State Centre on Climate Change

Annual Progress Report 2020-21

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Results: Monitoring of Glaciers in Chenab Basin

Chenab basin is one of the major river basins which originate from Himachal Himalaya near Baralacha Pass and is on the north of the Pir Panjal Ranges. Two rivers viz. Chandra and Bhaga originates from this place and flows in opposite direction before they confluence each other at a place known as Tandi near Keylong. Besides this, another major sub basin i.e., Miyar Sub basin has been studied in detail for having an updated information on the glaciers of Miyar sub basin in the catchment. Based on the data analysis for 2001 and 2017/2018 using IRS LISS III satellite data, a total of 556 glaciers could be mapped which were clearly visible from the satellite image and occupies a total area of 1301.93 Km^2 in 2001. Sub basin wise classification of 556 glaciers reveals that in Chandra basin, a total of 226 glaciers could be mapped having a total area of 603.26 Km^2 Bhaga basin has 191 glaciers with a total area of 313.56 Km^2 and the Miyar sub basin, wherein a total of 141 glaciers could be mapped having a total area of 385.90 Km^2 Further classification of 556 glaciers based on different areal classes, it is found that the maximum number of glaciers(334) are within the areal range of 0-1 Km^2 wherein the total area occupied is 146.49 Km^2 and 130 glaciers are within the areal range of 1-3 Km^2 having total area of 222.12 Km^2. Besides this, in the category 3-5 Km2 and 5-10Km^2, a total of 37(145.65Km^2) and 34 (226.14Km^2) could be classified. As far as large glaciers are concerned, a total of 15 glaciers could be seen in the category 10-20 Km^2 and only 6 glaciers are within the areal range of >20Km^2 having a total area of 210.38 Km^2 and 351.15Km^2 respectively. Temporal analysis of 556 glaciers with reference to the data obtained from the analysis of LISS III images for 2017/2018 reveals the presence 571 glaciers occupying a total area of 1268.38 Km2 in comparison to 1301.93 Km^2 that was occupied in 2001 Further temporal analysis based on different areal ranges reveals that, total number of glaciers in areal range of 0-1 Km^2 varies from 334(2001) to 358(2018) and the area occupied varies from 146.49 Km^2 (2001) to 152.36Km^2 (2018) indicating an overall increase in the area by 5.87Km^2 within a span of about 17 years

(2001-2018) and the variation is mainly due to melting of large sized glaciers in the upper categories. The analysis further reveals that total 130 glaciers in 2001 has been reduced to 125 (2018) indicating an overall reduction of 2.79Km^2 within this category of glaciers. Besides this, the glaciers within the areal range of 3-5 Km^2, the number of glaciers varies from 37(145.65Km^2) to 33(129.84Km^2) reflecting a total reduction of 15.81 Km^2 during 2001 and 2018. The other category of glaciers within the areal range of 5-10 and 10-20 Km^2 indicates a total reduction of 5.66Km^2 and 5.48Km^2 respectively. Likewise, the large sized glaciers with area >20Km^2 also shows a reduction of 9.68 Km^2 between 2001 and 2018. In other words, we can say that Chenab basin based on the temporal analysis between 2001 and 2017/2018, reveals that total area of 556 glaciers has been reduced from 1301.93Km^2 in 2001 to 1268.38Km^2 in 2018 indicating a total vacation of glacier area by about 33.55Km^2 indicating about 2.57% glacier area loss in Chenab basin between 2001 and 2018. Further the 04 glaciers within the areal range 10-20 Km^2 and >20Km^2 shows fragmentation as a result of which the 03 glaciers have been counted into category 0-1 Km^2, 02 glaciers within 1-3 Km^2 and only 1 glacier within the areal range of 3-5 Km^2. Further it is found that maximum reduction is in the case of glaciers within the areal range of 3-5Km^2 (15.81Km^2) and 9.68Km^2 in case of >20Km2 sized glaciers, whereas 8.03 Km^2 area occupied by the glaciers after fragmentation of these large glaciers has been categorized into the lower category. In other words, we can say that the total area vacated per year varies from 0.34 to 0.93 Km^2 per year in small sized glaciers within the areal range of 0-5 Km^2 and 0.33 to 0.56 Km^2 per year in case of large sized glaciers i.e. with area more than 5 Km^2. Further as far as classification of clean and debris covered glaciers in Chenab basin are concerned, a total of 438 clean glaciers and 118 debris covered glaciers could be seen in 2001. Temporally these clean glaciers when seen with 2018 data, it is observed that these glaciers show a total loss of 19.18Km^2 i.e., area from 546.08Km^2 (2001) to 526.90Km^2 (2018), whereas the debris covered glaciers shows a loss of 14.92 Km^2 during 2001 and 2018

Table 1 Number of Glacier in different aerial ranges and aerial extent in Chenab Basin

Glacier Area (sq km)	No. Of glaciers in 2001	Area in (Sq. Km.)	No. Of glaciers in 2017	Area in (Sq. Km.)	Gain/Loss in Area	%Age gain/loss
0-1	334	146.49	358	152.36	**(+)5.87**	**(+)4.00**

1-3	130	222.12	125	219.33	**(-)2.79**	**(-)1.25**
3-5	37	145.65	33	129.84	**(-)15.81**	**(-)10.85**
5-10	34	226.14	34	220.48	**(-)5.66**	**(-)2.50**
10-20	15	210.38	15	204.90	**(-)5.48**	**(-)2.60**
>20	6	351.15	6	341.47	**(-)9.68**	**(-)2.75**
Total	556	**1301.93**	571	**1268.38**	**(-)33.55**	**(-)2.57**

Table 2 Area gain or loss by clean glaciers

Name of the sub basin	**No. Of clean glaciers in 2001**	**Area in (Sq.Km.)**	**No. Of debris covered glaciers in 2018**	**Area in (Sq.Km.)**	**Gain/Loss in Area**	**%Age gain/loss**
Chenab	**438**	**546.08**	**441**	**526.90**	**(-)19.18**	**(-)3.51**
Chandra	180	221.82	187	216.14	**(-)5.68**	**(-)2.56**
Bhaga	173	187.05	178	179.98	**(-)7.07**	**(-)3.77**
Miyar	85	137.21	85	130.78	**(-)6.43**	**(-)4.68**

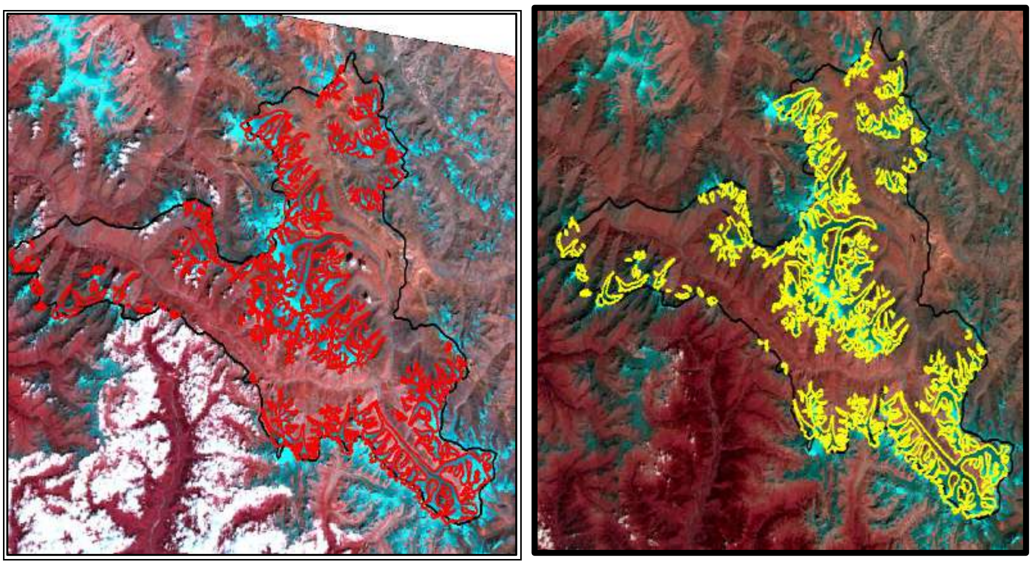
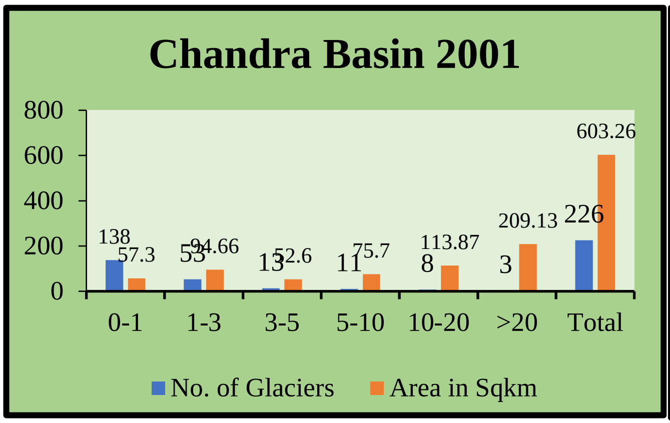
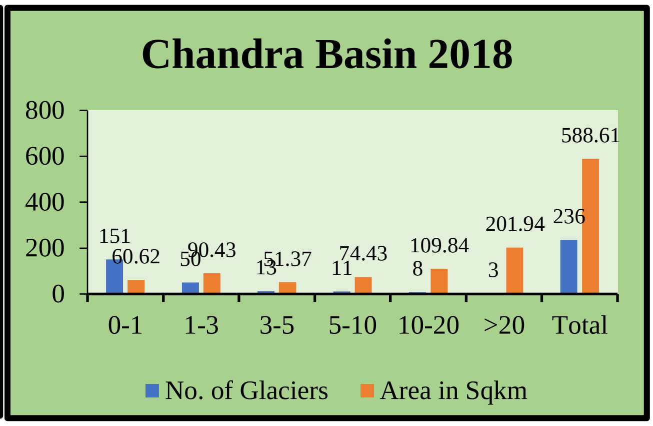


Figure 1 Glacier Layer in Chandra sub basin (2001) & Glacier Layer in Chandra sub basin (2018)





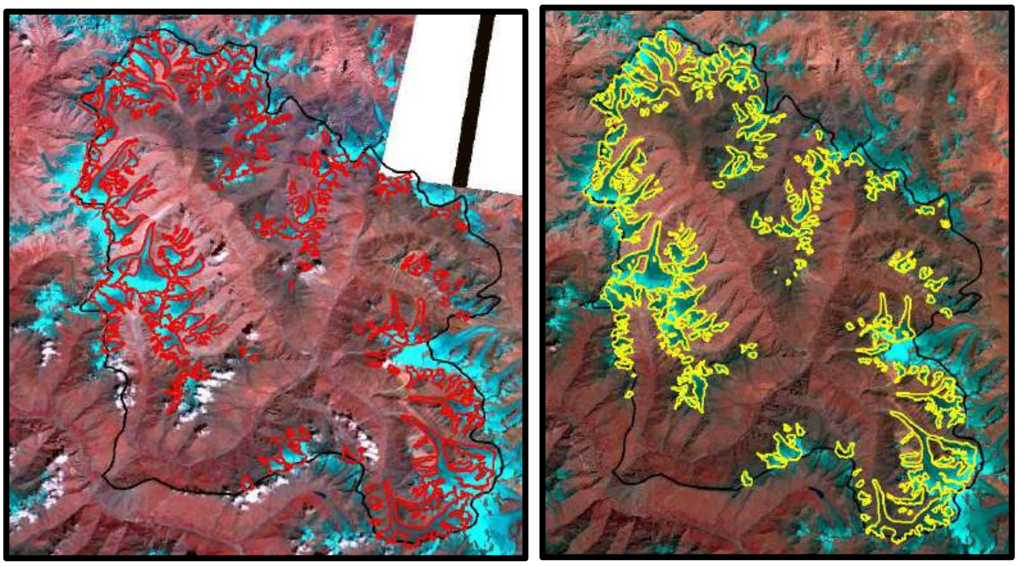
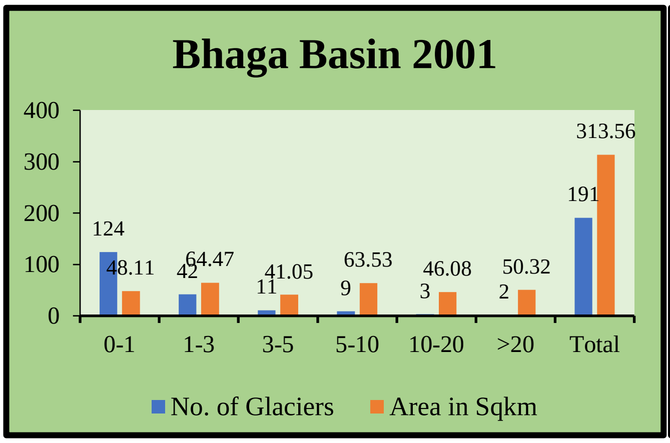
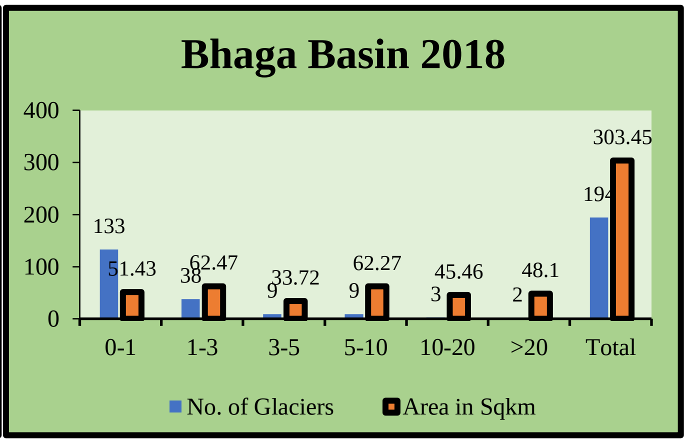


Figure 2 Glacier Layer in Bhaga sub basin (2001) & Glacier Layer in Bhaga sub basin (2018)





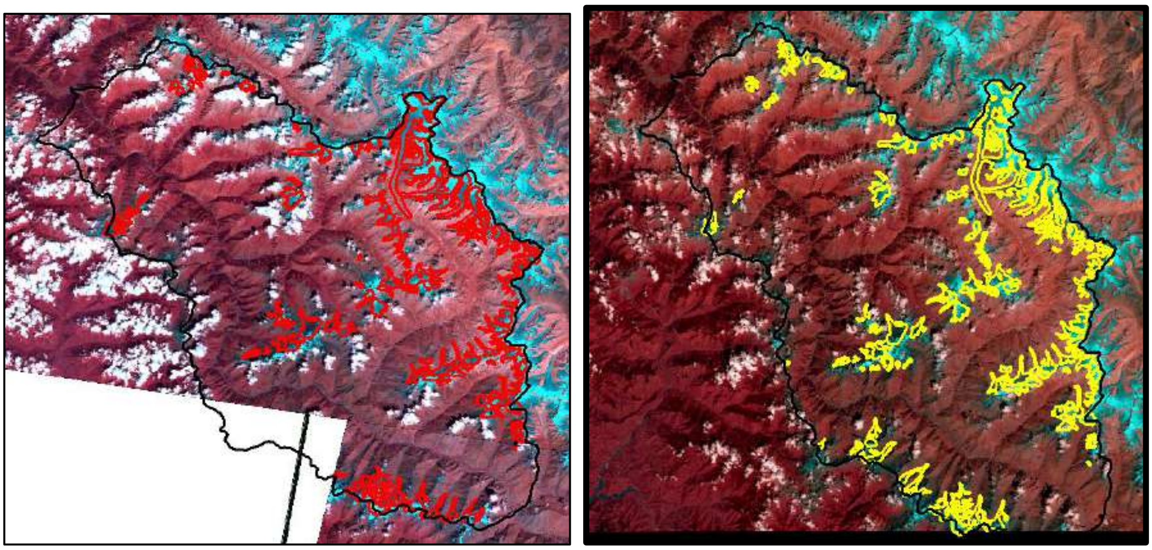
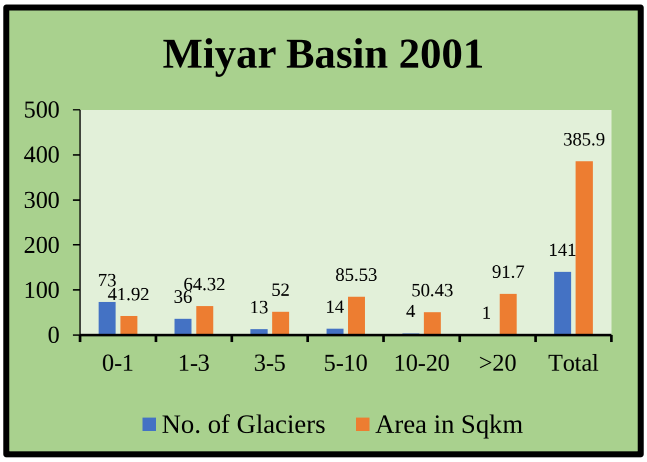
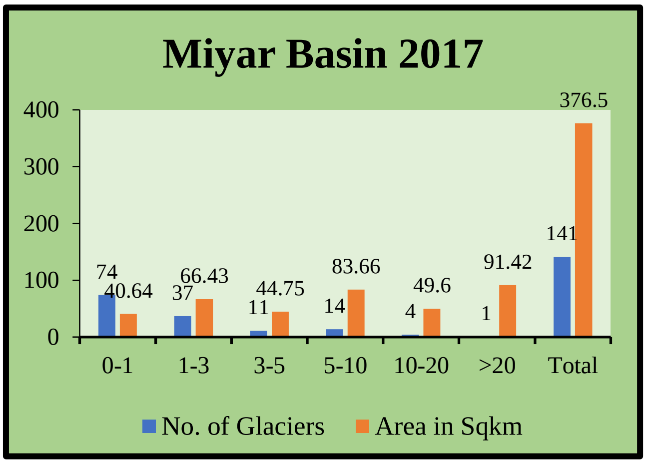


Figure 3 Glacier Layer in Miyar sub basin (2001) & Glacier Layer in Miyar sub basin (2018)





MONITORING OF GLACIERS IN BEAS BASIN

The Beas basin which comprises of three major sub basins as Upper Beas, Jiwa and Parvati has been studied using IRS LISS III satellite data for 2001 and 2016/2018 respectively. The Upper Beas and Jiwa sub basins have been studied using 2001 and 2016 satellite data whereas Parvati sub basin has been studied using 2001 and 2018 because of the non-availability of good quality satellite images. From the satellite images, a total of 215 glaciers could be delineated and were common in both the interpreting years comprising 38, 50 and 127 glaciers in Upper Beas, Jiwa and Parvati sub basins respectively. Further when these 215 were seen temporally, it is found that the total area occupied by 215 glaciers in 2001 has been reduced from 462.74 Km^2 to 446.98 Km^2 in 2016/2018 respectively indicating total loss of about 15.76 Km^2 or we can say that about 3.40% of the total area has been vacated in Beas basin during this period. The temporal analysis in different areal ranges further reveals that the maximum area loss could be seen in case of the glaciers within the areal range 5-10 Km^2 wherein about 7.13Km^2 area has been lost between 2001 and 2016/2018 reflecting a reduction of about 10% in the basin. Likewise, the glaciers within the areal range 1-3Km^2 and 3-5 Km^2 shows a reduction of 2.77Km^2 and 2.55 Km^2 during this period in the entire Beas basin. The small sized glaciers within the areal range of 0-1Km^2, the number varies from 124 (52.70Km^2) in 2001 to 128 (51.47Km^2) in 2016/2018. Likewise, the large glaciers with area between 10-20 Km^2 and more than 20Km^2, does show area loss of 1.33Km^2 (10-20Km^2) and 0.75Km^2 (>20Km^2) category glaciers. In other words, it is inferred that the moderate size glaciers with area 5-10Km^2 in Beas Basin have shown more area loss higher rate of area loss (7.13Km^2) than the small and large sized glaciers. The classification of the glaciers into clean and debris covered reflects that a total of 179 could be seen as clean glaciers indicating a loss of 11.24 Km^2 and 36 glaciers are debris covered indicating a loss of 4.52Km^2 between 2001 and 2016/2017 respectively.

Table 3 Number of Glacier in different aerial ranges & aerial extent in Beas Basin Basin

Glacier Area (sq km)	No. Of glaciers in 2001	Area in (Sq.Km.)	No. Of glaciers in 2016	Area in (Sq.Km.)	Gain/Loss in Area	%Age gain/loss
0-1	124	52.70	128	51.47	**(-)1.23**	**(-)2.33**
1-3	58	97.24	56	94.47	**(-)2.77**	**(-)2.84**
3-5	13	49.23	12	46.68	**(-)2.55**	**(-)5.17**
5-10	10	70.99	9	63.86	**(-)7.13**	**(-)10.04**
10-20	6	86.11	6	84.78	**(-)1.33**	**(-)1.54**
>20	4	106.47	4	105.72	**(-)0.75**	**(-)0.70**
Total	**215**	**462.74**	**215**	**446.98**	**(-)15.76**	**(-)3.40**

Table 4 Area gain or loss by clean glaciers in Beas Basin

Name of the sub basin	No. of clean glaciers in 2001	Area in (Sq.Km.)	No. of debris covered glaciers in 2018	Area in (Sq.Km.)	Gain/Loss in Area	%Age gain/loss
Beas	**179**	**222.50**	**179**	**211.26**	**(-)11.24**	**(-)5.05**
Up Beas	35	15.42	35	13.61	**(-)1.81**	**(-)11.73**
Jiwa	40	43.53	40	41.66	**(-)1.87**	**(-)4.29**
Parvati	104	163.55	104	155.99	**(-)7.56**	**(-)4.62**

Table 5 Area gain or loss by debris covered glaciers in Beas Basin

Name of the sub basin	No. of clean glaciers in 2001	Area in (Sq.Km.)	No. of debris covered glaciers in 2018	Area in (Sq.Km.)	Gain/Loss in Area	%Age gain/loss
Beas	**36**	**240.25**	**36**	**235.73**	**(-)4.52**	**(-)1.88**
Upp Beas	3	4.58	3	4.46	**(-)0.12**	**(-)2.62**
Jiwa	10	21.30	10	20.79	**(-)0.51**	**(-)2.39**
Parvati	23	214.37	23	210.48	**(-)3.89**	**(-)1.81**

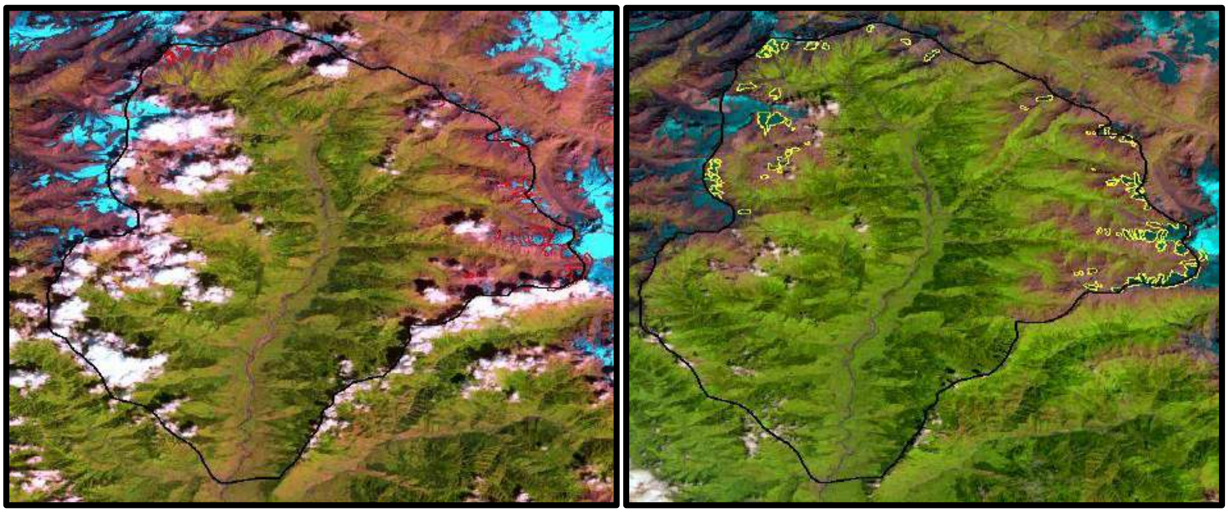
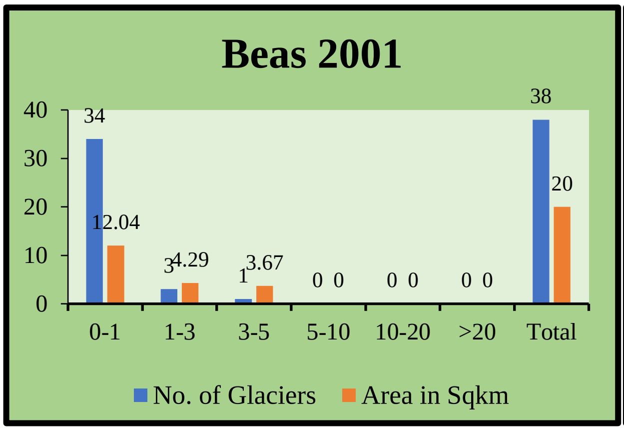
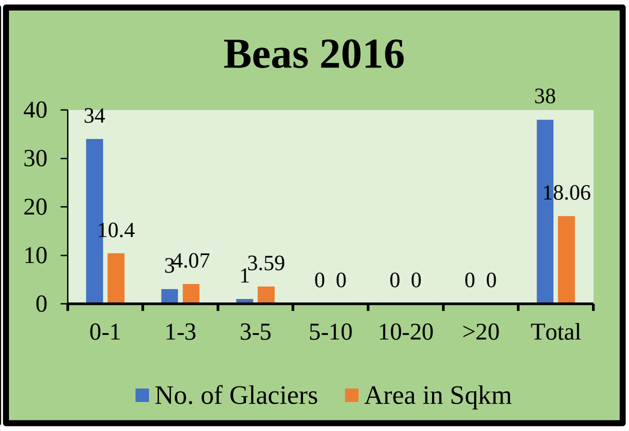


Figure 4 Glacier Layer Upper Beas Basin (2001) & Glacier Layer Upper Beas Basin (2018)





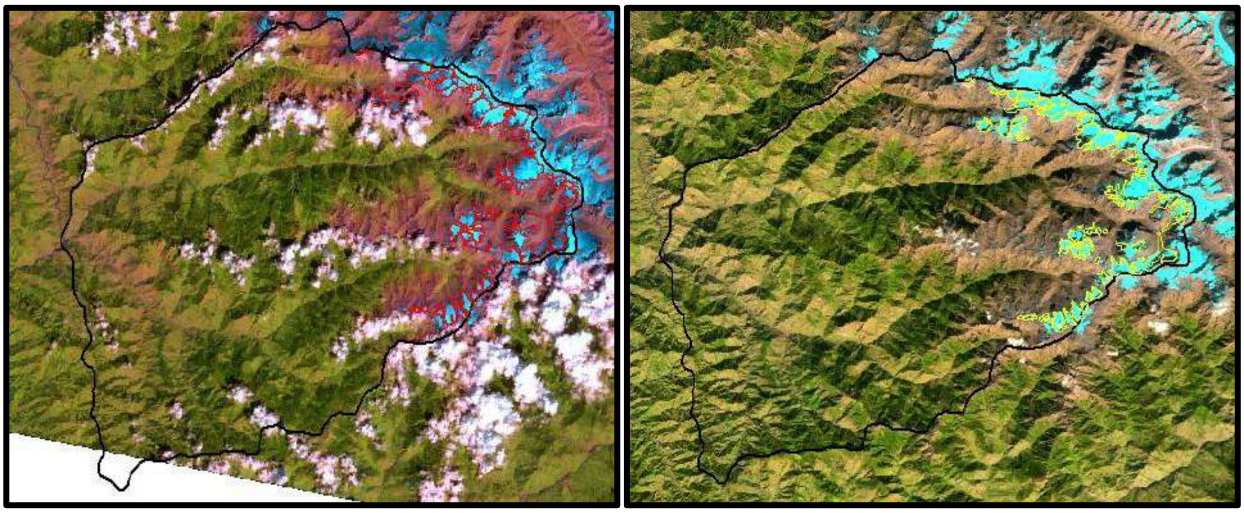
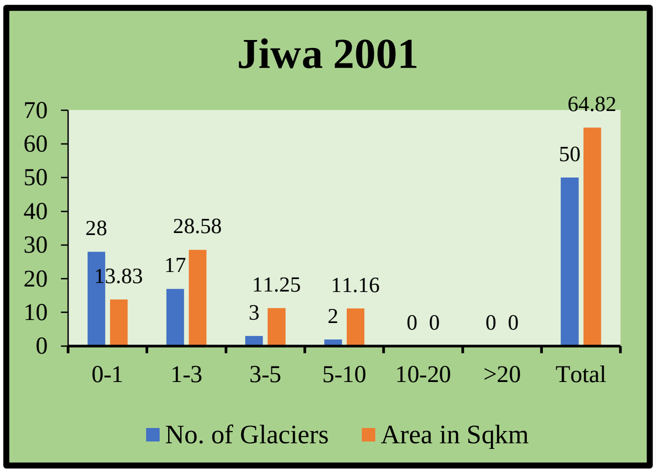
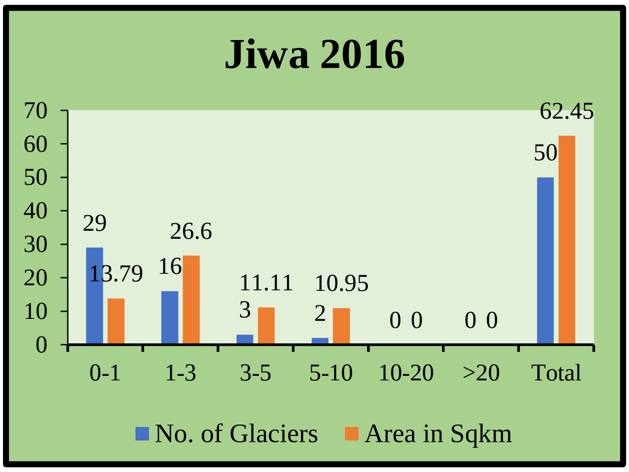


Figure 5 Glacier Layer Jiwa Basin (2001) & Glacier Layer Jiwa Basin (2016)





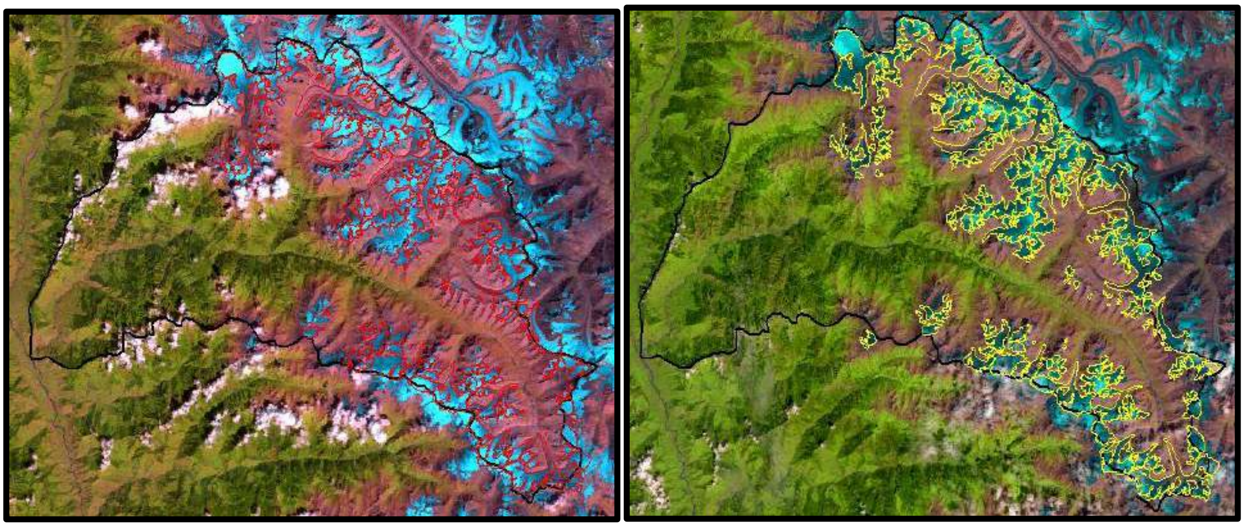
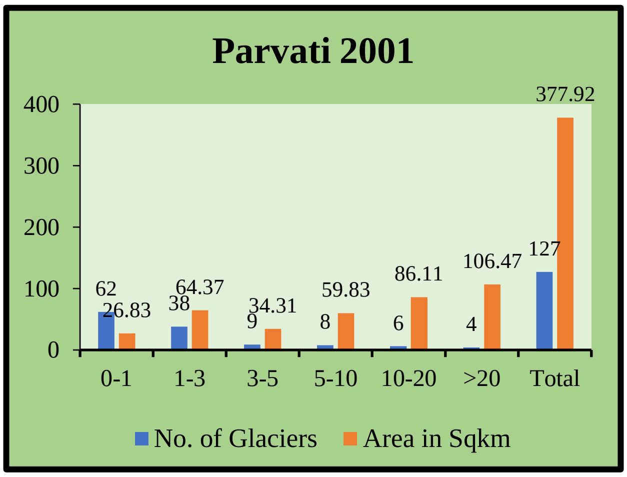
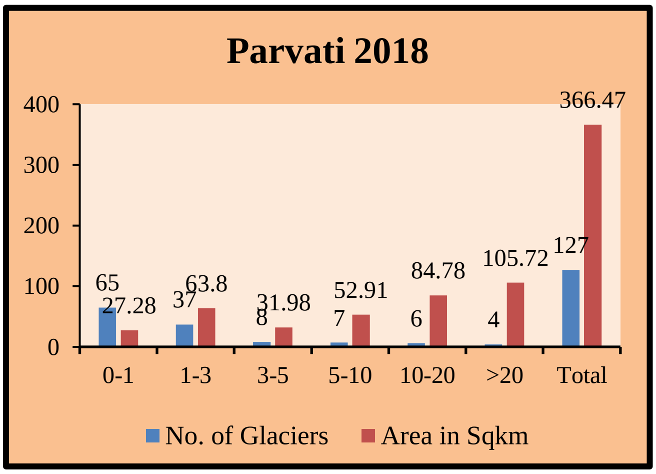


Figure 6 Glacier Layer Parwati Basin (2001) & Glacier Layer Parwati Basin (2018)





MONITORING OF GLACIERS IN RAVI BASIN

The Ravi basin which is on the south of the Pir Panjal Ranges in Himachal Pradesh shows the presence of 126 glaciers which could be delineated from the satellite images of IRS LISS III for 2001 and 2017 respectively. The temporal analysis of the 126 glaciers suggests that a total of 3.57 Km^2 area loss could be seen in between 2001(163.98Km^2) and 2017(160.41Km^2) or we can say that about 2.17% of the glacier area has been reduced in 2017 in comparison to 2001. Further maximum area loss could be seen in case of the glaciers falling within the areal range of 1-3Km^2, where the number varies from 39(70.13Km^2) in 2001 to 38(67.53Km^2) in 2017 reflecting a reduction of 2.60Km^2 area during this period. Likewise, the small sized glaciers falling within the areal range of 0-1 Km^2 shows a reduction of 0.60Km^2 and 0.27Km^2 in case of the glaciers within the areal range of 5-10Km^2. The glaciers within the areal range of 3-5 shows a reduction of 0.09 Km^2 between 2001 and 2017 and the large sized glaciers within the areal range of 10-20 Km^2 shows a total reduction of 0.01 Km^2 wherein only 1 glacier could be mapped within this category. In other words, we can say that in Ravi basin, maximum reduction could be seen in case of small sized glaciers i.e. 0-1 and 1-3 category glaciers, whereas the moderate sized glaciers (5-10) also show a comparatively higher glacier area loss during this period in this basin in comparison to large sized glaciers. The classification of 126 glaciers into clean and debris covered in Ravi basin suggest that 70 glaciers are clean and shows a reduction of 2.17Km^2 between 2001 and 2017 and 56 glaciers are the debris covered showing a total reduction of 1.41Km^2 in the basins during this period.

Table 6 Number of Glacier in different aerial ranges and aerial extent in Ravi Basin

Glacier Area (sq km)	**No. of glaciers in 2002**	**Area in (Sq.Km.)**	**No. of glaciers in 2017**	**Area in (Sq.Km.)**	**Gain/Loss in Area**	**%Age gain/loss**
0-1	78	40.55	79	39.95	**(-)0.60**	**(-)1.47**
1-3	39	70.13	38	67.53	**(-)2.60**	**(-)3.70**
3-5	3	11.33	3	11.24	**(-)0.09**	**(-)0.79**
5-10	5	30.67	5	30.40	**(-)0.27**	**(-)0.88**
10-20	1	11.30	1	11.29	**(-)0.01**	**(-)0.08**
>20	------	------	------	------	**------**	**------**
Total	126	163.98	126	160.41	**(-)3.57**	**(-)2.17**

Table 7 Area gain or loss by clean glaciers in Ravi Basin

Name of the sub basin	No. Of clean glaciers in 2001	Area in (Sq.Km.)	No. Of debris covered glaciers in 2017	Area in (Sq.Km.)	Gain/Loss in Area	%Age gain/loss
Ravi	70	67.45	70	65.28	(-)2.17	(-)3.21

Table 8 Area gain or loss by debris covered glaciers in Ravi Basin

Name of the sub basin	No. Of clean glaciers in 2001	Area in (Sq.Km.)	No. Of debris covered glaciers in 2018	Area in (Sq.Km.)	Gain/Loss in Area	%Age gain/loss
Ravi	56	96.53	56	95.12	(-)1.41	(-)1.46

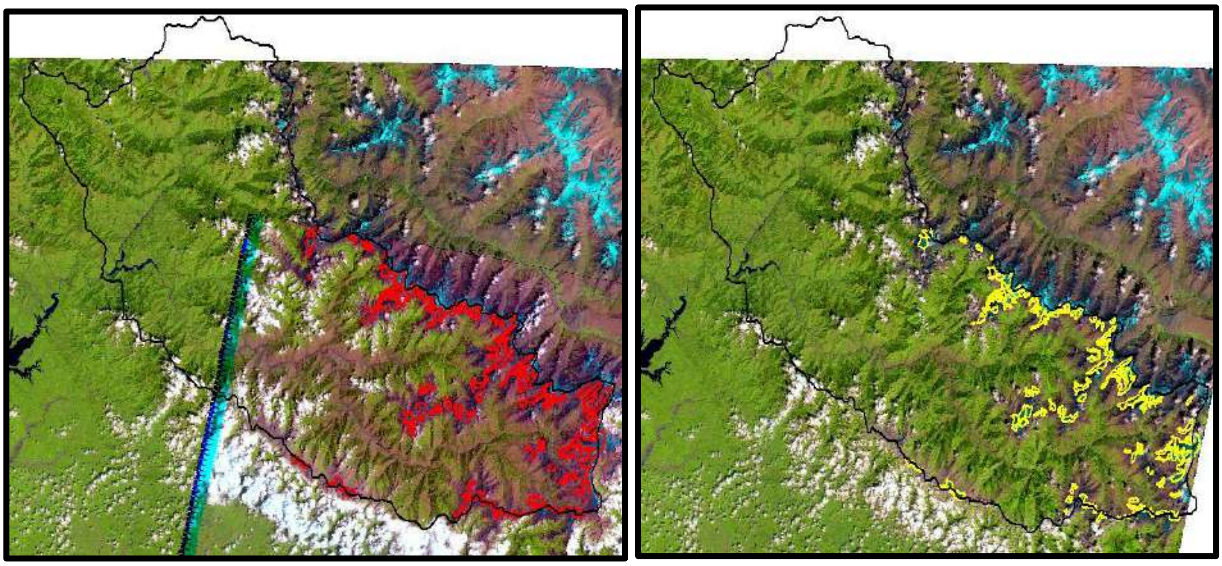
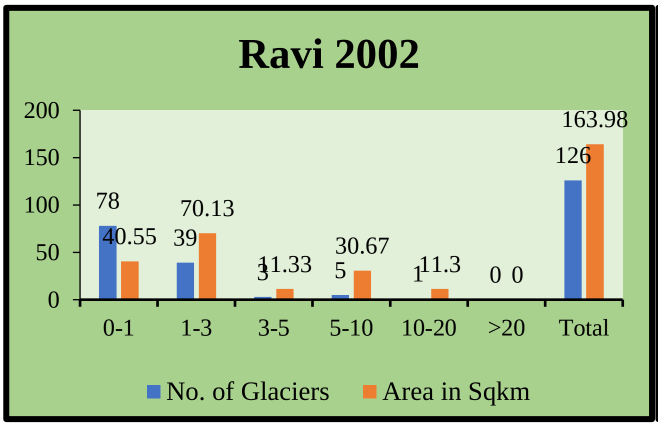
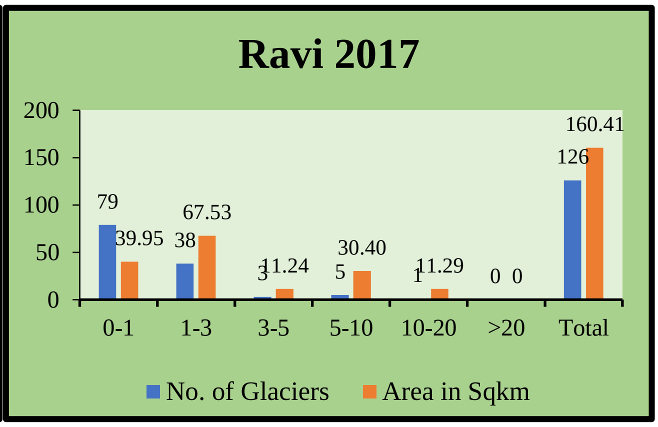


Figure 7 Glacier Layer Ravi Basin (2001) & Glacier Layer Ravi Basin (2017)





MONITORING OF GLACIERS IN SATLUJ BASIN

The Satluj river basin has been studied for two major sub basins i.e., Baspa and Spiti sub basins. The Spiti basin covers the areas within Himachal Pradesh and the adjoining Tibetan Himalayan region also.

MONITORING OF GLACIERS IN BASPA BASIN

Baspa River basin is one of the major sub basins of the Satluj River Basin and is located on the southeastern part of the State. From the satellite data analysis of LISS III images, a total of 79 glaciers could be mapped during 2001 which were clearly visible. The area occupied by 79 glaciers is 158.66 Km^2 comprising 52 glaciers within the areal range of 0-1 Km^2 occupying a total area of 21.64 Km^2, 15 glaciers are within the areal range of 1-3 Km^2 having a total area of 28.80 Km^2, 5 glaciers each are within the areal range of 3-5 and 5-10 Km^2 occupying a total area of 20.97Km^2 and 31.52Km^2 respectively. Besides this, only 2 glaciers within the areal range of more than 20Km^2 having a total area of 55.73 Km^2 have been mapped in the basin, The temporal variation of 79 glaciers w.r.t 2018 data suggest that , the total area of 79 glaciers have been reduced from 158.66Km^2 (2001) to 153.95Km^2(2018) indicating an overall reduction of 4.71Km^2 within a span of 17 years i.e. between 2001 and 2018 reflecting that about 2.88% of the total glacier area has been reduced between 2001& 2018The temporal variation of glaciers within different areal ranges suggest that the maximum reduction could be noticed in case of the small glaciers within the areal range of 0-1 and 1-3 Km^2 by 1.61Km^2 and 1.59Km^2 respectively, Besides this, the glaciers within the areal range of 3-5 and 5-10 Km^2 indicates a reduction of 0.56 Km^2 and 0.47Km^2 during 2001 and 2018 respectively and the large glaciers with area >20Km^2 indicates a total reduction of 0.48Km^2 during this period. The classification of 79 glaciers into clean and debris covered suggest that there are 54 glaciers are clean having a total area of 54.49Km^2 which have been reduced to 52.21 Km^2 in 2018 indicating a total reduction of 2.28Km^2 , whereas the 25 glaciers are debris covered showing a total reduction of 2.44 Km^2 between 2001 and 2018.

Table 9 Number of Glacier in different aerial ranges and aerial extent in Baspa Basin

Glacier Area (sq km)	**No. Of glaciers in 2001**	**Area in (Sq.Km.)**	**No. Of glaciers in 2018**	**Area in (Sq.Km.)**	**Gain/Loss in Area**	**%Age gain/loss**
0-1	52	21.64	52	20.03	**(-)1.61**	**(-)7.43**
1-3	15	28.80	15	27.21	**(-)1.59**	**(-)5.52**
3-5	5	20.97	5	20.41	**(-)0.56**	**(-)2.67**
5-10	5	31.52	5	31.05	**(-)0.47**	**(-)1.49**
10-20	------	------	------	------	**------**	**------**
>20	2	55.73	2	55.25	**(-)0.48**	**(-)0.86**
Total	**79**	**158.66**	**79**	**153.95**	**(-)4.71**	**(-)2.96**

Table 10 Area gain or loss by clean glaciers in Baspa Basin

Name of the sub basin	No. of clean glaciers in 2001	Area in (Sq.Km.)	No. of debris covered glaciers in 2018	Area in (Sq.Km.)	Gain/Loss in Area	%Age gain/loss
Baspa	54	54.49	54	52.21	(-)2.28	(-)4.18

Table 11 Area gain or loss by debris covered glaciers in Baspa Basin

Name of the sub basin	No. of clean glaciers in 2001	Area in (Sq.Km.)	No. of debris covered glaciers in 2018	Area in (Sq.Km.)	Gain/Loss in Area	%Age gain/loss
Baspa	25	104.19	25	101.75	(-)2.44	(-)2.34

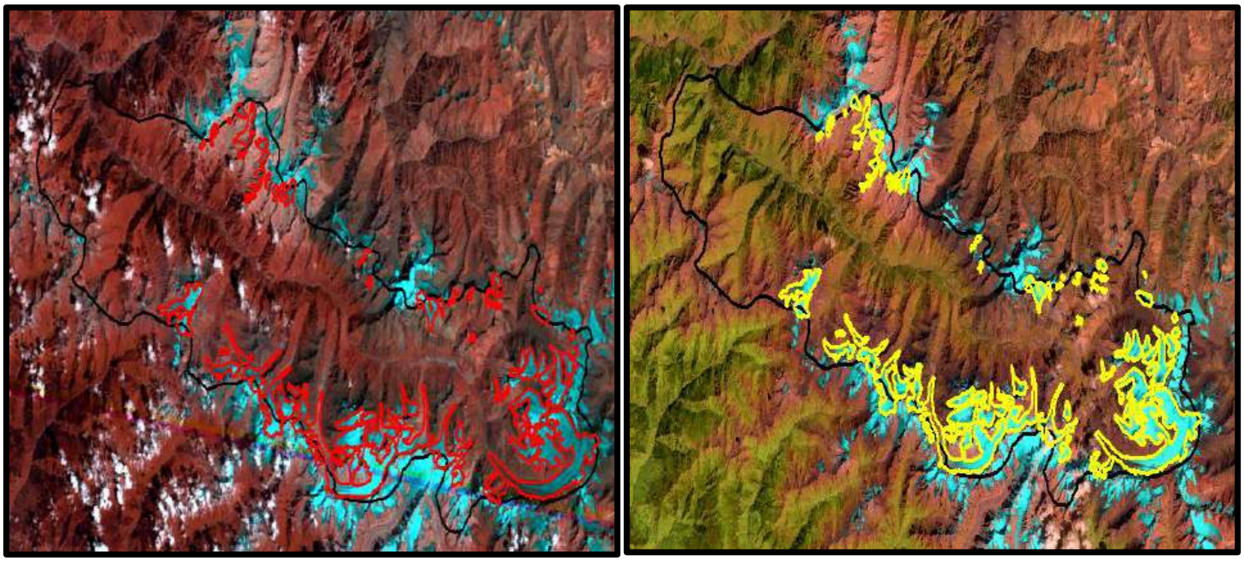
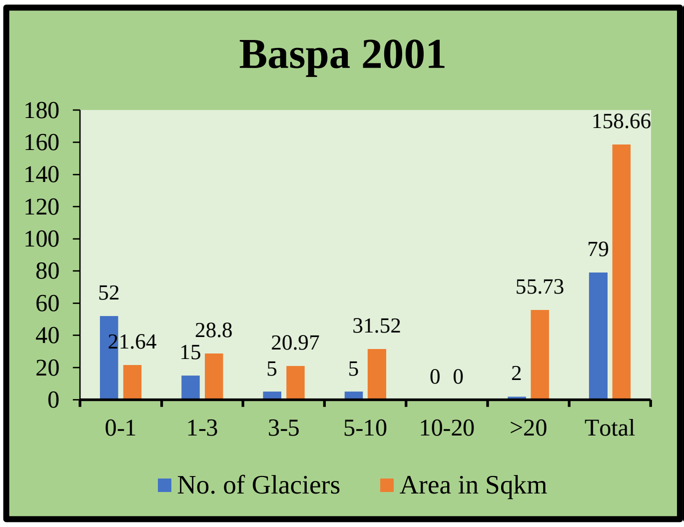
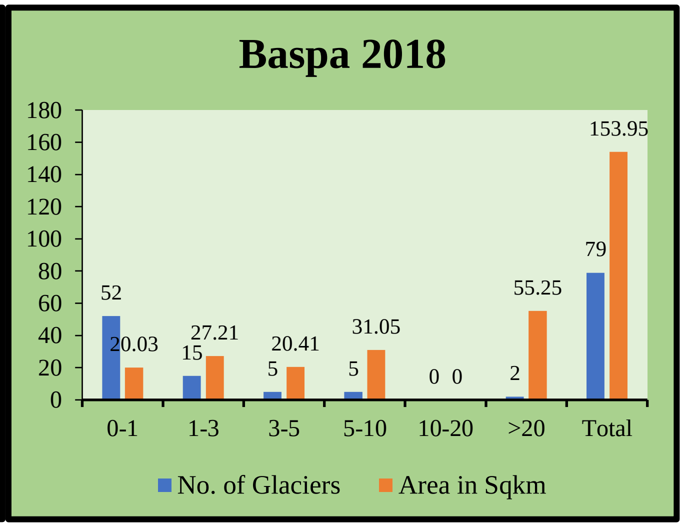


Figure 8 Glacier Layer Baspa Basin (2001) & Glacier Layer Baspa Basin (2001)





MONITORING OF GLACIERS IN SPITI BASIN

The Spiti River basin is one of the major sub basins of the Satluj River Basin and is located on the southeastern part of the State. From the satellite data analysis of LISS III images, a total of 512 glaciers could be mapped during 2001 which were clearly visible and further increased to 513 in 2018 due to addition of another glacier by virtue of fragmentation of large sized glaciers The area occupied by 512 glaciers is 482.56 Km^2 comprising 387 glaciers within the areal range of 0-1 Km^2 occupying a total area of 153.61 Km^2, 95 glaciers are within the areal range of 1-3 Km^2 having a total area of 152.18 Km^2, 15 and 12 glaciers are within the areal range of 3-5 and 5-10 Km^2 occupying a total area of 58.17Km^2 and 80.44Km^2 respectively. Besides this, only 3 glaciers within the areal range of 10-20 Km^2 having a total area of 38.16 Km^2 have been mapped in the basin. The temporal variation of 512 glaciers w.r.t 2018 data suggest that, the total number has increased to 513, whereas the area have been reduced from 482.56Km^2(2001) to 470.58Km^2(2018) indicating an overall reduction of 11.98Km^2 within a span of 17 years i.e., between 2001 and 2018 reflecting that about 2.48% of the total glacier area has been reduced between 2001& 2018. The temporal variation of glaciers within different areal ranges suggest that the maximum reduction could be noticed in case of the small glaciers within the areal range of 1-3 Km^2 by 10.19Km^2, whereas as the glaciers within areal range 0-1Km^2 shows a reduction of 0.55Km^2. Besides this, the glaciers within the areal range of 3-5 and 5-10 Km^2 indicates a reduction of 0.58 Km^2 and 1.07Km^2 during 2001 and 2018 respectively and the large glaciers with area within areal range 10-20Km^2 indicates a total reduction of 0.69Km^2 during this period. The classification of 512 glaciers into clean and debris covered suggest that there are 403 glaciers are clean having a total area of 335.02Km^2 which have been reduced to 325.82 Km^2 in 2018 indicating a total reduction of 9.20Km^2, whereas the 109 glaciers are debris covered showing a total reduction of 2.78 Km^2 between 2001 and 2018.

Table 12 Number of Glacier in different aerial ranges and aerial extent in Spiti Basin

Glacier Area (sq km)	No. of glaciers in 2001	Area in (Sq.Km.)	No. of glaciers in 2018	Area in (Sq.Km.)	Gain/Loss in Area	%Age gain/loss
0-1	387	153.61	395	154.16	**(-)0.55**	**(-)0.35**
1-3	95	152.18	88	141.99	**(-)10.19**	**(-)6.69**
3-5	15	58.17	15	57.59	**(-)0.58**	**(-)0.99**

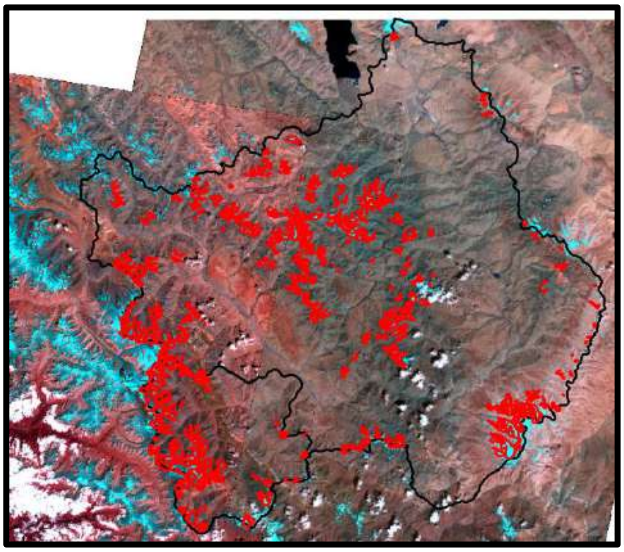
5-10	12	80.44	12	79.37	**(-)1.07**	**(-)1.33**
10-20	3	38.16	3	37.47	**(-)0.69**	**(-)1.80**
>20	------	------	------	------	------	------
Total	**512**	**482.56**	**513**	**470.58**	**(-)11.98**	**(-)2.48**

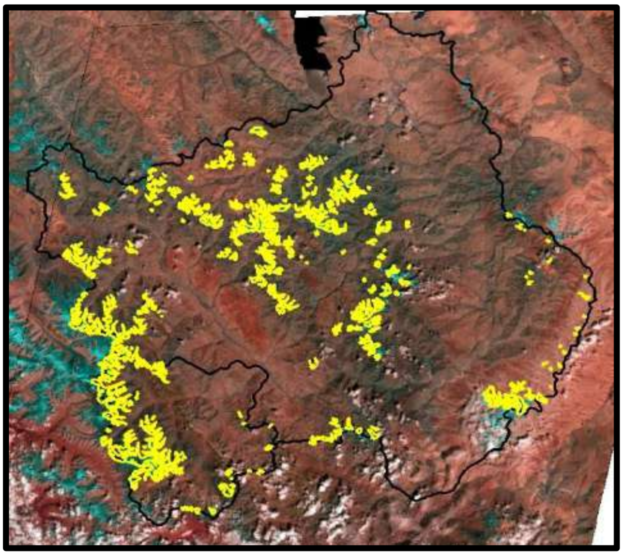
Table 13 Area gain or loss by clean glaciers in Spiti Basin

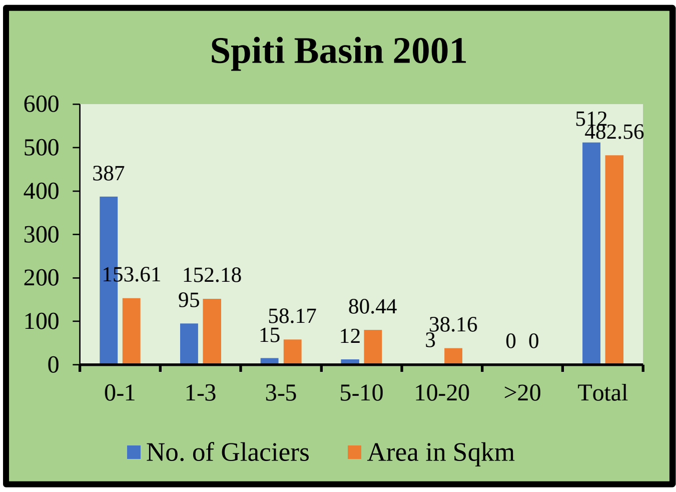
Name of the sub basin	No. of clean glaciers in 2001	Area in (Sq.Km .)	No. of debris covered glaciers in 2017	Area in (Sq.Km.)	Gain/Loss in Area	%Age gain/los s
Spiti	403	335.02	403	325.82	(-)9.20	(-)2.74

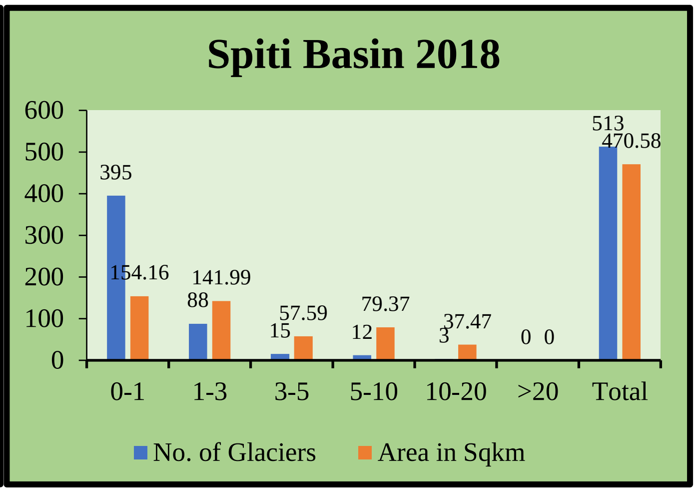
Table 14 Area gain or loss by debris covered glaciers in Spiti Basin

Name of the sub basin	No. of clean glaciers in 2001	Area in (Sq.Km.)	No. of debris covered glaciers in 2018	Area in (Sq.Km.)	Gain/Loss in Area	%Age gain/loss
Spiti	109	147.53	109	144.75	(-)2.78	(-)1.88









As far as the overall status of the glaciers mapped in different basins is concerned, it is found that the Chenab basin out of 556 glaciers, 339 glaciers are showing a retreating trend, whereas 17 glaciers not show any change or are the stable between 2001 and 2018. The Beas basin, out of 215 glaciers mapped, 211 are showing a retreating trend, whereas 4 glaciers does not show any change between 2001 and 2016/17. Likewise, the Ravi basin, 121 glaciers show a retreating trend and 5 glaciers does not show any change out of the 126 glaciers mapped in 2001.The Satluj basin, wherein the Baspa basin 77 glaciers show a retreating trend and 2 glaciers does not show change, whereas 455 glaciers in Spiti basin shows a retreating trend out of 512 mapped in 2001, whereas 57 glaciers does not show any change during this period. Thus, in other words, it is inferred that majority of the glaciers mapped in 2001 in different basins shows a retreating trend of varying proportions except few glaciers as stable one during 2001 and 2018 period. As far as the area vacated per year is concerned, the results obtained through remote sensing method and the ground observations as made by GSI reveals that there is close proximity between the two results i.e. the Bara Sigri glacier in Chandra basin shows total area vacated to be 0.02 km^2 /yr , whereas as per GSI observation it is also 0.022km^2/yr and the average of all the glaciers in Chandra sub basin is 0.86 km^2/yr, Bhaga it is 0.59 km^2/yr, Spiti as 0.70 km^2/yr, Baspa as 0.27 km^2/yr, Ravi as 0.23$km^2$2/yr, Beas as 0.49 km^2/yr.

2. PILOT PROJECT ON SNOW-ICE HARVESTING AT POOH VILLAGE, DISTRICT KINNAUR HIMACHAL PRADESH

The study is being carried out in collaboration with SASE Chandigarh wherein, the PI is from the SASE Chandigarh and the CO-PI from the Himachal Pradesh Council for Science, Technology & Environment, (HIMCOSTE) Shimla. Under this project all field-based parameters for the development of the methodology were to be developed by the PI end i.e., SASE Chandigarh, from the Sr.No.1-5 of the objectives envisaged, whereas from Sr. No. 6&7 were to be completed at the Co-PI end i.e., by the HIMCOSTE. The Sr. No.6 mainly envisaged to have the thematic Maps of Drainage, Contour, Slope, Aspect, Land use, Land cover and Geomorphology of the project site, and the snow accumulation pattern using satellite data against Sr.No.7 of the objectives envisaged. Since this project was envisaged for three years, but could be carried forward due to technical reasons for which the grants for the IInd and IIIrd years were not released by DST. However, the work which was completed at the CO-PI end is as per the details.

INTRODUCTION

The demand of water for drinking and irrigation consumption is increasing day by day. Availability of water is insufficient to meet the demand. This is more predominant in all the southern located inhabitation, where glaciers are not there and the source of water is only seasonal snow. There are many villages in Kinnaur, Lahaul & Spiti and Chamba districts of Himachal Pradesh, which are southerly located and source of water is only seasonal snow since there are no glaciers. Due to High intensity and less frequent snowfall, less water is available which further results in water scarcity for irrigation and drinking water. Also, due to increase in temperature early snow melt takes place which again results in less water availability in late summer.

The problem is when water is needed more in late summer for irrigation sufficient water is not available. This water scarcity can be met by one of the methods being implemented in this project.

i. Main causes of the problem:
ii. Population increase
iii. More land development
iv. Climatic variations
v. less snow fall frequency with high intensity
vi. Avalanche occurrence

vii. Early snow melt
viii. During early winter less water is used for irrigation
ix. Less water available during late summer for irrigation

Besides this, it was proposed to use the spring water to make artificial glacier during early winter when less water is being used by the farmer for irrigation. More Snow will be accumulated at desired location by using snow fence so that more water is available during late summer. But the final outcome could not be achieved, due to the financial constraints as only the first-year grant was received by the implementing institutions under the project, and thus the desired result could not be achieved.

OBJECTIVES

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

The objectives from Sr. No.1-5 were to be taken up by the SASE, Chandigarh and Sr.6 & 7 by HIMCOSTE Shimla.

PROJECT AREA

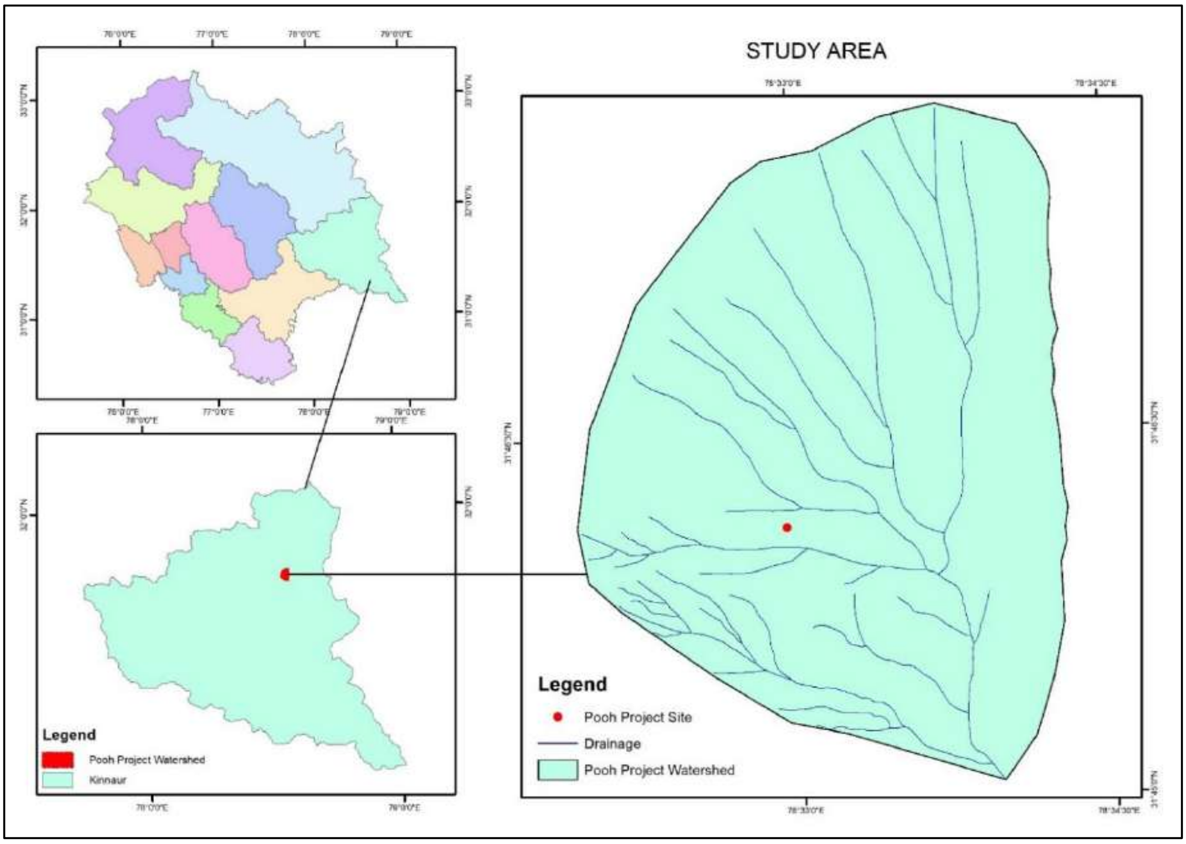


Figure 9 Study Area Village Pooh at Kinnaur district, Himachal Pradesh

COMMUNITY BACKGROUND

The Kinnaur district has been carved out of Mahasu tehsil in 1966. Kinnaur District has no urban Population it's completely a rural community. The Kinnaur has 3 tehsil/ CD Blocks: Pooh, Kalpa and Nichar. The Pooh tehsil has 97 villages in 2011. The Pooh tehsil is completely dominated by tribal population. There are 5471 households with 23,206 population. Out of total Population 12474 were males and 10732 were females. The sex ration of the Pooh Tehsil was 842 females / 1000 males. The economy of the pooh tehsil is primarily dependent on agriculture the crop season is limited to only six Months due to severe cold and snowfall. The total workers in the district were 17020 according to 2011 population.

METHODOLOGY FOLLOWED

The cartosat DEM (30-meter resolution) has been used for contour generation by using arc GIS software. The Slope and Aspect has also been drawn from Cartosat DEM by using ArcGIS Software. The land use land cover of the study area has been digitized from LISS III high resolution satellite data. The Geomorphology of the study area has also been digitized from LISS III satellite data. The Snow cover of the study area has been drawn by using ERDAS Software using NDSI model.

NORMALIZED DIFFERENCE SNOW INDEX (NDSI)

In general, the reflectance of snow is high at the red end of the visible spectrum. It tends to decline in the near-infrared region until 1090 nm, where slight gain in reflectance occurs and gives a minor peak at approximately 1090 to 1100 nm. One of the important difficulties in snow cover monitoring is the presence of cloud cover. Cloud has strong reflectivity in visible, NIR and SWIR regions while snow absorbs in SWIR, and this difference can be utilized for snow/cloud discrimination. Normalized Difference Snow Index (NDSI) utilize the normalized ratio of green and SWIR and is used as an automated approach for snow mapping addressing the shadow and cloud problems in snow bound areas.

Normalized Difference Snow Index was calculated using the ratio of green wavelength (band 2) and SWIR (band 5) of AWiFS sensor:

Normalised Differential Snow Index (NDSI) = (*band*2 - *band*5) / (*band*2 + *band*5)

To estimate NDSI, DN numbers were converted into reflectance. This involves conversion of digital numbers into the radiance values, known as sensor calibration, and then estimation of reflectance from these radiance values and the final product after running algorithm Shown in Fig: 2. Various parameters needed for estimating spectral reflectance are maximum and minimum radiances and mean solar exo-atmospheric spectral irradiances in the satellite sensor bands, satellite data acquisition time, solar declination, solar zenith and solar azimuth angles, mean Earth- Sun distance etc. (Markham and Barker, 1987; Srinivasulu and Kulkarni, 2004).

Snow cover extent is generated scene-wise. In this product, snow and cloud extents are given. Estimate of cloud is important because, at times, snow is covered by cloud and this may be classified as non-snow area, leading to erroneous conclusions.. If any pixel is identified as snow on any one date then this pixel will be classified as snow on final product. Therefore, this product is generated basin-wise. AWiFS data has been used for calculating area monitoring algorithm. An algorithm is developed to provide changes in the areal extent of snow (Kulkarni et. al., 2006). Snow extent is estimated at an interval of 5-days depending upon availabilities of AWiFS data. In 5-daily product, snow.

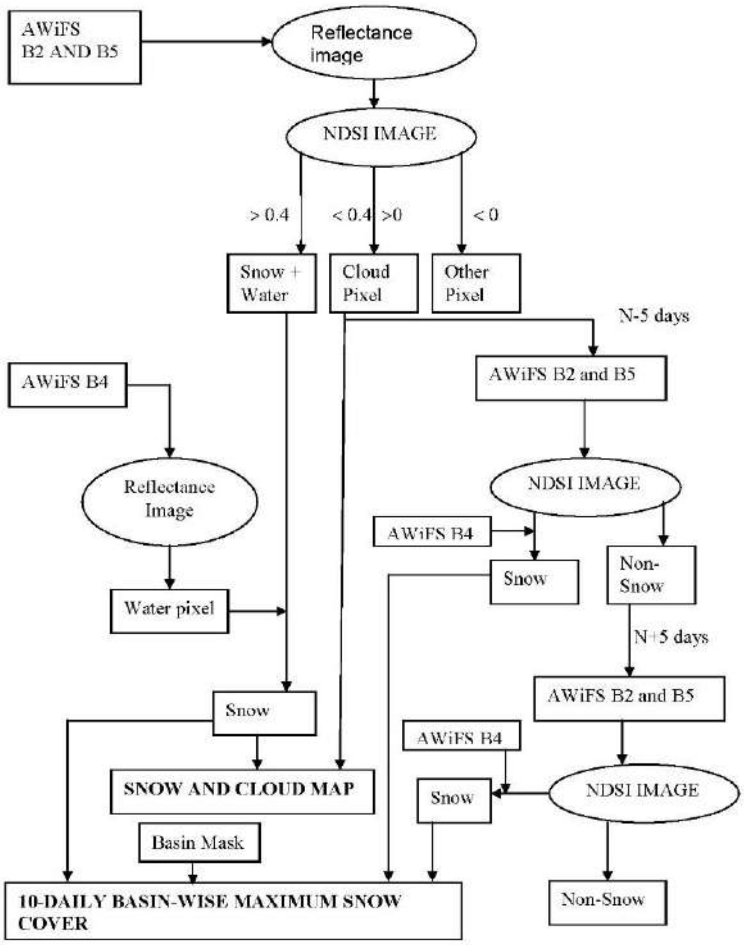


Figure 10 Algorithm for snow cover mapping using AWiFS data

OBJECTIVE 6: TO GENERATE SLOPE, ASPECT, MORPHOLOGICAL MAP OF THE STUDY AREA

The Contour, Drainage Slope and Aspect map have been drawn from Cartosat DEM (30 m Resolution). The closely spaced contours reflect that the project site- Pooh in District Kinnaur of Himachal Pradesh has Steep

Slope (Fig11a). The lowest range of contour was 2420 and highest was 5020. The drainage pattern of the site is dendritic, the main Nala of the Site is Tinku Nala. The Drainage System Shows Four Stream order of the project site in the Figure 11 (b).

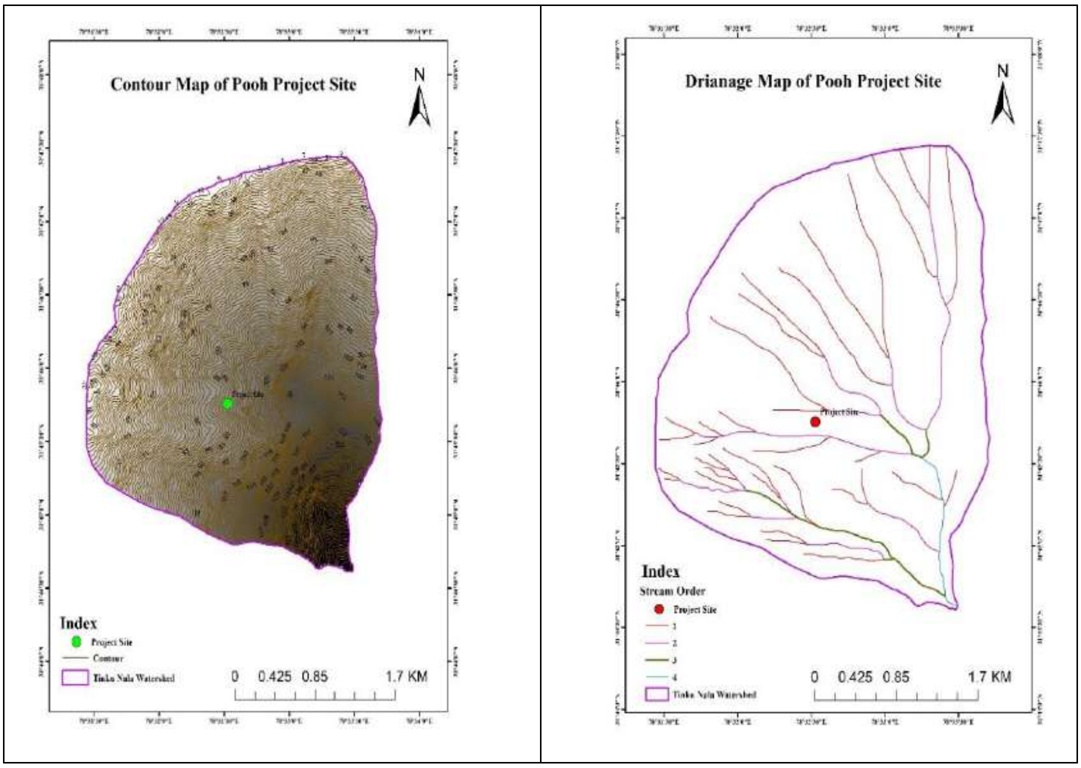


Figure 11 (a) Contour Map of Project Site & (b) Drainage Map of Project Site

SLOPE AND ASPECT

The slope and aspect map of the project site have been generated using Cartosat DEM. The project site in the study area have been categorized in the table 15. The categorization of the slope has been taken from NBSS & LUP. The Study area reflects Steep to very Steep Slope in the most of the area (fig12 a). The aspect map has been drawn for mountainous regions to know the direction of the slope of the mountains. The aspect of the Study area ranges direction from North, Northeast, East, Southeast, South, Southwest, West, and Northwest. Whereas the project site has been located in Southeast of the Mountain (fig12 b).

Table 15 Classification of Slope

Symbol	Range	Description
A	< 5 below	Very Gentle
B	5-10	Gentle
C	10-15	Moderate
D	15-25	Steep
E	> 35 above	Very Steep

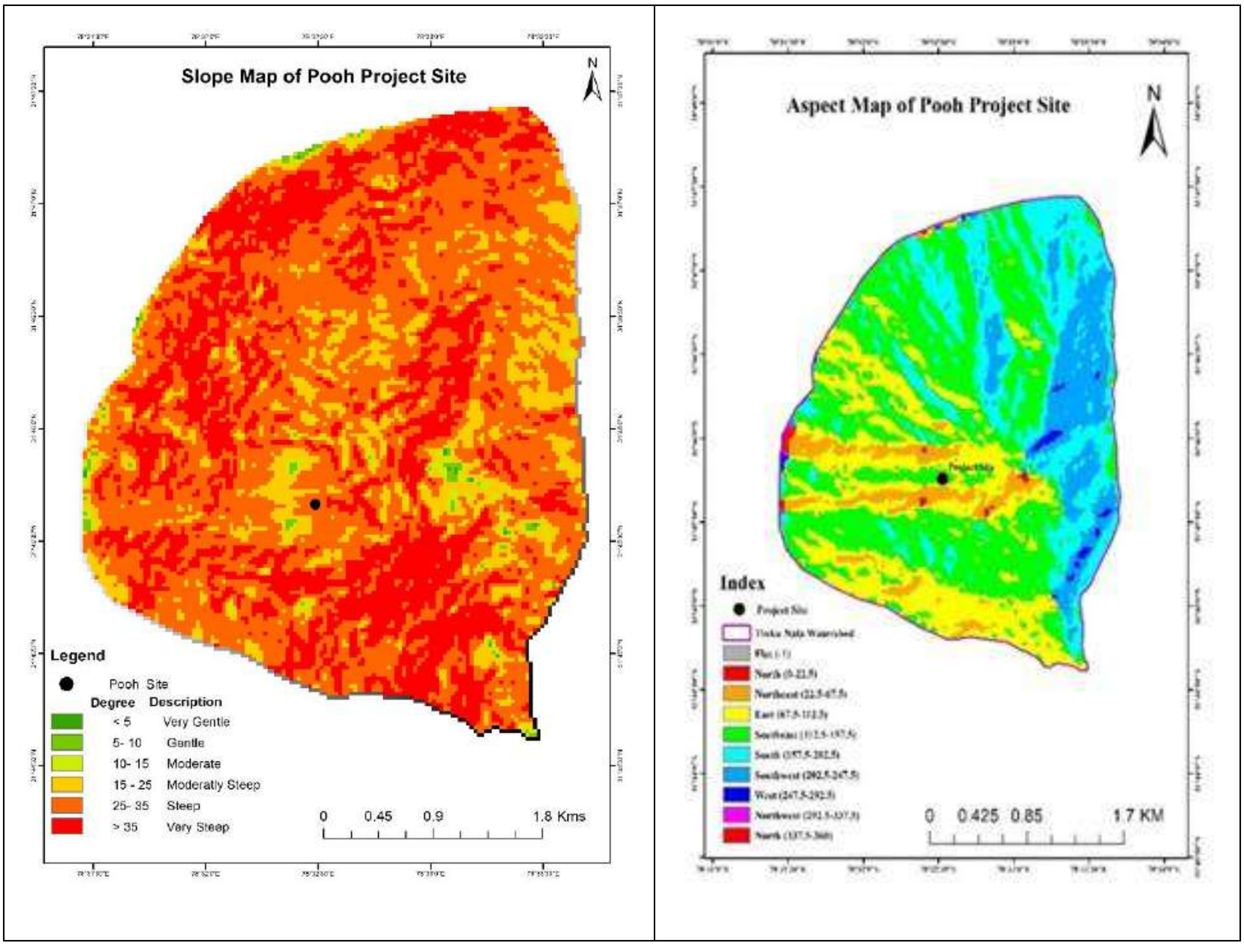


Figure 12 (a) Slope Map of Project Site & b) Aspect Map of Project Site

The land use land cover and Geomorphology maps have been drawn by using high resolution satellite imageries. The land use land cover of the study area has 12.60 km^2 wastelands out of 14.26 km^2 followed by grasslands which constitutes 0.90 km^2 area (Fig14 a). There has one patch of agriculture land which is hill cut terraces has 0.65 km^2 area. The morphology of the study area can be categorized as Dissected Hill Moderate (DHM), Glaciated valley (GV) And Hill Cut Terraces (HCT) comprised of area 13.34 km^2, 0.29 km^2 and 0.51 km^2 respectively (Fig14 b).

Figure 13 Photos: Field Work for surveying the Demonstration Site at 4500mts above m.s.l

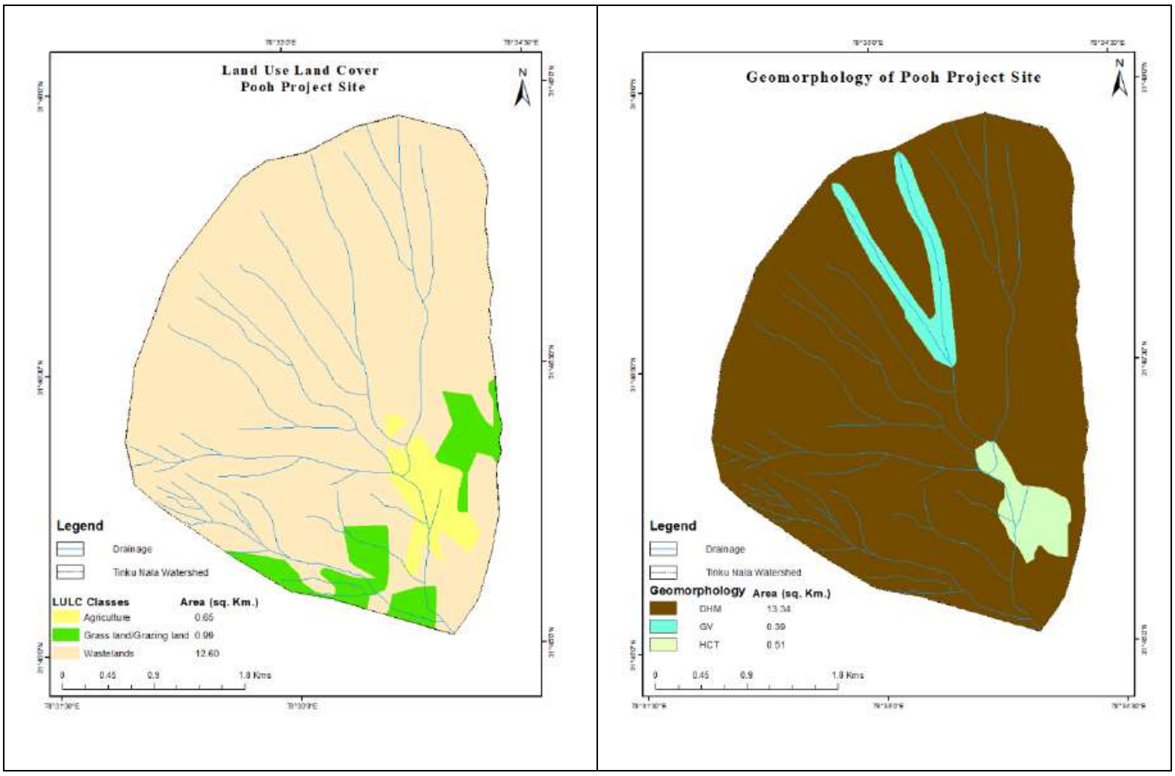


Figure 14 (a) LULC Map of Project Site & (b) Geomorphology Map of Project Site

OBJECTIVE 7: TO STUDY THE CHANGE DETECTION OF SNOW-ICE ACCUMULATION PATTERN USING ARCHIVE SATELLITE DATA AS WELL AS THE LATEST HIGH RESOLUTION SATELLITE DATA

The total area of the watershed is 14.24Sq.KM. 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.

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 in the following table:

The total area of the watershed is 14.24Sq.KM. 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 is available for the month of 21st Sept, 5th October and 10th October, which reveals an average 0.63 sq. Km snow cover at an altitude between 4410-4620 m. above mean sea level. Athough the satellite imagery of 10th October is also available but on this date there is negligible snow has been recorded.

In 2006 there are five satellite imageries avaialble but all of these are devoid of snow. In 2007, three imageries are available for16th and 30th September with negligible snow and another satellite imagery dated 10th October represents 2.08 Sq. km snow cover at an elevation of 4260 m. above mean sea level. Same trend has been seen in the next years of study, in 2008 four seen of satellite imagery is available three for the month of September in which only one satellite imagery dated 29th September showed an average area of 2.68 sq. km at an altitude of 4230 m. above mean sea level and one for the month of October in which negligible snow is recorded. In 2009 two satellite imagery is available on dated 29th September and 13th October. Only 13th October represents snow cover which is 0.42 sq. km at altitude of 4740m.

In 2010, there are 19 satellite imageries showing an average snow cover 6.26 sq.km. The few satellite imageries of 2010 show negligible snow cover and some are cloudy and blur. In 2011, 35 satellite imageries are available for different months with average snow cover is 11.93 sq. km. In 2012 25 satellite imageries are available for different months and dates of winter season and an average snow is 10.48 sq.km. In 2013 about 50 satellite seen area available for different months and dates covered an average snow 10.13 sq.km. In 2014, 45 satellite imagery is available with an average 9.29 sq.km snow cover. In 2014 four satellite imageries are available for different months and dates covered an average snow 13.16 sq.km at an altitude of 2430-4410m amsl.

In 2015 number of satellites available for different months of the study area and dates of Snow Precipitation covered an average snow 10.84 sq. km while some satellite images were blur and cloudy. In 2016, there are four images available cover an average of 6.23 sq.km. of the total area. In 2017, 6.80 sq.km and in 2018 the snow-covered area was about an average of 6.78 sq.km.

Chronological snowline of Pooh project site					
Years	**Date/Month**	**Row/Path**	**Area (Sq. Km)**	**Avg. Area (Sq. Km)**	**Altitude (m)**
2005	21st Sept	96-50	0.51 (10% Cloud)	0.63	4620
	05th Oct	94-49	0.75		4410
	10th Oct	95-45	No Snow Cover		No Snow Cover
2006	06th Sept	94-49	No Snow Cover	_	No Snow Cover

	26th Sept	98-48	No Snow Cover		No Snow Cover
	30th Sept	94-49	No Snow Cover		No Snow Cover
	05th Oct	95-48	No Snow Cover		No Snow Cover
	10th Oct	96-48	No Snow Cover& Partly Cloudy		No Snow Cover& Partly Cloudy
2007	16th Sept	97-50	No Snow Cover	2.08	No Snow Cover
	30th Sept	95-49	No Snow Cover		No Snow Cover
	10th Oct	97-50	2.08		4260
2008	10th Sept	97-47	No Snow Cover	2.68	No Snow Cover
	24th Sept	95-50	Cloudy		Cloudy
	29th Sept	96-48	2.68		4230
	09th Oct	98-49	No Snow Cover		No Snow Cover
2009	29th Sept	97-48	No Snow Cover	0.42	No Snow Cover
	13th Oct	95-47	0.42		4740
2010	29th Sept	98-48	No Snow Cover	6.26	No Snow Cover
	03rd Oct	94-46	0.63		4650
	08th Oct	95-46	0.26		4830
	18th Oct	97-48	No Snow Cover		No Snow Cover
	22nd Oct	93-45	No Snow Cover		No Snow Cover
	27th Oct	94-48	7.47		3450
	06th Nov	96-48	2.29		3600
	15th Nov	93-45	Cloudy		Cloudy
	20th Nov	94-49	-----		-----
	05th Dec	97-49	0.31		3990
	09th Dec	93-48	-----		-----
	14th Dec	93-48	-----		-----
	24th Dec	94-47	0.28		4680
	29th Dec	96-48	-----		-----
	27th Jan	97-48	10.05		3150

	10th Feb	95-48	14.24		Completely covered with Snow
	20th Feb	97-48	12.94		2640
	11th Mar	96-49	10.64		2970
	23rd Apr	95-48	9.79		3450
2011	3rd Jan	98-47	14.24	11.93	Completely covered with Snow
	07th Jan	94-46	14.24		Completely covered with Snow
	12th Jan	95-48	13.05		2730
	22nd Jan	97-47	12.90		2700
	26th Jan	93-48	-----		-----
	27th Jan	98-49	12.68		2820
	01st Feb	99-49	12.28		2820
	10th Feb	96-47	14.24		Completely covered with Snow
	25th Feb	99-50	13.36		2640
	10th Mar	92-50	-----		-----
	15th Mar	93-46	13.17		2730
	16th Mar	98-48	12.32		3000
	30th Mar	96-50	10.64		3330
	23rd Apr	96-50	9.60		3540
	17th May	96-49	Cloudy		Cloudy
	29th Sept	99-50	No Snow Cover		No Snow Cover
	3rd Oct	95-50	No Snow Cover		No Snow Cover
	05th Oct	93-48	No Snow Cover		No Snow Cover
	10th Oct	94-48	No Snow Cover		No Snow Cover
	13th Oct	97-49	No Snow Cover		No Snow Cover
	23rd Oct	99-50	No Snow Cover		No Snow Cover

	29th Oct	93-48	No Snow Cover		No Snow Cover
	03rd Nov	94-48	No Snow Cover		No Snow Cover
	06th Nov	97-49	No Snow Cover		No Snow Cover
	13th Nov	96-48	No Snow Cover		No Snow Cover
	22nd Nov	93-48	No Snow Cover		No Snow Cover
	27th Nov	94-48	No Snow Cover		No Snow Cover
	30th Nov	97-49	No Snow Cover		No Snow Cover
	02nd Dec	95-48	No Snow Cover		No Snow Cover
	12th Dec	97-47	No Snow Cover		No Snow Cover
	16th Dec	93-48	No Snow Cover		No Snow Cover
	19th Dec	96-50	2.48		3780
	21th Dec	94-48	-----		-----
	26 Dec	95-48	-----		-----
	28th Dec	93-48	No Snow Cover		No Snow Cover -----
2012	03rd Jan	93-44	10.47	10.48	3090
	21st Jan	93-46	13.52		2430
	27th Jan	93-46	14.24		Completely covered with Snow
	31st Jan	95-48	12.50		2730
	29th Feb	96-48	13.01		2790
	15th Mar	99-49	11.86		3210
	19th Mar	96-48	11.95		3090
	05th Apr	96-48	8.83		3360
	28th May	97-49	1.48		4020
	21st June	97-48	-----		-----
	20th Sept	96-48	No Snow Cover		No Snow Cover
	25th Sept	97-49	No Snow Cover		No Snow Cover
	05th Oct	99-49	No Snow Cover		No Snow Cover
	09th Oct	95-45	No Snow Cover		No Snow Cover

	14th Oct	96-45	No Snow Cover		No Snow Cover
	19th Oct	97-48	No Snow Cover		No Snow Cover
	23 Oct	93-48	No Snow Cover		No Snow Cover
	02 Nov	95-48	No Snow Cover		No Snow Cover
	07 Nov	96-45	No Snow Cover		No Snow Cover
	16 Nov	93-48	No Snow Cover		No Snow Cover
	10 Dec	93-48	Cloudy		Cloudy
	13 Dec	96-47	Cloudy		Cloudy
	22 Dec	95-45	11.77		2820
	25th Dec.	93-45	10.37		3210
	30th Dec.	97-45	9.62		3300
2013	06th Jan	96-47	8.36	10.13	3270
	08th Jan	94-43	9.01		3120
	13th Jan	96-45	12.34		2880
	16th Jan	98-48	6.88		3390
	20th Jan	94-47	14.24		Completely covered with Snow
	21st Jan	99-49	14.24		Completely covered with Snow
	25th Jan	95-47	14.24		Completely covered with Snow
	27th Jan	93-46	14.24		Completely covered with Snow
	01 Feb	94-46	14.08		2520
	08th Feb	93-46	14.24		Completely covered with Snow
	09th Feb	98-47	14.24		Completely covered with Snow

	11th Feb	96-47	14.24		Completely covered with Snow
	18th Feb	95-48	14.24		Completely covered with Snow
	20th Feb	93-45	14.24		Completely covered with Snow
	21 Feb	99-48	14.24		Completely covered with Snow
	25 Feb	94-46	14.24		Completely covered with Snow
	28 Feb	97-48	13.99		2550
	02 March	95-49	13.98		2550
	04 March	93-46	13.96		2550
	05 March	98-48	13.24		2790
	17March	98-48	12.64		2820
	19March	96-47	12.20		2880
	12 April	96-47	9.77		3360
	17 April	97-48	10		3390
	06 May	96-47	8.83		3300
	23 May	97-47	2.01		3990
	08 June	93-46	2.19		4200
	30 June	95-46	2.07		4230
	4 oct	95-46	Cloudy		No Snow Cover
	9oct	96-48	Cloudy		No Snow Cover
	14oct	97-48	-----		-----
	16oct	95-47	-----		-----
	18oct	93-46	-----		-----
	23oct	94-48	-----		-----
	24 oct	99-49	-----		-----

	02 Nov	96-48	-----		-----
	12Nov	98-48	8.35		3720
	16Nov	94-45	7.35		3450
	21Nov	95-48	4.32		3660
	26Nov	96-48	1.73		3810
	1Dec	97-47	0.89		3870
	10 Dec	94-46	-----		-----
	15 Dec	95-45	-----		-----
	16 Dec	100-49	-----		-----
	19 Dec	98-48	-----		-----
	20 Dec	96-48	-----		-----
	23 Dec	99-49	1.69		3750
	25 Dec	97-48	8.11		3280
2014	03Jan	94-45	3.65	9.29	3360
	04Jan	99-48	2.20		3750
	23 Jan	98-48	14.24		Completely covered with Snow
	28 Jan	99-48	12.81		2700
	01 Feb	95-48	12.64		2850
	16 Feb	98-48	-----		-----
	20 Feb	94-45	13.82		2580
	25 Feb	99-48	13.17		2640
	07 March	97-47	12.75		2850
	12 March	98-48	-----		-----
	16 March	94-46	12.69		2640
	17 March	99-49	-----		-----
	21 March	95-48	12.84		2820
	31 March	97-47	12.12		3090
	02 April	95-47	12.18		3000

	05 April	98-48	11.23		3210
	09 April	94-46	-----		-----
	10 April	99-49	10.83		3270
	12 April	97-48	10.77		3270
	14 April	95-48	12.77		2970
	24 April	97-47	9.78		3420
	26 April	95-47	11.03		3150
	28 April	93-46	10.25		3270
	01 May	96-47	9.78		3390
	03 May	94-46	-----		-----
	04 May	99-49	-----		-----
	08 May	95-46	8.49		3570
	09 May	100-49	4.42		3960
	18 May	97-48	-----		-----
	20 May	95-47	7.85		3420
	25 May		7.56		3720
	03 June	93-47	6.43		3840
	04 June	98-47	3.19		4020
	06 June	96-48	5.01		3870
	09 June	99-50	Cloudy		Cloudy
	20 June	94-48	4.39		4050
	10 Sept	96-48	Cloudy		
	29 Sept	95-48	No Snow Cover		No Snow Cover
	01 Oct	93-47b	Blur		Blur
	04 Oct	96-48	No Snow Cover		No Snow Cover
	23 Oct	95-48	No Snow Cover		No Snow Cover
	30th October	94-46d	0.79		4410
	02 Nov	97-48	No Snow Cover		No Snow Cover
	01 Dec	98-49	-----		-----

	20 Dec	97-49	-----		-----
2015	01st Jan.	97-49c	8.55	10.84	3360
	5th January	93-50b	11.97		3210
	16th January	100-51a	12.32		3060
	01 Feb	96-48	Cloudy		Cloudy
	4th February	99-46c	14.24		Completely covered with Snow
	17 Feb	92-49a	Cloudy		Cloudy
	4th March	95-47d	14.11		2430
	06 march	93-48	14.24		Completely covered with Snow
	4th April	94-48	Cloudy		Cloudy
	10 April	100-49	12.0		2970
	12 April	98-46c	11.27		3210
	03 May	95-47	Cloudy		Cloudy
	23 May	99-48	2.28		4020
	24 May	92-50b	Cloudy		Cloudy
	10 June	93-47	Cloudy		Cloudy
	11 June	98-47	Cloudy		Cloudy
	15 June	94-47	Cloudy		Cloudy
	16 June	99-49	Cloudy		Cloudy
	20 June	95-46	Cloudy		Cloudy
2016	11 Jan		3.87	6.23	3810
	24 Jan		4.06		3570
	28 Feb		8.7		3330
	3 Mar		8.31		3270
	02 may	90-47	No Snow Cover		No Snow Cover
2017	06 Jan	94-47	Partly Cloudy	6.80	----
	03 April	96-48	9.15		3540

	02 May	97-47	5.44		3780
	04 June	94-47	2.12		4200
	04 Sept	98-49	No Snow Cover		No Snow Cover
	03 Sept	96-48	No Snow Cover		No Snow Cover
	13 Sept	95-48	No Snow Cover		No Snow Cover
	28 Sept	98-48	Partly Cloudy		Partly Cloudy
	02 Oct	94-47	No Snow Cover		No Snow Cover
	03 Oct	99-47	No Snow Cover		No Snow Cover
	08 Oct	100-48	No Snow Cover		No Snow Cover
	12Oct	96-47	No Snow Cover		No Snow Cover
	17 Oct	97-47	No Snow Cover		No Snow Cover
	27 Oct	99-47	No Snow Cover		No Snow Cover
	15 Nov	98-48	No Snow Cover		No Snow Cover
	18 Dec	95-47	10.52		2970
	28 Dec	96-47	Cloudy		
2018	30 Jan	94-47	6.55	6.78	3450
	04 Feb	95-47	3.51		3570
	23 Feb	94-48	7.74		3000
	05March	96-48	12.94		2970
	19 March	94-47	9.63		3060
	22 April	96-48	6.61		3840
	21 May	97-48	1.40		4770
	04 June	95-47	0.48		4770
	24 June	99-48	No Snow Cover		No Snow Cover
	01 Sept	96-48	Cloudy		Cloudy

B. DISASTER MANAGEMENT IN HIMACHAL PRADESH

1. MONITORING OF PARECHHU LAKE

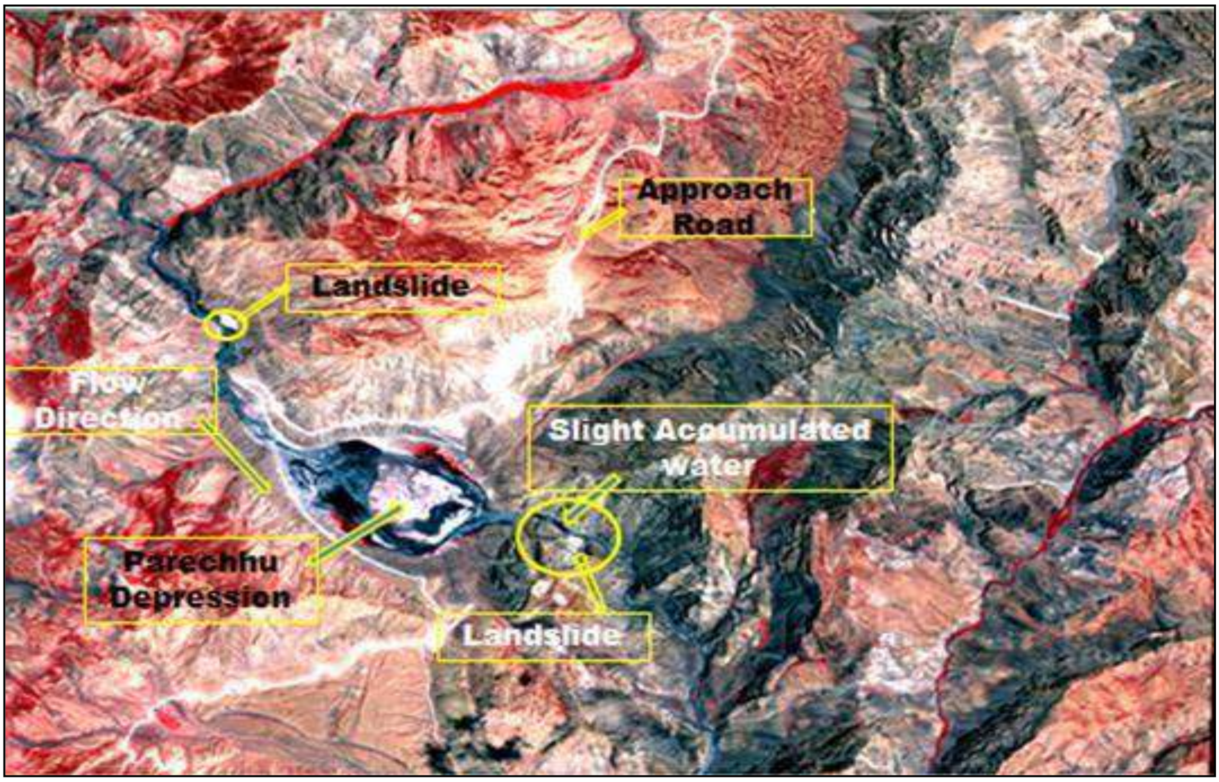


Figure 15 Satellite View of Parechhu Lake on 27 June 2020 through IRS-R2-LISS IV-96-48 Image

The State Centre on Climate Change (SCCC) under the aegis of the HP Council for Science Technology & Environment (HIMCOSTE) has been monitoring regularly the Parechhu Lake formed in the Tibetan Himalayan Region since its inception in 2004. The monitoring is being done using satellite data from April to October every year during the ablation season.

OBSERVATIONS

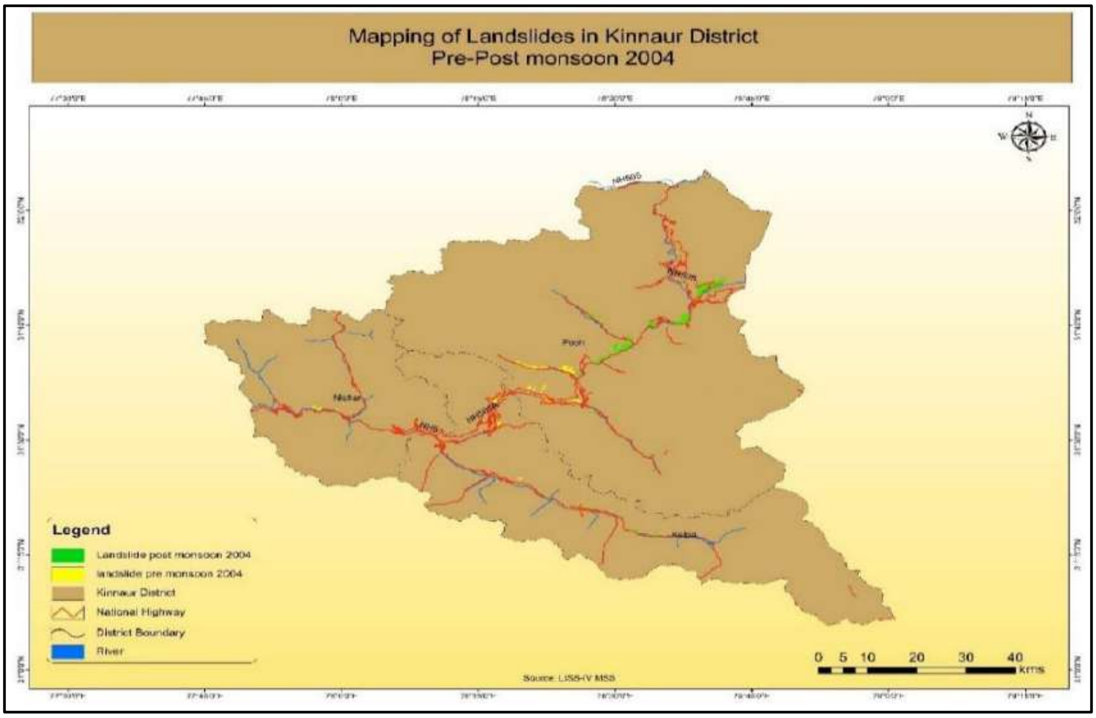
Based on the analysis of IRS-R2-L4-96-48-B-27 June 2020 satellite data having spatial resolution of 5.8mts, the following observations are made: -

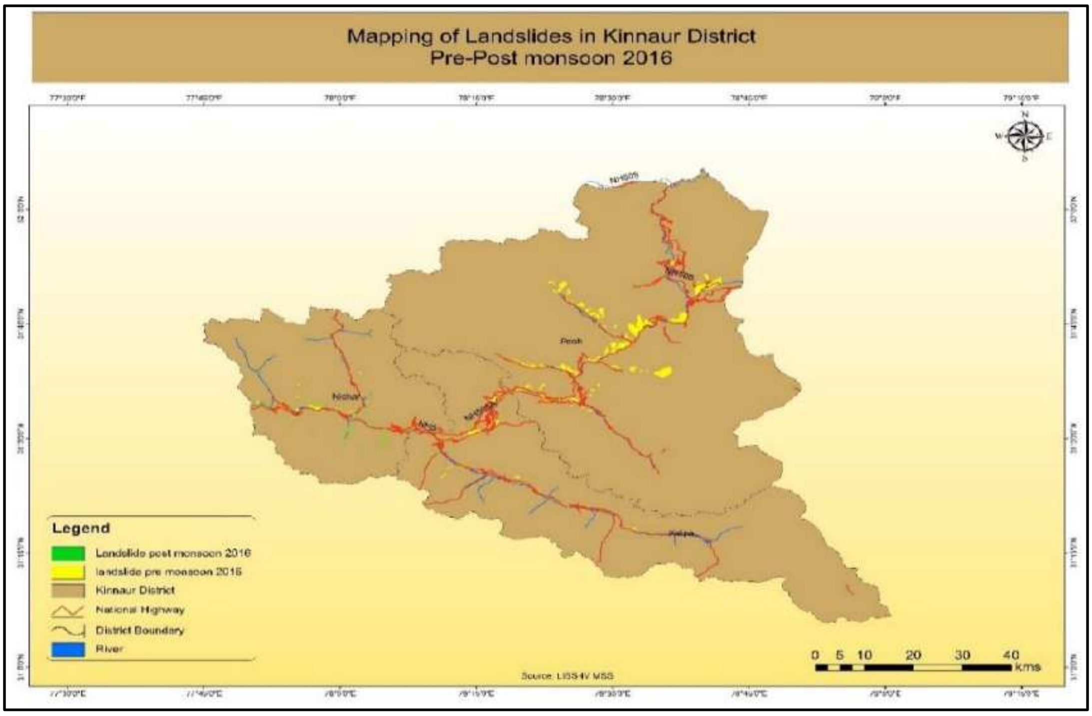
- The accumulated water in the lake depression seems to be flowing through the peripheral sides, with some water on the upstream side.

- The central part is comparatively free from any accumulation except a small portion on the downstream side where some accumulation could be seen.
- The inflow and the outflow seem to be normal.
- Two landslides could be observed along the river course one on the upstream side of the depression on the left bank of the Parechhu River and the second on the downstream side of the depression on the right bank of the Parechhu River.
- Along the river course on the downstream side, slight accumulation of water could be seen which may have been resulted due to the encroachment of the landslide in the river course on the right bank.
- The landslide on the left bank on the upstream side also seems to be encroaching the river course, but no significant change in the river flow could be seen.
- The region is now observed to be well connected because of the developmental activities like road network developed in the area.
- Based on the satellite data interpretation, there does not seem to be any threat from the Parechhu Lake as on day but needs regular monitoring till its freezing.

2. VULNERABILITY AND RISK ANALYSIS OF GEO-HAZARDS IN HIMALAYAN REGION

The vulnerability of the geologically young and not so stable steep slopes in various Himalayan ranges, has been increasing at a rapid rate in the recent decade due to inappropriate human activity like deforestation, road cutting, terracing and changes in agriculture crops requiring more intense watering etc. Kinnaur is a mountainous district having rugged topography and deep and narrow valleys and steep slopes which make it very prone to different types of slope failure namely Land sliding, Slumping/Creeping, Rock fall, Shooting Stones, etc. The main objective of the present work was to carry out landslide hazard zonation mapping using LISS-IV Data during 2004-2016 in the pre and post monsoon period. Major landslides have been marked along the Hindustan -Tibet Road and also it is observed that most of the landslides have been occurred due to the ongoing developmental process like road widening etc. Besides this, the areas which seem to be highly dissected comprising of unconsolidated glaciated sediments have been taken as the major landslide prone zones along which landslides can activates in future also. The important landslides of the district are Malling landslide, Dubling landslide, Spillow landslide, Khadra Dhaank landslide, Lippa landslide, Pangi Nala landslide, Powari landslide, Sapni landslide, Brua landslide, Kuppa landslide, Urni landslides, Sholding landslide, Nathpa landslide etc. Based on the interpretation of the LISS IV satellite data products during pre and post monsoon period, the following observations are made:

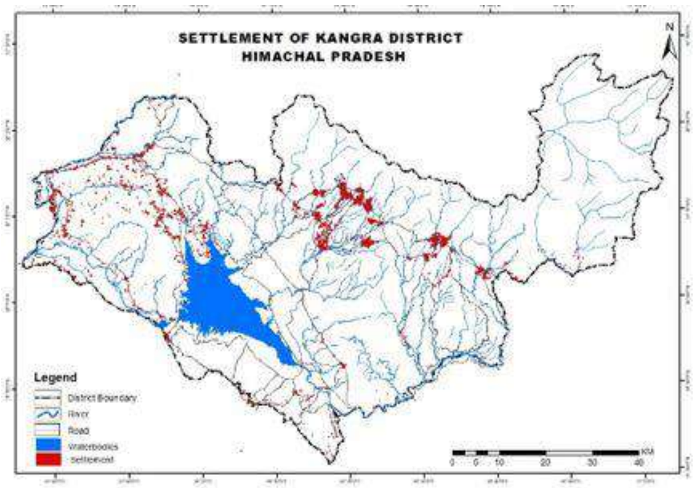


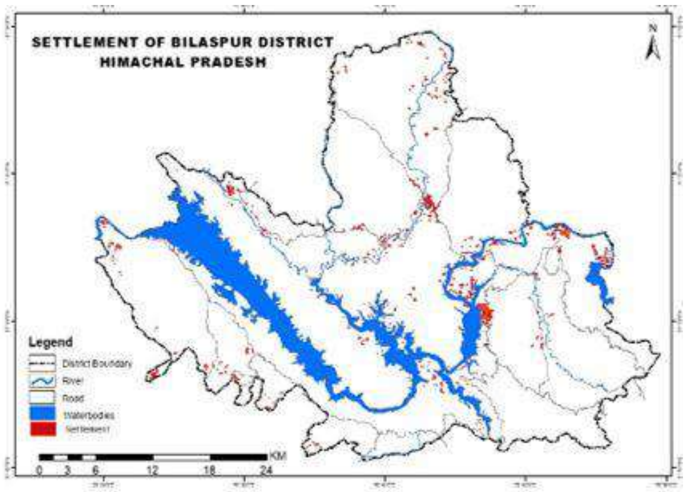


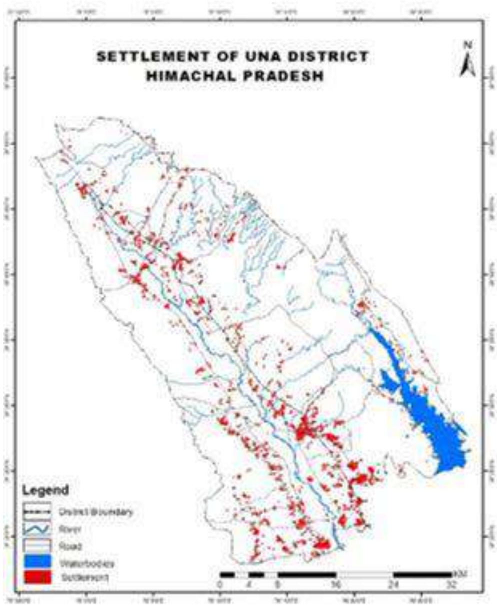
The results have been compiled within the three Administrative Blocks of the District i.e., Nichar, Kalpa and Pooh Blocks. In the Nichar Block which comprises of the areas close to the bordering district of Shimla, the landslides that could be mapped in this part are mainly along the right bank of Satluj River, where the slopes are generally on higher side and the down cutting of the hill slope has resulted into the occurrence of few landslides/landslips reaching up to the river bed. Another major reason for the occurrence of landslides or the landslips is the deposition of the material which has been excavated from the upper catchments where some developmental activities are being carried out and the material has been dumped along the hill slope which further accelerates the erosional process. As far as the landslide and the landslide prone zones in the Baspa valley are concerned, majority of the landslides and landslide prone zones are mainly confined along the right bank of the Baspa River on the downstream of Sangla village. Besides this, few landslides comprising of scree deposits have also been marked upstream of Sangla along the right bank of the Baspa river. Few landslides have also been observed on the left bank in the downstream of Sangla near the confluence of the Baspa and Satluj River. Further northwards in the Pooh Block, most of the landslides /landslide zones have been marked along the Hindustan-Tibet national Highway on the right bank of the Satluj River. Along the Taiti Garang and Ropa Gad, again the landslides are along the road axis and majority of them area on the left bank of these steams which joins the Satluj River on its right bank. Further northwards few landslide zones have also been marked in Pooh area along the highway. The geological setup of the pooh Block mainly comprising of the Granitic rocks which are overlain by garnetiferous micaceous quartzites grading into schist belong to the Salkhla Group which are further overlain by the slates and phyllites of the Batal Group. Along the road section, the region has become highly fragile due to the fractured nature of the rocks and developmental activities with the results the region is highly dissected and is prone for different erosional processes of mass movement. To summarise it is observed that majority of the landslides in Kinnaur district are along the road axis and supported by the phyllites/schists and granitic rocks. The region where the phyllites and schist are highly fractured in nature and by virtue of the dissected nature, the region is highly prone for erosional activity. Besides this, the agriculture activity in some of the areas has also resulted to increase the pore pressure of the underlying meta sediments resulting undergo erosional processes to have major landslides like Powari and Urni landslides.

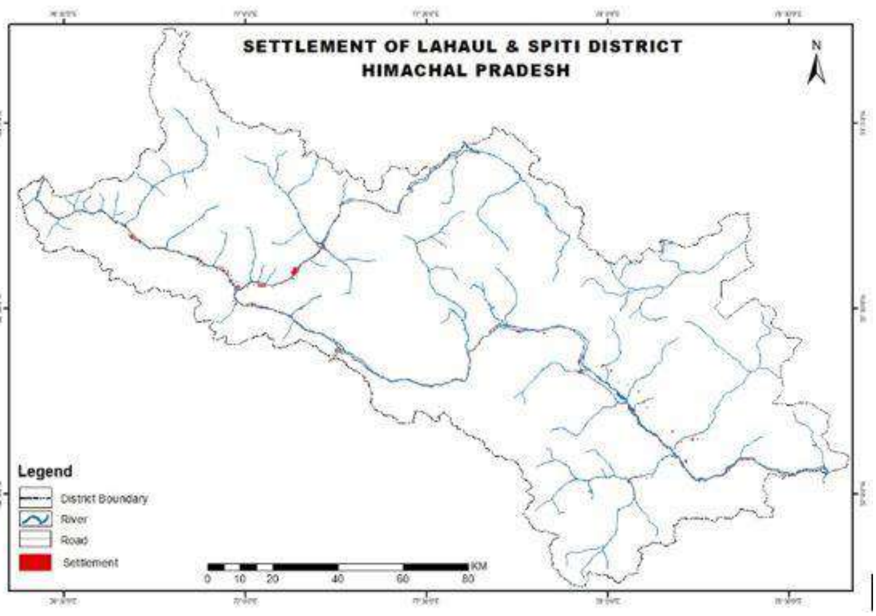
3. STATUS OF GEO-RESOURCES AND IMPACT ASSESSMENT OF EXO-GENIC GEOLOGICAL PROCESS ON NW-HIMALAYA ECOSYSTEM

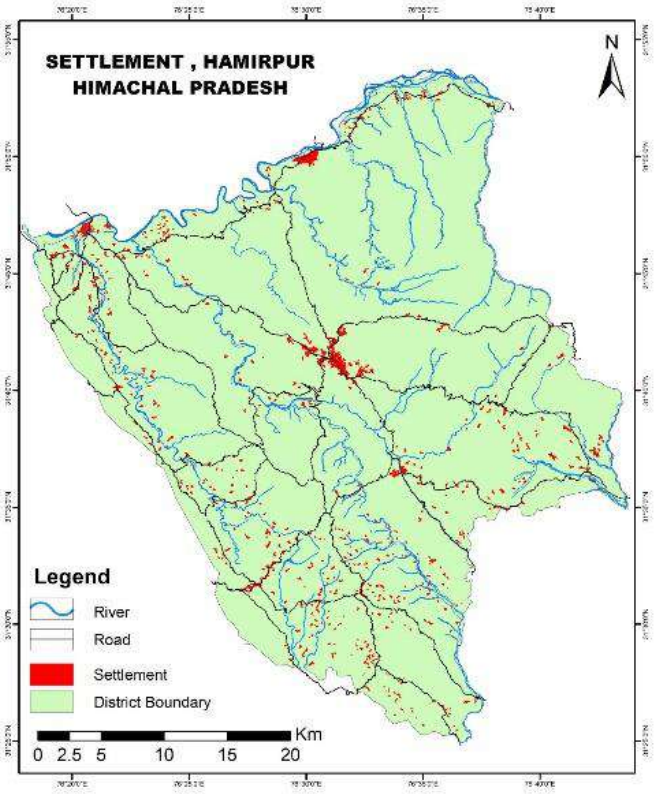
District-wise Mapping of Settlement: Generation of Geodatabase of Settlement in the Quaternary deposits location district wise of Himachal Pradesh from High resolution satellite Imageries.



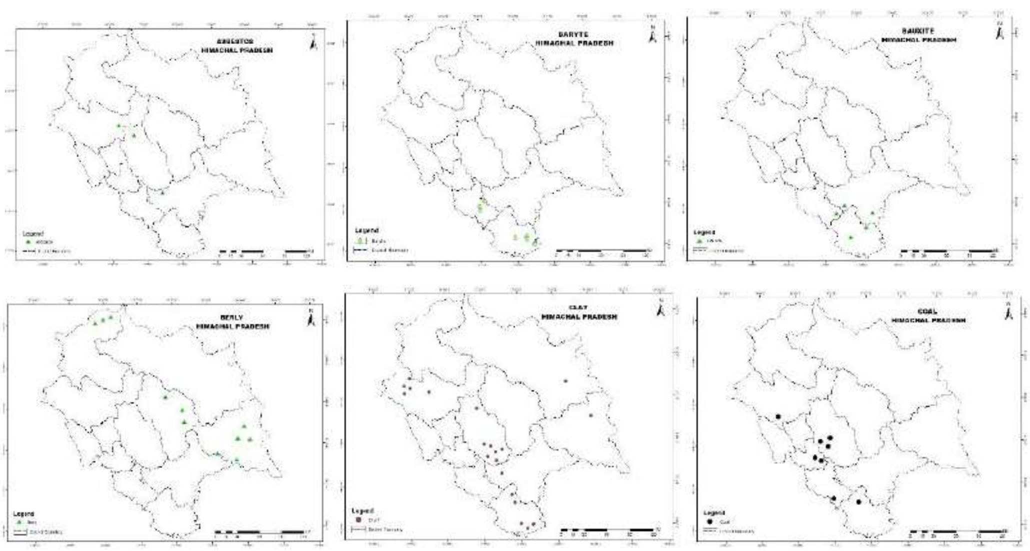


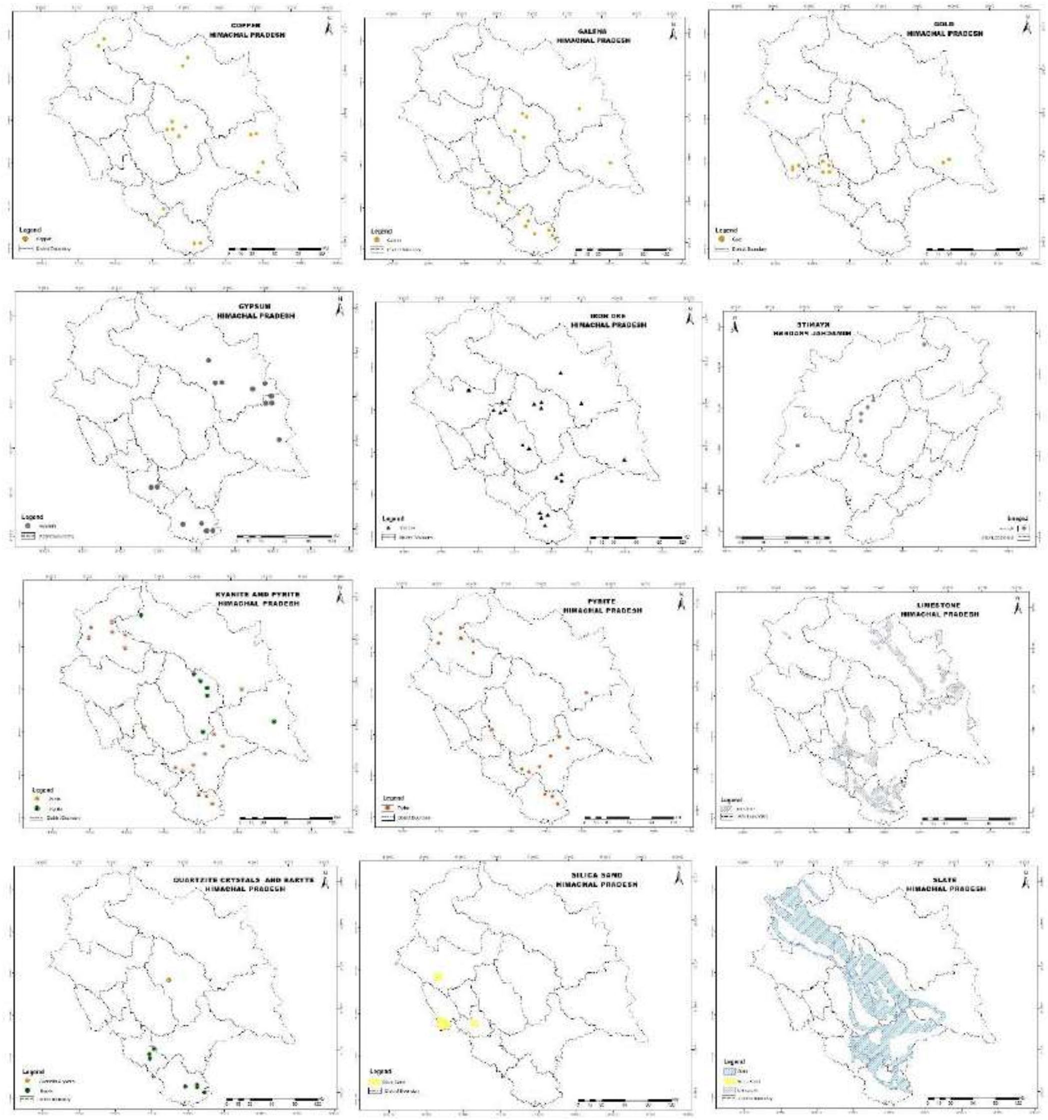






MINERAL RESOURCES: Generation of Geodatabase of Mineral Resources of Himachal Pradesh from High resolution satellite Imageries.





Snow Cover Mapping of Ravi Basin of different months from September to July and Different Years 2014-15, 2015-16, 2017-18, 2018-19 and 2019-20. (Conversion of Projection from polyconic to UTM, Conversion of Raster Data into Vector, Reclassifying the data, Computation of Area and Mapping).

4. GLACIAL LAKE OUTBURST FLOODS (GLOFS)

INVENTORY OF MORAINE DAMMED GLACIAL LAKES (GLOFS) IN SATLUJ, BEAS, CHENAB AND RAVI BASINS IN HIMACHAL PRADESH USING IRS LISS III AND LANDSAT 8 SATELLITE DATA FOR 2019

The comparative analysis based on the results obtained from the analysis of LISS III data products during 2019 have been done with that of results obtained from 2018 for all the total number of lakes and the lakes with area more than 10ha in each basin i.e., Spiti basin (Basin 1), Lower Satluj basin (Basin 2) and Upper Satluj Basin (Basin 3). Based on the LISS-III satellite data analysis (96-48,96-49,97-48,97-49,98- 48,98-49,99-49,100-49 and 146-38) for 2019, a total of 562lakes have been delineated comprising 458 lakes as the small one with area less 5ha, 53 lakes with area 5- 10ha and 51 lakes with area more than 10ha. Maximum number of lakes mapped from LISS III data falls in the path-row96-48(153) and 99-49(238). Further out of 562 lakes mapped, 62 are mainly the high-altitude wetlands comprising 1 from Spiti basin, 1 from Lr. Satluj and 60 from the Upper Satluj basin. The comparative analysis based on LISS-III satellite data reveals that total number of lakes varies from 581(2016) to 642(2017) to 769(2018) and 562 (2019) indicating an overall increase of about 10%between 2016-17, and about 19% between 2017-18 and reduction of about 26% between 2018-19 respectively. As far as the big lakes with area more than 10ha are concerned, total number of big lakes varies from 55 (2017) to 49(2018) to 51(2019) indicating a fluctuating trend in the lakes with area >10ha.The total variation in the number of lakes mapped in Upper Satluj basin based on LISSS III data varies from 443(2016) to 450(2017) to 495(2018) to 437(2019), in Lower Satluj basin the number varies from 72(2016) to 102 (2017) to 98(2018) to 52(2019) and in case of Spiti sub basin it varies from 66(2016) to 90(2017) to 176(2018) to 73(2019) indicating about 1%increase (2016-17) and about 10% (2017-18) and a reduction of about 11% (2018-19) in case of Upper Saltuj basin, 41% increase between (2016-17) and about 2% reduction (2017-18) and a reduction of about 46% (2018-19) in case of Lower Satluj and about 36% increase between 2016-17 and about 95% increase between 2017-18 and a reduction of about 58% (2018-19) in case of Spiti basin could be seen. Further in Spiti basin the lakes with Ids 1682RS(0.40ha), 1683RS(1.09ha), 1684RS (1.95ha),1685RS (1.44ha), 1686RS (1.59ha) and 1687RS (1.57ha) are some of the water bodies which have been developed along the nala section coming along the village Chicham just upstream of Kaza on the left bank formed in series. All these water bodies are although small but needs monitoring. Thus, from the above analysis, it is clear that although the maximum number of lakes are being formed in the Upper Satluj basin of the study area, but the reduction in the total number of lakes could be seen in all basins which is mainly due to the non-availability of good quality snow free and cloud free LISS III satellite date coverage during 2019.

Thus, to summaries based on the results obtained by using AWIFS and LISS III data products, the results obtained using AWIFS indicates an overall reduction of about 16% in total number of lakes mapped in 2019 in comparison to 2018 reflecting 40% reduction in case of Spiti basin, 53% from Lower Satluj and 10% from the Upper Satluj basin and the maximum lakes (89%) of the total229 have been mapped from Upper Satluj, 3% and 7% from Lower Satluj and Spiti basins respectively. In case of the bigger lakes with area >10ha, a reduction of about 55% could also be seen in 2019(31) in comparison to 2018(69) with majority of the lakes (30) forming part of the Upper Satluj basin, 0 from the Lower Satluj basin and 1 from the Spiti basin, out of which 11 are the high-altitude wetlands and the remaining 19 are from the glacial origin. Besides this on 5 November 2019, where in total 116 lakes have been mapped, out of which 51 lakes are with area more than 10ha comprising 17 lakes as the high-altitude wetlands and the remaining 34 are the lakes from glacial origin as a whole in the entire study area. Likewise, LISS-III data indicates a decrease of about 26% in terms of the total number of lakes with about 4% increase in case of the lakes with area more than 10ha. The comparative analysis based on LISS-III satellite data reveals that total number of lakes varies from 581(2016) to 642(2017) to 769(2018) and 562 (2019) indicating an overall increase of about 10% between 2016-17, and about 19% between 2017-18 and reduction of about 26% between 2018-19 respectively. Thus the data base based on AWIFS data product is reflects a complete inventory of lakes in the Satluj catchment with a coarse resolution (56mts) as the data product used covers the complete study area and also free from the impact of clouds as well as not much snow could be seen on 3rd October 2017, whereas the LISS-III data products reflects a more detailed inventory of the lakes with a set of fine resolution(23.5mts) reflecting more detailed information about the lakes with small dimensions.

Table 16 Distribution of lakes in different sub basins in Himachal Pradesh based on LISS III satellite data analysis for 2019.

	Name of the basin	No. of lakes with area >10ha	No. of lakes with area between 5-10 ha	No. of lakes with area <5ha	Total No. of lakes
1.	Chenab	04(2018) 05(2019)	10(2018) 11(2019)	240(2018) 226(2019)	254(2018) 242(2019)

	Bhaga	01(2018) 02(2019)	04(2018) 03(2019)	79(2018) 46(2019)	84(2018) 51(2019)
	Chandra	02(2018) 02 (2019)	03(2018) 03(2019)	59(2018) 47(2019)	64(2018) 52(2019)
	Miyar	01(2018) 01(2019)	03(2018) 05(2019)	102(2018) 133(2019)	106(2018) 139(2019)
2.	Beas	03(2018) 04(2019)	04(2018) 4(2019)	58(2018) 85(2019)	65(2018) 93(2019)
	Jiwa	00(2018) 00(2019)	00(2018) 00(2019)	15(2018) 41(2019)	15(2018) 41(2019)
	Parvati	03(2018) 03(2019)	01(2018) 02(2019)	23(2018) 32(2019)	27(2018) 37(2019)
	Beas	00(2018) 01(2019)	03(2018) 02(2019)	20(2018) 12(2019)	23(2018) 15(2019)
3.	Ravi	03(2018) 01(2019)	02(2018) 02(2019)	61(2018) 34(2019)	66(2018) 37(2019)
4.	Satluj	49(2018) 51(2019)	57(2018) 53(2019)	663(2018) 458(2019)	769(2018) 562(2019)

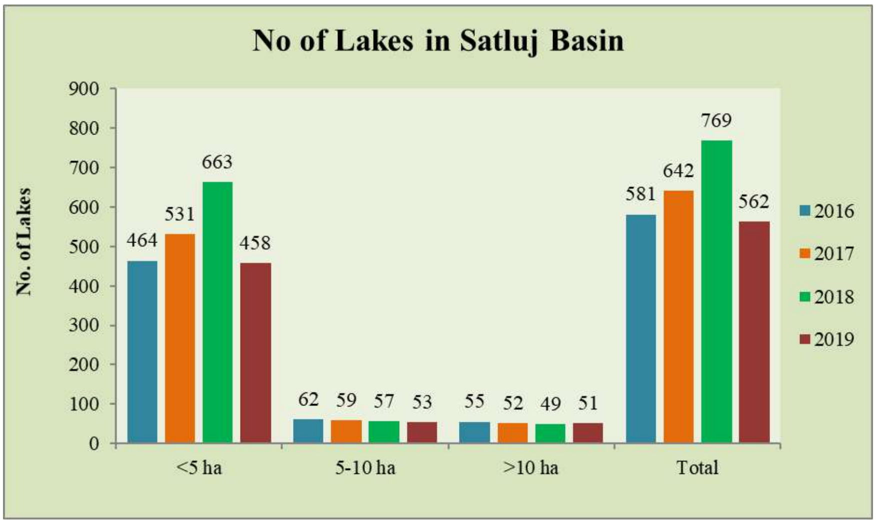


Figure 16 Distribution of lakes in Satluj basin

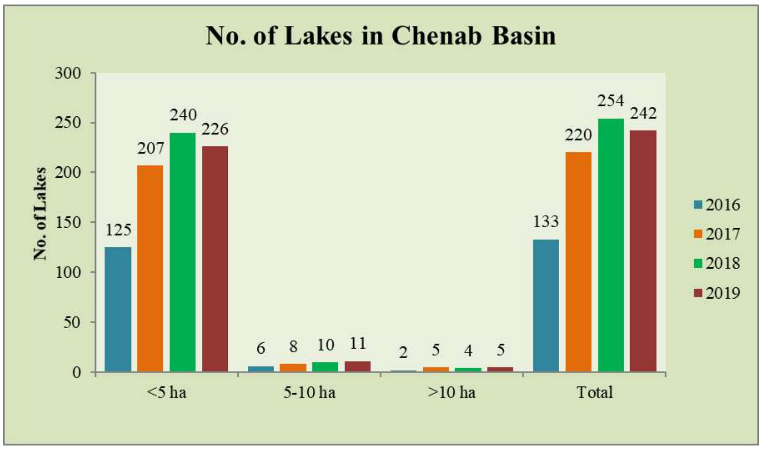


Figure 17 Distribution of lakes in Chenab basin

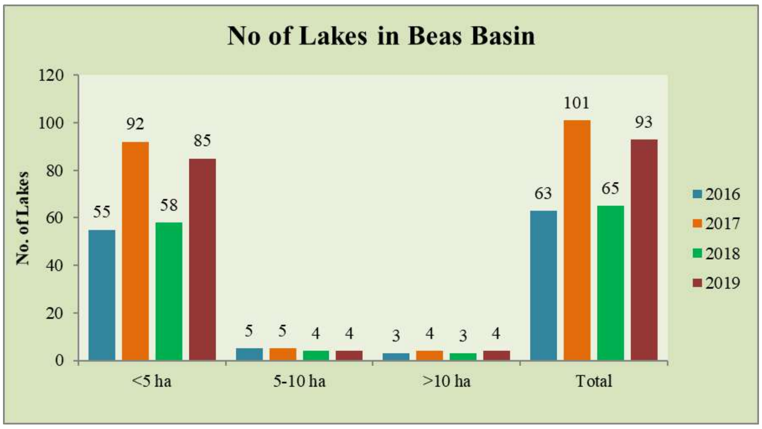


Figure 18 Distribution of lakes in Beas basin

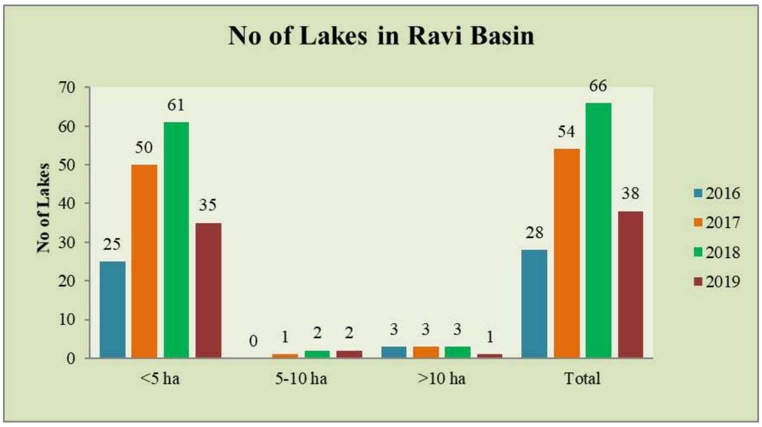


Figure 19 Distribution of lakes in Ravi basin

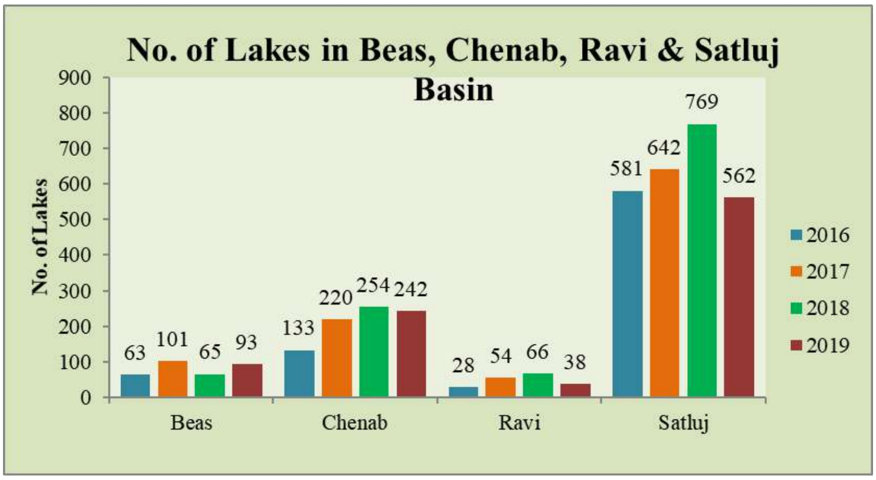


Figure 20 Distribution of lakes in Chenab, Beas, Ravi & Satluj basin

DISTRIBUTION OF LAKES WITH AREA MORE THAN 10HA

Based on the satellite data interpretation for the year 2019, the study area has been studied to understand the temporal variation of all such lakes with area more than 10ha. In Satluj basin the total number of such lakes has increased from 40(2013) to 42(2015) to 55(2016) to 52(2017) to 49 (2018) to 51 (2019) respectively based on LISS III satellite data. Likewise in other basins, i.e., in Chenab, the number of lakes varies from 3(2013) to 4(2015) to 2(2016), 5(2017) to 4(2018) and 5(2019). In Beas basin the number varies from 2(2013) to 2(2015) to 3(2016) to 4(2017) to3(2018) and 4(2019). In the Ravi basin, the number of lakes varies from 2(2013) to 3(2015) to 3(2016) to 3(2017) and 3(2018) respectively. The lakes with HWL are mainly the high-altitude wetlands in high altitude regions.

Table 17 Distribution of lakes with area more than 10ha in different sub basins in Himachal Pradesh based on LISS III satellite data analysis.

Sr. No.	Lake Id.	2015	2016	2017	2018	2019
Bhaga						
1	6	----	6.21	10.23	9.92	10.94
2	11	10.39	7.92	9.84	11.21	10.40
Chandra						
3	1	90.51	90.18	115.51	95.03	98.68

4	3	151.42	131.58	179.64	160.99	162.07
Miyar						
5	209	----	----	16.08	15.06	15.97
Jiwa						
	----	----	----	----	----	----
Parvati						
1	21	12.68	13.81	12.88	13.14	14.56
2	26	13.52	11.28	15.47	13.82	15.21
3	50	----	10.01	14.58	13.30	11.83
Upper Beas						
4	6	----	7.54	10.86	9.82	10.47
Ravi						
1	10	16	12.05	14.42	14.63	???
2	16	30.97	27.28	34.50	11.35	
3	31	11.72	11.2	12.16	12.38	
Satluj						
1	49HWL	23	----	----	38	24.58
2	67	12	13.04	8.06	8	24.58
3	85	----	----	----	----	34.89
4	86	9	10.88	10.11	10.06	10.10
5	87	9	10.06	9.38	10.5	10.41
6	99	19	18.37	17.12	18.8	14.72
7	101	24	24.65	21.37	22.8	21.10
8	122	7	16.16	15.34	16.5	16.86
9	173	3	9.32	7.65	----	13.20
10	184	----	----	----	----	23.32
11	209	33	36.38	----	----	33.76
12	145(HWL)	41584	41646.22	41498.50	41233.9	41640.43
13	179	25	26.26	25.07	25.6	24.26

14	184	27	19.51	19.15	25.5	19.96
15	210(HWL)	57	64.32	59.43	59.17	63.72
16	894	10	----	9.90	9.7	10.15
17	1063HWL	45	39.79	----	----	44.09
18	138(HWL)	26065	26538.79	25891.56	25634.8	25920.91
19	178	205	190.71	204.05	206.39	201.14
20	181	13	13.72	18.07	19.28	12.39
21	1093(HWL)	5515	5676.31	5787.38	5854.36	5992.49
22	1094HWL	16	13.83	12.82	12.62	14.85
23	1128	23	24.45	23.95	25.14	25.00
24	1133	17	15.23	16.09	15.86	16.18
25	1153	63	64.41	66.74	69.2	74.10
26	1155	16	16.38	16.14	17.47	14.27
27	1156(HWL)	11	11.85	11.56	11.69	11.74
28	1164	15	15.12	14.94	14.86	16.08
29	1092HWL	----	14.69	13.63	----	14.13
30	1363HWL	----	28.25	17.77	----	22.24
31	1375HWL	----	47.91	43.26	----	28.96
32	1510	----	54.52	54.37	54.38	52.93
33	1512	----	23.53	23.62	24.23	21.47
34	1518	----	13.78	12.53	14	12.19
35	1527	----	11.17	10.47	11.43	11.37
36	1548	----	17.95	14.62	19.91	17.41
37	1557RS	----	69.88	96.36	80.87	92.85
38	1349HWL	----	352.60	292.13	322.95	335.79
39	1095(HWL)	----	17.26	14.31	15.58	17.22
40	1565	----	16.38	18.11	17.36	19.13
41	1566(HWL)	----	22.81	24.35	18.76	10.77
42	1782(HWL)	----	----	----	29.1	30.65

43	1774RS	----	----	----	11.69	12.93
44	1771RS	----	----	----	12.22	14.99
45	1776RS	----	----	----	----	13.98
46	1654	----	----	----	----	22.28
47	2180	----	----	----	----	23.56
48	1039HWL	----	----	----	----	12.16
49	1144HWL	----	----	----	----	89.47
50	2167HWL	----	----	----	----	214.31
51	1146	----	----	----	----	10.60

(HWL-High Altitude Wetlands) (RS-River Section)

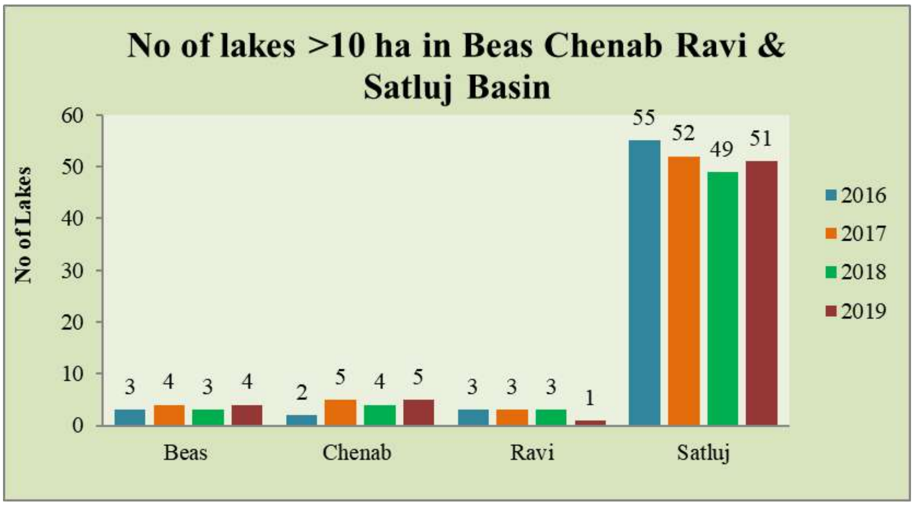


Figure 21 Distribution of lakes with area>10 Ha in Chenab, Beas, Ravi & Satluj basin in 2016, 2017, 2018 & 2019

CONCLUDING REMARKS

Based on the IRS-RS2-LISS-III satellite data having spatial resolution of 23.5mts and Landsat 8 MSS satellite data having spatial resolution of 30mts for the year 2019, the study area was analyzed in order to make an updated inventory of moraine dammed glacial lakes known as GLOFs (Glacial Lake Outbursts Floods) in Himachal Himalaya comprising the Satluj, Chenab, Beas and Ravi basins. The Satluj basin has been studied in detail right from its origin from the Tibetan Himalaya, whereas the other basins have been analyzed for their areas of interest in Himachal Pradesh. The results based on the analysis thus obtained reveals that in Satluj basin, a total of 562 lakes from the Satluj catchment covering 8 satellite imageries (96-48,96-49,97-48,97-49,98-48,98-49,99-49,100-49) having spatial resolution of 23.5 mts. have been mapped during 2019.

Further based on the LISS-III satellite data analysis for *2019 in Satluj basin, a* total of 562 lakes have been delineated out of which about 81% (458) lakes are the small one with area less than 5ha, about 9% (53) falls within the aerial range of 5-10ha and about 9% (51) are the big one with area more than 10ha. The comparative analysis based on LISS III data reveals that total number of lakes in the Satluj catchment varies from 642(2017) to 769(2018) to 562(2019) reflecting an overall increase of about 19% between 2017-18 and a reduction of about 26% between 2018-19, which is mainly due to the non-availably of good quality LISS III data products in 2019. Out of the 562 lakes/wetlands mapped in 2019 using LISS III satellite data, basin 1 i.e., Spiti basin constitutes about 12% (73) of the total lakes mapped (562) which is about 58% less than 2018 (176). Likewise, basin 2 i.e., the Lower Satluj basin constitutes 9% (52) of the total lakes mapped which is about 46% less than 2018 (98) and the Upper Satluj basin i.e., the basin 3 constitutes of 77% (437) lakes in 2019 which is about 11% less than 2018 (495).

As far as the big lakes based on LISS III satellite data is concerned, the analysis reveals that the number varies from 52 (2017) to 49(2018) to 51(2019) reflecting an overall increase of about 4% between 2018-19.The Parechhu Lake in the Tibetan Himalayan Region was also monitored separately during the ablation period of 2019 and does not show any major change in its water spread and seems to be stable based on the observations made which have been reported to SJVNL as well as to the Government during 2019. Besides this, the landslide on the upstream side of the lake depression was also monitored in order to assess any change in the water level by virtue of the landside which may block the river course causing major threat like that of the Parechhu formation during the year 2004.

Along the course of main Satluj River, few isolated pockets have also been observed which shows accumulated water in the upper catchment of the Tibetan Himalayan Region and within the Spiti basin i.e., sub basin 1. In Spiti basin the lakes with Ids 1682RS(0.40ha), 1683RS (1.09ha), 1684RS (1.95ha), 1685RS (1.44ha), 1686RS(1.59ha) and 1687RS(1.57ha) are some of the water bodies which have been developed along the nala section coming along the village Chicham just upstream of Kaza on the left bank formed in series All these water bodies are although small but needs monitoring as this is along the river course and can cause major damage in case if it bursts. Thus, the lakes/water bodies coded with abbreviation *RS with their IDs* are some of the locations where accumulated water could be seen and these are the permanent features which needs regular monitoring in order to assess any temporal change in their behavior in the time to come.

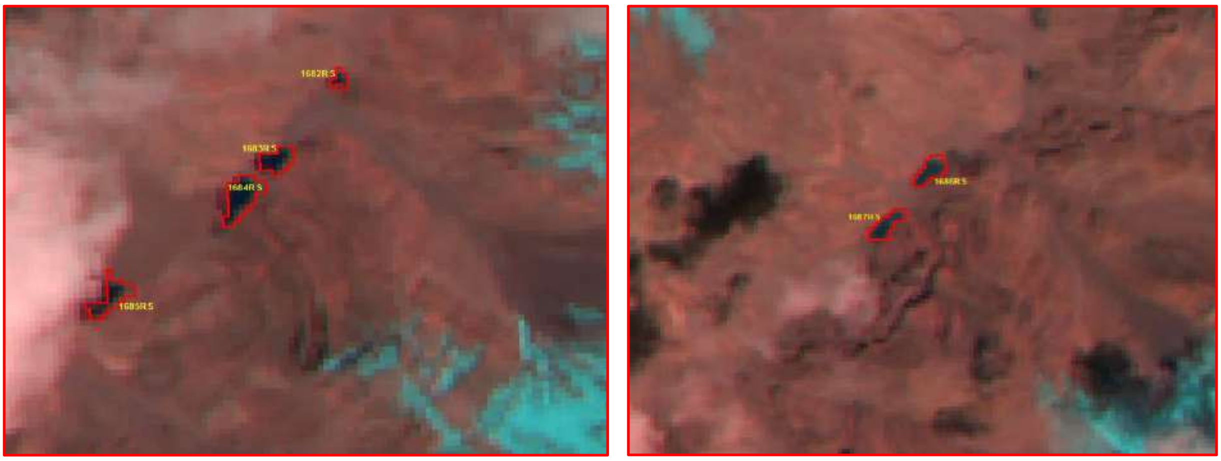
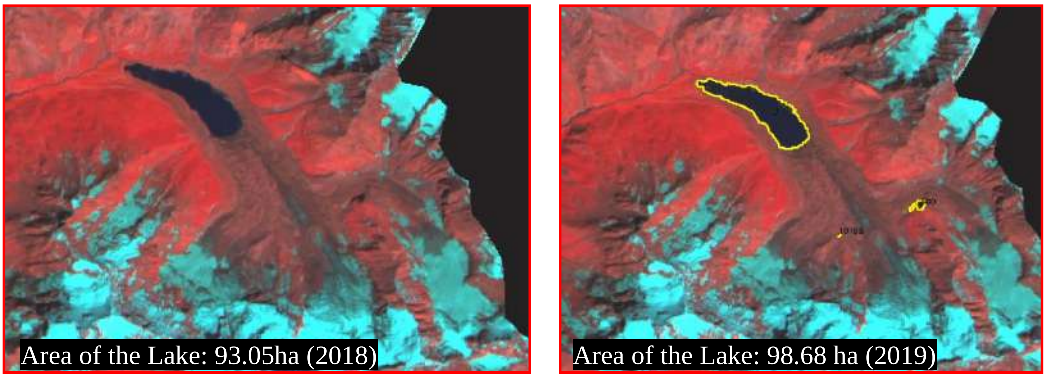


Figure 22 Accumulation of water along river course in Spiti basin

The Chenab basin comprising mainly of (Chandra, Bhaga, Miyar) as sub basins has a total of 242 lakes (2019) comprising (52lakes in Chandra sub basin, 84 lakes in Bhaga sub basin and 139 in the Miyar sub basin) respectively. Thus, the Chenab basin as a whole has 242 (2019) lakes in comparison to 254 lakes (2018),220 (2017),133(2016), which is about more than four times than the lakes which were identified earlier using 2001 (55) satellite data (Randhawa et.al. 2005) and about 81% increase w.r.t 2016 and about 10% increase with that of 2017 and about 4% decrease with respect to 2018, which may be due to the data quality in 2019. When these 242 lakes seen based on their aerial range, it has been found that maximum lakes (226) fall in the category where the area is less than 5 hectare, 11 lakes where area is between 5-10 hectare and only 05 where area is more than 10 hectare indicating increase of 25% in case of bigger lakes i.e., lakes with area more than 10ha and 10% increase in case of the lakes with area between 5-10ha w.r.t 2017 and a decrease of about 6% in case of the lakes with area less than 5 ha. to 13.6 indicates some of the pictures of the lake formation in different sub basins of Chenab basin as per the satellite image, which needs regular monitoring in order to assess any change in their behavior.

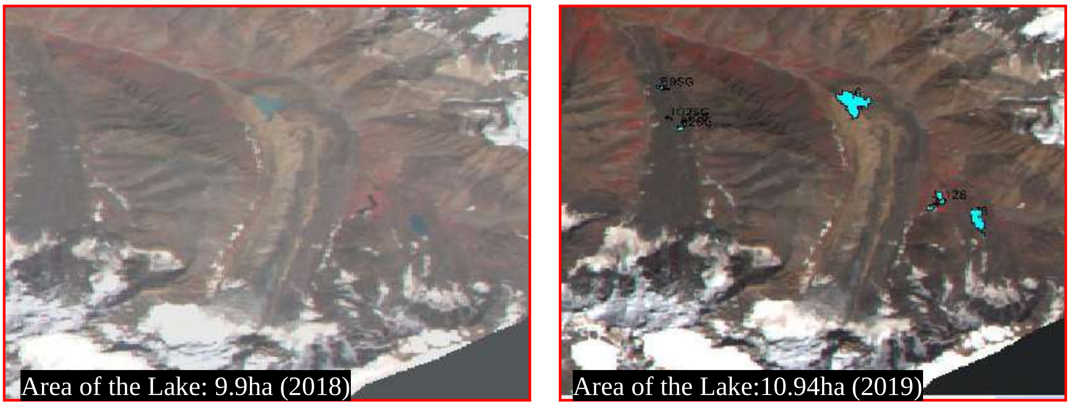


Potentially vulnerable lake having a deep-water column

Figure 23 Moraine dammed lake formation at Geepang Gath Glacier Snout in Chandra Basin

Potentially vulnerable lake having comparatively shallow water column

Figure 24 Moraine Dammed Lake Formation at the Snout of Samudri Tapu Glacier



Potentially vulnerable lake having a good water column

Figure 25 Moraine Dammed Lake Formation at the Glacier Snout in Bhaga Basin

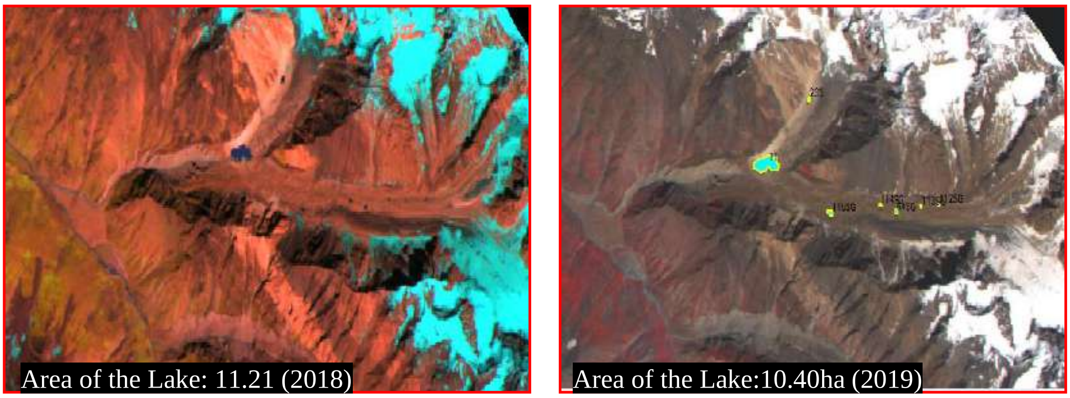
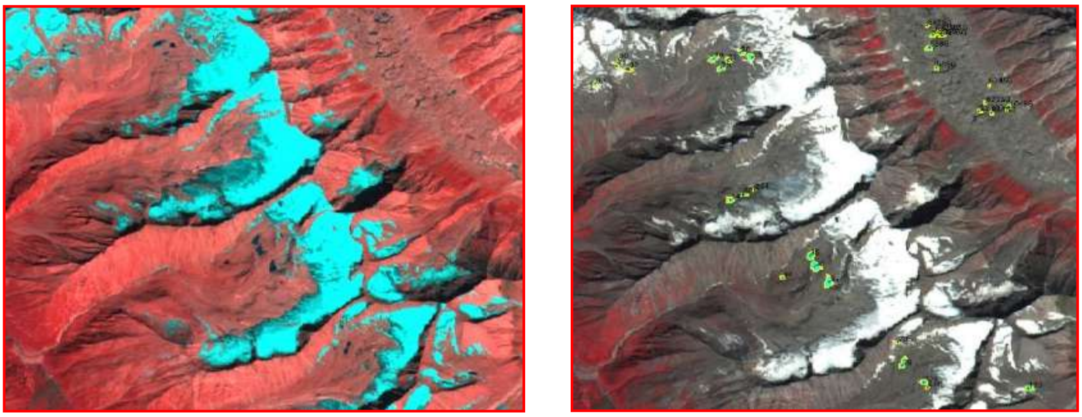


Figure 26 Moraine Dammed Lake Formation at the Glacier Snout in Bhaga Basin



Lake formation in front of the glacier in Miyar basin. The high frequency indicates the effect of climate change in the valley

Figure 27 Moraine Dammed Lake Formation at the Glacier Snout in Miyar Basin

The Beas basin (Upper Beas, Jiwa, Parbati), has a total of 93 lakes comprising (12 lakes in Upper Beas, 41 lakes in Jiwa and 37 lakes in Parvati sub basins) have been delineated during the year 2019 indicating an increase of about 43% as mapped in 2018 although the cloud cover in case of Jiwa and Upper Beas sub basins was on higher side as a result of which the area is not fully exposed. Further analysis of these 93 lakes reveals that 85 lakes are smaller one having area less than 5 hectare, 04 lakes with aerial range between 5-10 hectare and 04 lakes which are having area more than 10 hectare in 2019 indicating an overall increase of about 46% in case of the lakes with less 5ha and about 33% increase in case of the bigger lakes with area more than 10ha in comparisons to 2018, whereas the lakes with area 5-10 ha does not show any change. Likewise in Ravi basin, a total of only 37 (2019) could be mapped in comparison to 66 lakes which were mapped in 2018 in comparison to 54 lakes that of 2017. When seen based on aerial distribution, it is found that 02 lakes are having area between 5-10 hectare and 35 lakes are such which have area less than 5 hectare

As far as the temporal variation of all such lakes with area more than 10ha is concerned, there has been a considerable increase in their total number in Satluj basin i.e., the total number of such lakes varies from 55(2016) to 52(2017) to 49(2018) and 51(2019) respectively. Likewise in other basins, i.e., in Chenab, the number of such lakes varies from 2(2016), 5(2017) to 4(2018) and 5 (2019), in Beas basin the number varies from 3(2016) to 4(2017) to 3(2018) and 4(2019) and in the Ravi basin, the number of lakes varies from 3(2016) to 3(2017) to 3(2018) and no lake could be seen in 2019 respectively. Thus, it is very important that since these lakes are the big one and needs to be monitored regularly in terms of their spatial behavior, so that any eventuality arising out of these lakes could assessed well in advance in order to a minimize the post disaster effects in the catchments. Besides this, the other category of lakes in each basin with area between 5-10ha are also potential sites which can cause considerable damage in if any one of these bursts.

Based on the above analysis carried out for 2019, it is found that there is a considerable increase in the total number of lakes in each basin with respect to the preceding years which reflects that formation of such lakes i.e., moraine dammed glacial lakes or the lakes due to the melting of Himalayan glaciers in the Higher Himalayan region is on the increasing side. The analysis further reveals that the higher number of smaller lakes i.e., the lakes with area less than 5 hectare indicates that the effect of the climatic variations is more pronounced on the glaciers of the Himalayan region resulting in the formation of small lakes in front of the glacier snouts due to the damming of the morainic material resultant of the melting of the glaciers. The recent tragedy of 2013 in the Uttrakhand Himalaya has also been correlated with the bursting of a lake having a total area of about 08 hectare in front of the snout of the Chorabari glaciers that caused widespread damage in the downstream areas besides the heavy rainfall (Dobhal et.al.2013). Thus, the magnitude of such lakes as far as the destruction is concerned cannot be overruled. Besides this, the lakes with area >10 hectare and the area between 5-10 hectare can be seen as the potential vulnerable sites for causing damage in case of bursting of any one of them. Thus, a proper monitoring of all such lakes is very much essential in the Himalayan region in order to avoid any eventuality like in Uttrakhand in future, which will not only save the precious human lives but also the public and the Govt. property.

GLACIAL LAKE OUTBURST FLOODS (GLOFS):
A CASE STUDY OF GEEPANG GATH GLACIAL LAKE, LAHAUL & SPITI AND CHAMBA DISTRICT, HIMACHAL PRADESH

STUDY AREA

This lake has known by various names. Some call it Ghepan Gath, Geological Survey of India (GSI) people call it Ghepang Gath, Gaddis' call it Ghepan Ka Alyas. Ghepan is the most revered deity of Lahaul Valley that's why he is called Raja Ghepan, the King. A peak by the same name rises above the Sissu village that stands tall like an Emperor. A solitary tower keeping a constant vigil. A massive rock face guarding the valley of Lahaul. A turquoise gem specked with tiny icebergs, hidden away in an unknown valley, encased by barren rocky snow-clad mountains. Enchanting its rare visitors by its pristine looks. Being born of a receding glacier at one end and giving birth to a roaring stream on another. By standing at its shores, one can witness nature at work and impact of climate change. The area of this lake had increased from 27 ha in 1976 to 98.68 ha in 2019. The area which has been investigated comprise of mainly the catchment along the Sissu Nala and the further downstream along the Chenab River by taking an immediate corridor along the valley further downstream up to the district Chamba.

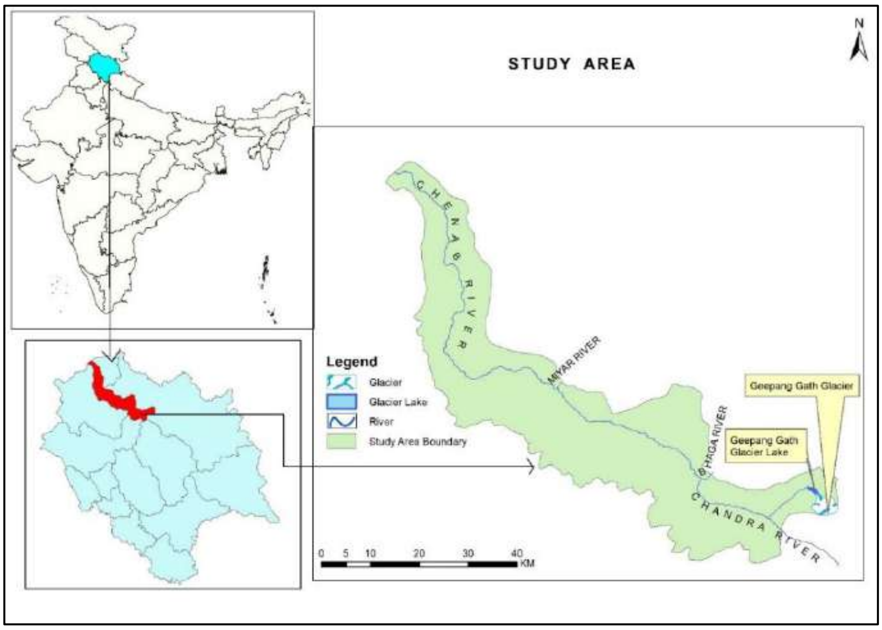


Figure 28 Location Map of the Study Area

The High-resolution Satellite Data Product has been used

a. LISS III (path/ row: 95/48, dated on 19/10/17 and path/ row: 94/47, dated on 07/11/17)

b. SRTM 30-meter Digital Elevation Model (DEM)

ELEVATION AND DRAINAGE

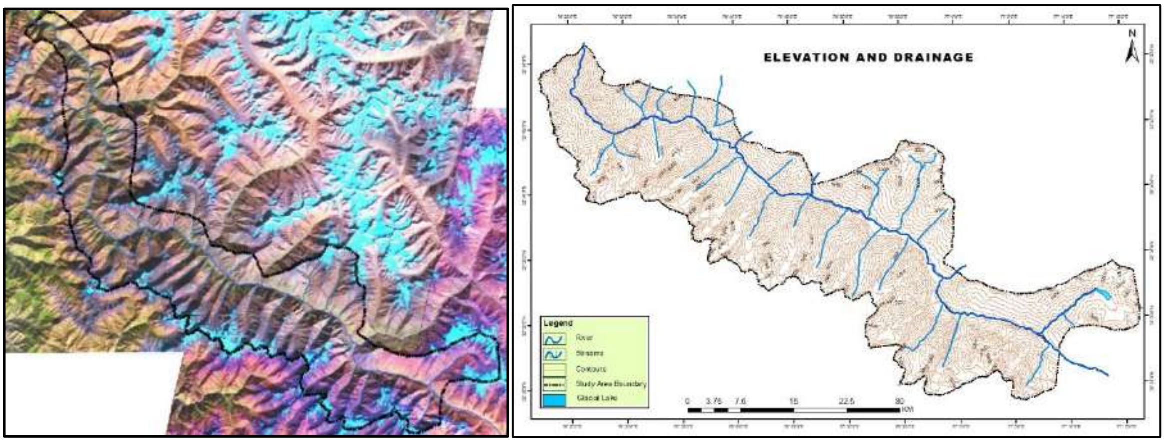


Figure 29 Elevation and Drainage Map

LAND USE LAND COVER (LULC) OF THE DOWNSTREAM OF GEEPANG GATH GLACIAL LAKE

Figure 30 Land Use Land Cover of Geepang Gath Glacial Lake

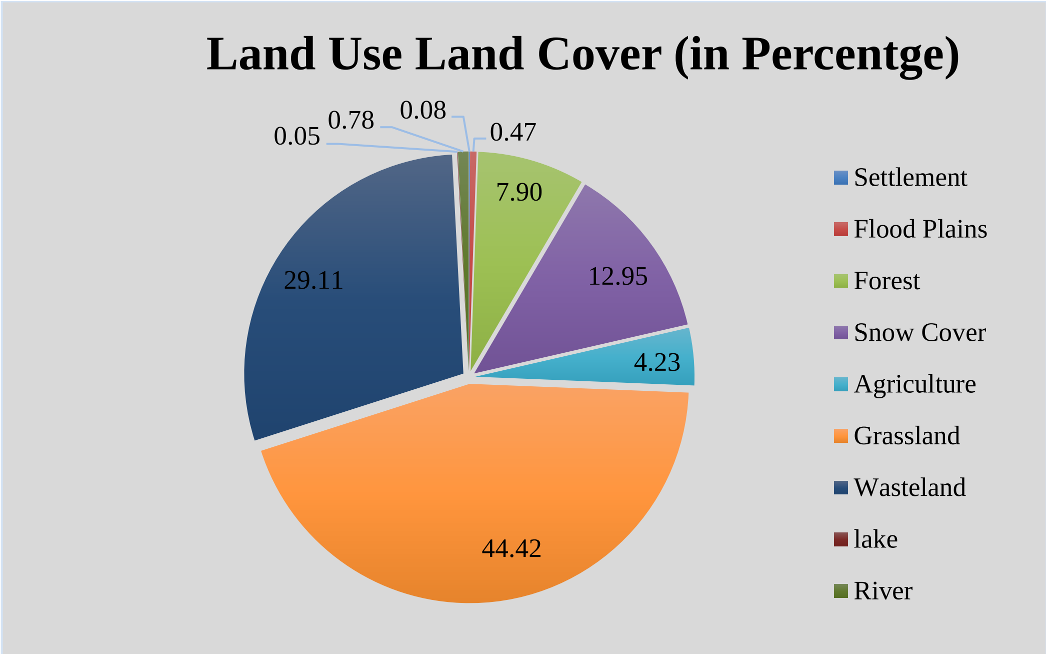


Figure 31 Land Use Land Cover of Geepang Gath glacial lake in Percentage

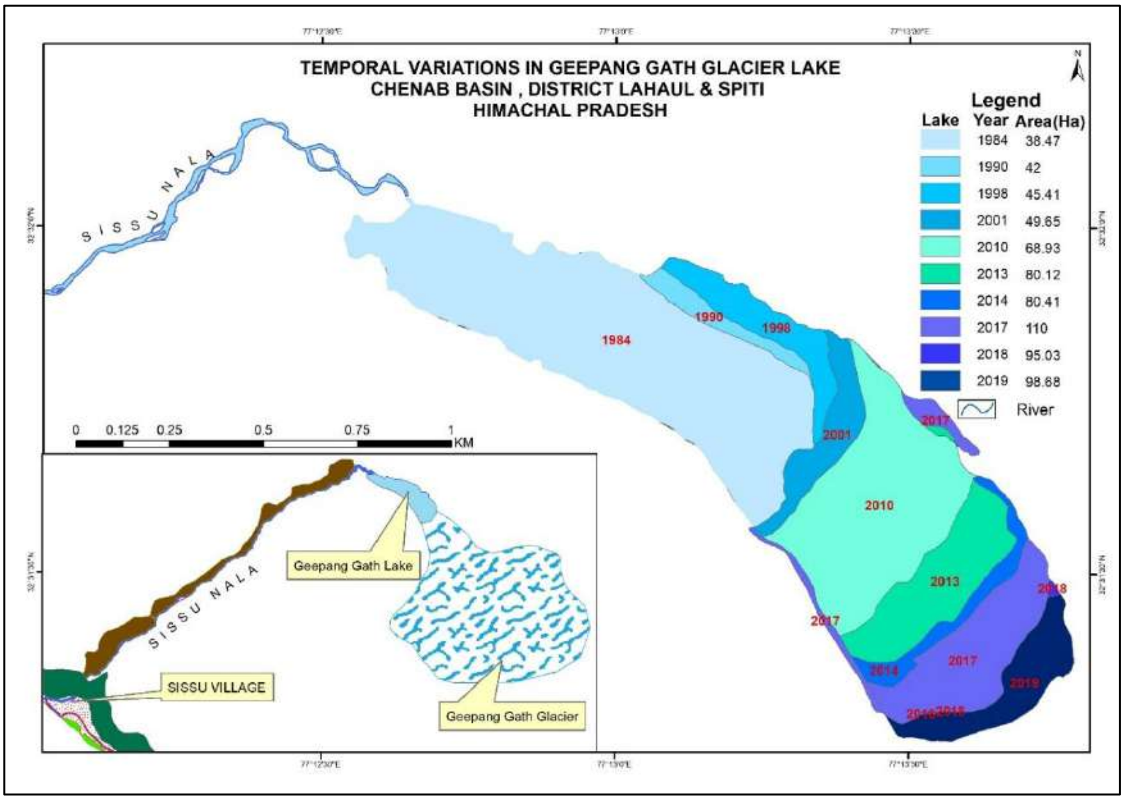


Figure 32 Temporal variations of Geepang Gath glacial lake

FORMATION OF MORAINE DAMMED GLACIAL LAKE AT GEEPANG GATH GLACIER

Geepang Gath is a glacier in the Chandra River basin on the right bank. The Sissu Nala originating from this glacier joins the Chandra River on its right bank near Sissu village in the valley. This glacier is located at an elevation of 4100 meters above mean sea level and the maximum and minimum altitude of the glacier are as 5728 meters and 4170 meters. At the snout of the glacier i.e., at the frontal part of the glacier, a lake has been identified which was also reported by Survey of India as per the Survey of India toposheets with 1:50,000 scale having a total area of 27 ha. (1975). This lake has been formed by virtue of the damming of the morainic material that is why this is called moraine dammed glacial lake or pro glacial lake as it is formed in the front part of the glacier. Thus, glacial lake is defined as water mass existing in a sufficient amount and extending with a free surface in, under, besides, and or in front of a glacier and originating from glacier activities and/or retreating processes of a glacier. As per the Survey of India toposheet, the lake area has been mapped as 27 ha which when seen on the satellite data for its temporal variation over the years, it has been observed that the lake area varies 36.47 ha (1984) to 42 ha (1990) to 45.41 ha (1998) to 49.65 ha (2001) to 68.93 (2010) to 80.12 ha (2013) to 80.41 ha (2014) and 110 ha (2017) (Fig. 5). As per the satellite data analysis of 2018, the lake area has been found to be reduced to 95.03 ha which may be dewatering of the lake but again in 2019, the area of the lake has increased to 98.63 ha. The discharge of Sissu Nala is mainly dependent on this glacier.

Based on the field-based studies carried out by National Centre for Polar and Ocean Research (MoES) Govt. of India has carried out the bathymetric studies of the Geepang Gath Glacier Lake and the average lake depth has been estimated as 33.19 metres using Sonar method. Based on the lake area and the depth, the lake volume and Q_{max} was calculated using the following empirical relations.

Q_{max}= 75 $(V/1000000)^{0.67}$ m^3/s

Q_{max}= 0.72 $V^{0.53}$ m^3/s

Q_{max}=0.0048 $V^{0.896}$ m^3/s

Qmax=0.00077 V1.017 m3/s

Qmax=75 V0.67 m3/s

Bathymetry survey on Ghepang Gath Lake using RCV boat fitted with echo-sounder and GPS

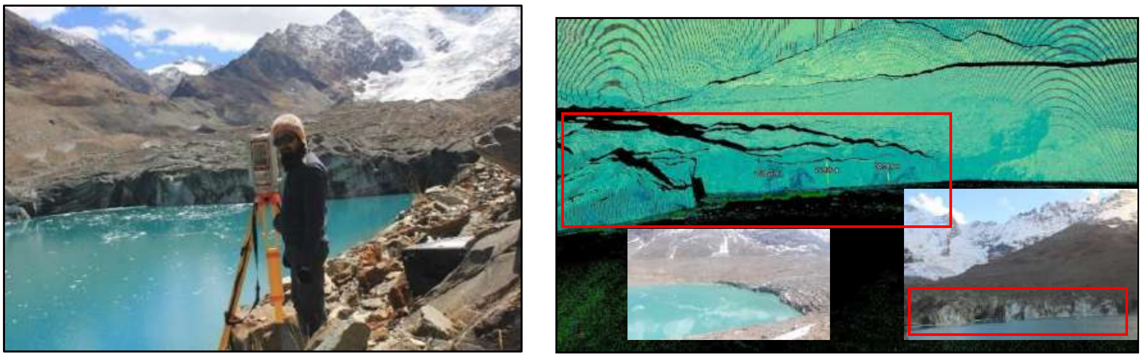


Figure 33 TLS survey for measuring calving rate and glacier terminal height at water ice interface

Based on the spatial extent of the lake estimated for different areas, the lake volume it contains and if it bursts, the maximum discharge estimated is as per the Table:1 which is the highest in 2017 (835.43 m^3/s) and lowest in the year 1976 (325.98 m^3/s).

Table 18 The lake Volume and Qmax was calculated using the following Empirical Relations

S.N.	Year	Area (Ha)	Volume (m^3)	Q_{max} in Hundred m^3/s	Q_{max} in Thousand m^3/s	Q_{max} in Ten thousand m^3/s	Q_{max} in ten Thousand m^3/s	Q_{max} in Million m^3/s
1	1976	27	896.27×10^4	3.25	3.48	0.81	0.90	3.41
2	1990	42	1394.19×10^4	4.38	4.40	1.20	1.41	4.58
3	1998	50	1659.76×10^4	4.92	4.83	1.41	1.69	5.15
4	2013	80.12	2659.59×10^4	6.75	6.20	2.15	2.73	7.07
5	2015	90.51	3004.49×10^4	7.33	6.61	2.40	3.10	7.67
6	2016	90.18	2993.54×10^4	7.31	6.60	2.39	3.08	7.65
7	2017	110	3651.47×10^4	8.35	7.33	2.86	3.78	8.74
8	2018	95.03	3154.53×10^4	7.57	6.78	2.51	3.25	7.93
9	2019	98.68	3275.70×10^4	7.76	6.92	2.59	3.38	8.13
h_{av} for 2017 = 33.1952 m								

ZONATION ALONG THE IMMEDIATE CATCHMENT IN DOWNSTREAM OF GEEPANG GATH GLACIER

The flood zonation of downstream of Geepang Gath glacial Lake: 3 buffer Zones at 100-meter interval have been drawn from river (Fig: 33).

Fig. 34 Represents Quaternary deposits of the flood zonation of down Stream of Geepang Gath glacier.

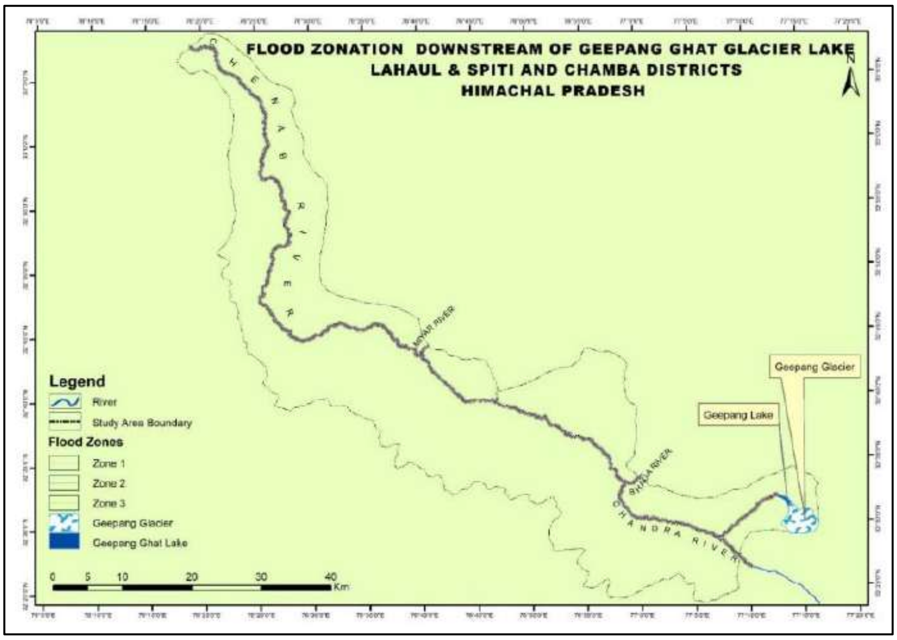


Figure 34 Flood zonation downstream of Geepang Gath glacial lake

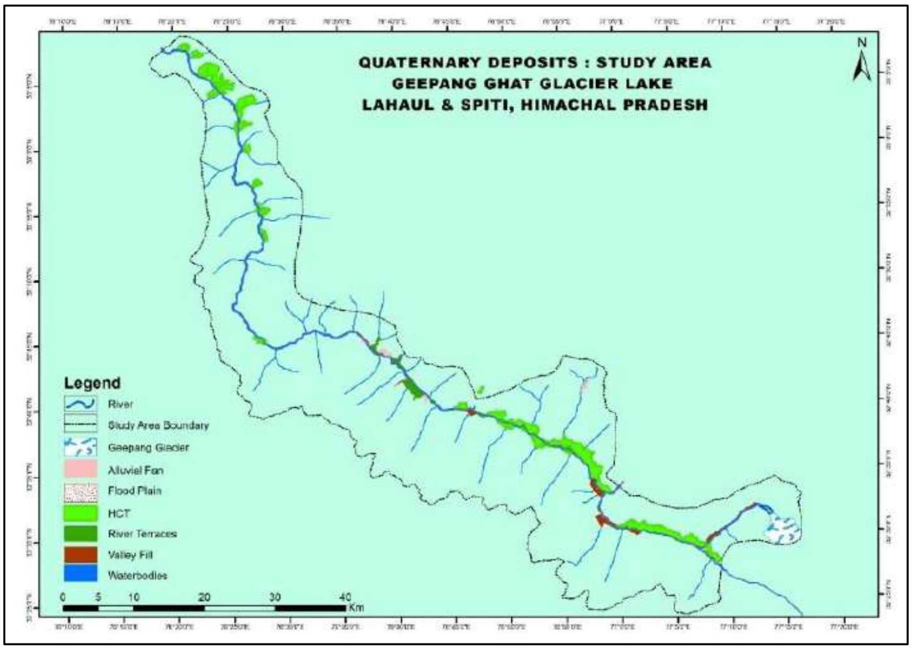


Figure 35 Quaternary deposits of Geepang Gath glacial lake

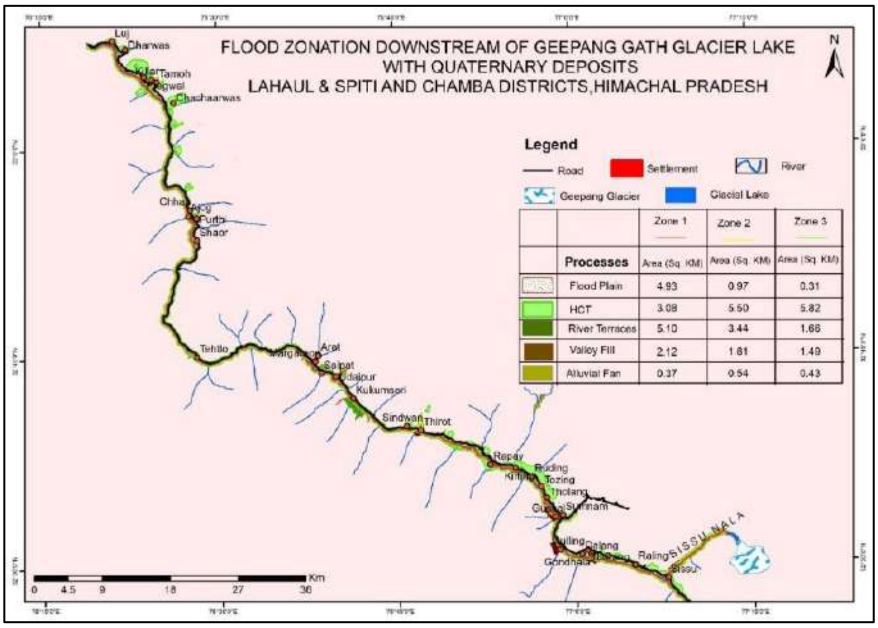


Figure 36 Flood zonation downstream of Geepang Gath glacial lake

Zone 1: Red Zone Area (Fig. 35):

- This zone lies between 0 to 100 meters from the river.
- River terraces constitutes 5.10 km^2 area followed by flood plains constitute of 4.93 km^2 area.
- Hill cut terraces has also been identified (3.08 km^2).
- Valley fills comprise of 2.12 km^2 area and alluvial fan being the lowest (0.37 km^2).

Zone II: Yellow Zone Area (Fig. 35):

- This zone lies between 100 to 200 meters from the river.
- Hill cut terraces have been identified as most dominant feature (5.50 km^2).
- River terraces constitute of 3.44 km^2 area followed by Valley fill constituting of 1.81 km^2.
- Flood plains comprises of 0.97 km^2 area and alluvial fan was lowest (0.53 km^2)

Zone III: Green Zone Area (Fig. 35):

- This zone lies between 200 to 300 meters from the river.
- Hill cut terraces have been identified as most dominant feature (5.82 km^2).
- River terraces constitute of 1.66 km^2 area followed by Valley fill constitute of 1.43 km^2 area.
- Alluvial fans comprise of 0.43 km^2 area and Flood Plain was lowest (0.31 km^2).

SEGMENT WISE MAPPING OF FLOOD ZONATION OF DOWNSTREAM OF GHEPANG GATH GLACIAL LAKE

In the view of the larger coverage of the study area along the river course. The entire area has been studied in different segments (9) depicting 3 buffer Zones i.e., Zone 1, Zone II and Zone III at 100-meter interval drawn from the river.

5. UNDERSTANDING THE IMPACT OF CLIMATE CHANGE ON SMALL HYDRO POWER PROJECTS IN HIMACHAL PRADESH

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.

ACHIEVEMENTS

- Generation of Landuse /Landcover for Ghanvi–II using ASTER DEM 30 m resolution data.
- Generation of Landuse / Landcover for Aleo II and Thirot Power projects using ASTER DEM 30 m resolution data.

THE LAND USE LAND COVERS OF THE GHANVI-II PROJECT

With the long-term archive of Landsat and Landsat-like image data, the development of GLC data products at 30 m resolution has become feasible. Such products have been considered as a superior option for the next generation of GLC maps, since most significant human activities on the land system can be captured at this scale. During past two decades, the extraction of land cover information from Landsat-like imagery has been intensively studied, and a variety of automated and semi-automated methods/algorithms have been developed. These have been applied to a number of national and regional land cover mapping projects using Landsat imagery. For instance, a set of 30 m land cover data with 13 different classes was produced by MDA (MDA, 2014), which covers the USA and a large proportion of Africa and Asia.

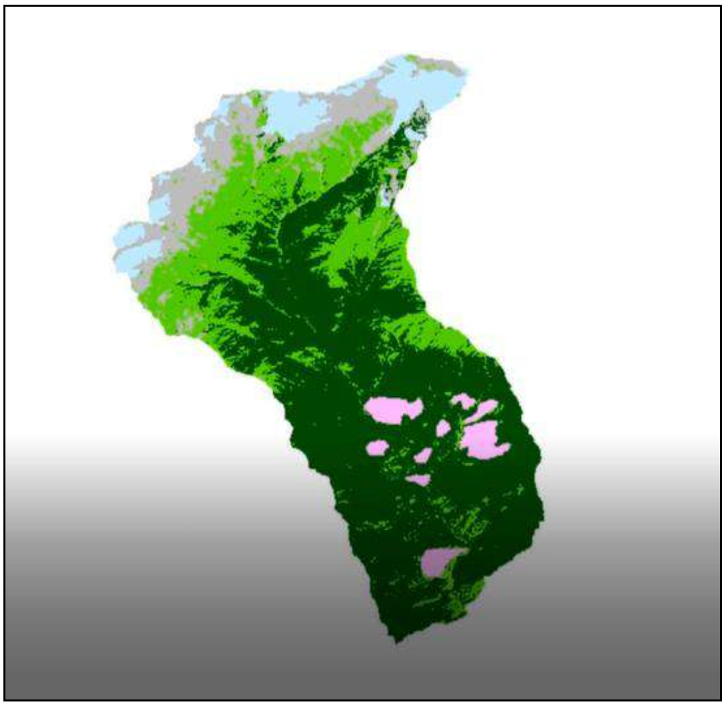


Figure 37 Classification of Landuse Landcover

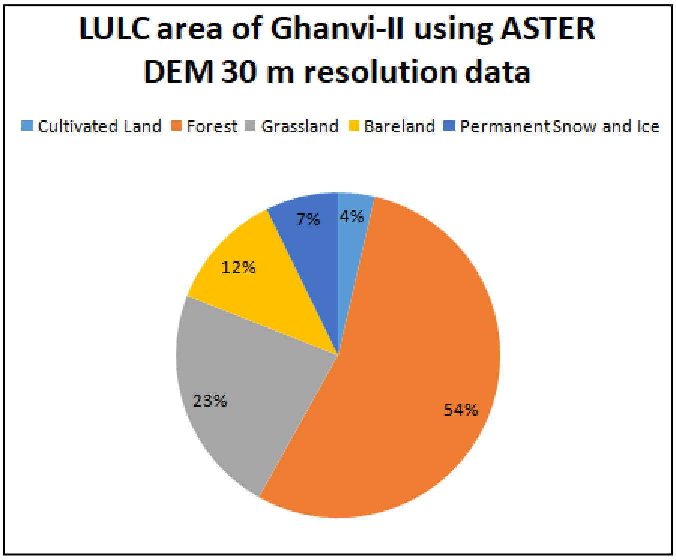


Figure 38 LULC area of Ghanvi-II using ASTER DEM 30 m resolution data

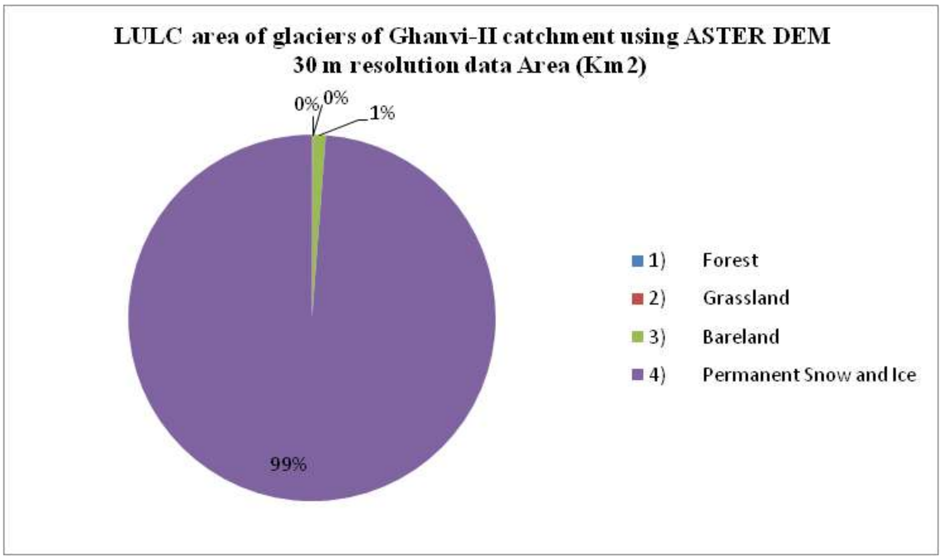


Figure 39 LULC area of glaciers of Ghanvi-II using ASTER DEM 30 m resolution data

THE LAND USE LAND COVERS OF THE ALEO-II HYDROELECTRIC PROJECT KULLU, H.P.

The Land Use Land Covers of the Aleo-II Hydroelectric Project Kullu, H.P. was generated using ASTER DEM 30 m resolution data.

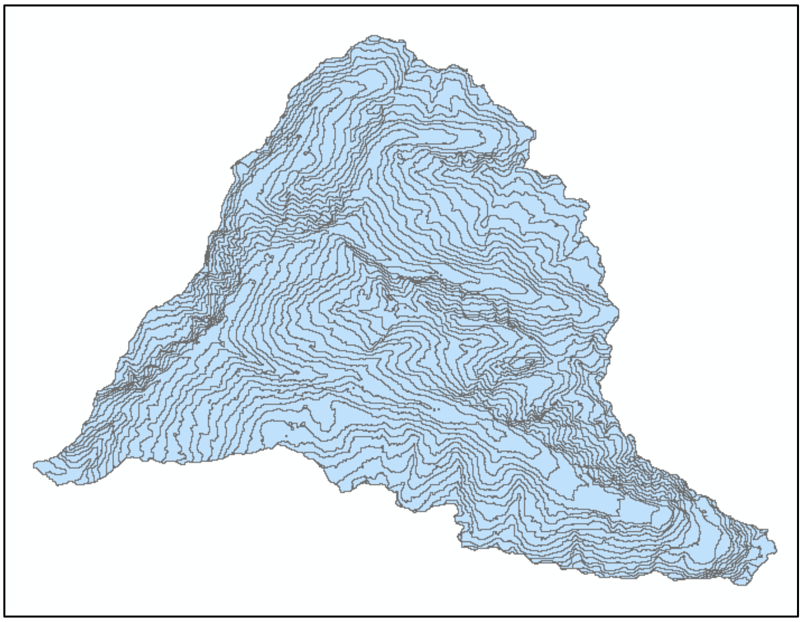


Figure 40 100m contours of Clipped Reclassified DEM

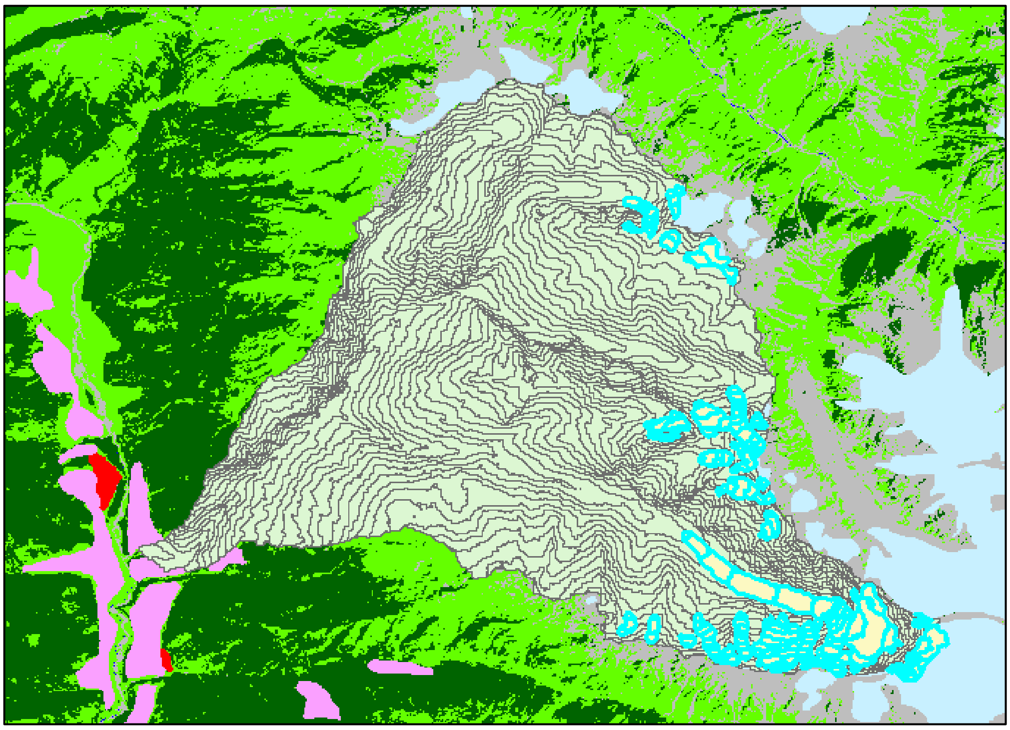


Figure 41 LULC of the catchment in colored pattern with different land classes

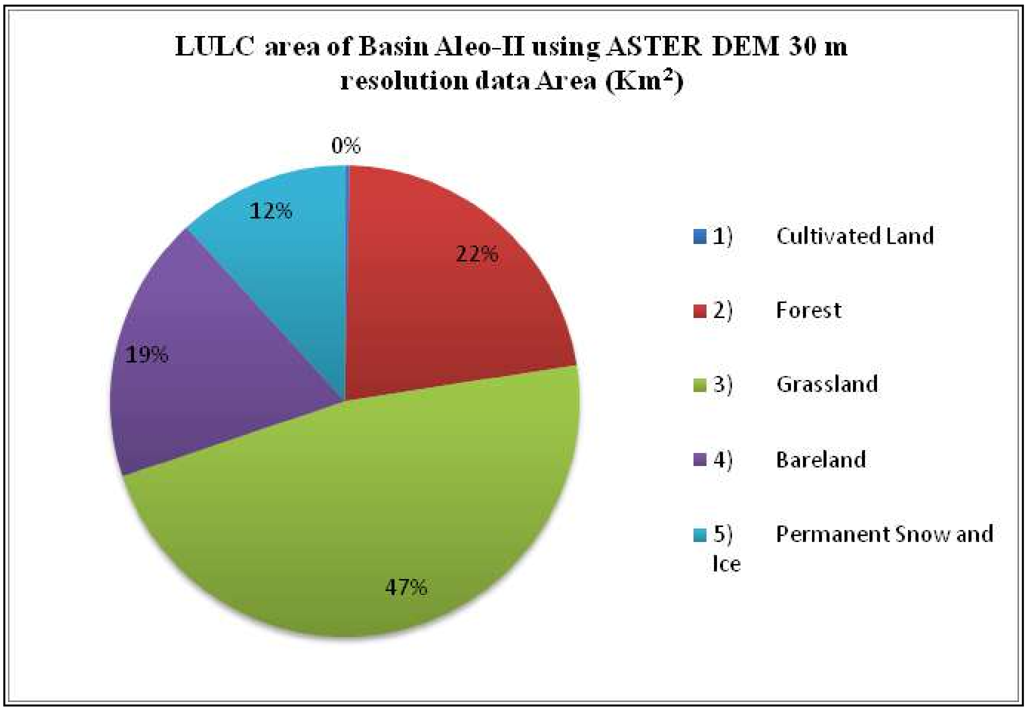


Figure 42 LULC of the glaciers and Catchment

THE LAND USE LAND COVERS OF THE THIROT HYDROELECTRIC PROJECT LAHAUL & SPITI, H.P.

The Land Use Land Covers of the Thirot Hydroelectric Project Lahaul & Spiti, H.P. was generated using ASTER DEM 30 m resolution data.

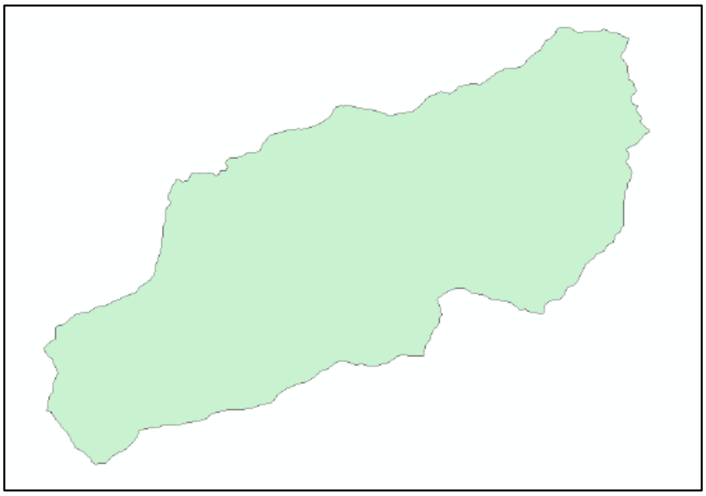


Figure 43 Catchment area of Thirot Hydroelectric Project Lahaul & Spiti, H.P.

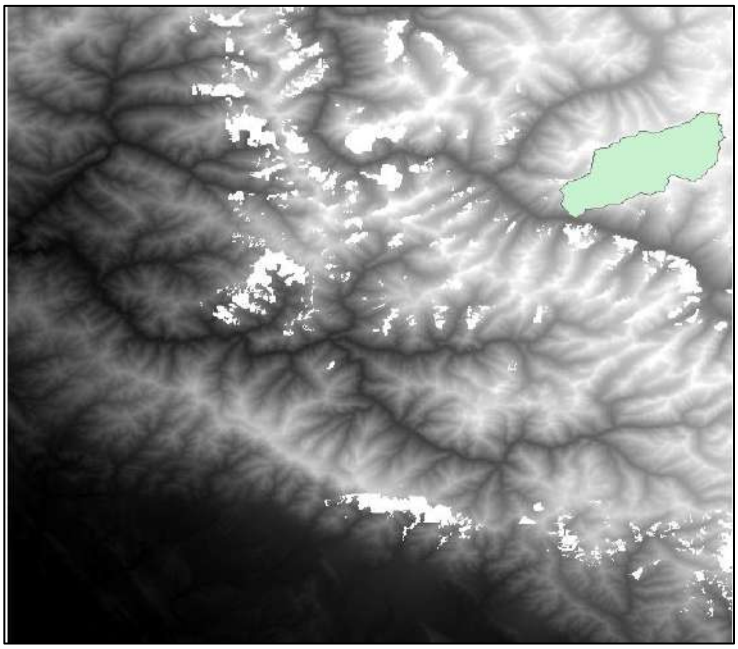


Figure 44 DEM of Thirot Hydroelectric Project Lahaul & Spiti, H.P.

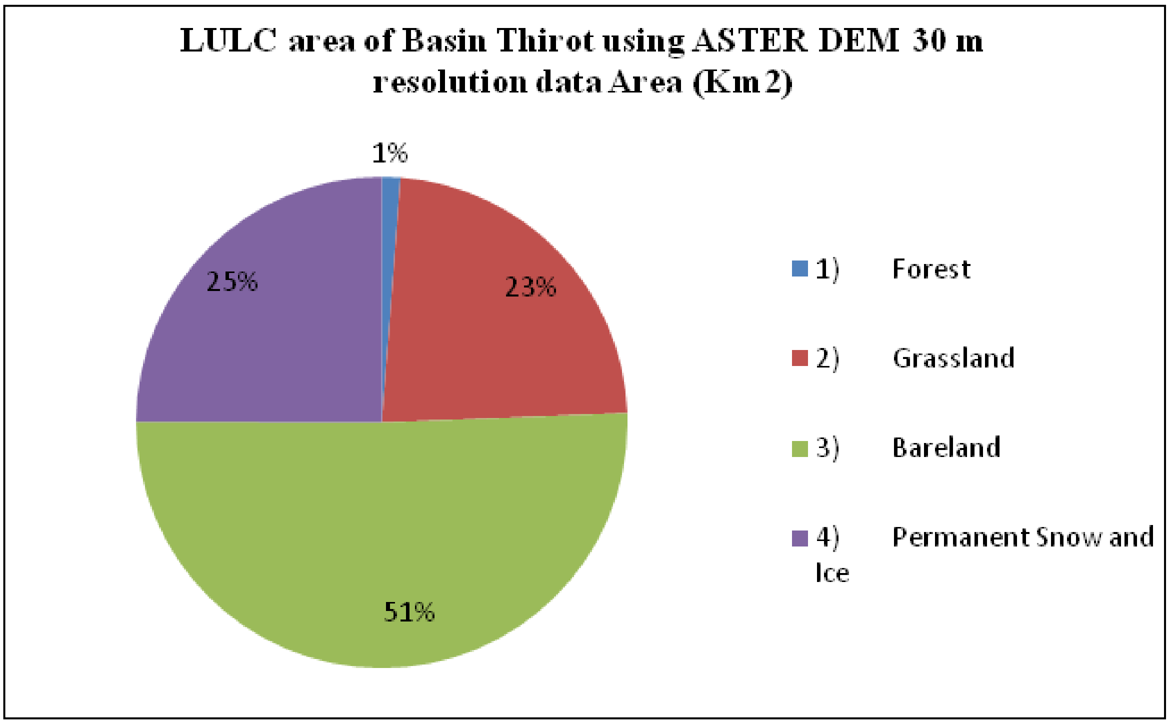


Figure 45 LULC of the glaciers and Catchment

6. NATIONAL WETLAND INVENTORY AND ASSESSMENT (NWIA) PHASE II

Himachal Pradesh is a hilly and mountainous state situated between 30° 22´ and 33° 12´ north latitude and 75° 47´and 79° 4´ east longitudes. The territory of the state is mountainous, except for a few pockets bordering Punjab and Haryana, which have a sub-mountainous topography.

Altitude in different areas ranges from 350 to 7000 metres above the mean sea level. Wide differences in geo-physical features account for considerable variation in the climate and rainfall of different sub- regions of the State. Physiographic ally, the State is part of the Himalayan system. From south to north it can be topographically divided into three zones: 1) The Shivalik's or outer Himalayas, 2) Inner Himalayas or mid Himalayas, and 3) Alpine zone or the Greater Himalayas.

Table 19 Category-wise wetland distribution in Himachal Pradesh

S. No.	Wetland Type Code	Wetland Type	2017-18		2006-07	Change	
			Wetland Area	% of wetland area	Wetland Area	Wetland Area	% of wetland area
1.	1100	Inland-Natural	57174	56.9	56942	57.4	233
2.	1200	Inland-Man-made	43267	42.3	42326	42.6	941
3.	2100	Coastal-Natural	0	0.0	0	0.0	0
4.	2200	Coastal-Man-made	0	0.0	0	0.0	0
Total			**100441**	**100**	**99268**	**100**	**1174**

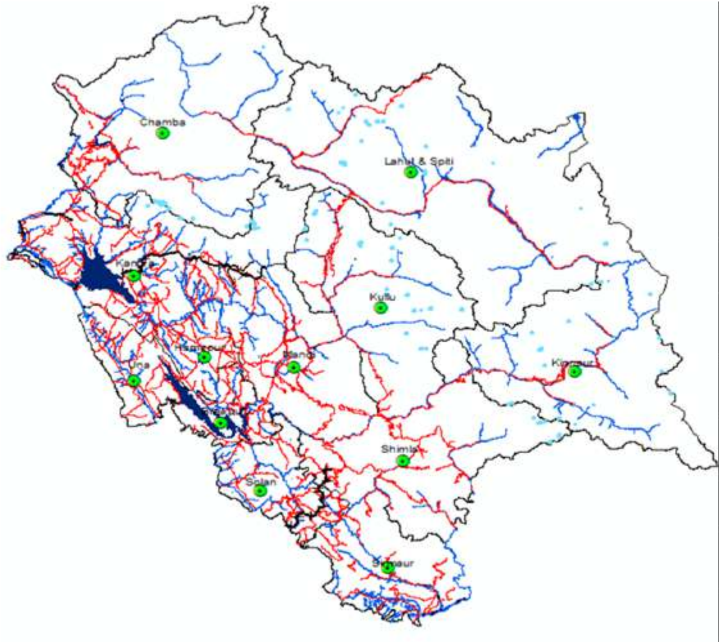
The altitude of the Shivalik Zone varies from 350 metres to 1500 metres above the mean sea level. The annual rainfall varies from 1500 mm. to 1800 mm. Since it is made up of consolidated deposits, which can erode easily, the zone experiences deforestation and a high rate of soil erosion. It is suitable for the cultivation of maize, wheat, ginger, sugarcane, paddy, table potatoes and citrus fruits. The altitude of the inner Himalayas or the mid- mountains ranges between 1500 metres and 4500 metres above mean sea level. The quality of soil in these areas ranges from silty loam to clay loam to dark brown colour and is useful for seed potatoes and temperate fruits. The Greater Himalayas or the Alpine zone has an altitude of 4500 metres above mean sea level. This area comprises Kinnaur district, Pangi tehsil of Chamba district and some areas of Lahaul and Spiti. Rainfall is scanty in this zone. The soil has high texture with variable fertility.

The climate of Himachal Pradesh varies from semi- tropical to the semi-arctic depending on the altitude. It has three seasons, which have an impact on its economic development. The rainy season lasts from July to September, winter from October to March and summer from April to June.

Table 20 Decadal wetland Inventory and change analysis

Himachal Pradesh																
																Area in ha
S. No.	Wetland Type Code	Wetland Type			2017-18			2006-07			Decadal Change		Disappeared		New	
		Level-I	Level-II	Level-III	Number	Wetland Area	% of wetland area	Number	Wetland Area	% of wetland area	Number	Wetland Area	Number	Area in ha	Number	Area in ha
1	1101	Inland	Natural	Lakes	11	73	0.1	11	73	0.1	0	0	0	0	0	0
2	1102			Ox-Bow Lakes/ Cut-Off Meanders	0	0	0.0	0	0	0.0	0	0	0	0	0	0
3	1103			High Altitude wetland	87	798	0.8	87	666	0.7	0	132	0	0	0	0
4	1104			Riverine wetland	0	0	0.0	0	0	0.0	0	0	0	0	0	0
5	1105			Waterlogged	8	39	0.0	7	36	0.0	1	3	0	0	1	3
6	1106			River/stream	67	56264	56.0	67	56167	56.6	0	97	0	0	0	0
7	1201		Man-made	Reservoirs/ Barrages	26	43199	43.0	20	42270	42.6	6	929	0	0	6	397
8	1202			Tanks/Ponds	7	34	0.0	5	25	0.0	2	9	0	0	2	8
9	1203			Waterlogged	3	34	0.0	3	30	0.0	0	4	0	0	0	0
10	1204			Salt pans	0	0	0.0	0	0	0.0	0	0	0	0	0	0
11	1205			Aquaculture ponds	0	0	0.0	0	0	0.0	0	0	0	0	0	0
12	2101	Coastal	Natural	Lagoons	0	0	0.0	0	0	0.0	0	0	0	0	0	0
13	2102			Creeks	0	0	0.0	0	0	0.0	0	0	0	0	0	0
14	2103			Sand/Beach	0	0	0.0	0	0	0.0	0	0	0	0	0	0
15	2104			Intertidal mud flats	0	0	0.0	0	0	0.0	0	0	0	0	0	0
16	2105			Salt Marsh	0	0	0.0	0	0	0.0	0	0	0	0	0	0
17	2106			Mangroves	0	0	0.0	0	0	0.0	0	0	0	0	0	0
18	2107			Coral Reefs	0	0	0.0	0	0	0.0	0	0	0	0	0	0
19	2201		Man-made	Salt pans	0	0	0.0	0	0	0.0	0	0	0	0	0	0
20	2202			Aquaculture ponds	0	0	0.0	0	0	0.0	0	0	0	0	0	0
Total					209	100441	100	200	99268	100	9	1174	0	0	9	408

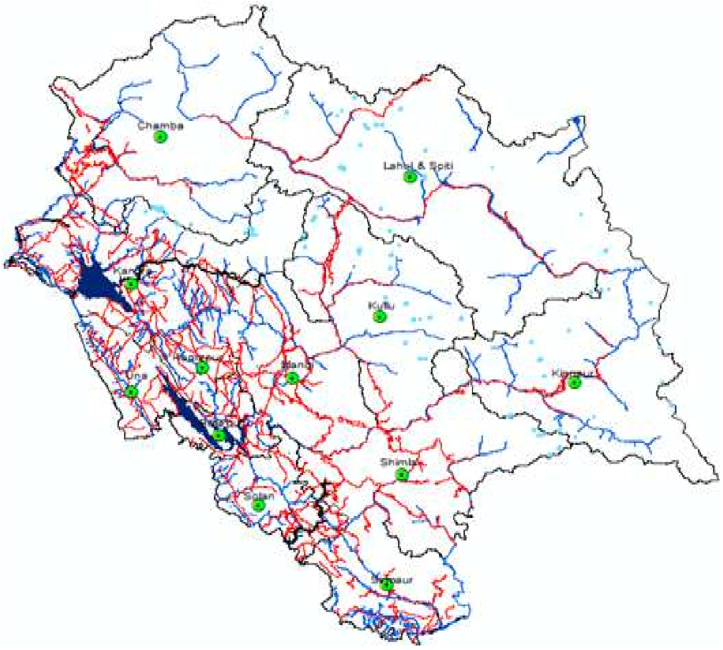
Five prominent North Indian perennial rivers-Sutlej, Beas, Ravi, Chenab and Yamuna-flow through the State, out of which Beas, Ravi and Chenab originates from the Higher Himalayan regions of the State, where s the other two rivers i.e., Satluj and Yamuna passes through the State. The river system in the Himalayas cannot be exploited for irrigation as fully as in the plains, but it is the source of water for the Indus river basin. The undulating terrain limits the utility of these rivers for irrigation. During the rains, the flow in the rivers is heavy and in winter, with snowfall and the water frozen at higher altitudes, they shrink into narrow streams. These rivers, however, provide ample scope for the generation of hydel power, and the State has total estimated power potential of 27,436 MW out of which 10,519 MW has been harnessed.



Symbol	Description		
	Level-I	Level-II	Level-III
	Inland	Natural	Lake/Pond
			High altitude lake
			Riverine Wetlands
			Waterlogged
			River/Stream
		Man-made	Reservoir/Barrage
			Tank/Pond
			Waterlogged

Legend

Figure 46 Wetlands of Himachal Pradesh Timeframe 2006-07



Symbol	Description		
	Level-I	Level-II	Level-III
	Inland	Natural	Lake/Pond
			High altitude lake
			Riverine Wetlands
			Waterlogged
			River/Stream
		Man-made	Reservoir/Barrage
			Tank/Pond
			Waterlogged

Legend

Figure 47 Wetlands of Himachal Pradesh Timeframe 2017-18

Himachal Pradesh has (~ 100441ha) area under wetlands and accounts 1.8 % of total geographical area of Himachal Pradesh. High altitude wetland forms the dominant wetland category, that constitute around 41.6 % of total wetland area. Rivers/Streams occupies 32.1% area. Decadal changes (2017-18 vs 2006-08) shows an overall increase in wetland area from (99268 ha to 100441 ha i.e., 1174 ha). Man-made reservoir/Barrage and Natural wetlands (Rivers/streams & High-altitude Wetlands) reported increase in area.

Major changes are due to transformation of high-altitude wetlands and further addition of reservoir/ barrage particularly Chamera-III, Thopan Powari, Kol Dam reservoir, Malana reservoir, Karcham Reservoir, Parwati sainj –II Hydel project have been added in 2017-18 increasing the total wetland area from (42270 ha to 43199 ha i.e., 929 ha) over the decade.

7. MASON TRAININGS ON HAZARD-RESISTANT CONSTRUCTIONS

This training made masons aware not only of the critical principles of hazards resistant construction but also provided some practical skills in appropriate and relevant details of Rural Housing Technologies that people use in different regions of India. The objective of this training curriculum is to strengthen the practicing Masons on Hazard Resistant Construction Techniques and features through theoretical and practical sessions.

This training is meant to guide Masons on construction of engineered houses up to two stories and does not cover construction of engineered buildings with reinforced concrete frame for multi storey buildings. The major outcome of the workshop was:

1. Construct CL stubs and mark CL and level. Protect stubs from damage. Protect stubs from damage.
2. Always check dimensions and corners by 3-4-5 method or equal diagonal method.
3. Check the level of construction at different levels.
4. Check that the courses are in level.
5. After checking the level plumb, the bob.
6. Apply mortar to brick face before putting it in the course and fill all the mortar joints.
7. Consume mortar within 30-60 minutes of adding water.
8. Ensure perfect bond.
9. Provide RC band and corner steel as per design and detail.

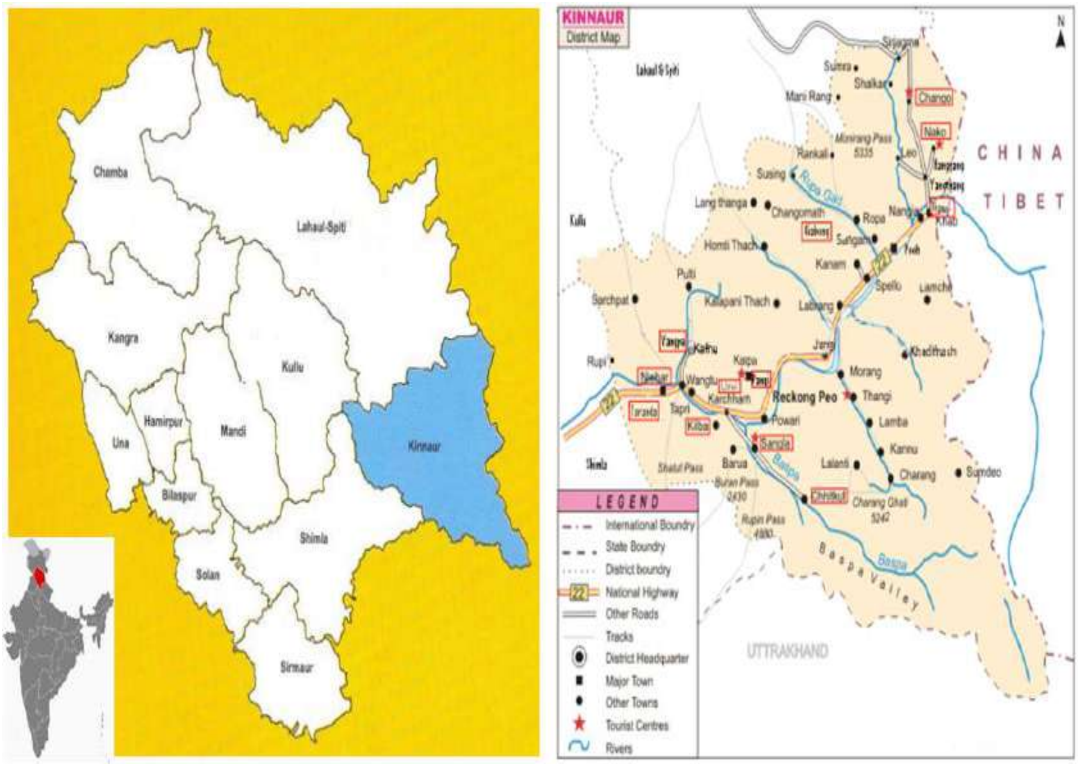
Figure 48 During training masons learning techniques and completed demo building with labels

C. AGRI-HORTICULTURE SECTOR

1. IMPACT OF CLIMATE CHANGE ON AGRICULTURE SECTOR IN KINNAUR DISTRICT, HIMACHAL PRADESH

Agriculture is amongst the most vulnerable sectors to be affected by climate change owing to its sensitivity to variations in temperature and rainfall patterns, frequently occurring weather extremes, and continued exposure to atmospheric carbon dioxide. Simultaneously, it is one of the most endangered areas to the effects of environmental change, inferable from its affectability to outrageous and abrupt varieties in temperature and precipitation. So, the status study was with a view to ascertain the impact of climate change on agricultural activities in District Kinnaur.

Kinnaur is located between 77°45’ and 70° 00’35” East longitude and 31°05’50” to 32° 05’15” north latitude and bounded by Tibet and Uttaranchal on the east, Shimla district in south-west, Kullu and Lahaul-Spiti district in the north-west, about 235 km from the state capital, Shimla. The economy of Kinnaur is



predominantly agriculture based where as large as 67.09 per cent of the total working force is engaged in tilling the cultivable land. The space of arable land is small and the cultivation is common on narrow strips along the browse of the mountains.

METHODOLOGY

To better understand the impact of climate change variable of temperature and precipitation (rainfall) vis-à-vis parameters of agriculture productivity the following methods were employed: Trend analysis, Standardized Anomaly Index (SAI) and Multivariate Linear Regression Model with the help of Software XL-Stat 2019 and SPSS 2020.

OUTCOME

To capture the nerve of climatic changes in the district, temperature (min, max, diurnal), and rainfall parameters are considered as explanatory indicators. Based on the statistical analysis, Mann Kendall trend test**,** the maximum and diurnal temperature showed significant changes during the *Kharif* crop season for the study period spanned across 28 years, while for Rabi crop season, only the diurnal temperature underwent statistically significant changes.

CURRENT CLIMATE TRENDS –DISTRICT KINNAUR

During the *Kharif* season, the maximum temperature rose at the rate of 0.02°C per year (as exhibited by Sen's slope), After 1999, maximum temperature remained above the long-term average except for the years 2001,2002,2005,2008,2011,2013 and 2014 indicating an overall warming trend. Rainfall, on the other hand, did not show any significant variation from 1990 to 2018. During Rabi crop season, Diurnal temperature registered statistically significant increase of 0.02 °C per year in District Kinnaur. As per the outputs from Mann Kendal Tests, an overall increased productivity trend is recorded for Maize, Barley and Common millets, wherein wheat showed the decreasing trend of -0.014t $ha^{-1}year^{-1}$ Maize showed an increased crop yield of 0.019t $ha^{-1}year^{-1}$ common millet, barley and total vegetable showed increasing trend of 0.006, 0.015 and 0.338t $ha^{-1}year^{-1}$ respectively.

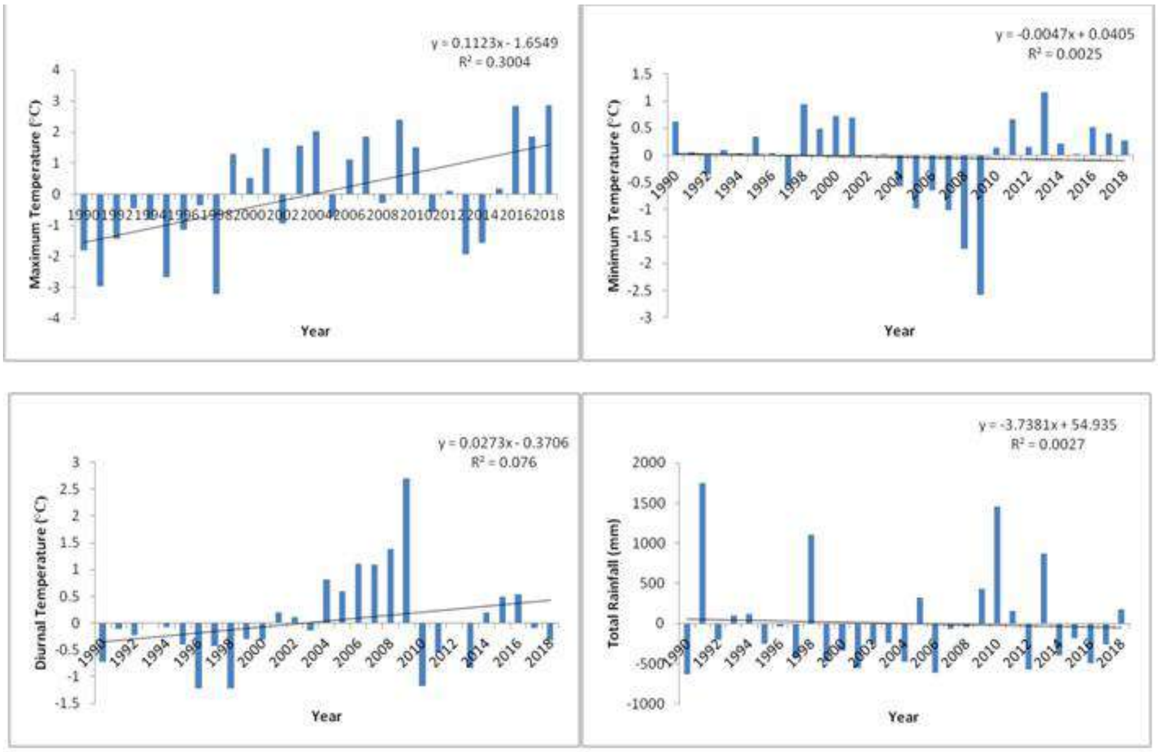


Figure 49 Variations in Climatic Parameters Minimum T, Maximum T, Diurnal T and Rainfall during Kharif Crop season (1990-2018), District Kinnaur, HP

CLIMATE CROP ANALYSIS

To ascertain the relationship between climatic variability and crop productivity, a correlation analysis was performed using the statistical tool – *Pearson's coefficient*. The results revealed a strong relationship between climate variability and productivity of *Rabi* crop such as Wheat whereas negligible association was observed for the *Kharif* crops (Rice and Maize) in District Kinnaur (Table 6). While testing the effects of variability in maximum temperature, diurnal temperature, and rainfall, a significant and positive trend (0.587) was observed for Rice crop productivity (with a p-value 0.001). The effects of variability in maximum temperature, diurnal temperature, and rainfall, a significant and positive trend (coefficient value 0.587 with p-value 0.001 for rice), with coefficient value 0.357 and p-value 0.031 for maize and 0.56, -0.53 with p-value 0.001, 0.002 for Common millets. The regression outcome of detrended[2] climatic variables of minimum, maximum, diurnal temperature and rainfall with the productivity of selected crops. For all assessed crop varieties *viz.*, Wheat, Barley, Rice, Maize, Ragi and Common millets only 12.6%, 12.8%, 35.6%, 15.4%, 8.2% and 9.0% of productivity variability could be explained from temperature and rainfall variations in the district.

2. IMPACT OF CLIMATE CHANGE ON HORTICULTURE SECTOR IN KINNAUR DISTRICT, HIMACHAL PRADESH

Climate change has emerged as a real concern for the horticulture sector with visible changes in productivity, quality of crop yields, and acreage already being reported around the globe. Crop production systems in South Asia and sub-Saharan Africa are observed to be at undisputable climatic exposure, where temperature increase is already closer to or beyond the threshold, which is having a limiting impact on overall vegetative growth. A far greater impact of extreme dry and wet spells compared to changes in long-term mean precipitation is also being reported on fruit crop productivity. The Himalayan ecosystem offers an enabling environment characterized with favorable micro-climatic conditions for cultivation of a wide range of horticulture crop such as apples, plums, peaches, bananas, mangoes, pineapples, citrus fruits, walnuts and more. In Himachal Pradesh, which is known as the fruit bowl of India, around 71 per cent of the 6.86 million people are dependent on the agriculture/horticulture sector for employment and income sources. There is heightened exposure to climate change induced vulnerability on sectors and individual crop's sustainability.

To this effect, a study was conducted with a view to ascertain the impact of climate change on horticulture sector in District Kinnaur. Seasonal trends on climatic variables i.e., minimum, maximum and 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*.

CLIMATE CROP ANALYSIS

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 and diurnal temperature increased by 0.01°C per year from 1990 to 2016. Maximum temperature increased by 0.02°C per year from 1990 to 2016 during ***flowering period.*** Meanwhile, the maximum temperature increased by 0.04°C per year from 1990-2019 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, Pear productivity showed maximum sensitivity to climatic variations during all phenological stages (66.5%, 55.2%, 55.2%). For Apple and Walnut crop significant correlation was observed and for flowering and fruit setting i.e., (57.8% and 47.6%) and (29.2% and 39.1%) respectively. For Apricot (81.2%, 84.8%) during pre-flowering and flowering, Almond (32.5% and 36%) and Grapes (41.2% and 64%) during pre-flowering and fruit setting. For Plum crop only one climate variable i.e., mean maximum temperature impacts 23.1% during the fruit setting and development stage. With respect to individual crops, the observed variations in productivity for Pear crop from 1990-2019 is explained by the variations in climatic parameters to the extent of 66.5% during pre-flowering stage, 55.2% during the flowering stage and 55.2% during the fruit setting and development stage.

D. FORESTRY SECTOR

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

The study is being carried out in collaboration with IHBT, Palampur under NMHS programme of MoEF&CC, Govt. of India.

OBJECTIVES

- **i.** To map and characterize timberline zone in Himachal Pradesh region of western Himalaya.
- **ii.** To study plant populations, community structure and functional ecology in the LTER sites.
- **iii.** To study effect of changing snow cover extent on species recruitment patterns.
- **iv.** To study phenology of key species, net primary productivity, nutrient dynamics and ecophysiology in the LTER sites.
- **v.** To undertake predictive modelling for projecting future changes in vegetation.
- **vi.** To integrate with modelled projections, the scenario studies by involving local stakeholders for

understanding the future of their landscape.

This long-term ecological study will not only enhance the understanding of the relationships of vegetation & environment but also a pre-requisite for documenting impacts of global climate change. The Long-Term Ecological Research Plots (LTER) have been established at Khanjar, Trilokinath & Muling of Lahaul & Spiti, Chhitkul of Kinnaur and Pangi of Chamba district based on probabilistic sampling among representative timberline species. At these LTER plots ecosystem functions viz. key species phenology, net primary productivity & nutrient dynamics are being studied. The biotic and abiotic parameters generated through LTER and climate simulation studies will be utilized to train ecological models. In addition, ‘Scenario Studies’ by involving local communities and other stakeholders will be undertaken. These scenario studies will provide a useful context for addressing questions of future climate change and thus, the increased involvement of local communities in assessing climate change impacts will enable people to be more responsible for sustainable utilization of natural resources**.**

ACHIEVEMENT

The snowline of the 4 LTER sites had been delineated by AWiFS satellite imageries from year 2005 to 2015.

Figure 50 Sensor of Portable Photosynthesis Instrument and performing Plant Moisture Stress in *Betula utilis*

Figure 51 Imprints for opening and closing of stomata in *Betula utilis leaves*

Figure 52 Khanjar (Lahaul & Spiti) LTER site visited in August, 2020

Figure 53 Chitkul (Kinnaur) LTER Site visited in October, 2020

E. WEBINAR/WORKSHOP

1. WEBINAR ON CRYOSPHERE UNDER WARM CLIMATE: EFFECT ON WATER SECURITY

The H.P. Council for Science, Technology & Environment (HIMCOSTE) and the Indian Institute of Science Bangalore (IISc), Bengaluru in order to understand the impact of climate change on the hydropower projects in Himachal Pradesh envisaged a study entitled "Understanding influence of climate Change on small hydro-power projects in Himachal Pradesh, India". The study was initiated about a year ago which would help in estimating the 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.

In the present era of climatic variations, affecting the Himalayan cryosphere which encompasses all frozen water consisting of snow, ice and permafrost (including seasonally frozen ground) are undergoing changes under warmer climate. The recent advances in observational and modelling techniques have provided unique information on cryosphere of Himachal Pradesh and its influence on water availability.

Therefore, a half day webinar was organized in collaboration with Divecha Centre for Climate Change, Indian Institute of Science, Bengaluru and State of Himachal Pradesh. In this webinar current state of cryosphere, potential changes in future and its influence on hydro power generation and livelihood of people was discussed. This webinar provided platform to discuss latest scientific outcome with policy makers, scientist, academicians, stakeholders and the investors in power sector of Himachal Pradesh. Around 200 participants attended webinar on 1st February 2021.

2. BRAIN STORMING DISCUSSIONS ON DRAFT DOCUMENT ON SCIENCE, TECHNOLOGY AND INNOVATION POLICY (STIP) OF THE STATE HIMACHAL PRADESH

Advancement in application of Science, Technology and Innovation (STI) has raised the expectations of people in every walk of life. Over the last couple of years, the unprecedented developments in STI have greatly influenced the human civilization. The STI can exist separately on their own in disconnected spaces, but it is their integration that leads to new value creation and hence economic order. Therefore, there is a need to create the necessary framework for enabling this integration in the identified priority areas by exploiting indigenous resources, its strength and the capacity.

If we talk about the state specific policies, the Science, Technology and Innovation inputs assume greater significance in the hill states like Himachal Pradesh in view of its geographical constraints and the challenges for its development. The State Government is in the final stage of formulation of its Science Technology & innovation Policy-2020 for Himachal Pradesh. The 19 Issues which have been taken into account in the new STIP-2020 have the relevance from the States perspective and have the linkage in one or the other way. The priority areas envisaged under the STI Policy for the State are the Creating Ecosystem for Innovation, STI Interventions for Self-Employment for Livelihood Security, Infrastructure & Human Resource Development, Sustainable Management of Natural Resources, Clean and Green Technologies, Delivery System for S&T Output, Institutionalization of Strategies and Action Points with the State Government Departments, Linkage & Synergy with UN Sustainable Development Goals etc. The methodology adopted by H.P. Council for Science, Technology & Environment (HIMCOSTE) in formulating the STI Policy for HP followed a constitution of a Core Group of renowned scientists from different fields like Plant Genetics & IPR, Agriculture, Horticulture, Engineering, Applied Biotechnology, Forestry, Biosciences & Biodiversity, Remote Sensing & Water, Wildlife, Mathematics, Meteorology and Climate Change and Physics etc. from different Universities and Research Institutions and now at the consultation stage with the various stakeholder departments.

In the State STI Policy, the core issues of concern requiring structural mechanism and the models to address the pressing challenges of the energy, environment, climate change, food and nutrition, water and sanitation, habitat, affordable health care, skill building and unemployment have been taken care while formulating the STIP Policy for the State. To work further for giving a final shape to the document, a half day Brain Storming session involving the Working Group Members, Stakeholder Departments, Academic and Research Institutions operating in the State was organized on 26th March 2021 at Hotel Holiday Home under the Chairmanship of Principal Secretary (Env. S & T), Govt. of Himachal Pradesh.

Figure 54 Glimpse of the Half Day Workshop at HHH, Shimla on 26th March 2021

F. PUBLICATIONS

1. Decomposition of continuous soil–gas radon time series data observed at Dharamshala region of NW Himalayas, India for seismic studies

   Journal: Journal of Radioanalytical and Nuclear Chemistry; https://doi.org/10.1007/s10967-020-07575-x

   Authors: Sunil Dhar[1] Surjeet Singh Randhawa[2] Arvind Kumar[3] Vivek Walia[3] Ching-Chou Fu[4] Harish Bharti[2] Arun Kumar

2. Moraine dammed Lakes Inventory in Satluj, Ravi, Chenab and Beas of Himachal Pradesh, India

   Journal: Springer

   Book: Water, Cryosphere, and Climate Change in the Himalayas

   Authors: Surjeet Singh Randhawa, Sunil Dhar, Bhanu Prakash Rathore, Rajesh Kumar, Neha Thakur, Pooja Rana, Duni Chand Rana, Ajay Kumar Taloor

3. Towards climate-adaptive development of small hydropower projects in Himalaya: A multi- model assessment in upper Beas basin

   Journal: Journal of Hydrology: Regional Studies

   Authors: Tejal S. Shirsat[a] Anil V. Kulkarni[a] Andrea Momblanch[b] S.S. Randhawa Ian P.Holman[b]

4. Impact of climate change on agriculture, horticulture and forestry in Himachal Pradesh- A Review

   Journal: The Bede Athenaeum

   Authors: Bharti Harish,* Sharma Priyanka, Panatu Aditi, Randhawa S.S., Thakur Nishant

5. Temporal Changes in Tree Species Composition in Karsog Area of Northwest Himalaya;

   Journal: Journal of Biodiversity

   Authors: Harish Bharti*, Pankaj Sharma, Kiran Lata, Abhay Mahajan, Ritesh Kumar, Priyanka Sharma and S. S. Randhawa

6. **In Press-**Recent updates on glacier changes in Himalaya-Karakoram (H-K) region and its attribution to latitudinal effect

   Authors-I. M. Bahuguna1*, B. P. Rathore1, A. S. Jasrotia2, S. S. Randhawa3, S. K. S. Yadav4, Sadiq Ali2, Nishtha Gautam3, Joyeeta Poddar4, Madhukar Srigyan1, Abhishek Dhanade1, Purvee Joshi1 Sushil Kumar Singh1 and D. R. Rajak1

G. SCIENCE, TECHNOLOGY & INNOVATION (STI) POLICY

The H.P Council has finalized the draft of the Science Technology & Innovation Policy (STI) for the State of Himachal Pradesh. The draft has been finalized, document was submitted and thereafter the document is again being taken up for refining. As per DST guidelines, Mapping for the Science & Technology Needs in consonance with the Sustainable Development Goals (SDGs) is being taken up after which the document would be refined.

The vision of the STI policy is, Strengthening and promoting STI in the State by providing the environment and opportunity to the innovators and stake holders for overall sustainable development of the mountain regions and the upliftment and betterment of the society by taking technology from lab to land in an eco-friendly manner with a decentralized and bottom-up approach.

OBJECTIVES

Considering the peculiarity of the hilly terrain, living conditions, difficult livelihood, development needs, environment conservation, the stakes for STI intervention are rather high. Hence, the following objectives have been set forth.

I. To strengthen the Research and Development (R&D) Institutions and Innovation centers.

II. Identify priority R&D areas and provide platform for fostering scientific research and innovations for promoting sustainable development in the State.

III. Promotion and development of appropriate ecosystem for innovation and documentation of innovations in the form of reports, Intellectual Property Rights (IPRs), publications etc.

IV. To promote use of STI in identified priority areas by harnessing natural/indigenous resources and development of new mechanisms for transforming knowledge to technology business incubators and science led appropriate livelihood options.

V. To supplement and complement the national objectives of self-reliance, technological competence and the maximum use of indigenous resources for the socio-economic development.

VI. To promote sustainable development of Himalayan natural resources and to leverage Traditional

Knowledge System (TKS) including ‘vocal for local’ philosophy.

VII. To promote an environment for the enhanced public-private participation in the R&D activities.

VIII. To popularize Science and Technology among school and college students and developing scientific temper amongst the different sections of the society.

CHALLENGES

I. Reorientation of academic institutions towards application of science for sustainable development and livelihoods by addressing the mountain specificities viz. inaccessibility, fragility, marginality, diversity or heterogeneity, niche and human adaptations.

II. Integration of innovations for skill development in Research and Development (R&D) space.

STRATEGIES

I. Creating Ecosystem for Innovation

II. STI Interventions for Self-employment and Livelihood Security

III. Infrastructure and Human Resource Development (HRD)

i. Perspective Planning for Science and Technology (S&T) Interventions

ii. Optimal Use of Available Infrastructure and Resources

iii. Building Human and Institutional Capacities in the State Specific Cutting-Edge Areas

iv. Strengthening Scientific Temper

IV. Sustainable Management of Research and Development (R&D) on Natural Resources

i. Environment Protection

ii. Biodiversity and Ecosystem Services

iii. Disaster Management and Forecasting

iv. Climate Change and Mitigation

V. Clean and Green Technologies

i. New and Renewal Energy and Energy Conservation

ii. Green Chemistry
iii. Green Financing

VI. Delivery System for Science and Technology (S&T) Output

i. Information and Communication Technology (ICT)

H. MAPPING OF S&T NEEDS OF THE STATE OF HIMACHAL PRADESH

Mapping of Science and Technology needs in the State is being carried out by focusing on the following objectives.

i. To identify the core problems, issues and possible solutions through secondary sources in the State.

ii. Inventorisation and mapping of identified issues in relevant sectoral areas of the State requiring S&T interventions based on secondary sources.

iii. Documentation of the findings.

iv. Moreover, sector wise mapping and R&D infrastructure mapping has been carried and different sectors that are specific to the State have been identified as follows.

1. Agriculture, Horticulture, Animal Husbandry, Veterinary (SDG No. 2-Zero hunger)

2. Education, Eco-Tourism and MSME (SDG No. 8-Decent work & economic growth)

3. Research and Development (R&D), Enhancing academia-industry partnership by enhancing innovation in S&T intervention, Civil-Infrastructure (SDG No. 9- Industry, innovation & infrastructure)

4. Solid waste management, Environment education and awareness (SDG No. 11- Sustainable cities & communities)

5. Clean energy (bio-fuels), Conversion of biodegradable waste to biogas (SDG No. 13-Climate action and SDG 7-Affordable & clean energy)

6. Biodiversity management and Disaster management (SDG No. 15-Life on land)

7. Data analytics for business decision making (SDG No. 12-Responsible consumption and production)

8. Health & Family welfare, pharmaceutical sector (SDG No. 3-Good health & wellbeing).

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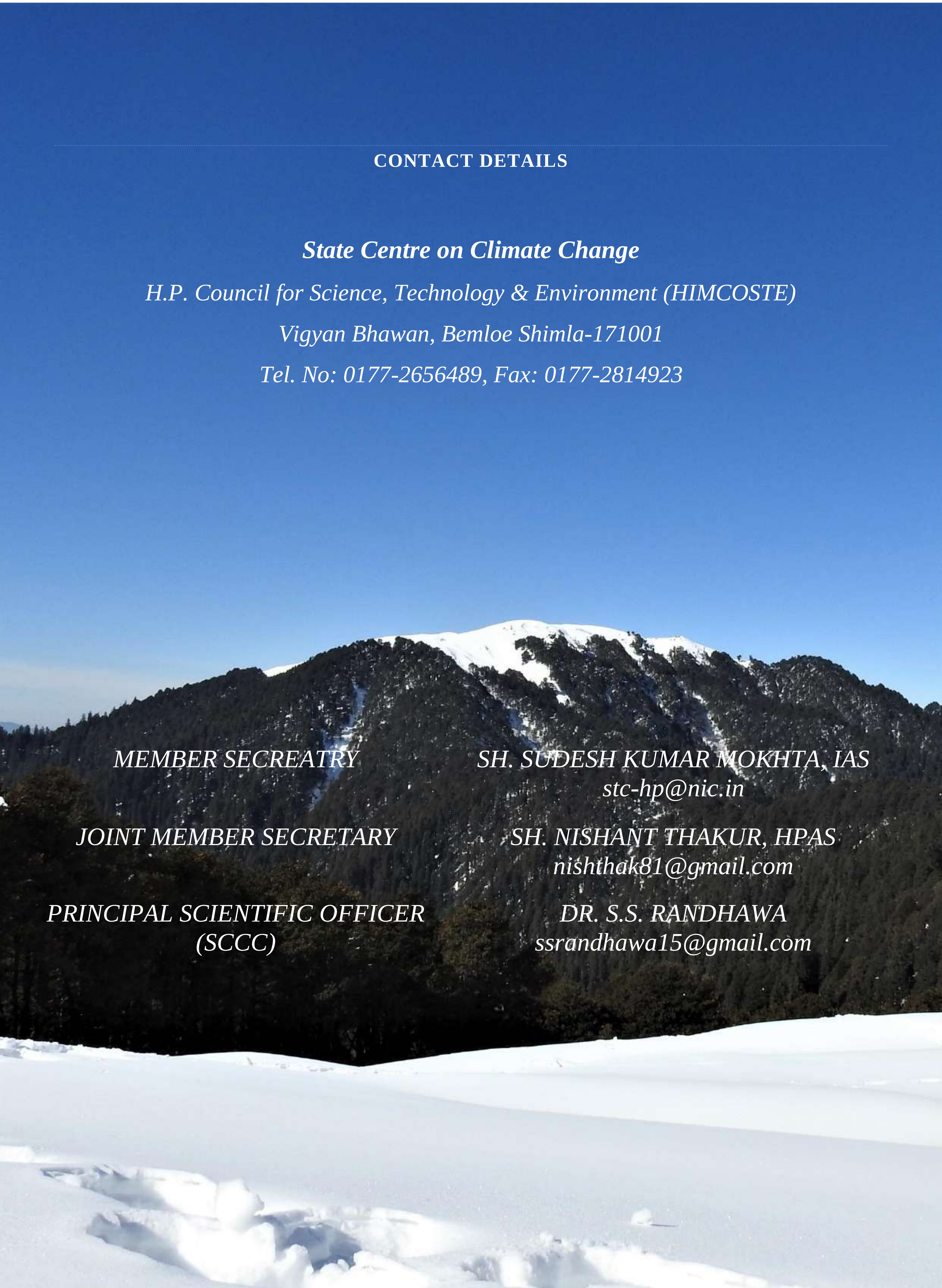

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