ANNUAL PROGRESS REPORT

2023-24

STATE CENTRE ON CLIMATE CHANGE

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SNOW & GLACIERS STUDIES

1. CRYOSPHERE, SCIENCE & APPLICATION PROGRAM (CAP)

The glacier outline of the Satluj basin for the year 2020 was generated using different spatial resolution satellite images (LISS IV, Sentinel optical data, and Landsat ETM+ data) and ArcGIS 10.8 software. The glaciers were mapped manually based on visual interpretation. There are three sub basins within the Satluj basin: the lower Satluj basin, the Spiti basin, and the upper Satluj basin. Total 1700 glaciers were mapped in these basins.

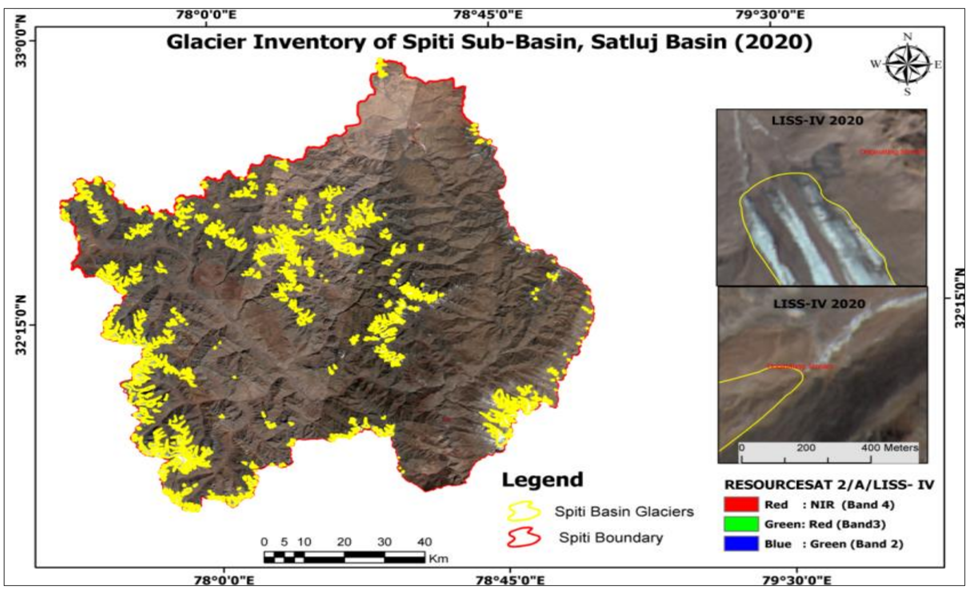


Figure 1 Glaciers inventory of Spiti basin on LISS IV-2020 data

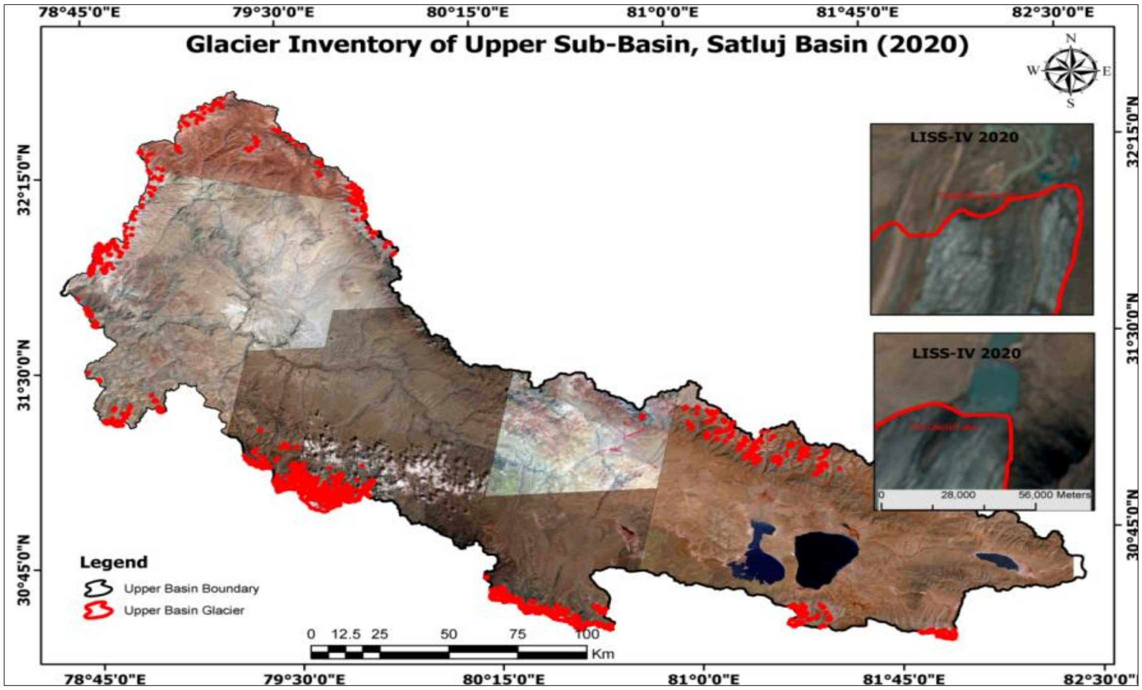


Figure 2 Glaciers inventory of Upper Spiti basin on LISS IV-2020 data

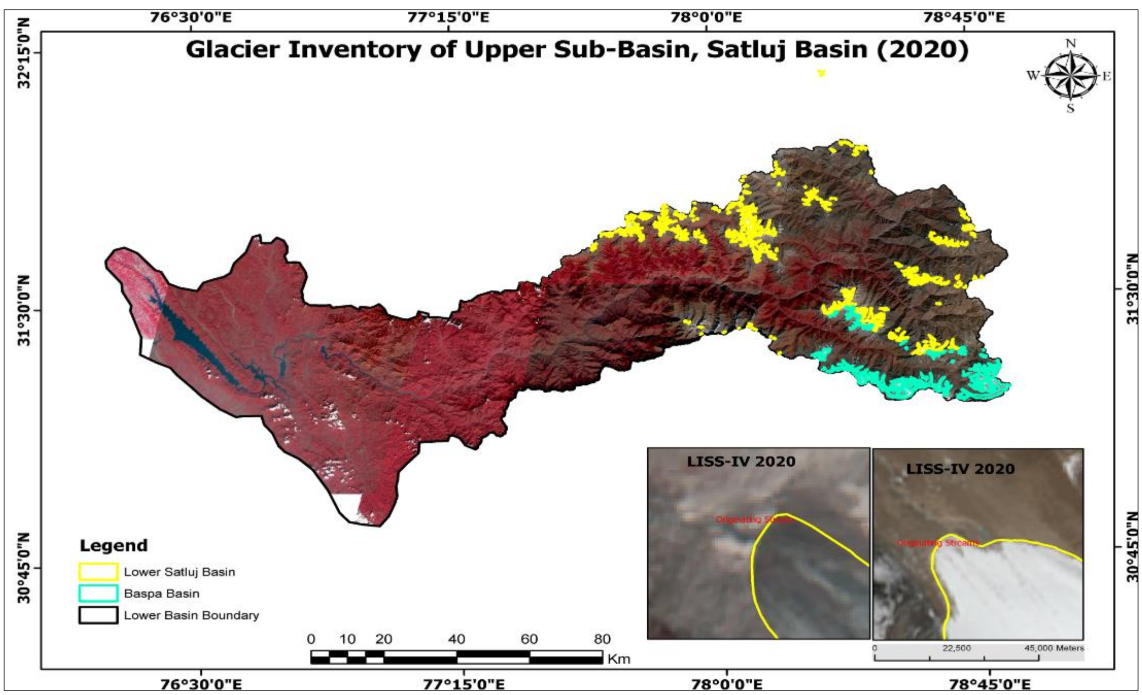


Figure 3 Glaciers inventory of Lower Satluj basin on LISS IV-2020 data

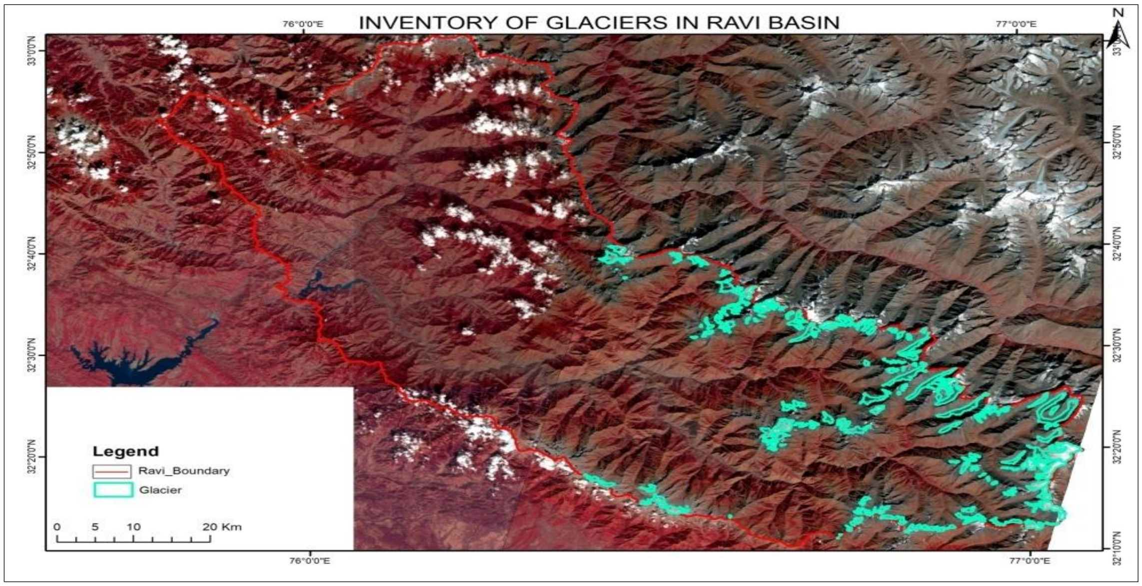


Figure 4 Glaciers inventory of Ravi basin on LISS IV-2020 data

Pro-glacial lakes and moraine-dammed lakes were mapped for the year 2020 based on visual interpretation and manual delineation from satellite images of different spatial resolution using ArcGIS 10.8 Software.

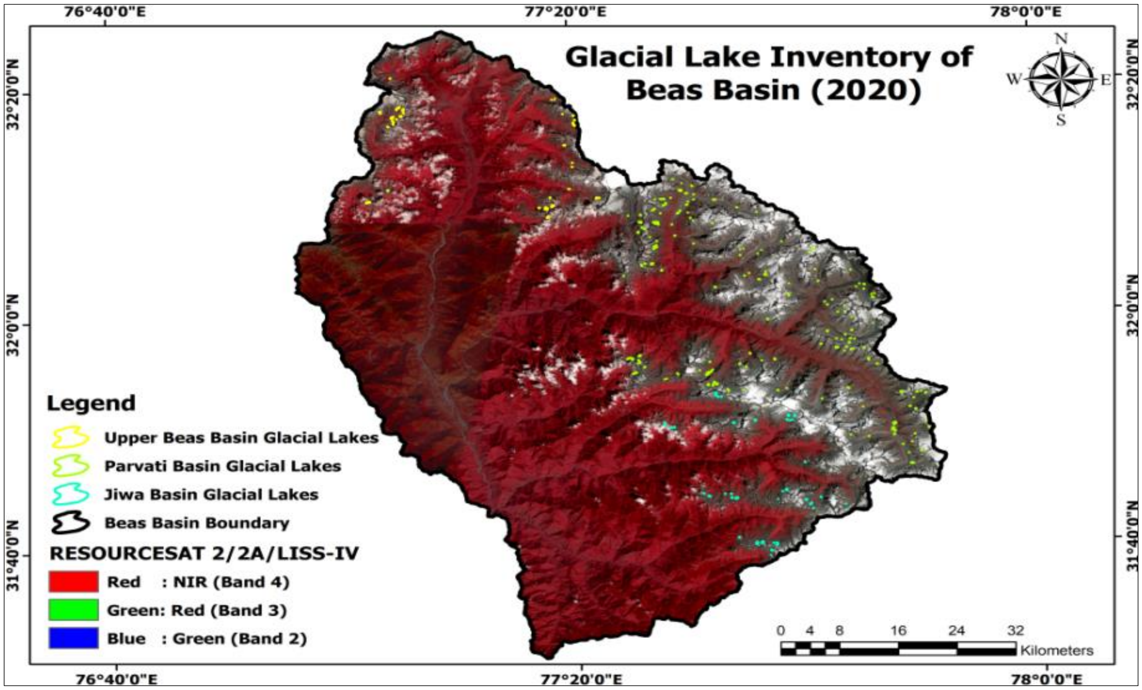


Figure 5 Glacial lake inventory of Beas basin on LISS IV-2020 data

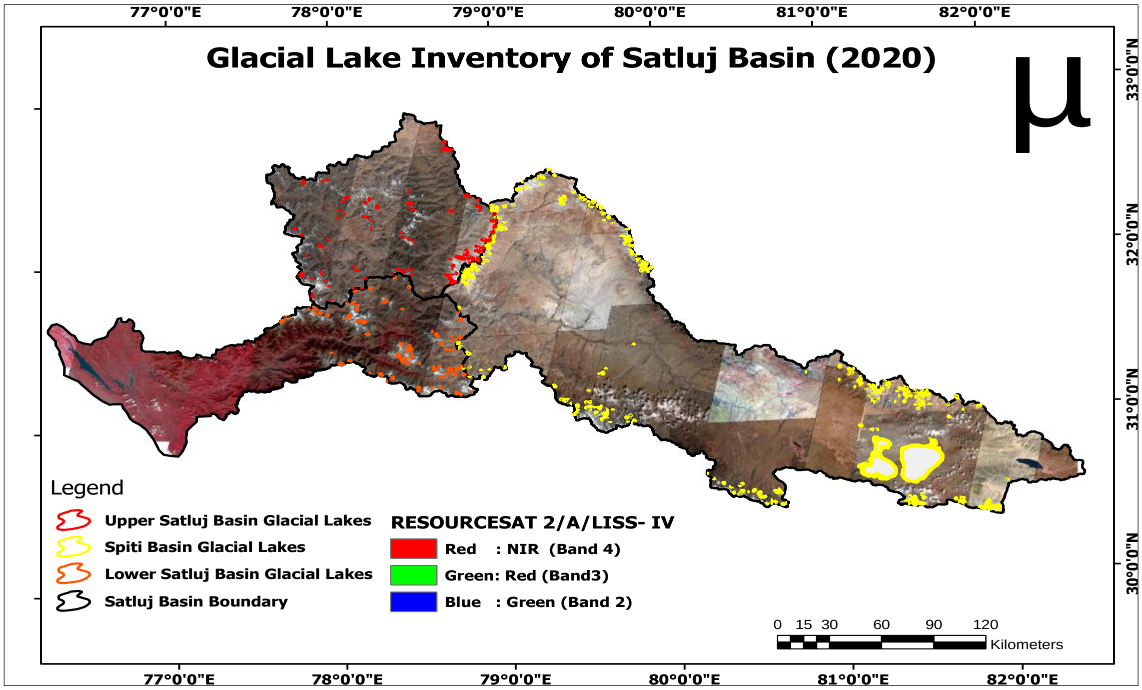


Figure 6 Glacial lake inventory of Satluj basin on LISS IV-2020 data

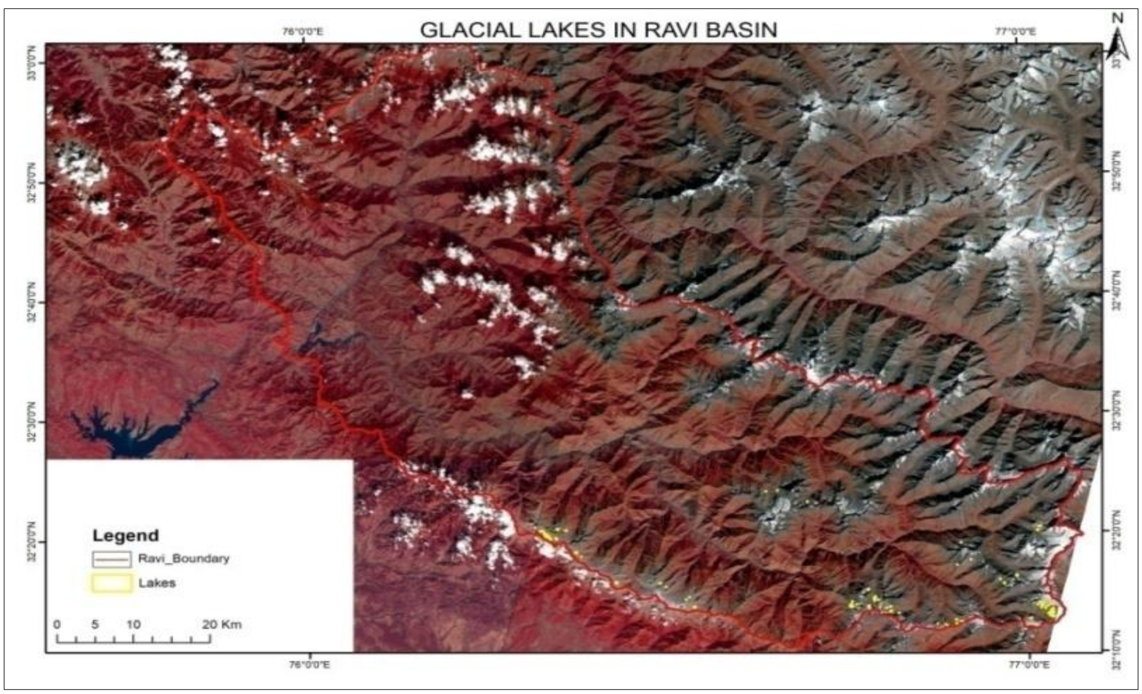


Figure 7 Glacial lake inventory of Ravi basin on LISS IV-2020 data

Using high resolution remote sensing data with ArcGIS 10.8 software, change detection of glaciers for the Chenab basin at a 1:10000 scale has been completed.

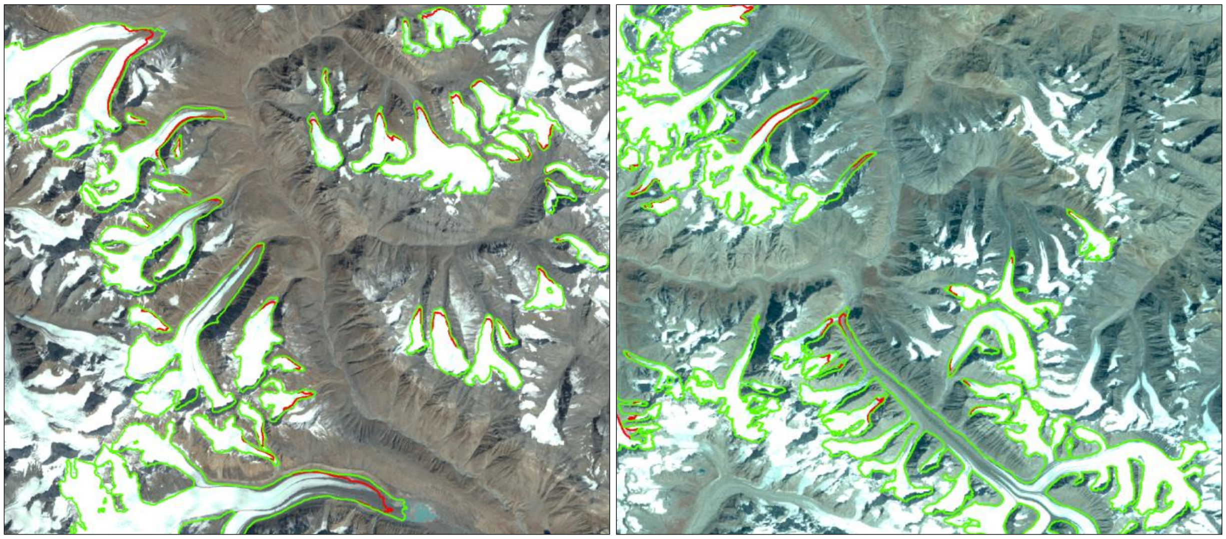


Figure 8 Temporal changes in Chandra basin glaciers

2. IMPACT OF CLIMATE CHANGE IN WATER FLOW PATTERN OF SATLUJ CATCHMENT (SJVNL) JOINT STUDY WITH IISC BANGALORE

Objectives under project:

- Inventory of all glaciers in Satluj catchment right from its origin in the Tibetan Himalayan region from 1980 onwards on a decadal basis using different sets of satellite data
- Seasonal snow cover assessment in the Satluj catchment from 2004 onwards,
- Collection of runoff data from 1990 onwards,
- Collection of precipitation and temperature data from 1990 onwards,
- Mass balance estimation of glaciers of Satluj river basin,
- Reconnaissance survey in Satluj river basin.

Different satellite data sets, including LANDSAT 02 to LANDSAT 08 and LISS-IV, were obtained in order to make an inventory of all glaciers and generate a multi-temporal glacier outline in the Satluj catchment, starting from their origin in the Tibetan Himalayan Region. Glaciers Inventory for Satluj catchment for the year 2000 using LANDSAT 07 and for the year 2020 LANDSAT 08 data sets was completed.

3. MONITORING OF PARECHHU LAKE

Parechhu Lake is a shallow geomorphic depression located in the Spiti Sub Division of District Lahaul & Spiti. It is formed by the Parechhu River and meets the Spiti River on its left bank close to Sumdo. The Sumdo Kaurik fault that passes close by and the area's unstable geology trigger landslides, which obstruct the downstream river channel and create a buildup of water in the depression. Since 2001, this lake has been under constant observation during the ablation season, which runs from April to September, due to its reputation of destruction. The lake was routinely observed in 2023, and the results on the spread of water were submitted to both the government and the SJVNL.

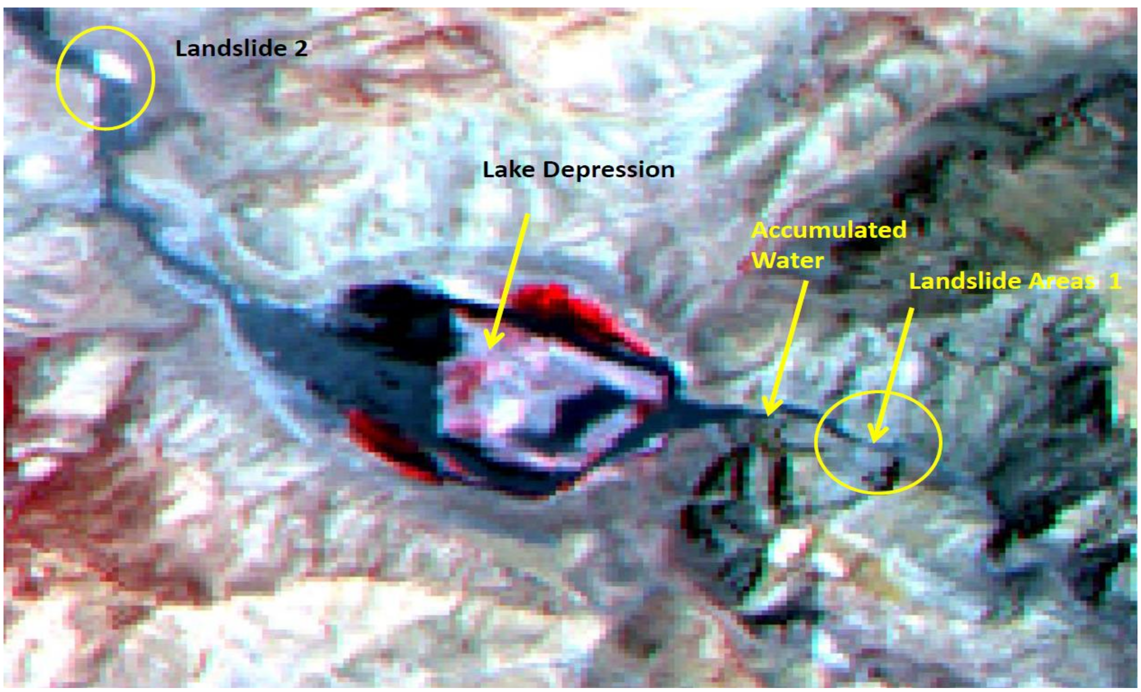


Figure 9 Parechhu lake as seen through IRS-R2-L3-97-48 on 4th August, 2023

OBSERVATIONS

Based on the analysis of IRS-R2-L3-97-48 on 4th August 2023, high resolution satellite data having spatial resolution of 23.5 meters, following observations were made: -

- The accumulated water in the lake depression could be seen along the periphery of the depression and extending downstream up to the point where landslide seems to have caused slight blockade of the river course i.e., about 727.26 meters from the lower point of the lake depression.

- Slight accumulation could also be seen along the braded channels in the upper part along with a small patch on the frontal part of the depression.
- Based on the tonal difference in the river flow, near the landslide 1, the slide seems to have caused a slight blockade in the river course could be seen resulting to have the accumulation of the water along the stream that extends upwards all along the peripheral side in the frontal portion of the lake depression.
- The effects of the landslide number 2 on the upper part along the Parechhu River could also be seen reflecting some accumulation along the river course.
- The inflow and outflow seem to be comparatively normal as on 4th August 2023 except slight accumulation in the outflow near the landslide 1.
- Based on the satellite image, the landslide might affect the outflow in the frontal part and inflow from the upper part needs to be monitored regularly in view of present status and in view of the melting of the snow cover from the higher catchments.

Based on the satellite data interpretation for the month from 4th August 2023, there was no threat from the Parechhu Lake on that day, but needs regular monitoring yearly as the ablation process undergoes (May to October) yearly and also needs the landslide monitoring in order to assess further changes in the river flow/ blockade etc.

4. MONITORING OF GLACIAL LAKES AND WATER BODIES IN SATLUJ CATCHMENT USING REMOTE SENSING AND GIS TECNIQUES DURING 2022

Mountain ecosystems harbor a wide range of significant natural resources and play critical role in the ecological and economic processes of the Earth. Deforestation, landslides, land degradation, desertification and Glacier Lake Outbursts Flooding (GLOFs) are some of the common environmental issues in the mountain regions. The major challenge currently faced by the mountain environment is the escalation of these issues through atmospheric as well as man-induced changes.

The main objectives of the study are to monitor the water spread area of the all the moraine dammed glacier lakes/ water bodies on monthly basis in the entire Satluj Basin during April to

November 2023 based on the inventory of the lakes during the preceding year prepared using space data.

STUDY AREA AND DATA USED

The investigations have been carried out in the Satluj basin right from its origin from the Mansarover Lake in Tibetan Region. The river Satluj is one of the main tributaries of Indus and has its origin near Mansarover Lake and Rakes Tal in Tibetan Plateau at an elevation of about 4,500 m (approx.). The study area has been divided into three major sub basins i.e., Spiti as sub basin number 1, Lower Satluj as sub basin number 2 and Upper Satluj in Tibet catchment as basin 3. The Satluj River travels about 300 km (approx.) in Tibetan plateau in North-Westerly direction and changes direction towards South-West and covers another 320 km.(approx.) up to Bhakra gorge where 225m high straight gravity dam has been constructed. This western Himalayan basin is highly rugged terrain with abundant natural water resource in the form of snow pack. The Satluj basin is geographically located between 30° 00' N, 76° 00' E and 33° 00’ N, 82° 00’ E. The Nathpa dam is a 62.5 m high concrete dam located on Satluj River at Nathpa. The dam is a main component of the 1,500 MW Nathpa Jhakri Hydro-Electric Project – NJHEP. The project is located in the state of Himachal Pradesh and derives its name from the names of two villages in the project vicinity - Nathpa in Kinnaur district and Jhakri in Shimla district - in the interiors of Himachal Pradesh. The project was conceived as a run-of-river type hydro power development, harnessing hydro-electric potential of the middle reaches of the river Satluj. The project's dam has been constructed near village Nathpa and its power house has been constructed on the left bank of the river Satluj at village Jhakri. The project stretches over a length of about 50 Km from the dam site to the power house site, on the Hindustan- Tibet Road (NH-22). Characteristics of the Satluj basin and inaccessibility of the major part of it make remote sensing application ideal for hydrologists to monitor glacial lakes and water bodies in the basin. Most of the area in the present study falls in the inaccessible high mountain region of Himalayas. Hence, the monitoring of glacial lakes / water bodies was done using remote sensing method. The images acquired by AWiFS (Advanced Wide Field Sensor) sensor, LISS III and LISS IV of IRS-RS2 & RS2A (Indian Remote Sensing) Satellite were used in the present study.

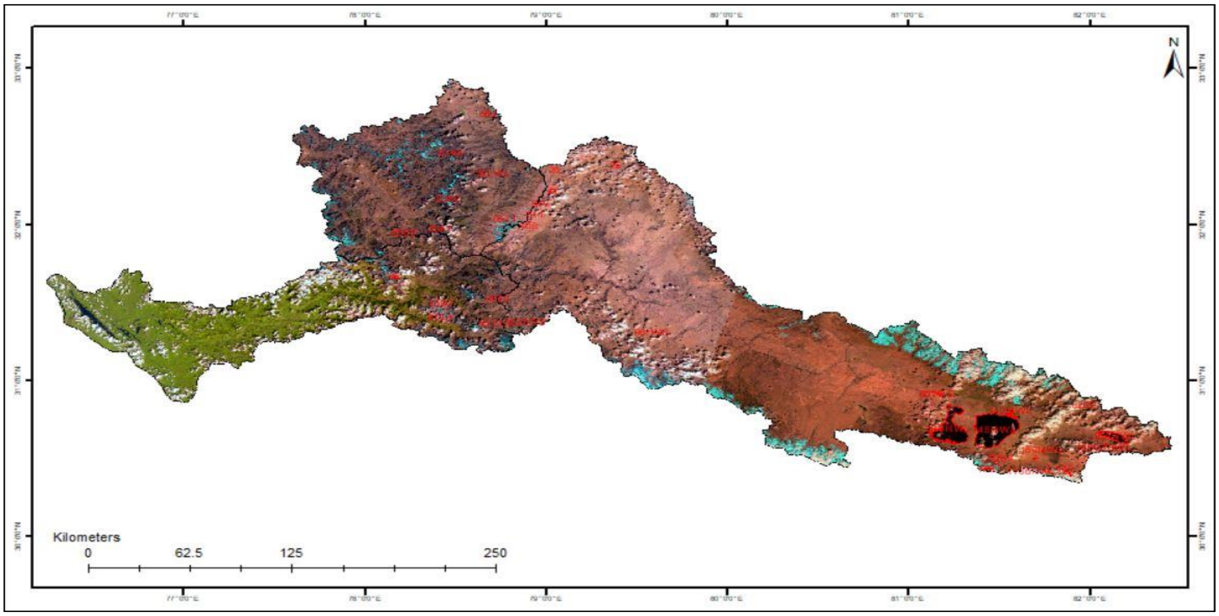


Figure 10 False Colour Composite of Satellite images covering Satluj basin

STATUS OF LAKES AS ON APRIL 2023

During April 2023, only data product for 11th April 2023 could be obtained of AWiFS (Fig 11) having its maximum area under the impact of seasonal snow. The interpretation of satellite data reveals presence of 42 lakes comprising 3 lakes from Spiti and 2 lakes from Lower Satluj i.e., sub basin number 1 & 2 and 37 lakes from the Upper Satluj basin i.e., sub basin number 3. Further detailed analysis reflects those 11 lakes identified are smaller with area less than 5 ha in upper Satluj Basin, 11 lakes are with areal range 5-10 ha and 20 lakes are with area greater than 10 ha (Fig 12). Further analysis of 42 lakes reveals that 20 lakes are the high-altitude wetlands falling in the Upper Satluj basin. Based on the areal distribution of these 20 high altitude wetlands, 11 are with area more than 10 ha, 5 lies within range of 5 - 10 ha and 4 with area less than 5 ha (Fig 13).

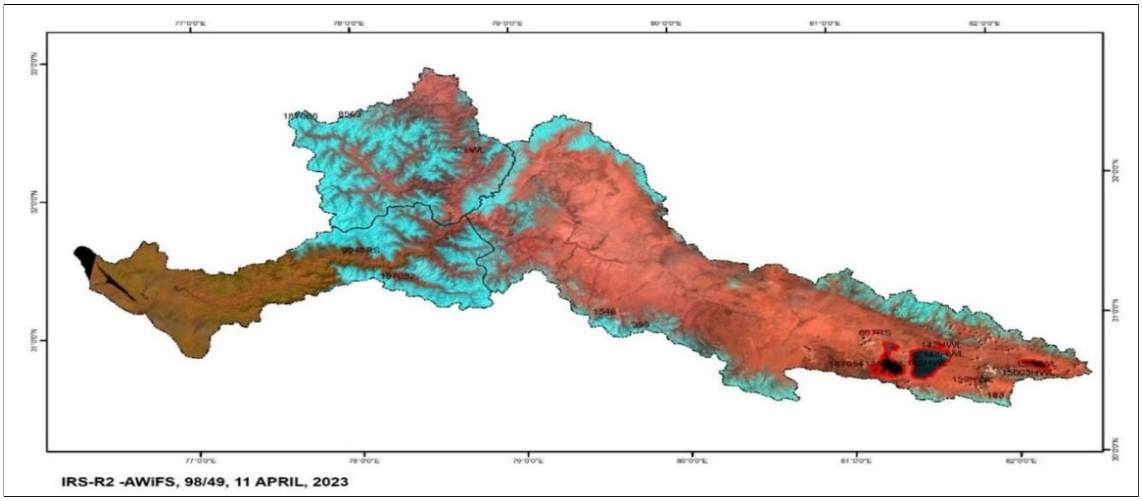


Figure 11 IRS-R2 -AWiFS, 98/49, 11th April, 2023

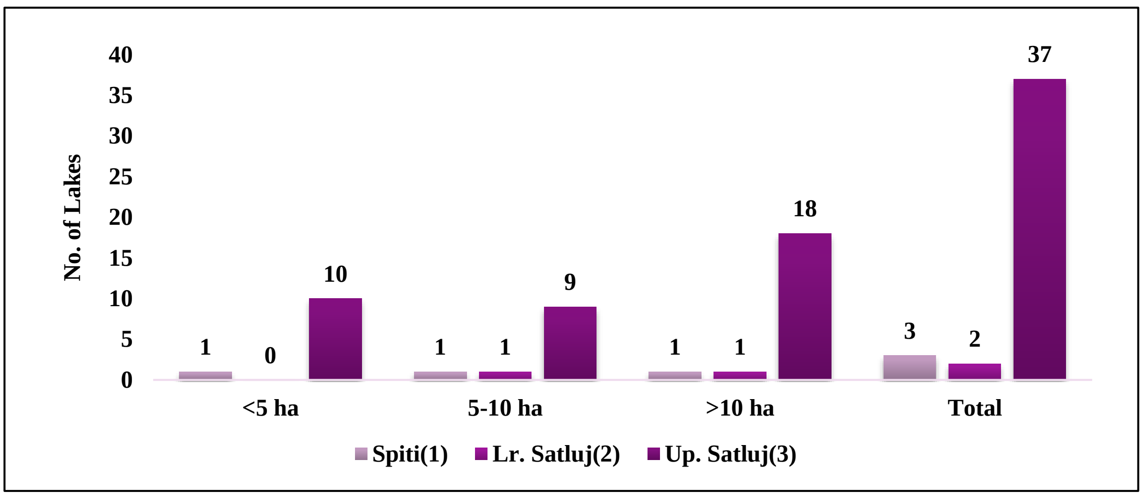


Figure 12 No. lakes based on IRS-R2 -AWiFS, 98/49, 11th April, 2023

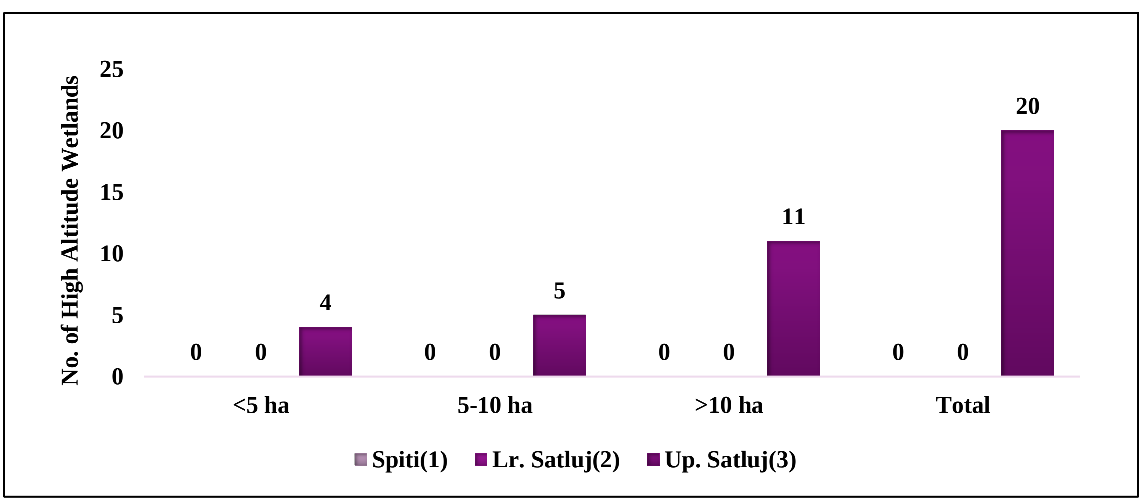


Figure 13 No. of high wetland lakes based on IRS-R2 -AWiFS, 98/49, 11th April, 2023

STATUS OF LAKES AS ON MAY 2023

In May 2023, two data sets covering the 29th of May 2023 for path rows 98-46 and 98-51 with some gaps in the Upper Satluj catchment were used for interpretation. A total of 38 lakes were discovered from the satellite data analysis because of the area's lacking coverage and the effects of cloud and snow cover. Of these 38 lakes, 8 are located in the Lower Satluj sub basin, 11 in the Spiti sub basin, and nineteen in the Upper Satluj sub basin (Fig. 14).

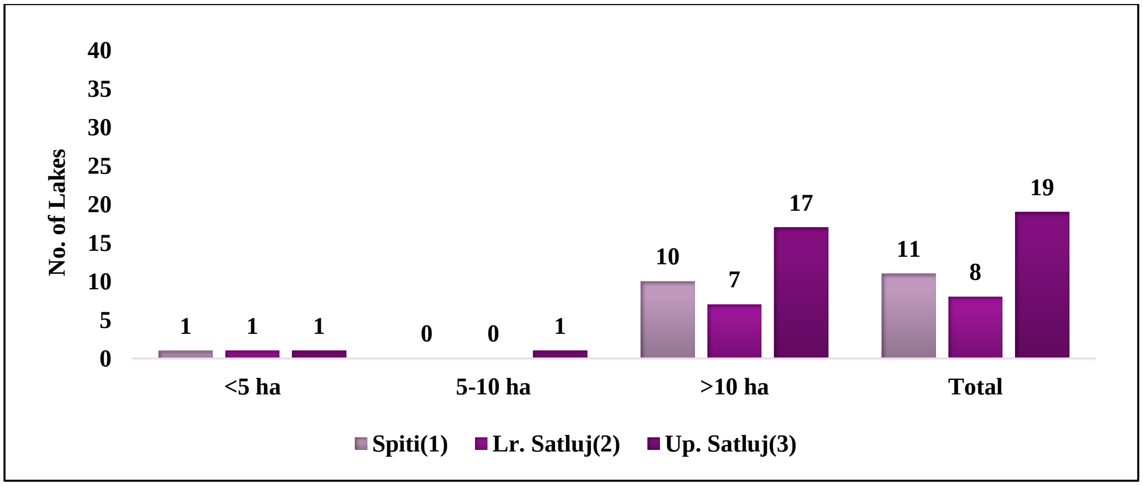


Figure 14 No. lakes based on IRS-R2- A-AWiFS, 98/46 and 98/51, 29th May, 2023

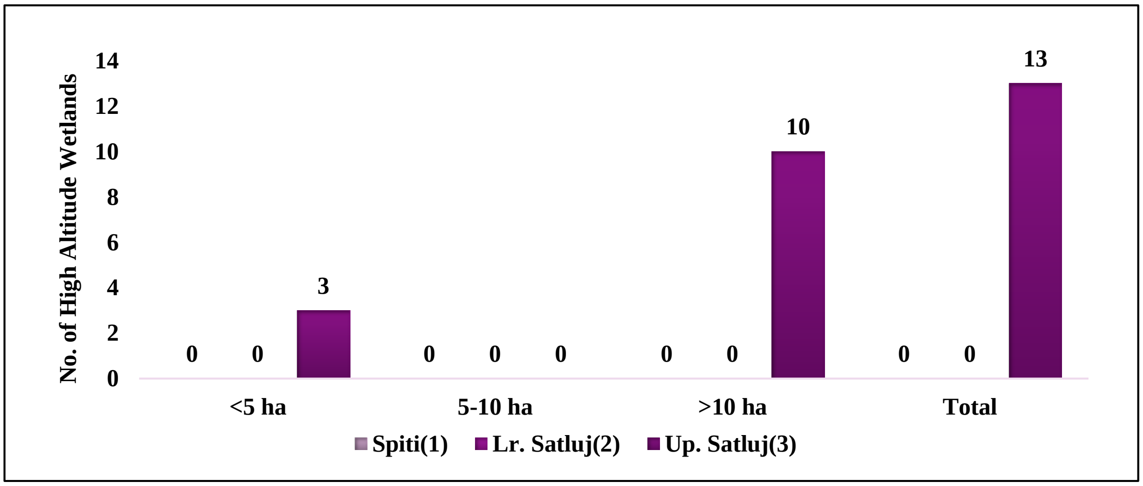


Figure 15 No. of high wetland lakes based on IRS-R2- A-AWiFS, 98/46 and 98/51, 29th May, 2023

Of the 38 lakes, 34 have an area greater than 10 hectares, 1 has an area between 5 and 10 ha, and 3 are minor, with an area less than 5 ha. In the Lower Satluj subbasin's river portion, seven lakes have been recognized. Upon comparing the 25 lakes found in May 2023 to the same month the year before, it can be seen that 10 lakes have decreased in area while 15 have showed an increase in size.

STATUS OF LAKES AS ON JUNE 2023

Two AWiFS satellite images with path rows 97-50A and 97-50B for the period of June 17, 2023, were available, however they were partially covered in snow. A total of 59 lakes were mapped, out of which 17 were from the Spiti subbasin, or basin number 1, 4 from the Lower Satluj basin, or subbasin number 2, and 38 from the Upper Satluj basin, or subbasin number 3. A more thorough examination of the data reveals that 24 of the lakes are small, having an area of less than 5 ha, 14 have an area between 5 to 10 ha, and 21 have an area more than 10 ha (Fig 16).

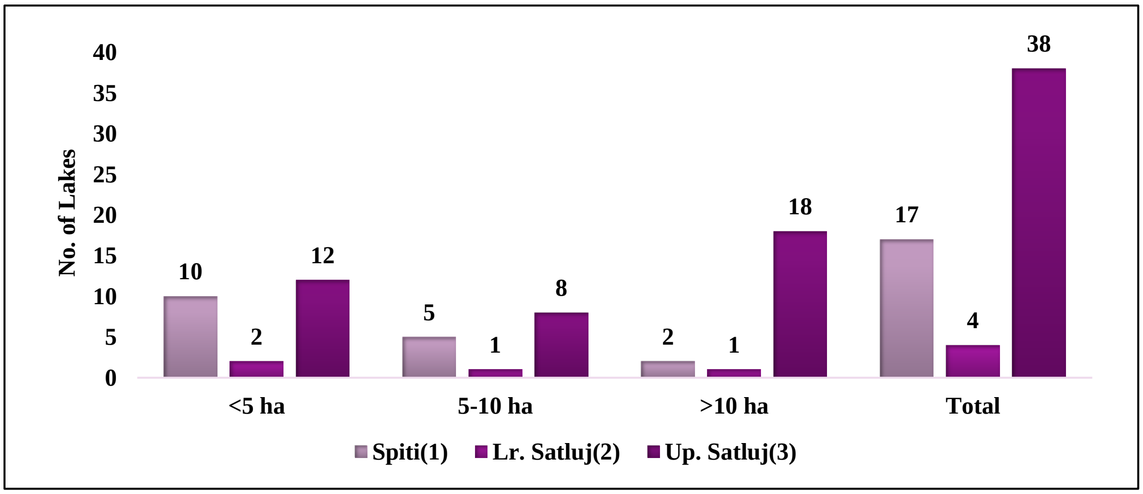


Figure 16 No. of lakes based on IRS-R2-AWiFS, 97/50 A and 97/50 B, 17th June, 2023

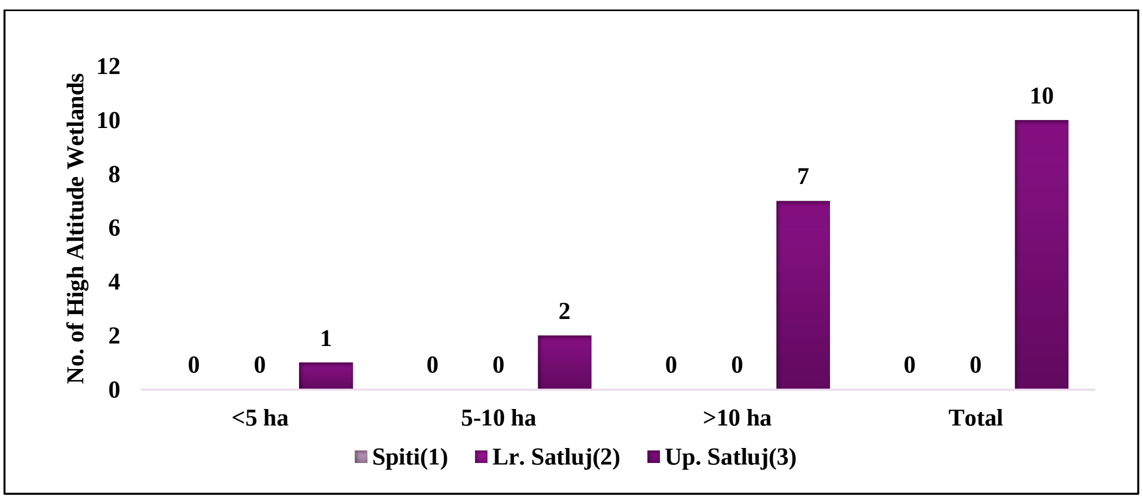


Figure 17 No. of high-altitude wetland lakes-based IRS-R2-AWiFS, 97/50 A and 97/50 B, 17th June, 2023

Similarly, a study of 59 lakes reveals that 10 of the lakes are high-altitude wetlands in the Upper Satluj basin, with 1 wetland being tiny and having an area of less than 5 ha, 2 being within the range of 5-10 ha, and 7 being larger than 10 ha (Fig 17). Based on a comparative analysis, 41 lakes saw a gain in their water spread area relative to 2022, while 18 lakes had a drop in area.

STATUS OF LAKES AS ON JULY 2023

During the month of July 2023, no cloud free satellite data was available as a result of which no information was retrieved.

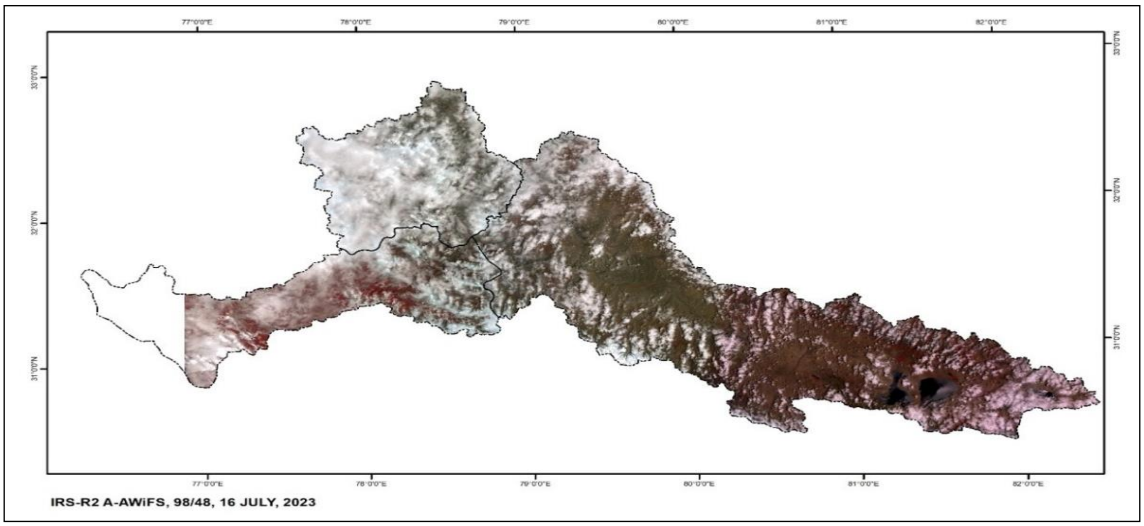


Figure 18 IRS-R2 A-AWiFS, 98/48, 16th July, 2023

STATUS OF LAKES AS ON AUGUST 2023

Based on the study of satellite data for the month of August 2023, three data sets for August 31st were mosaicked, providing partial coverage of the Satluj Basin. The study of these three products on the 16th, 28th, and 31st of August 2023 revealed a total of 412 lakes in the watershed, compared to 350 lakes in 2022, with 55 from Spiti, 58 from Lower Satluj, and 299 from Upper Satluj subbasin (Fig 19 & 20). Additional analysis of 412 lakes reveals that 229 have an area of less than 5 ha, including 37 from Spiti, 44 from Lower Satluj, and 148 from Upper Satluj basin. Similarly, 80 lakes are such which have the area more than 10ha and are considered big lakes comprising 5 from Spiti, 5 from Lower Satluj and 70 from Upper Satluj basin. Furthermore, 36 lakes were identified as high-altitude wetlands, with 10 having an area less than 5 ha, 11 having an area between 5-10 ha, and 15 having an area greater than 10 ha, all of which are located in the

Upper Satluj basin (Fig 21). When these 412 lakes were examined temporally in comparison to 2022 data, only 355 lakes were compared for temporal variation, with 212 lakes/wetlands showing an increasing trend in their water spread and 143 lakes/wetlands showing a decreasing trend in their water spread. The remaining lakes/wetlands that were not compared form the baseline data for monitoring during the next ablation season, which might be relevant because these lakes/wetlands were not mapped in 2022 due to snow cover changes or are new and thus mapped only this year. The 12 lakes with ids RS are mostly formed due to the accumulation of water along the main Satluj river course with 11 from the Upper Satluj sub basin and 1 from the Lower Satluj sub basin.

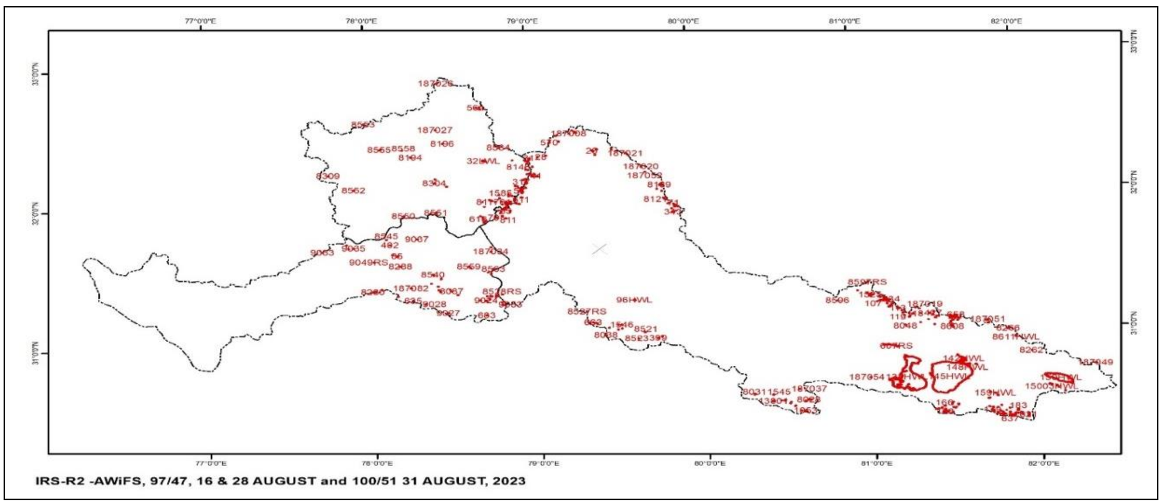


Figure 19 IRS-R2 -AWiFS, 97/47, 16 & 28 Aug and 100/51 31st August, 2023

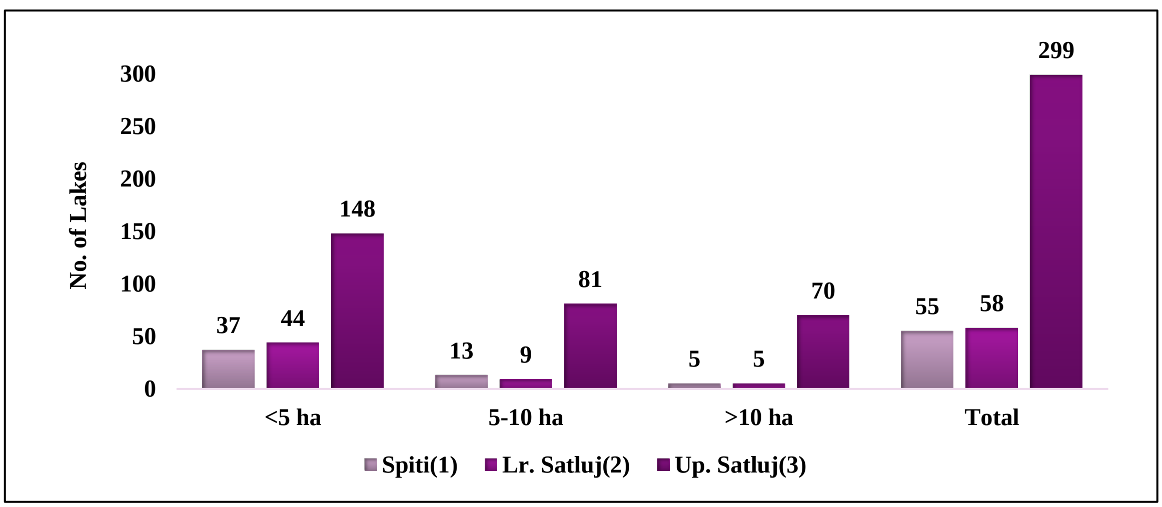


Figure 20 No. of lakes based on IRS-R2, AWiFS, 99/48, 97/47, 16th & 28th August and 100/51, 31st August, 2023

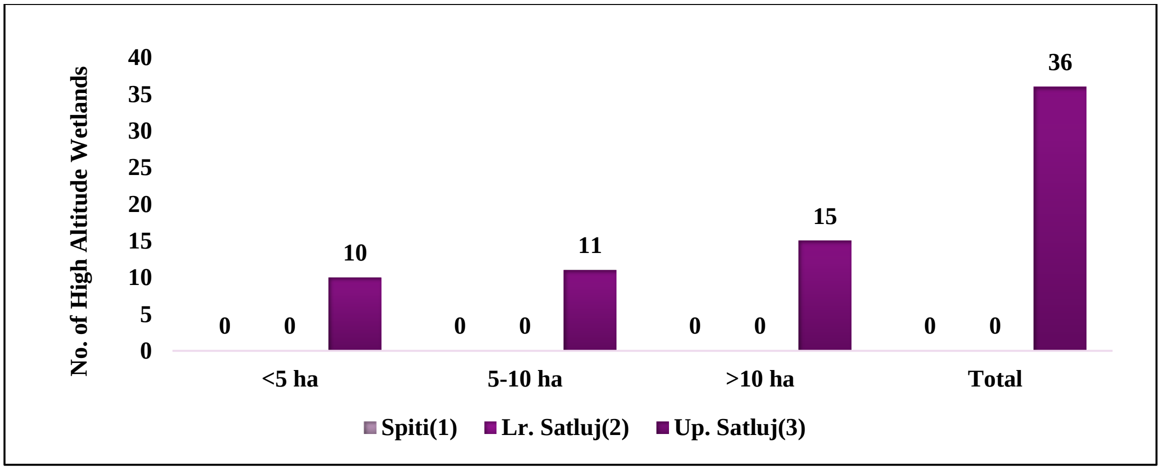


Figure 21 No. of high-altitude wetland lakes based on IRS-R2, AWiFS, 99/48, 97/47, 16 & 28th August and 100/51 31st August, 2023

STATUS OF LAKES AS IN SEPTEMBER 2023

During September 2023, a total of 05 scenes were evaluated, with only two data products (2nd and 26th September) having full coverage and the rest (4th, 12th, and 14th September). Based on data quality and coverage, a total of 466 lakes were mapped, compared to 414 lakes in 2022, with 67 lakes from the Spiti basin, 58 from the lower Satluj, and 341 from the upper Satluj basin. Further research of 466 lakes reveals that 270 lakes have an area of less than 5 ha, including 45 from Spiti, 44 from Lower Satluj, and 181 from Upper Satluj basin. Similarly, 113 lakes have an extent of 5-10 ha, including 16 from Spiti, 9 from Lower Satluj, and 88 from the Upper Satluj basin.

Similarly, 83 lakes with an extent greater than 10 ha are classified large lakes, including 6 from Spiti, 5 from Lower Satluj, and 72 from the Upper Satluj basin (Fig 22). Further examination of 466 lakes reveals that 39 lakes are classified as high-altitude wetlands, with 11 having an extent less than 5 ha, 13 having an area between 5 and 10 ha, and 15 having an area greater than 10 ha, all of which are part of the Upper Satluj basin (Fig 23). When these 466 lakes were viewed temporally in relation to 2022 data, 438 lakes were compared for temporal variation, with 280 lakes/wetlands showing an increasing trend in their water spread and 158 lakes/wetlands showing a decreasing trend in their water spread. The lakes that were not compared provide baseline data for next year's monitoring.

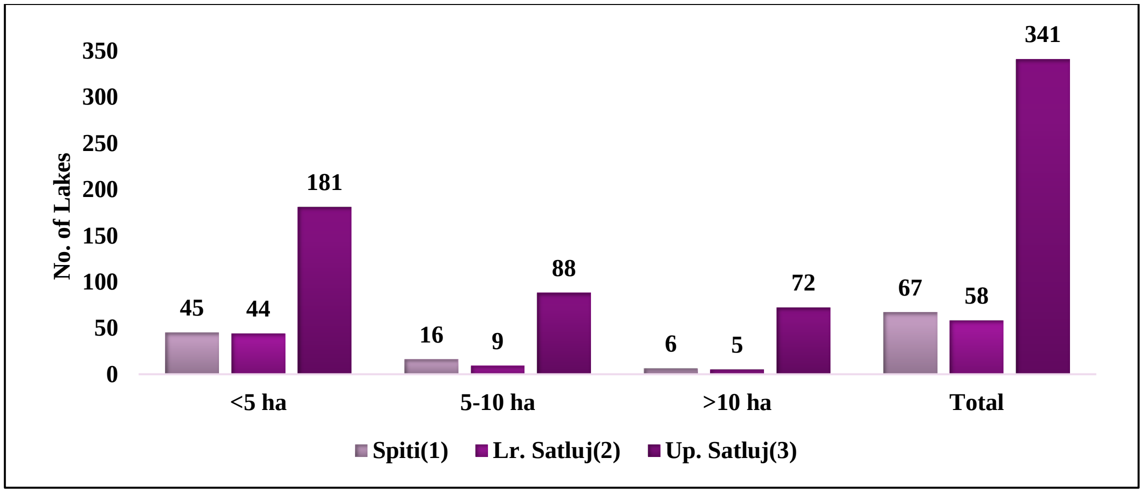


Figure 22 No. of lakes based on IRS- R2, AWiFS, September, 2023

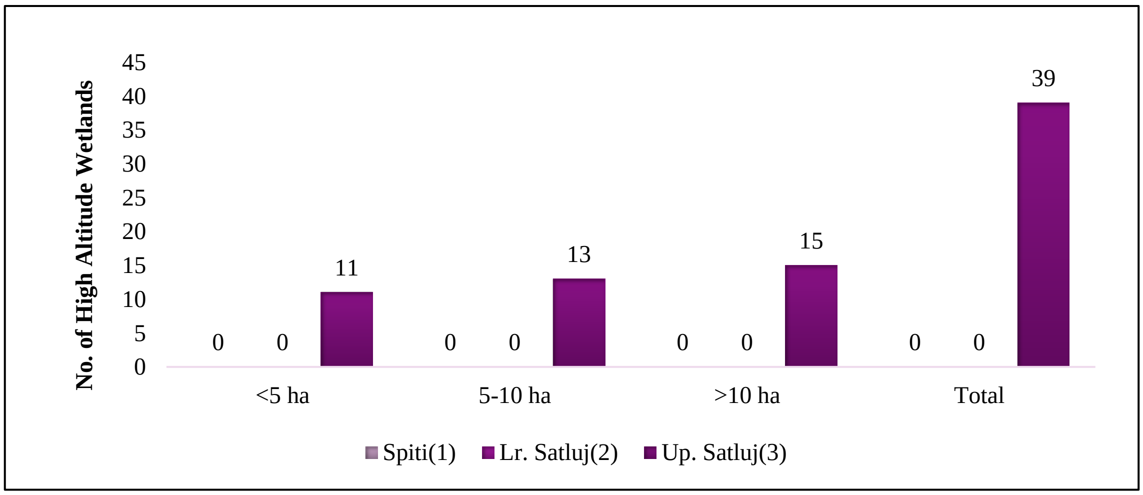


Figure 23 No. High altitude wetland lakes based on IRS- R2, AWiFS, September, 2023

STATUS OF LAKES AS ON OCTOBER 2023

During October 2023, three AWIFS data packages were available for the 5th, 6th, and 15th of October. The examination of these data products revealed the presence of 417 lakes in the overall watershed, compared to 174 (2022), with 54 from Spiti, 43 from Lower Satluj, and 320 from the Upper Satluj subbasin. Further analysis of 417 lakes revealed that 243 had an area of less than 5 ha, including 38 from Spiti, 32 from Lower Satluj, and 173 from the Upper Satluj basin. Further investigation finds that 95 lakes lie within the area range of 5-10 ha, including 11 from Spiti, 8 from Lower Satluj, and 76 from the Upper Satluj basin.

Similarly, 79 lakes with an area of more than 10ha were identified as major lakes, including 5 from Spiti, 3 from the Lower Satluj basin, and 36 from the Upper Satluj basin (Fig 24). Aside from that, when these 417 lakes were studied for their source, 36 lakes were recognized as high-altitude wetlands comprising part of the Upper Satluj basin, with 10 with an area less than 5 ha, 11 with an extent between 5-10 ha, and 15 with an area greater than 10 ha (Fig 25). When 417 lakes/wetlands were analyzed temporally with data from 2022, only 348 lakes/wetlands could be compared, with 188 lakes/wetlands showing a decreasing trend in their water spread and 160 lakes/wetlands showing an increasing trend.

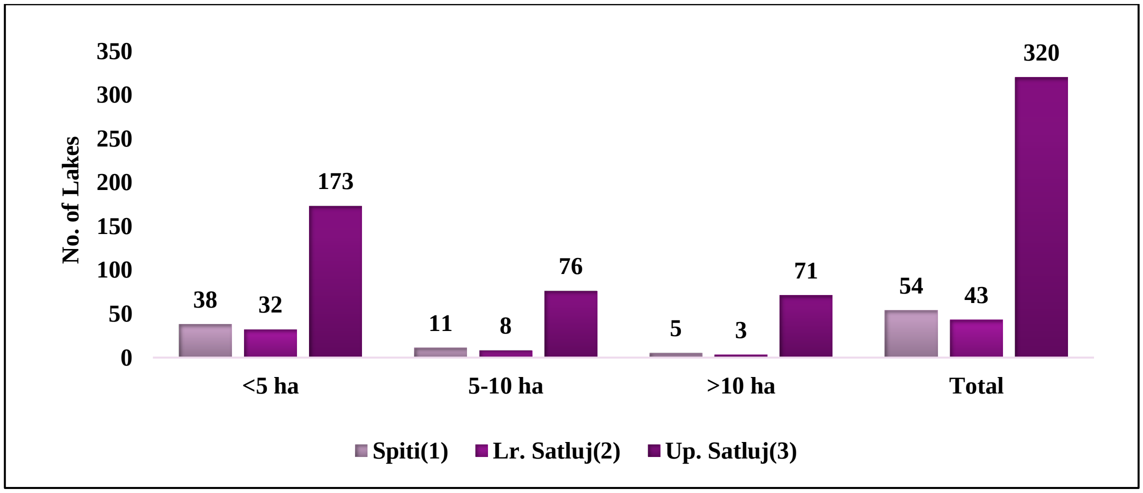


Figure 24 No. of lakes based on IRS-R2, AWiFS, October, 2023

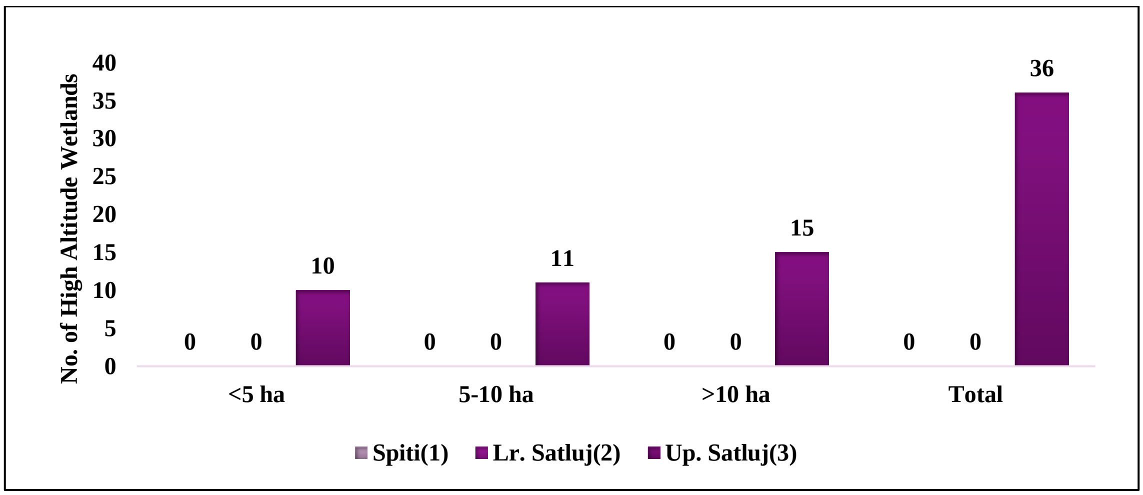


Figure 25 No. of high-altitude wetland lakes based on IRS-R2, AWiFS, October, 2023

STATUS OF LAKES AS ON NOVEMBER 2023

During November 2023, merely three scenes on the 13th of November were obtained, reflecting some snow cover affects, resulting in only 36 lakes being delimited. Furthermore, a closer look of these 36 lakes reveals that 16 are part of the Spiti subbasin, 3 are part of the Lower Satluj basin, and 17 are part of the Upper Satluj basin (subbasin number 3). Further study reveals that 11 lakes are small (less than 5 ha), 9 are 5-10 ha, and 16 are large (more than 10 ha) (Fig 26).

When these 36 lakes were viewed from their source, it was discovered that 09 of them were primarily high-altitude wetlands, with one having an area less than 5 ha and eight having an area greater than 10 ha, all of which are located in the Upper Satluj subbasin (Fig 27). Furthermore, investigation suggests that 10 of the 36 lakes were produced along the river flow as a result of water damming for one or more reasons. Furthermore, these 36 lakes/wetlands were observed temporally in relation to 2022, and it was discovered that only 28 lakes/wetlands could be compared, with 13 lakes/wetlands characterized by a reduction in their water spread, 15 lakes/wetlands showing an increase in their water spread w.r.t. 2022, and the remaining lakes/wetlands that were not compared serving as the baseline data for the next ablation season.

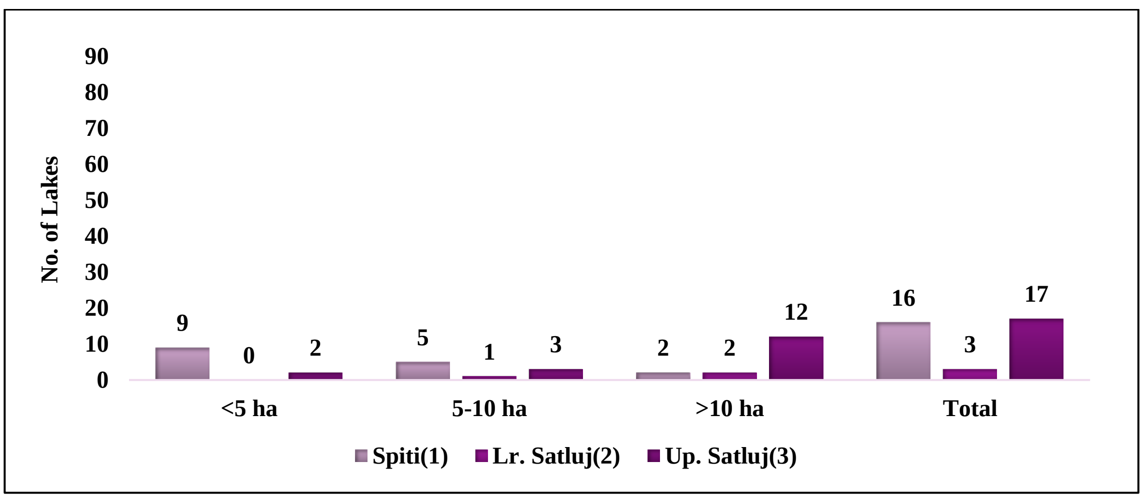


Figure 26 No. of lakes based on IRS, R2-AWiFS, November, 2023

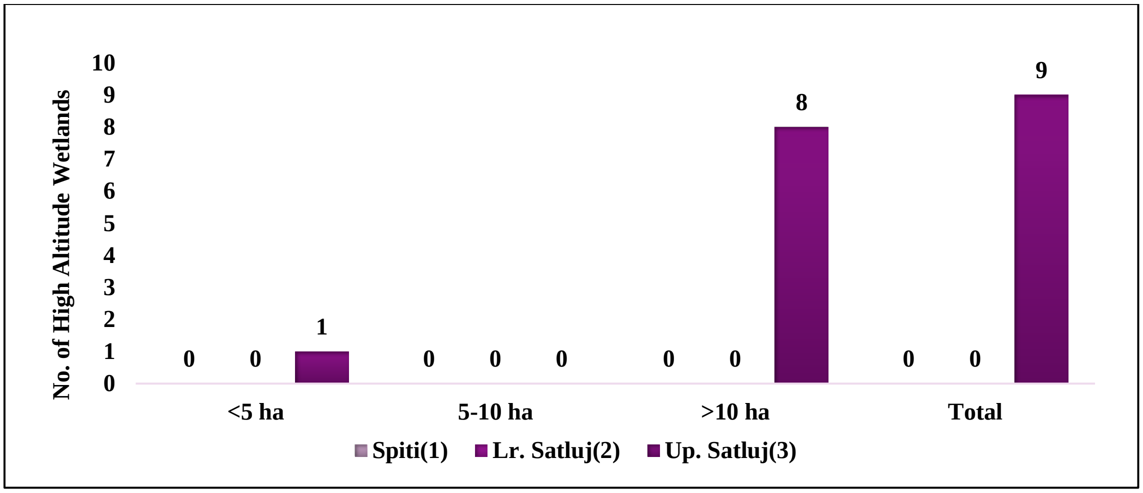


Figure 27 No. of high-altitude wetland lakes based on IRS, R2-AWiFS, November, 2023

INVENTORY OF LAKES BASED ON LISS III SATELLITE DATA FOR 2023

Using IRS LISS-III Resourcesat 2/2A satellite data sets with a spatial resolution of 23.5 m, a thorough inventory of glacier lakes/high altitude wetlands in the Satluj watershed was created, and the results were compared to 2022. The inventory based on LISS-III satellite data is more detailed since this sensor has a higher spatial resolution (23.5 m) than AWiFS (56 m), allowing for more information about the topography. Satellite data for the months of July to October 2023 were sought for, and high-quality cloud-free data was chosen for mapping purposes since the glacier surfaces are entirely exposed at this time and are likely to provide more detailed information about the glaciers.

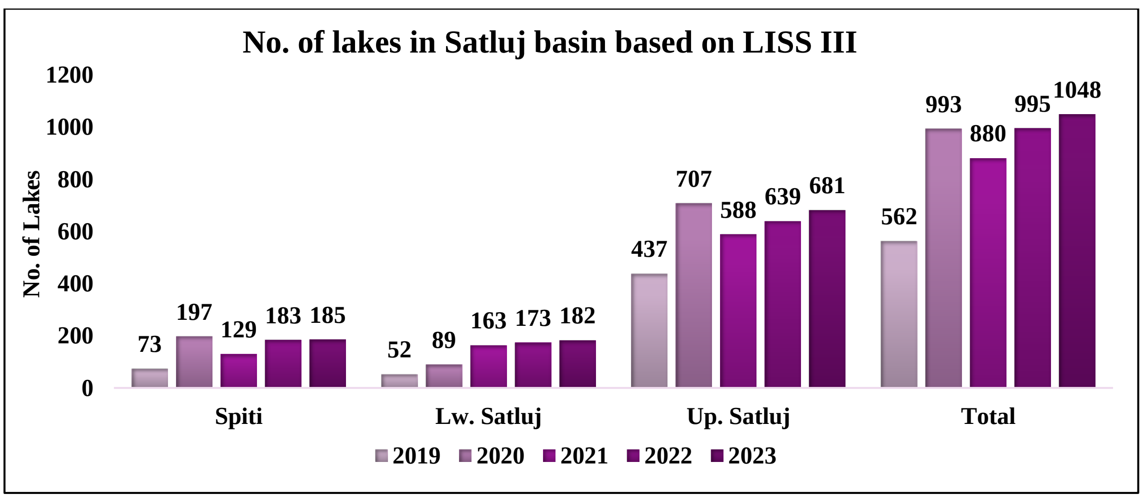


Figure 28 No. of lakes based on LISS III in Satluj basin

The study area was covered by LISS-III coverage, primarily by seven numbers of scenes inside 96/48, 96/49, 97/48, 98/48, 98/49, 99/49, and 100/49 paths and rows, and these data products were examined using visual interpretation techniques and the same methodology used for AWIFS satellite data. Based on visual interpretation techniques using the above-mentioned LISS III satellite data products for the above-mentioned paths-rows, a total of 1048 lakes and wetlands were delineated in 2023 in the study area, comprising 185 from the Spiti basin, 182 from the Lower Satluj basin, and 681 from the Upper Satluj basin, respectively, in comparison to the total number of lakes delineated in 2022 (995) 2021 (880), 2020 (993), 2019 (562), and 2018 (769) (Fig 28).

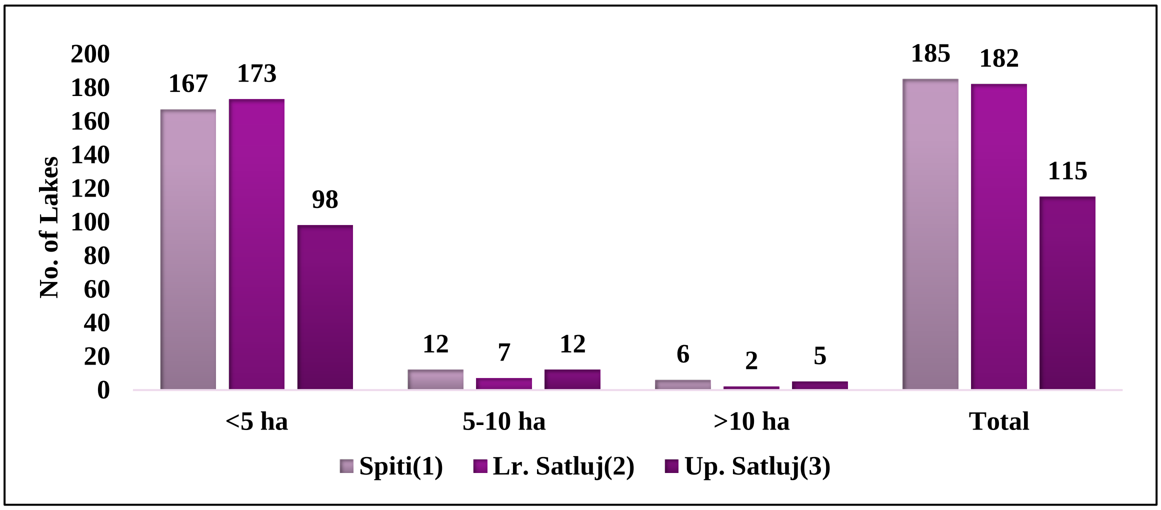


Figure 29 No. of lakes based on IRS-R2, LISS III, 96/48 and 96/49

Further detailed analysis for 2023 using LISS III analysis revealed that in the area covered under path rows 96/48 and 96/49, a total of 482 lakes (Fig 29) primarily covering the areas from basins 1 and 2 were delineated in comparison to 478 (2022), 384 lakes (2021), 362 lakes (2020), 153 lakes (2019), and 275 lakes (2018) respectively. The temporal analysis of the 482 lakes delineated from LISS III satellite images for 2023 with respect to 2022 shows that 378 lakes /wetlands have shown an increase in their water spread compared to 2022, whereas 80 lake/wetlands have decreased in area relative 2022. The lakes /wetlands which were not seen temporally forms the base line data for next year ablation as either these were not formed during 2022 due to one or the other reason or are the new formed and mapped during 2023.

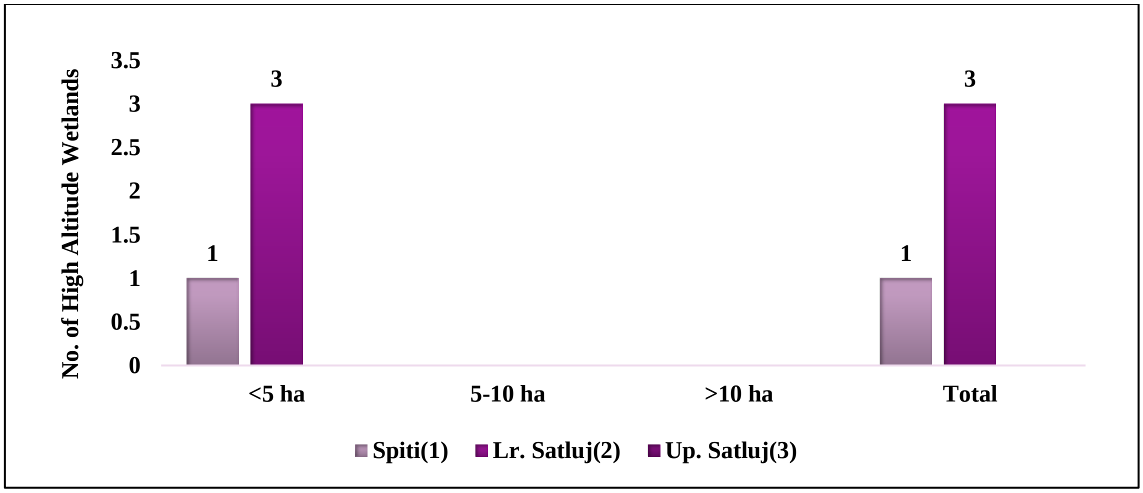


Figure 30 No. of high-altitude wetland lakes based on IRS, R2- LISS III, 96/48 & 96/49

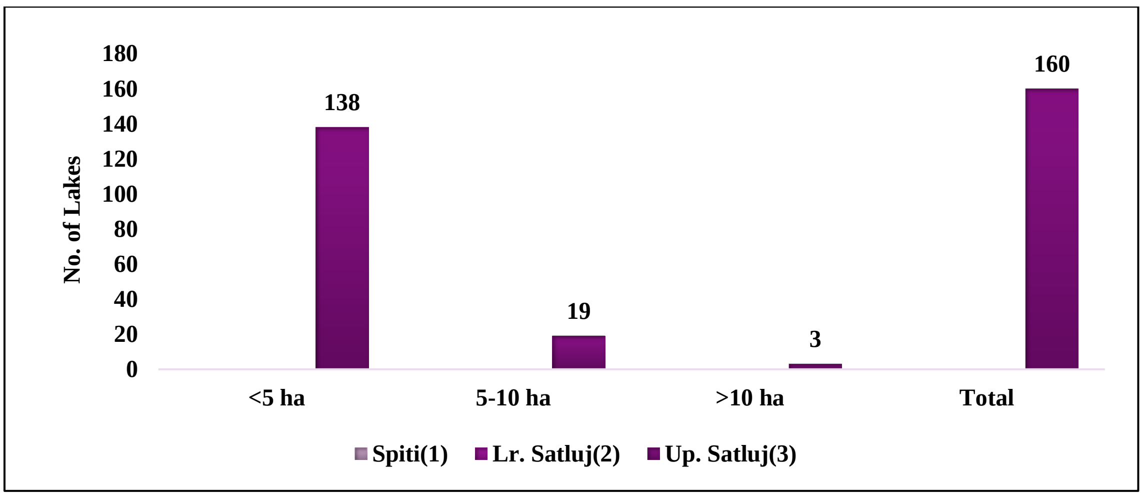


Figure 31 No. of lakes-based IRS R-2, LISS III, 97/48 and 97/49

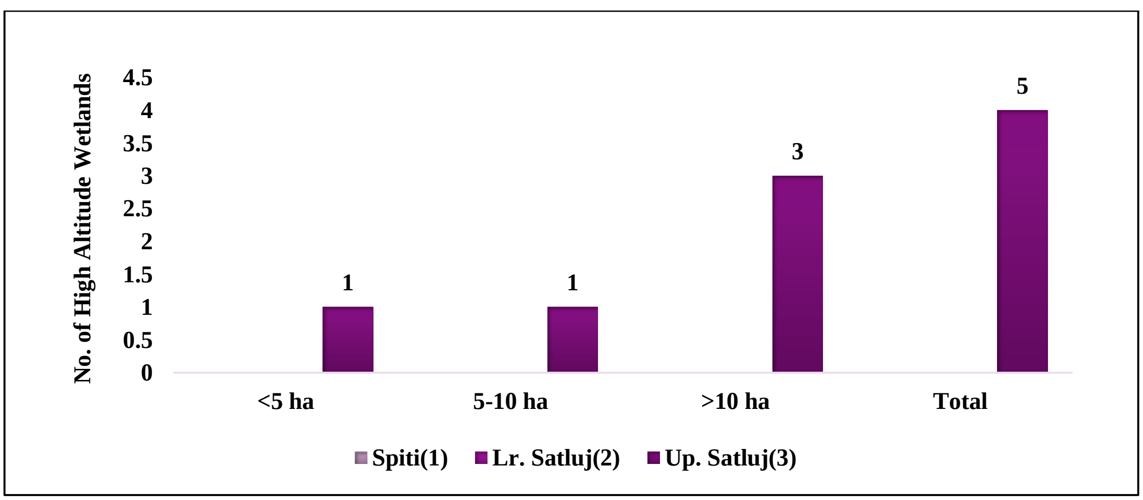


Figure 32 No. of high-altitude wetland Lakes based IRS R-2, LISS III, 97/48and 97/49

Only the Upper Satluj sub basin makes up path rows 99/49 and 100/49. According to interpretation based on satellite data for 99/49 and 100/49 (Fig 33), 348 lakes were mapped in 2023 compared to 362 (2022), 311 (2021), 348 (2020), and 275 (2019) from the Upper Satluj basin. Additionally, 271 of these 348 lakes have been categorized as small lakes, having an area of less than 5 ha, as opposed to 281 in 2022. This represents a drop of roughly 4% in the case of small lakes in the Upper Satluj basin. Similarly, 40 lakes have been defined as the big ones with area more than 10ha against the 42 lakes (2022) indicating a decrease of roughly 5% in the category of bigger lakes, and 37 lakes have been defined with area ranging between 5-10 ha against 39 lakes (2022), suggesting a decrease of 5% in 2022.

In 2023, out of 348 mapped from 99/49 and 100/49 path rows LISS III images, an additional 57 lakes were classified as high-altitude wetlands. These consisted of 40 wetlands with an area less than 5 ha, 5 within the range of 5-10 ha, and 12 with an area more than 10 ha (Fig 33) compared to 43 (2022), 42 (2021), 51 (2020), and 45 (2019) similarly.

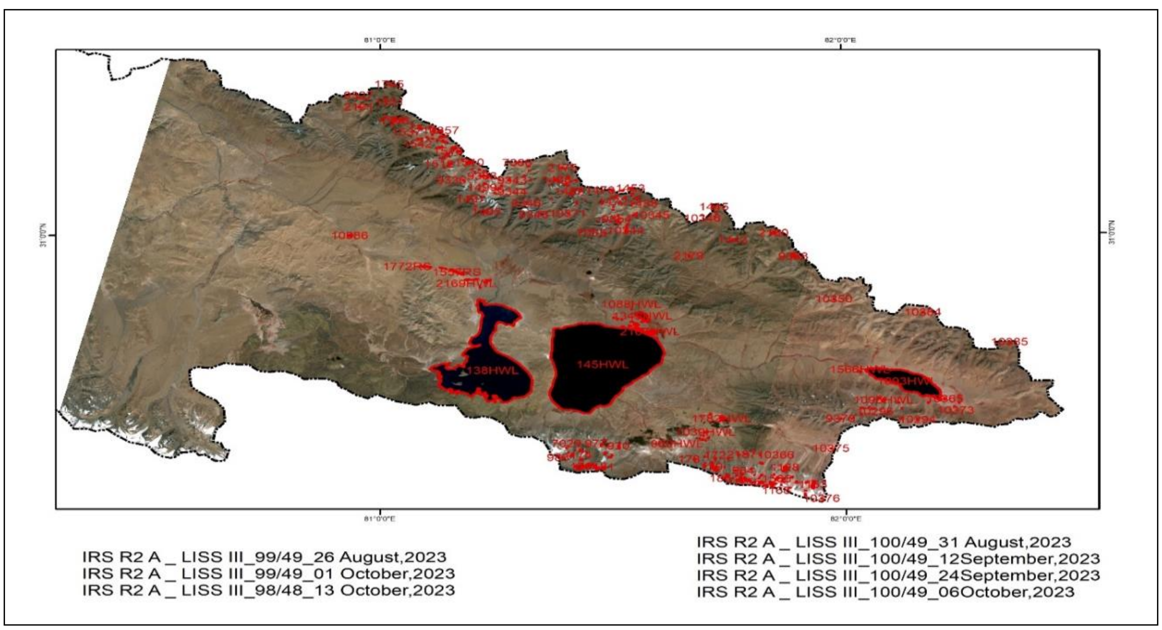


Figure 33 IRS-R2, LISS III, 99/49 & 100/49

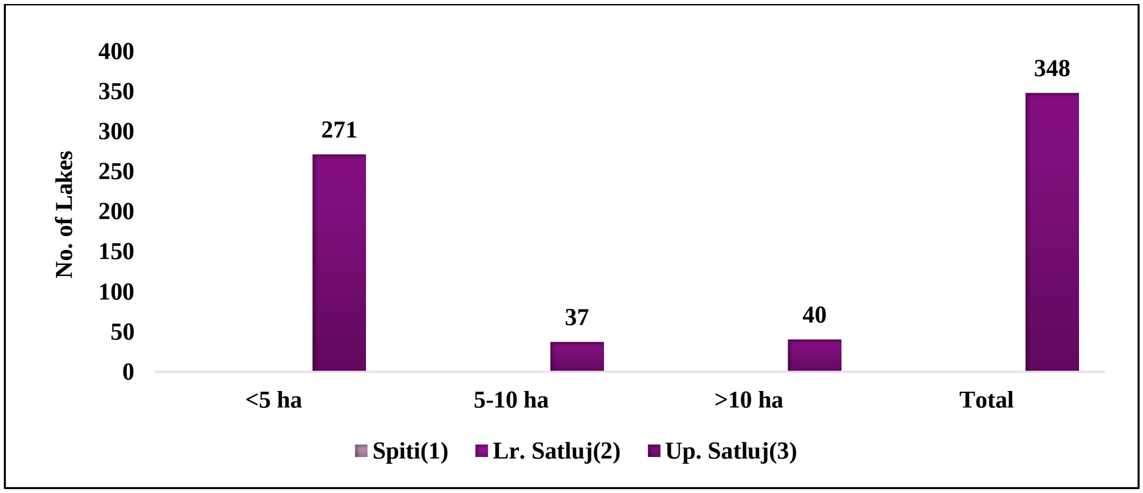


Figure 34 No. of lakes based on IRS-R2, LISS III, 99/49 & 100/49

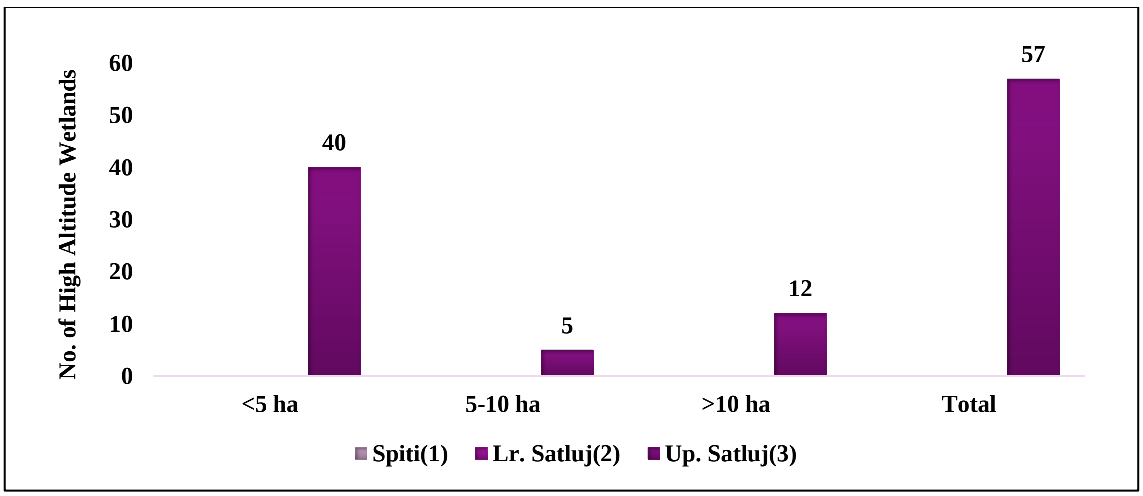


Figure 35 No. of high-altitude wetland lakes based on IRS-R2, LISS III 99/49 & 100/49

Based to an assessment of LISS III satellite data, the Upper Satluj basin is more likely to see lake formation, possibly as a result of the region's greater temperatures relative to higher latitudes. There has been a total of 437 lakes examined in the Upper Satluj basin in 2019; this number has increased by 244 lakes compared to 2020, 707 lakes in 2020, 588 lakes in 2021, 639 lakes in 2022, and 681 lakes in 2023. There was a decrease of 26 lakes from 2020, an increase of 93 lakes from 2021, and a decrease of 42 lakes from 2022 (Fig 36). Minor variances might be the result of poor-quality cloud-free and snow-free data coverage based on LISS III satellite data not being available.

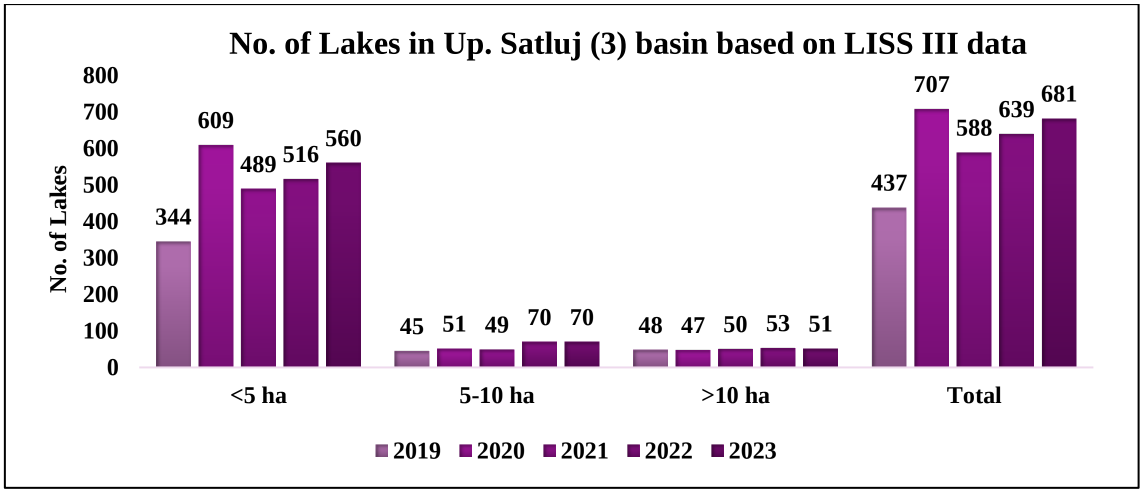


Figure 36 No. of lakes in Upper Satluj (3) basin based on LISS III data

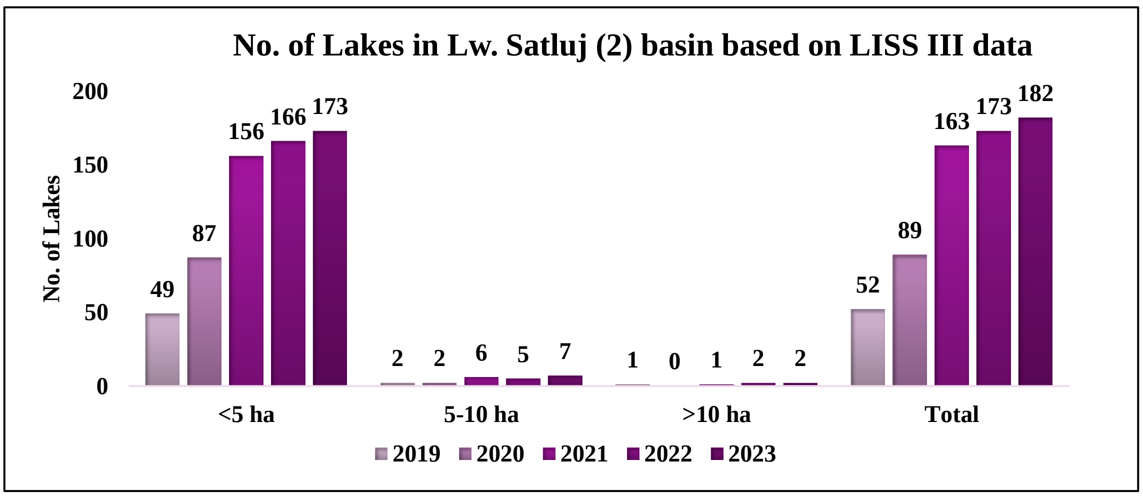


Figure 37 No. of lakes in Lower Satluj (2) basin based on LISS III data

Likewise, in Lower Satluj basin, total number of lakes mapped varies from 52 (2019) to 89 (2020) to 163 (2021) to 173 (2022) to 182 (2023) reflecting a gradual increasing trend of lake formations in Lower Satluj basin with an overall increase of 130 lakes (about 71%) compared to 2019, 93 lakes (51%) compared to 2020, 19 lakes (about 10%) compared to 2021 and 9 Lakes (about 5%) compared to 2022 based on the results obtained from LISS III satellite data analysis (Fig 37).

Similarly, in Spiti basin the total number of lakes mapped varies from 73 (2019) to 197 (2020) to 129 (2021) to 183(2022) to 185 (2023) with an overall increase of about 61% (112 lakes) w.r.t to

2019, decrease of about 6% (12 lakes) w.r.t. to 2020 and further increase of about 30% (56 Lakes) w.r.t. to 2021 and 1.08% (2 Lakes) w.r.t. to 2022 (Fig 38) and the difference is mainly due to the data quality which is either due to snow cover or cloud cover impacts.

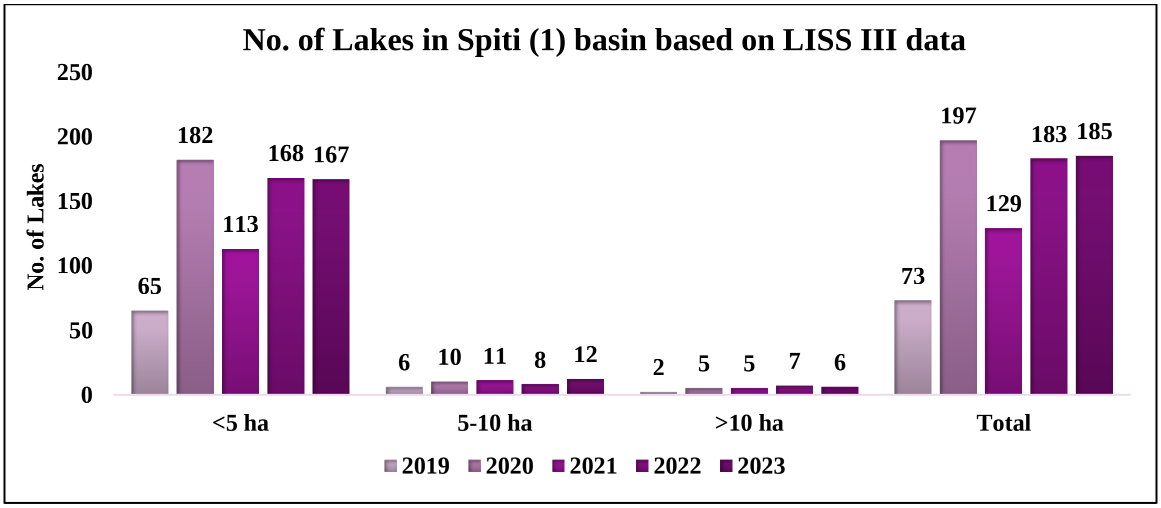


Figure 38 No. of lakes in Spiti (1) basin based on LISS III data

BASIN WISE COMPARATIVE ANALYSIS

A comparative analysis with 2022 was conducted using the satellite data analysis for AWiFS and LISS III sensors during 2023. Each of the three basins—the Spiti basin (basin 1), Lower Satluj basin (basin 2), and Upper Satluj basin (basin 3)—had its total number of lakes and lakes with an area larger than 10 ha examined over time.

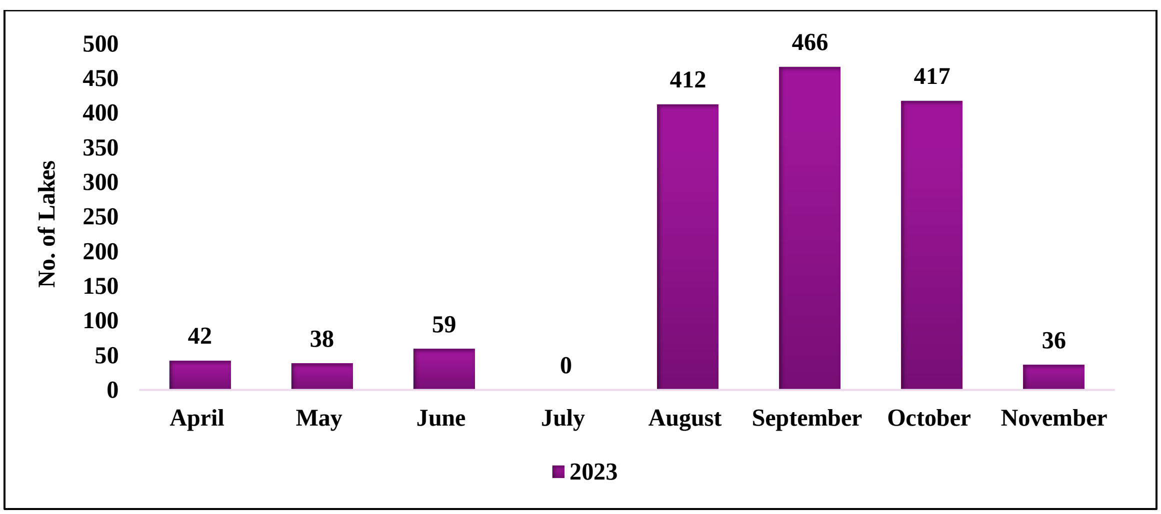


Figure 39 Total no. of lakes based on AWiFS satellite data during (April-November) 2023

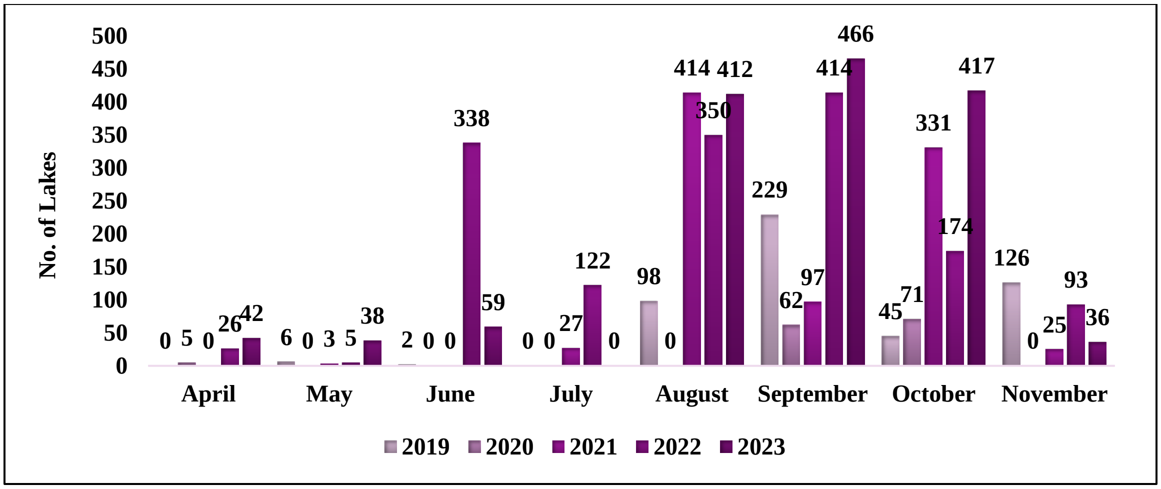


Figure 40 Comparison of total no. of lakes based on AWiFS satellite data during 2019, 2020, 2021, 2022 and 2023

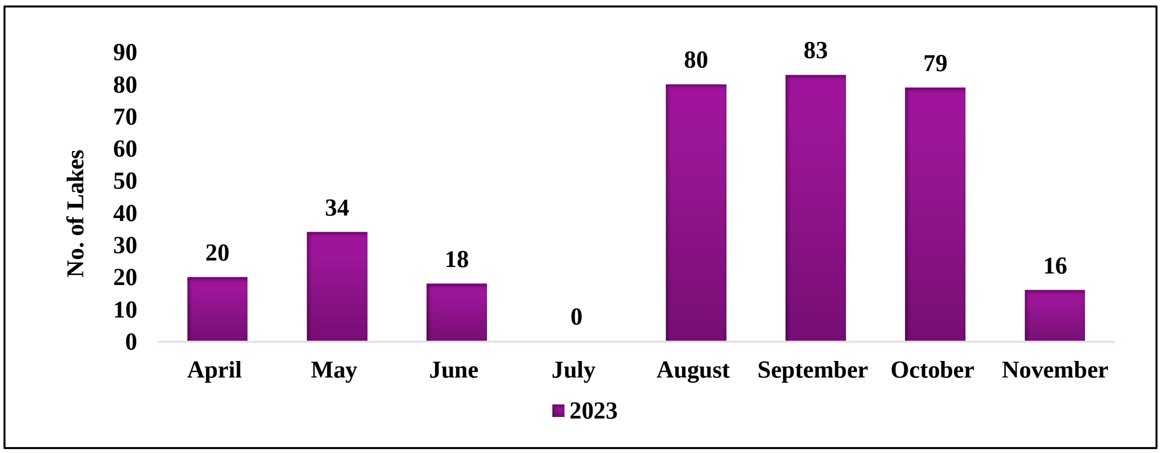


Figure 41 Total no. of lakes > 10 ha based on AWiFS satellite data during (April-November) 2023

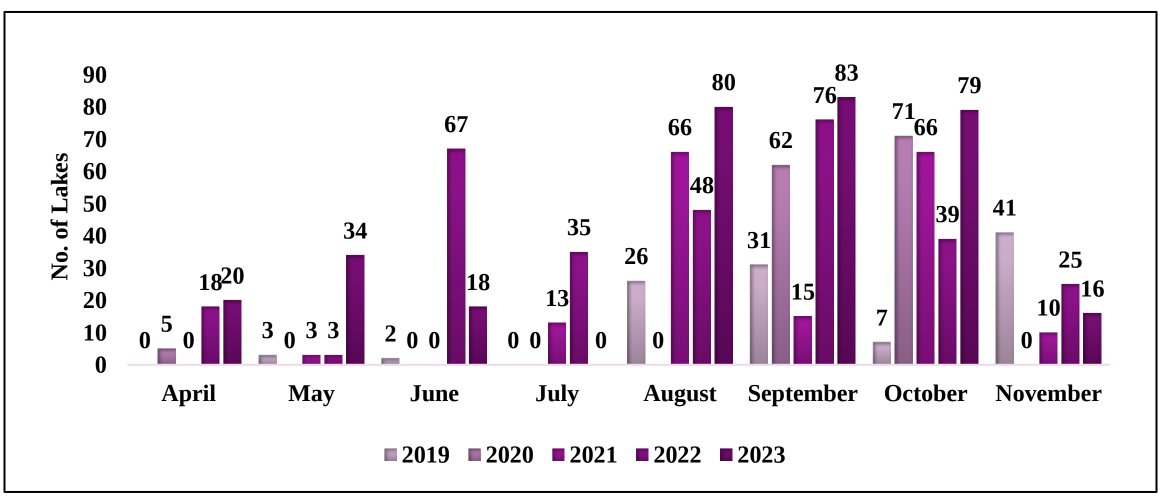


Figure 42 Total no. of lakes >10 ha based on AWiFS satellite data (2019-2023)

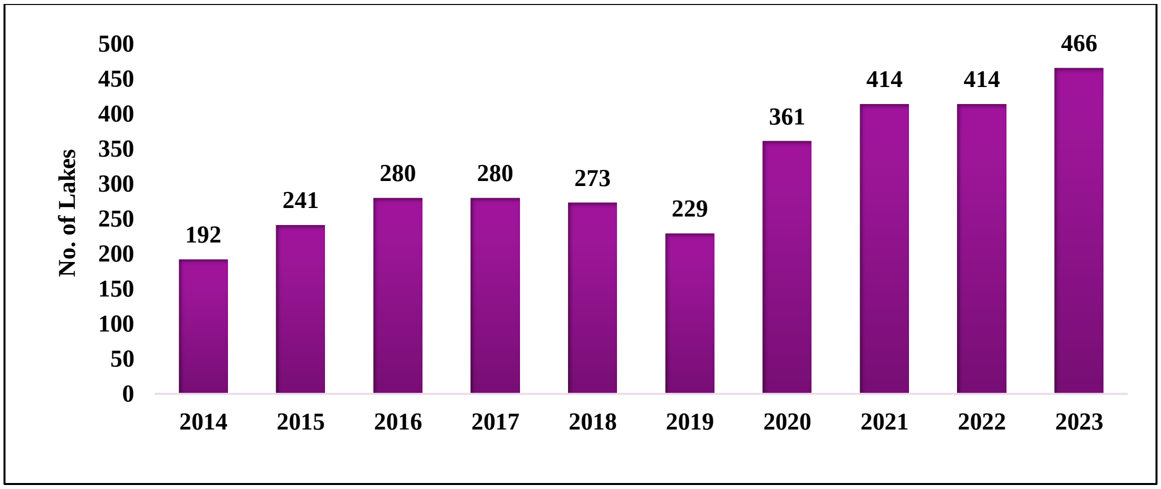


Figure 43 Total no. of lakes based on AWiFS Data (2014-2023)

Table 1 Basin wise distribution of total number of lakes in Satluj Catchment during the year 2023 based on LISS III Satellite data interpretation

Date of Pass	No. of lakes in basin 1	No. of lakes in basin 2	No. of lakes in basin 3	Total no. of lakes (2023)	Total no. of lakes with area >10 ha
96/48 & 96/49	185	182	115	482	13
97/48 & 98/48	0	0	160	160	3
98/49	0	0	58	58	3
99/49 & 100/49	0	0	348	348	40

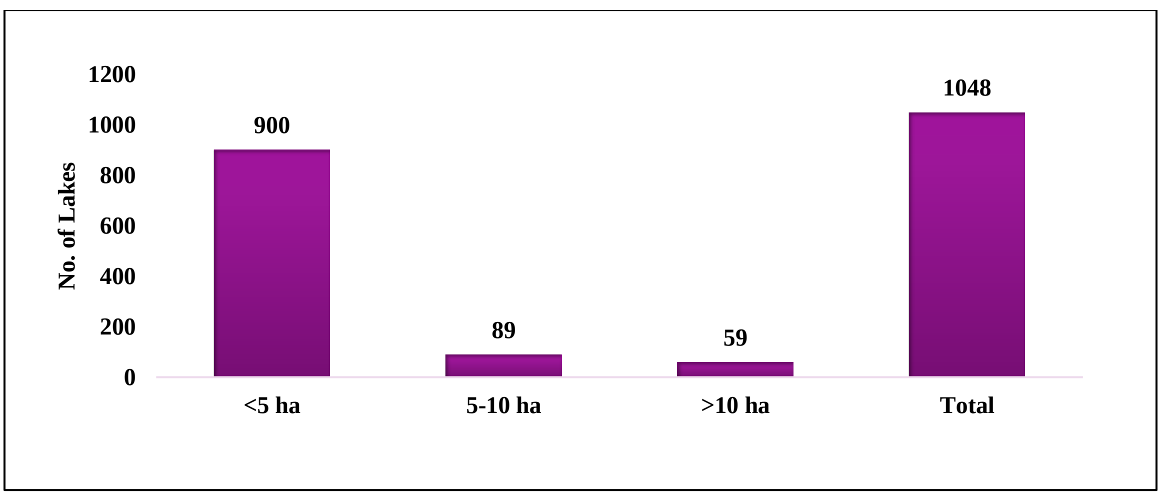


Figure 44 Total no. of lakes in Satluj basin based on LISS III Satellite data (2023)

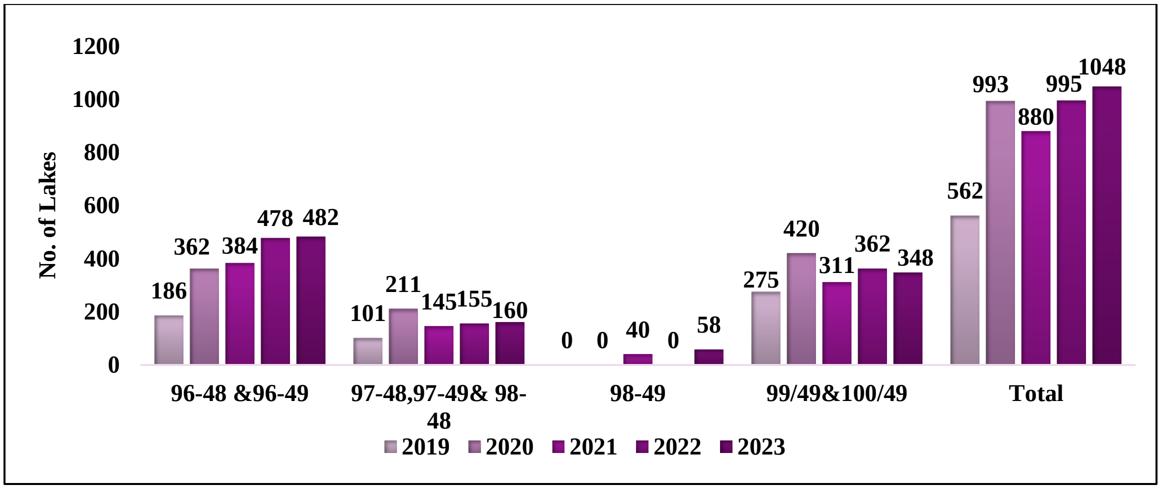


Figure 45 Total no. of lakes based on LISS III Satellite Data (2019- 2023)

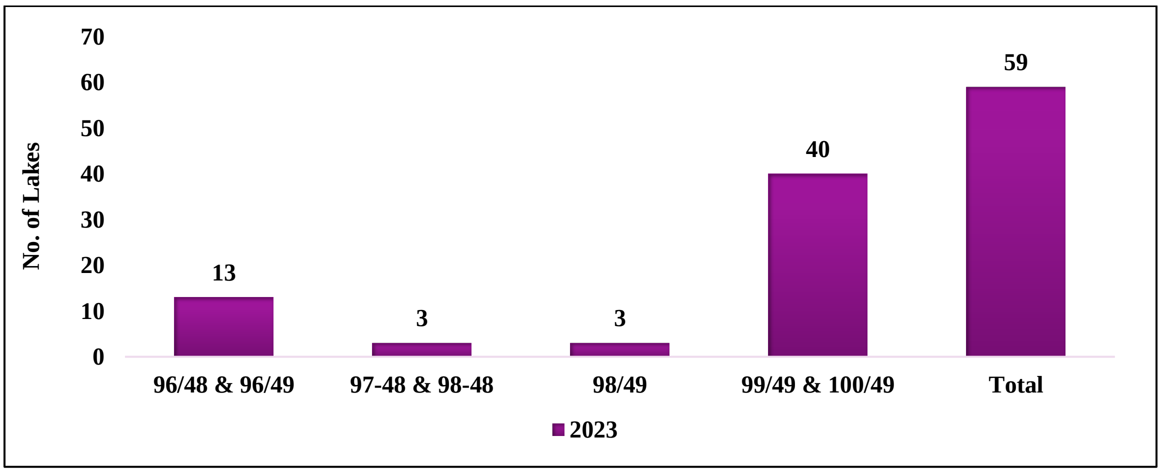


Figure 46 Total no. of lakes > 10ha based on LISS III Satellite Data 2023

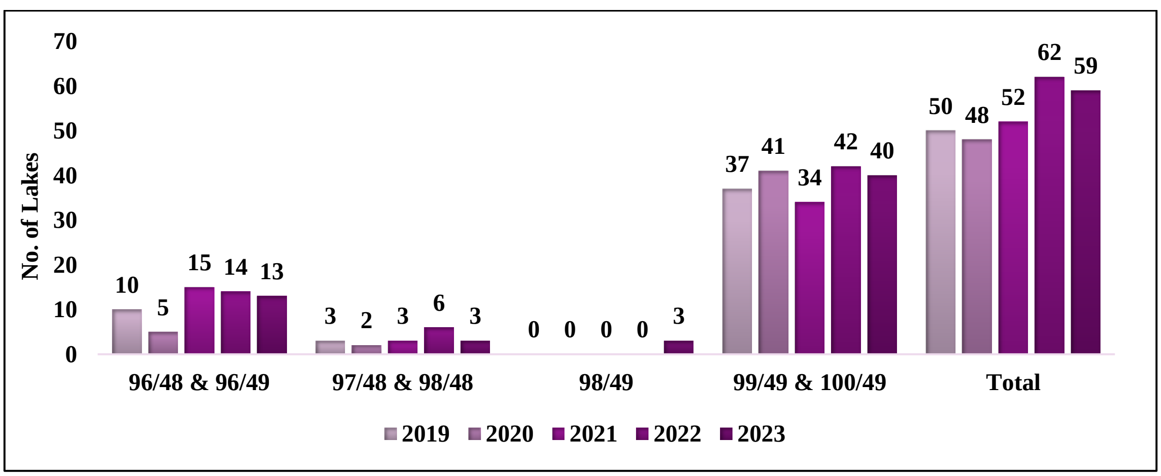


Figure 47 Total No. of Lakes >10ha based on LISS III Satellite Data 2019, 2020, 2021, 2022 and 2023

INVENTORY OF LAKES BASED ON LISS -IV SATELLITE DATA FOR 2023

Besides the two datasets generated during 2023 using AWiFS (56 m) and LISS-III (23.5 m), from 2020 onwards very high-resolution inventory using LISS IV with spatial resolution of 5.8 m are also being generated giving enhanced information of the catchment of any object up 5.8 m by virtue of which it has become possible to map all those lakes/water bodies of minute size (0.01 ha) as well up to clearly visible and can be digitized from pixel to pixel. Although the data procurement of the LISS IV sensor is always a challenge due to its very fine resolution and the less swath in comparison to the LISS III and AWiFS sensors, however an attempt was made in 2023 to procure cloud free and snow free data and was also analyzed. The data which was available mainly falls within 96/48a, 96/48b, 96/48c, 96/48d, 97/48a, 97/48b, 97/48c, 97/49b, 98/49a, 98/48c, 98/49c, 99/49 a, 99/49 b, 99/49 c, 99/49 d,100-49c.

INTERPRETED LAYER OF LISS-IV DATA IN SATLUJ BASIN IN 2023

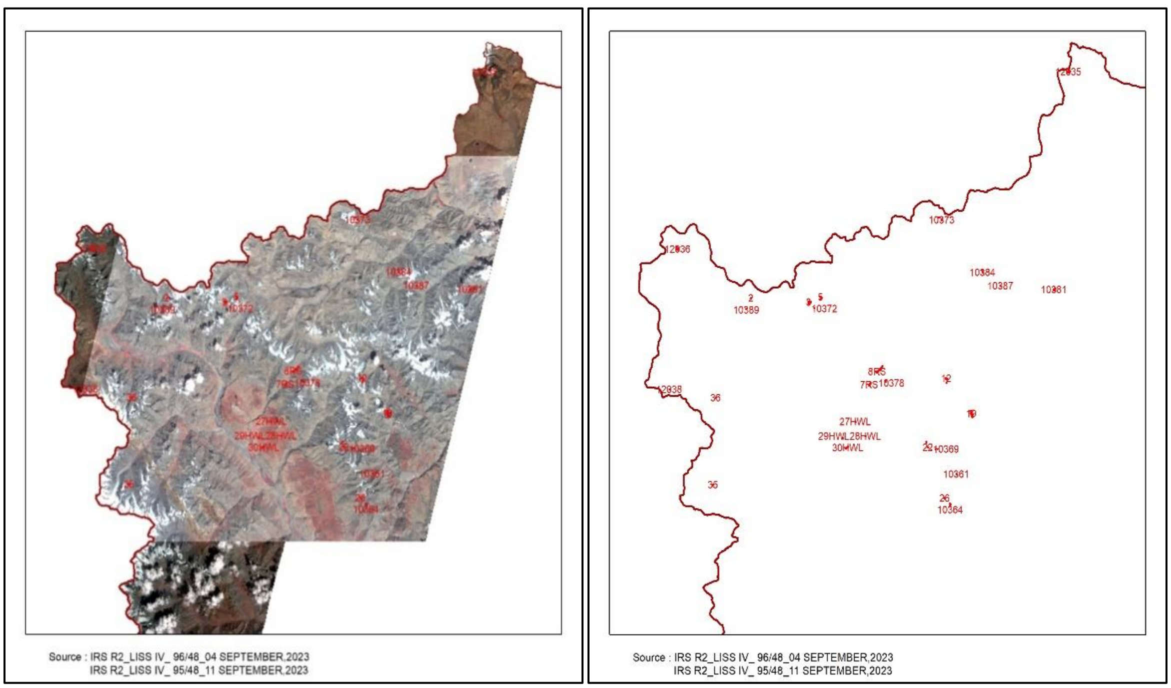


Figure 48 IRS R2, LISS IV, 96/48 a, 4th September and 95/48 b, 11^{th} September, 2023 and its interpreted layer

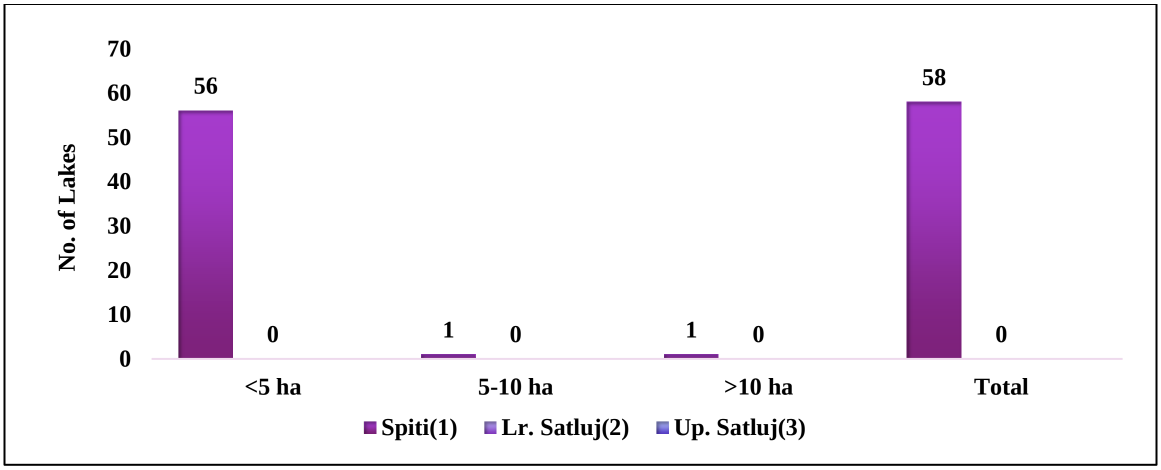


Figure 49 No. of lakes based on LISS-IV image (96/48a) during 2023

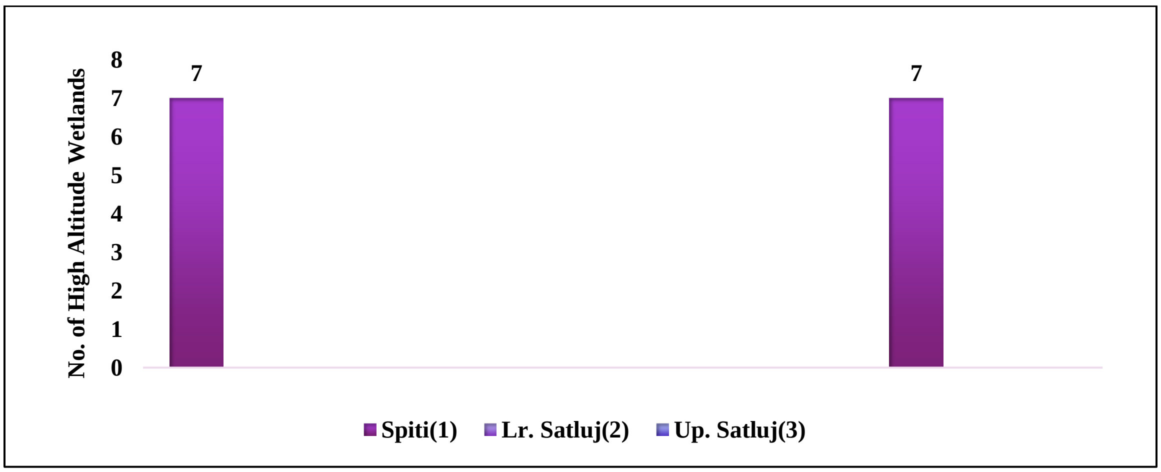


Figure 50 No. of high-altitude wetland lakes based on LISS-IV image 96/48a during 2023

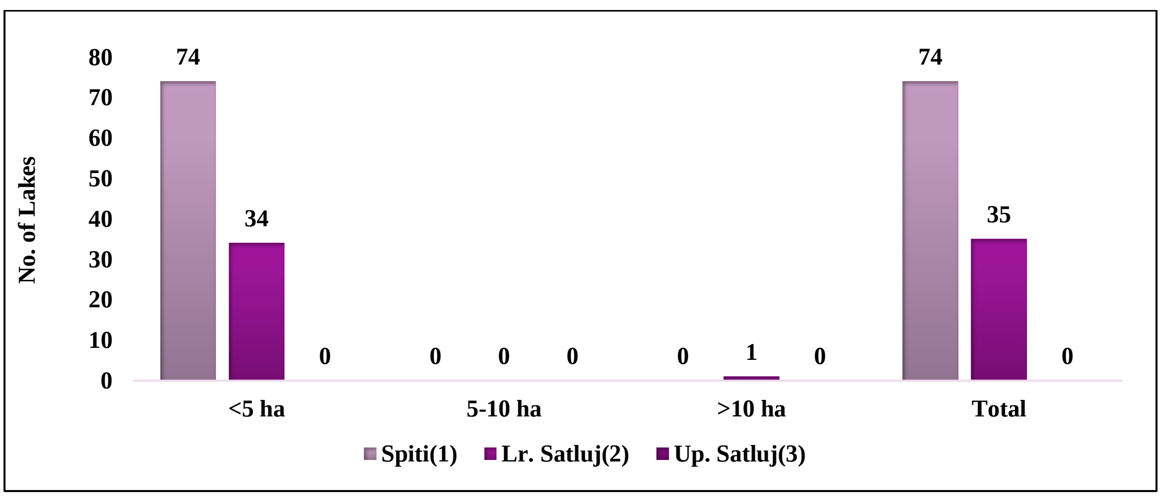


Figure 51 No. of lakes based on LISS-IV image (96/48c) during 2023

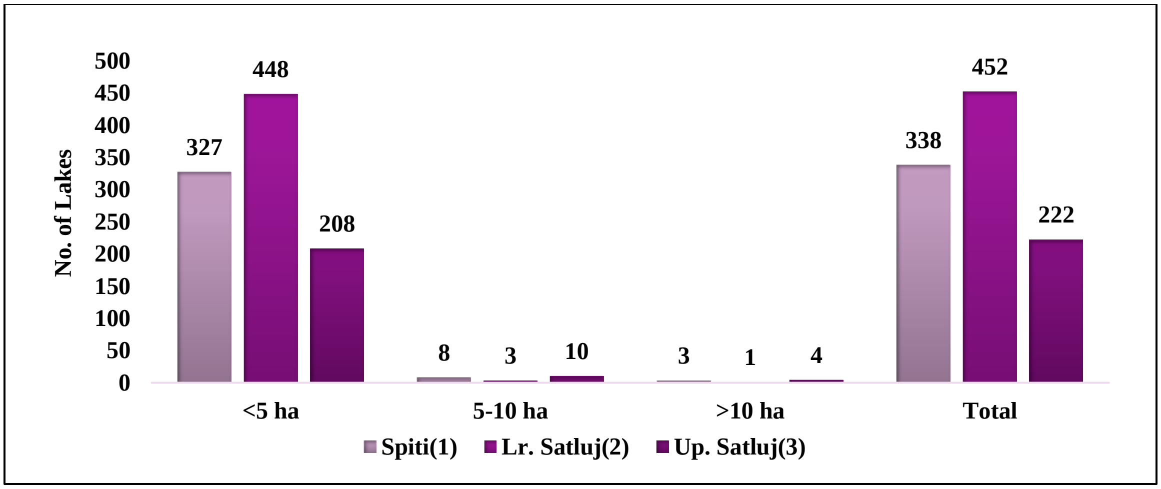


Figure 52 No. of lakes based on LISS-IV image (96/48 b & d) during 2023

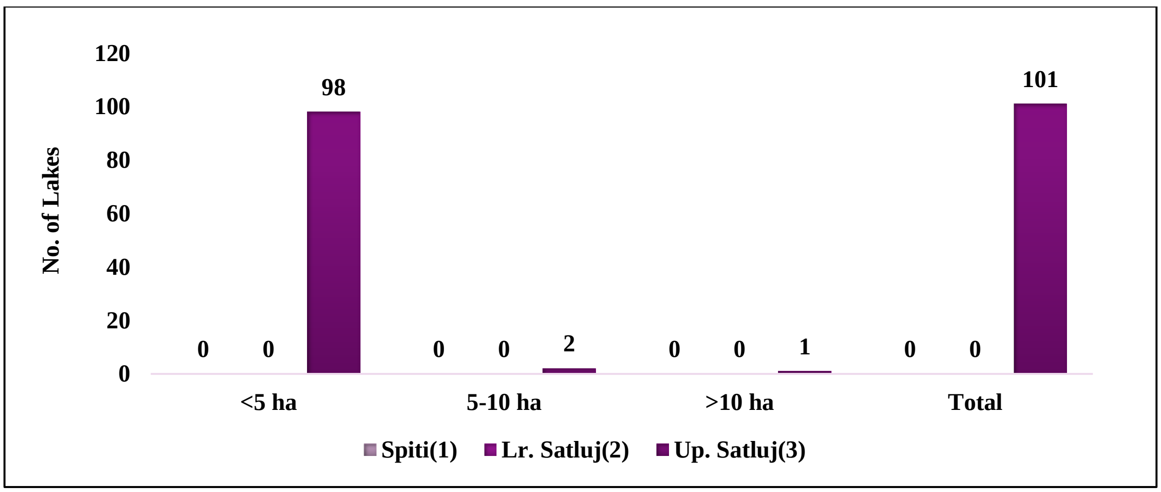


Figure 53 No. of lakes based on LISS-IV image (97/48 A & B) during 2023

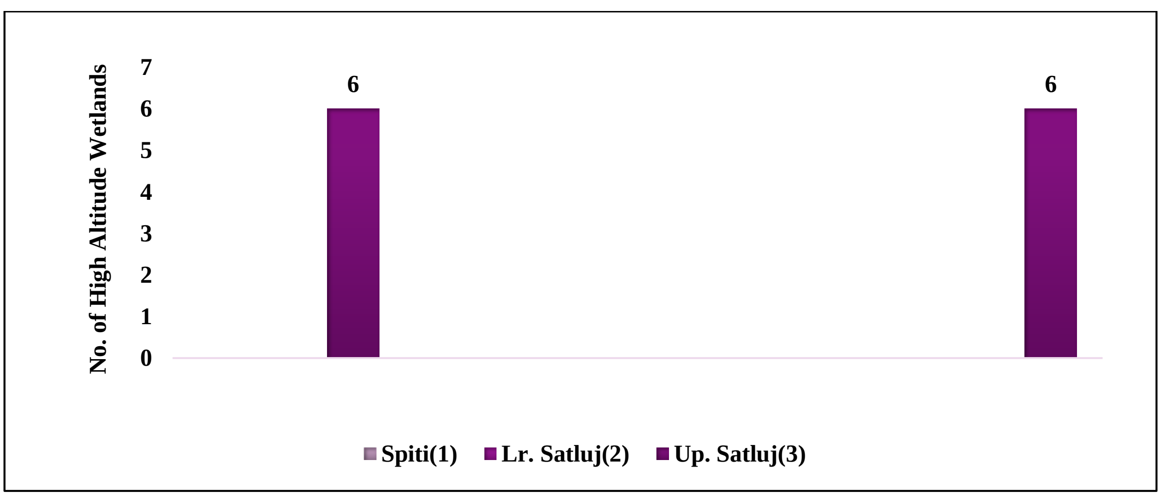


Figure 54 No. of high-altitude wetlands based on LISS-IV image (97/48 A & B) during 2023

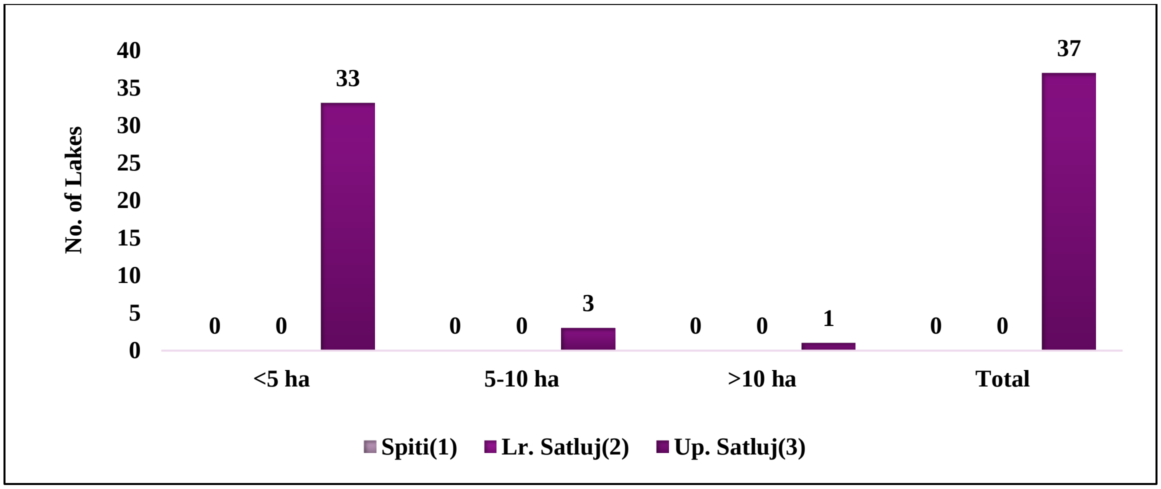


Figure 55 No. of lakes based on LISS-IV image (98/48c) during 2023

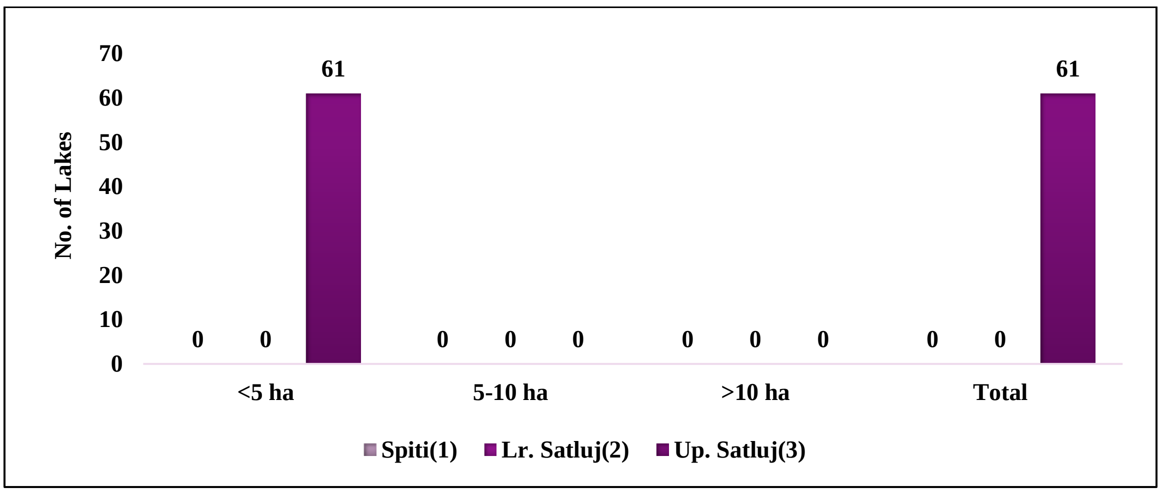


Figure 56 No. of lakes based on LISS-IV image (97-49 A & B) during 2023

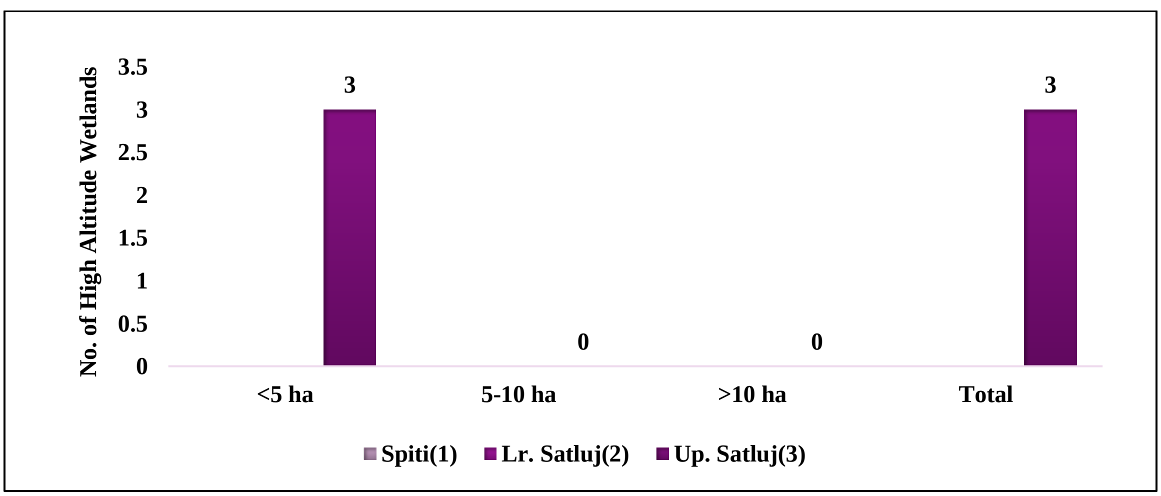


Figure 57 No. high wetland lakes based on LISS-IV image (97-49 a & b) during 2023

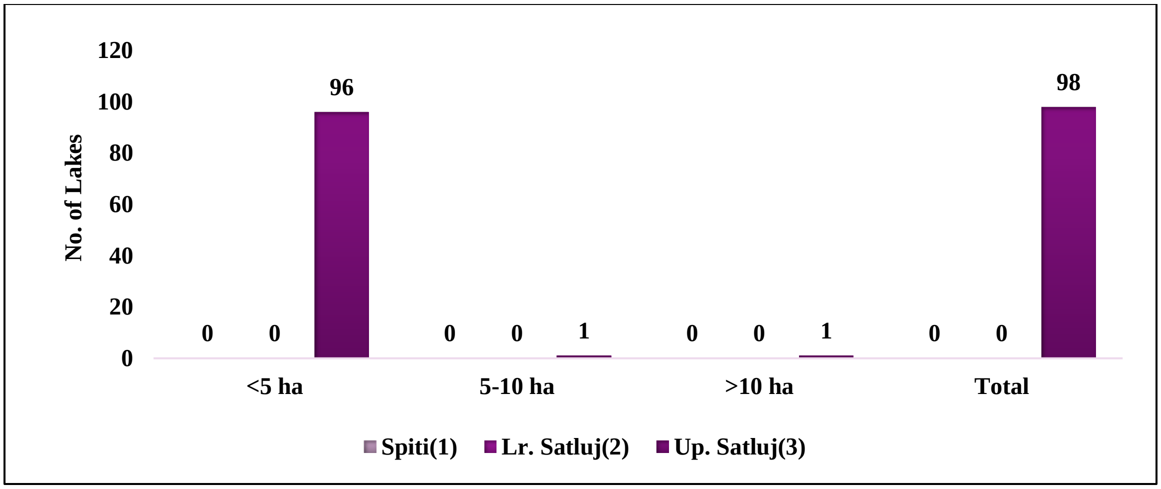


Figure 58 No. of lakes based on LISS-IV image (98-49 a & c) during 2023

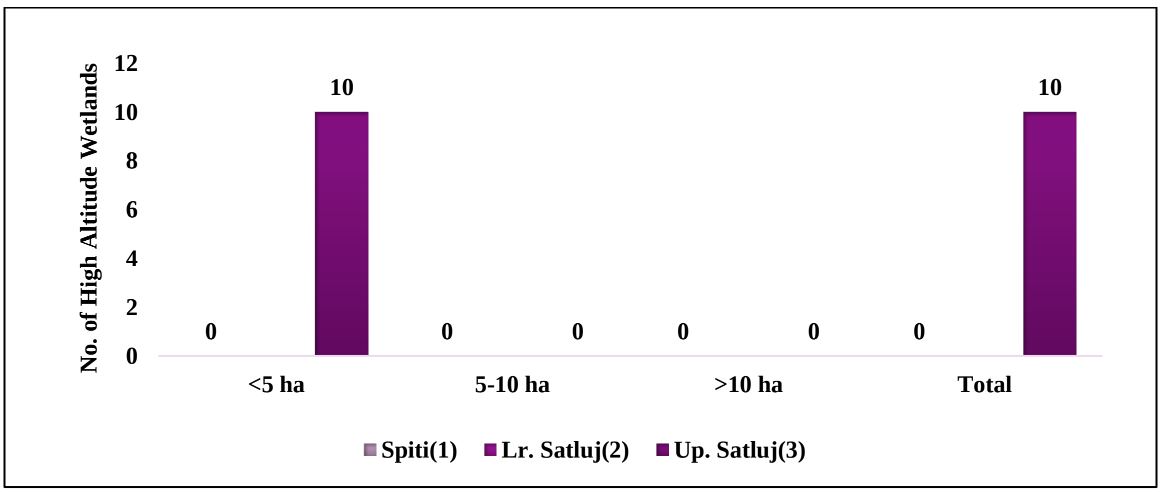


Figure 59 No. of lakes based on LISS-IV image (98-49 a & c) during 2023

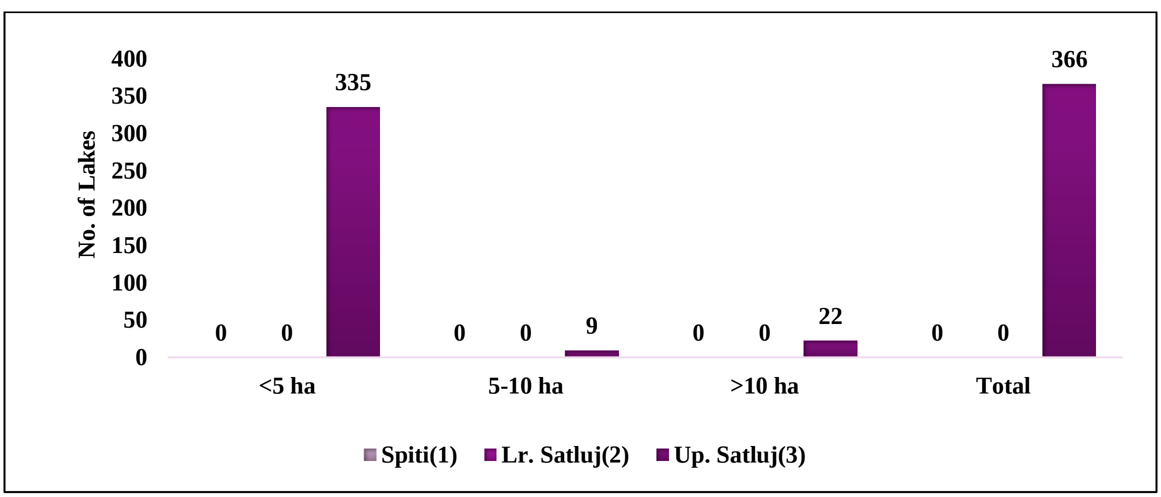


Figure 60 No. of lakes based on (99/49 a, b, c, & d) LISS IV during 2023

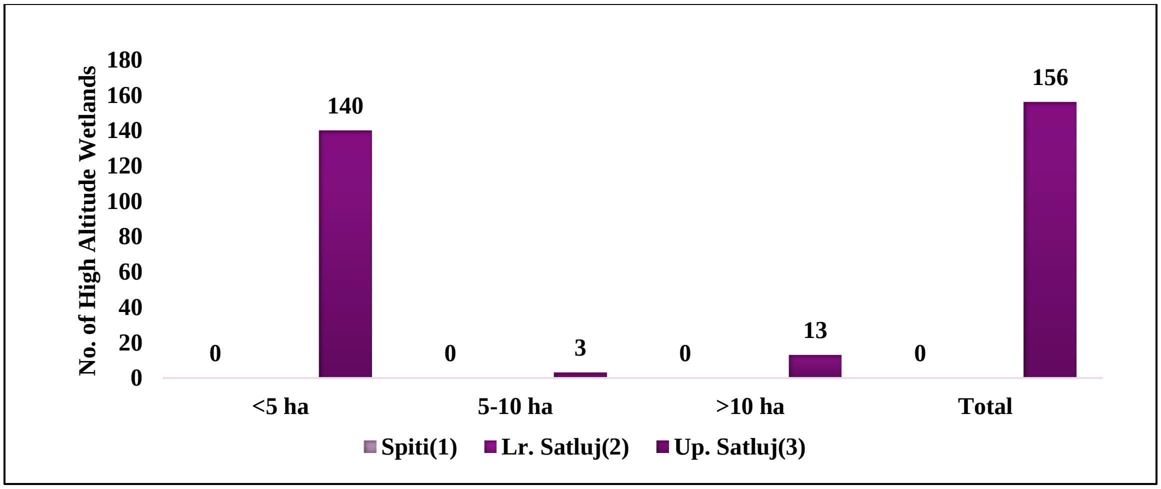


Figure 61 No. of high-altitude wetlands for (99/49 a, b, c, & d) LISS IV during 2023

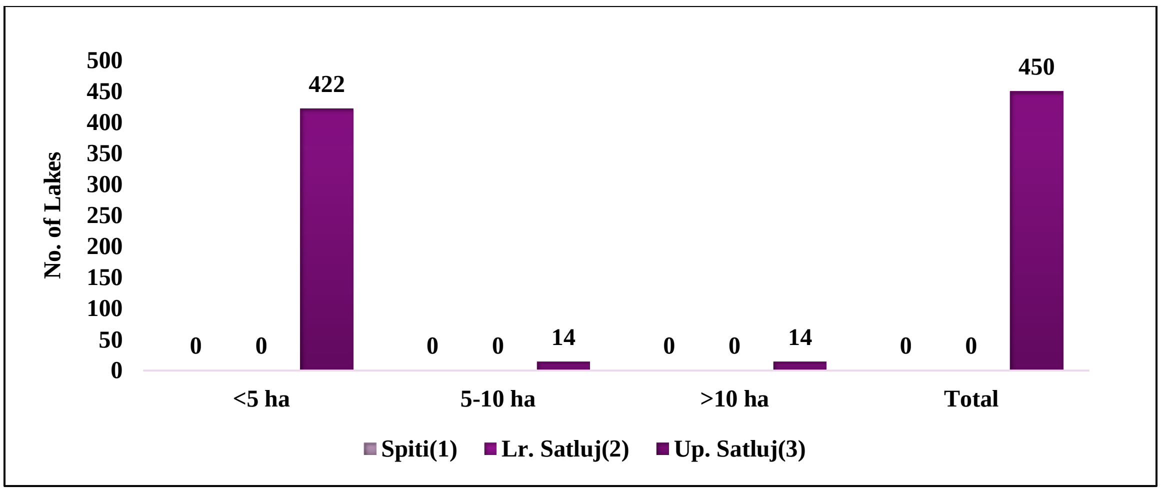


Figure 62 No. of lakes based on LISS-IV image (100/49 C) during 2023

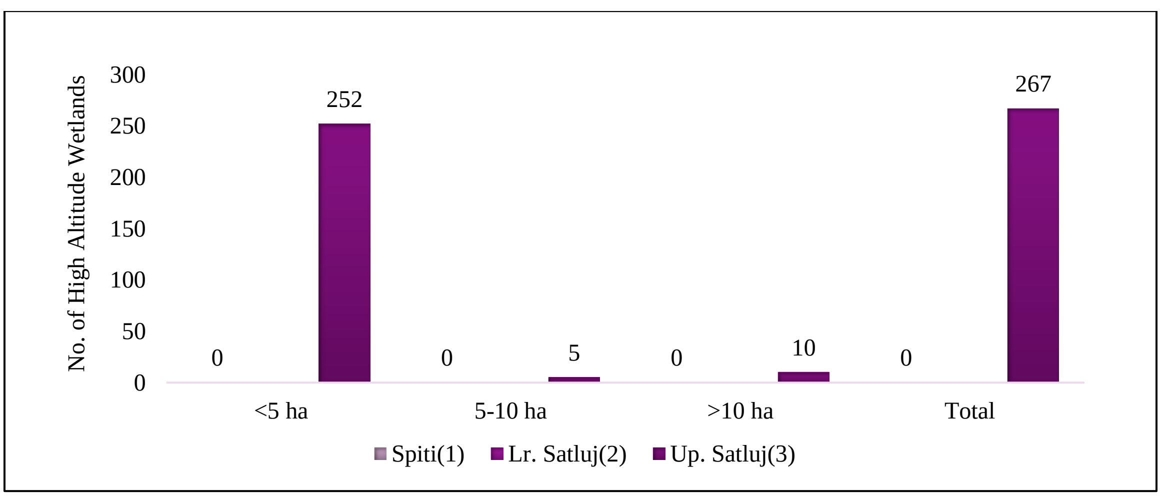


Figure 63 No. of high-altitude wetlands lakes based on LISS-IV image (100/49 C) during 2023

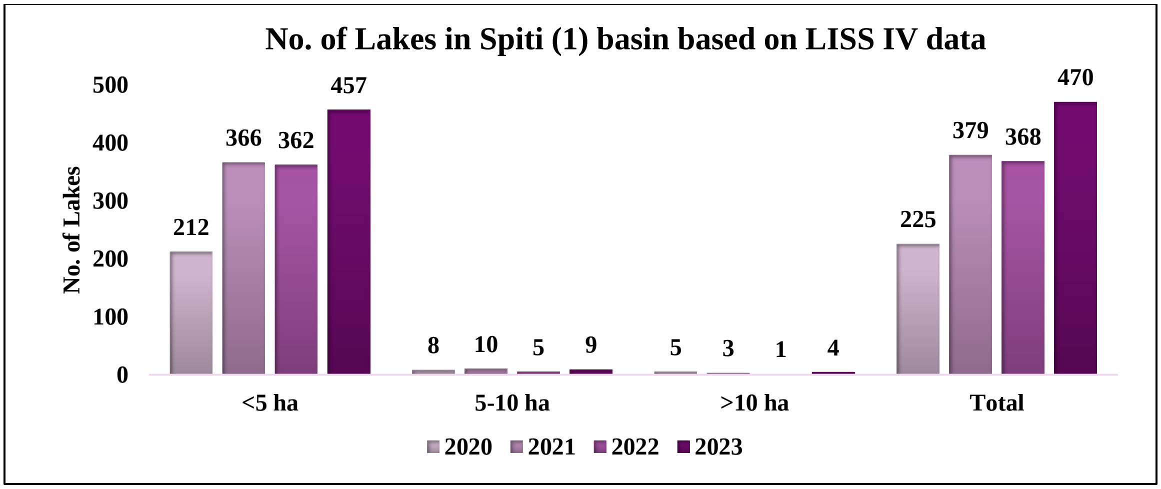


Figure 64 No. of lakes in Spiti basin (1) based on LISS-IV data from 2020 to 2023

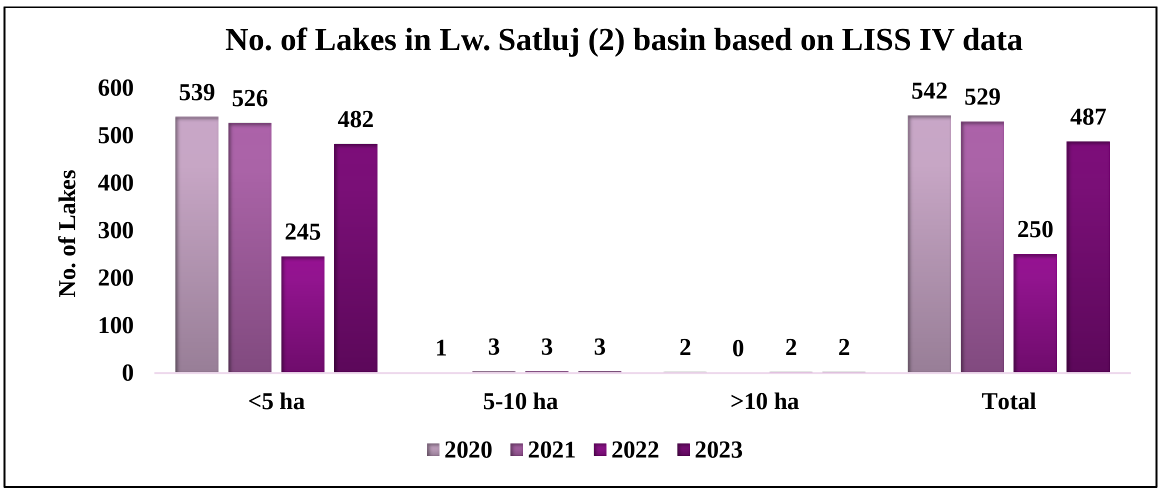


Figure 65 No. of lakes in Lower Satluj basin (2) based on LISS-IV data from 2020-2023

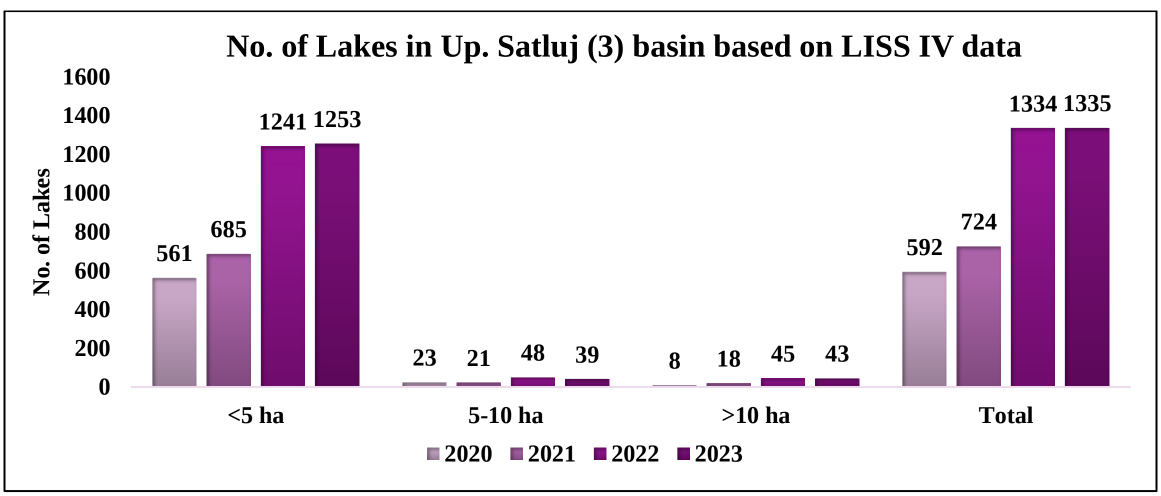


Figure 66 No. of lakes in Upper Satluj basin (3) based on LISS-IV data from 2020-2023

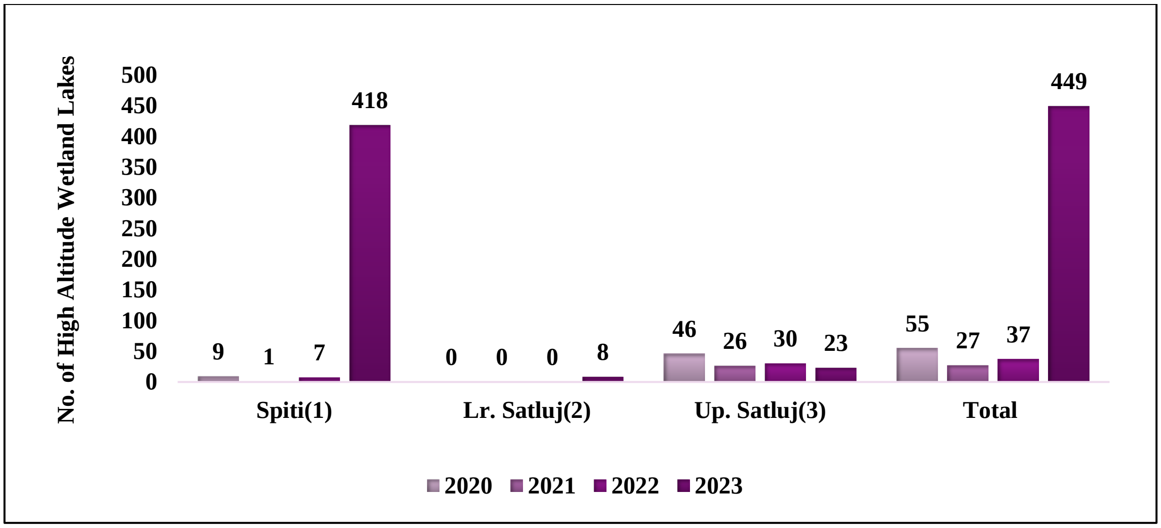


Figure 67 No. of high-altitude wetland lakes in Satluj basin based on LISS IV data from 2020 to 2023

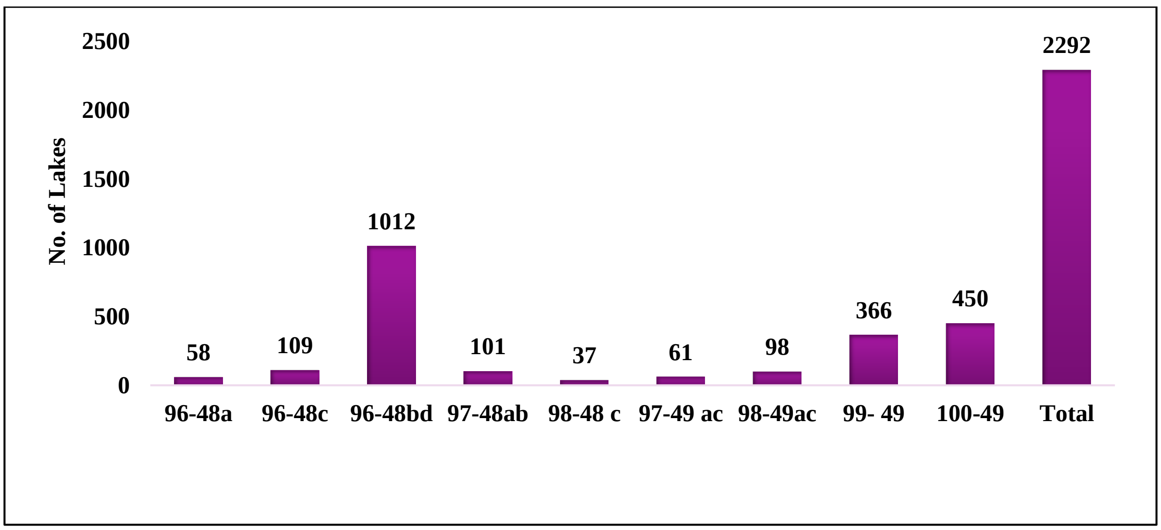
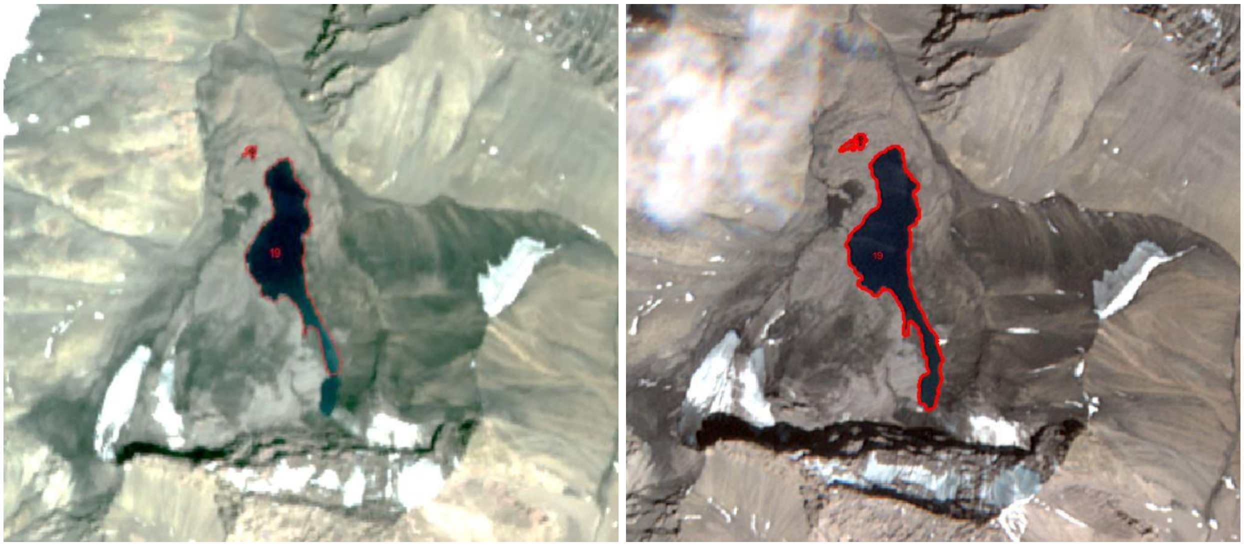


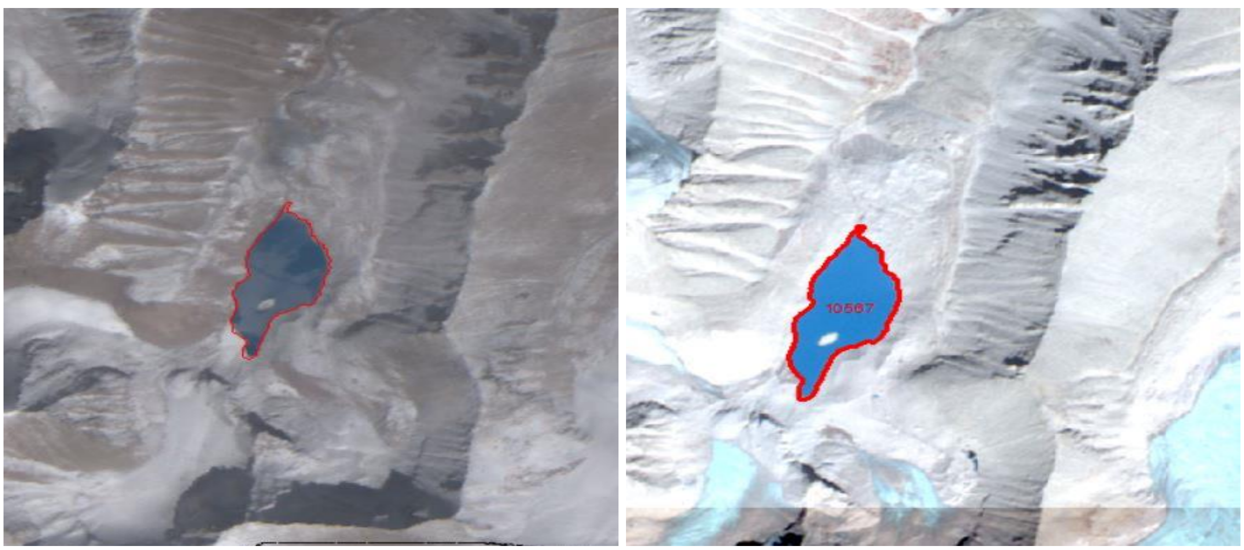
Figure 68 Total no. of lakes in LISS IV data during 2023

SATELLITE VIEW OF LAKES IN SATLUJ BASIN (LISS IV)



Area: 12.18 Ha (2022) Area: 13.60 Ha (2023)

Figure 69 Lake Id 19, L4, 96 48 (Spiti Basin)



Area: 16.31 Ha (2022) Area: 16.62 Ha (2023)

Figure 70 Lake Id: 10567, Pro Glacial Lake in Spiti basin

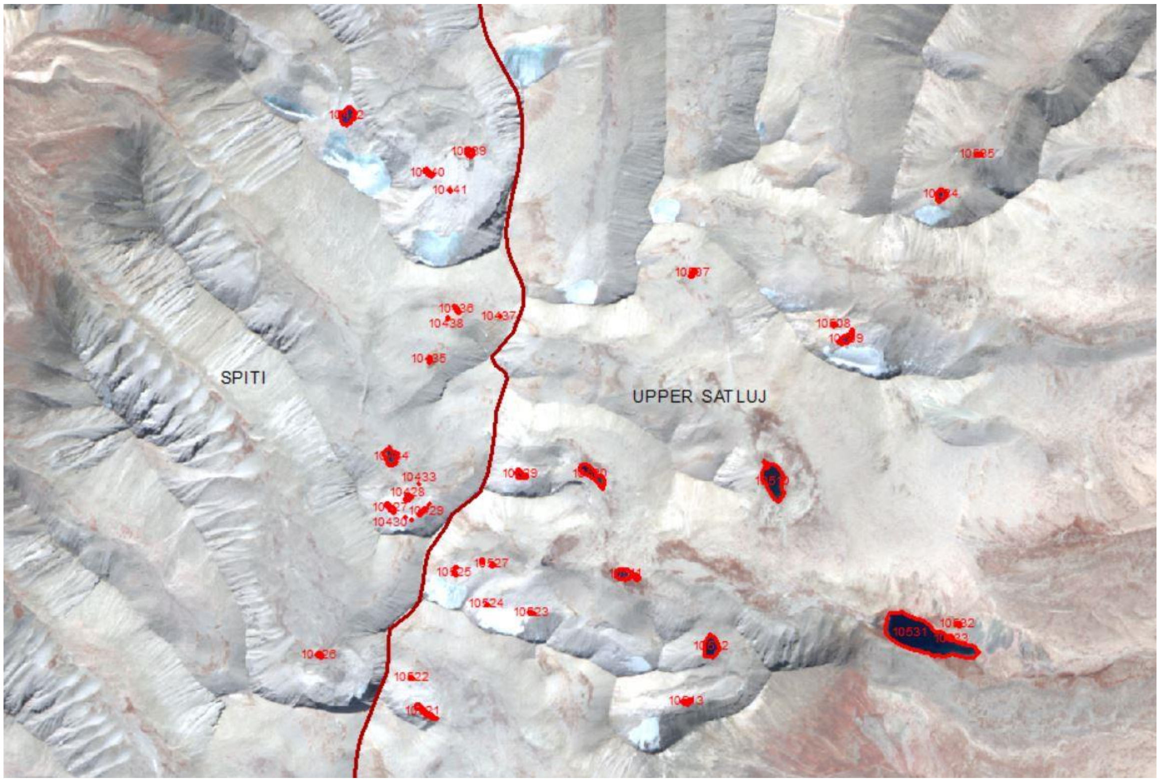


Figure 71 Lakes in Spiti basin and Upper Satluj basin

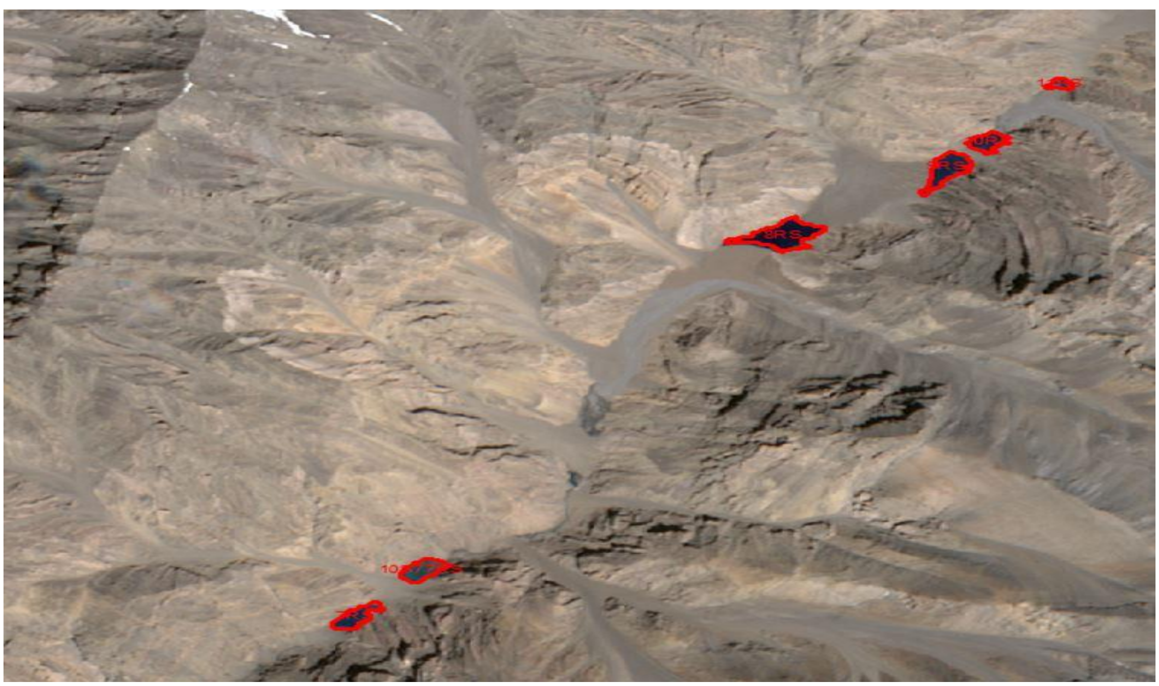


Figure 72 Formation of lakes in River section- Spiti basin

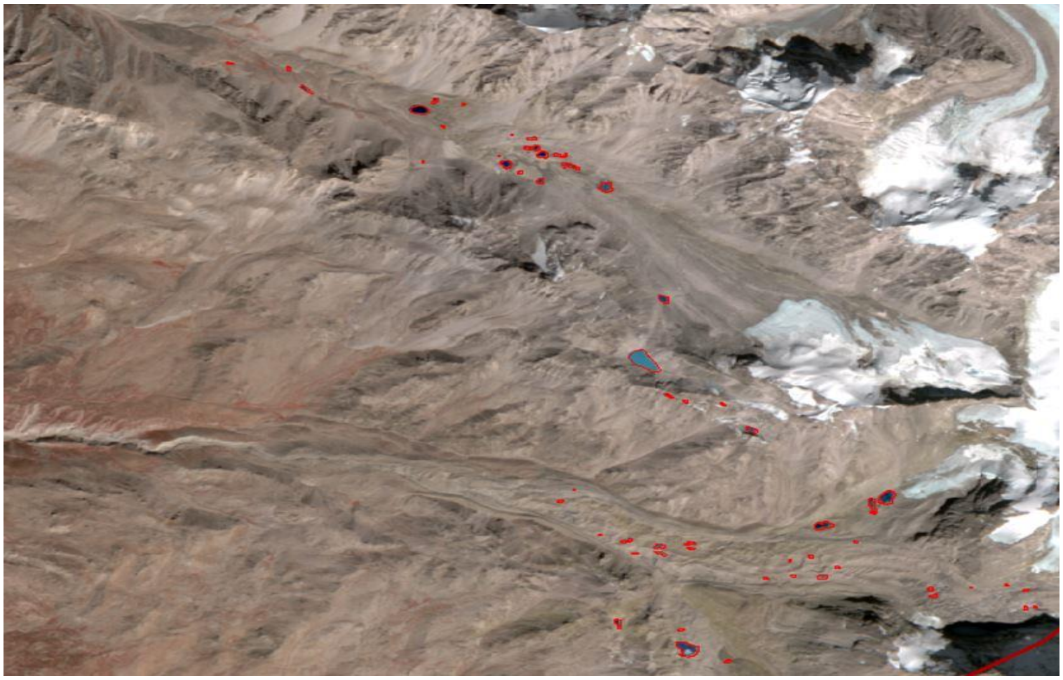


Figure 73 No. of lakes in Lower and Upper Satluj basin

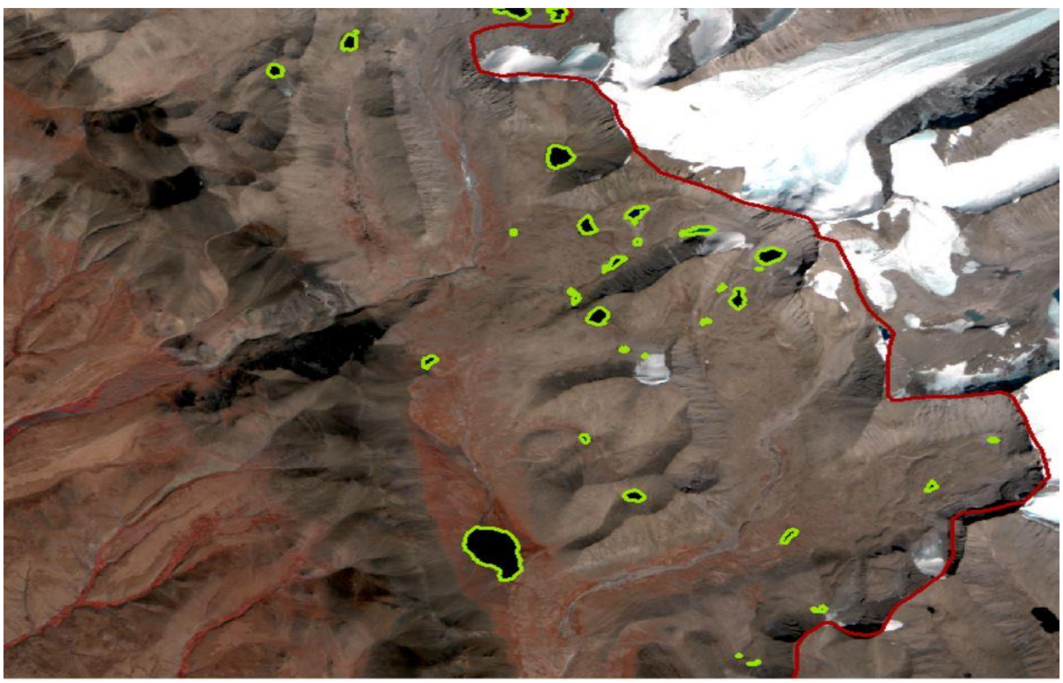


Figure 74 No. of lakes in Upper Satluj basin

5. FLOODS AND LANDSLIDES DURING MONSOON 2023

The State Centre on Climate Change actively assessed the floods, landsides and rainfall during the tumultuous events of the 2023 monsoon season in Himachal Pradesh. The India Meteorological Department recorded the highest number of floods and heavy rain occurrences (123) in Himachal Pradesh during the four-month monsoon season of 2023[1]. The state saw three distinct spells of extremely high precipitation during the 2023 monsoon season: the first one from July 7–11, 2023; the second from August 11–14, 2023; and the third from August 21–23, 2023, which caused extensive damage throughout the state.

RAINFALL TREND ANALYSIS IN HIMACHAL PRADESH

In order to supplement the view of heavy precipitation during the 2023, the rainfall analysis for the state was carried out using the available data from 20014-2023 during the period April-August each year. The rainfall data at five locations i.e., Mandi, Shimla, Bhunter in Kullu district, Kangra and Kalpa in Kinnaur district was used to validate and quantify the rainfall data.

Table 2 Monthly rainfall at Mandi district during 2014 -2023 (April-August)

Rainfall at Mandi district (Monthly Rainfall)										
Year	**No. of Rainy Days (April)**	**Total Monthly Rainfall (April)**	**No. of Rainy Days (May)**	**Total Monthly Rainfall (May)**	**No. of Rainy Days (June)**	**Total Monthly Rainfall (June)**	**No. of Rainy Days (July)**	**Total Monthly Rainfall (July)**	**No. of Rainy Days (August)**	**Total Monthly Rainfall (August)**
2014	4	33.00	8	76.50	10	155.40	21	414.60	10	89.60
2015	8	105.10	1	9.40	9	41.60	12	150	15	204.40
2016	2	11.90	7	127.00	0	0	12	185.70	10	138.90
2017	2	20.20	4	60.40	9	220.50	12	164.80	9	87.30
2018	3	47.10	1	6.20	3	51.6	14	229.60	11	173.4
2019	4	32.60	3	28.50	5	33.60	18	232.30	20	372.60
2020	8	73.90	9	97.50	16	190.70	13	176.50	19	451.00
2021	5	93.60	12	104.80	13	112.30	23	485.80	22	305.40
2022	5	13.20	18	150.80	9	96.40	24	571.80	20	525.40
2023	14	185.20	18	253.80	15.00	286.80	27	528.70	17	693.7

[1] https://www.business-standard.com/india-news/monsoon-2023-himachal-experienced-highest-number-of-floods-rain-events-123100100995_1.html

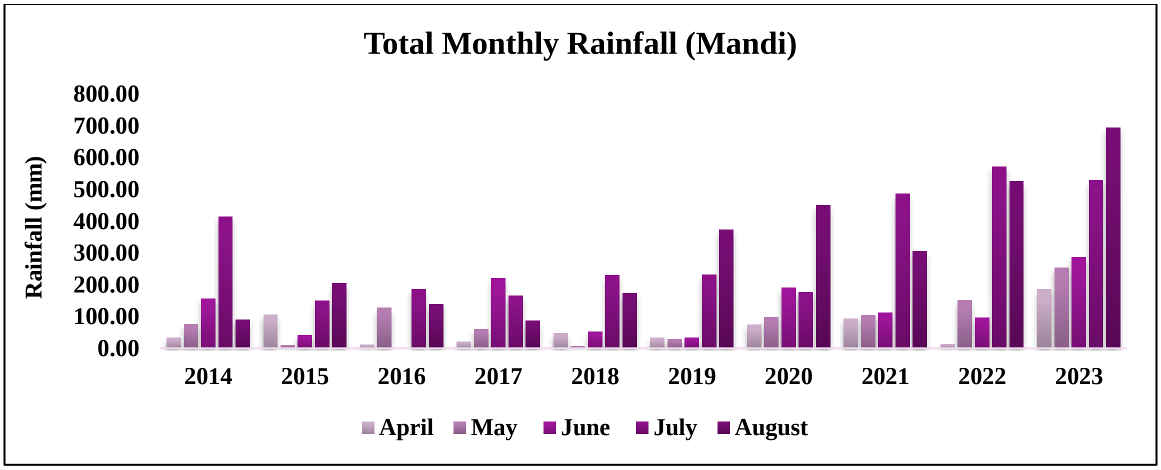


Figure 75 Total monthly rainfall at Mandi district during 2014-2023 (April-August)

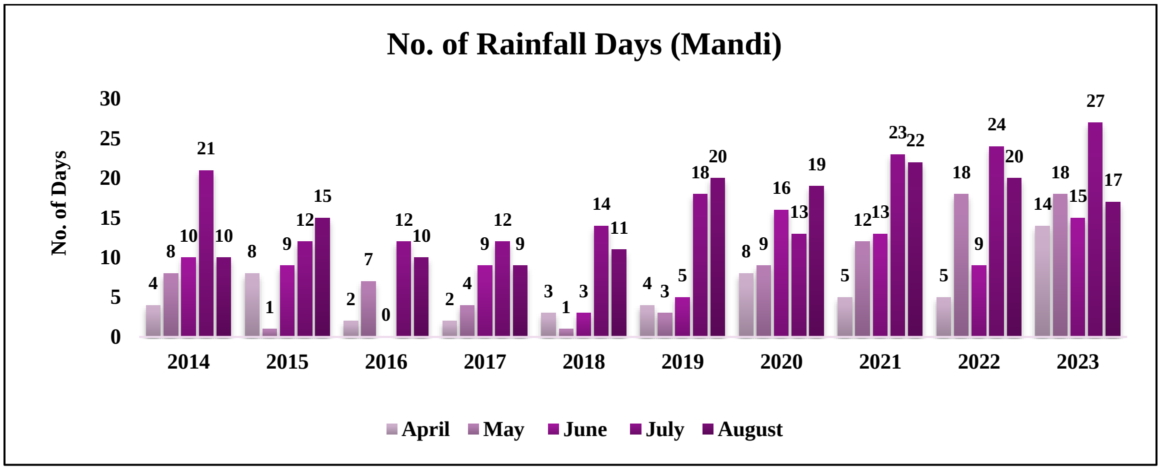


Figure 76 No. of rainfall days at Mandi district during 2014-2023 (April-August)

Table 3 Monthly rainfall at Mandi district during 2014 -2023 (April-August)

Rainfall Shimla (Monthly rainfall)										
Year	**No. of Rainy Days (April)**	**Total Monthly Rainfall (April)**	**No. of Rainy Days (May)**	**Total Monthly Rainfall (May)**	**No. of Rainy Days (June)**	**Total Monthly Rainfall (June)**	**No. of Rainy Days (July)**	**Total Monthly Rainfall (July)**	**No. of Rainy Days (August)**	**Total Monthly Rainfall (August)**
2014	7	68.90	11	65.00	13	218.00	22	560.10	8	47.40
2015	12	81.70	2	1.50	13	58.10	18	317.80	17	182.70
2016	4	21.10	6	81.50	9	118.80	18	316.50	17	267.20
2017	3	16.20	8	68.40	11	105.20	14	133.70	10	134.80
2018	8	56.20	7	20.60	5	128.50	19	398.50	14	313.70
2019	4	24.50	9	54.90	10	79.50	24	346.20	25	499.00

2020	10	94.20	13	124.00	11	183.20	22	232.90	22	156.90
2021	5	156.50	13	86.20	16	186.00	21	281.40	22	246.40
2022	0	0.00	14	227.40	14	139.50	28	433.90	27	514.30
2023	14	221.40	18	225.40	21	383.60	30	530.70	20	552.1

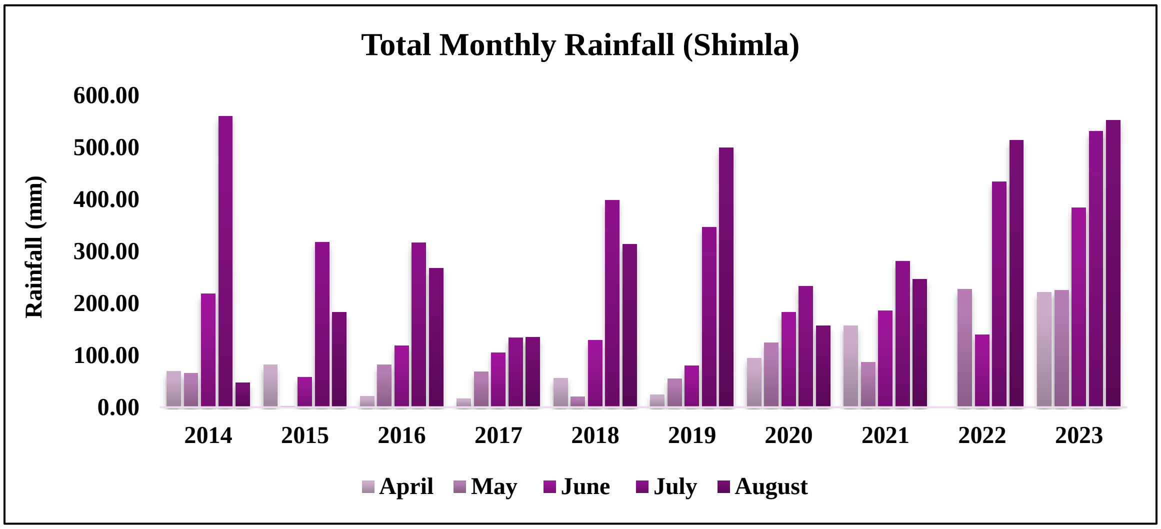


Figure 77 Total monthly rainfall at Shimla district 2014-2023 during (April-August)

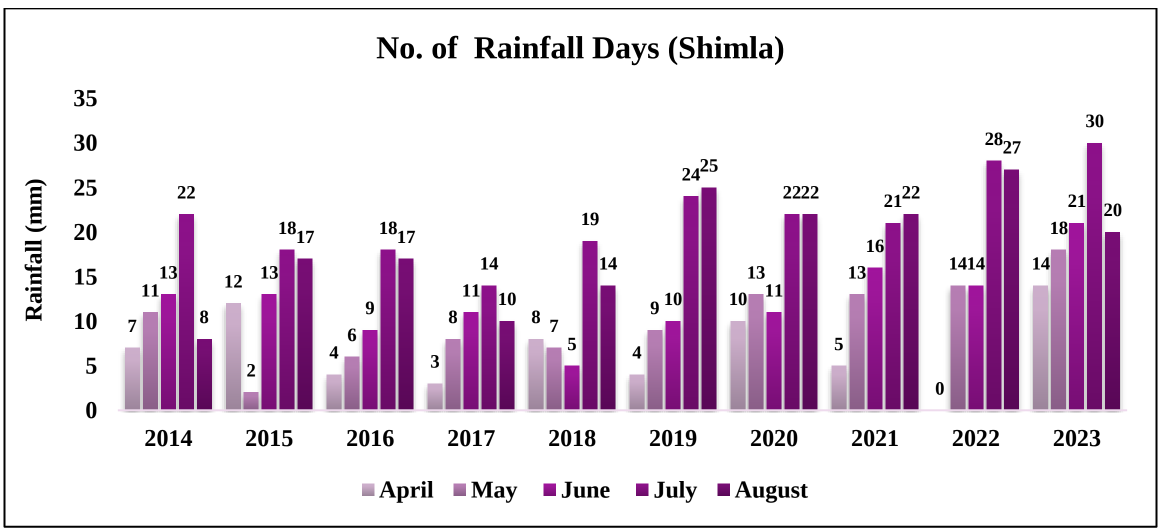


Figure 78 No. of rainfall days at Shimla district during 2014-2023 (April-August)

Table 4 Monthly rainfall at Bhuntar, district Kullu during 2014 -2023 (April-August)

Rainfall Bhuntar (Monthly Rainfall)										
Year	**No. of Rainy Days (April)**	**Total Monthly Rainfall (April)**	**No. of Rainy Days (May)**	**Total Monthly Rainfall (May)**	**No. of Rainy Days (June)**	**Total Monthly Rainfall (June)**	**No. of Rainy Days (July)**	**Total Monthly Rainfall (July)**	**No. of Rainy Days (August)**	**Total Monthly Rainfall (August)**
2014	8	66.10	12	92.8	10	44.50	13	106.80	4	10.5
2015	11	108.40	3	33.10	13	43.80	10	146	14	80.60
2016	4	62.60	6	42.10	0	0	15	57.10	15	137.00
2017	2	20.4	7	27.90	10	118.70	11	74.50	10	50.50
2018	9	61.40	6	17.50	4	11.1	14	104.10	9	69
2019	6	45.40	8	40.00	11	56.60	13	77.30	20	243.30
2020	16	96.90	13	52.60	12	52.8	16	88.70	17	153.90
2021	7	150.40	14	57.60	11	89.40	19	274.70	12	50.30
2022	9	13.40	17	80.00	15	92.30	26	239.30	18	201.90
2023	14	196.70	17	138.50	15	86.50	19	257.1	7	134.1

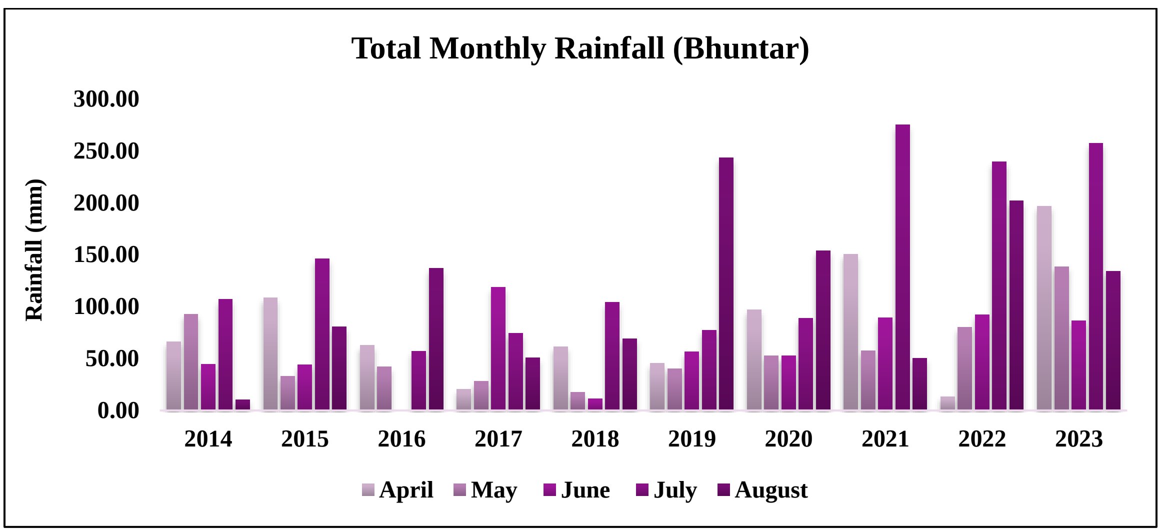


Figure 79 Total monthly rainfall at Bhuntar, district Kullu 2014-2023 during (April-August)

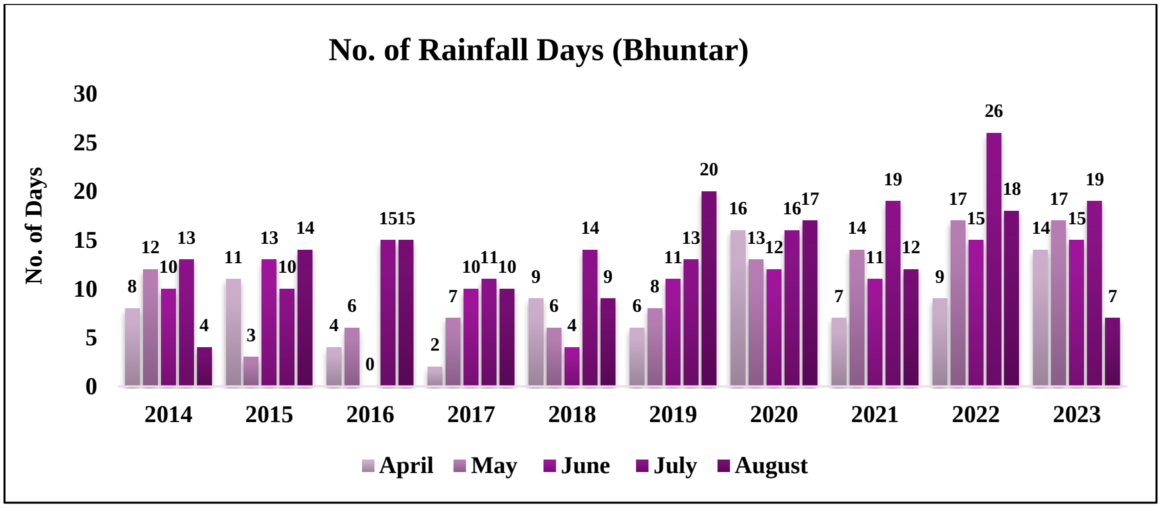


Figure 80 No. of rainfall days at Bhuntar, district Kullu during 2014-2023 (April-August)

Table 5 Monthly rainfall at Kangra district during 2014 -2023 (April-August)

Rainfall Kangra (Monthly Rainfall)										
Year	**No. of Rainy Days (April)**	**Total Monthly Rainfall (April)**	**No. of Rainy Days (May)**	**Total Monthly Rainfall (May)**	**No. of Rainy Days (June)**	**Total Monthly Rainfall (June)**	**No. of Rainy Days (July)**	**Total Monthly Rainfall (July)**	**No. of Rainy Days (August)**	**Total Monthly Rainfall (August)**
2014	6	71.10	6	59.10	9	132.30	22	606.90	10	145.00
2015	7	69.20	0	0.00	9	186.70	17	399.20	20	731.00
2016	2	10.00	6	55.30	0	0	19	450.30	12	456.00
2017	2	31.20	3	12.10	10	209.40	15	377.90	11	359.10
2018	8	60.00	5	50.80	4	44.4	20	461.90	15	881
2019	3	63.50	7	59.90	9	40.10	22	288.80	22	608.80
2020	10	62.70	10	98.00	14	147.40	21	387.80	24	814.60
2021	6	64.30	14	74.00	13	216.80	23	609.30	26	477.30
2022	3	2.80	12	56.90	12	175.00	30	863.80	23	1196.00
2023	12	122.30	16	213.20	19	336.00	28	595.50	22	628.3

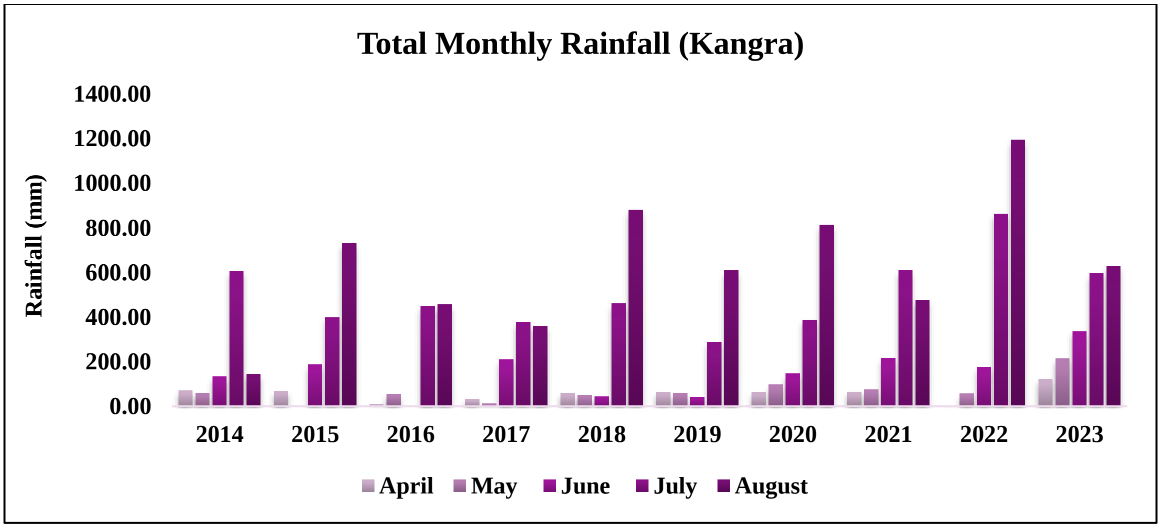


Figure 81 Total monthly rainfall at Kangra district during 2014-2023 (April-August)

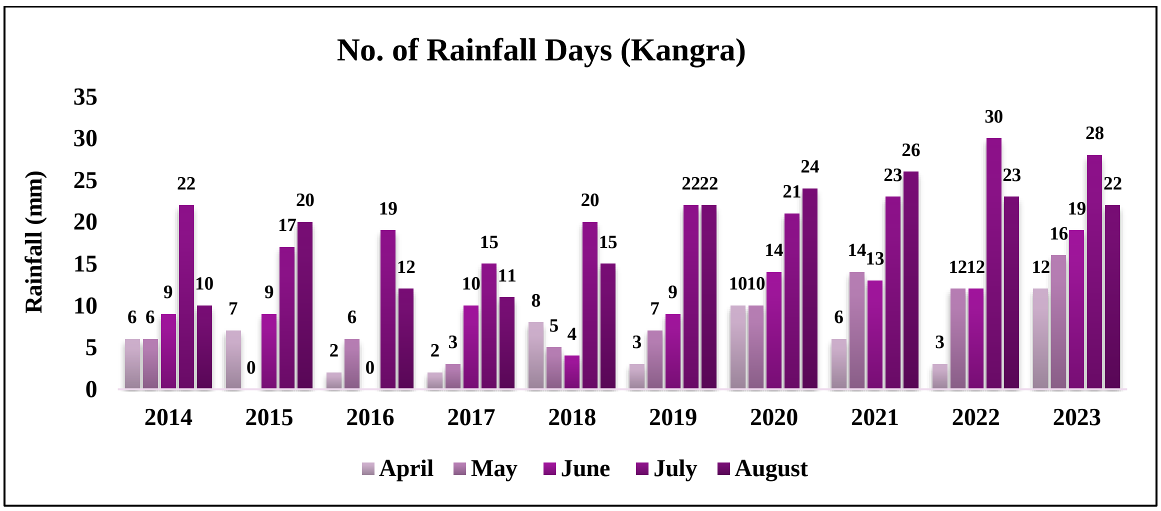


Figure 82 No. of rainfall days at Kangra district during 2014-2023 (April-August)

Table 6 Monthly rainfall at Kalpa, district Kinnaur during 2014 -2023 (April-August)

Rainfall Kalpa (Monthly Rainfall)										
Year	**No. of Rainy Days (April)**	**Total Monthly Rainfall (April)**	**No. of Rainy Days (May)**	**Total Monthly Rainfall (May)**	**No. of Rainy Days (June)**	**Total Monthly Rainfall (June)**	**No. of Rainy Days (July)**	**Total Monthly Rainfall (July)**	**No. of Rainy Days (August)**	**Total Monthly Rainfall (August)**
2014	9	51.60	9	55.30	5	7.00	11	69.30	6	12.90
2015	8	25.00	7	13.50	11	42.90	11	34.20	11	13.90
2016	5	64.40	8	17.00	0	0.00	9	28.20	16	44.60
2017	3	23.80	3	1.80	7	30.60	14	16.60	6	7.60

2018	9	38.20	5	16.40	3	7.2	15	57.80	6	25.2
2019	5	10.70	10	53.50	11	59.80	15	26.80	20	91.20
2020	15	51.00	13	25.40	12	21.00	13	44.90	13	17.80
2021	8	56.20	12	87.20	18	62.00	18	62.00	11	39.60
2022	14	20.20	13	50.60	9	14.20	19	58.40	17	50.90
2023	17	120.80	19	82.60	12	31.70	22	196.60	5	14.6

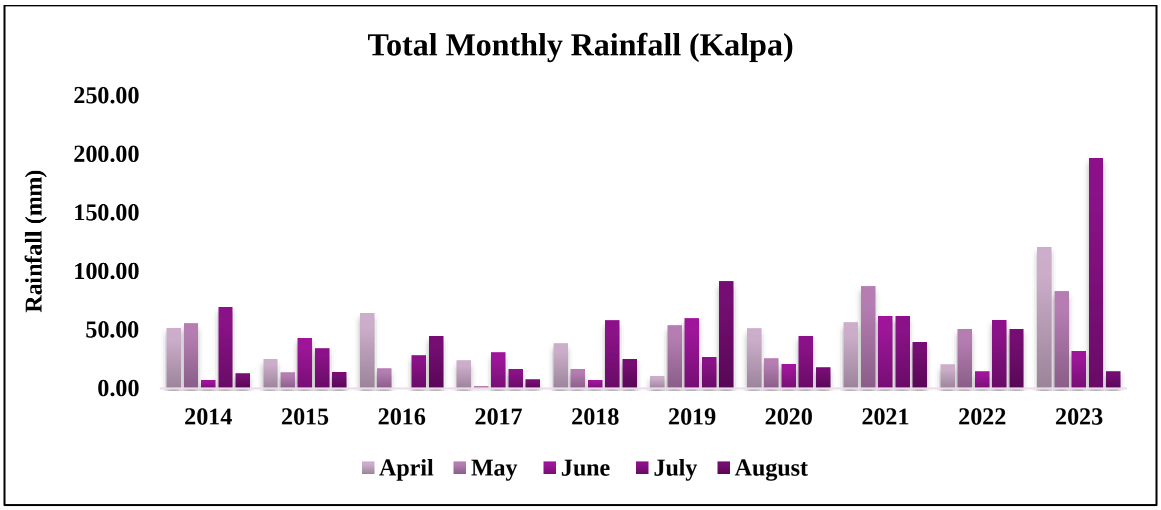


Table 7 Total monthly rainfall at Kalpa, district Kinnaur during 2014-2023 (April-August)

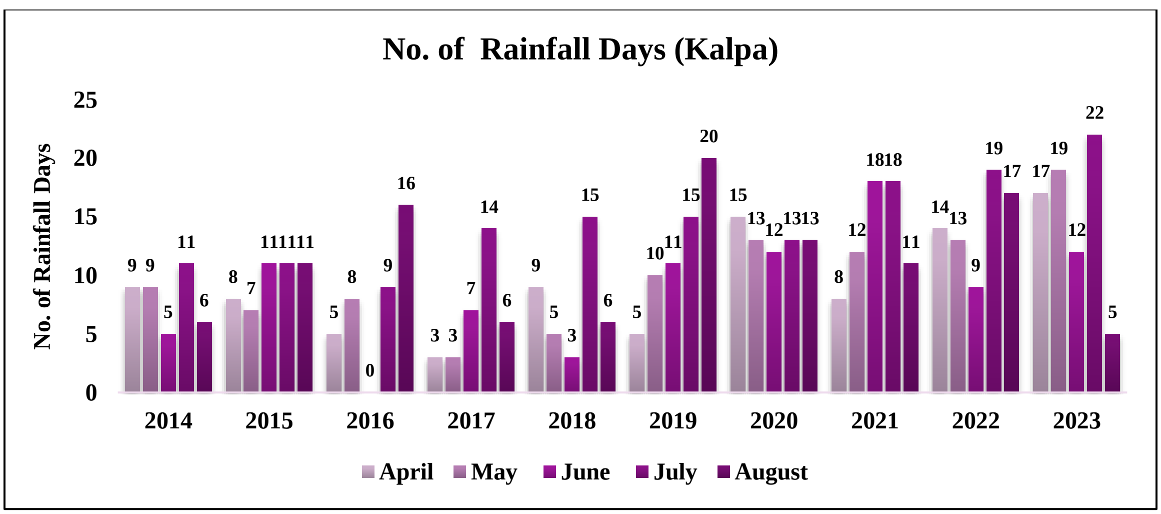


Table 8 No. of rainfall days at Kalpa, district Kinnaur during 2014-2023 (April-August)

DISTRICT WISE NO. OF FLASH FLOODS IN HIMACHAL PRADESH

Table 9 District wise no. of flash floods

S. No.	District	No. of Floods
1.	Bilaspur	01
2.	Chamba	04
3.	Hamirpur	01
4.	Lahaul & Spiti	25
5.	Kangra	01
6.	Kullu	20
7.	Kinnaur	12
8.	Mandi	10
9.	Shimla	05
10.	Sirmour	03
11.	Una	01
Total		83

DISTRICT WISE NO. OF LANDSLIDES IN HIMACHAL PRADESH

Table 10 district wise no. of landslides in Himachal Pradesh

S. No.	District	Total no. of landslides	Total area of landslides (Sq. Km)
1.	Bilaspur	172	1.14
2.	Chamba	437	7.36
3.	Hamirpur	287	1.39
4.	Kangra	366	2.3
5.	Kinnaur	144	2.48
6.	Kullu	634	4.73
7.	Lahaul & Spiti	56	1.33
8.	Mandi	1257	10.4
9.	Shimla	644	3.79
10.	Sirmour	924	6.35
11.	Solan	787	3.92
12.	Una	40	0.25
Total		**5748**	**45.44**

CLIMATE CHANGE STUDIES

6. A COLLABORATIVE STUDY ON FOSTERING CLIMATE SMART COMMUNITIES IN THE INDIAN HIMALAYAN REGION (IHR)

The state Centre on Climate Change had initiated a collaborative study on ***"Fostering Climate Smart Communities in The Indian Himalayan Region (IHR)"*** with G.B. Pant National Institute of Himalayan Environment, Mohal, Kullu. Under this study to achieve objectives a survey on "Vulnerability assessment in Indian Himalayan Region (IHR)" was conducted development block wise in two districts viz., Kinnaur and Sirmour.

SURVEY AT KINNAUR DISTRICT, HIMACHAL PRADESH

Survey was conducted in three development blocks of Kinnaur district namely Nichar, Kalpa and Pooh. The villages covered under this survey were Chhota Kamba, Nigulsari, Bari, Nichar, Chagaon, Sapni, Sangla, Batseri, Chhitkul, Kalpa, Ribba, Moorang, Pooh, Shyaso and Chango. A total of 300 respondents were surveyed. The following are key findings of the survey, based on people's perceptions:

Nichar Development Block:

- **Climate Change Impacts:** Decreased duration of the winter season, snow-fed areas turning into rain-fed areas, decreased snowfall intensity, and unpredictability in the onset of the monsoon season.
- **Increased Hazards:** Climatic-related hazards such as landslides, flash floods, and cloudbursts have increased, with most forest fires being anthropogenic.
- **Impact on Agriculture:** Major impacts observed on food production, leading to the abandonment of traditional crops. Increased incidence of insect pest diseases, prompting the use of pesticides and insecticides.
- **Livelihood Sources:** Farming is the primary source of income for most people, with some also engaged in business, wage labor, or government/private jobs.
- **Community Support and Facilities:** Strong community bonds with mutual support during calamities. Access to communication tools like mobile phones and TV. Availability of grants and insurance facilities to cope with climate impacts.

Kalpa Development Block:

- **Climate Change Effects:** Variations in snowfall and rainfall patterns, decrease in snowfall, increase in rainfall, and early onset of the monsoon season.
- **Hazards and Crop Impacts:** Increased climate-related hazards like landslides and droughts. Rise in insect pests affecting crop production. Reduction in availability of nutritious food items and water resources.
- **Livelihood and Resource Depletion:** Farming remains the primary income source, but significant impacts on livelihood due to climate change. Depletion of natural resources like water and forest cover.
- **Community Support and Facilities:** Strong community cohesion during calamities. Widespread access to mobile phones. Mixed responses regarding government support for coping with climate impacts. Good availability of food, information, education, and medical facilities.

Pooh Development Block:

- **Climate Vulnerability:** Already highly susceptible to weather conditions, experiencing decreased snowfall, rainfall, and winter season length.
- **Increased Hazards:** Rise in climate-related hazards such as landslides, cloudbursts, snow avalanches, and flash floods.
- **Challenges in Food Security:** Some areas facing food scarcity, especially in winter. Issues with access to irrigation and drinking water, occasional disputes over water.
- **Community Support and Facilities:** Adequate medical and educational support but lacking vocational training opportunities.

Figure 83 Glimpse during survey at Kinnaur district, Himachal Pradesh

Overall, the survey highlights the pressing need for comprehensive adaptation and coping strategies to address the multifaceted impacts of climate change on various sectors in the Kinnaur district.

SURVEY AT SIRMOUR DISTRICT, HIMACHAL PRADESH

The survey was conducted in two phases i.e., Phase-I and Phase-II, covered all the development blocks of Sirmour district, including Pachhad, Nahan, Paonta Sahib, Rajgarh, Sangrah, and Shillai. In each development block, five villages were selected, and 20 respondents were surveyed from each village. The villages covered were Narag, Mehando Bag, Sarahan, Mangarh, Bhagar Paori, Kuale Wala Bhood, Salani, Shambhuwala, Mahipur, Dadahu, Khurla Kharak, Kasar, Dhaulakuan, Taruwala, Dobri Salwala, Kadiyut**,** Sargaon, Dhamla, Dimbar, Saniyo, Nohradhar, Shamra, Khur, Sangrah, Haripurdhar, Shillai, Milla, Halahan, Kando and Rast resulting in a total of 600 respondents covered during the survey. As per people perception, major highlights of the survey were:

(PHASE-II) Rajgarh Development Block:

- **Changing Seasonal Dynamics:**

  Hot Day Surge: Residents have observed a discernible increase in the number of hot days, indicative of a warming trend in the climate.

  Reduced Winter Duration: Concurrently, the winter season has exhibited a reduction in its temporal span, indicating alterations in the traditional seasonal rhythm.

  Attenuation of Snowfall and Hailstorms: The once familiar occurrences of snowfall and hailstorms exhibited a perceptible decline, indicating a nuanced transformation in climatic manifestations.

- **Transformation of Snow-fed Areas:**

  Shift to Rain-fed Areas: Snow-fed regions are undergoing a transition to rain-fed areas, signifying a transformation in the hydrological landscape.

  Reduced Snowfall Intensity: The intensity of snowfall has decreased, impacting both environmental and agricultural dynamics.

- **Monsoonal Unpredictability**

  Irregular Onset: The onset of the monsoon season in the Rajgarh Development Block displays an unpredictable pattern, posing challenges to agrarian practices.

- **Escalation of Climatic Hazards:**

  Shift in Crop Patterns: The traditional cropping system has largely disappeared, with farmers gravitating towards cash crops.

  Pest Management Challenges: Insect, pest, and diseases have proliferated due to climate change, prompting the increased use of pesticides and insecticides.

- **Economic Implications:**

  Mainstay in Agriculture: Farming remains the primary source of income for the majority of the population.

  Diversification Efforts: Some farmers are diversifying into horticultural crops and floriculture in response to changing agricultural dynamics.

(PHASE-II) Sangrah Development Block:

- **Altered Precipitation and Winter Dynamics:**

  Declined Snowfall and Rainfall: Residents concur on a decrease in both snowfall and rainfall, signifying a noteworthy shift in precipitation patterns.

  Shortened Winter Duration: The traditional winter season has experienced a reduction in its temporal span, altering the customary climatic rhythm.

- **Water Scarcity and Conflicts:**

  Resource Scarcity: A prevalent concern among respondents is the scarcity of drinking and irrigation water, leading to heightened conflicts over this precious resource.

  Abandonment of Traditional Agriculture: In response to climate-induced water inadequacy, traditional crop cultivation is being abandoned by local communities.

- **Escalation of Climate-Related Hazards:**

  Growing Hazards: Hazards associated with climate change have multiplied over time, posing diverse challenges to the residents of Sangrah.

- **Diversification Efforts in Agriculture:**

  Shift to Horticulture: In response to changing agricultural dynamics, residents in select areas are exploring alternative cultivation practices, such as floriculture and fruit trees like apples, plums, and peaches.

(PHASE-II) Shillai Development Block:

- **Agricultural Transformations:**

  Traditional Crop Abandonment: The prevailing trend indicates a widespread discontinuation of traditional crop cultivation in the majority of the Shillai Block. Only a few pockets continue such practices.

  Farming as Primary Income Source: For the majority, agriculture remains the principal source of income, underscoring its economic centrality within the community.

  Diversification of Livelihoods: A minority engages in diverse occupations, including business ventures, government or private sector employment, and participation in wage work programs like MGNREGA.

- **Government Support and Impact Coping:**

  Limited Government Assistance: Some respondents report a perceived lack of government support in addressing the multifaceted impacts of climate change. This sentiment is particularly noteworthy in coping with the challenges faced.

  Challenges in Coping: Despite the resilient efforts of the community, challenges persist in the absence of comprehensive government assistance, hindering effective coping mechanisms.

- **Infrastructure Gaps and Essential Services:**

  Water, Education, and Medical Facilities: Disparities in the availability of essential services are reported in certain parts of Shillai Block. Concerns include inadequate water availability and storage facilities, limitations in educational infrastructure, and gaps in medical support.

Figure 84 Glimpse of survey at Pachhad, Nahan and Paonta Sahib development block, Sirmour district, Himachal Pradesh (PHASE-I)

Figure 85 Glimpse of survey at Rajgarh, Sangrah and Shillai development blocks of Sirmour district, Himachal Pradesh (PHASE-II)

These findings underscore the urgent need for awareness campaigns, sustainable water management strategies, effective disaster preparedness measures, and alternatives to chemical pesticides to address the challenges faced by villagers in Sirmour district due to climate change and related factors.

PUBLICATIONS

- Harish Bharti, Aditi Panatu, Yamini Thakur, Surjeet Singh Randhawa, Satpal Dhiman, S.K. Bhardwaj and Ranbir Singh Rana. "Climatic and Fruit Productivity Trends in Solan District, Himachal Pradesh, India". International Journal of Environment and Climate Change 13, no. 10 (August 24, 2023): 1036–1048. https://journalijecc.com/index.php/IJECC/article/view/2749

WORKSHOPS/TRAININGS

7. THREE DAYS TRAINING PROGRAMME ON "BLENDING TRADITIONAL HOUSING CONSTRUCTION PRACTICES WITH MODERN TECHNOLOGY"

The Himachal Pradesh Council for Science, Technology & Environment (HIMCOSTE), Shimla, in collaboration with the National Institute of Disaster Management (NIDM), Ministry of Home Affairs, Govt. of India, New Delhi, and the H.P. State Disaster Management Authority (HPSDMA), Shimla, organized a training program on *"Blending Traditional Housing Construction Practices with Modern Technology"*. The training program was organized at State Agriculture Management & Extension Training Institute (SAMETI), Mashobra, Shimla from 13 to 15 June, 2023 from 11:00 am to 5:00 pm for a total duration of six hours. This training programme had 39 participants from various departments. The sessions generated highly interactive, easily understandable points of action and implementation by individuals having responsible role in ULB, as Govt. stakeholder or as any responsible citizen. The course highlighted the importance of building resilience, preparedness, and mitigation measures to achieve the resilient urban environment through city disaster management planning.

Objectives of the programme were:

- To increase awareness of the key stakeholders on the need for adoption of traditional housing, building bye-laws, codes and earthquake resistant construction and planning standards with use of modern technology.
- To identify solutions to the challenges faced by planners, architects and engineers and showcase examples of ongoing faulty construction practices in Himanchal Pradesh.
- To promote retrofitting technique and understand the concept of build back better through past events, lessons and experience sharing of hilly areas with emphasis to Himachal Pradesh.
- Sensitization at state level by sharing and disseminate experiences, knowledge, information, innovations and ideas on safety of structures to create a safe built environment for hilly region.

During the three-day training programme, different technical sessions were organized with the expert's presentation/lecture which are following:

1. Dr. Amir Ali Khan, Associate Professor, NIDM, New Delhi in his lecture explained pre-training assessment-expectations, experience sharing & ground rule. Dr. Khan also explained the fundamentals of DRR and the necessity of developing safe hill areas. Disaster risk reduction and management, disaster safe construction, and the causes of several disasters, such as population increase, uncontrolled or poorly planned urban expansion, the development of exposed steep terrain, inexperience, and overexploitation were also discussed. He cited preparedness, mitigation, and prevention as the three key strategies for lowering susceptibility. He talked on hazard mapping, early warning systems, and structural and non-structural mitigating measures.
2. Sh. K.C. Nanta, State Town Planner, Himachal Pradesh spoke on the topic "Blending Traditional Housing Construction Practices with Modern Technologies". He shared the current scenario of the State with respect to the vulnerabilities and issues related to the development activities in the State. Traditional construction techniques vary from region to region depending on weather, material efficiency and seismic zone:
    - Kath-Kuni construction
    - Dhajji –Diwari construction
    - Dry stone construction
    - Mud construction

Figure 86 Kath-Kuni construction & Dhajji –Diwari construction

Figure 87 Dry stone construction & Mud construction

He also emphasized on the innovation for future constructions by explaining the following points:

- Blending modern construction technologies or using alternate materials for the construction. Kath-Kuni – RCC beams instead of Wood.
- The cost and time required for constructing Kath kuni houses can be reduced by replacing wood with other sustainable and cheap materials like bamboo (compressed bamboo beam) and stone with hempcrete.
- Bamboo and hemp are both abundant in parts of Himachal, which makes them indigenous, cheap, and easily accessible raw materials.
- In case of Dhajji wall, to increase the strength, galvanized wire mesh can be nailed both side of the wall to secure the stones against falling out.

3. Dr. S.K. Negi, Chief Scientist, CSIR-CBRI, Roorkee spoke on “Blending Traditional Housing Construction Practices with Modern Technology in Hilly Regions-Case Studies”. He highlighted that “By blending traditional construction practices with modern advancements, we can create structures that are not only resilient and durable but also culturally and aesthetically relevant to the local communities. This approach ensures that the unique characteristics of hilly regions are preserved while meeting the evolving needs of the inhabitants.”

4. Dr. Ajay Chaurasia, Chief Scientist, CBRI Roorkee, Uttarakhand spoke on "Need and challenges for mainstreaming resilient indigenous construction practices using modern

technology". Dr. Chaurasia acknowledged concerns raised by participants and provided examples while providing an outline of traditional architecture in Himachal Pradesh. He also discussed novel characteristics of the confined masonry including its ability to withstand earthquakes, cost effectiveness, use of locally accessible building materials and labour, low design effort, 25% reduction in the amount of natural resources used in building construction, and 25% reduction in carbon footprint.

5. Dr. Daniel C, Assistant Professor, Department of Civil Engineering & Science (HITS), Chennai spoke on “Modern Technologies and usage of Damper in Structures”. He also talked about and clarified the active control system. In order to keep the building stationary and the structure safe during an earthquake, the active control system's sensors identify the direction and magnitude of the counterbalance force that needs to be induced in the opposite direction. Additionally, Dr. Danial offers details on the hybrid simulation of a structural earthquake-resistant magnetorheological damper. He talked about the modern aspect of construction methods and emphasized how these technological developments may be integrated with traditional methods.
6. Sh. Nitin Sharma, HPSDMA, Government of Himachal Pradesh spoke on “Setup and initiatives” of state government. He explained about disaster management act, 2005 along with various initiatives by the HPSDMA in the state. Furthermore, he briefed about the observational network of Himachal Pradesh in the field of hydro-meteorological early warning system, landslide early warning system and dam safety portal etc.

Figure 88 Group photograph with team from NIDM, GoI, SAMETI-faculty, HIMCOSTE staff and participants from different stakeholder departments

8. TWO DAYS BRAIN STORMING ON THE CHALLENGES OF THE GEOLOGICAL HAZARDS PARTICULARLY EARTHQUAKES AND LANDSLIDES IN THE WESTERN HIMLAYAN REGION OF HIMCHAL PRADESH

In order to address the issues arising out of different kinds of hazards in general and the landslides and earthquakes in particular from the state's perspective, the H.P. Council for Science, Technology & Environment, (HIMCOSTE), Shimla and H.P. State Disaster Management Authority (HPSDMA, Govt. of Himachal Pradesh jointly organized two days brain storming workshop on *The Geological Hazards Particularly Earthquakes and Landslides in the Western Himalayan Region of Himachal Pradesh* on 5th-6th October 2023 at Hotel Peterhoff, Shimla.

Practitioners, administrators, researchers, technocrats, and policymakers were present in the workshop. The deliberation's talk mainly focused on the following broad themes:

- Vulnerability to Landslides, Risk Assessment, and Mitigation
- Assessment of Seismic Vulnerability, Instrumentation, and Risk in the Western Himalayan Region
- Improving Building Code Compliance in Hill Towns

KEY RECOMMENDATIONS

The following recommendations were made from the state's perspective as far as the landslides and earthquake mitigation and preparedness concerned.

EARTHQUAKES

1. Deployment of three broad band arrays with at least 24 stations (i.e., one array of 12 stations and two of 6 stations each) at the clusters of seismicity and locations of seismogenic sources namely at Chamba, Kangra and Kinnaur as it will play a crucial role in formulating strategies for disaster risk reduction as well as in understanding possible dangers.

2. Deployment of strong motion array across the State at the locations which were earlier in operation by IIT Roorkee.
3. The data recorded by accelerographs can be used to generate response spectra. Response spectra provide a tool for engineers to quantify the demands of earthquake ground motion on the capacity of buildings to resist earthquakes. The most direct description of an earthquake motion in time domain is provided by accelerograms that are recorded by SMA. The peak ground acceleration, duration, and frequency content of earthquake can be obtained from an accelerograms.
4. The data recorded by accelerographs is essential for developing Ground Motion Prediction Equations (GMPEs). GMPE is an empirical correlation between ground motion parameter and EQ characteristics (source, site and propagation path characteristics). Dependency of ground motion parameter on EQ characteristics is a regional property and thus it should be region specific. It is crucial for seismic hazard evaluation at a site.
5. The earthquake Early Warning System which is one of the best tools for seismic risk mitigations should be deployed in the state. Such systems are of utmost necessity for this state where an earthquake of high magnitude is due for last several years. The installation of Earthquake Early Warning Systems (EEWS) in Himachal Pradesh would be useful to save precious lives of the people of the state, if the action is taken by the govt without any delay.
6. Involving technical institutions and PRIs for the implantation of construction practice as per BIS criteria, Code of Practice and Guidelines across Himachal Pradesh.
7. Critical social infrastructure facilities like schools, hospitals, fire and emergency services, etc. must be assessed for earthquake resilience using the Rapid Visual Screening guidelines issued by NDMA by trained civil, structural or geo technical engineers and wherever required, seismic strengthening and retrofitting measures must be undertaken.
8. All urban centres with loose material underneath should be taken up for seismic micro zonation studies as the region has high seismic hazard potential. The results of such studies should be incorporated in the planning process for sustainable development.
9. Must have real time automatic weather station with forewarning feature which can warn the public at least 1 hr before the cloud burst and covers an area of 300 sq. km.

10. The SDMA must strengthen its institution by establishing an institute of disaster management and will also maintain a data base of all parameters which will act as a first response centre for Disaster Management in the state.
11. Revision A-line plan prepared for earthquake mitigation in white paper I issued in 2022.

LANDSLIDES

1. The main thrust should be towards Disaster Risk Reduction and Mitigation conforming to the Sendai Framework Guidelines and 10-point agenda as given by Hon'ble Prime Minister of India.
2. For a Himalayan state like Himachal Pradesh the DRR and Mitigation measures should be in accordance with the Sustainable Development Goals so that the developmental activities in this hilly state are not compromised.
3. The Macro Scale (1:50,000) Landslide Susceptibility Maps (NLSM maps) prepared by GSI, which are available for free download through BHUKOSH on GSI portal (http://www.gsi.gov.in) should be used in regional land use planning by the state authorities.
4. For a proper planning in respect of Road sectors and townships the upscaled task of Meso Scale LSM mapping (on 1: 10000 scale) along with Landslide Management Plan is required. As this is a humongous task, involvement of different agencies/institutes is required for different each sectors/ urban areas with the handholding of GSI. It will be an important step in minimizing and mitigating the risk associated with landslides. GSI can also help the departments and institutions in the state in capacity buildings, sharing of knowledge in building new applications.
5. Taking a reference from the Vulnerability map prepared by GSI, ranking of vulnerable districts should be made and the administrative authorities in the respective districts should plan and complete all the works in one go.
6. There is an urgent need that A preliminary study of all the sites affected by landslides/slope failures, especially during SW Monsoon 2023, may be conducted and site-specific studies may be planned for selected sites, wherever needed.
7. Repetition/duplication of Susceptibility Mapping and Regional Early Warning should be strictly avoided. The NLSM maps of GSI may be consulted by the state authorities before

taking a decision on taking up new susceptibility mapping in a particular area. It will save time, resources and money for the state authorities.

8. Low-cost Landslide Early Warning System (LEWS) should be a priority and local capacity building in mitigation and awareness on hill slope behavior should be transmitted down to the village level.
9. For a more successful and useful regional EWS, most vulnerable sites near any important corridors or infrastructure or locality should be identified for instrument-based monitoring and site specific EWS. It is recommended to develop a network of Automatic Weather Stations (AWS) with Doppler Radars at Taluka level in the concerned districts.
10. Regional rainfall induced LEWS of GSI to be furthered with collaboration with SDMA for which the HPSDMA need to be strengthened with few Geologists.
11. Data of all investigations needs to be collated and maintenance of repository is essential and the data should be shared periodically with SDMA and GSI for avoiding duplication.
12. The future construction activities in Shimla and other major townships in Himachal Pradesh should be strictly regulated in accordance with the existing codes and guidelines of regulatory authorities. If the need be the Building Bylaws should be modified.
13. Application of scientific & engineering knowledge into practice for meeting the challenges faced by landslide.
14. Scientific investigation prior to implementation of any large construction.
15. Community preparedness and awareness building.
16. There should be proper sewerage system in Himalayan region to avoid any seepage of water inside the soil on which building is located especially in sloppy region.
17. Any retaining wall should have proper weep holes not less than 8-inch size with boulders on the headword side of the boundary wall to avoid direct contact of weep holes with soil and maintain porosity behind the wall on the headword side.
18. Avoid construction of retaining walls on the head of the scrap of the slide zone; rather start controlling the slide from the toe region.
19. Landslide prone areas can be used as open recreational spaces, parks instead of development of civil structures.
20. Aizol Model for reducing risk & Tehri Town Development plan.

21. Preparation of Landslide Mitigation plan with timelines defining roles and responsibility of different stakeholders.

BUILDING BY LAWS

1. Update and detail out the white paper into clear Action Plans.
2. Conduct a Regulatory Capacity Assessment for two major Municipal Corporation/ Municipality to:

a. Examine the appropriateness of the building regulations with respect to the hazards that can affect the local body.

b. Assess the capacities with the MC/local body to enforce these regulations.

3. Instruct critical departments to develop five-year Resilience Action Plans in order to avail the Mitigation Funds in future.

Figure 89 Glimpse of two days brain storming workshop at Hotel Peterhoff, Shimla, Himachal Pradesh

9. CELEBRATION OF INTERNATIONAL DAY ON DISASTER RISK REDUCTION “FLAGSHIP AWARENESS PROGRAM OF THE HIMCHAL PRDAESH STATE DISASTER MANAGEMENT AUTHORITY ON DISASTER RISK REDUCTION”

Under SAMARTH celebration-2023, a flagship awareness program of the HPSDMA, Govt. of HP on Disaster Risk Reduction was celebrated at Hotel Holiday Home, Shimla on 13th October, 2023. The State Centre on Climate Change collaborated to organize the programme with HPSDMA, Govt. of HP. Hon’ble Chief Minister, Sh. Sukhvinder Singh Sukhu was the Chief guest of the programme, who launched “**School Safety Mobile App”,** book on **“Simplified Guidelines for Earthquake Safety of Buildings”** by CBRI Roorkee**, "Apprentice Guide for Rural Masons of Himachal Pradesh"** by CBRI Roorkee. In this programme, number of schools, individuals were awarded by Hon’ble Chief Minister on ***Best DM Plan on School Safety***, ***Best Photography and Video making on recent disaster*** and ***extraordinary work in Monsoon 2023***.

During the programme, Memorandum of Understanding was also signed between Central Building Research Institute (CBRI) Roorkee and HP Council for Science, Technology & Environment (HIMCOSTE) to develop a permanent demonstration site at Appropriate Technology Centre (ATC) of the HIMCOSTE at Rait in

Kangra district, Himachal Pradesh for demonstration of technology and dissemination of appropriate building materials and earthquake resistant construction practices/technologies.

10. TRAINING OF MASTER TRAINERS FOR MASONS

An own house is a dream of every individual in our country, but majority of the times the houses doesn't get designed by a certified Engineer or Architect; instead, they are designed and built by a Mason, that too many a times an untrained one. This raises a serious concern about the safety of such houses. In order to overcome this situation, HIMCOSTE decided to create a team of Master Trainers to further impart training to the Masons working on the grass root level.

To achieve this, HIMCOSTE in collaboration with CSIR-Central Building Research Institute, Roorkee organized 5 days training programmes in two batches (Batch-I w.e.f. 25th-29th September, 2023 and Batch-II w.e.f. 20th-24th November, 2023) to train the Junior Engineers of Himachal Pradesh in this field and convert them into the Master Trainers for Masons. With the help of this course, participants gained knowledge and necessary skills to become competent masons in the field and build safe, disaster-resistant structures. Participants obtained practical knowledge and abilities to efficiently handle site-related quality and safety issues in newly constructed buildings through a combination of lectures, demonstrations, and hands-on tasks.

OBJECTIVES

The main objectives of the course are as follows:

- To understand common site errors and their rectification
- To understand do's & don'ts related to building construction
- To enable participants to maintain quality of construction
- To improve skills of participants related to safety, quality, and planning

Figure 90 Group Photo of Participants of Training Programme-Batch I

Figure 91 Group Photo of Participants of Training Programme-Batch II

During the training programme, 28 Junior Engineers in the first batch & 32 in the 2nd batch from different districts of Himachal Pradesh were present. 10 technical sessions were conducted and lectures were delivered by the external experts and in-house faculty (Scientist) of CSIR-

CBRI, Roorkee. The technical sessions delivered by the scientists of CBRI, Roorkee were mostly based on the outcome of the R & D activities conducted under different projects.

OUTCOME

- 60 Master Trainers for Masons were trained.
- Understanding of Basics of Building Layout, Do's & Don'ts, Safety, quality etc.
- Improvement in safety of buildings.

Figure 92 Glimpse of technical sessions during the training programme at CSIR-CBRI, Roorkee

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