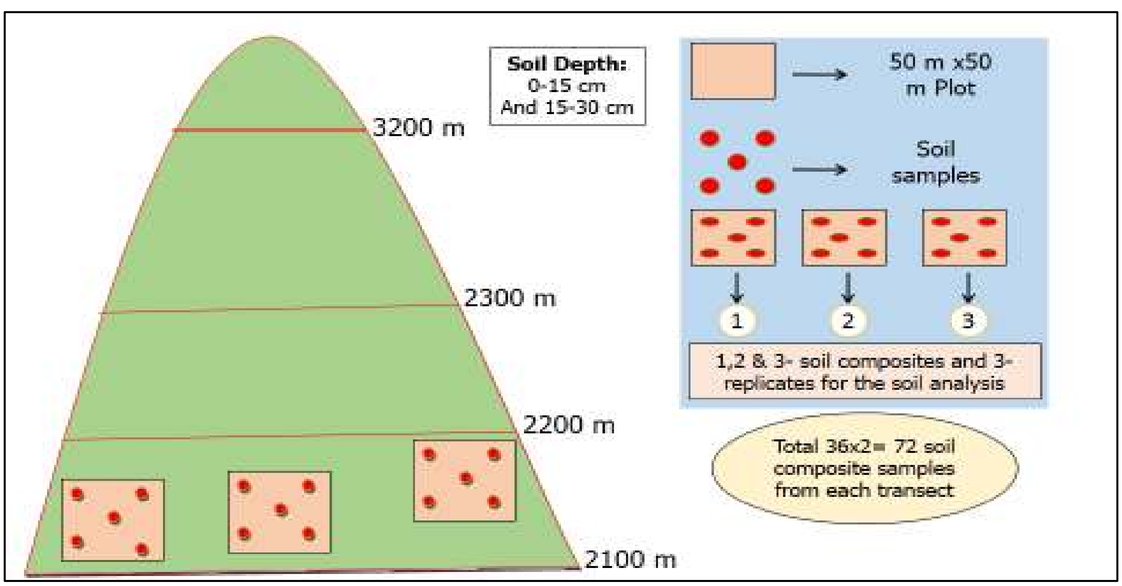


Fig.3: Soil sample collection across the altitude belts

Physico-chemical analysis of soil:

Collected soil samples were analyzed for physical and chemical parameters (i.e., soil moisture, pH, water holding capacity, soil organic carbon and organic matter) following standard laboratory methods.

- *Soil moisture content (%):* It was measured by taking a fixed amount of fresh soil sample (10 gm) and oven dried at 105º for 24 hours and take the dry weight of soil. The soil moisture content (SMC) was calculated by using the formula:

$$SMC\ (\%) = \frac{\text{fresh weight (g)} - \text{dry weight (g)}}{\text{Fresh weight (g)}} \times 100$$

- *pH:* Digital pH meter wa used for the determination of pH values of soil samples.
- *Water holding capacity WHC (%):* It was determined by Hilgard Cup method as described by Cassel and Neilson, 1986.
- *Soil organic carbon (%):* Organic carbon was determined by modified Walkley and Black (1947) method.
- *Soil Organic matter (%):* SOM was calculated by the method given by Walkley and Black (1934).

- **Forest vegetation sampling for disturbance intensity**

Considering that the studied forest vegetation plots were having diverse levels of anthropogenic disturbances, the evidences of disturbance (i.e., cut stumps and lopped individuals) were used to determine the intensity of disturbance (Rawal et al 2012) for each plot within given altitude belt (Fig. 5).

Fig.5: Evidences of anthropogenic pressure used for determining level of disturbance

- **Assessment of fern diversity**

  Towards preparing complete inventory of plants, the fern flora was assessed along the identified transect between altitude range 2500 to 3200 m asl. Enumeration was done in each altitude belt in identified plots of 50x50 m. In each plot 40 (1x1 m) quadrats were laid randomly for enumeration of terrestrial ferns. While the epiphytic ferns were assessed using 20 (25x25 cm) qudrats on 20 randomly placed tree boles (up to 2 m height only).

Results & Achievements:

- ***Floristic diversity assessment:***
  - A total 176 plant specimen were collected in their flowering and fruiting conditions from the study site and herbarium specimens prepared.

- The specimens included 136 herbs, 32 shrubs and 9 trees. Identification and authentication of specimens is in progress.

- ***Soil attributes***

  - The collected soil samples were analysed for physical and chemical parameters. Soil moisture containt, pH, water holding capacity, soil organic carbon and organic matter of the soil across altitudinal gradient were recorded. (Details in table:2.)

❖ *Soil moisture content (%) across elevation belts:*

The range of soil moisture content across the altitude varied from 23.8 to 40.8 % in 0-15 cm soil depth. For soil depth 15-30 cm the soil moisture content ranged from 14.4 to 40.1 %. In both the depths, soil moisture was lowest at 2100 m elevation belt. In general altitude belts beyond 2700 m asl represented higher soil moisture (Fig. 6.1.)

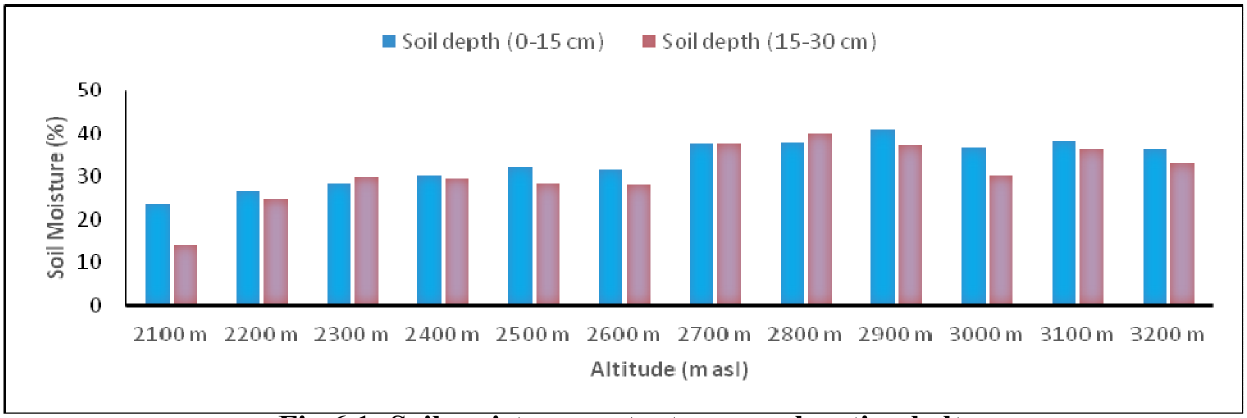


Fig.6.1: Soil moisture content across elevation belts

❖ *Soil pH:*

The pH range across elevation belts was 3.6 to 6.3 in 0-15 cm depth and in 3.9-5.5 for soil depth 15-30 cm (Fig.6.2.)

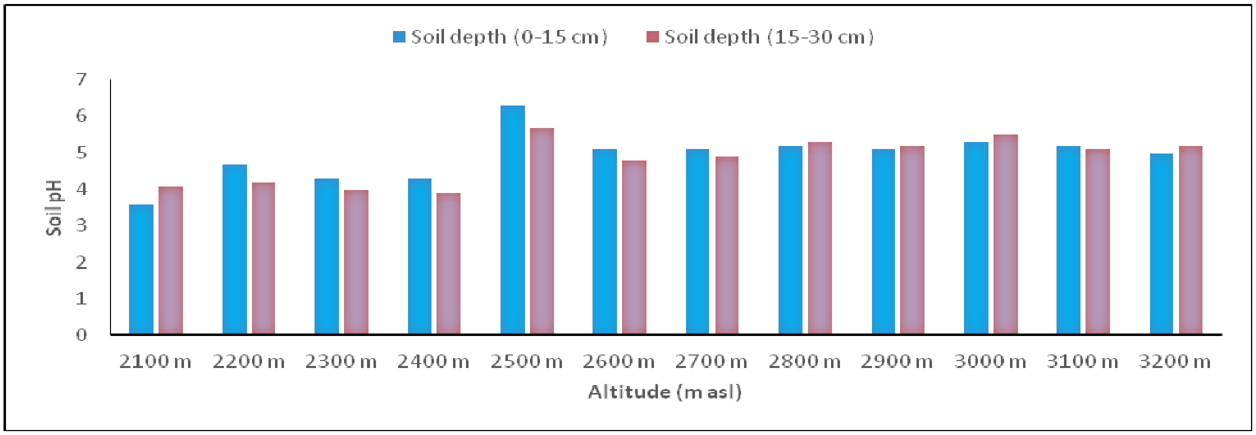


Fig.6.2: Soil pH across elevation belts

❖ *Soil Water Holding Capacity (%):*

The soil water holding capacity range along altitude gradient were observed between 33.6to 64.9 % in 0-15 cm depth, 29.8 to 58.6 % in 15-30 cm depth. In general, WHC was comparatively more in 0-15 cm depth. The WHC also showed greater values for elevation belts 2700-3000 m asl. (Fig.6.3.)

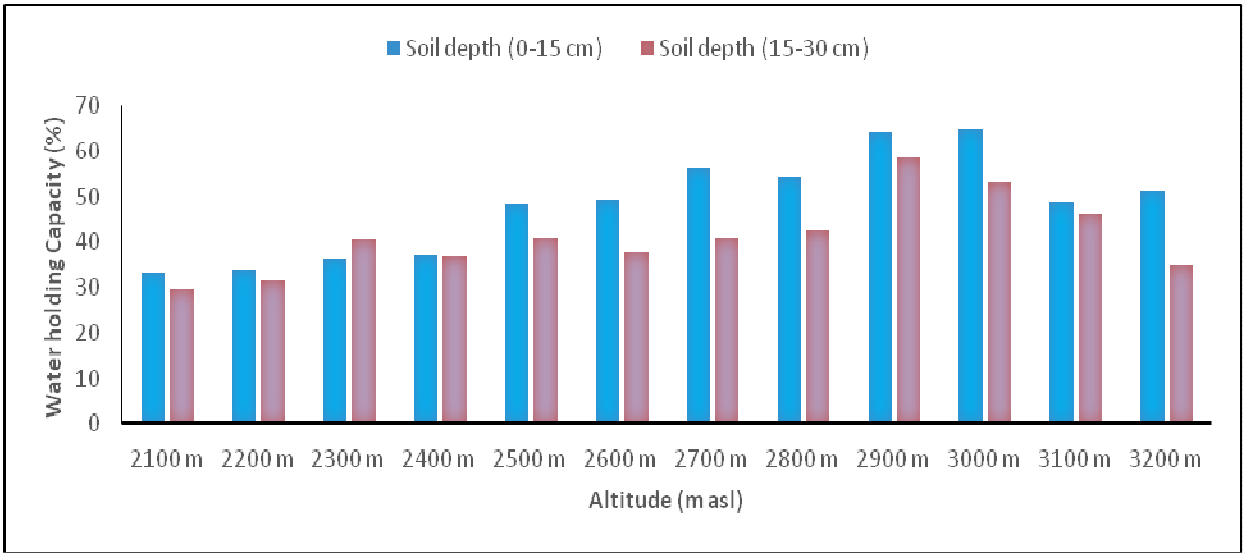


Fig.6.3: Soil water holding capacity across elevation belts

❖ *Soil Organic Matter (%):*

The soil organic matter range along the altitude was 9.2 to 18.0 % in 0-15 cm depth of soil, while it was 4.0 to 13.9 % in lower depth (15-30 cm). (fig.8.4.)

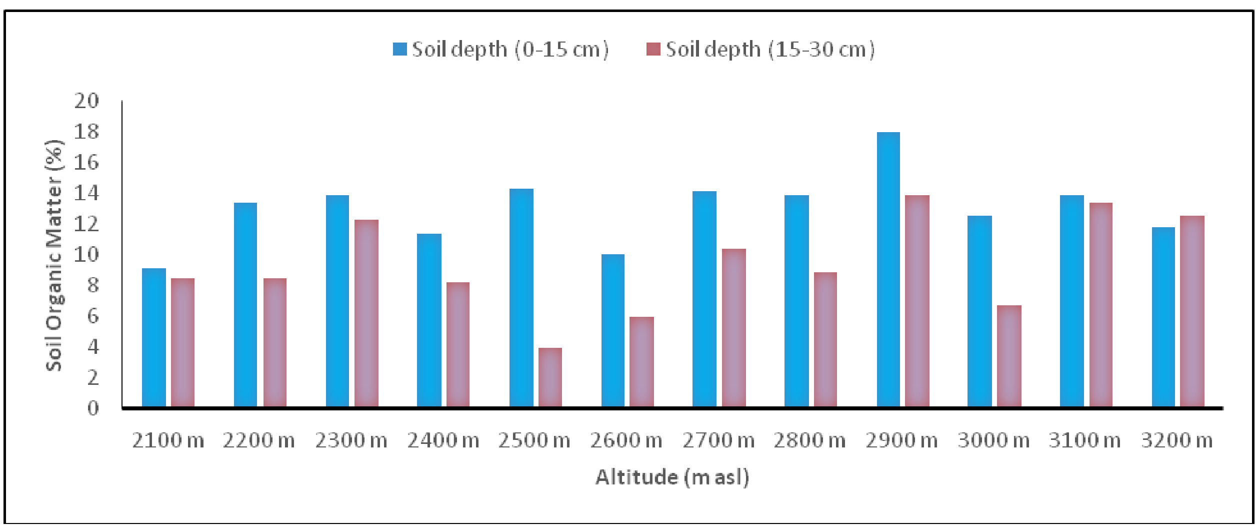


Fig.6.4: Soil organic matter across elevation belts

❖ *Soil Organic Carbon (%):*

The soil organic carbon ranged between 5.65 to 10.4 % in 0-15 cm depth and 2.34 to 8.06 % in 15-30 cm soil depth. In general no specific trends of soil organic carbon were revealing across elevation range (fig 6.5).

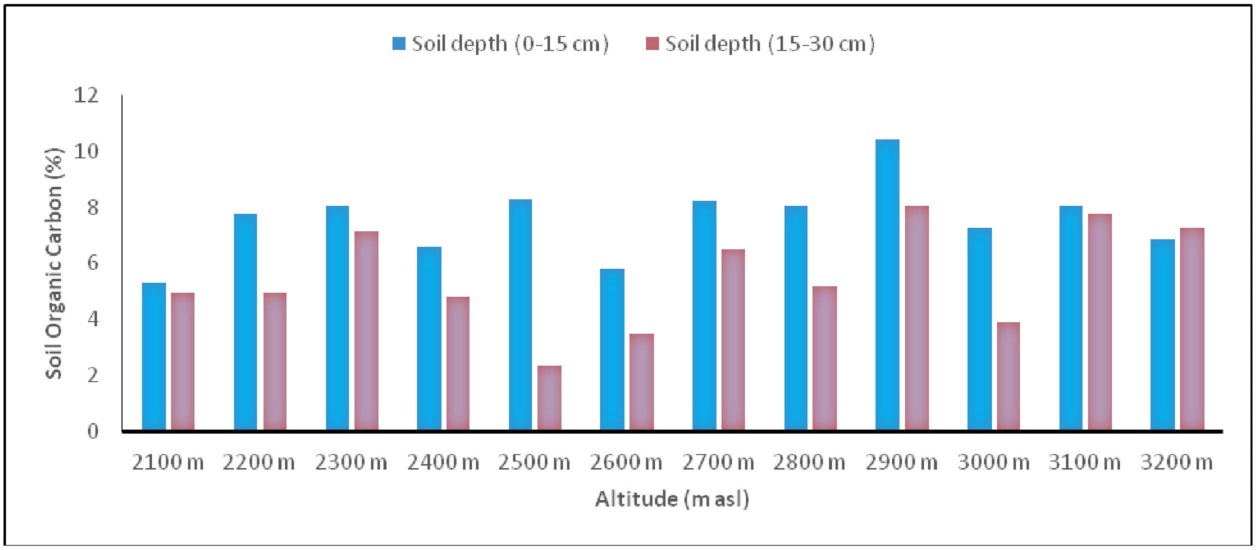


Fig.6.5: Soil organic carbon across elevation belts

Detailes of analysed parameters of soil are included in Table 1. Alaysis for other soil parameters (i.e., available nitrogen, phosphorus, and potassium) is in process.

Table:1. Details of analysed soil physical and chemical parameters across elevation belts

Elevation belt (m)	Soil Moisture (%)		Soil pH		Water Holding Capacity (%)		Soil Organic Carbon (%)		Soil Organic Matter (%)	
	Soil Depth									
	(0-15)	*(15-30)*	*(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	9.18	8.52
2200	26.68	24.95	4.7	4.2	34.2	31.66	7.8	4.94	13.44	8.52

2300	28.24	30.06	4.3	4.0	36.7	40.67	8.06	7.15	13.89	12.33
2400	30.17	29.83	4.3	3.9	37.3	36.97	6.63	4.81	11.43	8.29
2500	32.18	28.41	6.3	5.7	48.6	40.99	8.32	2.34	14.34	4.03
2600	31.83	27.93	5.1	4.8	49.7	38.01	5.85	3.51	10.08	6.05
2700	37.49	37.59	5.1	4.9	56.6	40.94	8.23	6.5	14.19	10.43
2800	37.89	40.05	5.2	5.3	54.6	42.67	8.06	5.2	13.89	8.96
2900	40.87	37.40	5.1	5.2	64.4	58.57	10.44	8.06	18.00	13.90
3000	36.63	30.37	5.3	5.5	64.9	53.16	7.28	3.9	12.55	6.72
3100	38.17	36.45	5.2	5.1	48.8	46.48	8.06	7.8	13.89	13.45
3200	36.35	33.02	5.0	5.2	51.4	34.91	6.89	7.28	11.87	12.55

- ***Assessment of disturbance intensity***

The data-sets generated from different altitude belts are under process of analysis.

- ***Assessment of fern diversity***

The quanlitative assessment of fern flora revealed a gradual decline of species richness from low to high elevation belts (fig 7.1).

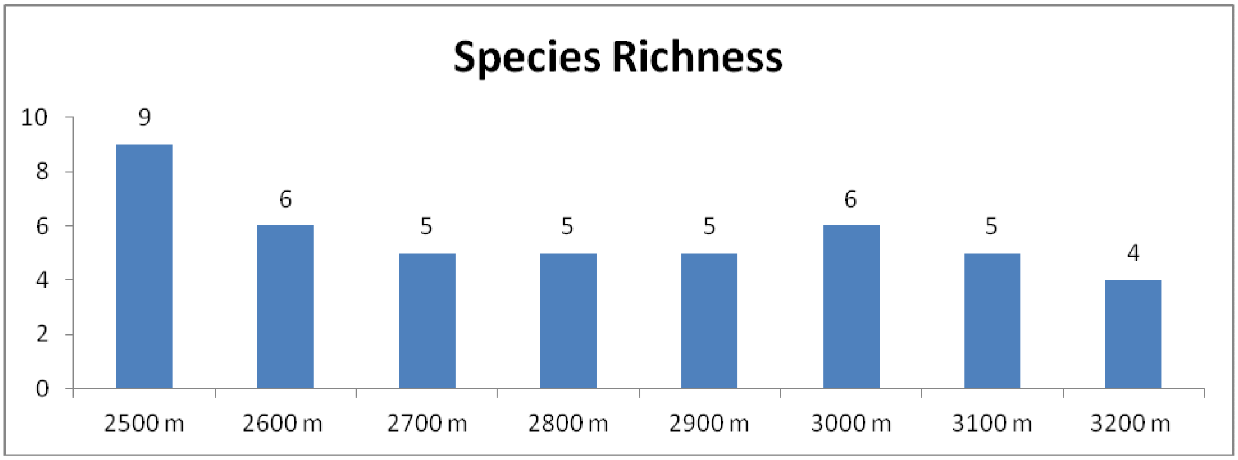


Fig. 6.1: Richness of fern species across elevation belts (2500-3200 m asl)

The quantitative assessment reveals that across elevation belts the frequency of occurrence for terrestrial ferns ranged from 41.7 to 75%. However, frequency of occurrence was invariably more (50-100%) for epiphytic ferns (Table 2).

Table 2: Frequency and density of terrestrial and epiphytic ferns across elevation belts.

Elevation belt (m asl)	Frequency (%)		Density Individual/ ha	
	Terrestrial	*Epiphytic*	*Terrestrial*	*Epiphytic*
2500	47.9	100	1050	3000
2600	62.5	93.3	975	2700
2700	41.7	95.0	425	2550
2800	62.5	81.7	500	2400
2900	75.0	85.0	550	2250
3000	68.8	88.3	450	2100
3100	62.5	75.0	500	1800
3200	50.0	50.0	375	300

The Shannon diversity index for ferns varied from 0.57 to 0.86 with maximum diversity at 2500 m asl (0.86) and lowest at 3200 m asl (fig.6.2).

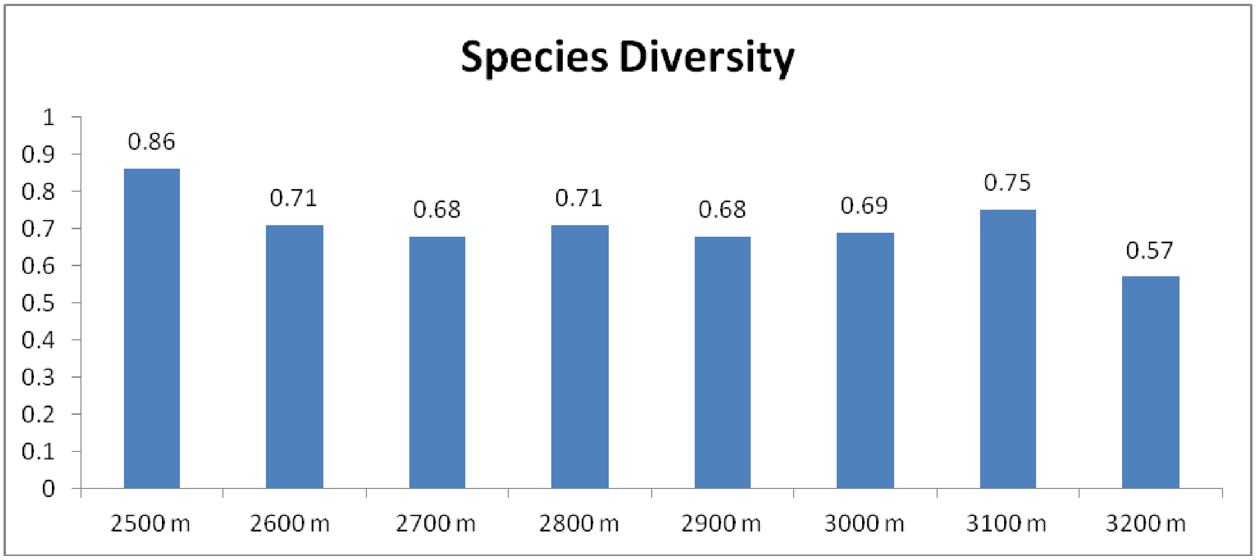


Table 3 includes the list of ferns identified from the study transect.

Table.3: Checklist of the ferns of the study transect

Terrestrial	Epiphytes	Lithophytic
Pteris wallichiana	*Lepisorus scolopendrium*	*Lepisorus scolopendrium*
Pteris dryopteris	*Polypodiodes amoena*	*Polypodiodes amoena*
Dryopteris conjugata	*Artromeris lehmani*	*Artromeris lehmani*
Dryopteris sparsa		*Davallia* species
Polystichum squarrosum		
Onchium contiguum		
Davallia species		
Dryopteris wallichiana		

- ***Installation of soil data loggers***

In addition, soil data loggers have been installed in studied transect at 200 m elevation bands (fig 7); details of soil data logger sites are included (Table 4).

Fig. 7: Installation of soil data loggers in study transect

Table. 4: Details of soil data loggers installed in study transect.

S. No.	Soil Depth (cm)	Elevation	Aspect	Latitude & Longitude
1.	15-20	2200 m	South West	30°20.034” N to 79°12.849” E
2.	15-20	2400 m	South	30°27.787” N to 79°12.867” E
3.	15-20	2600 m	South West	30°27 .814” N to 79°13.367” E
4.	15-20	2800 m	West	30°28'14.35” N to 79°33'12.38” E
5.	15-20	3000 m	West	30°28.767” N to 79°12.865” E
6.	15-20	3200 m	West	30°28.904” N to 79°13.014” E

Sub project: Plant diversity and community structure along altitudinal gradient in three sites of Indian Himalayan region

(Dr. Devendra Kumar)

Sanction No. and date -: Letter No: 1886/XII-86/2016 Date: 31/03/2016

Institution Name-:G.B. Pant National Institute of Himalayan Environment and Sustainable Development, Sikkim Unit, Pangthang-737103, Gangtok, Sikkim

Personal Details -:

Name and Address of the PI-: Dr. Devendra Kumar, G.B. Pant National Institute of Himalayan Environment and Sustainable Development, Sikkim Unit, Pangthang, Gangtok 737103, Sikkim
Name and Address of the Co PI-: NA

Partner Details-:

Sl.No.	Name/ Address	Work assigned to partners	Fund allocated to partners during the period
1.	G.B. Pant National Institute of Himalayan Environment and Sustainable Development, Sikkim Unit, Pangthang-737103, Gangtok.	Plant diversity and community structure along altitude gradient in Yuksam-Dzongri transect, West Sikkim, Eastern Himalaya	Nil (April to September, 2017)

Project Objectives -: Plant diversity and community structure along altitude gradient in Yuksam-Dzongri transect, West Sikkim, Eastern Himalaya

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
1.	Plant diversity and community structure along altitude gradient in three sites of Indian Himalayan region	50%	Under progress	Vertical transect of the study site is surveyed up to the 3000m asl and remaining survey are scheduled for mid-November

Summary of progress -: (with in 200 words)

During the current project tenure, as per the assigned objective "Plant diversity and community structure along the altitude gradient in Yuksam-Dzongri transect, West Sikkim, Eastern Himalaya", till date two field surveys were carried out, i) for the vegetation survey along the elevation gradient in Yuksam-Dzongri transect (Fig. 1, 2), and to collect the logger data, ii) for the vegetation survey along the elevation gradient from Teesta basin – Yumisangdung (1000-4000m asl), Lachun, North Sikkim with the synergy of NMSHE, TF-3. Across the Yuksam-Dzongri transect, elevation gradient between 3000-3800 m asl was surveyed and a total of 27 plots were enumerated for plant diversity and community structure. Results revealed the presence of 25 tree species belonging to 12 families (Table1), a total of 10shrub species belonging to 5 families and a total of 29 herb species belonging to 25 families across the elevation gradient covered till date. Ericaceae emerged as the most dominant family in both tree and shrub layers, however, Asteraceae was the most dominant in herbaceous layer. The IVI indicates that the *Abies densa* dominates the plots between3800 and 3200 m asl with *Sorbus microphylla* as its prominent associate, however, the *Tsuga dumosa* was observed as the dominant species in lower altitude (3100-3000 m asl) with different *Rhododendron spp*. as common associate (Table 2). Further, viewing the strong relation with available carbon and plant growth, the carbon sequestration rate measurement of timberline tree species was done along the horizontal transect between 3800 m asl to 4000 m asl (Fig. 2). Total nine major timberline sites were assessed for the estimation of total basal area, aboveground biomass, belowground biomass, total carbon, and stem density. The total basal area varied between 4.50(±2.41)-99.55(±1.90)m^2ha^{-1}. The total above ground biomass differed between 15.35(±7.38)-279.25(±3.04) $Mgha^{-1}$, while the total below ground biomass ranged between 9.85(±4.82)-144.76(±8.10) $Mgha^{-1}$. The total carbon was estimated between 11.59(±5.61)-195.03(±2.32) $Mgha^{-1}$. The minimum carbon was estimated 3989m asl and the maximum carbon was estimated at 3787m asl respectively. A strong correlation was observed between the studied parameters for carbon estimation (Table3). The final identification and data processing are under process for the Teesta basin - Yumisangdung vertical transect for species richness (especially trees) along the elevation gradient. Besides, regular attempts are in progress to get permission from the forest department, govt. of Sikkim for the remaining field activities.

Name of the PI-: Dr. Devendra Kumar

Signature -:

Date-: 10.11.2017

Table 1. List of tree species along the vertical transect (3000-3800m asl)

Sl. No.	Species Name	Family
1	*Abies densa* Griff.	Abietaceae
2	*Betula alnoides* Buch.-Ham.exD.Don	Betulaceae
3	*Betula utilis*D.Don	Betulaceae
4	*Viburnum nervosum* D. Don	Caprifolicaceae
5	*Pieris villosa* Wall. ex C.B. Clarke	Ericaceae
6	*Rhododendron arboreum* Sm.	Ericaceae
7	*Rhododendron barbatum* Wall.ex G.	Ericaceae
8	*Rhododendron falconeri* Hook.f.	Ericaceae
9	*Rhododendron grande* Wight	Ericaceae
10	*Rhododendron hodgsonii* Hook.f.	Ericaceae
11	*Rhododendron lanatum* Hook.f.	Ericaceae
12	*Rhododendron thomsonii* Hook.f.	Ericaceae
13	*Rhododendron wightii* Hook.f.	Ericaceae
14	*Rhododendron decipiens* Lacaita	Ericaceae
15	*Litse asericea* (Wall. ex Nees) Hook. f.	Lauraceae
16	*Magnolia campbelli* Hook.f. & Thomson	Magnoliaceae
17	*Tsuga dumosa* (D.Don) Eichler	Pinaceae
18	*Prunusnepalensis* Hook. f.	Rosaceae
19	*Sorbus microphylla* (Wall. ex Hook.f.) Wenz.	Rosaceae
20	*Prunus rufa* Wall. ex Hook.f.	Rosaceae
21	*Acer caudatum* Wall.	Sapindaceae
22	*Symplocos dryophila* C.B. Clarke	Symplocaceae
23	*Symploco stheifolia* D. Don	Symplocaceae
24	*Eurya acuminata* DC.	Theaceae
25	*Vitex sp.*	Verbenaceae

Table 2. Importance Value Index (IVI) of tree species along the study elevation transect

Altitude (m asl)	Site	Plot	Importance Value Index (IVI)										
			A. densa	*M. campbellii*	*R. arboreum*	*R. falconeri*	*R. hodgsonii*	*S. microphylla*	*T. dumosa*	*V. cordifolium*	*Prunus rufa*	*Acer caudatum*	*R. barbatum*
3800	**1**	1					62.33	103.005					
		2					58.37	62.88			54.79		
		3	82.534										
3700	**2**	4						80.422					
		5	87.642				83.43						
		6	59.02				83.038	82.88					
3600	**3**	7	90.57				97.983						
		8	102.236				80.03						
		9	101.68				95.99						
3500	**4**	10	125.807				101.70						
		11	129.327				74.96			48.47			
		12	117.693				76.68						
3400	**5**	13	74.90				97.762						

		14	107.364				83.58						
		15	97.946				62.06						
3300		16	92.542				78.34						
	6	17	69.79				86.357			52.61			
		18	96.263			50.51	44.74						
3200		19	116.844										61.69
	7	20	110.865			43.30							65.9
		21	100.987			48.14							51.38
3100		22	40.58		46.92	55.57				111.685			
	8	23				36.39			45.42			80.03	
		24				40.98			155.506	47.85		55.64	
3000		25	24.36			53.61			97.601				
	9	26	10.59		69.409				57.25				
		27			70.14	79.482							

IVI values of dominant species across different study plots along the elevation gradient of 3000-3800m asl.

Table 3: Relationship between studied parameters of carbon estimation in Dzongri timberline in Khangchendzonga National Park

	Altitude (m asl)	**TBA (m2/ha)**	**AGB (Mg/ha)**	**BGB (Mg/ha)**	**TC (Mg/ha)**	**SD (N/ha)**
Altitude (m asl)	1					
Total Basal Area (TBA: m^2/ha)	-0.661	1				
Above Ground Biomass (AGB: Mg/ha)	-0.773*	0.957**	1			
Below Ground Biomass (BGB: Mg/ha)	-0.738*	0.961**	0.989**	1		
Total Carbon Density (TC: Mg/ha)	-0.764*	0.962**	0.998**	0.996**	1	
Average Stem Density (SD: N/ha)	-0.151	0.569	0.553	0.656	0.094	1
*. Correlation is significant at the 0.05 level.						
**. Correlation is significant at the 0.01 level.						

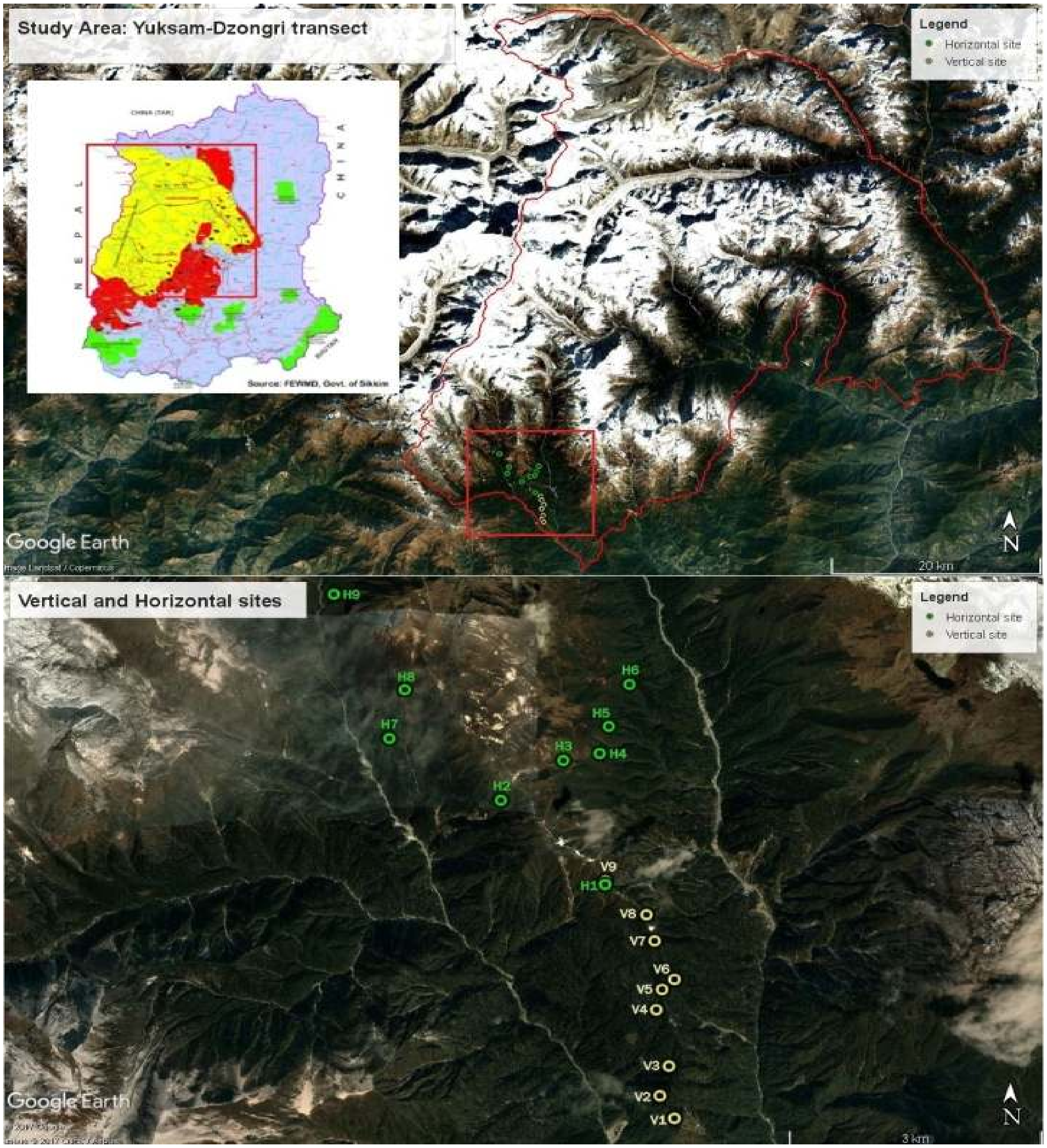


Figure-1: Sites and Study area

1. H1-H9: Horizontal transect (along the timberline of Dzongri region; indicated by green spots)
2. V1-V9: Vertical transect (elevational gradient sites between 3000-3800m asl; indicated by white spots)
3. The red color boundary delineates the Khangchendzonga National Park; in inset: all the studied sites till date.

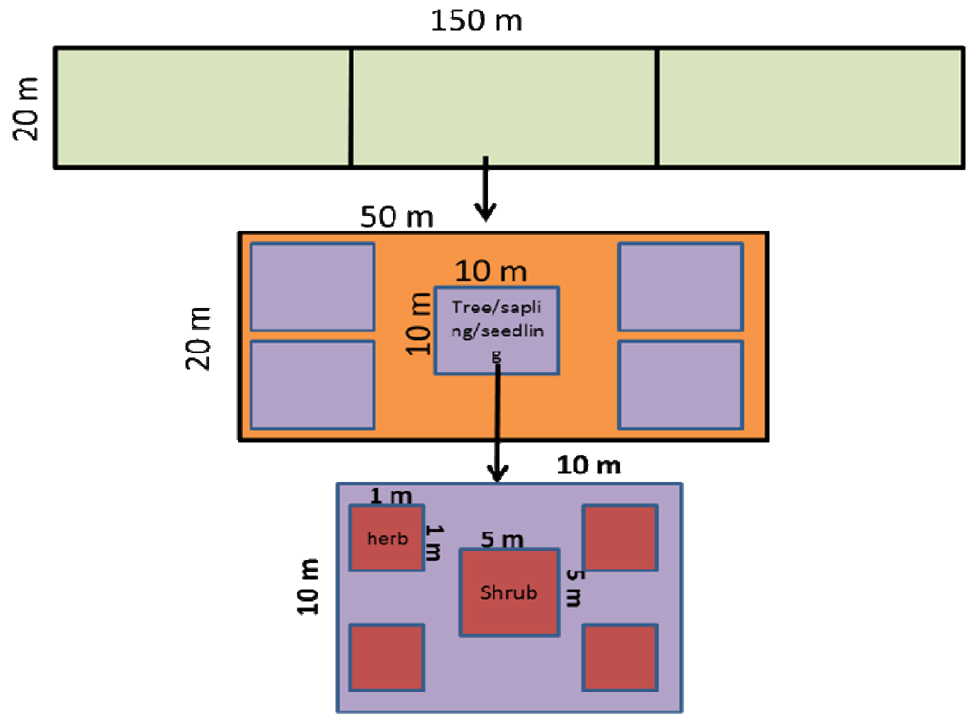


Figure-1. Methodology used for the vegetation assessment along an elevational gradient

Each site along the elevational gradient consisted of mother plot of 150 m x 20 m dimension. Within each mother plot, three plot of 50 m x 20 m dimension was established adjacent to each other at each of the elevation bands. Within each plot of 50 m x 20 m, five sub-plots of 10 m x 10 m were laid for tree (girth >30 cm), sapling (girth 30≤11 cm) and seedling (girth ≤10 cm) enumeration. A 5 m x 5 m plot was laid within the 10 m x 10 m for shrub enumeration. The 10 m x 10 m plot further contained four 1 m x 1 m plots laid in a random fashion for herb inventory.

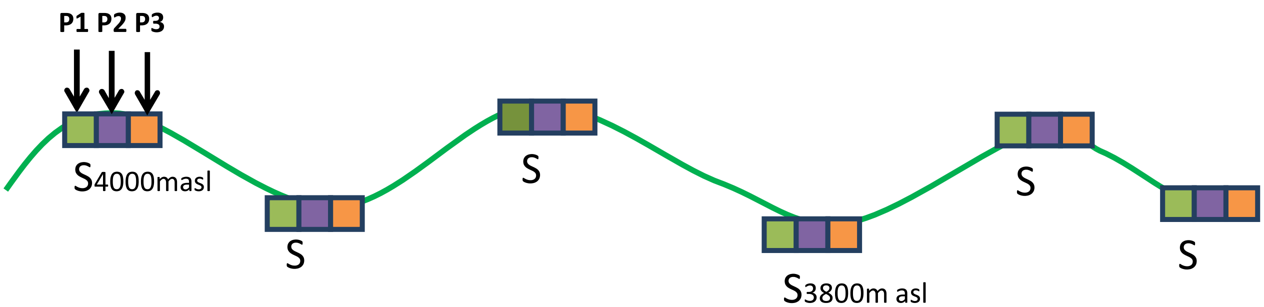


Figure 2. Methodology used across the horizontal timberline transect in Dzongri region

S: sites across the timberline in Dzongri region; a total of nine sites (area in each site: 150 × 20 m^2) were assessed, P1, P2, P3: vegetation assessment plots in each site a total of three 50 × 20 m^2 plots were surveyed for each site.

Methodology for Biomass estimation:

Above ground biomass density (AGB):We calculated AGB by multiplying the GS with the biomass expansion factor and volume weighted average wood density (Brown and Lugo, 1992).

$$AGB = V \times D \times BEF$$

Where, AGB = Aboveground biomass, Mg of dry matter ha^{-1}, V = Commercial tree volume, m^3 ha^{-1}, D = Volume weighted average wood density, Mg of oven-dry matter per m^3 of green volume, BEF = Biomass expansion factor (ratio of aboveground oven-dry biomass of trees to oven-dry biomass of commercial volume), dimensionless (Penman *et al*, 2003).

Below ground biomass density (BGB): The BGB was calculated using the regressing equation $BGB = \exp\{-1.059 + 0.884 \times \ln(AGB) + 0.284\}$given by Crains*et al.* (1997). However, the Total Biomass Density (TB) was calculated by adding-up the AGB and BGB. Similarly, the Total carbon density (TC) was calculated using the formula:$TC = TB \times Carbon\,\%$ Based on species composition, the carbon % of 46 was taken in our study, as the conifers constitute more than 50% of total tree species (Gairola*et al*., 2011; Sharma *et al*., 2010; Manhas *et al*., 2006; Negi *etal*., 2003).

Annexure 6

Sub project: To understand timberline tree phenological responses, nutrient conservation strategies, tree-water relations, seed ecology and regeneration in response to warming climate

(Dr. G.C.S.Negi)

Sanction No. and date -: Ref no: NMHS/LG-2016/009 Date: 31-03-2016

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

Name and Address of the PI-: Prof. S.P. Singh, FNA, Chairman, Central Himalayan Environment Association, Nainital (Uttarakhand)

Partner Details-:

Sl No	Name/ Address	Work assigned to partners	Fund allocated to partners during the
1	Dr. G.C.S. Negi, Scientist F, GBPNIHESD, Kosi-Almora	To understand tree phenological responses, nutrient conservation strategies and tree-water relations in response to warming climate	Rs. 6,10,600.00

Detailed Work Elements:

- Micro-climatic data collection during field work
- Data collection on major phenophases and leaf characters of selected species
- Measurements on leaf area, leaf mass and leaf nitrogen retranslocation

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

Sl No	Quantifiable Deliverables (as per sanction	Output/ achievements	Performance in terms of Monitoring	Remarks
1	Creation of database and knowledge products on vegetation science and tree-soil water relations of timberline in Uttarakhand.	• Monthly micro-climatic data on atm. temperature, atm. humidity, soil temperature and soil moisture (30 cm depth) from the five forest stands studied for phenological observations was collected (Fig. 1; Plate 1).		Data for all these parameters is being collected.
		• Database on phenology of leafing, flowering, fruiting and leaf drop of major timberline trees species (viz., *Abies spectabilis, Betula utilis, Quercus semecarpifolia, Rhododendron arboreum* and *R. campanulatum*) of Chopta-Tungnath (Uttarakhand) was collected from May- October 2017 (Fig. 2; Plate		Research papers will be developed after completion of phenological cycle in April-May 2018 and data syntheses.

Summary of progress -: (within 200 words)

At the Chopta-Tungnath (Uttarakhand) area micro-climatic data (June - October 2017) indicates that peak atmospheric temperature, atmospheric humidity, soil temperature and soil moisture occurs during August (Fig. 1). However, soil moisture and relative humidity was more or less throughout the study period. Leaf bud break and leafing in all the species occurred in May (except *Q. semecarpifolia* in which it occurred in early June) accompanied by peak flowering in *R. arboreum* and *R. campanulatum*. In rest of the species flowering takes place in early June (except *B. utilis* in which it takes place in mid-October). Leaf drop initiation takes place in October and completes before leafing in the next leafing period. In case of *B. utilis* leafdrop occurs during October-November. Mature leaf mass among the five species varied from 0.007 g/needle (*A. spectabilis*) to 1.08 g/leaf (*R. campanulatum*), and leaf mass loss varied from 36.2% (*R. arboreum)* to 45% *(Q. semecarpifolia).* Leaf nitrogen concentration in mature leaves varied from 1.83% (*B. utilis*) to 3.81% (*A. spectabilis*) and leaf nitrogen retranslocation was computed ranging from 41.5% (*B. utilis*) and 66.8% (*R. arboreum*) (Table 1).

Name of the PI-: Signature -:

Date-: 27.11.2017

Fig.1: Microclimatic data of stands of different forest species selected for phenological observations at Tungnath. Values are mean across 10 observations each month. (June-October 2017).

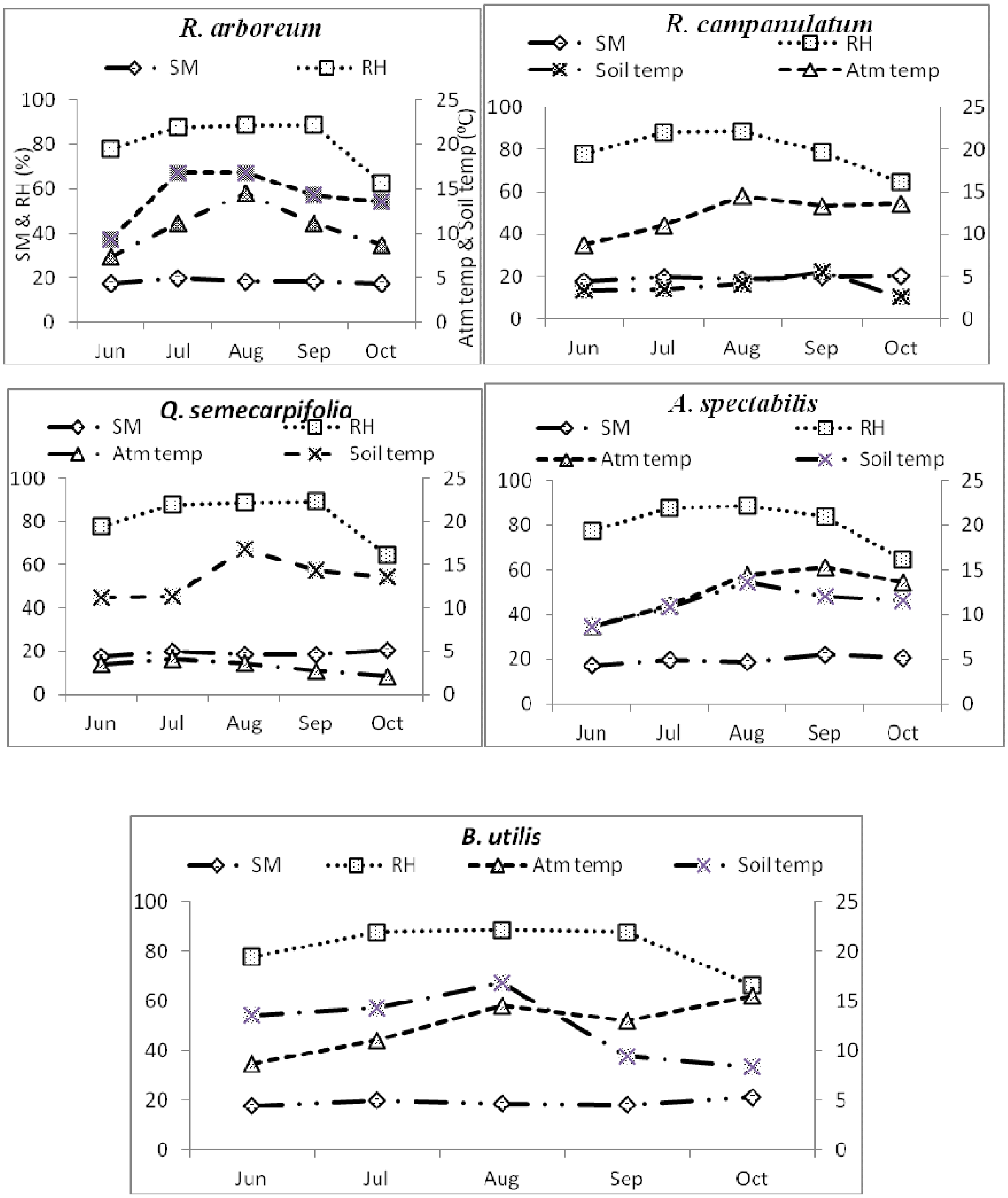


Fig. 2: Phenological events in different forest trees species expressed as % of 100 marked individuals of each species.

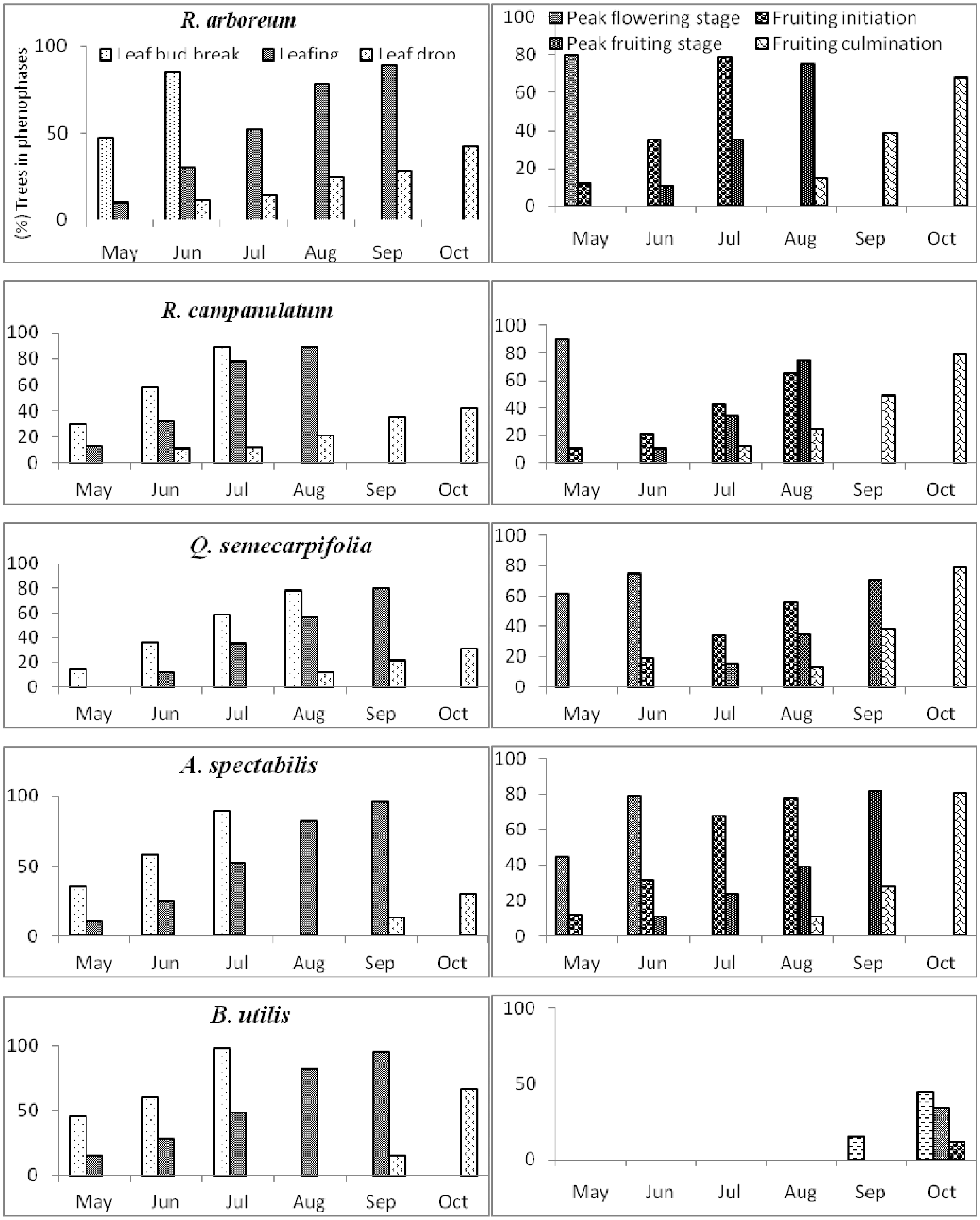


Fig. 3: Mean leaf weight (g/leaf) of different species selected for phenological observations (June-October 2017).

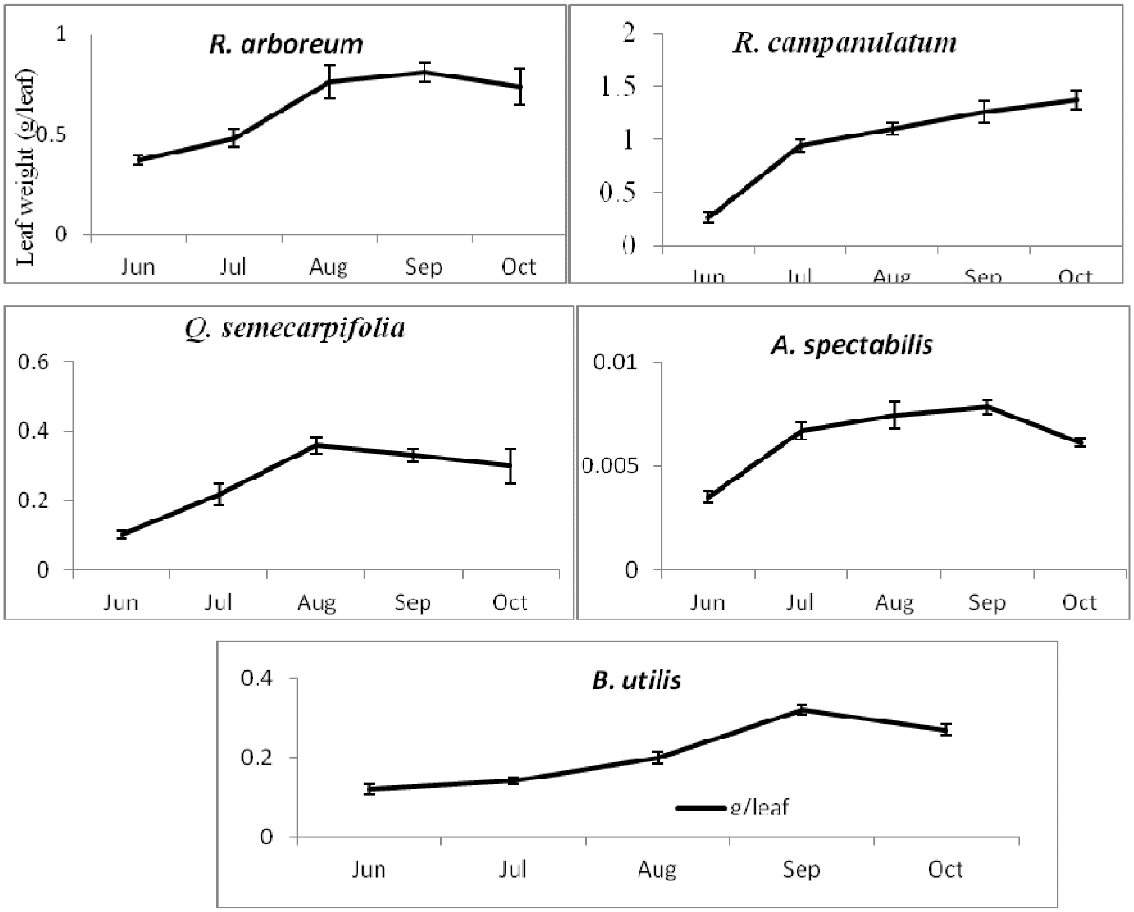


Table. 1: Leaf mass loss (%) and Leaf N- retranslocation in different species (2016-17 growth cycle of leaves).

Forest tree species	Mature leaf mass (g/leaf)	Mature leaf N – concentration (%)	Leaf- mass loss (%)	Leaf N- retranslocation
R. campanulatum	1.08	3.2	37.9	65.6
Q. semecarpifolia	0.354	2.82	45.0	56.4
R. arboreum	0.870	2.92	36.2	66.8
B. utilis	0.226	1.83	42.5	41.5
A. spectabilis	0.007	3.81	42.9	56.7

Plate 1: Microclimatic data measurement at Tungnath timberline (*Betula utilis* and *Rhododendron campanulatum* are seen in the background and *Danthonia cachemyriana* - senescent tussock grass is seen in the foreground)

Plate 2: A stand of *B. utilis* marked for phenological observations at Tungnath timberline

Annexure 7

Sub project: Tree Water Relation: Another perspective determining altitudinal limits of timberlines in the Himalayan region

(Dr. Ashish Tewari)

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**
Assistant professor,
Department of Forestry & Environmental Science
D.S.B. Campus
Kumaun University, Nainital

Name and Address of the Co PI-: NA

<u>Project Objectives</u> -:

1. To assess the sensitivity and response of the Himalayan tree line to water relation parameters.

2. To determine the drought adaptation mechanisms of different species to assess their survival potential.

3. To study the role of microsite facilitation in drought avoidance and growth.

4. To assess the impact of water deficits and warming on seed maturation and seedling dynamics.

5. To develop base line data on timberline tree water relations.

Summary of progress -:

Tree Water Potential

Tungnath Site:

During the summer season all the tree species were moderately stressed 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 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 change between pre-dawn and mid day water potential was always more than10 bars for all the species (Table 1).

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 2)

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 and *Rhododendron arboreum* 58.6±7.60 m mol m^2/sec. *R. campanulatum* and *Betula utilis* had relatively higher conductance 232.9±3.01 and 279.9±27.3 m mol m^2/sec. The afternoon leaf conductance ranged between 105.7± 3.92 and 249±24.9 m mol m^2 /sec. In the rainy season *B. utilis* had the highest morning leaf conductance 304.6±5.23 m mol m2 /sec followed by *Rhododendron* species and was lowest for *Q. semecarpifolia* 117.9± 7.95 m mol m2/sec. The afternoon conductance values were lower than the morning conductance values. (Table 3)

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 4).

Soil Moisture content

Tungnath site:

Across the transect from base to the top the soil moisture across different depths ranged between 33.4±4.30 and 45.4±1.06% during the summer season and in the rainy season between 64.2±0.48 and 83.6±2.85%. The top soil layers were drier than the deeper layers (Table 5).

Chitkul Site (H.P.):

The trend was opposite at this site during the autumn season and the top soil layer had more moisture than the deeper layers. The values ranged between 31.7± 3.52 and 10.32± 0.43% (Table 6).

Seed Maturation:

Work on seed maturation indices of *Q. semecarpifolia* and *R. campanulatum* was started. 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%. In *R. campanulatum* no germination had occurred till September 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. The seed maturation work on *A. pindrow* and *B.utilis* has commenced.

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		
Abies pindrow	11.29 ± 0.42	9.52 ± 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	9.29 ± 0.47
B.utilis	8.11± 0.19	8.58 ± 0.18
Rainy Season		
Abies pindrow	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

Table 2. 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**
Abies pindrow	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 3. Leaf Conductance of trees of selected species in summer and rainy season at Tungnath:

Species	**Leaf Conductance** ***(m mol*** m^2***/sec)***	
	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

Table 4. 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 5. Soil Moisture Content % in two different seasons (Summer & Rainy) at Tunganath site along the transect

Location	Soil Depth (cm)	Moisture Content %	
		Summer	Rainy
Top	0-10	37.5 ± 0.21	67.9 ± 1.19
	10-20	38.7 ± 0.84	76.4 ± 0.96
	20-30	43.8 ± 3.04	83.6 ± 2.85
Mid	0-10	37.7 ±1.26	66.29 ± 1.38
	10-20	42.2 ± 1.29	70.5 ± 0.90
	20-30	45.4 ± 1.06	80.46 ± 1.04
Base	0-10	33.4 ± 4.30	64.2 ± 0.48
	10-20	38.9 ± 1.40	66.8 ± 1.87
	20-30	42.8 ± 0.80	82.7 ± 0.26

Table 6. Soil Moisture Content % in autumn seasons at Chitkul Site

Soil Depth	Moisture Content (%)
0-10cm	31.7 ± 3.52
10-20cm	20.5 ± 3.60
20-30cm	10.32 ± 0.43

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

Annexure 8

Sub project: Tree growth response of selected tree species of timber line to climate variability across the Indian Himalayan Region.

(Dr. P.S. Ranhotra)

Sanction No. and date -: 1886/XII-86/2016, 12th May 2016

Institution Name-: Birbal Sahni Institute of Palaeosciences

Personal Details -:

Name and Address of the PI-: PARMINDER SINGH RANHOTRA Birbal Sahni Institute of Palaeosciences, 53, University Road Lucknow
Name and Address of the Co PI-: AMALAVA BHATTACHARYYA BirbalSahni Institute of Palaeosciences, 53, University Road Lucknow RAJESH JOSHI, GBPNIHESD, Almora

Partner Details-:

Sl No	Name/ Address	Work assigned to partners	Fund allocated to partners during the period
1.	Parminder Singh Ranhotra, Scientist-C, BirbalSahni Institute of Palaeosciences, 53 University Road, Lucknow (UP) - 226007	Tree-ring sampling as tree ring cores of selected tree species from various abrupt tree-line and an undisturbed forest sites from J&K, UK and Sikkim. Cross-dating and Standardization of the samples. Chronology development and analysis of tree growth characteristics Determination of climate–tree-growth relationships	Rs. 9,54,400.00 First year budget Rs. 9,00,000.00 Equipment Rs. 4,77,200.00 IInd installment Deposit slip Ch003063 BoI,Dated 23/1/2017.

Project Objectives -:

i. To reconstruct past spatio-temporal climatic changes and variability in timberline in IHR.

ii. To study relationship between tree ring growth and climate change in different climate regime across IHR.

iii. To study sensitivity of tree ring growth of selected tree line species to climate change.

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
1.	For the developed chronology of Tungnath area, the correlation between tree ring width and temperature and also correlation between tree ring width indices and precipitation have been developed.	Significant relationship with the precipitation and weak relationship with temperature		
2	The upper shift rate of *Abies*in the Tungnath area has been calculated.	~1.6 meters per decade		
3	The samples collected from Daksum and Sinthan, Kashmir J&K has been processed and initial counting has been done.	Oldest *Abies* tree recorded is 460 years old.		

Summary of progress -:

For the *Abies* samples from Tungnath area (UK), the correlations has been developed between tree ring width and climate (temperature and precipitation). With temperature the correlation (Fig A) is Negative for April, May, June and July months and positive with October and November months. Post monsoon warm condition favours the tree growth by extending the growing period. But the negative correlation in the month of December and January might be because respiration become higher than photosynthesis due to freezing temperature. For precipitation the correlation (Fig B) is negative for June, July, September and October months indicate that the high precipitation during summer cause low tree growth in tree line areas. The high moisture might be responsible for crossing the threshold limit of photosynthesis.From the Tungnath area (Uttarakhand) the upward tree-limit shift rate of *Abiesspectabilis*was calculated at a rate of ~1.6 meters per decade.

Carried out field work in May and September 2017 to Daksum (~2400 m amsl) and Sinthan top (~3800 m amsl), south Kashmir. Amongst dominant conifers,*Abiesspectabilis*grow densely on slopes till ~3500 m amsl, followed by *Pinuswallichiana*. Stunted *Juniperus* reach above *Abies*limit. In broadleaved trees*Acer* form patches till ~3300 m amsl, overtopped by *Betulautilis*. *Rhododendron* form dense patches on slopes reachingabove ~3600 m amsl. The ground taxa are well covered by the elements of Poaceae, Asteraceae, Ranunculaceae, Polygonaceae, Rosaceae, Saxifragaceaeetc. Collected 426 cores from 213trees of *Abiesspectabilis* from altitudinal range of 3200 - 3500 m amsland ~2400 m amsl;112 cores from 56 trees of *Betulautilis*between altitudes 3400 to 3620 m amsl; 60 cores from 30 trees of *Pinuswallichiana*between altitudes 3380 to 3600 m amsl. 35 surface (moss) samples are collected from the altitudinal range of 2300 to 3800 m amsl.

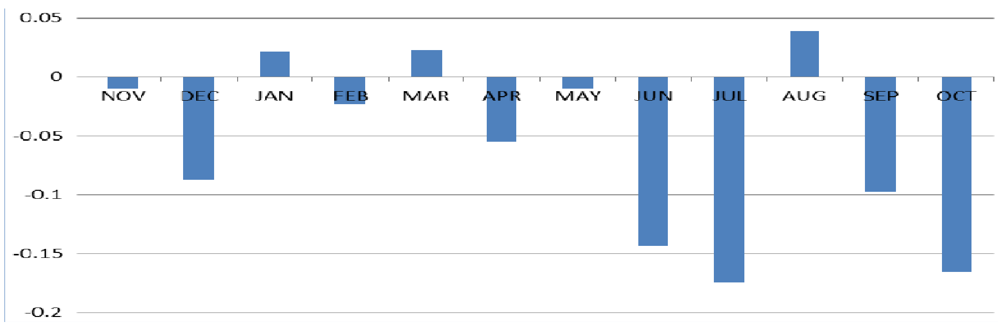


Figure A.

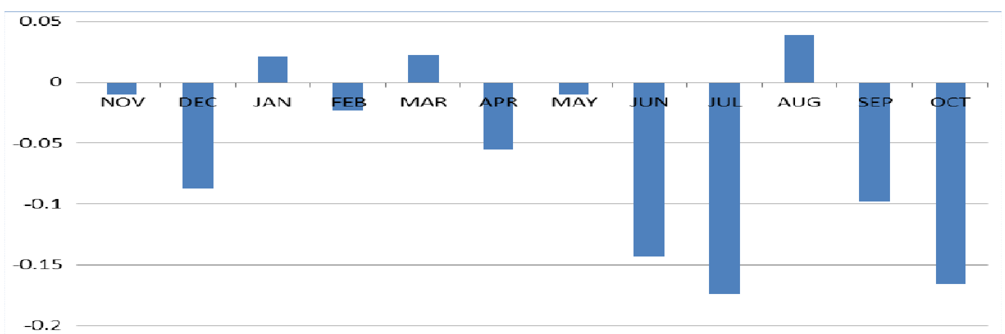


Figure B.

Name of the PI-:Parminder Singh Ranhotra

Signature -: 

Date-:30/11/2017

Annexure 9

Sub project: To understand the impact of depletion of snow-melt water o growth of tree seedlings, grassland species composition and selected functional processes

(Dr. B.S.Adhikari)

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

Aim: An obvious possibility for alpine and subalpine ecosystems is that global climate change will advance the timing of snowmelt and the onset of plant growth and flowering and fruiting in angiosperm. And such phenological shifts might further affect plant communities by altering the relative fitness of species with different strategies of growth and reproduction. This lead us to study the impacts of snow cover characteristics and the timing of snowmelt on the plant phenology, and species abundance in the short term and species composition in the long term. The project is funded under an umbrella of 'Timberline and altitudinal gradient ecology of Himalayas, and human use sustenance in a warming climate' being coordinated under Central Himalayan Environmemnt Association (CHEA), Nainital.

Location: The study was performed atTungnath 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 *Quercussemecarpifolia, Rhododendron arboreum*, *R. campanulatum*, *Abiespindrow*, *A. spectabilis,* and *Sorbus*sp., whereas the alpine meadows in and around Tungnath were dominated by diverse grasses and *Herbacioeus* plants.

Methods: A total of 5 communities viz.*Trachydium*,Mixed *Herbacioeus*, *Polygonum*, Mixed *Danthonia*and *Danthonia*communities were selected as permanent sites to monitor structure, composition and phenology. 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. Then, soil samples were collected from each site randomly down to 20cm (0-10 and 10-20cm) and brought to laboratory for Physico-chemical analysis. The aboveground biomass from each site at three different places brought to the laboratory for further analysis.

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 senescent and fruit ripe) as per the "BiologischeBundesanstalt, Bundessortenamt und CHemischeIndustrie"(BBCH) scale (Hess et al., 1997) on a 20 days interval from May 2017to October 2017.

Also, we identified four transects having elevational gradient of 3000m to 3600m from treeline ecotone to alpine meadows to study changes in composition and phenology. At each elevational zone, we have identified and marked six 1X1m plots representing three each from ridges and depression. Presuming that the plots on ridges experience advance snowmelt and depression experience delayed snowmelt during winter. We are also preparing and excited to attempt snow manipulation experiments in three snow melt scenarios such as advanced snowmelt, delayed snowmelt and Open top chambers including a control.

HOBO data loggers have been installed at every 150m interval from 3000m to 3600m to record environmental variables such as ambient, soil temperature and relative humidity. Biomass and soil samples are also collected at regular intervals from all the plots to understand the influence nutrients in various phenophases.

Results:

A. **Changes in Plant Communities on the Basis of Different Climatic Factors:**

As a general trend the density was higher during the months of May and October in all the communities being highest in *Trachydium*and mixed *Herbacioeus* community (Table 1) and lowest in *Polygonum* and mixed *Danthonia* community. The data for community phenology for the period of May 2017 to October 2017 is still being processed.

Table 1: COMMUNITY AVERAGE DENSITY

Density(ind./sq.m.)	**Month**				
site	May	July	August	Sep	Oct
Trachydium	815.27	449.67	422.84	449.67	379.72
Mixed *Herbacioeus*	545.27	432.97	408.11	446.95	223.01
Mixed *Danthonia*	278.93	222.31	199.55	228.88	201.88
Polygonum	206.67	124.32	119.35	127.81	91.07
Danthonia	126.47	158.48	154.72	170.73	137.00

As a general trend species richness saw two peaks during month of July and September as a general trend. The species richness was highest in *Trachydium* and mixed *Danthonia* community in May while *Polygonum* was lowest. In July, August and September *Danthonia* had highest species richness while *Polygonum* has the lowest. In October mixed *Danthonia* had the highest species richness while *Trachydium* had the lowest (Table 2).

Table 2: COMMUNITY SPECIES RICHNESS

Species richness	**Month**				
site	May	July	August	Sep	Oct
Trachydium	19.33	30.00	28.00	30.00	11.33

Mixed*Herbacioeus*	18.67	31.33	28.33	31.33	21.33
Mixed *Danthonia*	19.33	30.00	28.00	30.00	24.00
Polygonum	17.00	27.67	26.33	27.33	15.00
Danthonia	13.33	32.67	30.33	31.33	18.00

Biomass samples were collected for the period between May and October 2017. The biomass for the month of July was processed while remaining samples are in the stage of processing. In the month of July the mixed *Danthonia* community has the highest biomass while *Trachydium* community has lowest biomass (Table 3).

Table 3: COMMUNITY BIOMASS

Biomass(G/sq.m)	July					
site	sb1	sb2	sb3	mean	SD	SE
Trachydium	30.93	70.40	35.60	45.64	21.57	7.19
Mixed *Herbacioeus*	70.00	90.53	69.73	76.76	11.93	3.98
Mixed *Danthonia*	140.67	170.93	122.33	144.64	24.54	8.18
Polygonum	128.27	79.13	119.13	108.84	26.13	8.71
Danthonia	60.63	115.07	66.70	80.80	29.83	9.94

Total species in community also show a general peak during the month of July and August. During May and August maximum species were present in *Polygonum* community while lowest was in mixed *Herbaceous* community. In July and September the highest species count was in *Danthonia* community while lowest was in mixed *Herbaceous* and mixed *Danthonia*. In October the highest species number was present in mixed *herbaceous* community while lowest in *Trachydium* community (Table 4).

Table 4: COMMUNITY TOTAL SPECIES COUNT

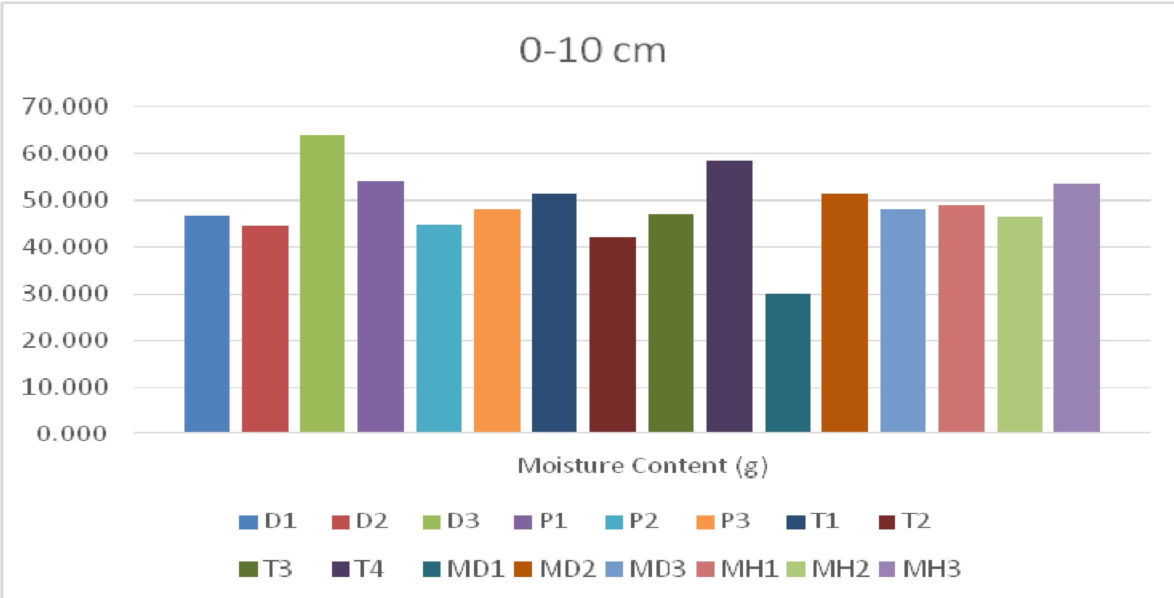
Total species	**month**				
site	May	July	August	Sep	Oct
Trachydium	25	46	42	46	16
Mixed *Herbaceous*	21	42	39	45	34

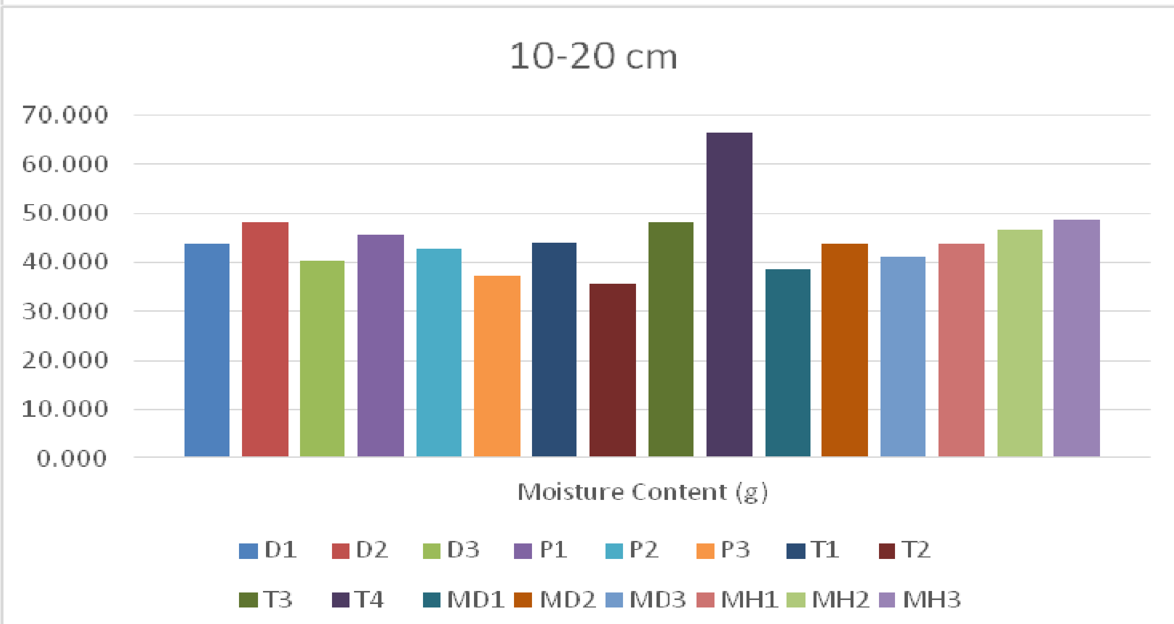
Mixed *Danthonia*	22	42	39	41	32
Polygonum	27	46	45	46	23
Danthonia	22	50	44	47	31

Soil samples were collected for the period between May and October 2017 from all communities. The sample for the month of July was processed while remaining samples are in the stage of processing. In the month of July the *Danthonia* community has the highest moisture content b/w 0-10 cm while mixed *Danthonia* has lowest (Table 5). In 10-20 cm soil layer all the communities have similar soil moisture content ranging from 40.97% to 46.92%.

Table 5: SOIL MOISTURE CONTENT

Soil Moisture content (%)	**July**					
site	F.wt.	D.wt.	M.C(%)	F.wt.	D.wt.	M.C(%)
Trachydium	215.50	115.17	46.56	238.33	140.70	40.97
Mixed Herbaceous	164.77	82.77	49.77	215.40	114.33	46.92
Mixed Danthonia	278.13	164.47	40.87	284.43	167.87	40.98
Polygonum	232.43	120.13	48.32	272.10	158.53	41.74
Danthonia	306.07	140.73	54.02	377.50	213.57	43.43





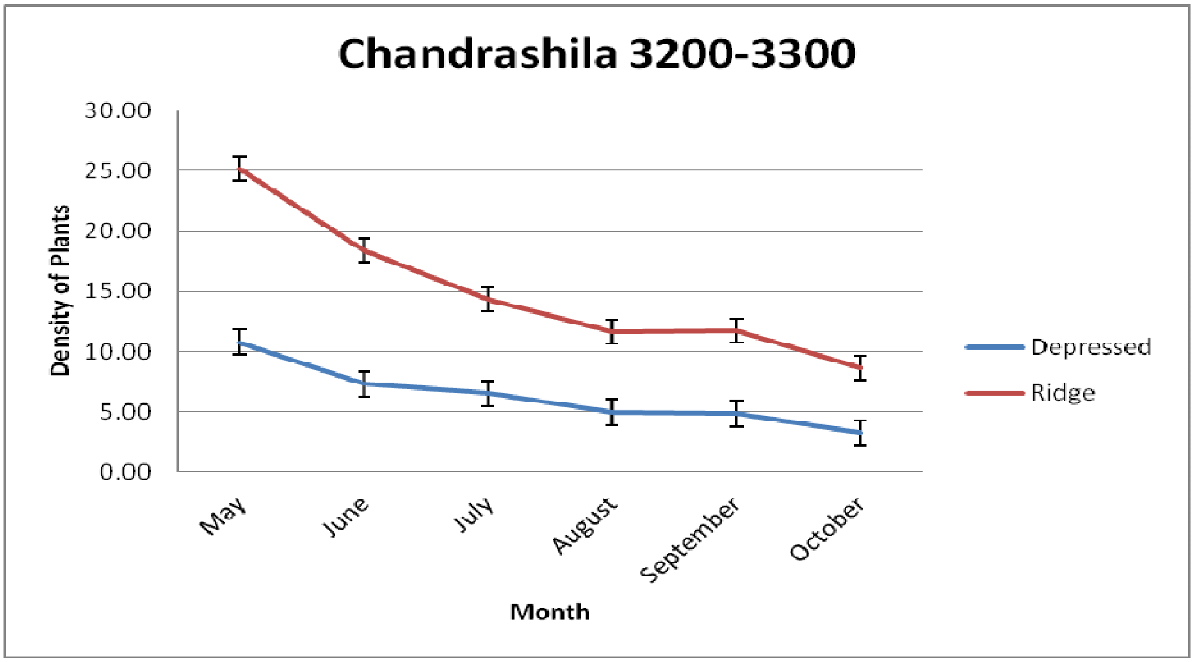
Soil moisture: July

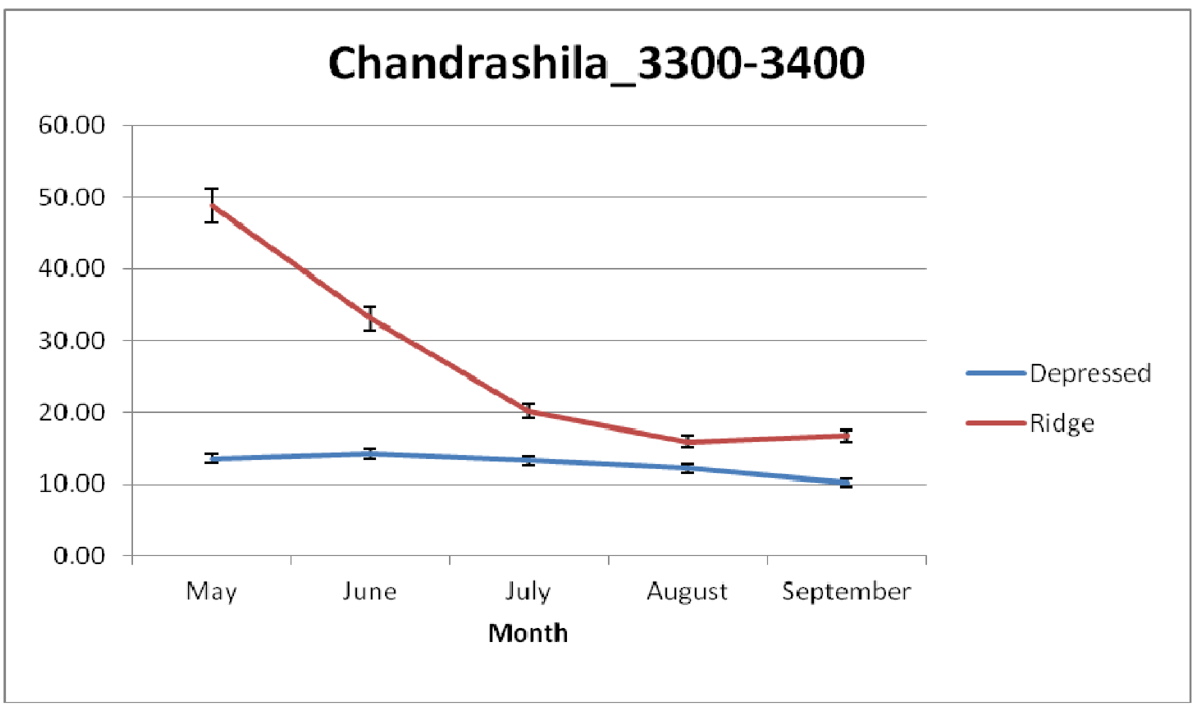
B. Changes in Herbaceous Vegetation and Phenology along Altitudinal Gradient:

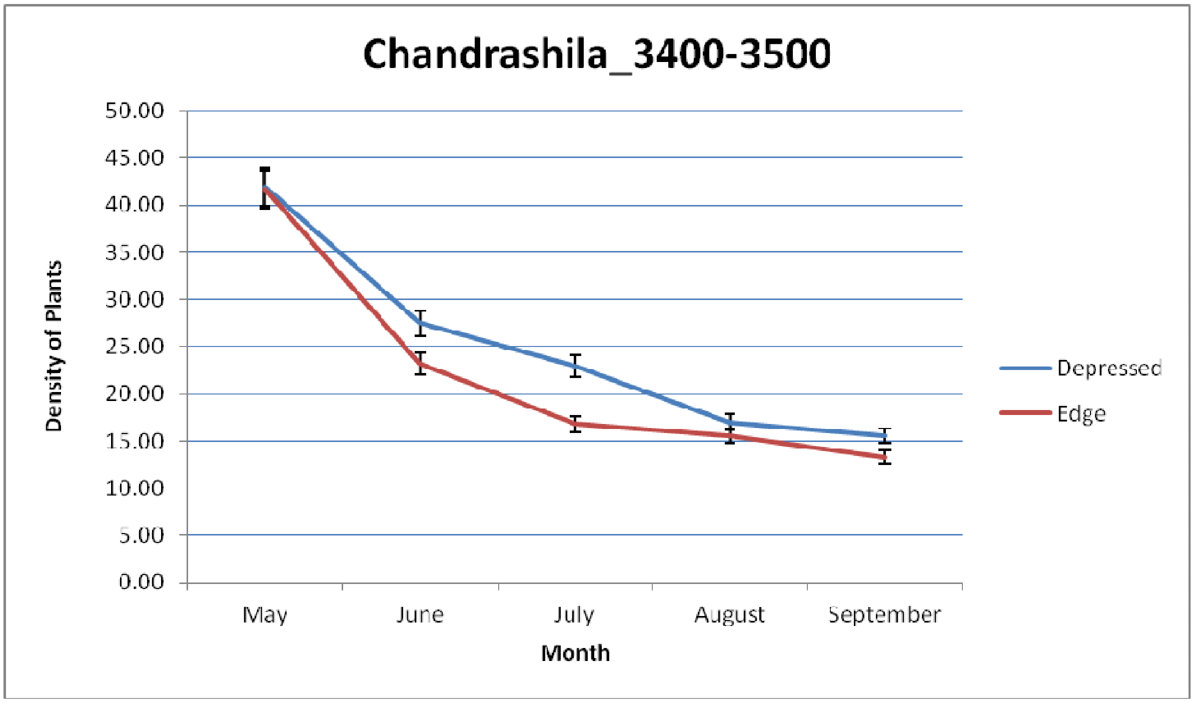
As a general trend the density was higher during the months of May which gradually decreases along with time. In each transact and altitudinal gradient the trend is same with few exceptions. The vegetation data of the month October is still under a process and the data for altitudinal phenology for the period of May 2017 to October 2017 is still being processed.

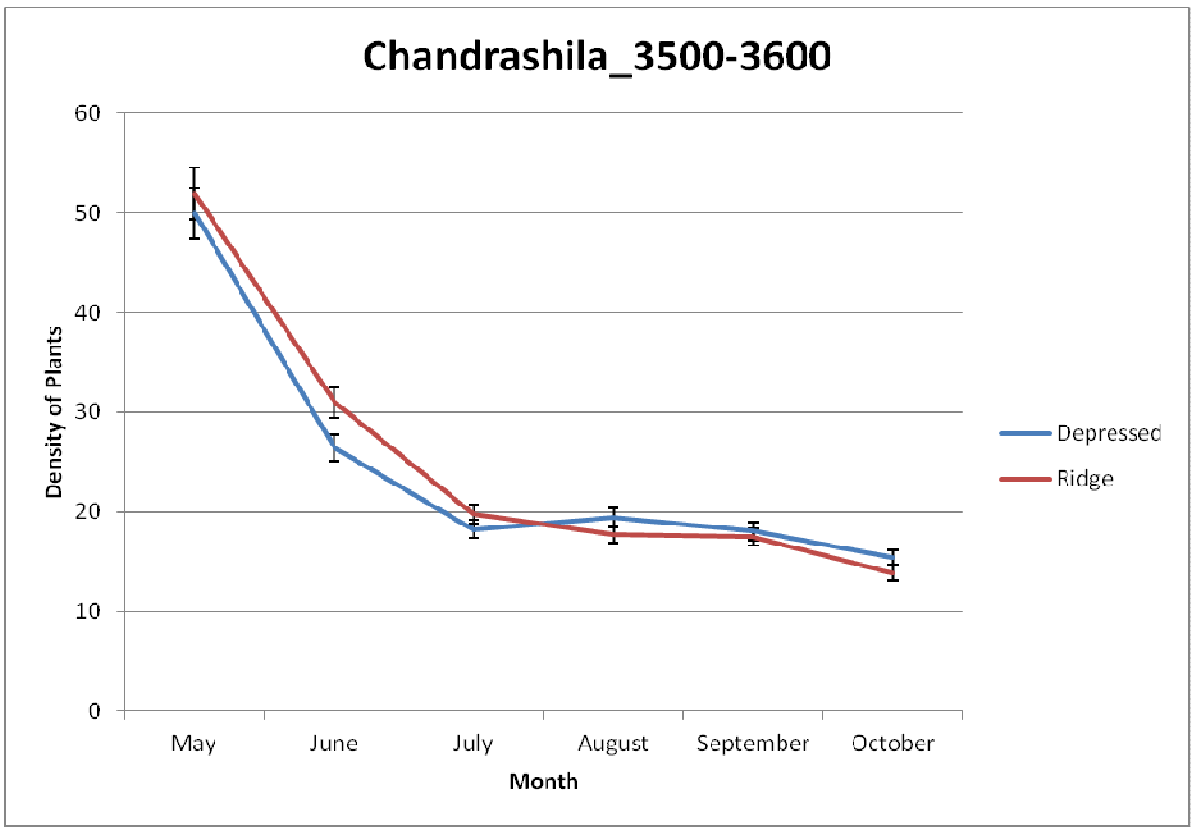
- **Chandrashila:**

The density of herbaceous vegetation in both depressed and ridge microhabitat decreases along with the month. This trend is evident in all four altitudinal gradient of this particular transact.



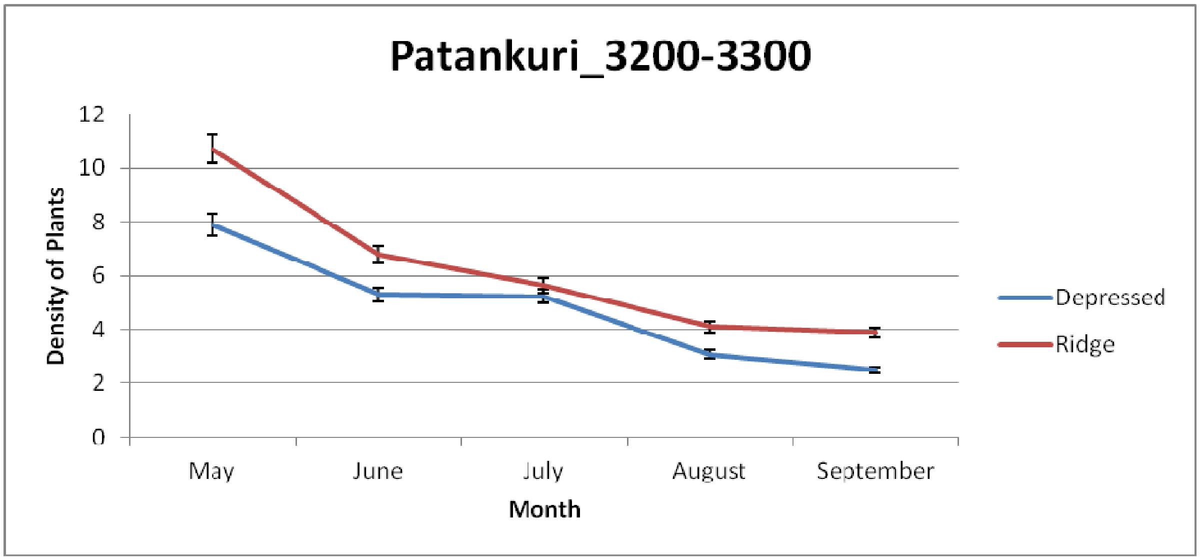


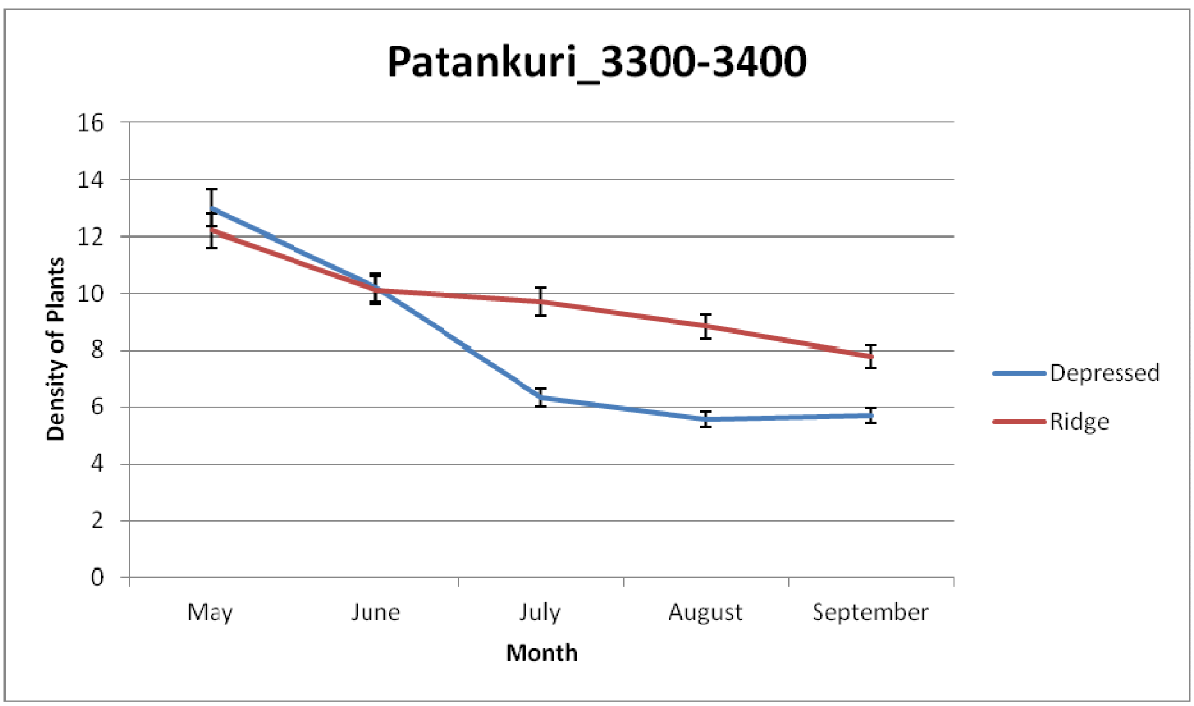

Chandrashila_3400-3500
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Density of Plants
May
June
July
August
September
Month
Depressed
Edge

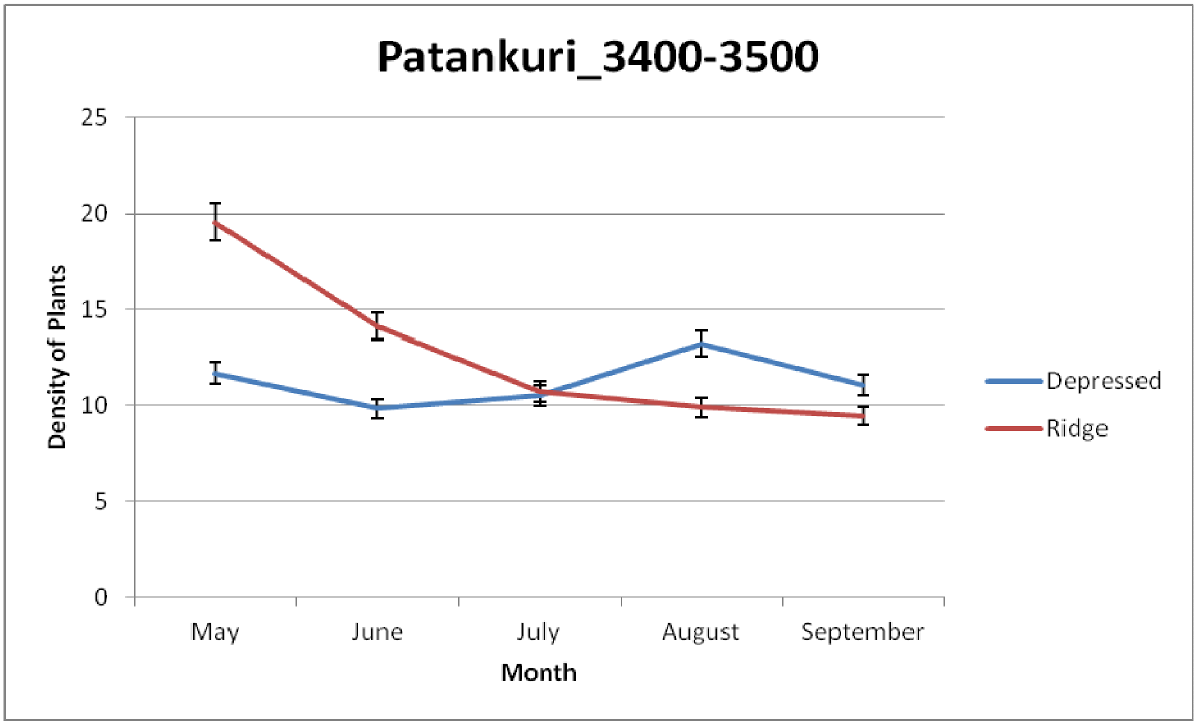

Chandrashila_3500-3600
60
50
40
30
20
10
0
Density of Plants
May
June
July
August
September
October
Month
Depressed
Ridge

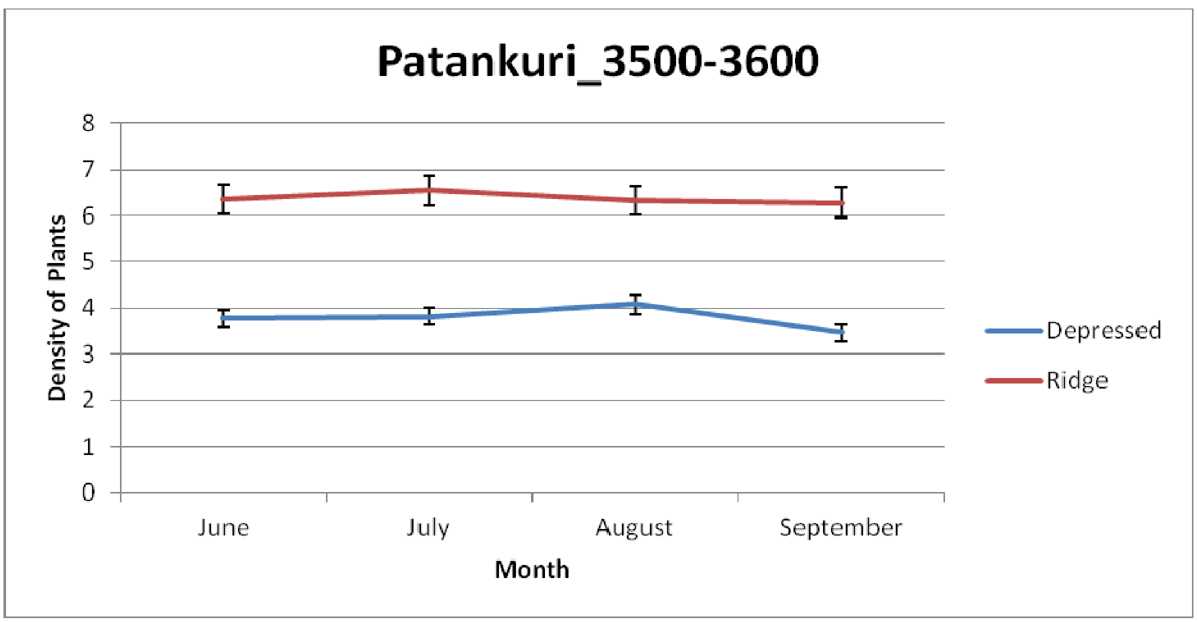
• **Patankuri:**

The density of herbaceous vegetation in both depressed and ridge microhabitat decreases along with the month. But this trend is not evident in all four altitudinal gradient of this particular transact. In the altitude range of 3400-3500 meter the density of the plants does not decrease significantly. In the month of august it rather increases. In the highest altitude range of 3500-3600 meter the herbaceous vegetation does not show significant decrease in density at all.



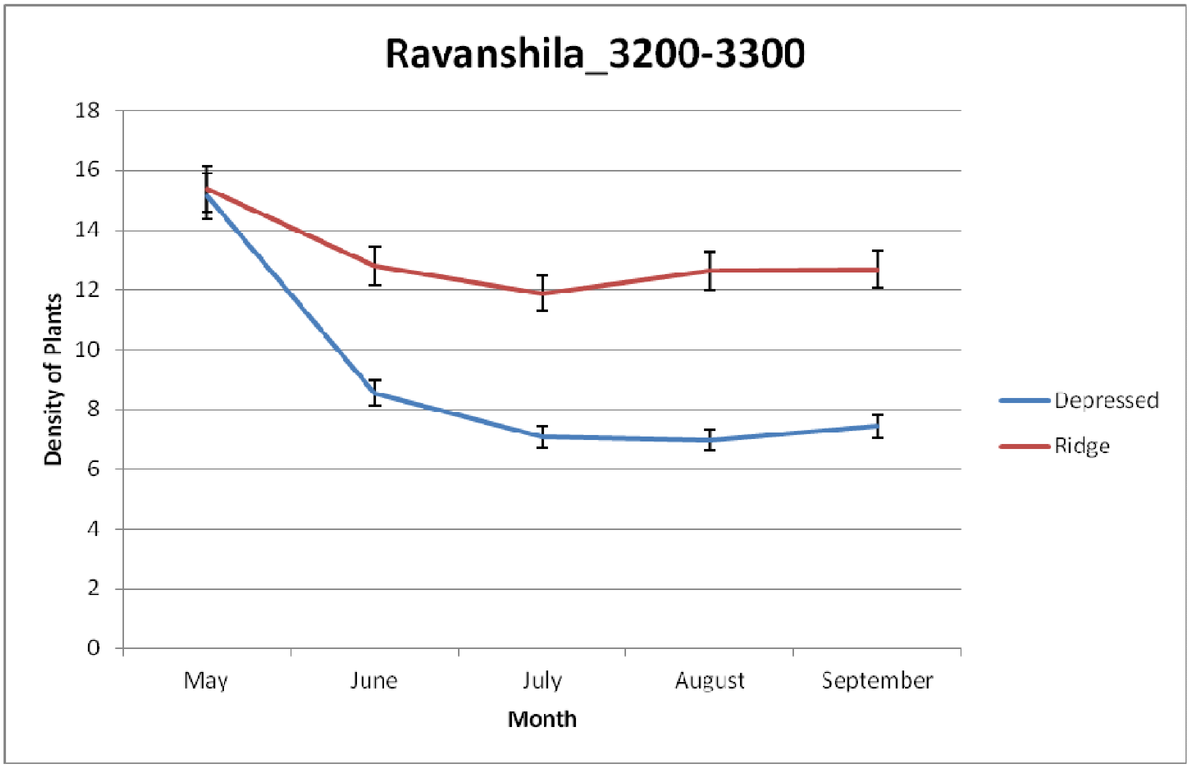


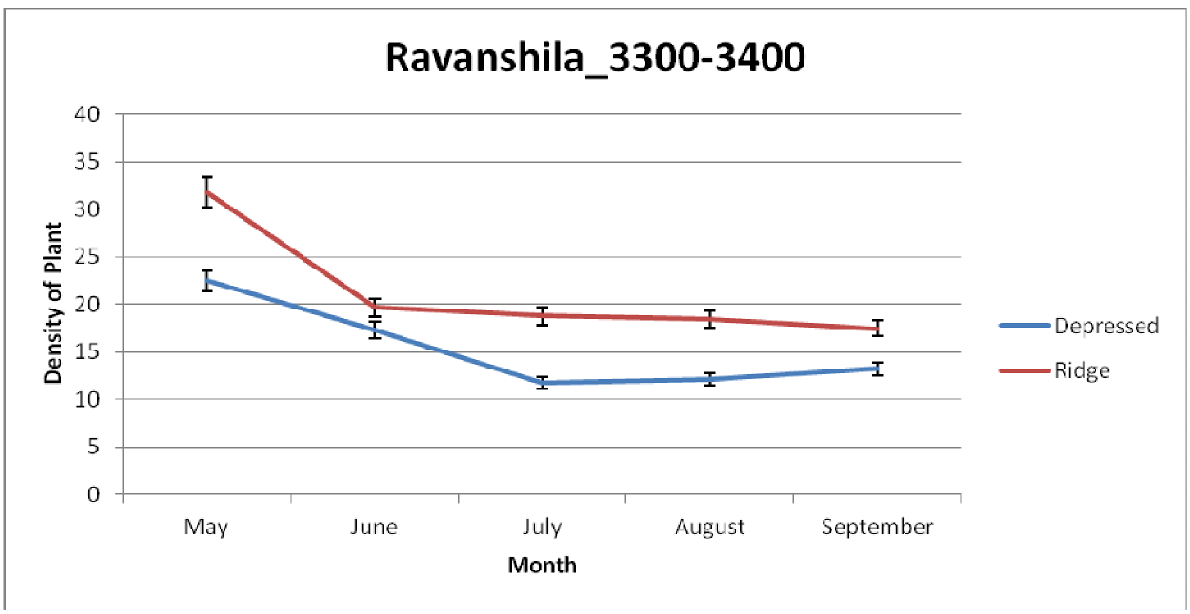




- **Ravanshila:**

The density of herbaceous vegetation in both depressed and ridge microhabitat decreases along with the month. This trend is evident in all four altitudinal gradient of this particular transact. In all three altitudinal range the decrease in the density mostly occurs in the time of May and June. After that time period the changes is not much significant.


Ravanshila_3200-3300
Density of Plants
0
2
4
6
8
10
12
14
16
18
May
June
July
August
September
Month
Depressed
Ridge


Ravanshila_3300-3400
Density of Plant
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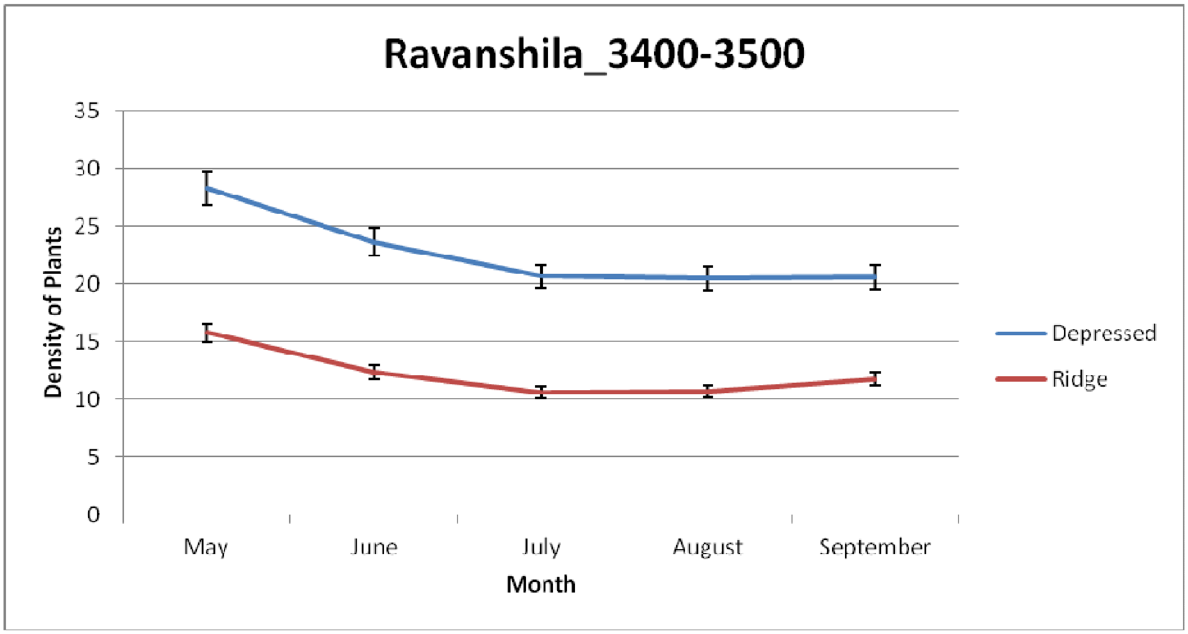
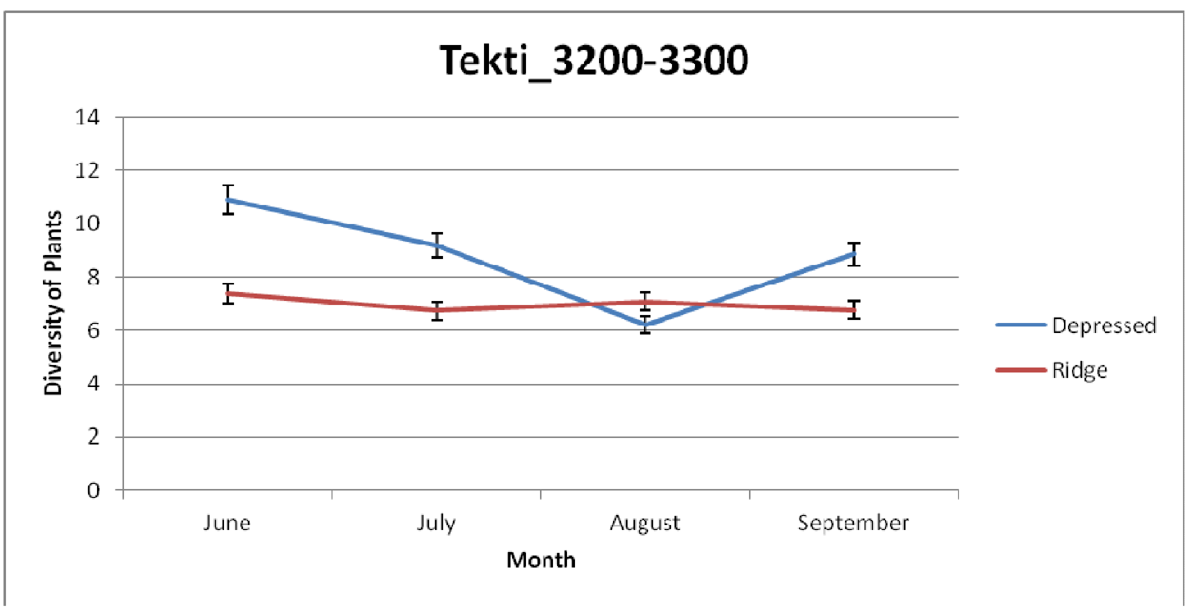
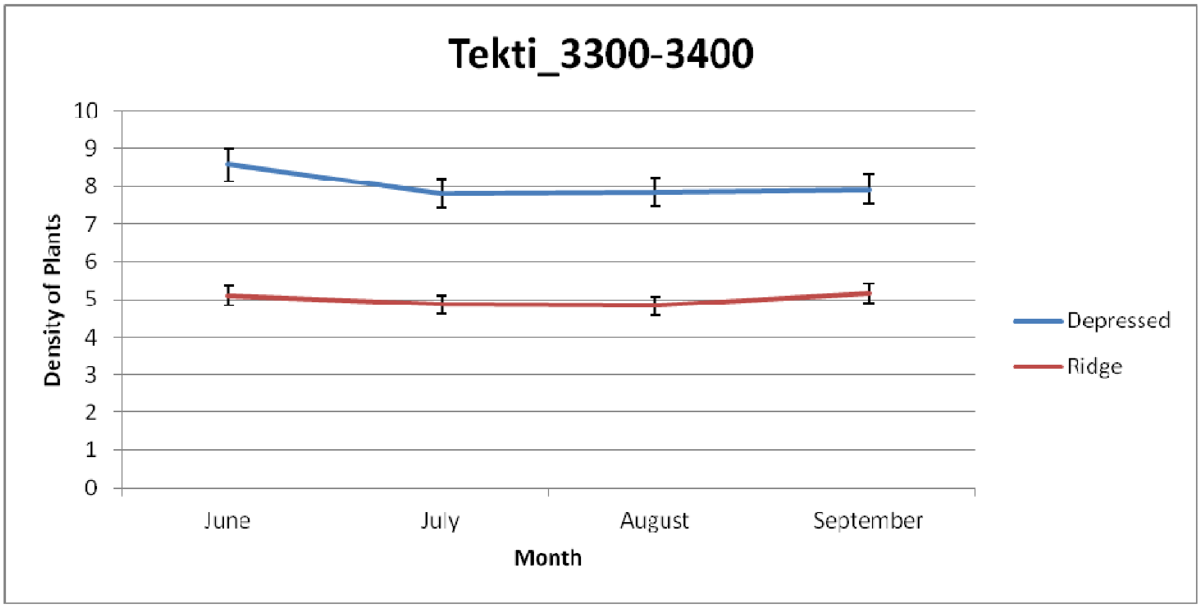
5
10
15
20
25
30
35
40
May
June
July
August
September
Month
Depressed
Ridge

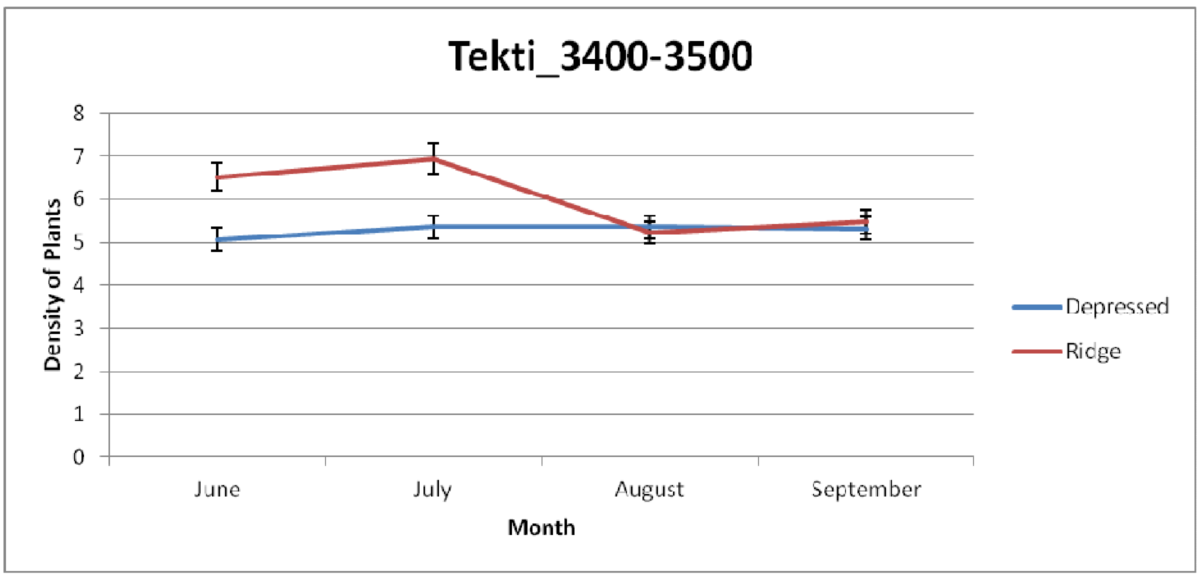


- **Tekti:**

The density of herbaceous vegetation in both depressed and ridge microhabitat changes in almost similar manner. In the lowest altitude range of 3200-3300 meter, the vegetation of depressed microhabitat shows a sudden decrease in density in the month of august but the vegetation of ridge microhabitat does not changes significantly. On the other hand the vegetation of the highest range of altitude (3400-3500 meter) shows a little increase in the density of the plants.







The analysis of phenological data for the month of May to October is still going on. The trend in the changes in plant phenology along the altitudinal gradient is expected after the completion of that process.

Annexure 10

Sub project: Demonstration of appropriate livelihood options and strengthening capacities of local communities in assessing carbon accumulation in and around timberline areas

(Dr. Pankaj Tewari)

Sanction No. and date -: NMHS/LG-2016/009 Dated 31/3/2016

Institution Name-: Central Himalayan Environment Association (CHEA), Nainital

Name and Address of the PI-: Dr. Pankaj Tewari
Central Himalayan Environment Association (CHEA)
06, Wadorf Compound, Mallital, Nainital
Uttarakhand

Name and Address of the Co PI-: None

Project Objectives -: Demonstration of appropriate livelihood options and strengthening capacities of local communities in assessing carbon accumulation in and around timberline areas

<u>Completion in the last six months in % (According to each Deliverables)-:</u>

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 livelihoods.	• Demonstration of Mushroom (*Pleurous mushroom*) turning successful. • Villagers/beneficiaries appreciated and adopted the off-season vegetable and protected cultivation. • Marigold cultivation as initiated floriculture by community members in timberline villages: its potential is high. • Technology and input support for high value vegetable and nutritious fodder among beneficiaries. • Meetings with government officials and several line departments for resource mobilization and maximizing benefits in project villages. • Identification of areas/activities for developing awareness material.	• Community Based organizations(CBOs) are working efficiently as a team in the villages. • Vermi composting in movable beds demonstrated for the first time and well adopted. • Protected andoff-season vegetable cultivation is well accepted by some progressive farmers for additional income generation. • Meeting with Temple committee for trek management with the help of shopkeepers in track (*Chanis*) under waste management and to ban the use of poly bags in timberline area. • Meeting with Horse Union formed to keep the	• 60 kg mushroom was produced worth Rs. 42,000 by community members /benefeciaries in 03 months. Expansion of intervention in area taken up with 50 kg mushroom spawns. • Around 1600 kg vegetable were produced under poly-houses (Tomato, Brinjal, Chilly, Cabbage, Cucumber, Green vegetables and Capsicum) and beside elf consumption income of Rs. 15,000 generated by 120 families in both villages. • 4 ha area covered under vegetable cultivation benefitting 120 families. • 1.5 ha area covered under improved fodder

			trek clean and to aware the tourists for the use of dustbins. • Meeting with government officials, market stakeholders and other organizations working in the region for extensive services and resource mobilization. • Baseline survey in Chitkul, Kinnaur, Himachal Pradesh for assessment of livelihood status in the region.	grasses in the terraces by seed sowing to ensure fodder availability in the vicinity of house and to reduce women drudgery. • Meeting with temple committee and *Chanis* is is positive mode for using natural flowers (marigold) and baskets of *Ringal* as *Prasad.* • Meetings with District Magistrate, senior officers to share project activities initiated and progress of the second year.
2	Promotion of citizen science through engagement of community groups.	• Beneficiaries skill developed by organizing training on *ringal* based handicrafts, vegetable nursery preparation, bird watching, measurement of carbon sequestration rate, etc. • Several campaigns and awareness programs were initiated among *Chanis*, local	• Promotion of Citizen Science Concept by developing 6 leaders from local communities in different sectors. • Better understandin g of resources and their sustainable use among	• 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 also involed government agencies. • Degradable bags

		porters and villagers on the use of poly bags and waste management.	the CBOs.	were distributed to *Chanis* along with awareness campaigns among horse/ponies owners and local porters to keep trek clean.

<u>Summary of progress</u> -: (with in 200 words)

During the first financial year (2016-17) of the project; for the first time the appropriate and low cost technologies were demonstrated in the selected remote villages close to timberline areas of Chopta – Tungnath. As per main objective of the study viz., livelihood enhancement and development comprises of interventions in horticulture, soil and water conservation, forestry, eco-tourism and off-farm activities. During this 06 month reporting period following activities were carried out:

50 demonstrations such as poly houses for off-season vegetable cultivation, poly line tanks for rain water harvesting, vermin composting for organic manure and mushroom cultivation were made; 08 training programmes such as basic training for improving *Ringal* handicrafts, introductory training for measuring forest carbon and bird watching for promoting eco-tourism under the supervision of experts; 10 awareness programmes and 05 workshops in the two selected villages (Makku and Sari) along with a formation of "Horse/ Ponies Union" in Chopta – Tungnath for a proper management of the temple track, control on the use of poly – bags by Chhanis and tourists.

During the first six months of second year, Project activities initiated during the first year were analyzed in group meetings in a participatory way, and necessary adjustments were made.

Assessment of the previous activities:

As mentioned above, 60 kg of *Pleurotus* mushroom was produced in three months span through pilot demonstrations with worth of Rs. 42,000.00 @ Rs. 700.00/kg in the nearby market. Around 1600 kg vegetable production was done by the villagers/beneficiaries with value of Rs. 35,000.00 including income of Rs. 15,000.00. The mushroom and vegetables grown were consumed locally, particularly in restaurants at Chopta-Tungnath. After getting the basic training for making quality Ringal handicrafts, beneficiaries/community members were found to be very confident preparing modern items as per demand such as dustbins, flower pots, pen stand, baskets, etc. cost ranging from Rs. 250.00-800.00 per item. A beneficiary of Makku village Mr. Bali Ram generated income of Rs. 16,800.00 by creating dustbins for CHEA which will be placed at Chopta-Tungnath track during next season.

Another pilot intervention of floriculture is turning successful in both the selected villages with *Tagetes erecta* (Marigold) as a pilot species.

Activities done in second year:

Our experience of year I indicated that mushroom cultivation was possible and a useful livelihood option. So in year II, its cultivation expanded by involving 10 households. In all 4 ha area has been covered under vegetable crops based on demands and technical inputs by experts for increasing the income of 120 families. To ensure availability of improved fodder; fodder seed has been distributed to the beneficiaries covering 1.5 ha area in common village land and terraces of individual land. The seed is of *Festuca arundinacea* (Dolni), *Dectylis glomerata* (Guchi), *Bromus inermis* (Broom), *Lolium perene* (Rai). To strengthen and popularize the Citizen Science, workshops and training programme on "Forest Carbon Sequestration Measurement" was organized under the supervision of Dr. G.C.S. Negi, Scientist-'F', GBPNIHESD in Sari village. The training was also conducted in Makku village along with an introductory training on Bird-watching for promoting eco-tourism in the region. For creating awareness among villagers, *Chanis*, local porters at village level several meetings, campaigns were organized in collaboration with the temple committee and horse union. Different means i.e. flex, banner, board, lectures, charts, etc. were applied for creating awareness among tourists, visitors, and locals communities. Meetings with temple committee and horse/ponies association were conducted regarding several issues like sanitation in Chopta track, installing dustbins during next season, control on the use of poly-bags etc. The degradable bags were distributed among *Chanis* to avoid pollution in the area.

For resource mobilization and ensuring convergence with line departments the project concept along with documents was shared. The major agencies contacted are horticulture department, veterinary department, district industry centre. A meeting was organized with District Magistrate of Rudraprayag at his office and he warmly supported our initiatives. 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. Technical support and monitoring was made by expert from horticulture department for having better production of vegetables under poly houses and in open. The training was organized and various issues of villagers were resolved. In continuation of demonstrating livelihood options in Chopta; a baseline survey to get an idea of the present scenario of livelihood status and future options in Chitkul and nearby areas was also carried out.

In the initiating period of the second year, a poster on "*Demonstration of appropriate livelihood options and strengthening capacities of local communities in assessing carbon accumulation in and around timberline areas*" enrolling the activities done in first year of the project was presented in an event having a theme of "*Indian Himalayan Timberline Research and Sustainable Development*", under the workshop entitled, " *Connecting Science with Practices and Policy for Resilience towards Climate Change Risks in Uttarakhand*" organized by Indian Himalayas Climate Adaptation Programme (IHCAP). In continuation to this, a abstract on "*Enhancing Sustainable Livelihood Options to Reduce Vulnerability and Increase Resilience towards Climate Change in Timberline Area, Himachal Pradesh*" was submitted in National Seminar on "*Himalayan Biodiversity: Characterization and Bioprospection for Sustainable Utilization*" organized by University of Kashmir. Also, a abstract titled, "*Promoting Appropriate Technologies for Sustainable Livelihoods of Communities around Chopta-Tungnath Timbelrine of Uttarakhand*" was submitted to 105th Indian Science Congress.

<u>Supporting data files/ maps/ tables/ figures of the results to be attached</u>

Name of PI:- Dr.Pankaj Tewari

Signature:

Date:

Figures: