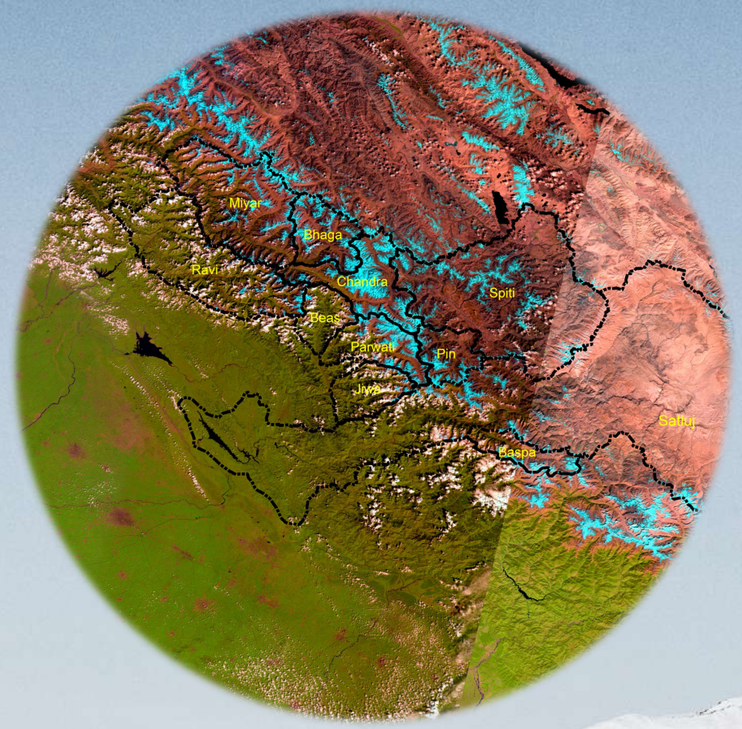
Conclusion

Based on the IRS-RS2-LISS-III satellite data having spatial resolution of 23.5 meters and Landsat 8 MSS satellite data having spatial resolution of 30 meters 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. 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 basins 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 Uttarakhand 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. 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. Therefore, a proper monitoring of all such lakes is very much essential in the Himalayan region in order to avoid any eventuality like in Uttarakhand in future, which will not only save the precious human lives but also the public and the Govt. property.

Vulnerability of Himachal Pradesh From Climate Induced Hazards (GLOFs)



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Introduction

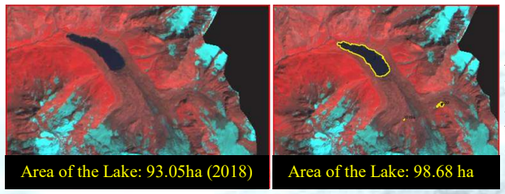
Mountain ecosystems harbor a wide range of significant natural resources and play a critical role in the ecological and economic processes of the Earth. Deforestation, landslides, land degradation, desertification, and Glacier Lake Outburst Flooding (GLOF) are some of the common environmental issues 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. Small changes in climate can produce significant regional or larger-scale effects. In particular, marginal environments are under high stress. Small changes in water availability, floods, droughts, landslides, and late frosts can have drastic effects on agriculture's economy. The most likely scenario in the mountain environment due to climate change will be that the mountain environment is likely to be among the most severely impacted ecosystems as a result of climate change.

Hazard Vulnerability of the State

Mountain areas are especially vulnerable to natural disasters where development over the years has further accentuated the problem by upsetting the natural balance of various physical processes operating in the mountain eco-system. The increased pressure on the mountain environment has contributed in some measure to environmental problems such as landslides, land subsidence, removal of vegetation and soil erosion. According to one estimate, about 58.36% of the land is subjected to intense soil erosion, majority of which is located in the Himalaya. The State of Himachal Pradesh, which forms part of the Northwestern Himalaya, is environmentally fragile and ecologically vulnerable. Natural hazards are matter of immediate concern to the State, as every year the State experiences the fury of nature in various forms like earthquakes, landslides, cloud bursts, flash floods, snow avalanches and droughts etc. The fragile ecology of the mountain State coupled with large variations in physio-climatic conditions has rendered it vulnerable to the vagaries of nature.

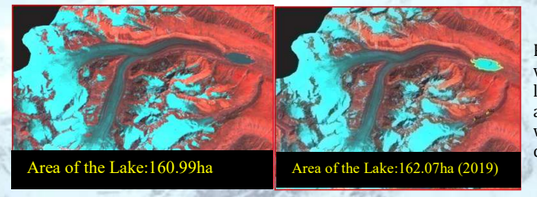
Methodology

The Landsat satellite data having spatial resolution of 8 meters and LISS-III satellite data having spatial resolution of 23.5 meters have been used for the delineation of the all moraine dammed glacial lakes (GLOFs) in different basins *viz*., Chenab, Beas, Ravi and Sutlej basins for the year 2019 in Himachal Pradesh.



Potentially vulnerable lake having a deep water column

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

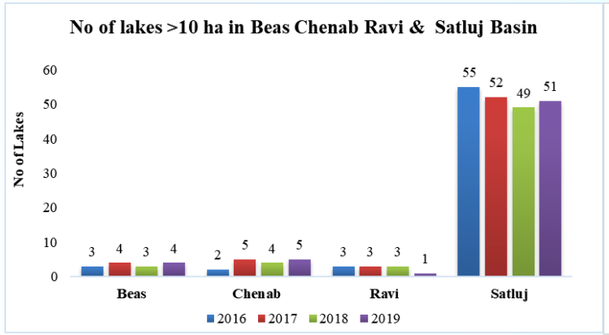


Potentially vulnerable lake having a deep water column

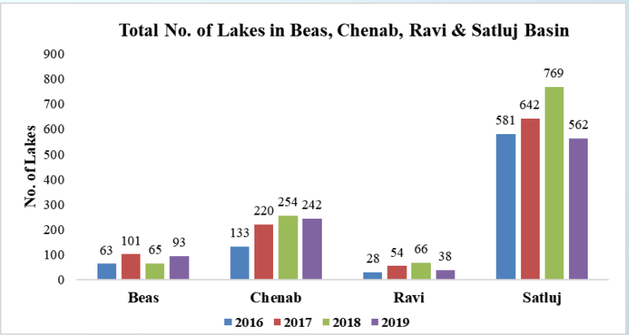
Moraine Dammed Lake Formation at the Snout of Samudri Tapu Glacier

Distribution of Glacial Lakes in Himachal Himalaya

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. The Chenab basin comprising mainly of (Chandra, Bhaga, Miyar) as sub basins has a total of 242 lakes (2019) comprising (52 lakes 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 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.



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



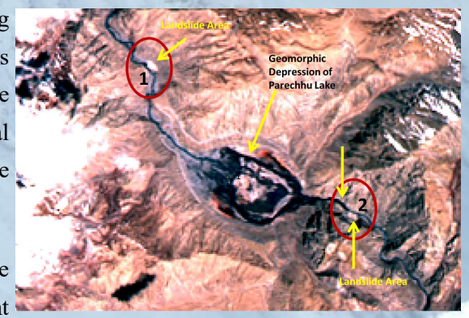
Distribution of lakes in different sub basins in Himachal Pradesh based on LISS III satellite data analysis for 2019

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. 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. 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 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.

Monitoring of Parechhu Lake during 2022

Parechhu Lake which has been known for its damage and since 2001 is being monitored every year during the ablation season from April to September. This year also the lake was monitored and its status was conveyed to all the stakeholders including SJVNL Shimla as well as the Government of Himachal Pradesh. On analyzing the IRS RS2 LISS-III Satellite data for May 2022 the following observations were made.



Parechhu Lake Seen through IRS-L3-R2A-96-48-18 April2022 Satellite Data

- The accumulated water in the lake depression could be seen through the peripheral sides 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 728.09 mts from the lower point of the lake depression.
- Based on the tonal difference in the river flow, near the landslide, the slide seems to have caused a slight blockade in the river course resulting to have the accumulation of the river flow that extends upwards all along the peripheral side in the frontal portion of the lake depression.
- The accumulated water along the river course in the frontal side and in the depressions seems to be more or less same except minor change on the upper part where accumulation may have slightly increased than as on 18 April 2022.