State Centre on Climate Change (SCCC) Annual Progress Report 2019-2020

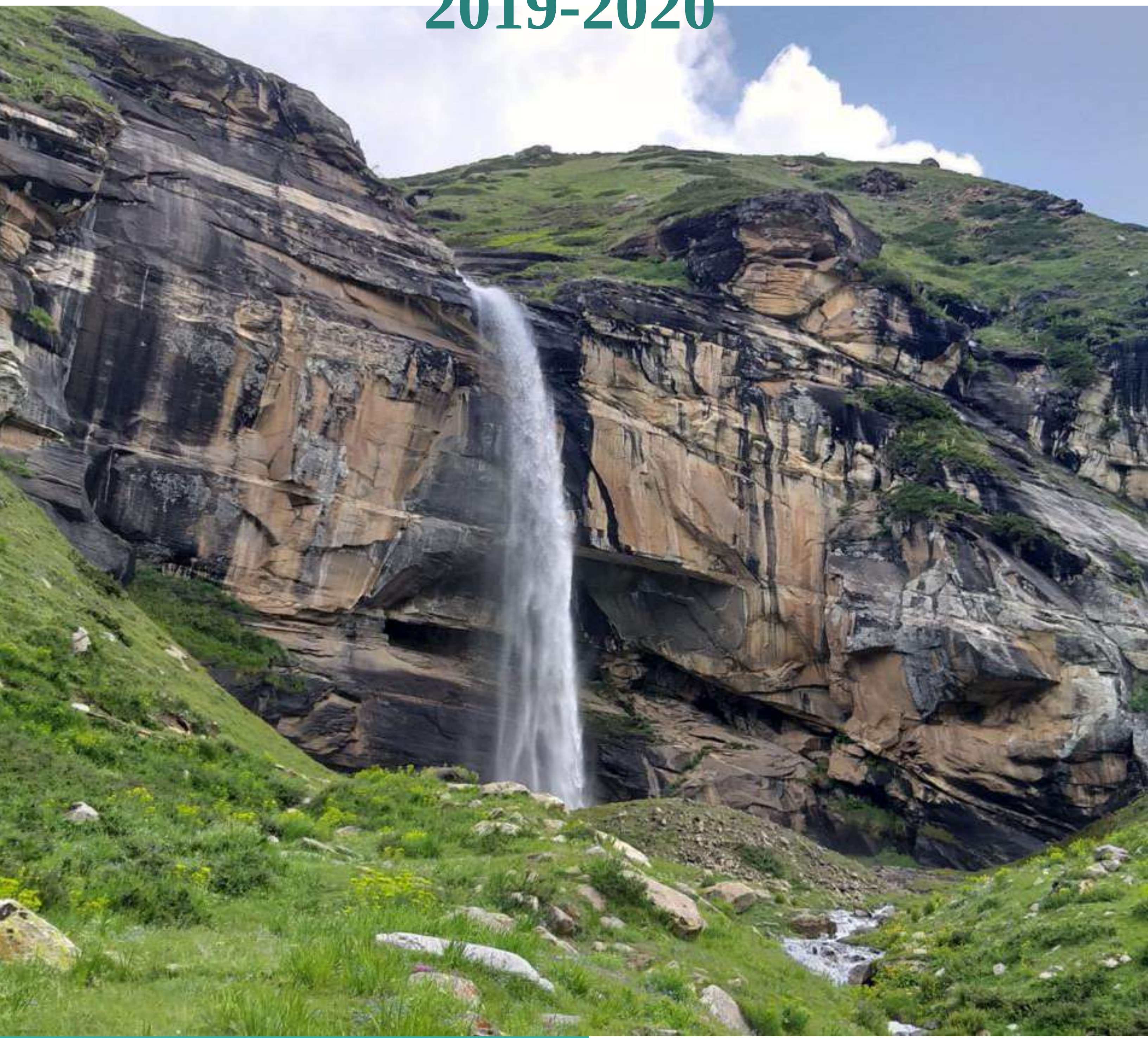


Table of Contents

Table of Tables

Table of Figures

A. SNOW AND GLACIERS STUDIES

1. Monitoring and estimation of mass balance of glaciers with different aspects in Baspa basin using space data and their validation with in-situ observations on Nardu Glacier.

Concluding Remarks:

Based on the investigations carried out in Baspa basin and the observations, made, the following inferences are made:

- SOI toposheets on 1:50,000 Scale reveals the presence of total 78 glaciers having total area of 240.95Km^2 in the whole Baspa basin.

- The classification of 78 glaciers suggest that the maximum number of glaciers are located along the north-western aspect i.e. 15(70.84 Km^2) and the least number of glaciers area along the eastern aspect i.e. 4 (7.52 Km^2). Besides this, on the other aspects, the number of glaciers varies from 11(27.71 Km^2) on the northern aspect, 12(69.70 Km^2) on the north-eastern aspects, and 13(26.51 Km^2), whereas on the south, south-eastern and western aspects, the number of glaciers is less than 10.

- The large sized glaciers based on their number and total area, it is found that the glaciers on the north, northeast and northwest are generally larger in size than the glaciers on the other aspects.

- The total 78 glaciers with area 240.95 Km^2 when seen in comparison to the total glaciers mapped from satellite data for 2001, it is observed that a deglaciation of about 34% could have occurred between 1962 to 2001. Besides this, it is worth to mention that the glaciers which have been digitised from SOI toposheets, their boundaries from satellite data could not be taken completely due to data constraints as a results of which their boundaries were not clearly visible and thus could not taken in 2001, by virtue of which there is more difference in the total area of glaciers in 1962 and 2001.

- From the satellite data, the glacier layers for 2001, 2006, 2011 and 2018 were generated using IRS LISS III and LANDSAT satellite data.

- A total of 79 glaciers with area 158.53 Km^2 have been mapped in 2001 with maximum 13 glaciers along the eastern aspect having a total area of 5.92 which indicates that although the number of glaciers mapped on this aspect is more but the glaciers are of smaller dimensions which is mainly due to the bifurcation of large glaciers along this aspect.

- The large sized glaciers as mapped on 2001 are along the northwest i.e. 12glaciers (53.39 Km^2), on the northern aspect with 10 glaciers (39.55 Km^2) and on north-eastern aspect with 5 glaciers (19.55 Km^2), whereas the glaciers facing south, southeast and southeast are generally small sized glaciers.

- The satellite data for 2006 reveals the presence of 79 glaciers having total area of 156.99 Km^2 indicating an overall reduction of about 1.22% of the glacier area between 2001 & 2006.

- The maximum number of glaciers as on 2006 are found to be on the northern aspect i.e. 10 glaciers with area 39.36 Km^2 , on the north-eastern aspect 5 glaciers (19.4 Km^2) and on north-western aspect with 12 glaciers (52.98 Km^2) indicating that these glaciers are generally large sized glaciers, whereas on the other aspects , the glaciers are generally small sized.

- In 2011, the total area of 79 glaciers has further reduced to 155.38 Km^2 indicating an overall deglaciation of about 1.02% between 2006 & 2011 and 1.98% between 2001 and 2011 respectively.

- Besides this, the large sized glaciers as on 2011 are along the north, northeast and northwest aspects and their number varies from 10 (39.23 Km^2), 5 (19.13 Km^2) and 12 (52.64 Km^2) respectively, whereas on the other aspects, the glaciers are of small dimensions.

- Satellite data of 2018 reveals the presence of 79 glaciers with area 153.68 reflecting an overall reduction of about 1.09% between 2011 & 2018 and about 3.05% between 2001 & 2018 in terms of the total area of the glaciers in Baspa basin from satellite to satellite data interpretation.

- Further investigations and analysis of the data reveals that total deglaciation of about 0.97% between 2001 & 2006, 1.02% between 2006& 2011 and 1.09% between 2011 & 2018 have been observed amongst the 79 glaciers mapped from satellite to satellite data interpretation, whereas a total of about 3.06% loss of glacier area or the deglaciation between 2001 & 2018 based on satellite data interpretation i.e. 79 glacier in 2001 have the glacier area of 158.53 Km^2 has been reduced to 153.68 Km^2 in 2018.

- The maximum deglaciation observed to be amongst the southeast (7.98%) and southwest (7.93%) facing glaciers, where as the east facing glaciers does show a total loss of about 7.26% mass during the period 2001 & 2018 reflecting that the southeast, southwest and east facing glaciers are deglaciating at a faster rate than the glaciers on the other aspects, and the same trend of deglaciation could also be seen during the period 2001 & 2006, 2006 & 2011 and 2011 & 2018.

- Further classification of glaciers based on different aerial ranges i.e.0-1,1-3,3-5,5-10 & >10 Km^2 and their analysis suggest that out of 79 glaciers mapped from satellite data, maximum number of glaciers (52) have been categorised as the small sized glaciers with area <1. When these glaciers are seen on a larger span (2001&2018) reflects a total deglaciation of about 7.67 % as a whole. Further analysis reveals that the maximum deglaciation is along the east facing glaciers (7.69%), 10.24% along the southeast facing and 7.62% along the southwest facing glaciers could be observed in case of the glaciers with area less than 1.

- Likewise the north facing glaciers with area <1 shows a total deglaciation of about (4.94%), northeast facing (6.94%), south facing (7.80%), west facing (6.72%), and northwest facing glaciers (7.80%) during the period 2001&2018.

- In general in case of the small sized glaciers with area <1 Km^2 , the rate of deglaciation varies from southeast, northwest , south, east, southwest, northeast, west and north aspects in the decreasing order.

- The glaciers within the aerial range 1-3 Km^2 suggest the presence of 15 glaciers i.e. about 19% glaciers in the Baspa basin are within the aerial range of 1-3 Km^2. When these 15 glaciers are seen temporally between 2001 & 2018, it is found that the total area of 15 glaciers varies from28.80 (2001) to 27.19 (2018) reflecting an overall reduction of about 5.59% of glacier area and further we can say that these glaciers area deglaciating at a rate of about 0.09 Km^2 per year between 2001 & 2018.

- As far as the aspect wise deglaciation in the decreasing order during this period (2001-2018) is concerned, the glaciers facing southwest shows reduction of 12.15%, glaciers facing northeast shows reduction of 6.94%, the east facing glaciers shows reduction of 5.83%, on northwest aspect shows reduction of 5.59%, southeast (4.66%) , on the south aspect reduction is about 4.07 Km^2 and on the western aspect it is about 1.76%.In other words we can say that the glaciers facing southwest shows maximum deglaciation and the western facing glaciers shows the least deglaciation during this period, where as in case of small glaciers with area less 1 Km^2, maximum deglaciation is along southeast aspect(10.24%) and the minimum is along the north facing glaciers (4.94%).

- In case of the glaciers with aerial range 3-5 Km^2, only 5 glaciers could be mapped out of 79 glaciers mapped indicating that about 6% of the total glaciers mapped falls within this category of aerial range. The total area occupied by the 5 glaciers is 20.84 Km^2 (2001) which has been reduced to 20.22 Km^2 in the year 2018 , thereby reflecting an overall reduction of about 3% between 2001 & 2018 in case of the glaciers having area between 3-5 Km^2.Further analysis reveals that this category of glaciers are located mainly along north, northeast ,southwest and northwest aspects , and out the maximum deglaciation (3.99%) has been observed within the glaciers along the northeast aspect and the minimum (1.31%) is along the northwest aspect. . The glacier facing north shows deglaciation of about 1.41% where as southeast facing glaciers shows deglaciation of about 3.97% amongst the glaciers having aerial range of 3-5 Km^2.

- In case of the glaciers within the aerial range of 5-10 Km^2 ,5 glaciers have been categorised into this category and comprise of total area of 31.52 Km^2 (2001), 31.32 Km^2 (2006) , 31.11

Km^2 (2011) and 30.97 Km^2 (2018) thereby reflecting an overall reduction of about 0.55 Km^2 i.e about 1.74% of the total area loss of 5 glaciers during 2001 & 2018.Futher maximum area occupied by these 5 glaciers is along the western aspect which varies from 10.92 Km^2 (2001) to 10.81 Km^2 (2011) to 10.76 Km^2 (2011) to 10.72 Km^2 (2018) reflecting an overall deglaciation of about 1.18% between 2001 & 2018 . The glaciers on the northeast aspect occupies a total of 9.14 Km^2 (2001) which has been reduced to 8.91 Km^2 (2018) indicating a deglaciation of 2.51%, along the northwest aspect facing glaciers the deglaciation is of the order of 1.07% and on the north it is of the order of 1.01% between 2001 & 2018 in case of glaciers with area between 5-10 Km^2.

- In case of large glaciers with area >10 Km^2, the analysis reveals the presence of only 2 glaciers comprising of total area of 55.73 Km^2(2001), 55.55 Km^2 (2006), 55.41 Km^2 (2011) and 55.31 Km^2 (2016) indicating deglaciation of 0.42 between 2001 and 2018 respectively. Further these 2 glaciers are located along north and northwest aspects and shows deglaciation of about 0.57% along north facing glaciers and about 0.87% loss along northwest facing glaciers during the period 2001& 2018.The intermediate period also shows similar trends of deglacations.

- Further analysis based on the classification of glaciers based on different aerial ranges, it is found that the large glaciers with area >10 Km^2 are los mass of about 0.57% within the span of about 17 years (2001& 2018) at a rate of about 0.02 Km^2 /year, whereas the smaller glaciers with area less than 1 Km^2, losses a total mss of about 7.67% at a rate of 0.09 Km^2/yr. The intermediate glaciers are losing their mass at a rate of 0.09 Km^2/yr within 1-3 sized glaciers, 0.03 Km^2/yr (3-5 sized glaciers) and 0.03 Km^2/yr (5-10 sized glaciers) based on the data analysis during 2001& 2018 period.

2. Integrated studies of Himalayan Cryosphere using space based inputs (ISHC).

A. Mapping of snow cover during 2018-19

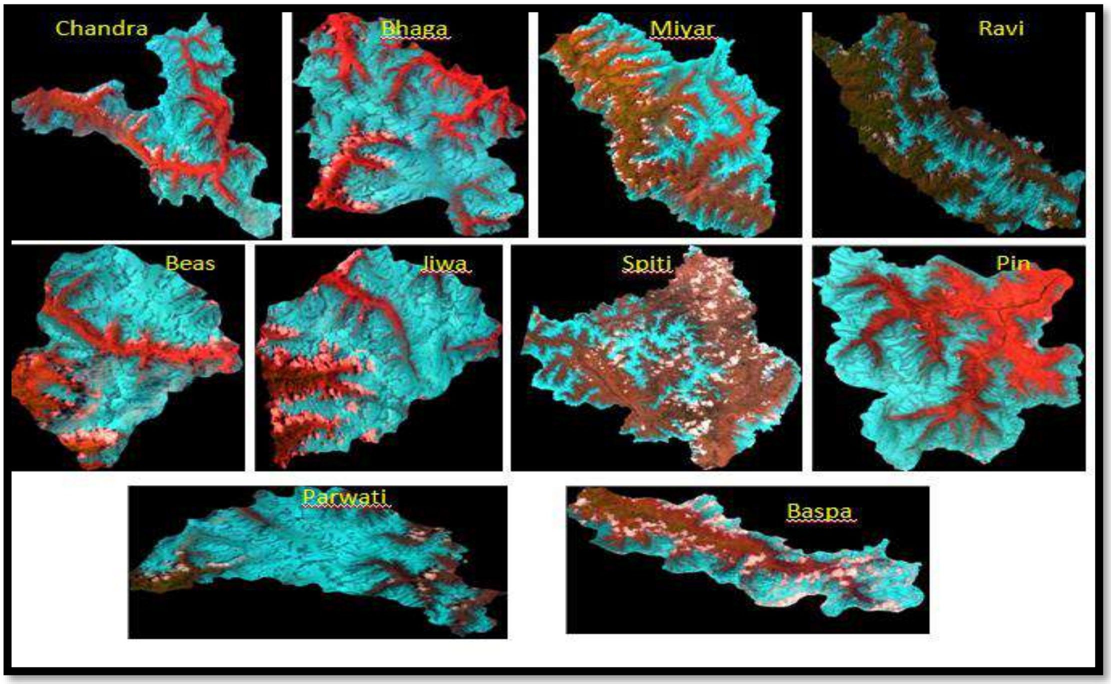


Figure 1 Mapping of Snow Cover during 2018-19 in Chandra, Bhaga, Miyar, Ravi, Beas, Jiwa, Spiti, Pin, Parwati and Baspa Basin

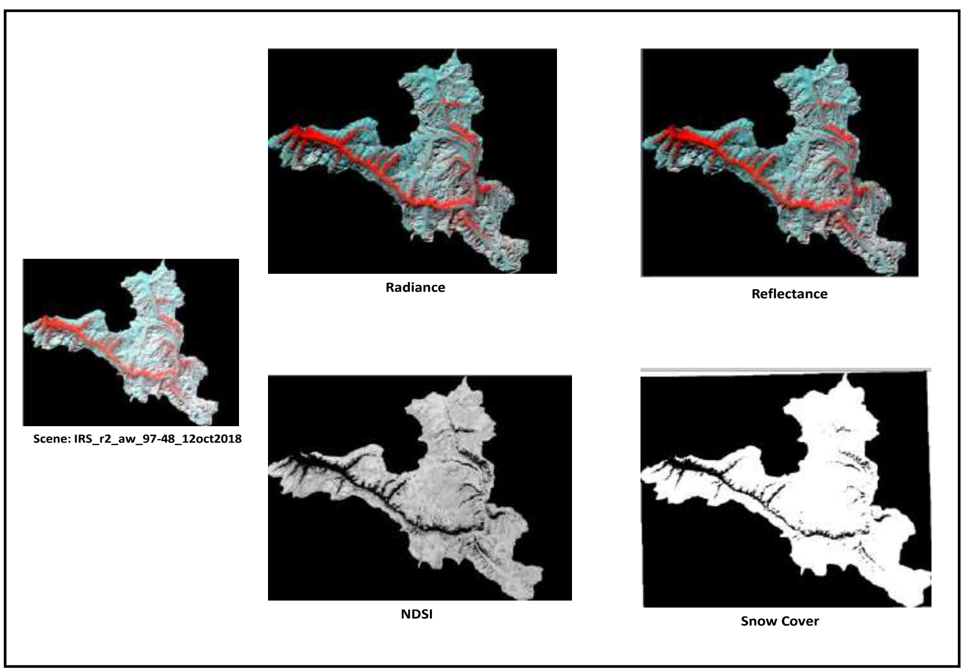


Figure 2 Radiance, Reflectance, NDSI & Snow Cover in Chandra Basin

Results:

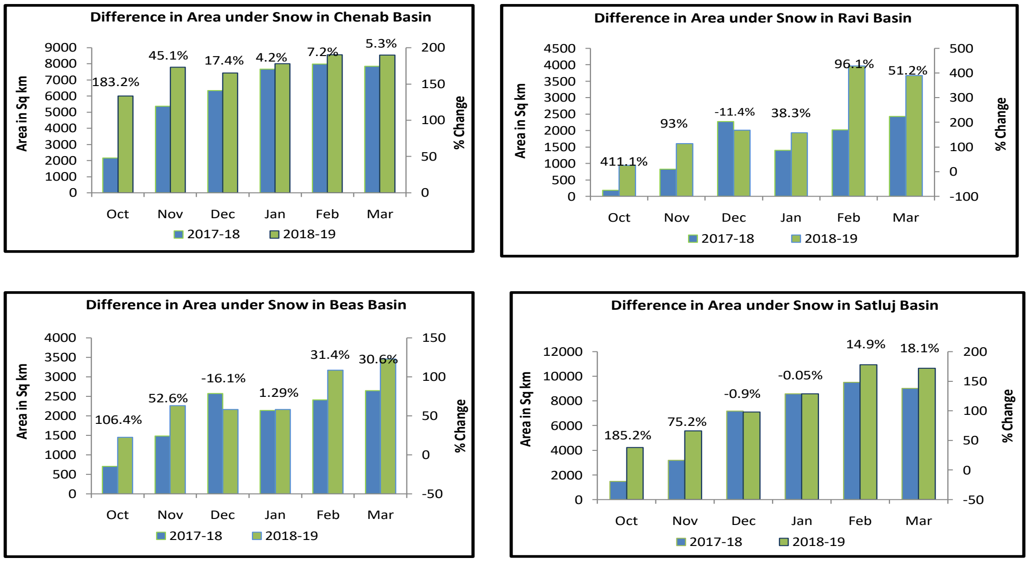


Figure 3 Difference in area under Snow in Chenab Basin, Ravi, Beas & Satluj Basin

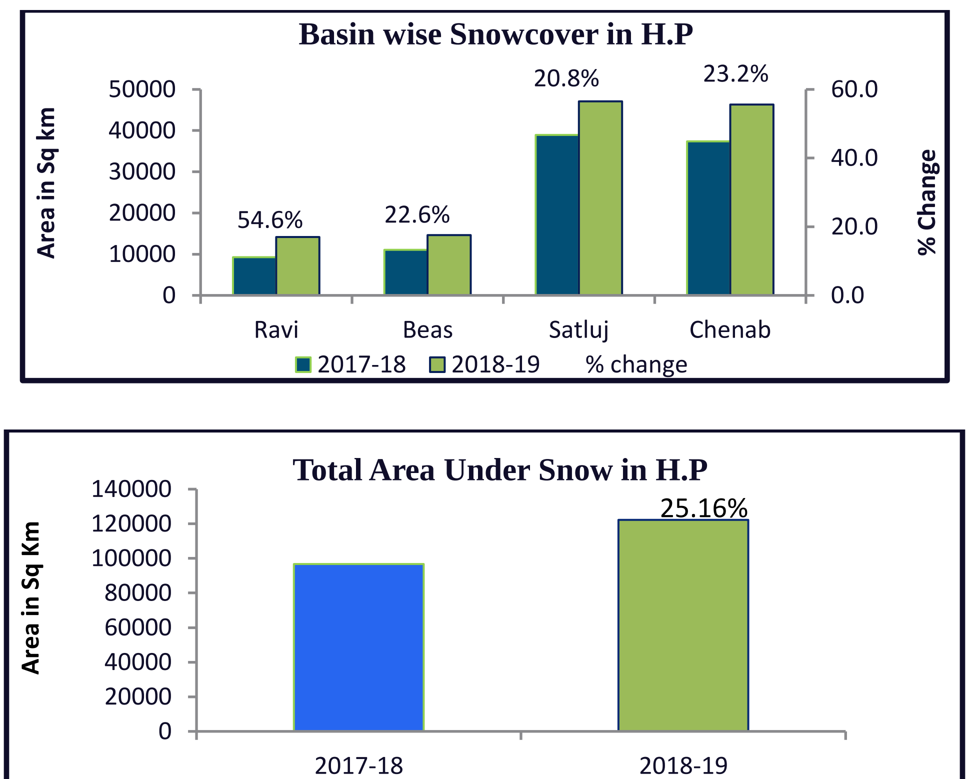


Figure 4 Basin wise Snow cover in Himachal Pradesh and total area under Snow in Himachal Pradesh

- The analysis has been made from the AWiFS satellite data for 2018-19 for assessing the total area under snow cover during the period October to March and its temporal analysis with that of the monthly averaged values of the total area under snow 2017-18, the following inferences are drawn:

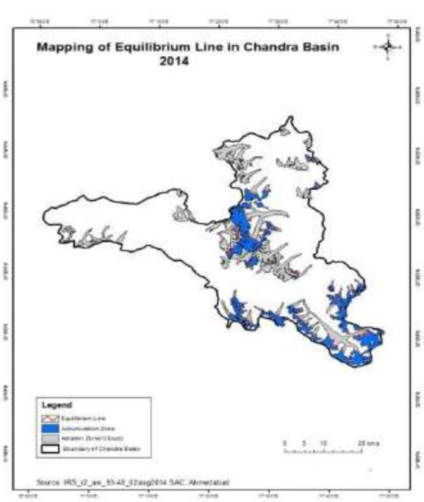
- Basin wise analysis from October to March in 2018-19 and its comparative analysis with that of 2017-18 reveals that, in Chenab basin, maximum increase is of the order of about 183.2% in the month of October, where as November shows an increase of about 45.1% and December, January shows an increase of about 17.4% and 4.2% respectively and February, March shows about 7.2% and 5.3% increase in comparison to 2017-18.

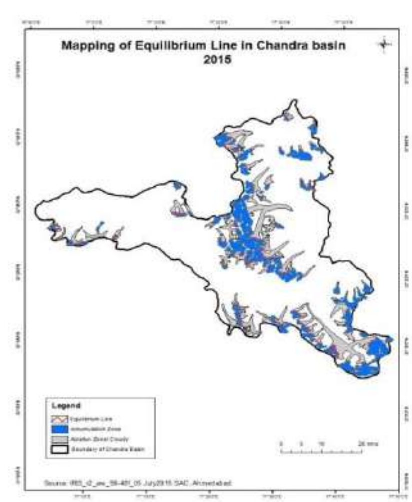
- Ravi basin shows overall increase of about 411.2% in October, while in November it shows an is increase of about 93% in 2018-19 whereas January, February and March shows 38.3%, 96.1% and 51.2% respectively, In December, total snow cover has decreased by 11.4% (2018-19) in comparison to 2017-18.

- Beas basin also shows a more or less similar trend of increase in October by about 106.45%, whereas November, February and March shows of 52.66%, 31.46%, 30.69% respectively in 2018-19, and there is reduction of 16.18 % in the month of December (2018-19).

- In Satluj basin it is concluded that during 2018-19 there is considerably increased snowfall in October (185.2%) and November (75.2%). Whereas December and January months showing reduction of 0.95% and 0.05% and the increase of the order of 14.9% and 18.1% respectively in February and March.

B. Accumulation Area Ratio (AAR) estimation from AWIFS satellite data for 2014-17.





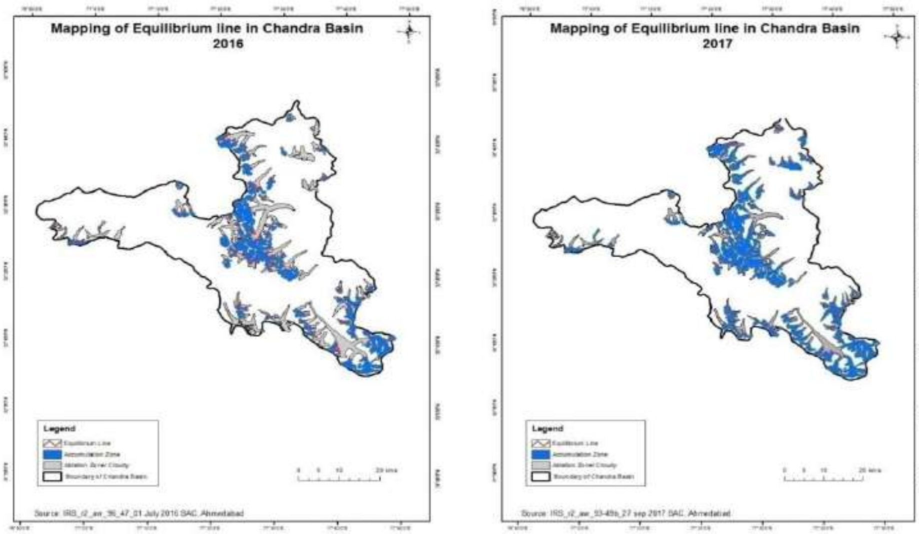


Figure 5 Mapping of equilibrium line in Chandra Basin for years 2014, 2015, 2016 & 2017

ID Object	area_sqkm (2016)	Sub_basin	Path_Row	Date	Area2014	AAR2014	Area_2015	AAR 2015	Area_2016	AAR	AREA_2017	AAR
14	**3.0801**	**Chandra**	**97/48**	**05-07-14**	**1.10932000**	**0.360157**	**1.02737000**	**0.333551**	**1.14743000**	**0.37253**	**2.2944000**	**0.744911**
15	**11.2685**	**Chandra**	**97/48**	**05-07-14**	**6.18213000**	**0.548623**	**3.81223000**	**0.33831**	**Cloudy**	**Cloudy**	**0.1326840**	**0.011775**
16	**3.8228**	**Chandra**	**97/48**	**05-07-14**	**1.91238000**	**0.500252**	**2.12266000**	**0.555259**	**3.23110000**	**0.845211**	**1.1362000**	**0.297214**
17	**2.4829**	**Chandra**	**97/48**	**05-07-14**	**Cloudy**	**Cloudy**	**0.67869800**	**0.273349**	**0.78163400**	**0.314807**	**Cloudy**	**Cloudy**
18	**2.6106**	**Chandra**	**97/48**	**05-07-14**	**Cloudy**	**Cloudy**	**Cloudy**	**Cloudy**	**Cloudy**	**Cloudy**	**Cloudy**	**Cloudy**
19	**3.1409**	**Chandra**	**97/48**	**05-07-14**	**1.76582000**	**0.562198**	**1.08382000**	**0.345064**	**1.81413000**	**0.577579**	**0.7822970**	**0.249066**
20	**11.9763**	**Chandra**	**97/48**	**05-07-14**	**8.38816000**	**0.700398**	**6.44813000**	**0.538409**	**Cloudy**	**Cloudy**	**2.1351000**	**0.178278**
21	**5.8662**	**Chandra**	**97/48**	**05-07-14**	**Cloudy**	**Cloudy**	**Cloudy**	**Cloudy**	**Cloudy**	**Cloudy**	**Cloudy**	**Cloudy**
22	**4.8265**	**Chandra**	**97/48**	**05-07-14**	**1.21826000**	**0.252409**	**2.45436000**	**0.508514**	**1.25302000**	**0.259611**	**0.6992620**	**0.144879**
23	**11.8211**	**Chandra**	**97/48**	**05-07-14**	**7.62131000**	**0.64472**	**4.99220000**	**0.422312**	**7.27629000**	**0.615533**	**7.5566000**	**0.639246**
24	**2.3610**	**Chandra**	**97/48**	**05-07-14**	**1.23822000**	**0.52445**	**1.18350000**	**0.501273**	**1.52812000**	**0.647237**	**1.0417700**	**0.441243**
25	**3.9894**	**Chandra**	**97/48**	**05-07-14**	**1.63520000**	**0.409886**	**1.41164000**	**0.353847**	**1.59212000**	**0.399087**	**Cloudy**	**Cloudy**
26	**6.3369**	**Chandra**	**97/48**	**05-07-14**	**4.96789000**	**0.783966**	**0.94633300**	**0.149338**	**5.25170000**	**0.828754**	**2.0156600**	**0.318085**
27	**2.5987**	**Chandra**	**97/48**	**05-07-14**	**1.80107000**	**0.693074**	**Cloudy**	**Cloudy**	**1.95611000**	**0.752736**	**Cloudy**	**Cloudy**
28	**2.6559**	**Chandra**	**97/48**	**05-07-14**	**Cloudy**	**Cloudy**	**1.58137000**	**0.595416**	**Cloudy**	**Cloudy**	**Cloudy**	**Cloudy**
29	**2.6418**	**Chandra**	**97/48**	**05-07-14**	**0.96838000**	**0.366565**	**0.93197700**	**0.352785**	**1.24688000**	**0.471987**	**0.3246970**	**0.122909**
30	**4.0249**	**Chandra**	**97/48**	**05-07-14**	**1.80731000**	**0.449036**	**1.30409000**	**0.324008**	**1.39564000**	**0.346754**	**0.9902530**	**0.246034**
31	**4.4391**	**Chandra**	**97/48**	**05-07-14**	**1.86873000**	**0.420974**	**2.10152000**	**0.473415**	**Cloudy**	**Cloudy**	**2.1818800**	**0.491518**
32	**7.0664**	**Chandra**	**97/48**	**05-07-14**	**Cloudy**	**Cloudy**	**4.84551000**	**0.685709**	**Cloudy**	**Cloudy**	**4.5305200**	**0.641133**
33	**2.8543**	**Chandra**	**97/48**	**05-07-14**	**2.08029000**	**0.728828**	**1.49876000**	**0.525089**	**1.07708000**	**0.377354**	**1.0645700**	**0.372971**
34	**12.8871**	**Chandra**	**97/48**	**05-07-14**	**Cloudy**	**Cloudy**	**7.54685000**	**0.585613**	**8.10811000**	**0.629165**	**5.7828200**	**0.44873**
35	**24.4953**	**Chandra**	**97/48**	**05-07-14**	**11.78110000**	**0.480953**	**11.97710000**	**0.488955**	**10.1131000**	**0.412859**	**14.978600**	**0.611489**
36	**3.3571**	**Chandra**	**97/48**	**05-07-14**	**Cloudy**	**Cloudy**	**Cloudy**	**Cloudy**	**Cloudy**	**Cloudy**	**0.6795970**	**0.202437**
37	**6.6536**	**Chandra**	**97/48**	**05-07-14**	**Cloudy**	**Cloudy**	**3.92318000**	**0.589632**	**1.32858000**	**0.199678**	**2.3579200**	**0.354382**
38	**2.3038**	**Chandra**	**97/48**	**05-07-14**	**Cloudy**	**Cloudy**	**0.54287200**	**0.235644**	**Cloudy**	**Cloudy**	**0.5084040**	**0.220682**
39	**7.4378**	**Chandra**	**97/48**	**05-07-14**	**Cloudy**	**Cloudy**	**3.52091000**	**0.473379**	**3.51418000**	**0.472475**	**3.6250200**	**0.487377**
41	**3.7832**	**Chandra**	**97/48**	**05-07-14**	**Cloudy**	**Cloudy**	**2.22513000**	**0.588162**	**0.91224000**	**0.241129**	**1.6023200**	**0.423536**
42	**6.3342**	**Chandra**	**97/48**	**05-07-14**	**Cloudy**	**Cloudy**	**1.73709000**	**0.27424**	**1.32154000**	**0.208636**	**2.7180300**	**0.429104**
43	**2.5078**	**Chandra**	**97/48**	**05-07-14**	**0.72386700**	**0.288651**	**Cloudy**	**Cloudy**	**1.55100000**	**0.61848**	**Cloudy**	**Cloudy**
44	**19.1524**	**Chandra**	**97/48**	**05-07-14**	**10.71900000**	**0.559669**	**10.73970000**	**0.560749**	**6.02847000**	**0.314763**	**5.5602500**	**0.290316**
45	**4.3420**	**Chandra**	**97/48**	**05-07-14**	**Cloudy**	**Cloudy**	**2.89661000**	**0.667113**	**Cloudy**	**Cloudy**	**2.3340200**	**0.537544**
46	**2.3339**	**Chandra**	**97/48**	**05-07-14**	**Cloudy**	**Cloudy**	**1.19789000**	**0.513258**	**Cloudy**	**Cloudy**	**1.6871600**	**0.722895**
47	**2.4891**	**Chandra**	**97/48**	**05-07-14**	**Cloudy**	**Cloudy**	**1.29970000**	**0.522151**	**1.71370000**	**0.688475**	**2.2273600**	**0.894837**
48	**3.2382**	**Chandra**	**97/48**	**05-07-14**	**Cloudy**	**Cloudy**	**2.16651000**	**0.66905**	**Cloudy**	**Cloudy**	**Cloudy**	**Cloudy**
49	**4.6621**	**Chandra**	**97/48**	**05-07-14**	**3.58315000**	**0.76857**	**1.24935000**	**0.26798**	**3.54394000**	**0.76016**	**1.6112500**	**0.345606**
50	**2.0366**	**Chandra**	**97/48**	**05-07-14**	**Cloudy**	**Cloudy**	**1.18535000**	**0.582031**	**1.29221000**	**0.634502**	**Cloudy**	**Cloudy**
51	**13.0495**	**Chandra**	**97/48**	**05-07-14**	**7.80409000**	**0.598039**	**6.31598000**	**0.484003**	**3.93068000**	**0.301214**	**5.1734500**	**0.396449**

52	**7.9671**	**Chandra**	**97/48**	**05-07-14**	**Cloudy**	**Cloudy**	**4.42771000**	**0.555751**	**3.07865000**	**0.386422**	**4.7641100**	**0.597975**
53	**2.0095**	**Chandra**	**97/48**	**05-07-14**	**Cloudy**	**Cloudy**	**1.31106000**	**0.652434**	**0.69384100**	**0.345282**	**Cloudy**	**Cloudy**
54	**12.1164**	**Chandra**	**97/48**	**05-07-14**	**Cloudy**	**Cloudy**	**8.04863000**	**0.664278**	**Cloudy**	**Cloudy**	**Cloudy**	**Cloudy**
55	**7.8127**	**Chandra**	**97/48**	**05-07-14**	**Cloudy**	**Cloudy**	**2.46650000**	**0.315703**	**3.74860000**	**0.479807**	**4.0288300**	**0.515676**
56	**2.4674**	**Chandra**	**97/48**	**05-07-14**	**Cloudy**	**Cloudy**	**Cloudy**	**Cloudy**	**1.57006000**	**0.636333**	**0.9086180**	**0.368256**
57	**2.4081**	**Chandra**	**97/48**	**05-07-14**	**Cloudy**	**Cloudy**	**2.04539000**	**0.84938**	**Cloudy**	**Cloudy**	**0.8376230**	**0.347836**
58	**27.2322**	**Chandra**	**97/48**	**05-07-14**	**Cloudy**	**Cloudy**	**7.01040000**	**0.257431**	**Cloudy**	**Cloudy**	**6.4338400**	**0.236259**
59	**4.5064**	**Chandra**	**97/48**	**05-07-14**	**Cloudy**	**Cloudy**	**3.71987000**	**0.82546**	**0.74044000**	**0.164308**	**1.6284800**	**0.361369**
60	**3.3599**	**Chandra**	**97/48**	**05-07-14**	**Cloudy**	**Cloudy**	**2.11497000**	**0.629472**	**2.42601000**	**0.722045**	**Cloudy**	**Cloudy**
61	**6.1883**	**Chandra**	**97/48**	**05-07-14**	**5.31652000**	**0.859121**	**3.53513000**	**0.571258**	**3.81870000**	**0.617081**	**3.2568800**	**0.526294**

Table 1 Results of estimation of Accumulation Area Ratio (AAR) of Chandra Basin for year 2014, 2015, 2016 & 2017

3. Pilot Project on Snow-Ice Harvesting at Pooh Village, District Kinnaur Himachal Pradesh

Area of Research-Earth Sciences & Sub Area-Glaciology

Objectives:

- To study the possibility of snow retention and water freezing techniques that can be implemented in the affected areas.
- To study the accumulation and ablation of wind drifted snow in and near the reservoir.
- To simulate and model water freezing and melting in the reservoir.
- To explore the methodology to delay frozen ice melting.
- Mass and energy balance estimation.
- To generate slope, aspect, morphological map of the study area.
- To study the change detection of snow-ice accumulation pattern using archive satellite data as well as the latest high resolution satellite data.

Methodology: In order to achieve the objectives of this pilot study the following methodology will be used:

(i) Snow Fence

A snow fence of size 100 m in length and 4 m in height will be installed in the formation zone near the reservoir so that the wind drifted snow gets accumulated near the reservoir.

(ii) Mass and energy balance of snow/ice

The snow stake and AWS will be installed in the reservoir and in the periphery of the experimental site to study the mass and energy balance of the snow and ice. Snow met parameters will be collected from AWS sensors.

(iii) Reservoir for accumulation of snow and freezing of water

A reservoir of size 45*25*1.3 m will be constructed near the field site for collection of snow and winter freezing of water in the form of ice so that water loss due to evaporation and seepage is reduced.

(iv) Effective freezing technique of water

When temperature is below sub zero the water will be brought to the reservoir from the source and water will be allowed to freeze naturally. The freezing rate of water will depend on the freezing technique which will work on the surface to volume ration principal.

(v) Remote sensing based mapping

Since the experimental site is inaccessible during winter. The snow information of the site will be gathered and analyzed by using satellite image. As per the objectives of the study the chronological snowline has been delineated. The detailed snow cover area along with various altitudinal gradients is given below:

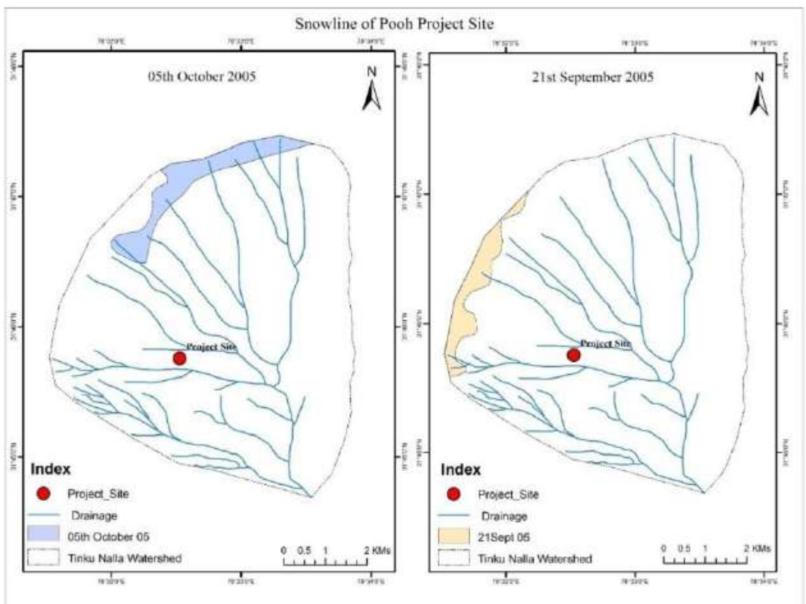


Figure 6 Snowline of Pooh Project Site for 21st September & 5th October Year 2005

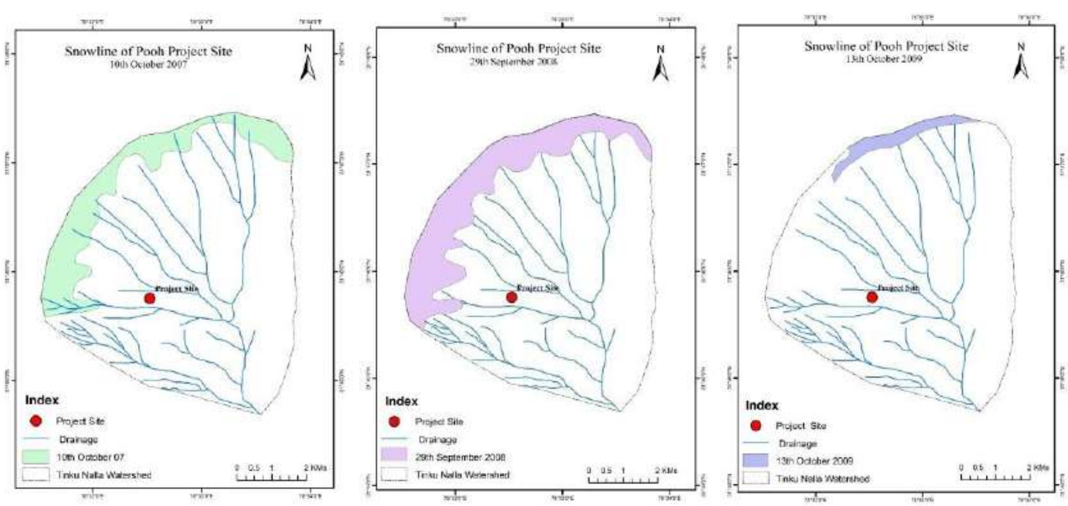


Figure 7 Snowline of Pooh Project Site for 10th October, 2007; 29th September, 2008 & 13th October, 2009

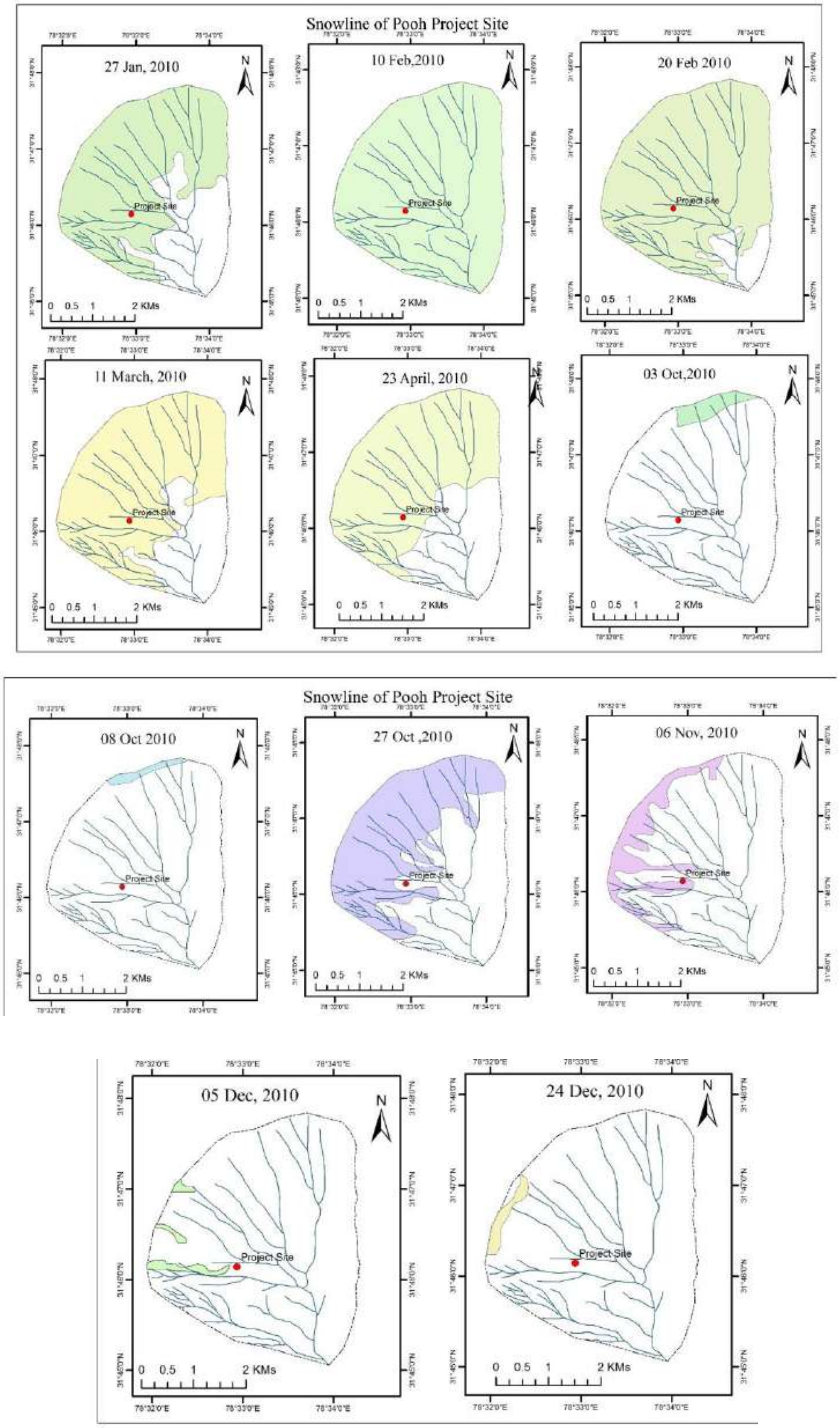


Figure 8 Snowline of Pooh Project for Year 2010

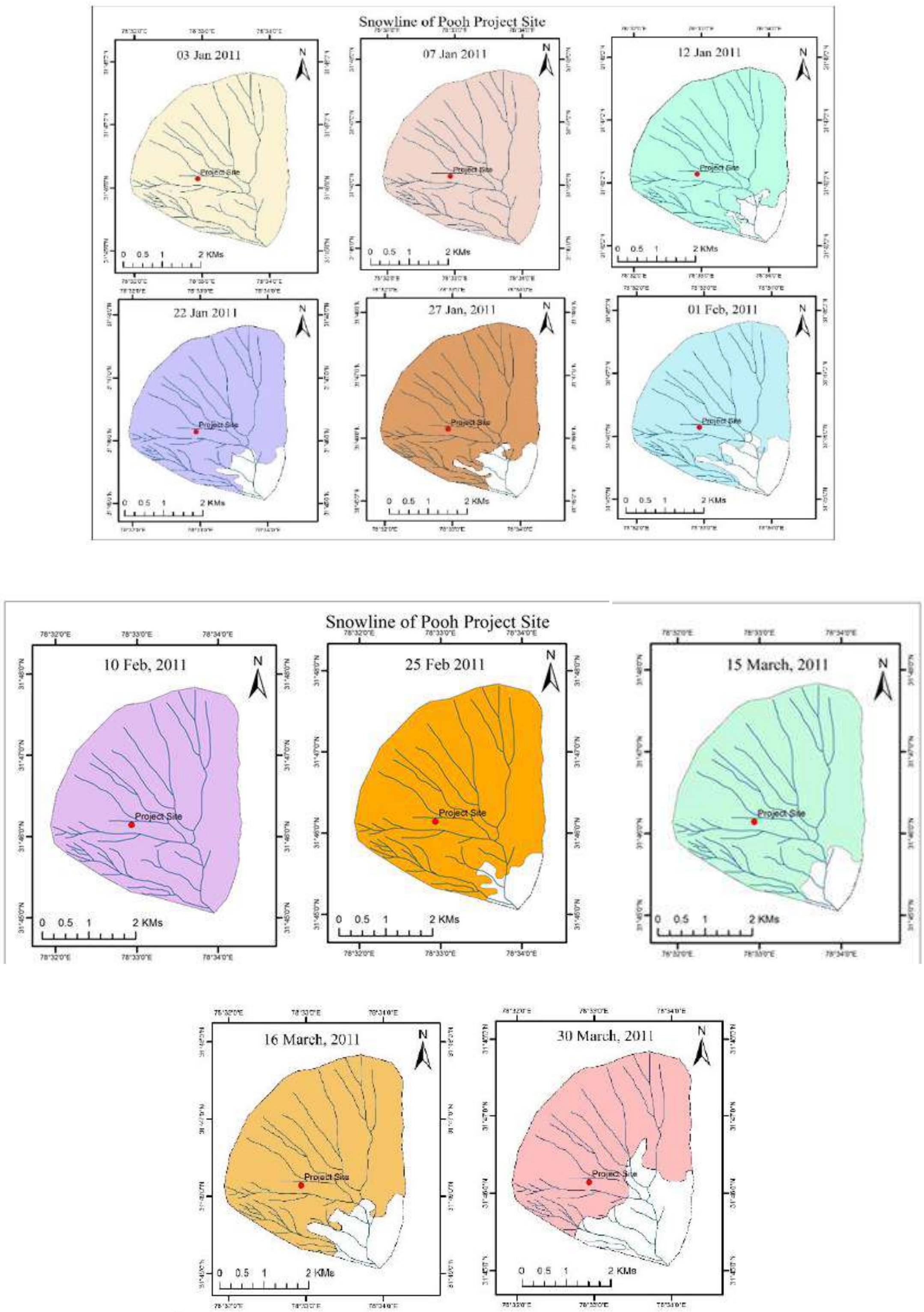


Figure 9 Snowline of Pooh Project Site for Year 2011

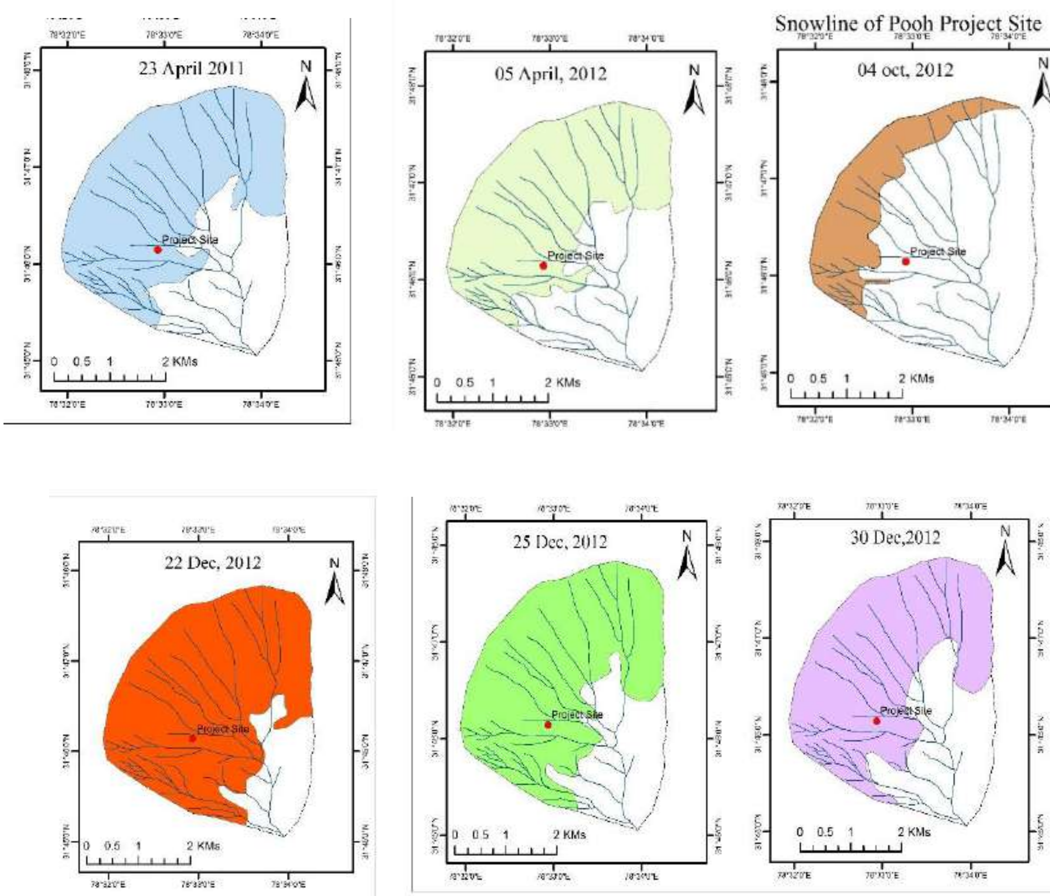
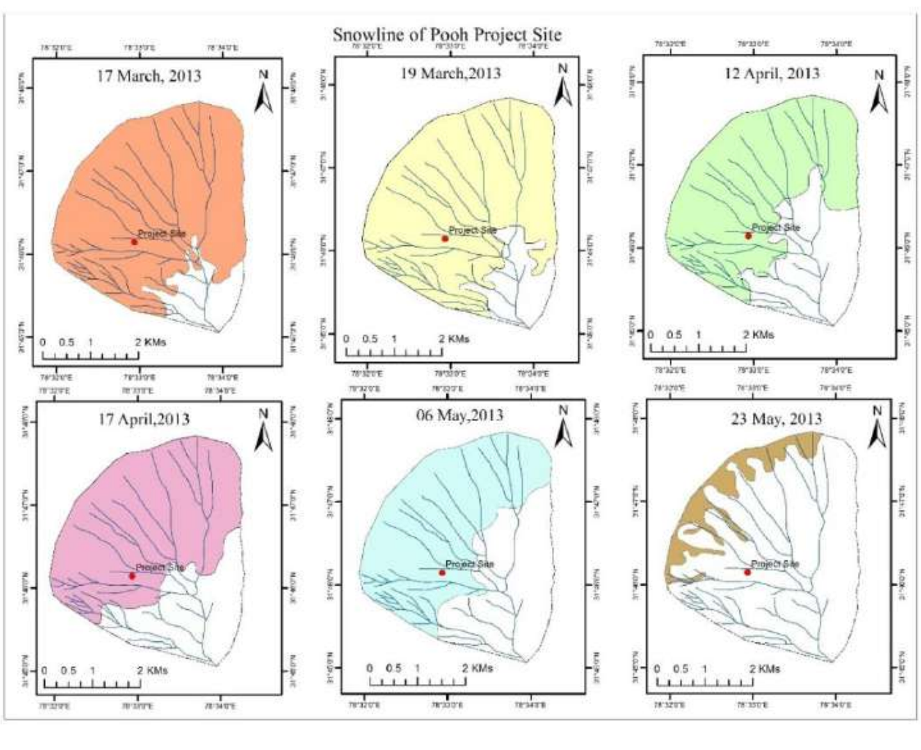
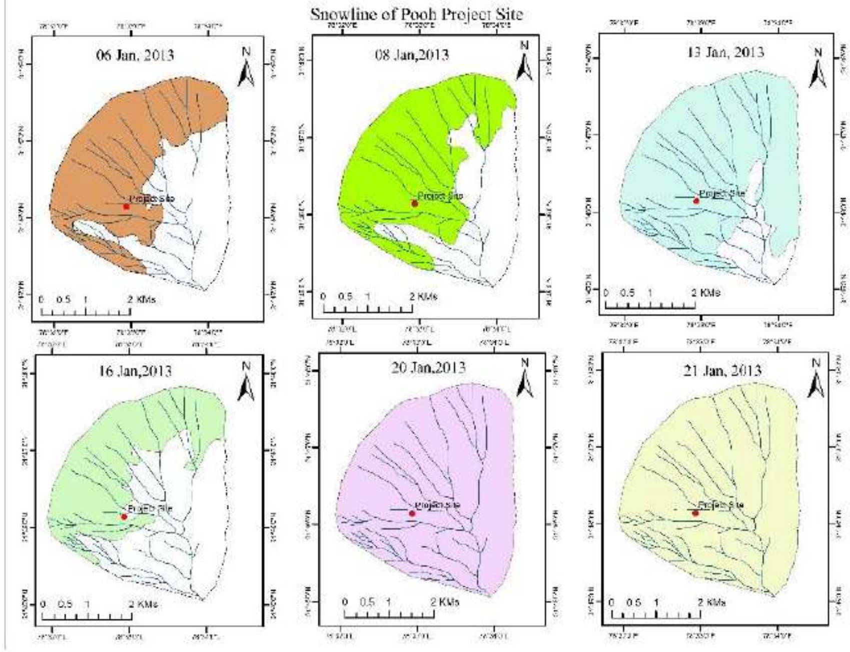
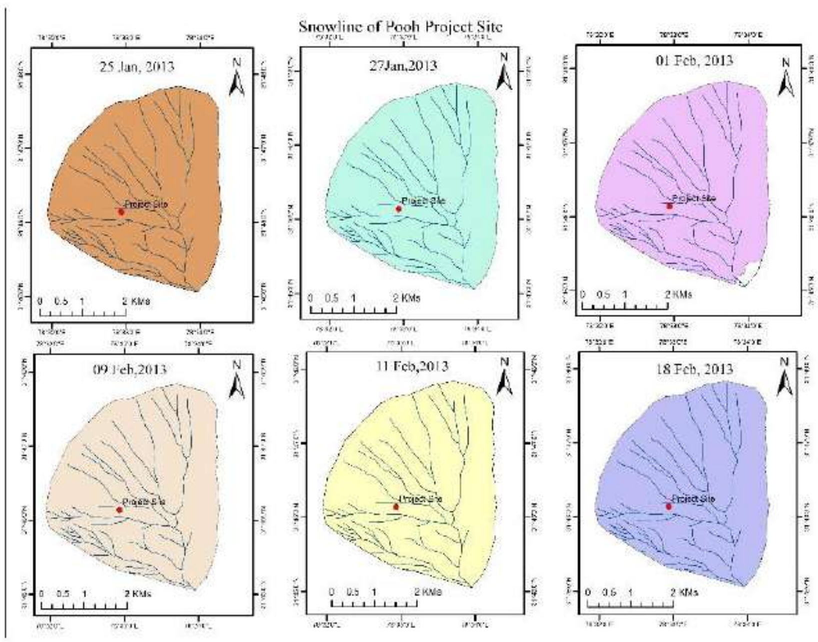
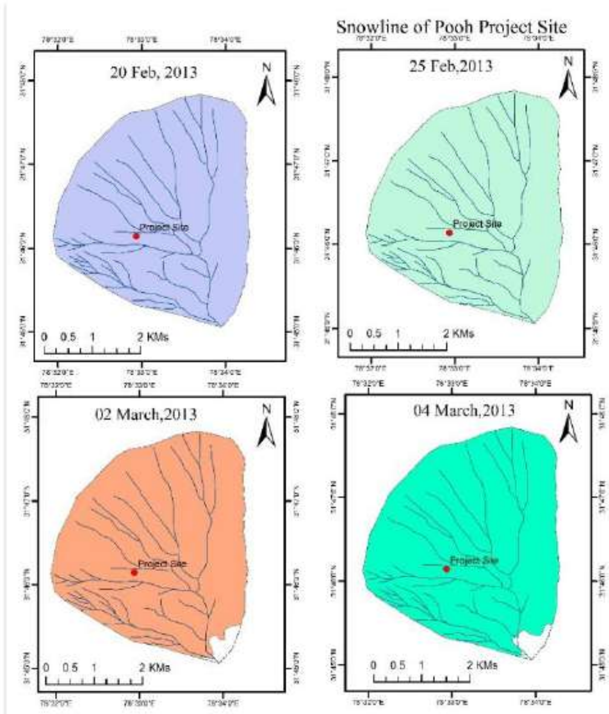


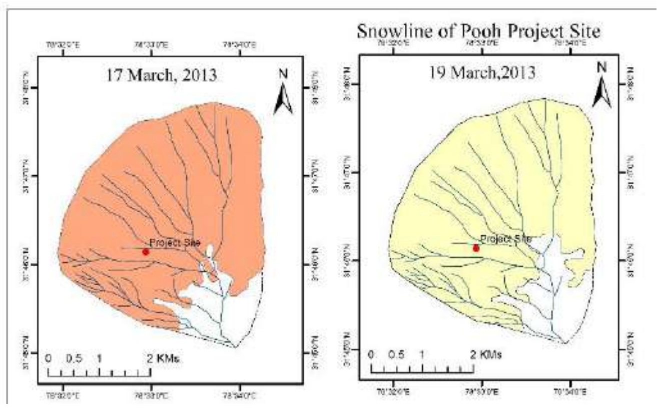
Figure 10 Snowline of Pooh Project Site for Year 2012

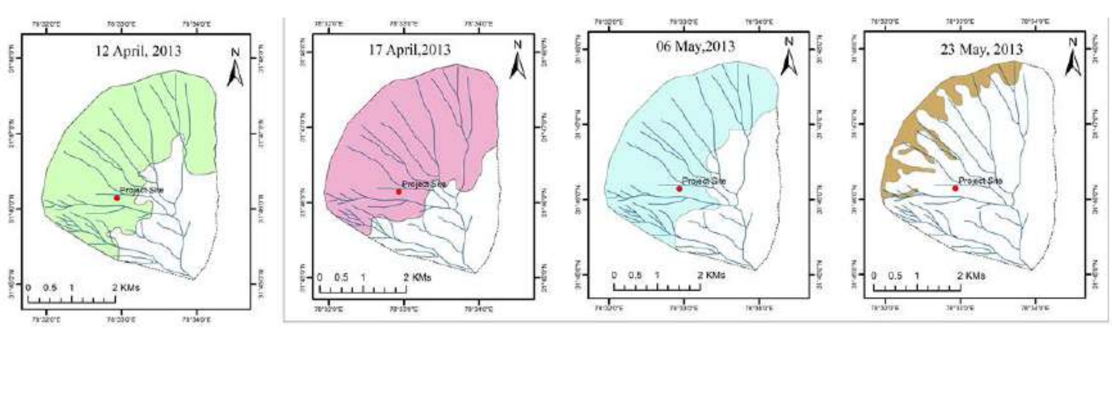



Snowline of Pooh Project Site
06 Jan, 2013
08 Jan,2013
13 Jan, 2013
16 Jan,2013
20 Jan,2013
21 Jan, 2013
Project Site
0 0.5 1 2 KMs
N


Snowline of Pooh Project Site
25 Jan, 2013
27Jan,2013
01 Feb, 2013
09 Feb,2013
11 Feb,2013
18 Feb, 2013
Project Site
0 0.5 1 2 KMs
N


Snowline of Pooh Project Site
20 Feb, 2013
25 Feb,2013
28 Feb, 2013
02 March,2013
04 March,2013
05 March, 2013
Project Site
0 0.5 1 2 KMs
N


Snowline of Pooh Project Site
17 March, 2013
19 March,2013
Project Site
0 0.5 1 2 KMs
N


12 April, 2013
17 April,2013
06 May,2013
23 May, 2013
Project Site
0 0.5 1 2 KMs
N

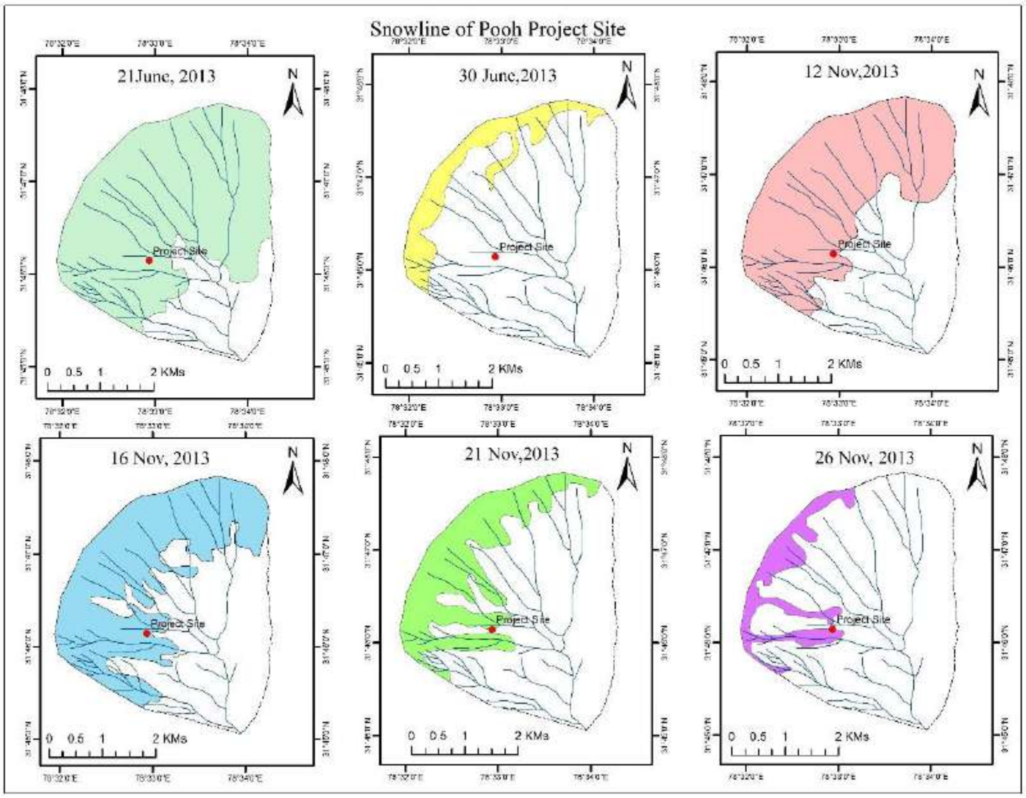
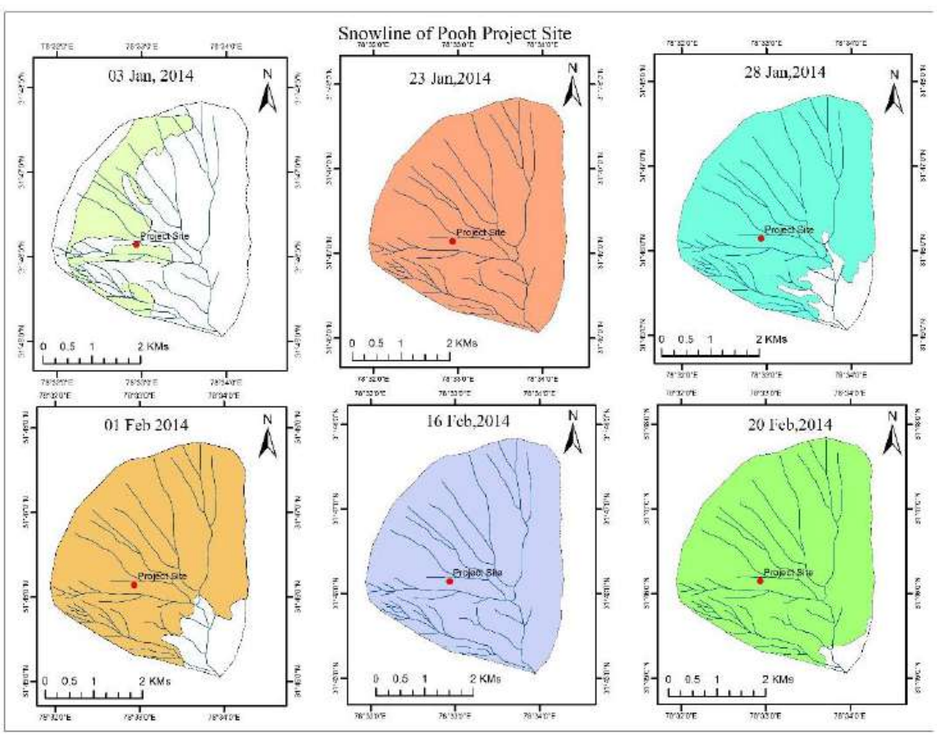
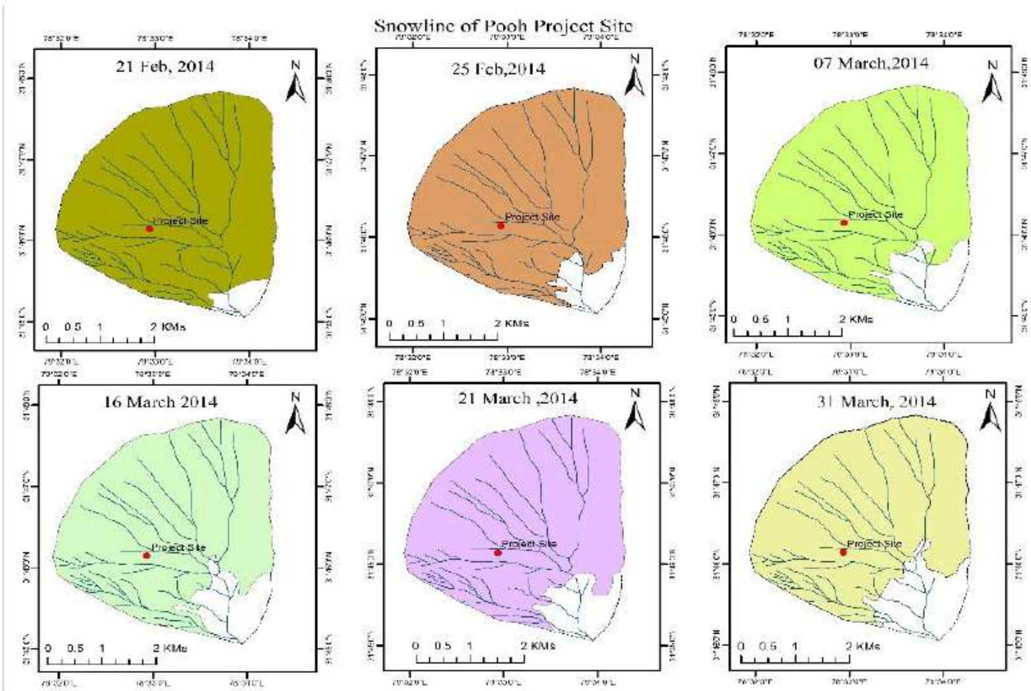
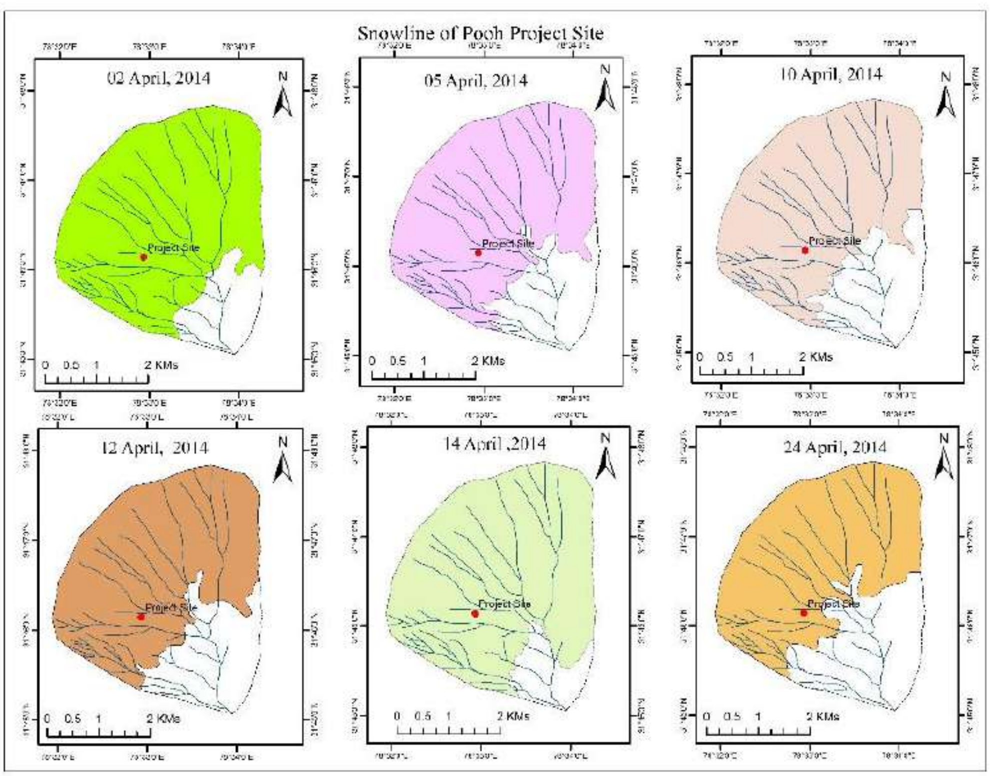


Figure 11 Snowline of Pooh Project Site for (36 scenes) Year 2013




Snowline of Pooh Project Site
21 Feb, 2014
25 Feb,2014
07 March,2014
16 March 2014
21 March ,2014
31 March, 2014
Project Site
0 0.5 1 2 KMs


Snowline of Pooh Project Site
02 April, 2014
05 April, 2014
10 April, 2014
12 April, 2014
14 April ,2014
24 April, 2014
Project Site
0 0.5 1 2 KMs

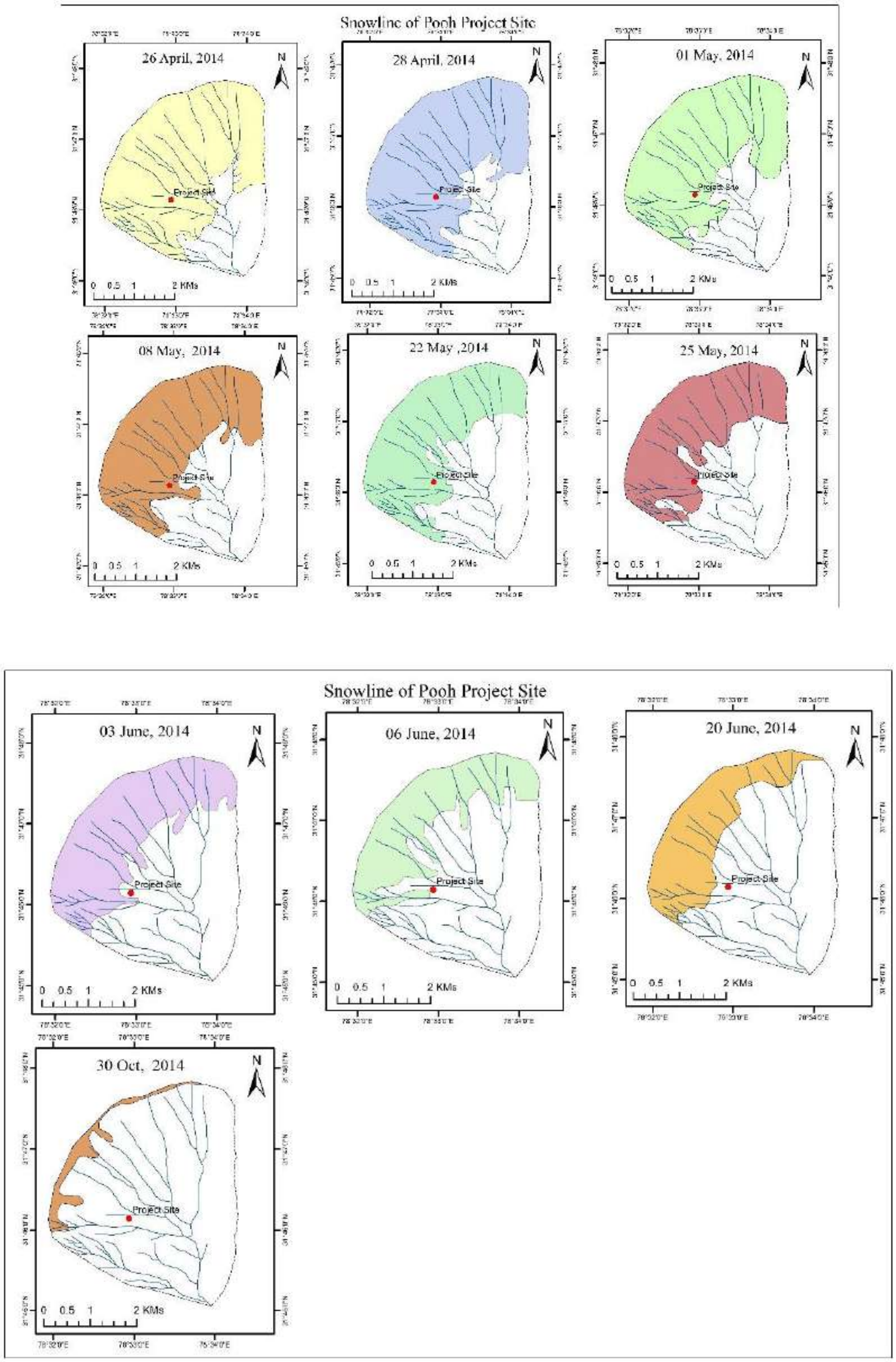


Figure 12 Snowline of Pooh Project site (28 scenes) for Year 2014

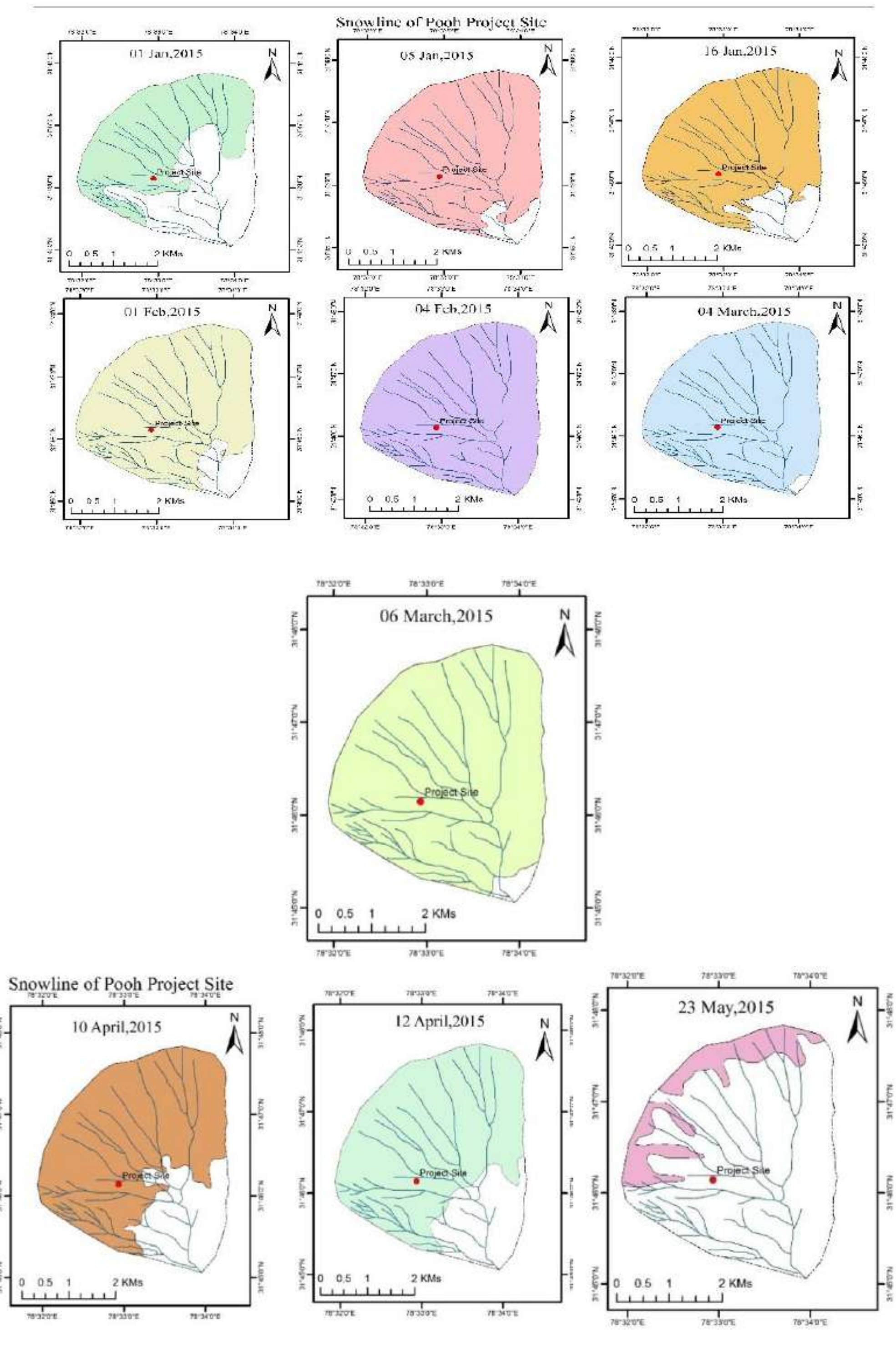


Figure 13 Snowline of Pooh Project Site for Year 2015

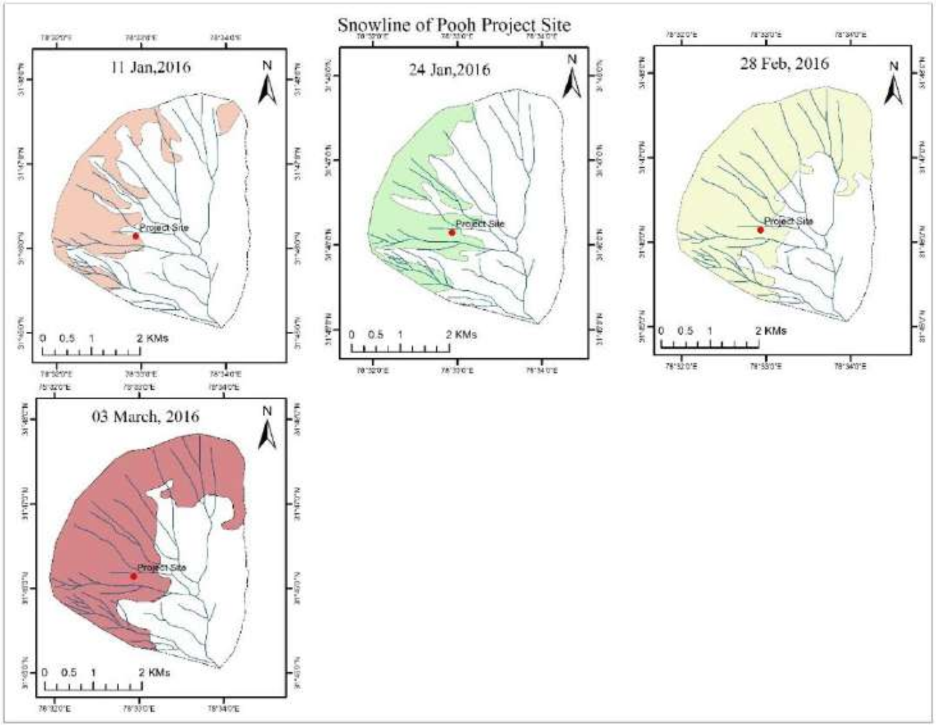


Figure 14 Snowline of Pooh Project Site for Year 2016

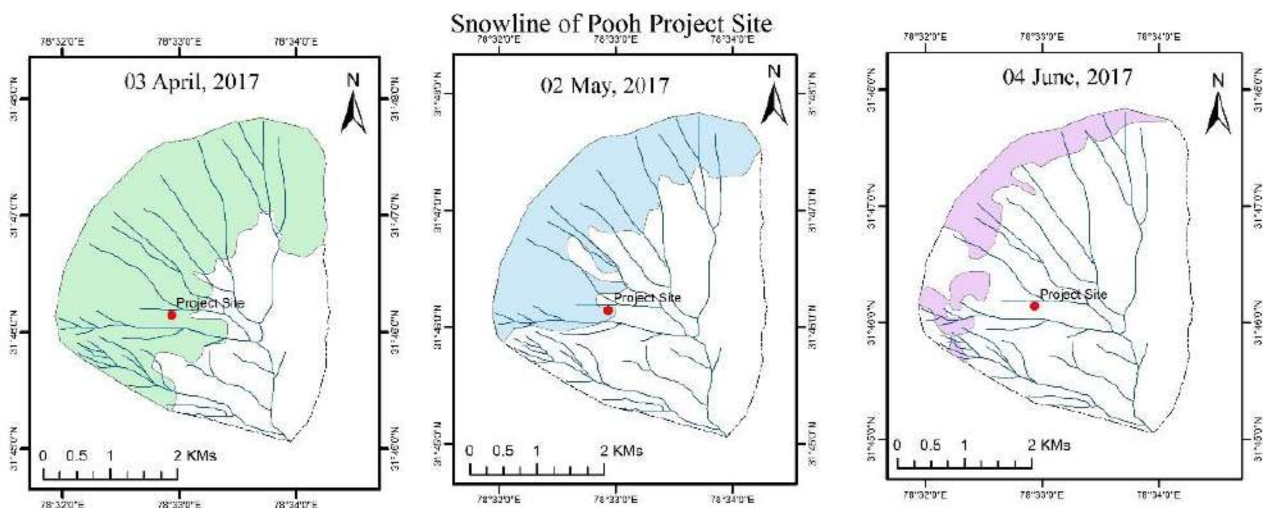


Figure 15 Snowline of Pooh Project Site for Year 2017

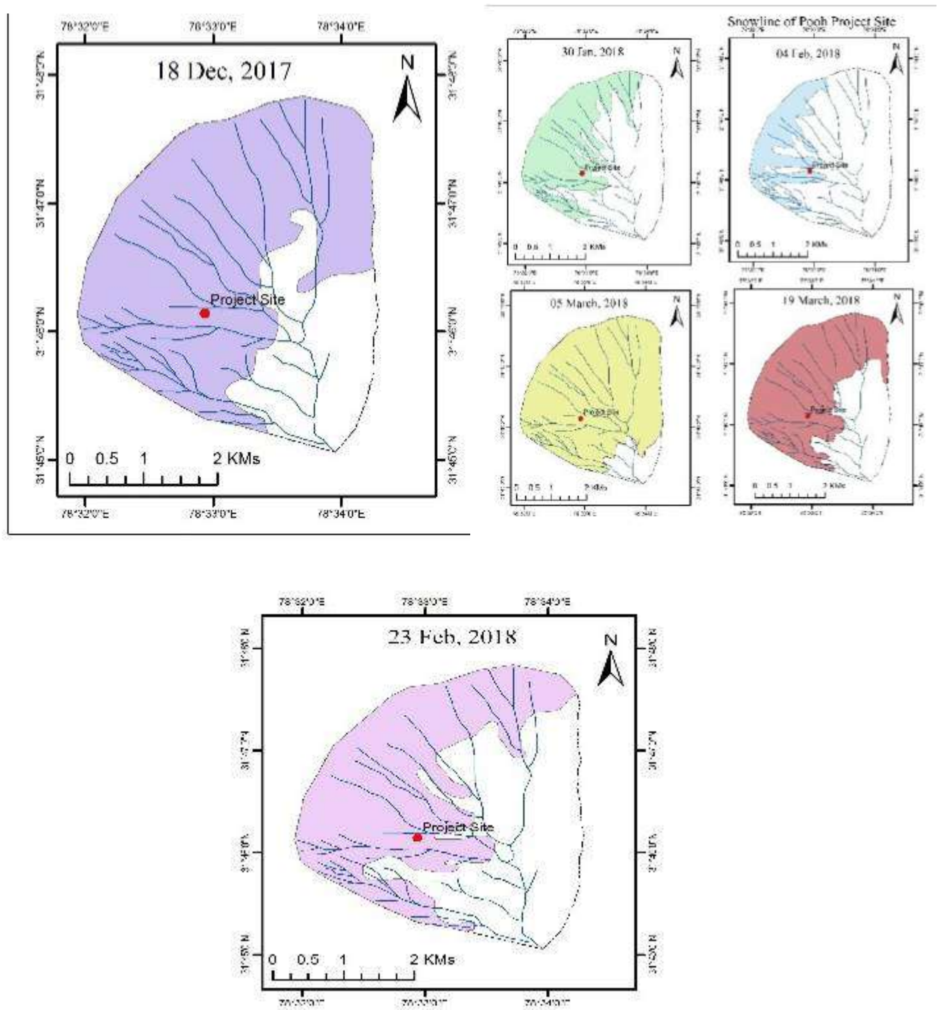


Figure 16 Snowline of Pooh Project Site for Year 2017 & 2018

The total area of the watershed is 14.24 Square kilometre It lies in Pooh village of district Kinnaur, Himachal Pradesh. The snowline has been delineated as per the AWiFS satellite data of various years in chronological order. In 2005 the AWIFS satellite imagery was available for the month of 21 Sept, 5 October and 10 October, which reveals an average 0.63 Square kilometre snow cover at an altitude between 4410 - 4620 m. above mean sea level. Athough the satellite imagery of 10 October is also available but on this date there is negligible snow has been recorded. In 2006 there were five satellite imageries avaialble but all of these were devoid of snow. In 2007 only two imageries were available for 30th September with negligible snow and satellite imagery dated 10 October represents 2.08 Square kilometre snow cover at an elevation of 4260 meter from above mean sea level. Same trend has been seen in the next years of study, in 2008 four seen of satellite imagery were available, three for the month of September in which only one satellite imagery dated 29 September showed an average area of 2.68 Square kilometre at an altitude of 4230 meter from above mean sea level and one for the month of October in which negligible snow is recorded. In 2009 two satellite imageries were available on dated 29 September and 13 October. Only 13 October represents snow cover which is 0.42 Square kilometre at altitude of 4740 meter.

In 2010, satellite imagery for 03rd October and 08th October showing an average snow cover 0.44 Square kilometre at an altitude between 4650-4830 meter from above mean sea level. The satellite imagery of 29 September, 2010 shows negligible snow cover. In 2011 only two satellite imageries were available for two different months and dates i.e.19 December and 28 December with average snow cover was 2.48 Square kilometre at an elevation of 3780meter. In 2012 eight satellites seen were available for different months and dates of winter season and an average snow is 11.66 Square kilometre at an elevation between 2430-3300 meter above mean sea level. In 2013 four satellite seen area available for different months and dates covered an average snow 12.45 Square kilometre at an altitude of 2880-3120meter amsl. In 2014 only 1 satellite imagery was available with 0.79 snow cover at an elevation of 4410m amsl. In 2014 four satellite imageries were available for different months and dates covered an average snow 13.16 Square kilometre at an altitude of 2430-4410meter amsl**.**

C. DISASTER MANAGEMENT IN HIMACHAL PRADESH

1. Monitoring of Parechhu Lake

Figure 17 Satellite view of Parechhu Lake through IRS RS2 LISS3 96-48 (3July 2019)

Observations:

On analyzing the IRS RS2 LISS III Satellite data for 3 July 2019 the following observations were made.

- The water flow in the lake depression seems to be comparatively more on the peripheral side and on the upstream side and downstream side of the depression; whereas the central part does not show any accumulation.
- Slight accumulation is seen along the landslide on upstream side, but the flow seems to be normal.
- Slight accumulation could also be seen in the frontal part of the along the downstream side.

- The inflow and outflow seems to be normal.
- Based on the satellite data interpretation, there does not seem to be any threat from the Parechhu Lake for the downstream areas. However continuous monitoring would be required as the ablation is still continuing for another two months and thus requires monitoring.

2. Monitoring of Glacial Lakes in Satluj River Basin

Image interpretation of glacial lakes (2019) of Satluj Catchment

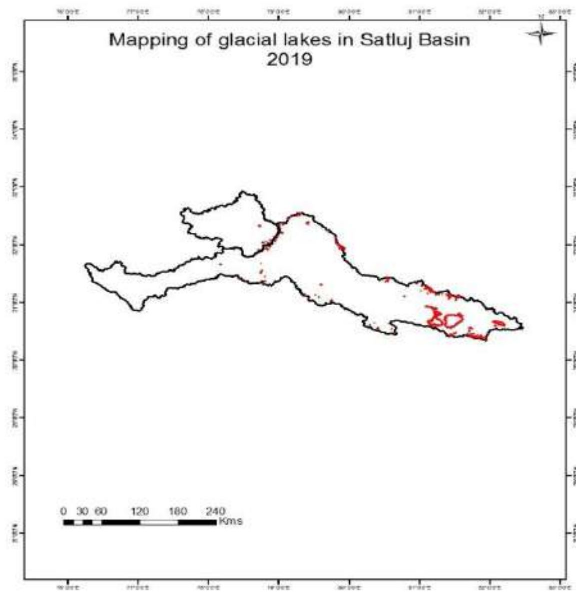


Figure 18 Glacial lakes of Satluj basin has been mapped using AWiFS data

3. Vulnerability and Risk analysis of Geo-hazards in Himalayan Region

Mapping of landslides from 2012-16 (pre and post monsoon) using LISS IV satellite data in Kinnaur district.

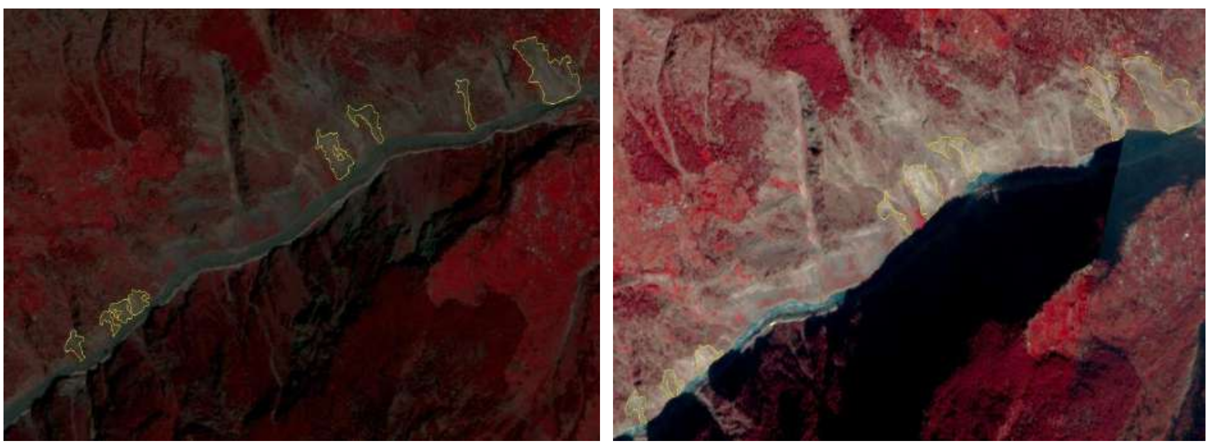


Figure 19 Kalpa block, 2016 (pre monsoon) Kalpa block, 2016 (post monsoon)

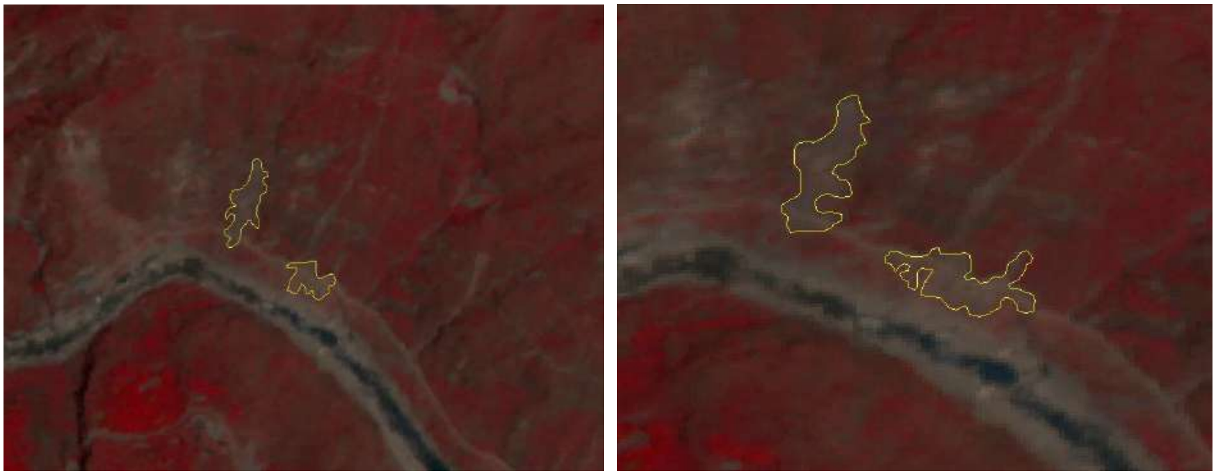


Figure 20 Nichar block, 2012 (pre monsoon) Nichar block, 2012 (post monsoon)

Mapping inventory has been prepared using LISS IV data from 2004 to 2016 (pre monsoon and post monsoon) and here are the screenshots of Kalpa and Nichar block.

4. Status of Geo-resources and Impact Assessment of Exo-genic Geological Process on NW-Himalaya Ecosystem

Quaternary deposits in Himachal Pradesh

Geology of Himachal Pradesh

The State of Himachal Pradesh is covered by the rocks ranging in age from Precambrian to Recent. The normal order of super-position of the rocks in the Lesser Himalaya has been affected by later events of thrusting. Owing to its complex tectonism and geological evolution, establishing a unanimously accepted geology and stratigraphy of Himalaya remained mired with debate and controversy- posing a natural deterrent.

S No.	District	Period	Group Formation	Description
1	Una	Quaternary	Alluvium, Terrace & Fluvial deposits	Alluvium, clay, sand, gravel, pebbles, boulders and cobbles
2	Kangra	Quaternary	Fluvioglacial/glacial/Interglacial deposits	Sand, silt, clay, gravel, pebble, cobble and boulders etc.(Moraine & Fluvial deposits)
3	Chamba	Quaternary	Fluvial / Fluvio-glacial / Alluvium	Boulder conglomerate, Sandstone , gravel beds, clays etc.
4	Hamirpur	Quaternary	Alluvium	Sand, Gravel, Pebble & Boulders and clay
5	Bilaspur	Quaternary	Alluvium; fluvial, terrace, piedmont	Sand, silt, clay, gravel, pebble, cobble and boulders etc.
6	Solan	Quaternary	Alluvium /valley fills/ Older alluvium	Sand with pebble and clay, medium to coarse grained sand with pebble of sandstone and lenses of clay

7	Sirmour	Quaternary	Alluvium /valley fills/ Older	Sand with pebble and clay & multiple cyclic sequence of medium to coarse grained sand with pebble of sandstone and lenses of clay
8	Mandi	Quaternary	Alluvium; Terrace & Fluvial deposits	Alluvium, clay, sands, gravels, pebbles, boulders and cobbles
9	Kullu	Quaternary	Alluvium; fluvial, terrace, piedmont	Sand, silt, clay, boulders, pebble and cobble etc.
10	Kinnaur	Quaternary	Alluvium, Terrace & Fluvial deposits	Alluvium, clay, sand, gravel, pebbles, boulders and cobbles
11	Lahaul & Spiti	Quaternary	Fluvial / Fluvio-glacial / Alluvium	Sand, silt, pebbles, cobbles, boulders
12	Shimla	Quaternary	Alluvium	Sand with pebble and clay, medium to coarse grained sand with pebble of sandstone and lenses of clay

Table 2 District- wise Quaternary Deposits of Himachal Pradesh

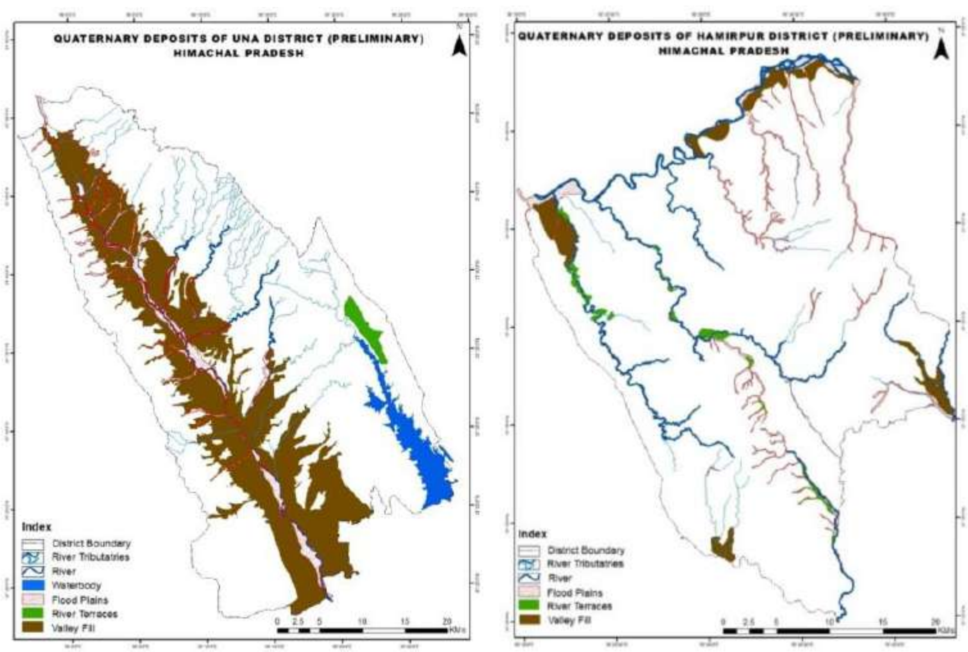


Figure 21 Quaternary Deposits of Una and Hamirpur District (Preliminary), Himachal Pradesh

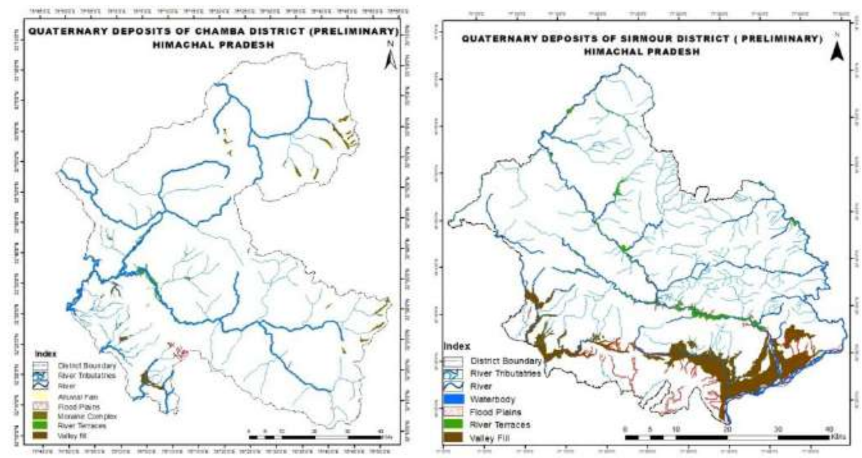


Figure 22 Quaternary Deposits of Chamba & Sirmour District (Preliminary), Himachal Pradesh

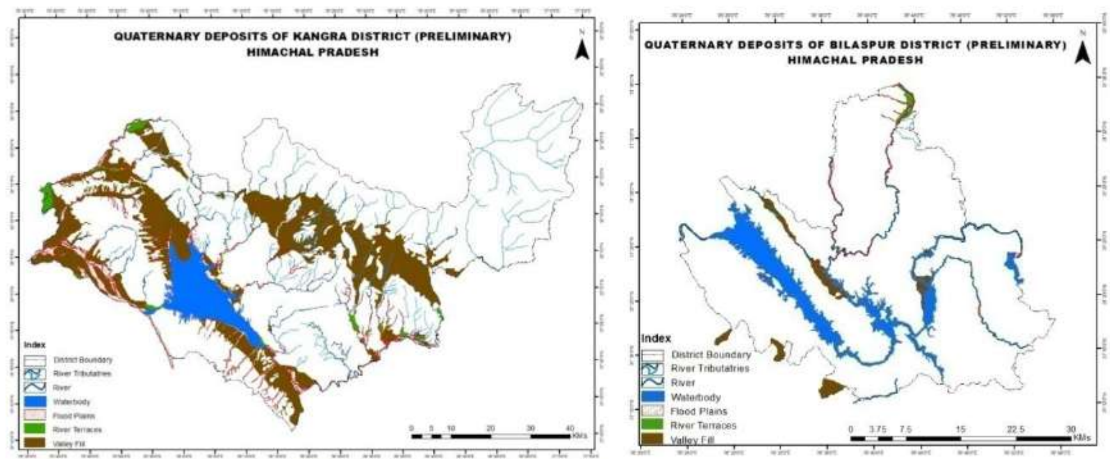


Figure 23 Quaternary Deposits of Kangra & Bilaspur District (Preliminary), Himachal Pradesh

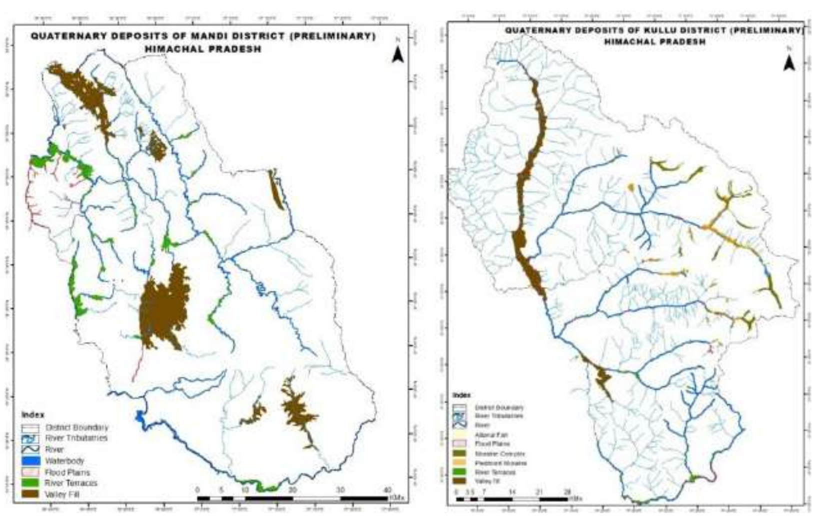


Figure 24 Quaternary Deposits of Mandi & Kullu District (Preliminary), Himachal Pradesh

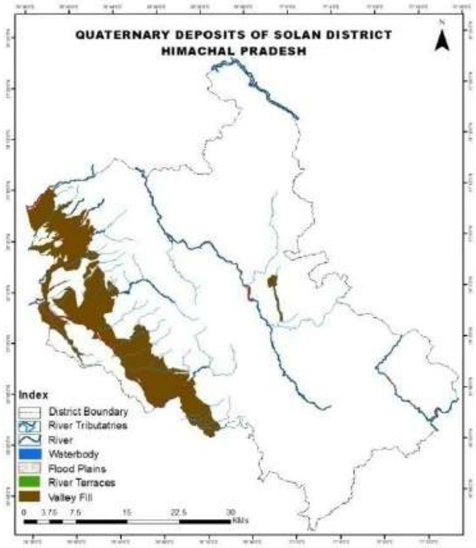


Figure 25 Quaternary Deposits of Solan District (Preliminary), Himachal Pradesh

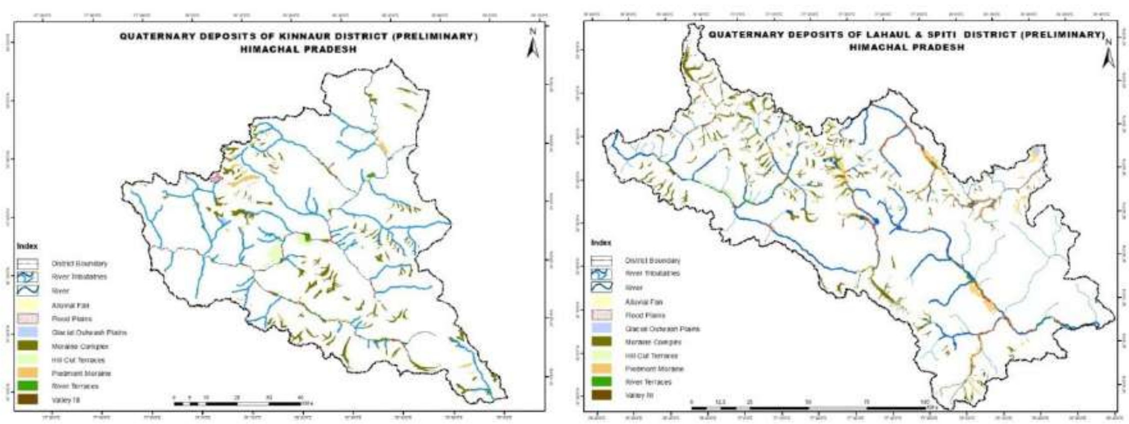


Figure 26 Quaternary Deposits of Kinnaur & Lahaul & Spiti District (Preliminary), Himachal Pradesh

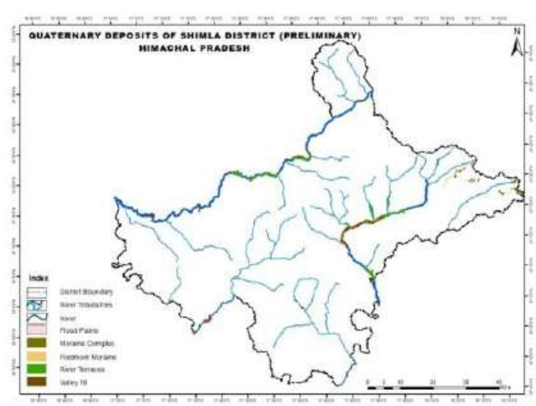


Figure 27 Area of Quaternary Deposits of Shimla District (Preliminary), Himachal Pradesh

Distribution of Quaternary deposits in Himachal Pradesh:

Overall distribution of Quaternary deposits in Himachal Pradesh as per the preliminary work delineated on LISS III and Landsat satellite data is 4481 km^2 which is only 8% of total geographical area of the state. Valley fill has highest contribution almost 50% (2440 km^2) in Quaternary deposits whereas alluvial fan has lowest contribution. As per the table 3 in Kangra district, 1103 km^2 of area lies under valley fills which is highest among all the districts followed by Una district (448 km^2) and Mandi district (257 km^2). Whereas in Shimla district (3.69 km^2) contributed lowest among the entire district just next to the Kinnaur district (6.33 km^2). In Himachal Pradesh 363 km^{2}area lies under the category of flood plains out of 4481 km^2 area of Quaternary deposits. Lahaul and Spiti district of the state comprises 110 km^2 is the highest among other districts whereas Shimla district (4.62 km^2) has lowest.

The quaternary deposits formed by fluvio-glacial are moraine complexes, alluvial fan, piedmont moraine and glacial outwash plains. Moraine complexes are found in higher altitude regions in Chamba Kullu, Kinnaur, Lahaul & Spiti and Shimla district of the State. The total area of moraine complexes of Quaternary deposits of the state is approximately 718 Km^2. Alluvial fanis a triangle-shaped deposit of gravel, sand and even smaller pieces of sediment, such as silt. This sediment is called alluvium. Alluvial fans are usually created as flowing water interacts with mountains, hills, or the steep walls of canyons. The total area of Alluvial fan of Quaternary deposits of the state is approximately 113 km^2.

In geology, a terrace is a step-like landform. Hill cut terrace formed in mountainous region near river valleys where slope of the hills are less. Hill cut terraces are found in Kinnaur (46 km^2) and Lahaul and Spiti (28 km^2). The glacial out wash plains are large areas of glacial sediment deposited by melt water streams furthest away from the glacial snout. They are formed from gravels, sands and clays, the clays being furthest away from the snout because the smaller particles are carried furthest. These glacial out wash plains are found in Kinnaur and Lahaul & Spiti comprising of 6.48 km^2 and 9.22 km^2 respectively.

S. No.	District	Valley Fill (Area in km^2)	Flood Plains (Area in km^2)	River Terraces (Area in km^2)	Moraine Complex (Area in km^2)	Alluvial Fan (Area in km^2)	Piedmont Moraine (Area in km^2)	Hill Cut Terraces (Area in km^2)	Glacial Outwash Plain (Area in km^2)
1	Una	448.13	57.81	6.94	-	-	-	-	-
2	Kangra	1103.61	55.51	150.28	-	-	-	-	-
3	Chamba	23.08	8.41	33.76	34.75	0.53	-	-	-
4	Hamirpur	36	33	9	-	-	-	-	-

5	Bilaspur	27.12	5.46	5.72	-	-	-	-	-
6	Solan	218.21	5.58	0.26	-	-	-	-	-
7	Sirmour	179.86	52.58	29.77	-	-	-	-	-
8	Mandi	256.87	9.45	56.04	-	-	-	-	-
9	Kullu	117.71	8.51	17.71	41.15	8.03	34.11	-	-
10	Kinnaur	6.33	12.81	41.11	207.66	2.81	57.52	45.52	6.48
11	Lahaul & Spiti	19.51	109.44	55.85	426.87	101.14	237.74	28.04	9.22
12	Shimla	3.69	4.62	17.02	8.11		4.83		
	Himachal Pradesh	2440.12	363.18	423.46	718.54	112.51	334.2	73.56	15.7

Table 3 District-wise Area of Quaternary deposits in Himachal Pradesh

Landslides in Himachal Pradesh

In Himachal Pradesh occurrence of landslides is a frequent and wide spread activity. Slope failure activities show increasing trends and there is not only upward rise in annual and decadal frequency of landslides but the number of years with exceptionally high occurrence during each decade has also increased. Landslide occurrence is very high in Shimla, Solan, Kinnaur and Mandi districts. The high intensity rainfall, particularly in monsoons, is one of the chief triggering factors for such incidents.

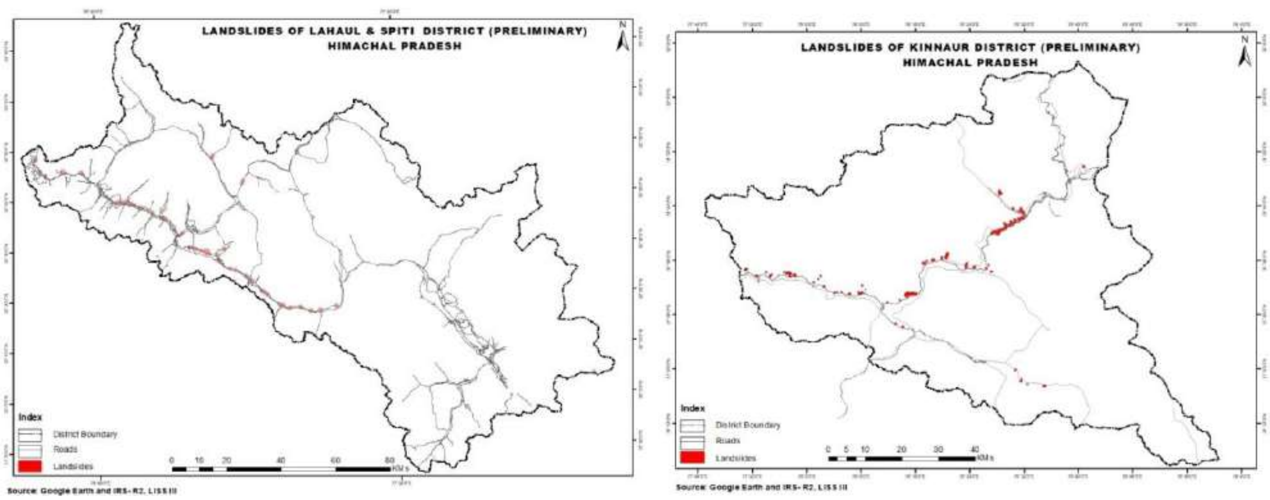


Figure 28 Landslides of Lahaul & Spiti & Kinnaur District (Preliminary), Himachal Pradesh.

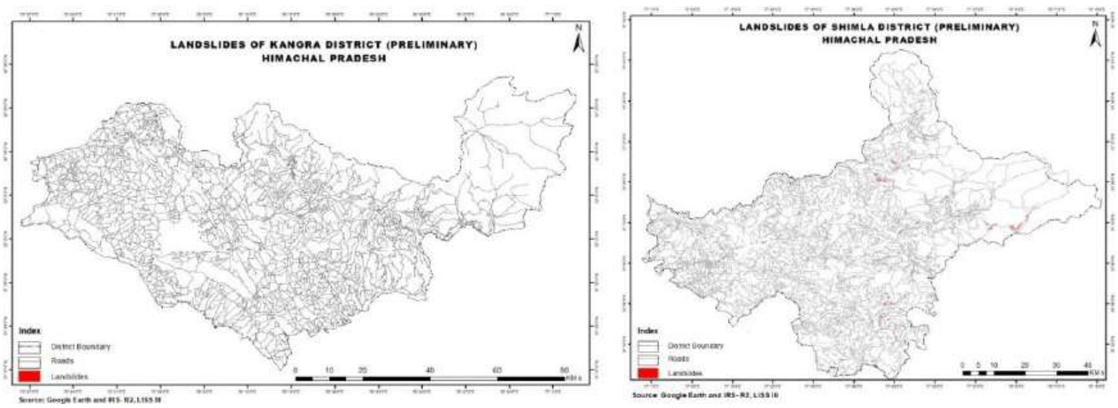


Figure 29 Landslides of Kangra & Shimla District (Preliminary), Himachal Pradesh.

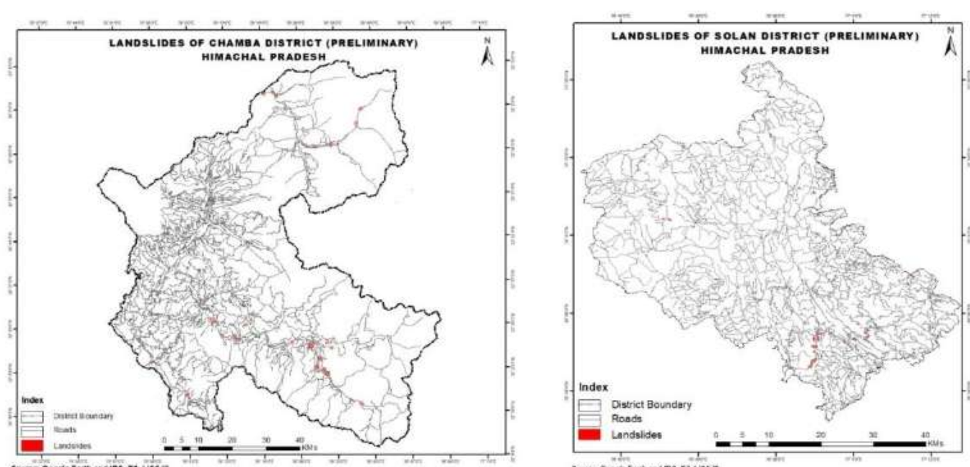


Figure 30 Landslides of Chamba & Solan District (Preliminary), Himachal Pradesh.

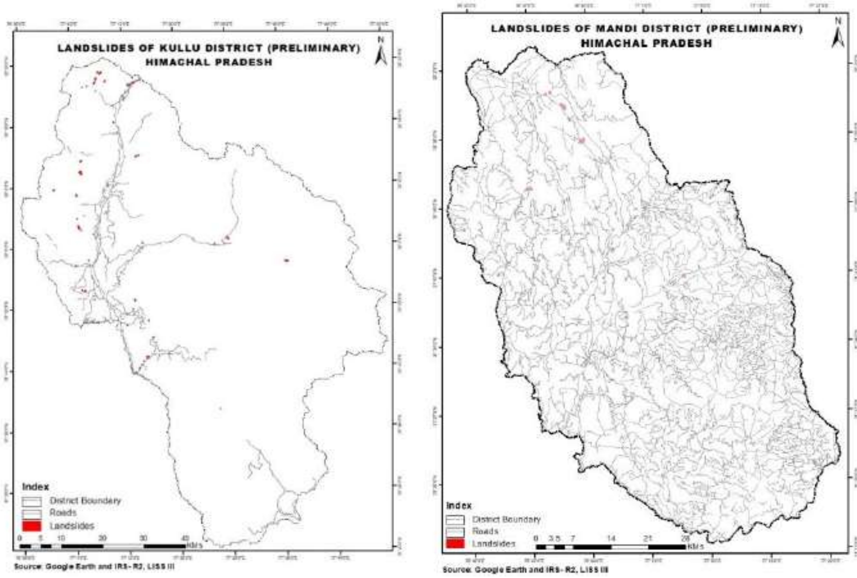


Figure 31 Landslides of Kullu & Mandi District (Preliminary), Himachal Pradesh.

5. GLACIAL LAKE OUTBURST FLOODS (GLOFS)

LISS III Based mapping of GLOFs in Satluj Basins (Spiti, Lower Satluj & Upper Satluj sub basins), Chenab (Chandra, Bhaga & Miyar Sub basins) Beas (Beas, Jiwa and Parvati) and Ravi in Himachal Pradesh.

Inventory of lakes based on LISS III satellite data for 2017:

IRS LISS-III Resource 2 satellite data having spatial resolution of 23.5 meters have been used for generating a more detailed inventory of glacial lakes/high altitude wetlands in Satluj catchment and was compared with that of the information generated for the year 2016 using LISS-III satellite data. The inventory based on LISS-III satellite data is more detailed one as this sensor has the better spatial resolution (23.5 meter) than AWIFS (56 meter) and thus gives more information about the terrain. Satellite data for the month of July to September 2017 was browsed and good quality cloud free data was selected for the mapping purpose as during this period the glacier surfaces are completely exposed and liable to give more detailed information about the glacier regions. The LISS-III coverage includes seven number of scenes within 96-48, 96-49 97-48, 97-49, 98-49, 99-49 and 100-49 path and rows and have been analyzed using visual interpretation techniques and the same methodology adopted for the AWIFS satellite data. As far as data availability is concerned, an attempt has been made to get the best quality data products during August/September, but still in parts the impacts of cloud cover or snow could be seen. Due to non-availability of good quality cloud free data during August /September, the available data during October has also been used in the interpretation purpose wherein the impact of fresh snow could be seen. Satellite data covering path row 96-48 & 96-49, although the data available is for the month 0f 30 September 2017 , but it shows some cloud cover restricting to have complete information of the area , where as the data covering 96-49 although is a clear product but some snow cover impact is clearly seen . The data covering 97-48, the available data for 18 August 2017 which has some cloud cover impact whereas in 97-49, data for 5 Oct 2017 have been used where some fresh snow could be seen. The data covering path row 98-49, the available data is of 28 September 2017 indicating some fresh snow cover. The data covering 99-49 the available data product used is for 3 October 2017 seems to be good quality one, whereas the data covering path row 100-49, the data available is 26 September 2017 is also a good quality one for interpretation purpose.

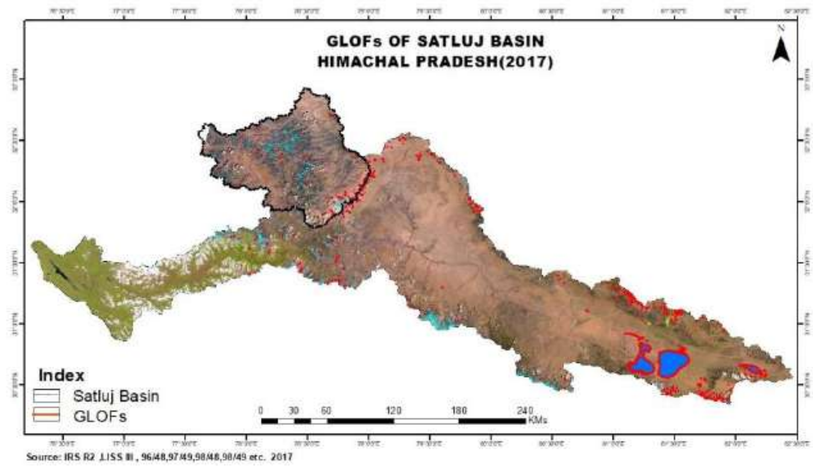


Figure 32 GLOFs in Satluj basin based on LISS III data

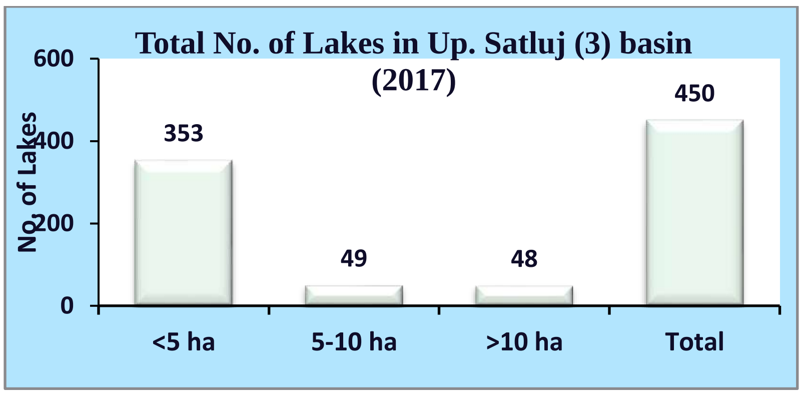


Figure 33 No. of Lakes in Up. Satluj (3) basin based on LISS III data

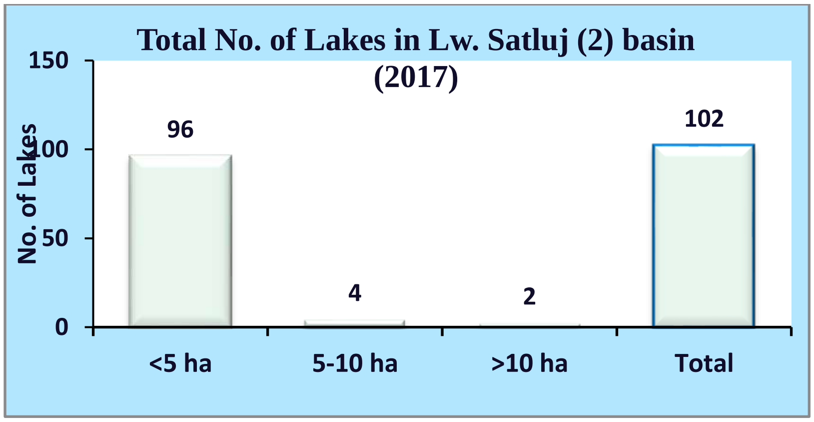


Figure 34 No. of Lakes in Lw. Satluj (2) basin based on LISS III data

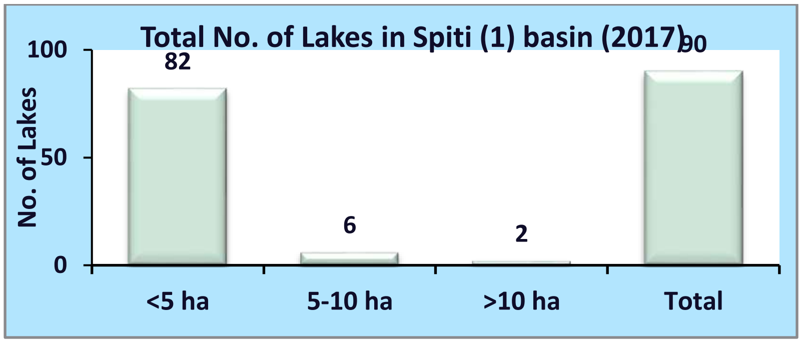


Figure 35 No. of Lakes in Lw. Satluj (1) basin based on LISS III data

GLOFs in Chenab Basin

Chenab basin is one of the major river basins which originate from near Baralacha Pass in Himachal Pradesh. Chenab River formed by confluence of two rivers Chandra and Bhaga in Tandi near Keylong. Besides this, another major sub basin i.e. Miyar Sub basin has been studied in detail for having an updated inventory of moraine dammed lakes in the catchment.

Mapping of GLOFs in Chandra Sub Basin

From the analysis of satellite data of IRS-RS2-L3 for 27 August 2017 and 13 September 2017 in Chandra basin, a total of 46 lakes have been delineated in the basin. Further it was found that out of these 46 lakes, maximum number of lakes i.e. 43 lakes are the small having area less than 5ha, 1 lake falls within the areal range of 5-10 ha and 2 lakes which have the area more than 10ha.

GLOFs of CHANDRA SUB-BASIN, CHENAB BASIN, HIMACHAL PRADESH (2017)									
Sr. No.	Lake id No.	Longitude	Latitude	Area (hectare) in 2017	Sr. No.	Lake id No.	Longitude	Latitude	Area (hectare) in 2017
1	1	77.22266	32.52323	115.51	24	106SG	77.29324	32.44949	0.25
2	3	77.5491	32.49895	179.64	25	107SG	77.29417	32.44888	0.25
3	6	77.61796	32.60471	9.45	26	108SG	77.29497	32.44968	0.76
4	8	77.71637	32.34339	1.47	27	109SG	77.29739	32.44992	0.31
5	9	77.72667	32.32659	0.57	28	119SG	77.59605	32.24071	0.26
6	18	77.4502	32.241	3.11	29	120SG	77.60069	32.24214	0.41
7	19	77.44833	32.24597	3.76	30	121SG	77.60057	32.24015	0.26
8	20	77.50415	32.54238	0.71	31	122SG	77.60286	32.23985	0.59
9	21	77.68345	32.31789	0.55	32	123SG	77.60422	32.2344	0.34
10	24	77.44291	32.24845	1.88	33	124SG	77.60571	32.23496	0.40
11	26	77.41932	32.24653	2.15	34	125SG	77.61208	32.23421	0.52
12	105	77.28897	32.44849	0.78	35	126SG	77.60825	32.22976	0.67

13	110	77.33368	32.37594	0.62	36	127SG	77.61549	32.21769	0.31
14	111	77.55058	32.73192	0.72	37	128SG	77.62267	32.21707	0.39
15	112	77.53722	32.7283	0.40	38	129SG	77.62774	32.21682	0.39
16	113	77.54111	32.72713	0.33	39	130SG	77.62762	32.21323	0.56
17	114	77.59424	32.63609	1.90	40	131SG	77.63802	32.19893	0.31
18	115	77.60638	32.63396	0.46	41	132SG	77.64148	32.1998	0.93
19	116	77.61096	32.62522	0.93	42	133SG	77.62081	32.19213	1.87
20	117	77.50264	32.65776	1.51	43	16SG	77.6382	32.2059	0.68
21	101SG	77.23402	32.50413	0.44	44	36SG	77.6269	32.21411	0.31
22	102SG	77.22817	32.50999	0.68	45	37SG	77.62826	32.21159	0.32
23	103SG	77.237	32.51052	1.13	46	3A	77.53413	32.50404	1.94

Table 4 GLOFs of Chandra Sub-Basin, Chenab Basin, Himachal Pradesh (2017)

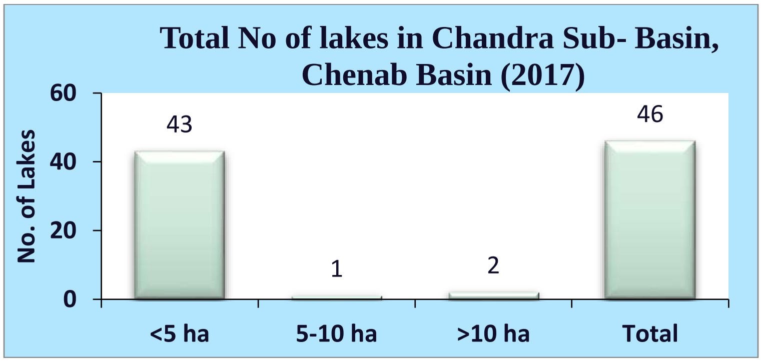


Figure 36 Total No of lakes in Chandra Sub- Basin, Chenab Basin based on LISS III data (2017)

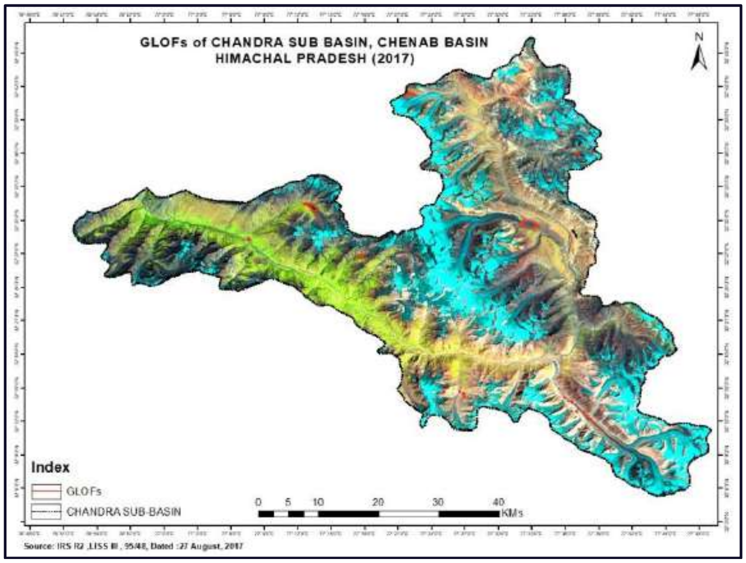


Figure 37 GLOFs of Chandra Sub- Basin, Chenab Basin, Himachal Pradesh (2017)

Mapping of GLOFs in Bhaga Sub Basin

Based on the satellite data analysis from IRS LISS-III of 13 September 2017 in Bhaga basin, which is a sub basin of the Chenab, it has become possible to delineate a total of 56 lakes in 2017. Further out of these 56 lakes mapped in 2017, majority of the lakes i.e. 50 lakes are small one with area less than 5 ha, 4 lakes are within the areal range of 5-10 ha and 2 lakes are having area more than 10 ha (Table 5 & Fig. 38).

GLOFs of BHAGA SUB-BASIN, CHENAB BASIN, HIMACHAL PRADESH (2017)									
Sr. No.	Lake id No.	Longitude	Latitude	Area (hectare) in 2017	Sr. No.	Lake id No.	Longitude	Latitude	Area (hectare) in 2017
1	1	77.17277	32.8699	3.42	29	119	77.10501	32.74559	0.92
2	2	77.28017	32.84468	7.41	30	120	77.1079	32.74516	0.29
3	6	77.32944	32.72401	10.23	31	121	77.18312	32.79911	0.60
4	7	77.34111	32.70706	1.08	32	122	77.01479	32.71104	0.71
5	8	77.34793	32.705	6.49	33	123	77.00036	32.69575	0.36
6	10	77.3212	32.63758	0.32	34	124	77.05959	32.67152	0.44
7	11	77.30815	32.63156	9.84	35	125	77.06505	32.66948	0.28
8	22	76.98165	32.86894	0.66	36	126	77.09444	32.67892	1.23
9	23	76.99772	32.89773	2.28	37	127	77.06025	32.91316	0.43
10	24	76.99326	32.92624	0.59	38	128	77.34237	32.70826	1.85
11	25	77.00851	32.91962	1.57	39	106SG	77.30461	32.72439	0.26
12	26	77.01878	32.90873	0.44	40	107SG	77.30344	32.72093	0.26
13	28	77.1177	32.9611	1.17	41	108SG	77.30325	32.71659	0.28
14	30	77.14524	32.93211	2.25	42	109SG	77.30627	32.71479	0.41
15	36	77.19927	32.90448	1.60	43	110SG	77.30729	32.71069	0.41
16	41	77.19444	32.75921	7.79	44	112SG	77.34764	32.62401	0.18
17	53	77.38433	32.7211	15.04	45	113SG	77.34169	32.62352	0.24
18	54	77.37789	32.72426	2.93	46	114SG	77.33419	32.62411	0.32
19	55	77.37726	32.7229	1.71	47	115SG	77.32698	32.62089	0.56
20	63	76.98211	32.86986	0.28	48	116SG	77.29561	32.52301	0.50
21	66	77.38299	32.58215	3.17	49	117SG	77.29728	32.51704	0.49
22	101	77.03819	32.84266	1.35	50	118SG	77.29615	32.51542	0.74
23	102	77.16265	32.8734	2.06	51	59SG	77.30292	32.72579	0.94
24	103	77.21355	32.87363	0.42	52	61SG	77.30487	32.72111	0.33
25	104	77.22556	32.87185	0.30	53	62SG	77.30505	32.71903	0.39
26	104	77.30401	32.77092	0.60	54	64SG	77.33786	32.62291	0.56
27	105	77.32747	32.76483	0.73	55	67SG	77.29336	32.50762	0.37

28	111	77.31675	32.63307	0.51	56	68SG	77.29304	32.51838	0.37

Table 5 GLOFs of Bhaga Sub-Basin, Chenab Basin, Himachal Pradesh (2017)

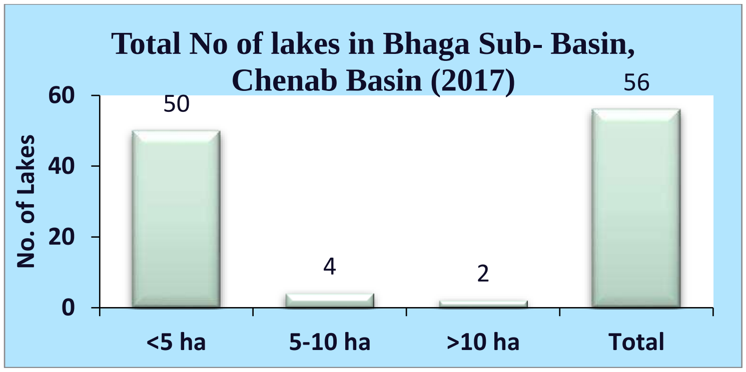


Figure 38 Total No of lakes in Bhaga Sub- Basin, Chenab Basin based on LISS III data (2017)

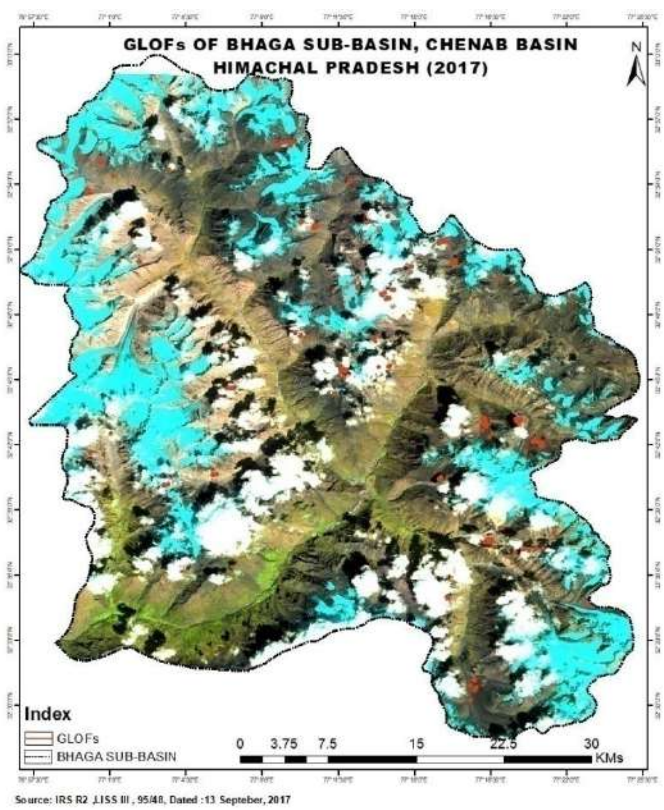


Figure 39 GLOFs of Bhaga Sub- Basin, Chenab Basin, Himachal Pradesh (2017)

Mapping of GLOFs in Miyar Sub Basin:

From the analysis of the IRS, LISS-III satellite data of 27 August 2017 in Miyar sub basin, it was found that total number of lakes have been delineated, out of which 97% lakes i.e. 114 lakes are small one with area less than 5ha, about 2% lakes i.e. 3 lakes are within the areal range of 5-10 ha and only 0.8% i.e. only 1 lake is having area more than 10 ha (Fig.40).

GLOFs of MIYAR SUB-BASIN, CHENAB BASIN, HIMACHAL PRADESH (2017)									
Sr. No.	Lake id Number	Longitude	Latitude	Area (hectare) in 2017	Sr. No.	Lake id Number	Longitude	Latitude	Area (hectare) in 2017
1	1	76.36212	33.30978	8.78	60	115	76.89482	32.83701	0.58
2	2	76.36007	33.30882	0.88	61	117	76.89567	32.83599	0.58
3	3	76.35664	33.29687	0.58	62	118	76.85989	32.80033	0.89
4	5	76.48813	33.2252	1.13	63	120	76.73271	32.88591	2.28
5	6	76.54675	33.21456	4.03	64	121	76.74853	32.9071	0.92
6	10	76.58972	33.18217	0.92	65	122	76.77145	32.95738	1.21
7	11	76.59258	33.17764	2.13	66	123	76.77992	33.00185	1.18
8	12	76.59238	33.16258	0.28	67	124	76.75994	33.0034	1.14
9	14	76.67033	33.14341	2.27	68	129	76.45804	33.24726	0.22
10	15	76.71354	33.16214	1.63	69	130	76.36364	33.30524	0.54
11	16	76.71984	33.16456	0.68	70	131	76.36634	33.30368	1.28
12	17	76.71972	33.13016	4.04	71	132	76.76577	33.13099	0.28
13	20	76.71329	33.12155	3.54	72	137	76.93766	32.77037	0.86
14	21	76.71024	33.12114	2.38	73	141	76.72436	33.03764	1.29
15	23	76.6992	33.08577	2.64	74	201	76.4251	33.24143	0.48
16	24	76.71571	33.08218	0.28	75	202	76.4355	33.24209	0.60
17	25	76.72764	33.06483	1.05	76	203	76.71645	33.16234	0.42
18	26	76.72601	33.06545	0.42	77	204	76.75484	33.01187	0.28
19	27	76.72322	33.06397	0.85	78	205	76.75511	33.01077	0.28
20	28	76.72217	33.06262	0.85	79	206	76.83114	32.92096	2.31
21	29	76.72078	33.06442	1.85	80	207	76.66621	32.91004	0.58
22	30	76.70298	33.06401	0.59	81	208	76.67038	32.90988	0.29
23	31	76.70295	33.06293	0.58	82	209	76.53673	32.84004	16.08
24	32	76.70437	33.06258	0.87	83	210	76.85802	32.82592	1.01
25	33	76.69865	33.05946	0.92	84	211	76.96737	32.90075	0.29
26	34	76.73349	33.02312	0.64	85	213	76.94237	32.90421	0.42
27	35	76.73889	33.02716	0.29	86	215	76.94219	32.92504	0.28
28	35	76.59367	33.17675	2.14	87	216	76.95445	32.96786	1.35
29	36	76.73953	33.02514	2.57	88	229	76.94967	32.77248	2.58
30	37	76.74207	33.02189	2.74	89	230	76.95637	32.78421	1.07

31	38	76.75596	33.0075	2.28	90	232	76.76108	32.91771	0.41
32	39	76.76129	32.95901	1.56	91	234	76.72652	33.03849	0.43
33	43	76.67106	32.92748	6.33	92	101SG	76.76155	33.06854	0.29
34	47	76.79135	33.09558	2.49	93	104SG	76.77592	33.05502	0.92
35	48	76.78516	33.09807	1.41	94	105SG	76.78138	33.08243	0.42
36	65	76.82281	33.06354	2.34	95	108SG	76.8627	33.02756	0.35
37	66	76.9197	32.98887	0.58	96	126SG	76.68135	32.95671	0.56
38	67	76.96643	32.98316	1.92	97	127SG	76.67728	32.96427	0.30
39	69	76.97512	32.98413	0.56	98	133SG	76.74926	33.08943	0.29
40	72	76.97828	32.96374	0.35	99	134SG	76.75823	33.0802	0.49
41	75	76.94607	32.9071	1.08	100	136SG	76.84921	33.04752	0.50
42	76	76.93049	32.86458	3.38	101	140SG	76.73909	32.95631	0.29
43	77	76.94826	32.77481	4.95	102	211SG	76.91132	32.82203	0.43
44	81	76.96932	32.76618	1.71	103	217SG	76.97663	32.95776	1.07
45	82	76.9509	32.75539	3.67	104	218SG	76.84655	33.04583	0.27
46	84	76.52877	33.18112	1.49	105	219SG	76.7967	33.08008	0.48
47	86	76.57193	33.12599	1.45	106	220SG	76.78174	33.07963	0.28
48	87	76.58107	33.11573	0.37	107	221SG	76.77241	33.05412	0.35
49	88	76.58293	33.1167	1.21	108	222SG	76.77268	33.05511	0.21
50	89	76.60078	33.13344	5.58	109	223SG	76.77047	33.05444	0.64
51	90	76.69985	33.14742	0.91	110	224SG	76.75569	33.07932	0.29
52	91	76.70147	33.14836	0.35	111	225SG	76.75479	33.0813	0.35
53	92	76.6983	33.1629	0.64	112	226SG	76.75475	33.084	0.29
54	106	76.78608	33.10098	0.71	113	227SG	76.74769	33.09913	0.22
55	110	76.97498	32.96837	0.36	114	228SG	76.76491	33.13201	0.28
56	111	76.95695	32.96864	0.58	115	54SG	76.76331	33.06903	1.50
57	112	76.97262	32.94529	0.78	116	55SG	76.76119	33.06626	1.06
58	113	76.96182	32.94334	1.89	117	93SG	76.75561	33.14154	0.29
59	114	76.943	32.92333	1.13	118	96SG	76.75476	33.08298	2.00

Table 6 GLOFs of Miyar Sub-Basin, Chenab Basin, Himachal Pradesh (2017)

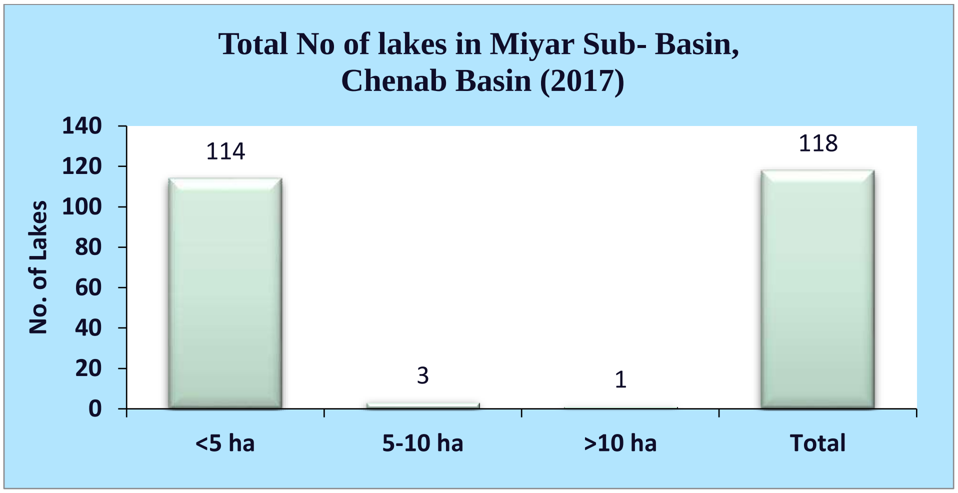


Figure 40 Total No of lakes in Miyar Sub- Basin, Chenab Basin (2017)

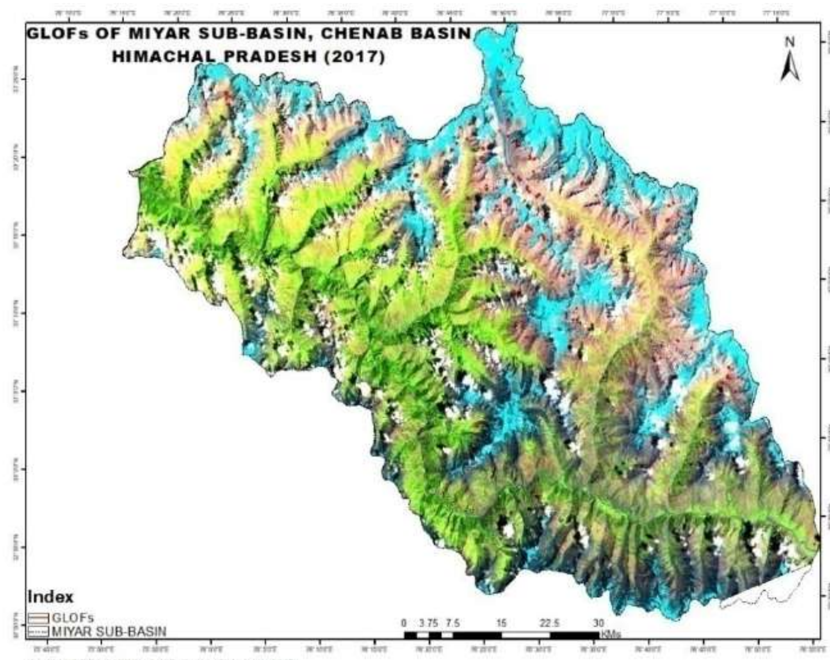


Figure 41 GLOFs of Miyar Sub- Basin, Chenab Basin, Himachal Pradesh (2017)

GLOFs in Beas Basin:

Beas is another major river in Himachal Pradesh which originates from Rohtang in Kullu district. Beas Basin has been divided into three sub basins i.e. Jiwa, Parbati and the Beas its own basin in Himachal Pradesh. Since the Beas basin falls in the transition zone, so the effect due to the climatic variations seems to be more pronounced which could be seen in the snow and glaciated regions of the state.

Mapping of GLOFs in Upper Beas Sub Basin:

The interpretation of IRS-LISS III of 7 October 2017 reveals the presence of total 25 lakes in the Upper Beas Basin upstream of Bhuntar (Fig 42). Lake Id's, location and area have been represented in table 7. Further analysis of the 25 lakes mapped in 2017 reveals that out of 25 lakes, 23 lakes are the small one with area less than 5ha and 1 each is having area between 5-10 ha and more than 10 ha respectively (Fig 42).

GLOFs of UPPER BEAS SUB-BASIN, BEAS BASIN, HIMACHAL PRADESH (2017)									
Sr. No.	Lake id Number	Longitude	Latitude	Area (hectare) in 2017	Sr. No.	Lake id Number	Longitude	Latitude	Area (hectare) in 2017
1	2	77.0793	32.28649	1.20	14	17	77.09098	32.29313	2.75
2	3	77.07869	32.29102	6.45	15	18	77.08048	32.28435	0.69
3	5	77.09462	32.30208	1.69	16	19	77.07984	32.2813	1.78
4	6	77.29922	32.15624	10.86	17	101	77.08512	32.289	0.55
5	7	77.30096	32.14353	3.12	18	102	77.0616	32.29819	0.62
6	8	77.2864	32.12978	1.04	19	103	77.06079	32.30004	0.61
7	9	77.28212	32.12481	1.90	20	104	77.22418	32.374	1.07
8	11	77.07028	32.1864	0.93	21	105	77.34093	32.28998	1.00
9	12	77.34094	32.27791	2.81	22	106	77.34318	32.2834	0.75
10	13	77.30801	32.16005	4.58	23	107	77.34259	32.27546	1.88
11	14	77.08841	32.30561	3.52	24	108	77.37158	32.17039	1.95
12	15	77.08551	32.30352	2.82	25	109	77.30665	32.15871	0.60
13	16	77.0951	32.29769	0.50					

Table 7 GLOFs of Upper Beas Sub-Basin, Beas Basin, Himachal Pradesh (2017)

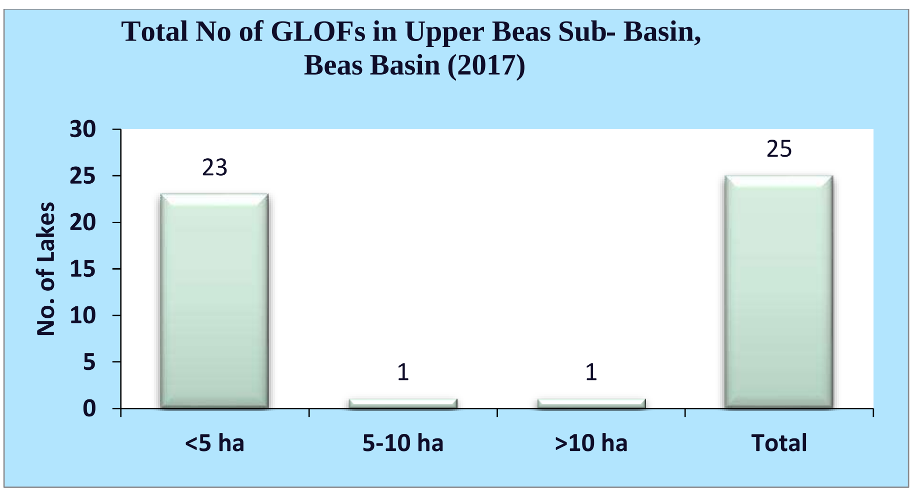


Figure 42 Total No of GLOFs in Upper Beas Sub- Basin,Beas Basin (2017)

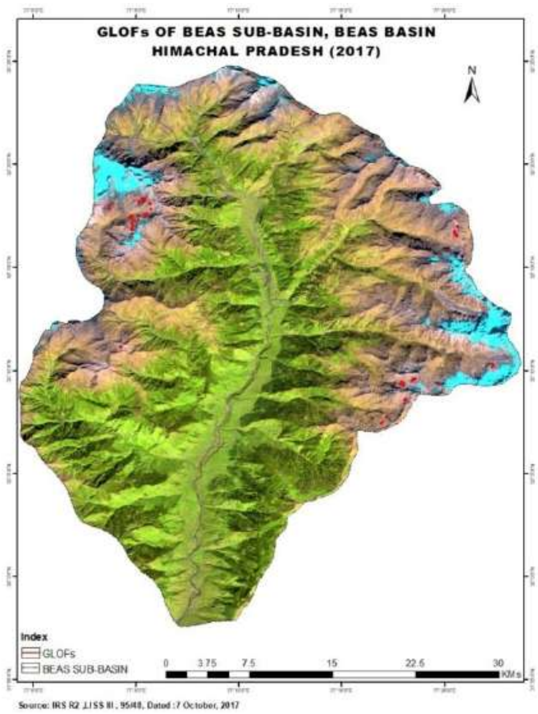


Figure 43 GLOFs in Upper Beas Sub Basin, Beas Basin, Himachal Pradesh (2017)

Mapping of GLOFs in Jiwa sub basin:

Jiwa sub basin which falls on the south-eastern part of the Beas River and comprises of the Jiwa and Sainj as two major tributaries of the Beas basin. From the analysis of the IRS-LISS-III satellite data of 7 October 2017, a total of 32 lakes could be mapped .Further out of 32 lakes mapped in 2017, 02 lakes are such which have the area between 5-10 ha Besides this, 30 lakes are such which have the area less than 5ha (Figure 44).

GLOFs of JIWA SUB-BASIN, BEAS BASIN, HIMACHAL PRADESH (2017)									
Sr. No.	Lake id Number	Longitude	Latitude	Area (hectare) in 2017	Sr. No.	Lake id Number	Longitude	Latitude	Area (hectare) in 2017
1	1	77.53712	31.88516	3.24	17	39	77.61116	31.65699	0.97
2	2	77.56181	31.84182	3.41	18	41	77.46169	31.84105	1.85
3	3	77.59262	31.84522	2.91	19	42	77.46267	31.84357	1.94
4	4	77.63933	31.84452	0.56	20	45	77.47112	31.83689	1.95
5	5	77.64076	31.85147	4.93	21	46	77.4755	31.83699	1.18
6	6	77.64949	31.85068	0.68	22	48	77.59013	31.66759	6.29
7	17	77.564	31.7338	2.08	23	101	77.53687	31.88187	0.17
8	18	77.56181	31.73271	1.77	24	102	77.53992	31.88	0.36
9	19	77.55589	31.7338	2.02	25	103	77.5446	31.88012	0.72
10	20	77.5549	31.7394	1.91	26	104	77.66249	31.78391	0.69
11	27	77.52408	31.73632	3.41	27	105	77.66988	31.72277	1.65
12	28	77.51614	31.74043	0.73	28	106	77.66338	31.72911	3.09
13	29	77.50634	31.74042	1.30	29	107	77.54902	31.73926	1.00

14	36	77.61939	31.66551	6.01	30	108	77.60827	31.65414	0.96
15	37	77.59812	31.66807	3.74	31	109	77.61012	31.65348	1.03
16	38	77.56514	31.67605	2.48	32	110	77.61434	31.66721	0.45

Table 8 GLOFs of Jiwa Sub-Basin, Beas Basin, Himachal Pradesh (2017)

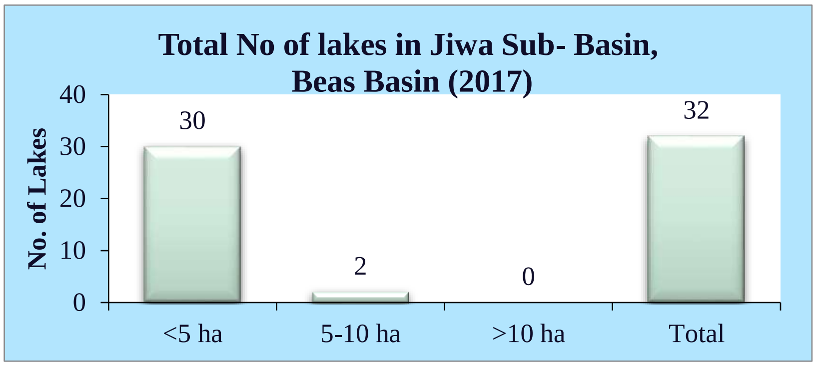


Figure 44 Total No of lakes in Jiwa Sub- Basin, Beas Basin (2017)

Figure 45 GLOFs of Jiwa sub Basin, Beas Basin, Himachal Pradesh (2017)

Mapping of GLOFs in Parvati sub basin:

Parvati is another major tributary of Beas Basin that joins the Beas River on its left bank near Bhuntar in Kullu district. Based on the satellite data analysis for 7 October 2017, a total of 44 lakes have been mapped. Further out of these 44 lakes mapped on 7 October 2017, 03 lakes have the area more than 10 ha, 2 lakes lie between the ranges 5-10 ha and 39 lakes fall under the category of area less than 5 ha.

GLOFs of PARVATI SUB-BASIN, BEAS BASIN, HIMACHAL PRADESH (2017)									
Sr. No.	Lake id Number	Longitude	Latitude	Area (hectare) in 2017	Sr. No.	Lake id Number	Longitude	Latitude	Area (hectare) in 2017
1	1	77.46549	32.16696	0.82	23	37	77.53989	32.03839	1.63

2	2	77.46922	32.16696	1.26	24	38	77.60512	31.98623	1.13
3	3	77.49298	32.17921	7.57	25	39	77.73165	31.95484	0.44
4	11	77.70026	31.97214	1.69	26	40	77.72714	31.94793	0.45
5	12	77.71282	31.94761	1.39	27	41	77.73392	31.94452	0.37
6	17	77.79025	31.82885	2.61	28	43	77.7923	31.82102	0.74
7	18	77.79158	31.83736	2.09	29	44	77.58732	31.94203	2.20
8	21	77.79003	31.8484	12.88	30	46	77.41121	31.93662	0.84
9	22	77.5723	31.92668	0.51	31	50	77.45515	32.13318	14.58
10	23	77.53896	31.8983	3.73	32	51	77.79489	31.83747	1.65
11	24	77.53289	31.89665	2.26	33	101	77.43494	32.07108	0.64
12	25	77.53487	31.90106	1.00	34	102	77.43456	32.14413	0.37
13	26	77.52648	31.91376	15.47	35	103	77.45883	32.13109	0.72
14	27	77.52659	31.89764	3.37	36	104	77.47144	32.1588	0.69
15	28	77.61283	32.05469	3.29	37	105	77.4706	32.1626	0.81
16	29	77.60399	32.04837	1.60	38	106	77.50655	32.13901	0.55
17	30	77.44924	32.07356	3.77	39	108	77.79309	31.84401	1.24
18	31	77.45568	32.09845	2.01	40	109	77.41764	31.93689	5.30
19	32	77.45632	32.09994	0.88	41	110	77.42854	31.9319	0.81
20	33	77.43299	32.13404	2.32	42	111	77.43527	31.9245	0.98
21	34	77.4348	32.13414	2.76	43	6SG	77.50591	32.16666	0.32
22	35	77.45217	32.15098	0.88	44	7SG	77.49476	32.16158	0.36

Table 9 GLOFs of Parvati Sub-Basin, Beas Basin, Himachal Pradesh (2017)

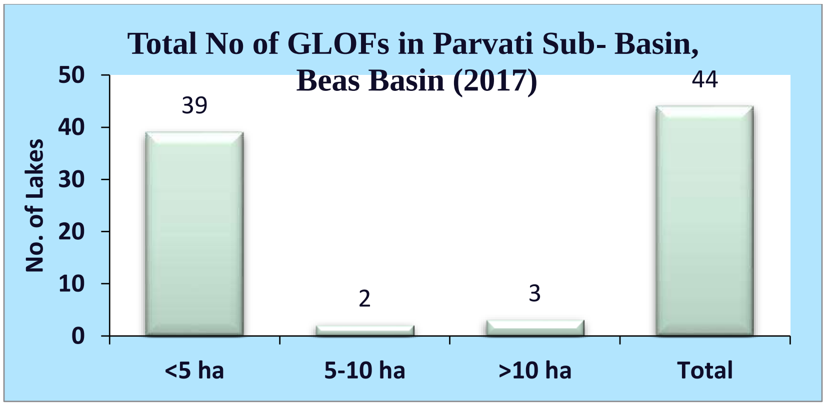


Figure 46 Total No of GLOFs in Parvati Sub- Basin, Beas Basin (2017)

Figure 47 GLOFs of Parvati sub basin, Beas Basin, Himachal Pradesh (2017)

Mapping of GLOFs in Ravi Basin:

Ravi is another major river that originates from Bara Bhangal of Kangra district and flows towards west and enters Chamba district and then culminates into the Ranjeet Sagar Dam beyond which it enters Punjab and then to Pakistan. After visual interpretation of IRS-LISS III satellite data of 20 September 2017 and 7October 2017, a total of 54 lakes have been delineated in Ravi basin. The analysis reveals that out of 54 lakes mapped in 2017, 50 lakes are the small one with area less than 5 ha, 1 lake comprise of the area within 5-10 ha and 3 lakes are such which have the area more than 10 ha (Fig 48), in other words we can say that about 93% lakes delineated in Ravi basin in 2017 are the smaller lakes.

GLOFs of RAVI BASIN, HIMACHAL PRADESH (2017)									
Sr. No.	Lake id Number	Longitude	Latitude	Area (hectare) in 2017	Sr. No	Lake id Number	Longitude	Latitude	Area (hectare) in 2017
1	2	76.32099	32.34259	0.60	28	111	77.01772	32.23398	1.84
2	2	76.63666	32.3937	1.65	29	112	77.01837	32.23183	0.43
3	4	76.9669	32.26156	2.49	30	113	77.02097	32.22968	0.38
4	7	77.03418	32.22512	3.51	31	114	77.01792	32.22878	0.99
5	8	76.89954	32.20648	0.63	32	116	77.01797	32.22628	0.38
6	9	76.80876	32.22465	3.51	33	117	77.02383	32.22583	1.11
7	10	76.78636	32.24298	14.42	34	118	77.03223	32.22358	1.74
8	17	76.32474	32.34245	2.32	35	119	77.02963	32.22017	1.78

9	29	76.69425	32.37938	1.21	36	120	77.03228	32.21947	1.25
10	31	76.75331	32.23264	12.16	37	121	77.03539	32.21887	0.57
11	32	76.75425	32.23671	2.70	38	122	77.03033	32.21532	3.77
12	33	76.7768	32.25551	3.61	39	123	77.03333	32.21592	0.79
13	34	76.81973	32.22245	1.07	40	124	77.03473	32.21497	1.88
14	35	77.03313	32.21854	0.56	41	126	77.03408	32.21292	0.31
15	37	76.98547	32.27172	1.55	42	127	77.04303	32.35594	0.90
16	37	76.98403	32.27275	2.68	43	128	77.03684	32.35619	0.36
17	101	76.52383	32.24305	2.03	44	129	76.84897	32.42083	2.43
18	102	76.53545	32.23344	3.57	45	130	76.74681	32.38421	4.55
19	103	76.75477	32.2271	0.93	46	131	76.3536	32.3357	2.12
20	104	76.76047	32.23502	0.80	47	132	76.3706	32.31203	4.25
21	105	76.7779	32.23123	1.16	48	133	76.36978	32.30988	0.67
22	105	76.80199	32.22932	3.04	49	134	76.42634	32.26941	5.77
23	106	76.80728	32.2309	0.87	50	135	76.48711	32.26849	2.80
24	107	76.8311	32.2065	0.43	51	136	76.49479	32.26295	0.61
25	108	76.89925	32.21207	0.92	52	15WL	76.34306	32.33191	4.02
26	109	77.01317	32.23108	0.75	53	16WL	76.32993	32.33653	34.50
27	110	77.01547	32.23423	1.19	54	39SG	77.0222	32.39675	1.01

Table 10 GLOFs of Ravi Basin, Himachal Pradesh (2017)

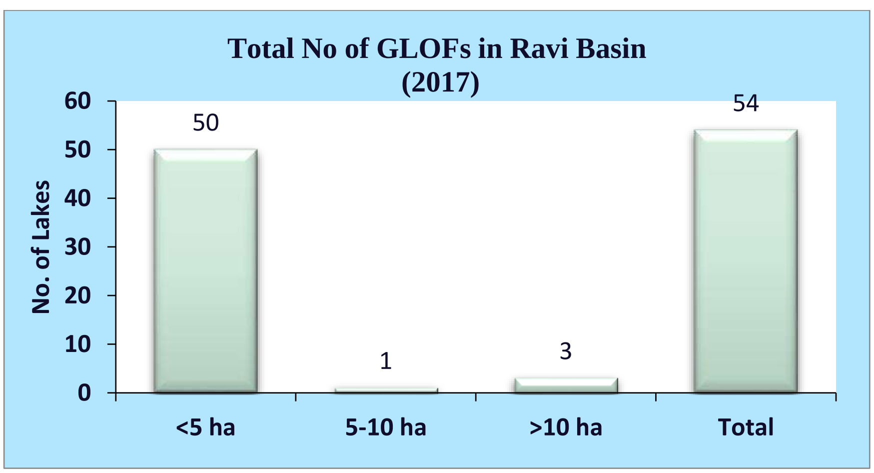
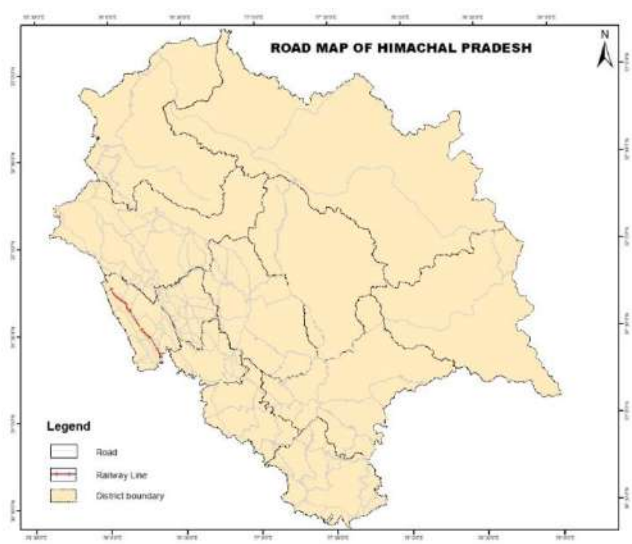


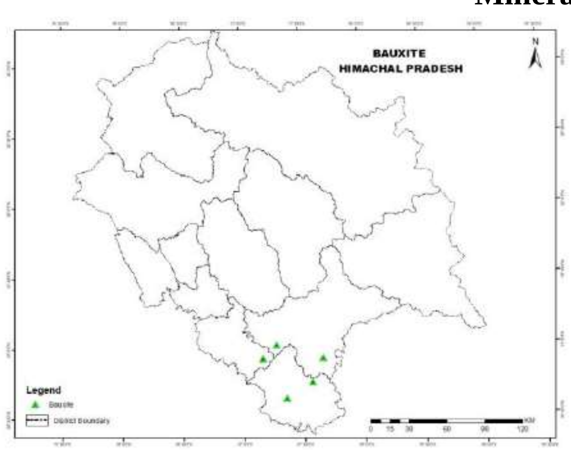
Figure 48 Total No of GLOFs in Ravi Basin (2017)

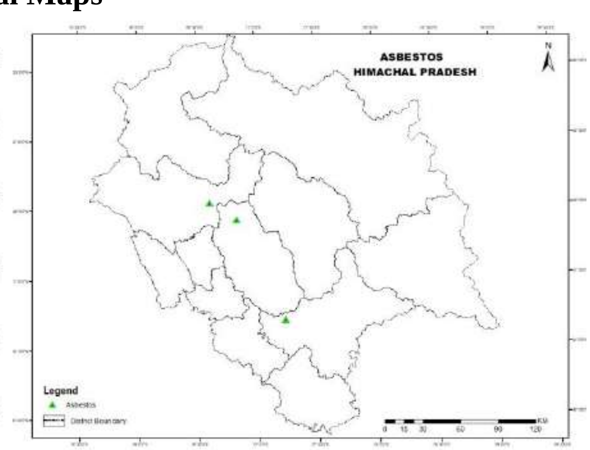
Figure 49 GLOFs of Ravi Basin, Himachal Pradesh (2017)

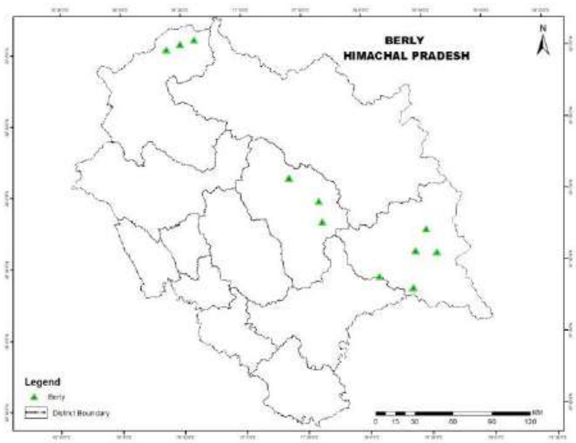
Geodatabase Generation of Roads

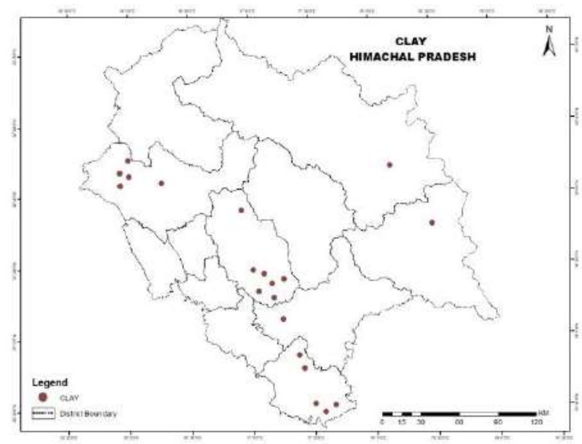


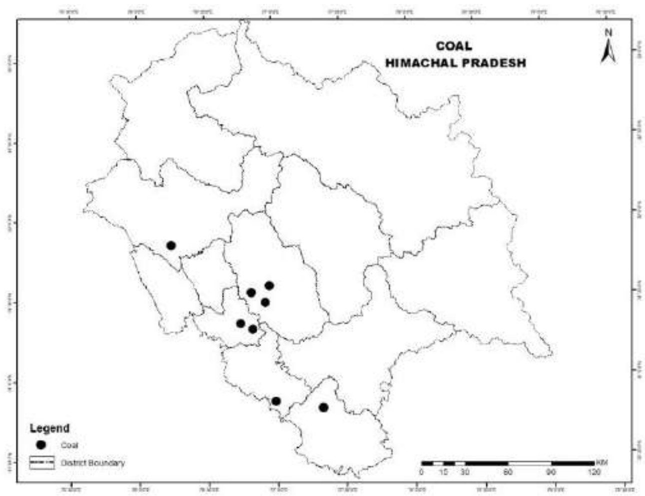
Mineral Maps

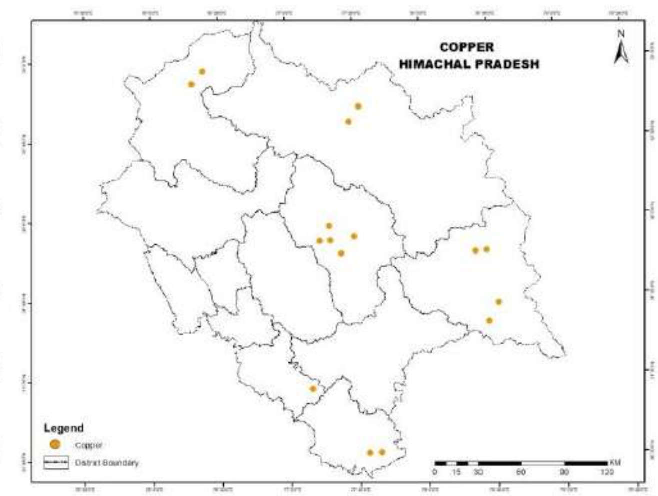


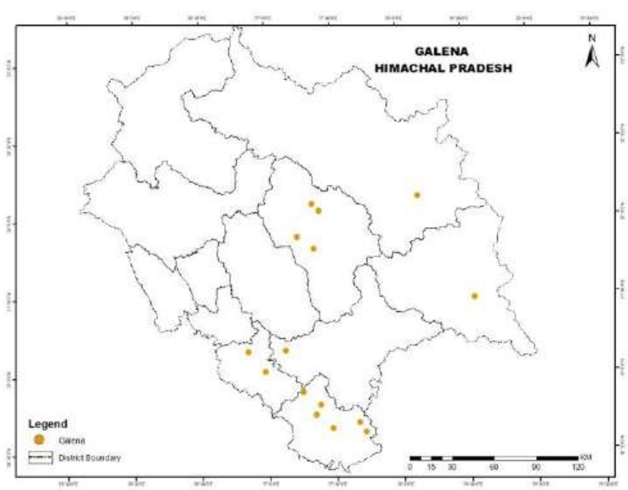


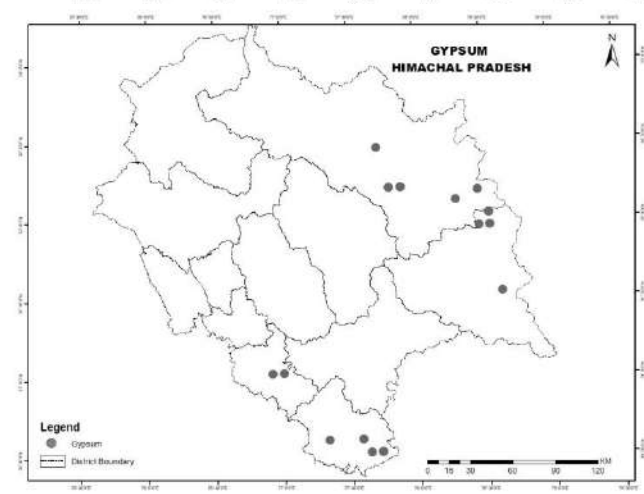

BERLY
HIMACHAL PRADESH
N
Legend
Berly
District Boundary
0 15 30 60 90 120
KM


CLAY
HIMACHAL PRADESH
N
Legend
CLAY
District Boundary
0 15 30 60 90 120
KM


COAL
HIMACHAL PRADESH
N
Legend
Coal
District Boundary
0 15 30 60 90 120
KM


COPPER
HIMACHAL PRADESH
N
Legend
Copper
District Boundary
0 15 30 60 90 120
KM


GALENA
HIMACHAL PRADESH
N
Legend
Galena
District Boundary
0 15 30 60 90 120
KM


GYPSUM
HIMACHAL PRADESH
N
Legend
Gypsum
District Boundary
0 15 30 60 90 120
KM

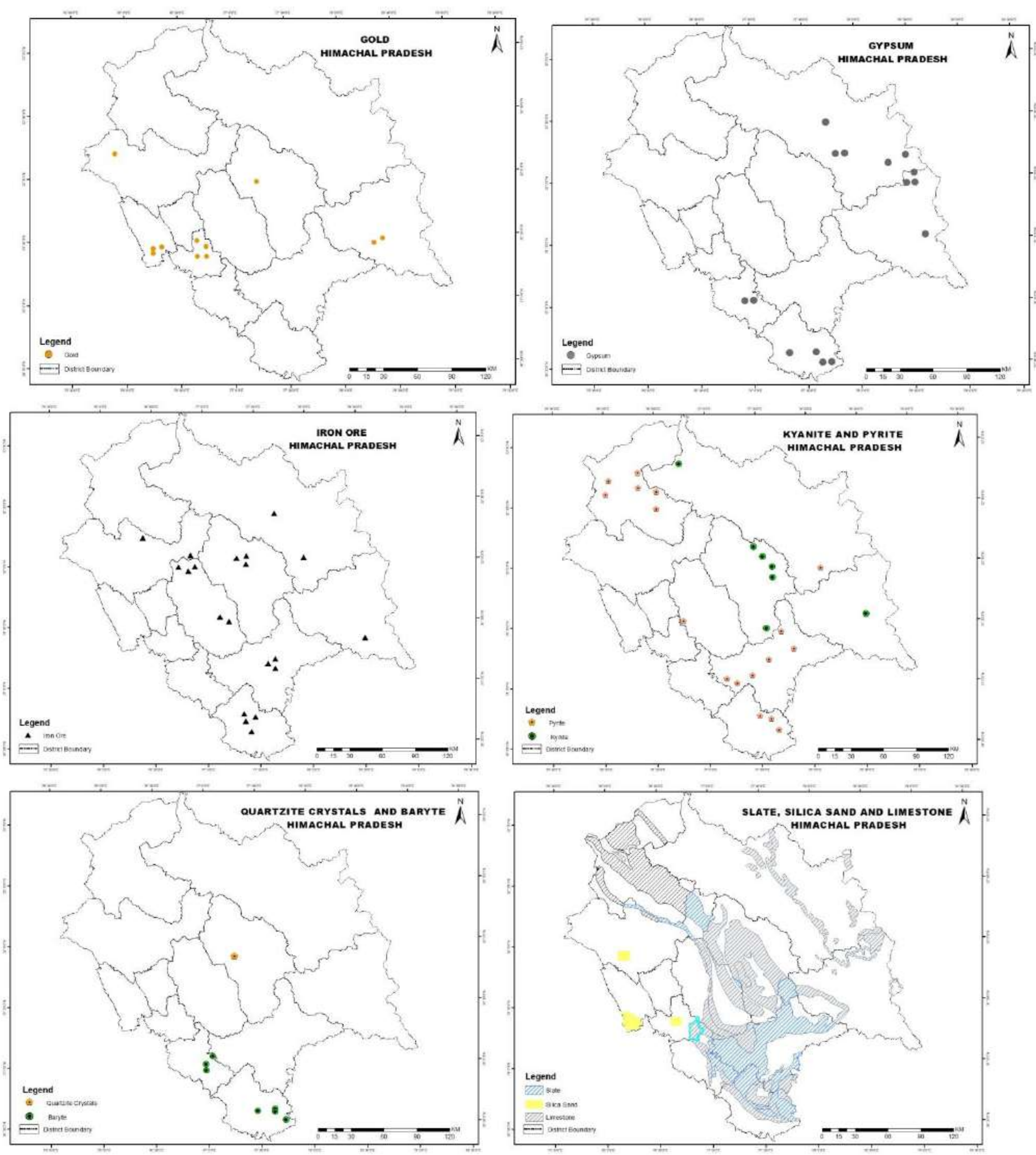


Figure 50 Road Map and Minerals map of Himachal Pradesh

6. Understanding the Impact of Climate Change on Small hydro power Projects

Area of Research: Earth & Atmosphere Sciences and Sub-area Himalayan Glaciology

The main objective of this proposal is to understand the influence of climate change on hydropower generation of small mini and micro power projects located in Himachal Pradesh. The identified sub-objectives are following:-

- To estimate changes in snow and glacier extent in individual sub basins where power projects are located.
- To estimate influence of snow, glacier and runoff changes on stream runoff and power generation.
- To understand influence of changing power generation scenario on sustainability of power plants.

Salient Research Achievements:

Data collection was done from Department of Agriculture, Shimla; Meteorological Centre, Shimla and Ghanvi-II Hydro Power Project. Regarding this project the AD Hydro Power Ltd. Manali, HP was followed up. The Land Use, Land Covers of the Aleo-II, Ghanvi-II and Thirot projects were generated. Government of Himachal Pradesh has proposed to build around six hundred and sixty micro and mini hydro power projects. Out of these sixty-six are already commissioned and generate 257 MW power. The overall investments in these power plants will be huge. To protect these investments and to meet national goals, we need to assess sustainability of water availability. Many of these power projects are located in High mountain region, where main source of water is snow and glacier melt. However, recent investigations have shown that pattern of snow and glacier melt is changing and influencing extent of snow and glacier extent. So we have chosen three small hydro power projects named Aleo-II, Ghanvi-II and Thirot. The Capacity of these three hydro power projects is less than 10 MW.

The first hydroelectric project is Ghanvi-II which is being conceived as a run-of-the-river scheme on Ghanvi khad a tributary of Satluj River in Shimla District of Himachal Pradesh. The project consists of a trench weir across Ghanvi khad near village Rungcha, vortex type desilting arrangement, storage reservoir, 1.4 km long head race tunnel, underground surge shaft, surface/underground penstock and an underground power house on the left bank of Ghanvi khad. Ghanvi village is 10 km from NH-22 at Jeori and 33 km from Tehsil Headquarter at Rampur Bushahr. This village is situated in hard area of 15/20 Pargana Notified by Govt. of Himachal Pradesh. The Project Ghanvi II is made on Satluj Basin and its capacity is 10 MW. The Catchment area of this project is 106.8 Km^2 and number of Glaciers is 8. The Glaciated Area is 51.4 Km^2. Zone of altitude is 1828 – 5651 meter. This power project is also selected for Phase-1. Latitude and longitude coordinates of Rampur Bushahr, Shimla District are 31.450926, 77.630768**.**
The second hydroelectric project is Aleo II which is made on Beas Basin. Its Capacity is 8 MW and Catchment area is 140.3 Km^2. The No. of Glaciers is 22 with Glaciated Area of 10.9 Km^2. The

Altitude zone is 1842- 6017 meter. This power project is also selected for Phase-1. This hydroelectric project is situated in Kullu district of Himachal Pradesh extended between 30° 20' 25'' N to 32° 25' 0'' N latitudes and 76° 56' 30'' E to 77° 52' 20'' E longitudes. It is bordered in the north by Lahaul and Spiti district, in the south-east by Kinnaur district, in the south by Shimla district, in the south-west and in the north-west by Mandi district.

The third Project is Thirot made up on Chenab Basin. Its Capacity is 4.5 MW and catchment area is 189.5 Km^2. The No. of Glaciers is 29 and the Glaciated Area is 32.5 Km^2. The Altitude zone is the project is 1842- 6017 meter, Selected for Phase-1. This power house is located in remote tribal valley of Lahaul in Lahaul and Spiti District on Thirot Nallah, originates near Gang Stang glacier. The power from this Power House is 91 Hydro Electric Development in Himachal Pradesh utilized in remote tribal area of Lahul and Pangi and surplus power available is utilized in Manali area of Kullu District. Coordinates of Thirot are 32.6604° N, 76.7805° E.

7. National wetland inventory and assessment (NWIA) Phase II.

Image interpretation of wetlands in H.P (2017-18) using LISS III images

Results:

Brief final Statistics		
Total wetland in 2017		98321.16ha
Total wetland in 2006		98015.6 ha
Total area increased		(305.56 ha in 2017 w r t 2006-07)
Not exist in 2017_18	Disappear (Dry)	NO
	Error of Commission	1 (41.59 ha)
New wetland		1 (2.28 ha)
Area decreased in existing		NO
Inland wetland (2017-18)		Total: 98321.16ha Natural: 56139.04 ha Man made:42182.16 ha
Area excluding river/stream (2017-18)		42762.96ha

Table 11 Image interpretation of wetlands in H.P (2017-18) using LISS III images

Decadal Wetland Change Analysis-Himachal Pradesh

Sr. No.	Status		2006-07		2017-18		Change (2017 - 2006 & 07) (ha)
			No. of Wetland/ Polygons	Wetland area (ha)	No. Of Wetland/ Polygons	Wetland area (ha)	
1	Wetlands exist in both time frames		169	97974.01	182	98318.93	+344.92
2	Additional/ new wetland mapped in 2017-18				1	2.28 ha	2.28
3	Wetland exist in 2006-07 but disappeared in 2017-18	Disappear	no	no			-41.59
		Wrongly mapped	1	41.59			
	Total		170	98015.6	183	98321.2	305.61

Table 12 Decadal Wetland Change Analysis-Himachal Pradesh

Figure 51 Image interpretation of wetlands in H.P (2017-18) using LISS III images

C. AGRI-HORTICULTURE SECTOR

1. Impact of Climate Change on Agriculture Sector in District Kangra, Himachal Pradesh

A study was conducted with a view to ascertain the impact of climate change on agricultural sector in the state with a pilot study in District Kangra, Himachal Pradesh. Seasonal trends on climatic variables i.e. minimum, maximum, and diurnal temperatures, and rainfall patterns (quantity and days) were conjugated with a standardized anomaly index and a multivariate regression analysis was conducted to unearth the climate and crop yield relationship.

Based on the statistical analysis, Mann Kendall trend test, the maximum and diurnal temperature showed significant changes during the *Kharif* and Rabi crop season for the study period spanned across 47 years for the time period 1971-2018. During Kharif crop season, the maximum temperature and Diurnal T rose at the rate of 0.017°C and 0.041°C per year respectively (as exhibited by the Sen's slope). Meanwhile the minimum temperature exhibited a decreasing trend of 0.016 °C. and for Rabi crop season maximum temperature and diurnal temperature rose at the rate of 0.039°C and 0.039°C per year respectively. Rainfall, on the other hand, did not show any significant variation from 1971-2018. However, in Rabi season there is less rainfall at the rate of (-0.051mm). As per the output from SAI, after 1992, maximum temperature remained above the long term average except for the years 1997, 2006 and 2008 indicating an overall warming trend. Meanwhile cooling trend was observed in case of minimum after 1992 temperature except for 2013 and 2014 years. Rainfall, on the other hand, also showed increase in rainfall from 1994 to 2018 except few years during the Kharif crop season. As per the outputs from SAI, maximum temperature showed a warming trend from 1994 onwards, except for dip in the year 2014 and 2015. Whereas no significant pattern was observed for minimum temperature and rainfall. As per the outputs from Mann Kendall Tests, an overall increased productivity trend is recorded for Wheat, barley, rice, gram, black gram and horse gram, wherein wheat crop had the lowest p-value (0.001) exhibiting significant changes in productivity compared to the other crops. Only potato crop registered a decline in productivity by 0.056 t ha^{-1} $year^{-1}$. To ascertain the relationship between climatic variability and crop productivity, a correlation analysis was performed using the statistical tool – *Pearson's coefficient*. By testing the effects of variability in maximum temperature, a negative correlation coefficient (-0.298 and-0.291) was observed for rice and black gram crop productivity (with a p-value of 0.031, and 0.034) respectively. I.e. an increase in maximum

temperature is expected to result in decline their productivity as corroborated from Mann Kendall trend test result. Secondary literature also supports these findings in certain cases. Singh et al. (2015), Mishra et al. (2015), and Gammans et al. (2017) reported similar trends for wheat, barley, maize, and paddy crops. Rainy days variations did not hold statistically significant relationship with variability in productivity for any of the crops during the study period.

Crops	Mean	Sen's slope	p-value
Wheat	1.411	0.028	<0.0001
Barley	1.096	0.012	0.000
Rice	1.256	0.006	0.013
Maize	1.538	0.004	0.165
Potato	10.695	-0.056	0.274
Gram	0.553	0.007	0.005
Black gram	0.335	0.003	0.019
Horse gram	0.310	0.004	0.002

Table 13 Mann Kendall Test Results – Crop Yields for Kharif and Rabi Season

For all assessed crop varieties viz. Wheat, Barley, gram, Rice, Maize, black gram, horse gram and only 20.7%, 7.7%, 8.0%, 19.7%, 18.1%, 9.3 % and 3.5% of productivity variability could be explained from temperature and rainfall variations in the district. With respect to individual crops, this means that the observed increase in productivity for Wheat, Barley, Rice, Gram, Black gram, and Horse gram from 1971-2009 is explained by the variations in climatic parameters only to the extent of 20.7% ,7.7%, 8.0%, 19.7%, 9.3% and 3.5% respectively. Similar interpretation stands for the decline in productivity for maize and potato. Factors of access to improved seed varieties, extensive fertilizer application, and better farm practices are touted to be the explanatory reasons for remainder variations in crop yield (Sharma, 2011).

2. Impact of Climate Change on Horticulture Sector in District Kangra, Himachal Pradesh

The status report was designed to elucidate statistical impact of climate change on productivity of horticulture crops in Himachal Pradesh with a study focused on District Kangra. Seasonal trends on climatic variables i.e. minimum, maximum, diurnal temperatures, and rainfall patterns (quantity and rainy days) were conjugated with a standardized anomaly index, and a multivariate regression analysis was conducted to unearth the climate and crop yield relationship as per the phenological stages of *pre-flowering, flowering, and fruit setting and development*. As per the analysis the average maximum temperature registered an inclining trend at a rate of 0.045°C per year between 1970-2018 (as exhibited by the Sen's slope) during the pre-flowering season i.e. between November – February. During the flowering season i.e. March to April the average maximum temperature increased by 0.04°C per year and minimum temperature showed decline in temperature by -0.02°C per year. Also, the average maximum temperature and diurnal temperature during fruit setting stage i.e. between May – August also registered an inclining trend progressing at a rate of 0.013°C and 0.04°C per year between 1970-2018. Rainfall during fruit setting stage show increase by 5.31mm. The remaining climatic variables did not exhibit any significant variation during the pre-flowering, and fruit setting and development stages.

Fruits Productivity	Mean	Sen's slope	p-value
Pear	2.476	0.182	0.002
Galgal	2.403	0.087	0.001
Loquat	3.090	-0.174	0.003
Papaya	8.630	-0.270	0.003
Guava	1.289	0.021	0.199
Litchi	0.531	0.040	0.00
Mango	0.794	0.033	0.002
Lemon	0.743	0.053	0.000
Orange	1.374	0.074	0.001

Table 14 Mann Kendall Test Results – Crop Yields for Fruit Crops (1980-2016)

Highly significant correlation between climate variability and productivity was observed during the pre-flowering stages, with a predominant impact on the productivity of Orange, Mango, Galgal (Citrus psedolimon) and Louqat. Orange productivity exhibited strong correlation with maximum and minimum temperatures during the pre-flowering period with coefficient values of 0.58 and 0.36 respectively. It also shows correlation with maximum and minimum temperatures during the flowering period. In case of Mango productivity increase in minimum temperature cause increase productivity during pre flowering and fruit setting stage by 0.37 and 0.45 respectively. Galgal productivity exhibited strong correlation with minimum temperatures during the pre-flowering and flowering period with coefficient values of 0.55 and 0.59 respectively. Productivity of loquat had a negative correlation with increase in minimum temperature during pre flowering season cause decline in productivity by -0.57 during the study period. With reference to variations in mean maximum temperature, guava crop showed significant negative correlation of -0.31 during the fruit setting season. That is with slight increase in maximum temperature, guava crops shows decreased in productivity.

3. Impact of Climate Change on Agriculture Sector in District Mandi, Himachal Pradesh

A status study was conducted with a view to ascertain the impact of climate change on agricultural activities in District Mandi. Seasonal trends on climatic variables i.e. minimum, maximum, diurnal temperatures, and rainfall patterns were conjugated with a standardized anomaly index and a multivariate regression analysis was conducted to unearth the climate and crop yield relationship.

The statistical assessment unearthed climate change as an instrumental component leading to significant shifts in cropping patterns and productivity in District Mandi.

Rice, Maize, crops showed significantly changing yields during 1970-2010 time periods, except for Potato, and Wheat Barley.

Climatic Variations: Mean maximum temperature increased by 0.035 °C per year during Kharif crop season. Meanwhile, the diurnal temperature exhibited an increasing trend of 0.05 °C per year. Rainfall did not register any statistically significant result during the study period.

Climate Crop Juxtaposition:

The results revealed a strong relationship between climate variability and productivity of Kharif crop such as Rice and maize whereas negligible association was observed for the Rabi crops (Wheat and barley) in District Mandi. The effects of variability in maximum temperature, diurnal temperature, and rainfall, a significant and positive trend (0.20, 0.34 and -0.54) was observed for Wheat crop productivity (with a p-value of 0.04, 0.03 and 0.01).

4. Impact of Climate Change on Horticulture Sector in District Shimla, Himachal Pradesh

A study was conducted with a view to ascertain the impact of climate change on horticulture sector in District Shimla. Seasonal trends on climatic variables i.e. minimum, maximum, diurnal temperatures, and rainfall patterns (quantity and rainy days) were conjugated with a standardized anomaly index, and a multivariate regression analysis was conducted to unearth the climate and crop yield relationship as per the phenological stages of *pre-flowering, flowering, and fruit setting and development*.

Higher variability in temperature and rainfall parameters observed during *pre flowering period as compared to flowering and fruit setting period* from 1990 to 2016. During *pre flowering period* maximum temperature increased by 0.02°C per year from 1990 to 2016. Maximum temperature increased by 0.01°C per year from 1990 to 2016 during *flowering period.* Meanwhile, the maximum temperature increased by 0.03°C per year from 1990-2016 during *fruit setting period.*

The statistical assessment of variations in climatic parameters of temperature and rainfall with changes in horticulture productivity registered maximum impact during the *pre-flowering* phenological stage i.e. for Apple crop with diurnal temperature and rainfall, while for flowering stage and fruit setting stage fewer statistically significant correlation was witnessed between fruit crops productivity and climatic parameters.

Amongst all the studied crops, Pomegranate showed maximum sensitivity to climatic variations during all three stages (24%, 26.3%, 25.5%) with significant correlation.

D. FORESTRY SECTOR

1. Understanding the Nature of Alpine Timberlines of Himalayas: Integrating Ecological and Scenario Studies for Assessing the Impact of Climate Change.

Project Title: Understanding the Nature of Alpine Timberlines of Himalayan: Integrating Ecological and Scenario Studies for Assessing the Impact of Climate Change. Under NMHS Programme of Ministry of Environment, Forest & Climate Change (MoEF & CC).

Lead Proponent	Member Secretary, Himachal Pradesh State Centre on Climate Change O/o HP Council for Science, Technology and Environment (HIMCOSTE) Vigyan Bhawan, Bemloe Shimla, Himachal Pradesh
Project Partners	CSIR-Institute of Himalayan Bioresource Technology (CSIR-IHBT) State Centre on Climate Change (SCCC), Shimla

Objectives under which work was carried out:

1. To map Timberline zone in Himachal Pradesh region of western Himalayas.
2. To study plant populations, community structure and functional ecology in the LTER sites.
3. To study phenology of key species, net primary productivity, nutrient dynamics and ecophysiology in the LTER sites.
4. To study effect of changing snow cover extent on species diversity and recruitment patterns.
5. To integrate with modeled projections, the scenario studies by involving local stakeholders for understanding the future of their landscape

Work Done

I. Studies at existing LTER sites

The existing LTER sites were visited for collection of data based on Leaf litter decomposition process, litter fall and temperature. The brief details are as follows: -

i. Leaf litter decomposition: The mass loss of leaf litter was recorded on litter bag samples placed earlier (since year 2015) in the timberline zone.
ii. Litter fall estimation: The litter fall was estimated for the months up to June from litter traps installed in the timberline zone.
iii. Temperature data was downloaded from data loggers placed in air, litter and soils, recorded at an interval of one hour.
iv. The regular data monitoring of data loggers *viz.* one at air level, ground level and at surface level to studying the temperature fluctuations was also undertaken in this quarter from the different LTER Sites. To study the nutrient dynamics, the leaf sample were also collected from the different identified sites time to time. The leaf sample from the litter bags and litter traps were also collected for the lab work.

a) Litter Collection from Litter traps

Litter was collected from the litter traps at Khanjar, Sural and Chitkul.

b) Litter collection for decomposition experiment

Leaf litter, twigs and reproductive parts of *Betula utilis* and *Pinus wallichiana* was collected from Khanjar, Mooling, Sural and Chitkul. Sample material was taken to lab and older litter discarded and fresh litter was kept. Oven dry at 70 C for 48 hours. 20cm X 20cm litter bags made of nylon mesh were prepared by filling leaves, twigs and reproductive parts in a fixed proportion to get 10gm of each bag and placed these bags in forest floor to check the decomposition and nutrient release pattern of litter.

c) Temperature Data

Hourly temperature data was recorded from the temperature loggers placed at Chitkul, Khanjar and Sural locations. Air temperature, soil temperature and surface temperature data was recorded.

(II) Laying of Modified Whittaker Plots

Under this objective three field visits were conducted to Khanjar, Triloknath of Lahaul & Spiti and Chitkul of Kinnaur district of Himachal Pradesh which covered the establishment of Modified Whittaker Plot of size 50m X 20m. The MWP, comprises one quadrate of 5x20 m is set for shrubs in the centre of plot, two quadrates in the main plot i.e. one at top left and one at lower right corner of MWP having size 2x5 m and 10 small quadrat for herbs. Species composition was calculated in all quadrates, sample of unknown species are collected for identification and GPS points was also recorded for future reference. Three data logger are placed at different levels, one at air level, one at ground level and one data logger at surface level to studying the temperature fluctuations. The data were recorded from the data logger. To study the nutrient dynamics the leaf sample were also collected from the different identified sites time to time.

Plot Locations:

Khanjar (Lahaul and Spiti)

GPS Coordinate of MWP			
S. No.	Latitude	Longitude	Elevation (m)
1.	32.86688	76.86036	3684
2.	32.86697	76.86019	3687
3.	32.86734	76.86027	3667
4.	32.86732	76.86045	3666

Triloknath (Lahaul and Spiti)

GPS Coordinate of MWP			
S. No.	Latitude	Longitude	Elevation (m)
1.	32.66883	76.69106	3646

2.	32.66867	76.69085	3642
3.	32.66901	76.69063	3616
4.	32.66904	76.69082	3620

Chitkul (Kinnaur)

GPS Coordinate of MWP			
S. No.	Latitude	Longitude	Elevation (m)
1.	31.33603	78.45947	3970
2.	31.33570	78.45926	3993
3.	31.33575	78.45908	3943
4.	31.33607	78.45928	3967

Table 15 Plot Locations of 3 LTER (Long Term Ecological Research) Sites

(III) Mapping of timberline zone in Himachal Pradesh region of western Himalaya

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

The alpine timberline zonation was performed for Himachal Pradesh using high resolution latest satellite data from (Sentinel 2A). New locations in the alpine timberline zone were identified using randomly generated points in QGIS software.

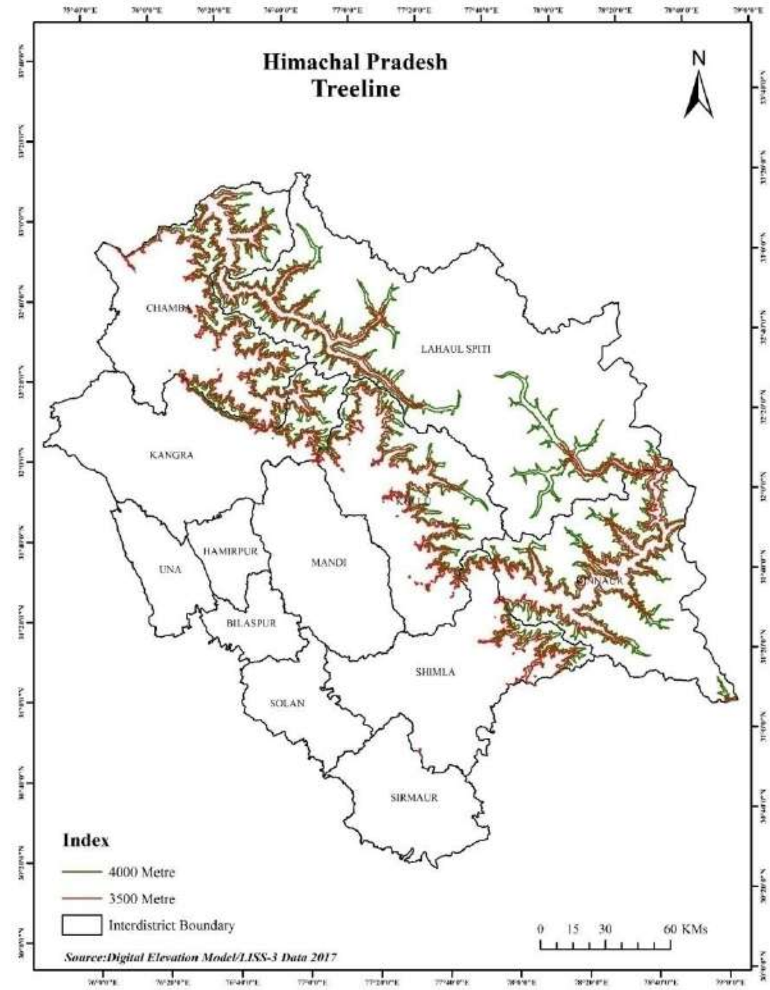


Figure 52 Himachal Pradesh Treeline Map

(IV) Physico-chemical analysis of samples:

A total of 18 leaf litter decomposition samples were analyzed for physico-chemical characteristics. Dry Weight (g), C/N ratio, K and Ca concentrations were determined for these samples. Besides, soil samples were analyzed for pH, moisture % and texture analysis.

Location & collection date(s)	Dry wt. (g)	Nitrogen (%)	Carbon (%)	C:N ratio	Phosphorous (%)	Potassium (%)	Calcium %
Chitkul							
Jun 2018	5.84±0.08	2.19±0.09	44.59±0.86	20.39±0.81	0.011±0.0005	0.15±0.01	0.61±0.04
Sep 2018	5.35±0.11	2.30±0.04	44.80±0.50	19.52±0.55	0.012±0.001	0.15±0.003	0.64±0.002

Mooling							
Jun 2018	5.83±0.09	1.77±0.02	39.99±0.39	22.67±0.44	0.011±0.0005	0.30±0.15	1.06±0.21
Sep 2018	5.19±0.09	2.01±0.05	39.63±1.59	19.80±0.97	0.014±0.002	0.25±0.02	0.81±0.12
Khanjar							
Jun 2018	5.69±0.28	1.93±0.04	44.42±0.75	22.97±0.85	0.011±0.0004	0.26±0.04	0.63±0.02
Sep 2018	5.36±0.28	2.08±0.03	44.37±0.69	21.29±0.23	0.012±0.001	0.20±0.05	0.68±0.02

Table 16 Physiochemical analysis of leaf Litter samples

(V) Mapping of snowline for the studied LTER sites

Under the proposed collaborative project on timberline, there are four research sites viz. Chitkul (Kinnaur), Triloknath, Khanjar and Muling (Lahaul & Spiti District of Himachal Pradesh) on which Long Term Ecological Research (LTER) is being carried out. These sites are set at an altitude ranging from 3500 to 4000m above mean sea level.

The snowline of the above mentioned LTER sites is delineated by AWiFS satellite imageries from year 2005 to 2015. The available data for 2015 is organized in a tabulate form in which year, month, snow cover area, lowest altitude of snowline and monthly average snow cover are enlisted as mentioned below: -
For the Chitkul watershed, for 2011, there were two satellite imageries viz. 23 and 28 December showing almost same snow cover with an average of 10.3 Km^2. For 2012, there were 10 satellite imageries from 3 January to 25 December. On 3 January there was full snow cover (21.96 Km^2) which was greatly reduced to an area of 4.71 Km^2 on 31 January. Further variations of snow cover in 2012 were shown in the table where 1 December observed complete snow cover in the Khanjar watershed. In year 2013, only two satellite imageries were available showed complete snow cover i.e. 21.96 Km^2 but in 2014 snow cover increased from 5.04 to 15.68 Km^2 (1 October to 30 October). There were five satellite imageries for year 2015 showed complete snow cover i.e. 21.96 Km^2 for Khanjar.

For the Mulling watershed, for year 2011, only two satellite imageries were available showed decreasing trend in the snow cover i.e. from 21.45 Km^2 to 18.66 Km^2 for an altitude of 3180 to 3960 amsl respectively. In year 2012, thirteen satellite imageries were available which showed complete snow cover i.e. 39.26 Km^2 from 8 January to 29 February. Snowline data from 4 October to 25 December showed a marginal change in snow cover as shown in Table 3. In year 2013, complete snow cover observed for two satellite imageries and in 2014, snow cover receded from 11.65 to 17.46 Km^2 from an altitude of 4290 to 3660 amsl. However in 2015, all the satellite imageries of Muling LTER site showed complete snow cover except 24 May which is 29.69 Km^2 only.

The data available for Triloknath LTER site is from 12 September 2012 to 4 October 2015, seventeen satellite imageries were available. For year 2013 the maximum snow cover recorded for 24 April was 42.51 Km^2 while other satellite imageries receives less snow. In year 2014, six satellite imageries were available, where 4 April receives the maximum snowfall with total area of 41.61 Km^2 and touches the lower reaches (2850m) of Triloknath and the trend gradually decreases till 4 October but on 2 November slight increase (12.61 Km^2) was observed. There were five satellite imageries for 2015, on 6 June maximum snow cover was at lowest altitude of 3540 meter. The average snows cover for September 15.22 Km^2 and for October was 18.62 Km^2.

(VI) Awareness programme and interaction with stakeholders for understanding the future of their landscape

Under this objective, the awareness strategies and plan of action has also been prepared which focused on developing the adaptation strategies against the climate change and environmental fluctuations so that the local stakeholders of the state get prepared for future. For the awareness programmes, brochures/pamphlets were also prepared in which the introduction of project, objectives, project outcomes and benefits to the local stakeholders were also mentioned. The brochure is prepared in a way that localities can easily understand the language and information covered.

List of Field surveys:-

S. No.	Field Survey (Date)	Location Sites
1.	24/05/18 to 02/06/18	a) Sural, Pangi, District Chamba b) Mooling, Teh. Lahaul District Lahaul & Spiti c) Khanjar, Teh.Udaipur, District Lahaul & Spiti
2.	15/06/18 to 18/06/18	Chitkul, Kinnaur
3.	22/06/18 to 02/07/18	a) Junda, Teh. Lahaul District Lahaul & Spiti b) Stingri, Teh. Lahaul District Lahaul & Spiti
4.	19/07/18 to 22/07/18	Chitkul, Kinnaur
5.	13/08/18 to 23/08/18	a) Khanjar, Lahaul & Spiti b) Mulling, Lahaul & Spiti
6.	29/08/18 to 03/09/18	Khanjar, Lahaul&Spiti Trilokinath, Lahaul&Spiti
7.	07/09/18 to 10/09/18	Chitkul, Kinnaur
8.	29/08/18 to 03/09/18	Khanjar and Triloknath (L&S)
9.	07/09/18 to 10/09//18	Chitkul (Kinnaur)
10.	06/10/18 to 16/10/18	Sural (Pangi), Mooling and Khanjar (L&S)
11.	25/10/18 to 01/09/18	Sural (Pangi)
12.	12/09/18 to 15/09/18	Chitkul (Kinnaur)
13.	04/12/18 to 06/12/18	CeHAB-Ribling (L&S)
14.	27/03/19 to 29/03/19	Barot, Badagram, Rooling and Kothikohad

Table 17 List of Field Surveys organized in Year 2019-20

2. Status of "Temporal change in Tree species composition in Temperate Forests of Himachal Pradesh"

The temporal study was designed to get a preliminary insight in to the current status of tree species in the selected forest divisions of Himachal Pradesh. To achieve the objective, tree communities were constituted (pure and mixed communities) and density (Ind/ha) were calculated for each dominant tree species. The total area under the selected forests was 57447.45 ha which was used as a sample area in the study. The temperate forests fallen under seven districts (Shimla, Kullu, Mandi, Kinnaur, Solan, Kangra and Chamba) covered most of the temperate area of the State. Status of each species (dominant tree species) was not only seen in one or two forests but throughout the selected forests of Himachal Pradesh which cover all aspects, elevation ranges and tree species important to the temperate region. Observed change in species density was not uniform in the selected forests because most of the forests have different year of enumerations. However, the data as per availability with comparable enumeration records revealed the following results:

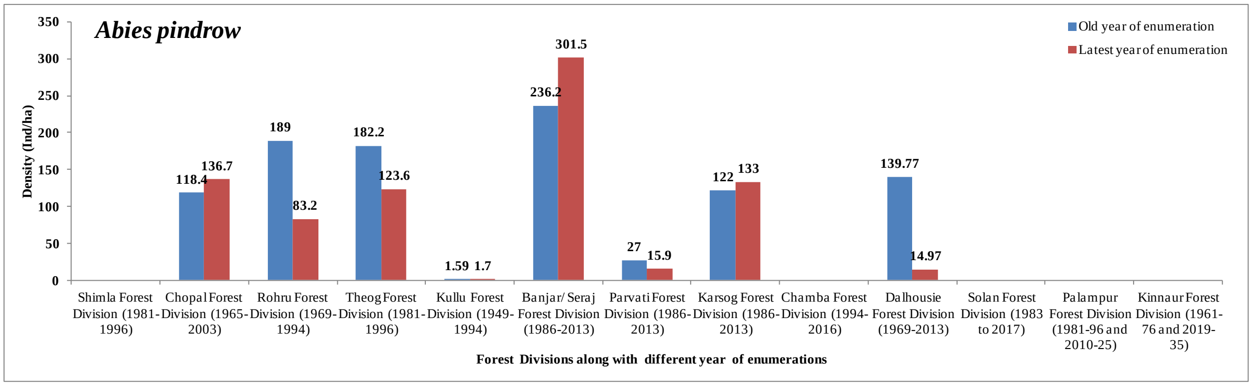


Figure 53 Status of *Abies pindrow* (Fir/Tosh) in the temperate forests of Himachal Pradesh and change in density along two different years of enumerations

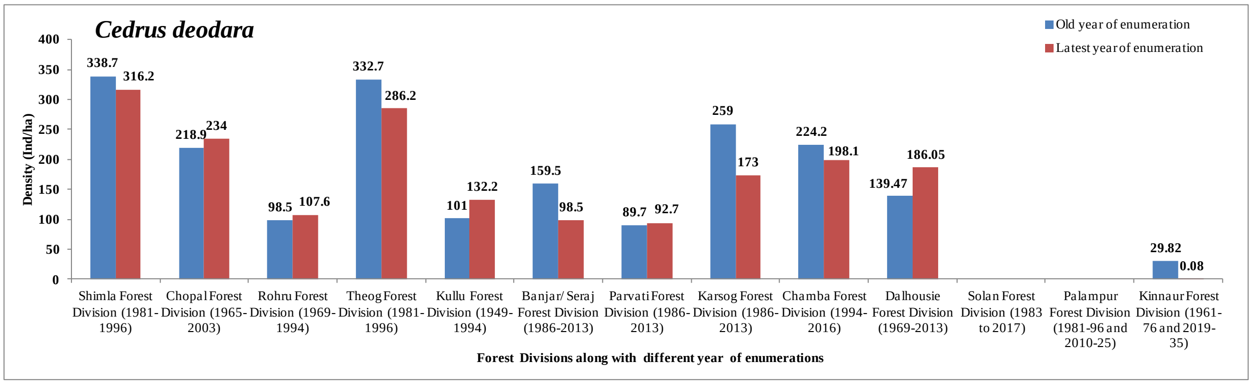


Figure 54 Status of *Cedrus deodara* (Deodar/Devdar) in the temperate forests of Himachal Pradesh and change in density along two different years of enumerations

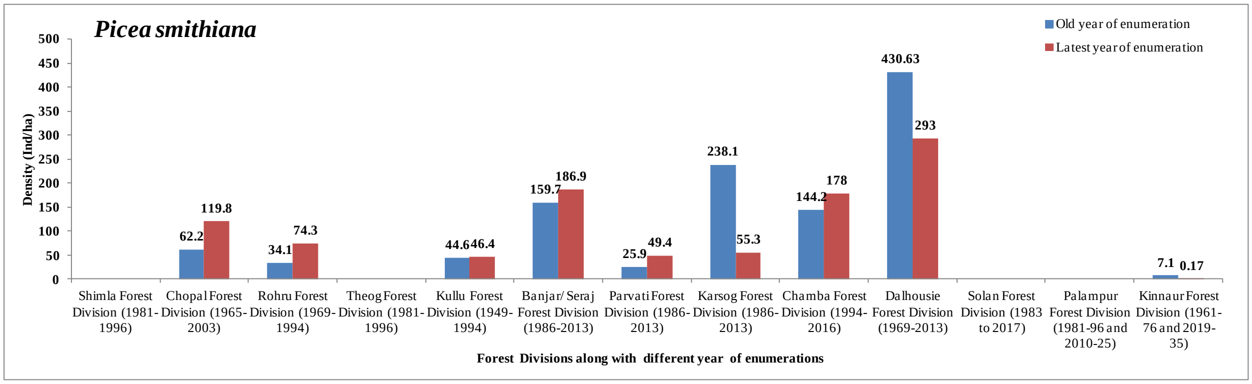


Figure 55 Status of *Picea smithiana* (Spruce/Rai) in the temperate forests of Himachal Pradesh and change in density along two different years of enumerations

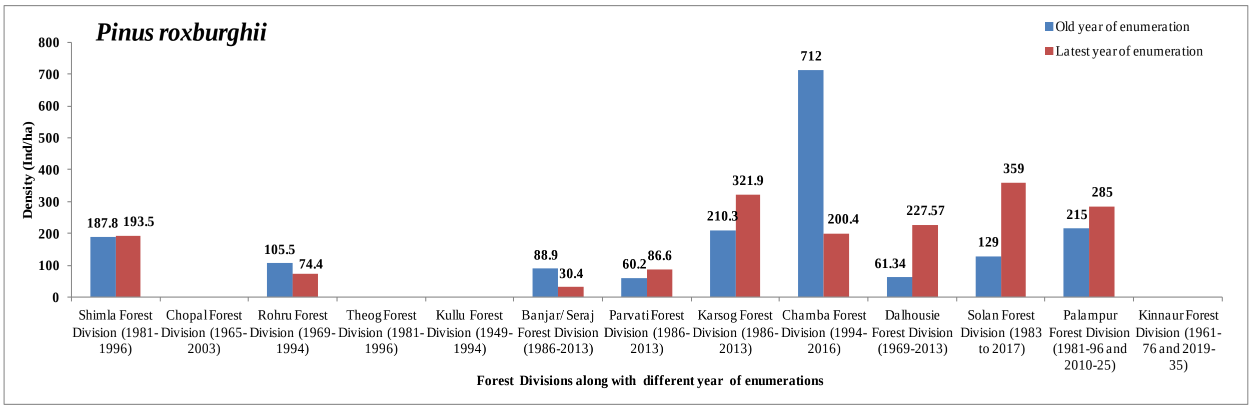


Figure 56 Status of *Pinus roxburghii* (Chir/Chirpine) in the temperate forests of Himachal Pradesh and change in density along two different years of enumerations

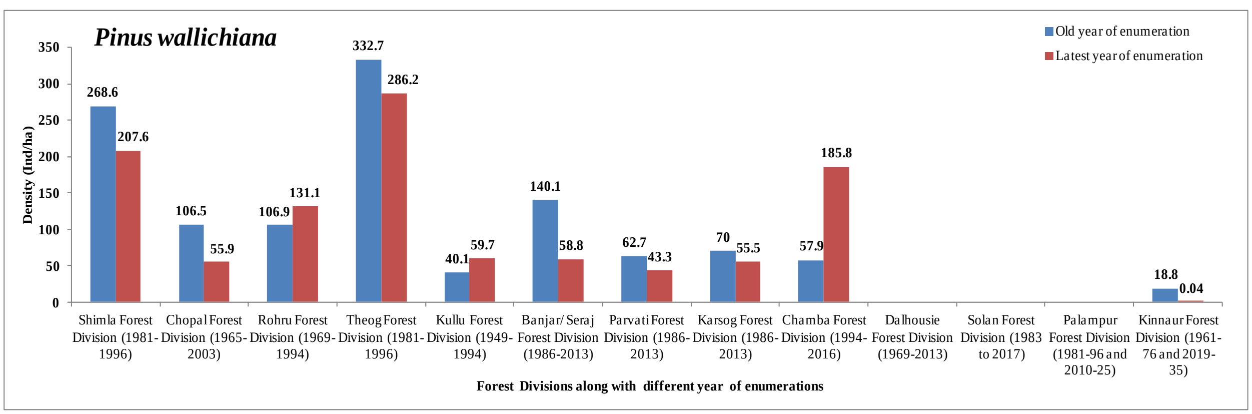


Figure 57 Status of *Pinus wallichiana* (Blue pine/Kail) in the temperate forests of Himachal Pradesh and change in density along two different years of enumerations

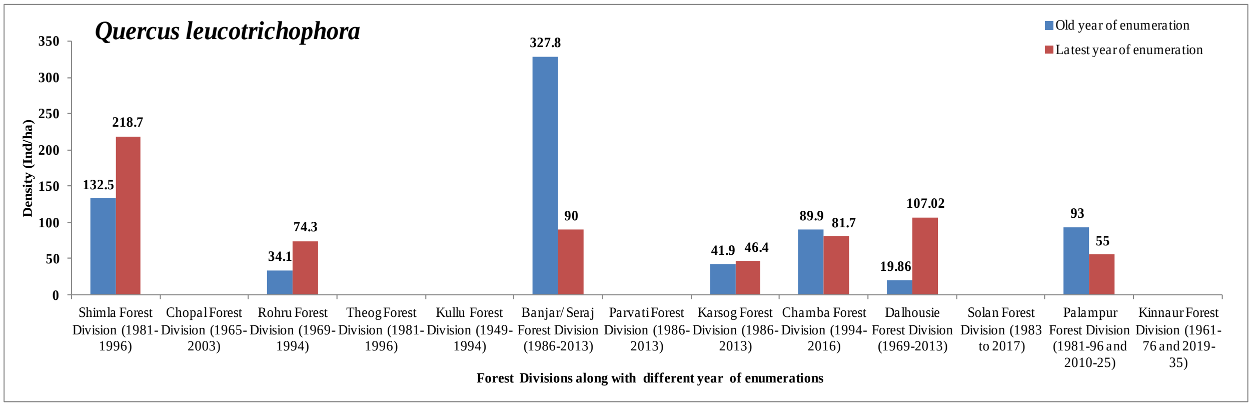


Figure 58 Status of *Quercus leucotrichophora* (Oak/Ban) in the temperate forests of Himachal Pradesh and change in density along two different years of enumerations

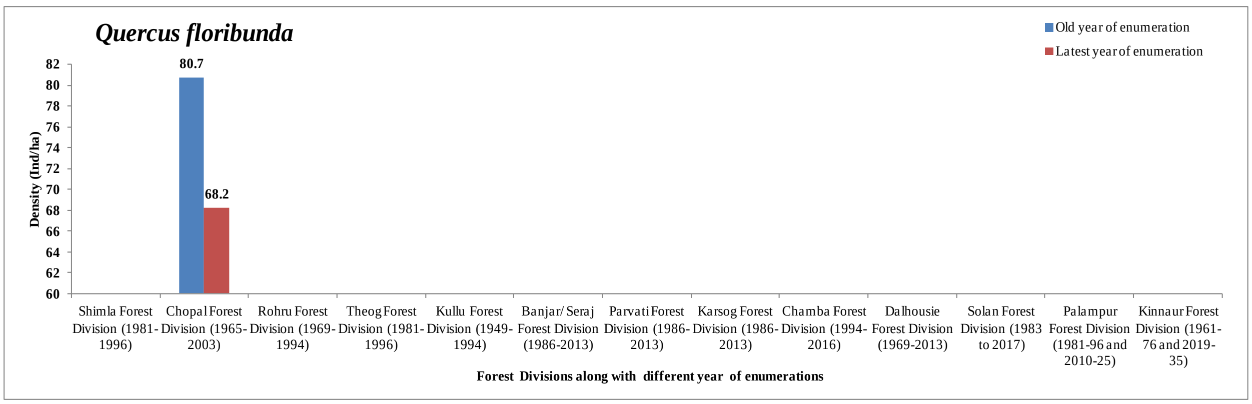


Figure 59 Status of *Quercus floribunda* (Green Oak/Mohru) in the temperate forests of Himachal Pradesh and change in density along two different years of enumerations

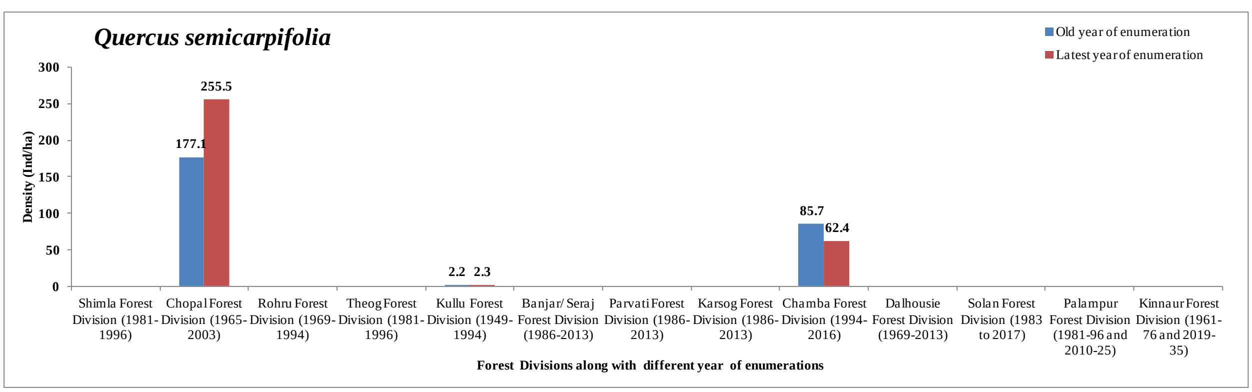


Figure 60 Status of *Quercus semicarpifolia* (Brown Oak/Kharshu) in the temperate forests of Himachal Pradesh and change in density along two different years of enumerations

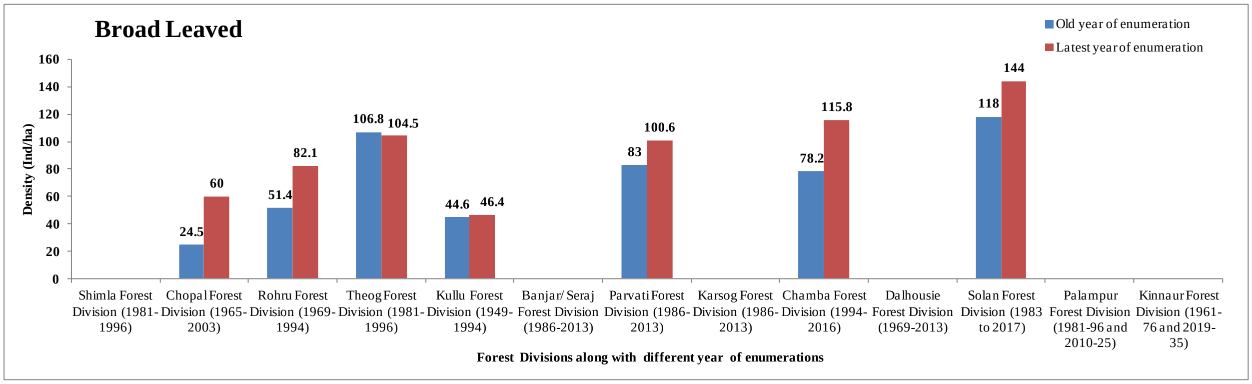


Figure 61 Status of Broad Leaved (All broad leaved species) in the temperate forests of Himachal Pradesh and change in density along two different years of enumerations

Finding revealed that *Abies pindrow* maintained good population in Chopal, Kullu, Banjar and Karsog Forest Division while this species showed decreased in trends in Rohru, Theog, Parvati and Dalhousie Forest Division. Studied showed that this species showed less regeneration rate in the forests if this species decreases by certain reasons it will take very long time to achieve tree height. *Cedrus deodara* one of the important temperate conifer species having good density in the forests, however, the decrease might be due to its great demand for timber. As this species have durable wood and generally recommended for the timber purpose in State. Plantation measure has also being done be different organizations, forest department and NGO's. Enumeration records of *Picea smithiana* showed that population density was increased in all selected forests except Karsog, Dalhousie and Kinnaur (due to localized anthropogenic activates). One observed reason during the report compilation for its increase is that compartment with *Abies pindrow* is far from people community or villages.

For *Pinus wallichiana*, the tree density was greatly reduced in all the selected forests except three forests *viz*., Rohru, Kullu and Chamba. As *Pinus wallichiana* is the second most alternative for timber wood and fuel wood after *Cedrus deodara* in Himachal Pradesh, that's why it is more used by the local stakeholders. Therefore, people dependency on this species may be one of the possible reasons for its decrease. The other reason behind the deceased population of A*bies pindrow*, *Cedrus deodara*, *Picea smithiana* and *Pinus wallichiana* is the moisture regime. The place where these species were present had good moisture regime and fertile soil therefore, the local stakeholders or people tried to encroaches these places for apple orchards and agriculture practices.

Beside these species, *Pinus roxburghii* is an important, fire hardy and temperature resistant tree species of Himachal Pradesh. Most of the people community or villages depend on this species for fuel, timber and resins. The density of this species decreases but due to its great regeneration power and acclimatizing (with changing environment) it still maintain good density in the forests. However, there is more need to find out the possible reason for above stated temperate species so that we can improve the management practices and conservation methods.

Along conifers, oak also serves as important broad leaved species in the temperate forest. There were three oak species documented as per the enumeration records available are: *Quercus leucotrichophora, Quercus floribunda* and *Quercus semicarpifolia*. Only few compartments were there which forms pure oak community but in most of cases these species found in mixed form (with conifers). These species are over utilized by the local people/community for fuel, fodder and timber. Species other then broad leaved showed a great and visible increase in density in all selected forests of Himachal Pradesh which showed good results. In conclusion, this report provides:

- ✓ Temperate tree species composition (conifers and broad leaved) of temperate forests
- ✓ General status of species dominance, community structure (pure and mixed) and density variations
- ✓ Provides baseline finding which can help to improve the management and conservation strategies in future.
- ✓ Also open scope and inputs of further research in forestry sector like, species wise studies throughout the temperate forests of Himachal Pradesh with ground proofing and the possible reason for their increase or decrease.

WORKSHOPS/MEETINGS ORGANIZED

Regional Workshop on "Challenges of Disaster Risk Reduction in Hill Towns of North-Western Himalayas"

In order to address the issues arising out of the hazards of various forms, whether natural or manmade from the Himalayan perspective, and the challenges for the disaster risk reduction in hill towns being faced by the mountain states of Himachal Pradesh, Uttrakhand, and the Union Territory of Jammu & Kashmir and Ladakh, a two days regional workshop was organized at Hotel Holiday Home (HHH) Shimla on 22 -23 October 2019 jointly by Himachal Pradesh State Disaster Management Authority (HPSDMA) and Himachal Pradesh Council for Science, Technology & Environment (HIMCOSTE) in collaboration with National Disaster Management Authority (NDMA) Ministry of Home Affairs, Govt. of India. This workshop was organized as part of the initiatives of the National Disaster Management Authority (NDMA), wherein they have proposed to organize workshops separately for the Northeastern and Northwestern Himalayan States of the country to address the challenges in disaster risk reduction in the hill towns and to come up with specific recommendations and solution to deal with such challenges.

The workshop was attended by the 150 practitioners, administrators, researchers, technocrats and policy makers from the northwestern Himalayans States and 60 staff from HIMCOSTE & HPSDMA. The discussions and deliberations were mainly focused within the domain of the following technical sessions and themes:

- Hazard Vulnerability & Risk Assessment
- Improving compliance with Building Bye-laws in Hill Towns
- Disaster Mitigation and Preparedness
- Improving Disaster Response and Recovery

Sh. Jai Ram Thakur, Hon'ble Chief Minister Himachal Pradesh was the Chief Guest on this occasion and inaugurated the two days workshop at Hotel Holiday Home on 22 October 2019. Smt. Sarveen Chaudhary, Hon'ble Minister (UD& Housing) was the Guest of Honour on this occasion and delivered the Special Address. Sh. Kamal Kishore, Hon'ble Member, NDMA was the Special Guest on this occasion and delivered the Keynote Address. Besides this, Smt. Kusum Sadrate, Mayor MC-Shimla Dr. Shrikant Baldi, Worthy Chief Secretary, Govt. of H.P., Prof. Ravi Sinha, IIT Bombay also participated in the inaugural session as the Special Guest and delivered their Special Addresses.

The book on the Guidelines with reference to the "School Safety Scheme" of the Govt. of Himachal Pradesh which have been prepared by the State Disaster Minister Authority (SDMA), Himachal Pradesh was launched by Hon'ble Chief Minister Himachal Pradesh, also launched two user friendly animated video clips, one having various Do's and Don'ts during and after the earthquake and the other on safe construction practices being adopted for the non engineering constructions for rural areas. These video clips would help in educating our rural masses and to know more about the earthquakes and their impacts on the society.

In two days regional workshop, four technical sessions were organized, which lead to deliberations and discussions on various issues, discussed by panelist along with stakeholders departments.

After discussions following recommendations were:

1. **Planning and Preparedness**

- There is an urgent need to have a risk sensitive land-use planning for all urban areas in the hill states. The Hazard Risk and Vulnerability Assessment (HRVA) study conducted by the State should be used to prepare risk sensitive land-use planning. The development plans of hill towns should be revised accordingly and these revisions should be carried out on regular basis in future.

- There is also a need to conduct microzonation studies of all hill towns, so that the development is sensitive to high earthquake hazard of the regions.
- There is need to carry out Hazard Risk Vulnerability Assessment (HRVA) vis-à-vis different hazards in the Himalayan region on regular basis so that new findings and studies and recent disasters are taken into consideration while carrying out hazards vulnerability assessment.
- The fire services should be strengthened as Multi Hazards Response Force in order to improve community preparedness.
- Special focus needs to be laid in training community members in Search and Rescue (SAR) and Medical First Response (MFR).
- The network of Emergency Operation Centers (EOCs) needs strengthening. The EOCs should be equipped with latest state of the art incident management system and communication tools.
- The Himalayan States should setup Mitigation Funds as have been as mandated in the DM Act, 2005 so that mitigation activities can be carried out to reduce potential losses.
- Use of remote sensing technology should be used more and more for disasters planning and response.
- The vulnerable locations and roads which are frequently hit by snow avalanches need to be identified and SASE may be requested to provide engineering designs for those locations so that mitigation measures can be undertaken.
- The hill-towns provide huge service to the country, as they act as carbon sinks and reservoir of forest. Opportunities need to be sought to link climate change adaptation, mitigation and disaster management.
- Adopt legally the National Disaster Management Guidelines for Seismic Retrofitting of Deficient Buildings and Structures released by NDMA, Government of India, in June 2014.
- Develop Undertake the preliminary (Level 3) seismic safety assessment of select structures.
- Perform detailed (Level 4) earthquake safety assessment to determine the preferred structures.
- Identify the retrofit scheme for each preferred structure.
- Provide funding for retrofitting, Undertake seismic retrofit of preferred structures.

- **Techno-Legal Regime**

- The construction in hill towns and all commercial construction in rural areas of hill states should adhere to National Building Codes (NBC). The states should devise Model Building Codes to be adopted by all the Urban Local Bodies (ULBs), and to be enforced for all commercial constructions in the rural area. These building bye-laws need to be revised on regular interval, as and when National Building Codes (NBC) are amended.
- There is also need to build the capacities of Town and Country Planning (TCP) Department and ULBs along-with Panchayati Raj Institutions (PRIs), so that they are effectively able to enforce these building bye-laws.
- Capacity building of private practitioners in this field is of utmost importance and regular training programme for them needs to be devised.
- All the agencies involved in granting planning permissions and construction permits should be automated, so that there is minimum delay in granting permission. This will foster positive attitude of people towards these agencies.
- There is also a need to carry out IEC activities, as to why the implementation of building bye-laws and TCP regulations is important for safety of the house owners and local residents.
- Place bye-laws on the website and make people aware of their legal standing;
- Prepare list of technical documents that are required to be submitted by the owners, when seeking approval for:
    - Constructing new structures, and
    - Modifying existing structures.
    - Place these documents on the website and make structural designers and potential owners aware of the same.
- Equip municipal offices with engineers currently employed in the different Departments of the Government of Himachal Pradesh, who have structural design background, are familiar with the bye-laws and have interest in structural design. They shall undertake Peer Review of Structural Designs of documents submitted by owners for approval.
- Develop a method for examining Structural Design the compliance to the relevant provisions of bye-laws and applicable national standards. Place this document on the website and make structural designers and potential owners aware of the process.
- Recruit young Civil Engineers (even on temporary basis) (with B.Tech. degree in civil engineering and M.Tech. Degree in structural engineering) who has good academic record and integrity. They

shall assist the senior engineers posted in the municipal offices for the express purpose of Peer Review of Structural Designs.

- Launch Peer Review of the Structural Designs submitted by owners for approval.
- Revise Bye-Laws to outlaw unsafe constructions and mandate essential requirements for incorporating minimum safety in the built environment.

- **Vulnerability Reduction**

- In order to reduce seismic vulnerability, retrofitting of hospital infrastructure and lifeline buildings should be carried out on priority for which adequate funds need to be provided.
- The States in the Himalayan region may be encouraged to seek external financial and technical assistance to reduce vulnerability to various hazards.
- Early Warning Systems
- In addition to working for early warning systems of different agencies, there is need to create earthquake early warning system in the State.

- Central government agencies have been mandated by the Govt. of India to create and issue early warning vis-à-vis this area. But except for IMD and SASE no other agencies such as Centre Water Commission (CWC), Geological Survey of India (GSI) have been issuing any alert despite clear mandate to do so. These institutions may be requested to share warnings and alerts on a regular basis.
- The SASE may be requested to share avalanche warning on 5X5 square meter grid with the States. The SASE may also be requested to share hazards zonation maps/atlas of avalanche at least for those areas which are unrestricted

- **IEC**
  - Regular IEC campaigns should be carried out through electronic/social media and other means so that general public is educated about Dos and Don'ts of various hazards.
  - Special focus may be placed to sensitize policy makers such as Ministers, MLAs, other public representatives and Bureaucrats.

- **Integration of Science, Research and Practice**

- There should be a regular dialogue and exchange of knowledge between scientists, researchers and practitioners so that preparedness, mitigation and response are based on current science.
- Since Himalayan region is highly prone to earthquakes, mapping of active faults needs to be carried out regularly
- There is need to strengthen the density of monitoring network for various hazards. Existing network of IMD for capturing precipitations, seismic activity is highly inadequate and needs strengthening. Similarly, landslide which is one of the main hazards of the Himalayas also needs to be monitored utilizing existing knowledge.
- The National Institute of Hydrology (NIH) has conducted dam failure scenario for Himalaya Region. The NIH may be requested to share this scenario with the concerned SDMA and DDMAs. The river basins which have been left out should also be covered by the NIH.
- There is need to standardize and combine all the landslides maps prepared by different agencies such as GSI, Wadia Institute of Himalayan Geology, GB Pant Institute of Himalayan Studies, Kullu and IITs in order to develop a consolidated and unified atlas.

- **Recommendations to Government of India/NDMA Response**

- Keeping in view, the hazard profile of Himalayan States, specific centrally sponsored schemes to address seismic, landslide, flashfloods and GLOF hazards needs to be launched on the pattern of National Cyclone Risk Mitigation Project, being implementing for the coastal states.
- National mitigation fund should be created as provided in the DM Act, (2005) so that states are encouraged to create their own State Mitigation Fund.
- Conveying early warning to the last mile is the biggest challenge. The NDMA/MHA may be requested to create a system such as Common Alert Protocol at National scale so that early warning can be disseminated to the last person in a targeted manner.
- Realistic scenario for earthquake, based on scientific evidence and information should be created so that mitigation activities can be undertaken by all the stakeholders accordingly.

- **Response**

▪ Keeping in view, the issue of connectivity the States needs to raise their State Disaster Response Force (SDRF) on the pattern of NDRF.

▪ In order to ensure timely restoration of roads, electricity and water supply central stores needs to be created at every 50 to 100 sq km so that necessary materials are available for restoration.

▪ In all new hospitals helipads should be constructed on the roof of the building, so that in case of emergency victim can be transported to the health facilities even when road connectivity is totally disrupted.

Figure 62 Glimpse of Regional Workshop

Himachal Pradesh Centre on Climate Change

HP Council for Science, Technology & Environment (HIMCOSTE)

Vigyan Bhawan, Bemloe Shimla-171001

Tel. No: 0177-2656489, Fax: 0177-2814923