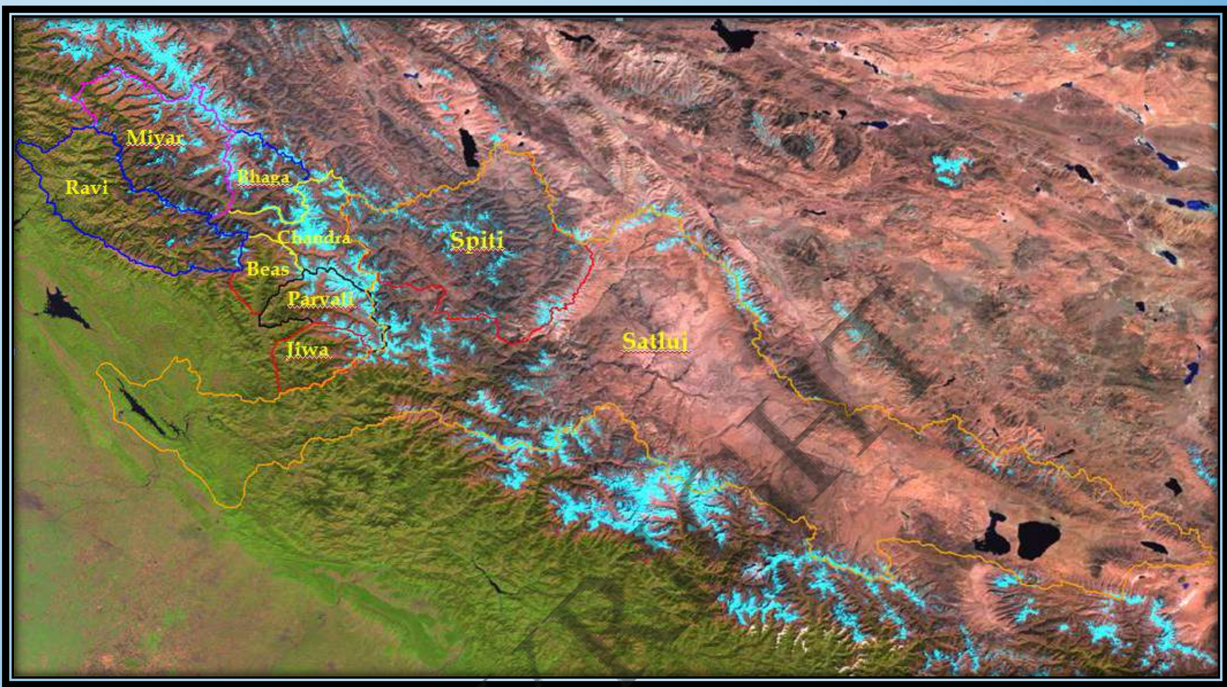
A Technical Report on the Inventory of Moraine Dammed Glacial Lakes (GLOF) in Satluj, Beas, Chenab and Ravi Basins in Himachal Pradesh Using IRS LISS-III Satellite Data (2019)



Spatial extent of different basins in Himachal Pradesh

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Abstract	**With the projected increase in the frequency and intensity of extreme events including floods, droughts, landslides etc which are attributable to climate change, disaster management need greater attention. Susceptibility of the State of Himachal Pradesh to the vagaries of climate change has now been well documented. Scientific insight gained from the analysis of multi spectral Satellite images carried out by the authors suggests that spatial extent of majority of glaciers is changing very fast leading to the formation of moraine dammed lakes. Formation of such lakes is posing potential threat to the infrastructure and human life thriving in the downstream areas of many drainage systems originating from the snow clad mountains ranges of the State. Various studies have been carried out on this vital issue of climate change and reveals that there is an alarming increase in such potential lakes which can be disastrous in the event of any break due to one or the other reasons. The present study has been carried out using LISS III satellite data for the year 2019.The mapping has been carried out in Chenab, Beas, Ravi and Satluj basins for the delineation of all such lakes in the higher regions. The area mostly being inaccessible where about 70% catchment as in case of the Satluj basin is on the international territory, so the investigation is inaccessible as in the present case where the mapping by any other conventional method is just not possible because of rugged topography of the area besides the area under International boundary, so the remote sensing technology has been found to be very useful in acquiring the information. Based on this, a complete inventory of moraine dammed glacial lakes (GLOFs) basin wise has been generated which forms the base line data for future monitoring as far as disaster preparedness in the state is concerned. Besides this, the monitoring of Parechhu lake has also been carried out separately using LISS IV data during the year 2018 and 2019 from April to September and the up to date status was conveyed to the Govt. of Himachal Pradesh and other stakeholders in the State. Based on LISS III satellite data analysis carried for 2019, the study reveals the presence of total 562 lakes (2019) in the entire Satluj basin indicating an overall decrease of about 19% with reference to 2018 data. In Chenab basin, the total no. of lakes that could be mapped in 2019 is 242 (84 in Bhaga sub basin, 52 in Chandra sub basin and 139 in Miyar sub basin) with an overall increase of about 4 %with reference to 2018. The Beas basin reflects the presence of total 93 lakes in 2019 in comparison to the 101 lakes as mapped in 2018, whereas the Ravi basin shows the presence of 38 lakes (2019) in comparison to 66 lakes of 2018. The regular monitoring of all such moraine dammed lakes is thus important and needs regular monitoring in order to meet out any eventuality at the pre disaster level.**
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CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGEMENT

The State Centre on Climate Change of the H.P. Council for Science Technology & Environment, HIMCOSTE took up the initiative to prepare an inventory of the moraine dammed lakes in all the four basins viz. Chenab, Beas, Ravi and Satluj basins using high resolution satellite data. The author is thankful to the Secretary (Env., S&T) Govt. of H.P., Member Secretary (EC) and the Joint Member Secretary, H.P. Council for Science Technology & Environment, HIMCOSTE for constant support and guidance and allowing us to undertake the investigation as part of the disaster management activities in the State Center on Climate Change of the State Council using space technology. Funding support form SAC –ISRO Ahmedabad under DMS program of ISRO is duly acknowledged.

A technical report on the inventory of moraine dammed glacial lakes (GLOFs) in Satluj, Beas, Chenab and Ravi Basins in Himachal Pradesh using IRS LISS III satellite data.

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Technical Report on the Inventory of Moraine Dammed Glacial Lakes (GLOFs) in Satluj, Beas, Chenab and Ravi Basins in Himachal Pradesh using IRS LISS III and Landsat 8 satellite data for 2019.

1. Background:

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 (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.

Mountain systems are particularly sensitive to climate changes. Since industrialization, human activities have resulted in steadily increasing concentrations of greenhouse gases-particularly carbon dioxide (CO2), methane (CH4), chlorofluorocarbons (CFCs) and nitrous oxide (NOx)- in the atmosphere. As these gases absorb some of the radiation emitted by the Earth rather than allowing it to pass through the atmosphere to space, there is general consensus that the Earth's atmosphere is warming.

The fifth Intergovernmental Panel on climate change (IPCC 2013) report states with 95 percent confidence that humans are the main cause of the current global warming. Most of the observed increase in global average temperatures since the mid-20th century is very likely [90 percent confidence] due to the observed increase in anthropogenic greenhouse gas concentrations. Global warming is the rise in the average temperature of Earth's atmosphere and oceans since the late 19th century and its projected continuation. Since the early 20th century, Earth's mean surface temperature has increased by about 0.8 °C (1.4 °F), with about two-thirds of the increase occurring since 1980. Warming of the climate system unequivocal and scientists are 95-100% certain that it is primarily caused by increasing concentrations of GHGs produced by human activities such as the burning of fossil fuels and deforestation. Climate model projections were summarized in the 2007 Fourth Assessment Report (AR4) by the (IPCC). They indicated that during the 21st century the global surface temperature is likely to rise a further 1.1 to 2.9 °C (2.0 to 5.2 °F) for their lowest emissions scenario and 2.4 to 6.4 °C (4.3 to 11.5 °F) for their highest.

Analysis of the temperature trend in the Himalayas and its vicinity shows that temperature increases are greater in the uplands than lowlands areas. Regional changes in climate have already affected diverse physical and biological systems in many parts of the mountain regions.

Shrinkage of glaciers, thawing of permafrost, late freezing and earlier break up of ice on rivers and lakes, pole ward and altitudinal shifts of plant and animal species, declines of some plant and animal population, and earlier emergence of insects have been observed (IPCC, 2001). Climate influences weathering processes, erosion, sediment transport, and hydrological conditions. It also affects the type, quantity, quality, and stability of vegetation cover and, thereby, biodiversity. Mountain systems are particularly sensitive to climate 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 economics. The most likely scenario in the mountain environment due to climate change will be as that the Mountain environments are likely to be among the most severely impacted ecosystems as a result of climate change.

- A warmer climate will cause lower-elevation habitats to move into higher zones encroaching on alpine and sub-alpine habitats.
- High-elevation plants and animals will lose habitat area as they move higher with some 'disappearing' off the tops of mountains. Rising temperatures thus increase the importance of connections between mountain areas.
- Rising temperatures may cause mountain snow to melt earlier and faster in spring shifting the timing and distribution of runoff. This in turn affects the availability of freshwater for natural systems and for human uses. Earlier melting leads to drier conditions with increased fire frequency and intensity.
- Glaciers around the world have been shrinking. Retreating glaciers decrease the reliability of water flows and change habitats.

2. Changing Weather Pattern over the Himalayan Region:

Both precipitation and temperature are considered significant indicators of State of Climate on account of their relation with earth's energy system. The hilly, undulating terrain with large relative relief variations experience significant variability both in precipitation and temperature. Comprehensive studies have been carried out by (Bhutiyaniet.al. 2007) on long term trends in maximum, minimum and mean annual air temperature across the north western Himalayas during the 20th century. The studies published in a series of research papers in international journals such as International Journal of Climatology, Climate change and Current Science, have established that the

North-Western Himalayan region has 'warmed' significantly during the last century at a rate, which is disturbingly higher than the global average. Effects of climate change are evident on decreasing winter snowfall component in total winter precipitation on the windward side and some portions of the leeward side of the PirPanjal Range since 1991, leading to delay in onset of winter and early spring and effective reduction in snowfall duration period. Coupled with rising summer temperatures, the glaciers are affected and they are in recession mode. This has given rise to a change in the nature of natural hazards in the area. Earth-flows and mud-flows, which were hitherto uncommon occurrences in the area, have been observed to occur in high altitude regions (>4500 m) over the glaciers. Consequently, these factors in combination have altered the discharge patterns in the Himalayan Rivers leading to an overall decreasing discharge in majority of NW Himalayan Rivers. These changes are attributed to enhanced anthropogenic (human related) activities in this region

In one of the studies carried out by (Bhutiyani et.al.) reveal that significant rise in the air temperature in the NW Himalayan region by 1.6^0 C in the last century with winter warming at a faster pace. The study included observations from Shimla station for the period (1901-2002) which indicates increasing trend in temperature at (significant 95% confidence level) and this trend has been consistent in case of mean maximum, mean minimum and mean annual temperatures. The warming is particularly conspicuous during winter season. Out of three stations which were monitored i.e. Leh, Shimla and Srinagar: Shimla experienced higher rate of warming in comparison to the other two stations. Analysis on decade to decade rates demonstrates that barring the decade of 1911-1920, the temperature rose comparatively at a lower rate till 1930, which period was followed by a cooler episode of decreasing or insignificant rise in temperatures. They further observed that real warming with modest rate manifested only during the decade of 1961-1970 and with an exception of 1981-1990 decade continued till the end of century. Warming rate was higher during the period from 1991-2002 as compared to the earlier decades and gross rise in the mean air temperature during 1980-2002 periods in the north western Himalaya as a whole was about 2.2^0 C.

Rates of increase of winter, monsoon and annual air temperature in ^{0}C in the last century computed by linear regression slope (Bhutiyaniet al.2007)

Table 2.1: Rates of increase of winter, monsoon and annual air temperature in ^{0}C in last century.

Station	Season	Winter bX100	Monsoon bX100	Annual bX100
Shimla	Mean Maximum	2.6*	2.8*	2.4*
	Mean Minimum	1.0*	-0.01	0.5

	Average Annual	1.8*	1.5*	2.0*
Srinagar	Mean Maximum	1.1*	0.2*	0.5*
	Mean Minimum	1.2*	0.2	1.0*
	Average Annual	1.1*	0.2	0.8*
Leh	Mean Maximum	1.3*	1.0*	1.7*
	Mean Minimum	0.4*	1.1*	1.3*
	Average Annual	0.6*	1.1*	1.6*
NW Himalaya	Mean Minimum	1.7*	0.4*	1.1*
	Average Annual	1.7*	0.9*	1.6*

(*Significant at 95% confidence level)

The other interesting observation that was recorded from the short term analysis which included 5 stations data from different altitudinal zones in Himachal indicates that the rate of increase in maximum temperature at higher altitudes was more than at the lower altitudes in the last century and the north western Himalayan region has warmed significantly higher than the global average. Likewise the results of the trend analysis of annual, winter and monsoon precipitation in the Northwestern Himalaya (Bhutiyani et al 2009) are as under:

Table 2.2:**Trend analysis of annual, winter and monsoon precipitation in the N.W Himalaya**

Sr.No.	**Station**	**Data Span**	**Trend Analysis**	
			Mann-Kendall's non-parametric text	**Linear regression coefficient 'b'**
a)	**Total Annual precipitation**			
1	Shimla	1866-2006	(-)*	(-)*
2	Srinagar	1901-1989	(+)*	(+)*
3	Leh	1901-1989	(-)*	(-)*
4	NWH	1866-2006	(-)*	(-)*
b)	**Total winter precipitation**			
1	Shimla	1866-2006	(-)*	(-)*
2	Srinagar	1901-1989	(+)*	(+)*
3	Leh	1901-1989	(-)*	(-)*
4	NWH	1866-2006	(+)*	(+)*
c)	**Total Monsoon precipitation**			
	Shimla	1866-2006	(-)*	(-)*
	Srinagar	1901-1989	(-)*	(-)*
	Leh	1901-1989	(-)*	(-)*
	NWH	1866-2006	(-)*	(-)*

(+) increasing trend, (-) decreasing trend,
**** Significant at 95% confidence level.***

Similarly the trend obtained for the snow fall at different altitude in Himachal Pradesh as per the study carried out by (Bhutiyani et al. 2007) are as under:

Table 2.3: Snow fall at different altitude in Himachal Pradesh

Sr.No.	Station	Snowfall Depth	
		Time period	Time period
1	Bhang	(-) (1974-2005)	(-)*(1991-2005)
2	Solang	(-) (1982-2005)	(-)* (1991-2005)
3	Dhundi	(-) (1989-2005)	(-) (1991-2005)
4	Gulmarg	(+) (1976-2005)	(-) (1991-2005)
5	Haddan Taj	(-) (1974-2005)	(-) (1991-2005)
6	Kanzalwan	(-) (1973-2005)	(+) (1991-2005)
7	Patseo	(-) (1983-2005)	(-) (1991-2005)

(+) increasing trend, (-) decreasing trend,
**** Significant at 95% confidence level.***

The increasing winter temperature at different stations in NW Himalayas as pr (Bhutiyani et al 2007) area as under:

Table 2.4: **Winter temperature at different stations in NW Himalayas**

Station	Time Period	Mean Max.	Mean Mini.	Av. winter	Remarks
Shimla	1901-2002	2.6	1.0	1.80	Bhutiyani et al.2007
	1991-2000*	1.83	-0.14	0.89	-----
	2001-2007*	3.42	0.74	2.80	-----
Solan	1991-2000*	0.99	-0.08	0.45	-----
	2001-2007*	2.84	-1.12	1.98	-----
Srinagar	1901-2002	1.1	1.2	1.1	Bhutiyani et al.2007
Leh	1901-2002	1.3	0.4	0.85	-do-
NW Himalaya)**	1901-2002	1.7	1.7	1.7	-do-
*: Increase in temp. relative to baseline of 1972-1990					
**: Average annual:1.6 ^{0}C					

Gross increase in winter mean air temperature in the last two decades in Himachal Pradesh as per (Bhutiyaniet al.2007) is as under:

Table 2.5: Winter mean air temperature in the last two decades in Himachal Pradesh

Sr.No.	Station	Mean Max.in ^{0} C	Mean Mini. In ^{0} C	Average winter ^{0} C
1	Bhang (2192)	4.0	1.8	3.8
2	Solan (2480)	4.4	2.0	3.8
3	Dhundi(3050)	5.6	1.0	3.2
4	Patseo (3800)	3.0	-3.0	0.0
5	Shimla(2200)	2.8	2.2	2.4
Average		**3.2**	**0.8**	**2.2**

In a study by Bhutiyani et al.(2009) on climate change and the precipitation variations in the northwestern Himalaya based on precipitation data from 1866-2006 no change in winter precipitation was observed but significant decreasing trend in the monsoonal precipitation was captured. Negative relationship between mean winter air temperature and snow fall amount recorded at different meteorological stations during this period reveal slow effect of rising temperature on the decreasing snowfall component in total winter precipitation and reduction in effective duration of winter on the windward side of PirPanjal Range. Interestingly meteorological stations of Himachal Pradesh like Shimla, Bahang, Solang and Patseo which were part of this study were all located on the windward side of the PirPanjal Range. The trend analysis of annual, winter and monsoonal precipitation of Shimla indicate a decreasing trend as opposite to the significant rising trend in winter, monsoon and annual temperatures. The cumulative winter fresh snow fall depths and temperature data records for the last three decades (prior to 2006) at Bahang, Solang, and Dhundi in Himachal Pradesh show significant trends from 1991-2005 onwards which period also recorded increase in winter air temperature.

3. Glaciations in the Himalaya:

During its geological history, the earth has experienced alternate cycles of warm and cold climates. During cold climate, glaciers and ice sheets have formed on the surface of the earth. Geological evidence suggests that the earth has experienced glaciations during, Perm-Carboniferous and in the Pleistocene period (Embleton and King, 1975). Precambrian tillites and boulder-beds are reported from many parts of the world, such as Scotland, U.S.A. Clear evidence of Carboniferous-Carboniferous ice age is also established in India and South Africa. The Carboniferous-Carboniferous glaciation was followed by Mesozoic era, during which the world temperature was higher than that of today and no evidence of glaciation was observed in the geological formations of that period. In Cenozoic era, large-scale glaciation was experienced, which includes glaciation during Pleistocene and Quaternary periods (Smith *et al.,* 2005). It has also influenced the present distribution of glaciers on the earth's surface. During Pleistocene the earth's surface had experienced repeated glaciation over a large land mass. During the peak of glaciation, the area covered by the glaciers was 46 Million sq. km. (Embleton and King, 1975). This was more than three times the present ice cover of the earth. Available data indicates that during the Pleistocene, the earth has experienced four or five glaciation periods separated by an interglacial periods. During an interglacial period, climate was warmer and deglaciation occurred on a large scale. The most recent glaciation reached its maximum advance about 20,000 years ago when the Himalayan snow line was depressed from 600 to 1000 meters lower than the present elevation due to fall of temperatures by 5 to 8ºC. At present total glaciated area on the earth is about 14.9 million sq. km. Out of this 2.5 million sq km is located in Arctic and 1.7 million sq km in the Greenland ice sheet (Flint, 1971). The remaining 0.7 million sq km area is distributed in the other parts of the World. Himalaya has one of the largest concentrations of glaciers outside the Polar Regions and some estimates suggest that the number could be as high as five thousand (Kulkarni and Bahuguna, 2001).

In the Himalaya, glaciers cover approximately 33000 sq km area, and this is one of the largest concentrations of glacier-stored water outside the Polar Regions. Melt water from these glaciers forms an important source into run-off of North Indian Rivers during critical summer months. This makes these rivers perennial and has helped to sustain and flourish the Indian civilization along the banks of Ganga and Indus. This supply is available during dry periods and naturally regulates the flow of large rivers thus compensating extremes of precipitation. Glacial activity also generates sediments. However there have been several evidences in recent geological history about the glacier mass fluctuations resulting in the stream runoff originating from them. Stream runoff is an important component in planning of water resources and micro and mini hydroelectric projects. Glacier mass fluctuations are also indicators of global climatic changes. In the context of the Himalayan glaciers, which are source of many giant north Indian rivers, systematic monitoring of Himalayan glaciers is of paramount importance in view of their large number and area covered.

Global warming has already caused a significant glacier ice loss since the Little Ice Age (AD 1550-1850) (Denton and Hughes, 1981) resulting in both glacier retreat and thinning (loss of ice volume). Many glaciers in the Himalayan mountain chain are reported to be gradually retreating (Mayeswki and Jeschke, 1979; Li *et al.,* 1998; Kulkarni and Bahuguna, 2002; Raina, 2004; Kulkarni and Alex, 2003; Kulkarni *et al.,* 2005; Kulkarni *et al.,* 2006). Catastrophic natural processes triggered by these glacier changes were responsible for considerable death and destruction throughout the mountains. These processes included ice avalanches, landslides and debris flows, outbursts from moraine-dammed lakes and also outbursts from glacier dammed lakes. Glacier avalanches have occurred where glaciers have retreated up steep rock slopes. Sources of debris flows are frequently moraine complexes exposed during glacier retreat, which may be ice-cored. Outbursts from moraine dammed lakes result from the catastrophic breaching of the moraine dam - a process that is commonly initiated by glacier avalanches - generated waves that overtop the moraine. Himalayan and Trans-

Himalayan glaciers are in general state of retreat since 1850 AD. Most of the Himalayan glaciers are covered by debris, which slows down their melting.

3.1 The Present Scenario:

It is estimated that the Himalayan glaciers provide around $8.6X10^6$ m^3 of water annually. The three great rivers of India-the Indus, the Ganges, and the Brahamputra collectively provide close to 50% ($320Km^3$) of the total country's utilizable surface water resources ($690Km^3$). Since the mid-1970s the average air temperature measured at 49 stations of the Himalayan region raised by 1° C with high elevation sites warming the most (Hasnain2000). This is twice as fast as the 0.6° average warming for the mid –latitudinal northern hemisphere over the same time period (IPCC 2001b), and illustrates the high sensitivity of mountain regions to climate change (Oerlemanns et. al., 2000).

Monitoring the snout of glaciers using in-situ and remote sensing methods has received the bulk of attention. More than 50 glaciers have been monitored over different time periods. In consonance with the global trend, the majority of glaciers in the Indian Himalaya have been retreating since the recording began around the middle of the nineteenth century (Raina 2009). Karakoram Himalaya is an exception to this trend (Hewitt, 2005): Fowler and Archer, 2006). There are temporal and spatial variations in the rates of retreat, the rates varying from < 5m/year to about 50m/year (Raina and Srivastava, 2008). The retreat was generally around 5-10m/year till up to late 1950s: the rate of retreat increased during mid-seventies, which continued up to mid-nineties, touching a value of 25-30 m/year in some glaciers. It is contended by some that there is a general slowing down in the rate of retreat in the late nineties and in the decade of 2000(Raina, 2009: Bali et al., 2010). But there is no consensus (Naithani et al, 2001, Bhambri et al, 2011a).

Based on the various studies carried out, it has been found that Himalayan glaciers are in a state of general retreat since 1850 (Mayewski & Jeschke 1979). The Khumbu glacier, a popular climbing route to the summit of Mt. Everest, has retreated over 5 km from where Sir Edmund Hillary and Tenzing Norgay set out to conquer the world's highest mountain in 1953. Gangotri glacier which is one of the best documented glaciers in the Indian Himalaya as far as its snout position demarcation is concerned. The snout of the glacier "Gaumukh" is about 18KM from the holy shrine of Gangotri. The snout of the glacier has been under the state of continuous recession since 1935 (Auden, 1937). GSI has monitored the snout of the glacier since 1935 till 1996. The data reveal that the glacier has retreated by 1147m, with an average rate of 19m/year between 1935 and 1996. The total area vacated by the glacier during 1935 to 1996 is estimated to be 5, 78,100 m^2 or 0.58Km^2 (Srivastava 2004).

Bara Sigri glacier a north westerly facing glacier in the Chandra valley with surface area of about 137 Sq. Km. and 27 Km length is one of the largest glaciers in Himachal Himalaya. Snout of the glacier, at present, is far away from the Chandra River, but in times past, as is revealed by the glacier landforms and the trim line, it must have extended right up to the present river valley. This glacier , as per the available records, had in the year 1793 AD, extended up to the river, and, in fact had blocked the course of the Chandra river (Egerton ,1864).Average retreat and the area vacated by the glacier along snout front, over the last nine decades-1906 to 1995 is 4.33 sq.km. During 1906-1956, the area vacated was the highest till data (3.44sq.km) and during the period 1963-1977 it was at the minimum (0.24sq.km.) and could be attributed to the positive trend in the snow cover variation in the Himalayas that resulted in the positive mass balance recorded by some of the glaciers in the adjacent areas of Himachal Pradesh. The glacier recession once again accelerated during 1977-1995 and likewise could be attributed to the conditions that led to the negative trends in the snow cover variation and the mass balance recorded in adjacent Chhota Sigri glacier by the DST teams and in adjacent parts of Himachal Pradesh by the GSI.

Zemu glacier is the largest glacier in the eastern Himalayas with a total surface area of about 42 $km^2$and a linear length of about 20 km. The glacier, as compared to the snout position, as fixed by La Touche, revealed a linear shrinkage of about 414m between 1909 and 1965 (Raina & Bhattacharya 1973). This glacier was under continuous observation of the GSI teams from 1977 to 1986 and is reported to have vacated an area of about 52,443m^2 along the snout front from 1965 onwards. There have, however, been periods -1979-80 and 1984-85, when the glacier snout has been reported to have shown slight advance.

At present the rivers have shown 3-4% surplus water due to a 10% increase in the melting of the glaciers of the western Himalayas, and a 30% increase in the eastern Himalayan glaciers. But, after 40 years, most of these glaciers will be wiped out and then South Asia will have water problems. In March 2002, UK's Department of International Development funded a project called Sagarmatha (Snow and Glacier Aspects of Water Resources Management in the Himalayas) to assess the impact of deglaciation on the seasonal and long term water resources in snow-fed Himalayan rivers. This study was vital for policy-makers and especially those working on interlinking of rivers, as the flows available in rivers are likely to change dramatically over the decades depending on the region. The study which reveals some major facts about the melting mountain majesties and warming glaciers is an eye-opener.

In Upper Indus, the study sites show initial increases of 14% and 90% in mean flows over the next few decades which will be followed by decreasing flows by 30% and 90% of baseline in the subsequent decades in a 100-year scenario. For Ganges, the response of the river near the glacier in Uttarkashi is different from downstream Allahabad. At Uttarkashi, flows peak at between 20% and 33% baseline within the first few decades and then recede to 50% of baseline after 50 years.

Near the source of the Brahmaputra, there is a general decrease in decadal mean flows for all temperature scenarios as glaciers are few in the area and flows recede as the permanent snow cover reduces with increasing temperature. The catchments in the eastern Himalayas which benefit from high precipitation of the summer monsoon, are more vulnerable to impacts of deglaciation than those in the west where the monsoon is weaker.

In short, the deglaciation in the Himalayas is influenced by various factors, climatic, regional etc. However, the main underlying factor is ever increasing warming on the mountains, chiefly because of excess emission of greenhouse gases and Asian brown cloud. The ongoing ice melting is only the tip of the iceberg that will hit us in the near future. As the Indian economy depends to a great extent on agriculture- a highly climate sensitive sector and the knowledge about potential climate change impacts on agriculture has special significance. Agriculture productivity is sensitive to two broad classes (a) direct effects from change in temperature and (b) indirect effects through changes in soils, distribution and frequency of infestation by pests, insects, diseases or weeds etc. Several studies predict that rice and wheat yield would decline considerably with climatic changes in India. As the mountain areas accounts only 21% of the total geographical area of India, where about 60-70% population largely depends on agriculture, horticulture and animal husbandry related activities for their livelihood. If the present trend of climate change continues, this will have an adverse effect on their lifestyles.

4. 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. Geologically the Himalaya is considered to be the youngest mountain chains in the world and is still in the building phase. Natural hazards are matter of immediate concern to the State of Himachal Pradesh, 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. The incidence of cloudbursts in the last few years has baffled both the meteorologist and the common man equally. Notwithstanding, the continuous efforts made by the Government to cope with natural hazards through relief and rehabilitation measures, landslides and snow avalanches continue to inflict widespread harm and damage to human life as well as property. The roads that are the State's lifeline are repeatedly damaged, blocked or washed away by one or other acts of nature. In the circumstances, the Government has to divert the already scarce resources of the state for relief and rehabilitation measures as opposed to long term development.

In the Himalayas, during the retreating phase a large number of lakes are being formed either at the snout of the glacier as a result of damming of the morainic material known as moraine dammed lakes or supra glacial lakes formed in the glacier surface area. A glacial lake is defined as a water mass existing in a sufficient amount and extending with a free surface in, under, beside and/or in front of a glacier and originated by glacier activities and/or retreating processes of a glacier. Most of these lakes are formed by the accumulation of vast amounts of water from the melting of snow and by blockade of end moraines located in the down valleys close to the glaciers. In addition, the lakes can also be formed due to landslides causing artificial blocks in the waterways. The sudden break of a moraine/block may generate the discharge of large volumes of water and debris from these glacial lakes and water bodies causing flash floods namely GLOF. A Glacial Lake Outburst Flood (GLOF), also known as a jökulhlaup in Icelandic (A jökulhlaup is technically a sudden and often catastrophic flood that occurs during a volcanic eruption, but is also used to describe other sorts of glacial flooding), can occur when a lake contained by a glacier or a terminal moraine dam fails. This can happen due to erosion, a buildup of water pressure, an avalanche of rock or heavy snow, an earthquake, or if a large enough portion of a glacier breaks off and massively displaces the waters in a glacial lake at its base. Many countries has a series of monitoring efforts to help prevent death and destruction that are likely to experience due to these events. The importance of this situation has magnified over the past century due to increased population, and the increasing number of glacial lakes that have developed due to glacier retreat. There are a number of GLOF events that have been reported worldwide. There are number of such events that have happened in Nepal Himalayas but no such event has been reported so far from Indian Himalayas. On the basis of earlier studies carried out in Himachal Himalayas in Satluj basin, there are about 38 such lakes in entire Satluj basin out of which 14 falls in Himachal part. Similarly 50 moraine dammed lakes in Chenab basin and 5 supra glacial lakes have been mapped using remote sensing. The state of Himachal Pradesh invariably experience flash floods, the cause of which is unknown. In the year 2000, the Satluj valley experiences the heaviest floods causing loss of more than 800 crores. It is still a matter of investigation weather the floods were caused by cloud bursting or due to Glacier Lake Outburst Floods (GLOF) phenomena. The formation of landslide dammed lakes in high altitude zones such as Parachoo in the upper catchment of Spiti basin in Tibet caused tremendous threat to the life and property located in the downstream areas. It is therefore necessary that a constant and repeated monitoring of the upper catchment areas having international dimensions required to be carried out on a regular basis.

5. Distribution of Glacial lakes in Himachal Himalaya:

Based on the analysis carried out for the year 2018 in all the basins in Himachal Pradesh using LISS III satellite data, the distribution of total number of lakes is as per Table 5.1. The inventory thus generated is further divided into the number of lakes based on their aerial range with area more than 10 ha, 5-10 ha and the lakes with area less than 5 hectare. Thus the Satluj basin as a whole includes a total of 769 lakes out of which 663 are of smaller dimensions i.e. with area less than 5 ha, 57 lakes with aerial range between 5-10 ha and 49 lakes with area more than 10ha indicating an overall increase of 127 lakes with that of total number lakes as mapped in 2017 in Satluj basin indicating an overall increase of about 16% in the Satluj basin (Fig 5.1).Likewise in Chenab basin(Chandra, Bhaga, Miyar) a total of 254 lakes could be delineated in Chenab basin comprising (64 lakes in Chandra sub basin, 84 lakes in Bhaga sub basin and 106 in the Miyar sub basin) respectively. Thus the Chenab basin as a whole has 254 lakes (2018) in comparison to 220 (2017), 133 lakes (2016), 192(2015) number of the total lakes in the basin which is about four times more than the lakes which were identified earlier using 2001 (55) satellite data (Randhawa et.al. 2005) and about 15% increase w.r.t 2017 and about 32% with that of 2015. When these 254 lakes seen based on their aerial range, it has been found that maximum lakes (240) falls in the category where the area is less than 5 hectare, 10 lakes where area is between 5-10 hectare and only 04 where area is more than 10 hectare indicating a reduction of about 20% in case of bigger lakes i.e. lakes with area more than 10ha and about 25% increase in case of the lakes with area between 5-10ha w.r.t 2017(Fig 5.2) and an increase of about 15% in case of the lakes with area less than 5 ha. In Beas basin (Upper Beas, Jiwa, Parbati), total number of lakes 65 comprising (23lakes in Upper Beas(8% less than 2017), 15 lakes in Jiwa (53% less than 2017) and 27 lakes(about 38% less than 2017) in Parvati sub basins) have been delineated during the year 2018 indicating a reduction of about 35% less lakes mapped in 2018 in comparison to 2017 which is mainly due to the fact that the cloud cover in case of Jiwa basin is comparatively on higher side as a result of which the area is not fully exposed. Further analysis of these 65 lakes reveals that 58 lakes are smaller one having area less than 5 hectare, 04 lakes with aerial range between 5-10 hectare and 03 lakes which are having area more than 10 hectare in 2018 indicating an overall reduction of about 36% in case of the lakes with less 5ha and about 25% reduction in case of the bigger lakes with area more than 10ha in comparisons to 2017 , where as the lakes with area 5-10 ha does not show any change(Fig 5.3). Likewise in Ravi basin, a total of 66 lakes have been mapped in 2018 in comparison to 54 lakes that of 2017. When seen based on aerial distribution, it is found that 03 lakes are having area more than 10 hectare, 02 lakes are having area between 5-10 hectare and 61 lakes are such which have area less than 5 hectare (Fig 5.4).The comparative analysis of total number of lakes formed in each basin between 2018 & 2015 suggest that in Beas basin, a decrease of about 36% (38 lakes), in Chenab increase by about 32% (62 lakes), in Ravi by about 94% (32lakes) and in Satluj basin by 97% (379 lakes) could be seen(Fig 5.5).

Table 5.1: Distribution of lakes in different sub basins in Himachal Pradesh based on LISS III satellite data analysis for 2018.

	Name of the basin	No. of lakes with area >10ha	No. of lakes with area between 5-10 ha	No. of lakes with area <5ha	Total No. of lakes
1	**Chenab**	**05(2017) 04(2018)**	**08(2017) 10(2018)**	**207(2017) 240(2018)**	**220(2017) 254(2018)**
	Bhaga	02(2017) 01(2018)	04(2017) 04(2018)	50(2017) 79(2018)	56(2017) 84(2018)
	Chandra	02(2017) 02(2018)	01(2017) 03(2018)	43(2017) 59(2018)	46(2017) 64(2018)
	Miyar	01(2017) 01(2018)	03(2017) 03(2018)	114(2017) 102(2018)	118(2017) 106(2018)
2	**Beas**	**04(2017) 03(2018)**	**05(2017) 04(2018)**	**92 (2017) 58(2018)**	**101(2017) 65(2018)**
	Jiwa	0(2017) 0(2018)	02(2017)0(2018)	30(2017) 15(2018)	32(2017) 15(2018)

	Parvati	03(2017) 03(2018)	02(2017) 01(2018)	39(2017) 23(2018)	44(2017) 27(2018)
	Beas	01(2017) 0(2018)	01(2017) 03(2018)	23(2017) 20(2018)	25(2017) 23(2018)
3	**Ravi**	**03(2017) 03(2018)**	**01(2017) 02(2018)**	**50(2017) 61(2018)**	**54(2017) 66(2018)**
4	**Satluj**	**52(2017) 49(2018)**	**59(2017) 57(2018)**	**531(2017) 663(2018)**	**642(2017) 769(2018)**

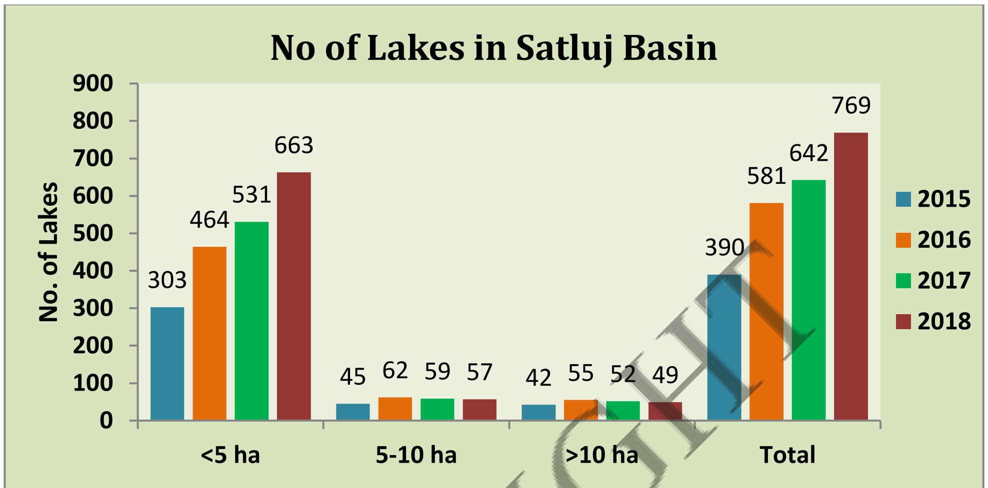


Fig.5.1 Distribution of lakes in Satluj basin

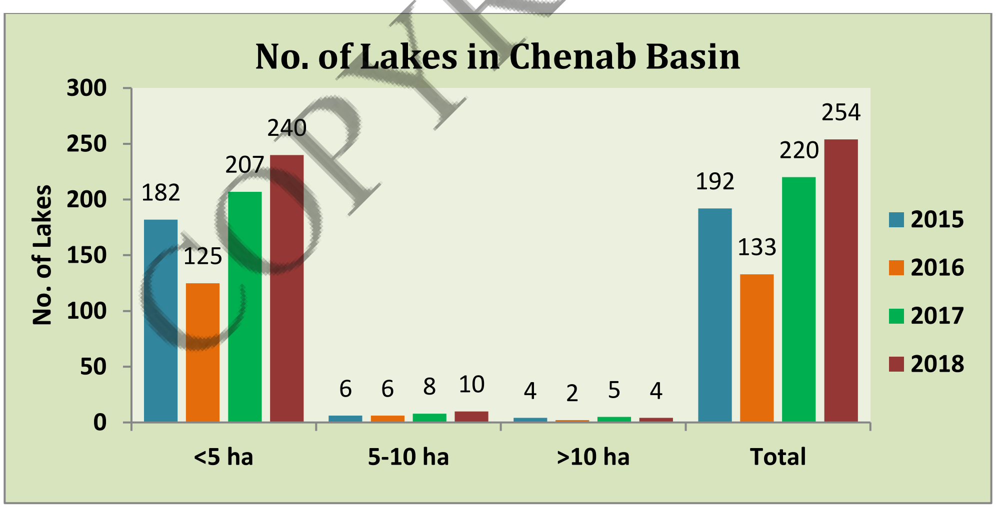


Fig.5.2 Distribution of lakes in Chenab basin

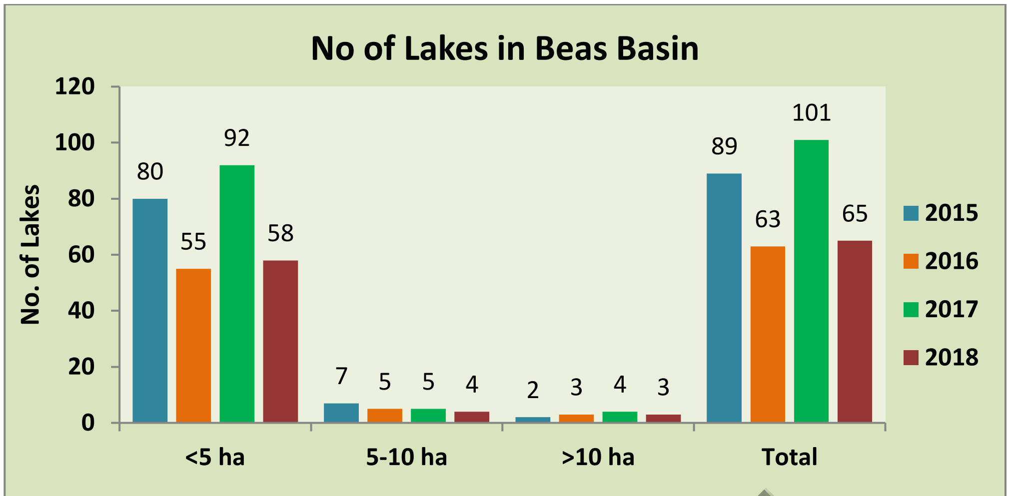


Fig.5.3 Distribution of lakes in Beas basin

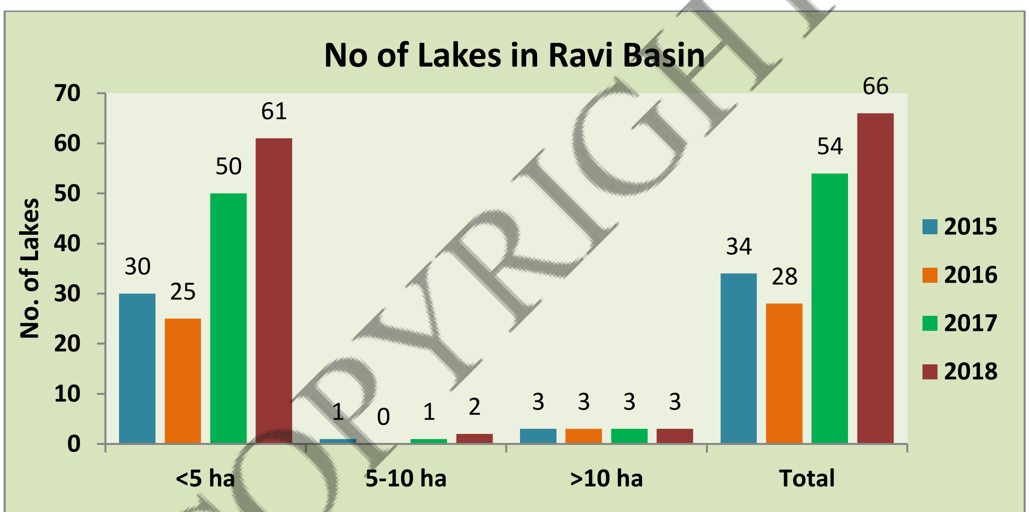


Fig.5.4 Distribution of lakes in Ravi basin

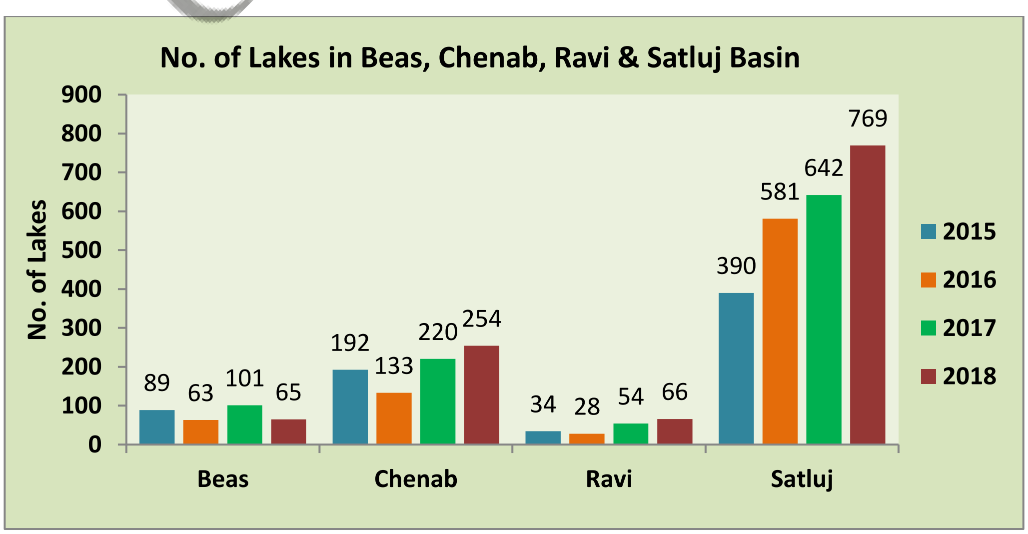


Fig.5.5 Distribution of lakes in Chenab, Beas, Ravi & Satluj basin

5.1 Distribution of lakes with area more than 10ha

Based on the satellite data interpretation for the year 2018, the study area has been studied to understand the temporal variation of all such lakes with area more than 10ha. In Satluj basin the total number of such lakes has increased from 40(2013) to 42(2015) to 55(2016) to 52(2017) to 49 (2018) respectively. Likewise in other basins, i.e. in Chenab, the number of lakes varies from 3(2013) to 4(2015) to 2(2016), 5(2017) and 4(2018), in Beas basin the number varies from 2(2013) to 2(2015) to 3(2016)to 4(2017)and 3(2018)and the Ravi basin, the number of lakes varies from 2(2013) to 3(2015) to 3(2016) to 3(2017) and 3(2018) respectively (Table 5.1.1 & Fig 5.1.1). The lakes with HWL are mainly the high altitude wetlands in high altitude regions.

Table 5.1.1: Distribution of lakes with area more than 10ha in different sub basins in Himachal Pradesh based on LISS III satellite data analysis.

Sr. No.	Lake Id.	2015	2016	2017	2018
Bhaga					
1.	6	----	6.21	10.23	9.92
2.	11	10.39	7.92	9.84	11.21
3.	53	11.66	----	15.04	----
Chandra					
4.	1	90.51	90.18	115.51	95.03
5.	3	151.42	131.58	179.64	160.99
Miyar					
6.	209	----	----	16.08	15.06
Jiwa					
7.	----	----	----	----	----
Parvati					
8.	21	12.68	13.81	12.88	13.14
9.	26	13.52	11.28	15.47	13.82
10.	50	----	10.01	14.58	13.30
Upper Beas					
11.	6	----	7.54	10.86	9.82
Ravi					
12.	10	16	12.05	14.42	14.63
13.	16	30.97	27.28	34.50	11.35
14.	31	11.72	11.2	12.16	12.38
Satluj					
15.	49	23	----	----	38
16.	67	12	13.04	8.06	8
17.	86	9	10.88	10.11	10.06
18.	87	9	10.06	9.38	10.5
19.	99	19	18.37	17.12	18.8
20.	101	24	24.65	21.37	22.8
21.	122	7	16.16	15.34	16.5
22.	154	----	----	----	----
23.	580	----	----	----	----

24.	173	3	9.32	7.65	----
25.	177	3	----	----	----
26.	614	----	----	----	----
27.	615	----	----	----	----
28.	184	----	19.51	19.15	----
29.	202	10	12.37	10.81	----
30.	209	33	36.38	----	----
31.	645	----	----	----	----
32.	656	----	----	----	----
33.	96	----	----	----	----
34.	669	----	----	----	----
35.	680	----	----	----	----
36.	681	----	----	----	----
37.	683	----	----	----	----
38.	684	----	----	----	----
39.	98	----	----	----	----
40.	109	----	----	----	----
41.	112	----	----	----	----
42.	113	----	----	----	----
43.	114	----	----	----	----
44.	134	----	----	----	----
45.	142	343	----	----	----
46.	145(HWL)	41584	41646.22	41498.50	41233.9
47.	148	59	----	----	----
48.	179	25	26.26	25.07	25.6
49.	184	27	19.51	19.15	25.5
50.	210(HWL)	57	64.32	59.43	59.17
51.	237	----	----	----	----
52.	607	----	----	----	----
53.	608	----	----	----	----
54.	731	39	40.52	31.60	33.98
55.	1001	12	14.44	11.02	13.9
56.	63	10	12.38	----	----
57.	97	11	8.85	8.78	----
58.	133	12	----	----	----
59.	811	10	11.50	9.71	10.3
60.	894	10	----	9.90	9.7
61.	1031	21	----	62. 1.65	----
63.	1059	16	19.92	----	----
64.	1060	52	79.08	----	----
65.	1063	45	39.79	----	----
66.	138(HWL)	26065	26538.79	25891.56	25634.8
67.	1073	32	----	----	----
68.	1078	172	----	----	----
69.	159	14	----	----	----
70.	178	205	190.71	204.05	206.39
71.	181	13	13.72	18.07	19.28
72.	1085	27	27.52	24.47	----
73.	1093(HWL)	5515	5676.31	5787.38	5854.36
74.	1094	16	13.83	12.82	12.62
75.	1099	11	11.77	----	----
76.	1128	23	24.45	23.95	25.14
77.	1133	17	15.23	16.09	15.86

78.	1150	54	----	----	----
79.	1153	63	64.41	66.74	69.2
80.	1155	16	16.38	16.14	17.47
81.	1156(HWL)	11	11.85	11.56	11.69
82.	1164	15	15.12	14.94	14.86
83.	1170	15	----	----	----
84.	85	----	25.70	27.38	33.51
85.	635	----	13.32	15.08	15.12
86.	1336	----	18.38	----	----
87.	1344	----	15.26	12.99	14.52
88.	1348	----	24.40	20.62	----
89.	1092	----	14.69	13.63	----
90.	1363	----	28.25	17.77	----
91.	1375	----	47.91	43.26	----
92.	1445	----	10.18	8.22	8.84
93.	1453	----	11.03	9.82	10.27
94.	1510	----	54.52	54.37	54.38
95.	1512	----	23.53	23.62	24.23
96.	1518	----	13.78	12.53	14
97.	1527	----	11.17	10.47	11.43
98.	1528	----	10.04	8.77	10.23
99.	1548	----	17.95	14.62	19.91
100.	1557	----	69.88	96.36	80.87
101.	1349	----	352.60	292.13	322.95
100.	1095(HWL)	----	17.26	14.31	15.58
101.	1565	----	16.38	18.11	17.36
102.	1566(HWL)	----	22.81	24.35	18.76
103.	5006	----	----	----	11.6
104.	1687RS	----	----	----	17
105.	1654	----	----	----	18.5
106.	208	----	----	----	35
107.	1012(HWL)	----	----	----	45.3
108.	1782(HWL)	----	----	----	29.1
109.	185	----	----	----	10.8
110.	1774RS	----	----	----	11.69
111.	1771RS	----	----	----	12.22

(HWL-High Altitude Wetlands)

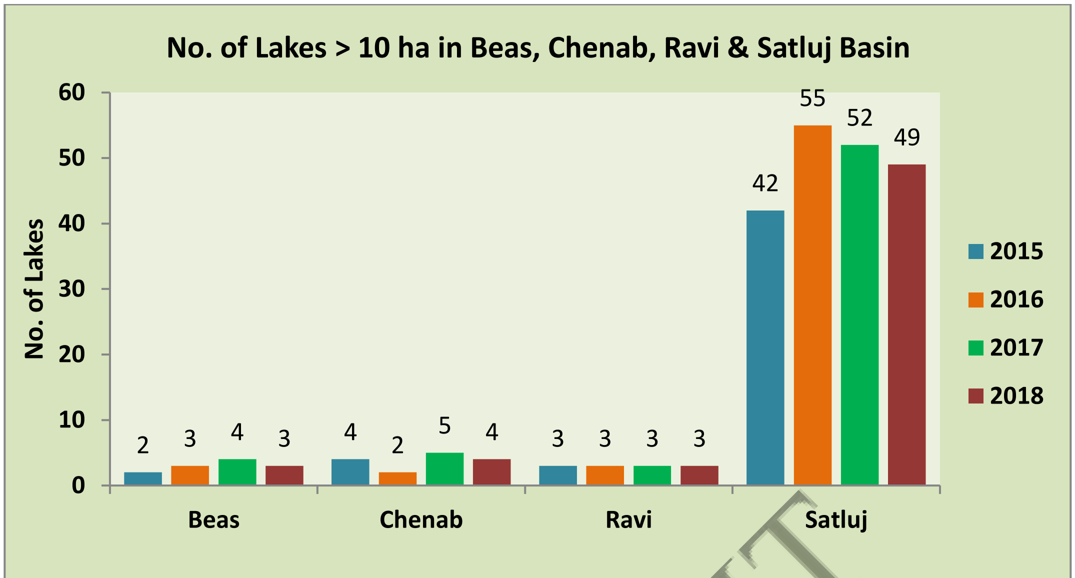


Fig.5.1.1 Distribution of lakes with area>10 Ha in Chenab, Beas, Ravi & Satluj basin in 2015, 2016, 2017& 2018

6. Objectives of the Study

The main objectives of the study is to have an updated inventory for the monitoring of all the moraine dammed glacier lakes/ water bodies in the upper catchments of the Satluj, Beas, Ravi & Chenab basins in Himachal Pradesh using high resolution satellite data of LISS III for the year 2019.

7. Study area and data used

The study area comprises of all the basins/sub basins located within the Satluj, Beas, Ravi and Chenab River basins in Himachal Pradesh. The Satluj basin has been studied in detail right from its origin Mansarovar Lake in Tibetan Region using AWIFS and LISS III satellite for monthly temporal variation, whereas the other basins viz. Chenab, Ravi, Beas have been studied for their area of interest in Himachal Himalaya only. The river Sutlej is one of the main tributaries of Indus and has its origin near Manasarovar and Rakas lakes in Tibetan plateau at an elevation of about 4,500 m (approx.). The entire Satluj basin has been divided in three sub basins viz. Spiti as sub basin number 1, Upper Tibet as 3 and Lower Satluj sub basin number 2.Likewise the other basins comprises of Ravi, Beas (Jiwa and Parvati), Chenab (Chandra, Bhaga and Miyar) which have been studied in detail for mapping of the moraine dammed lakes (GLOFs) and are as per Fig.7.1

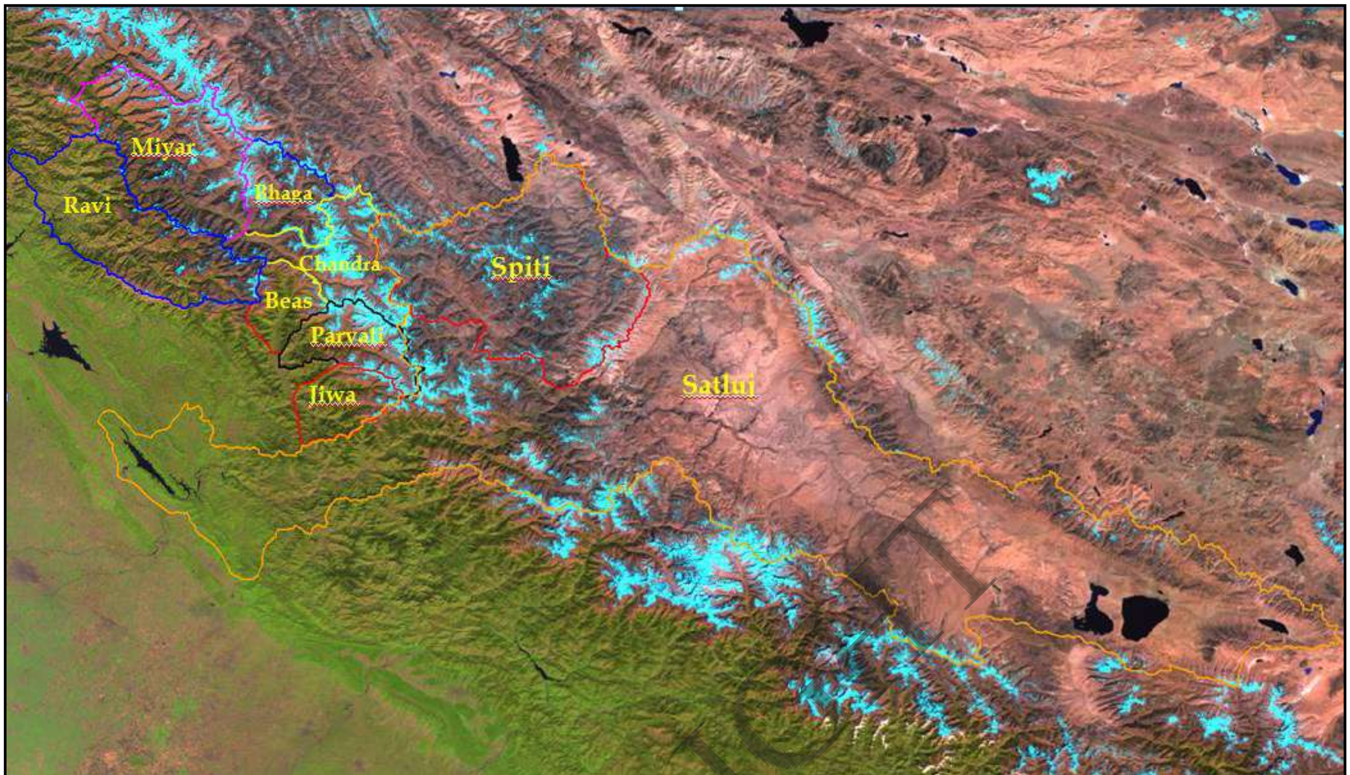


Fig. 7.1: Different sub basins in Himachal Pradesh

8. Methodology

The Landsat satellite data having spatial resolution of 8mts and LISS III satellite data having spatial resolution of 23.5mts 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. Satluj basin has been studied in detail right from its origin from Mansarovar Lake in the Tibetan Himalayas. The cloud free data during the months of August-September/October 2019 has been used for the mapping purpose (Table 8.1). The geometric rectification was done using polynomial transformation of third order with resulting Root Mean Square (RMS) error less than one pixel. The basin boundaries were superimposed on the satellite image and the lakes which are visible and clearly demark able were delineated using ERDAS software. The lake boundaries were digitized using ERDAS Imagine vector module tools. The digitized polygons have been cleaned for open ends and built into a polygon layer. All the polygons have been assigned polygon ID's. Water spread area is considered to represent the boundary of lake. The flowchart explaining the methodology is given in Fig. 8.1

Table 8.1: Satellite data used for investigation during 2019

Sr. No.	Date of Pass	Path –Row	Satellite Sensor
1	03 Sep-19	94-47	Resourcesat2/LISS III
2	10-Sep-19	94-47	Resourcesat2/LISS III
3	21-Oct-19	94-47	Resourcesat2/LISS III
4	10-Sep-19	94-48	Resourcesat2/LISS III
5	21-Oct 19	94-48	Resourcesat2/LISS III
6	08-Sep-19	95-47	Resourcesat2/LISS III
7	15-Aug-19	95-48	Resourcesat2/LISS III
8	15-Sep-19	95-48	Resourcesat2/LISS III
9	20-Aug-19	96-48	Resourcesat2/LISS III
10	14-Oct-19	96-48	Resourcesat2/LISS III
11	03-July-19	96-49	Resourcesat2/LISS III
12	20-Aug-19	96-49	Resourcesat2/LISS III
13	12-Oct-19	97-48	Resourcesat2/LISS III
14	12-Oct-19	97-49	Resourcesat2/LISS III
15	06-Sep-19	98-48	Resourcesat2/LISS III
16	06-Sep-19	98-49	Resourcesat2/LISS III
17	22-Oct-19	99-49	Resourcesat2/LISS III
18	10-Oct 19	100-49	Resourcesat2/LISS III
19	10-Sep-19	147-37	Landsat 8

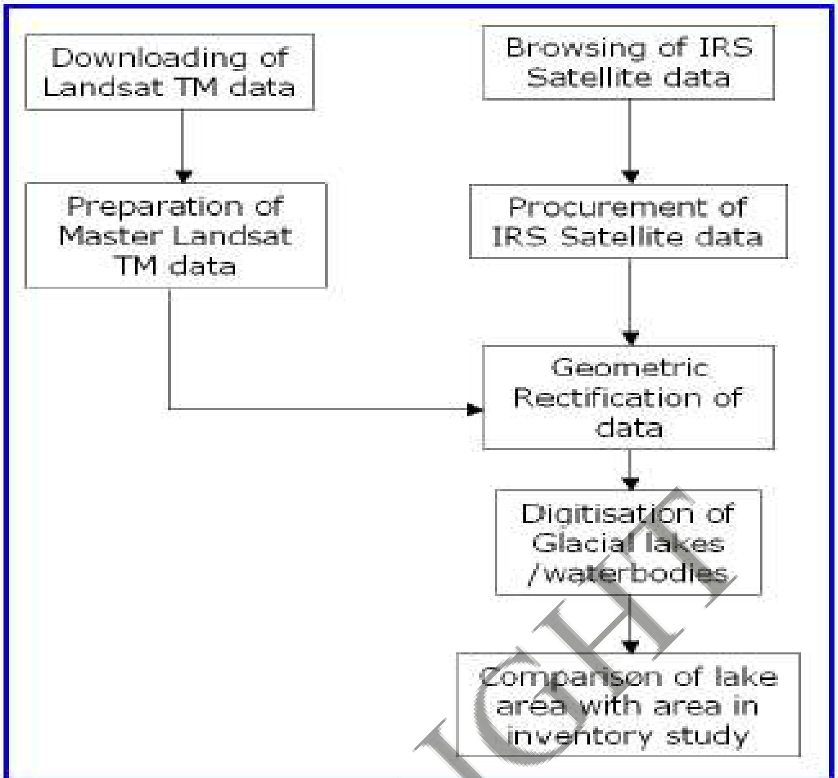


Fig 8.1: Flow Chart Methodology

9. Monitoring of Parechhu Lake during 2019

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.

9.1 Observations derived from the satellite data analysis:

Parechhu Lake is a small geomorphic depression along the Parechhu River which joins the Spiti River on its left bank near Sumdo in Spiti Sub Division of District Lahaul &Spiti. The fragile geology of the area and the Sumdo Kaurik fault passing nearby causes activation of the landslides which results in chocking of the river course in the downstream, this causes accumulation of the water in the depression. During the year 2019, the lake was regularly monitored and its findings about the water spread were reported to the SJVNL as well as to the Govt.

Fig 9.1 Satelllite View of Parecchu Lake through IRS RS2 LISSIII 96-48, 03 July 2019

Observations:

On analyzing the IRS RS2 LISS III Satellite data for 03 July 2019 the following observations were made.

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

- Based on the satellite data interpretation, there does not seem to be any threat from the Parechhu Lake for the downstream areas. However continuous monitoring would be required as the ablation is still continuing for another two months and thus requires monitoring no other LISS-III satellite data could be obtained during the year 2019 as a result of which Parcehhu lake was not monitored after July 2019.

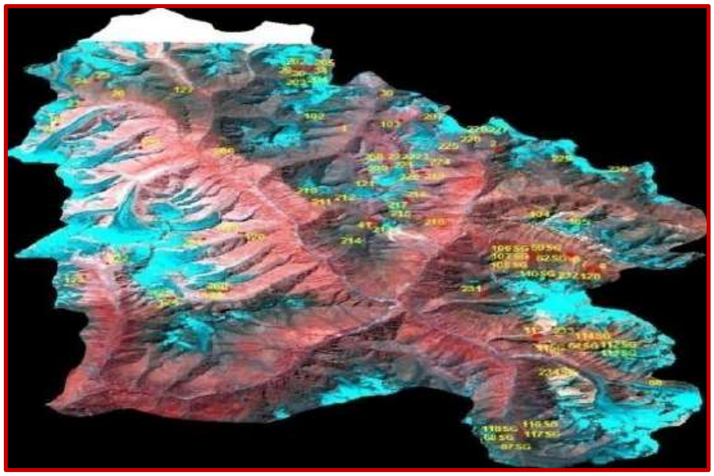
10. LISS III & Landsat 8 Based inventory of moraine dammed glacial lakes in Chenab (Chandra, Bhaga & Miyar Sub basins) Beas (Beas, Jiwa and Parvati),Ravi & Satluj Basins in Himachal Pradesh.

10.1 Inventory of lakes in Chenab Basin

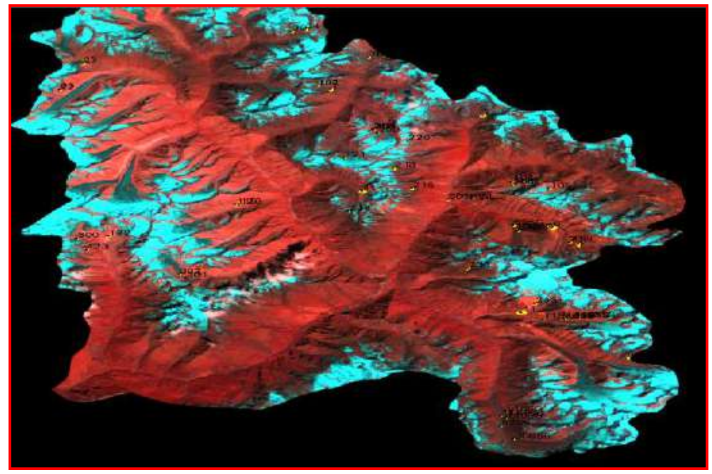
Chenab basin is one of the major river basins which originate from Himachal Himalaya near Baralacha Pass. Two river viz. Chandra and Bhaga originates from this place and flows in opposite direction before they confluence each other at a place known as Tandi near Keylong. Besides this, another major sub basin i.e. Miyar Sub basin has been studied in detail for having an updated inventory of moraine dammed lakes in the catchment.

10.1.1 Inventory of lakes in Bhaga Sub Basin

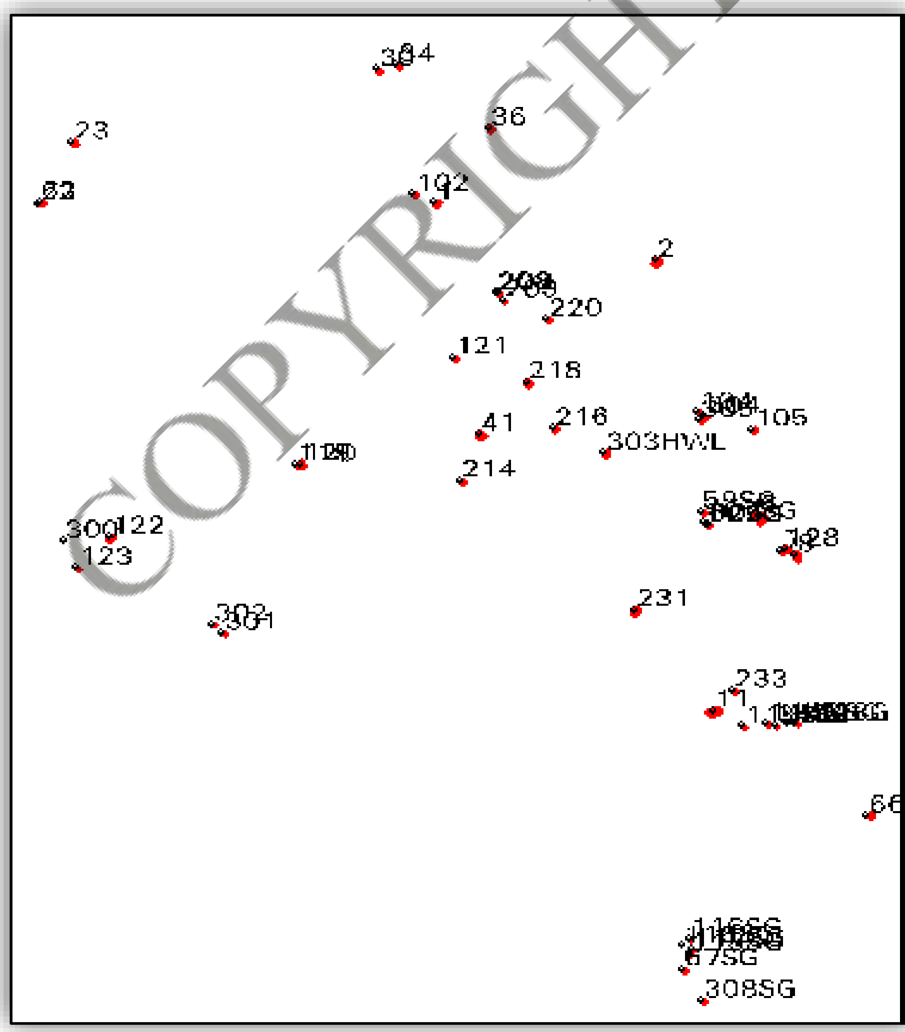
Based on the satellite data analysis from IRS LISS-III 10 September 2019 in Bhaga basin, which is a sub basin of the Chenab, it has become possible to delineate a total of 51 in 2019 (Table 10.1.1.1. & Fig.10.1.1.1) in comparison to 84 lakes mapped in 2018 and 21 in 2016 and 56 in 2017(Fig.10.1.1.3). Further out of these 51 lakes mapped in 2019, majority of the lakes i.e. 46 lakes are small one with area less than 5ha, 4 lakes are within the areal range of 5-10 ha and 02 lakes are having area more than 10ha(Fig 10.1.1.2). The lakes with ids 6 &11 are having area more than 10 ha in 2019 and their number has increased with respect to 2018 by virtue of the fact that the lake with id 6, which showed a reduction in its area 2018 in comparison to 2017 has now increased in 2019 i.e the area has increased from 9.92ha (2018) to 10.94ha(2019) and thus has been counted into the lakes category having area between >10ha., Further out of 51 lakes mapped, 43 lakes could be seen temporally and found that out of 43 lakes mapped 16 lakes are showing an increase in their spatial extent and 27 lakes showing reduction in their spatial extent in 2019 when compared with that of 2018 data and the lakes which could not be compared forms the base line data for their monitoring during the next ablation season 2020.



IRS-R2-L3-95-48-27-Aug-2018



IRS-R2-L3-95-48- 10 September 2019



Lake Inventory in Bhaga Basin based on IRS-R2-L3-95-48-10-Sep-2019
Fig.10.1.1.1

Table 10.1.1.1: Aerial extent of lakes in Bhaga Sub Basin

Sr. No.	Name of the Basin	Name of Sub-Basin	Lake id Number	Longitude	Latitude	Area (hectare in 2019)	Area (hectare in 2018)	Change in Area w.r.t. 2018
1	Chenab	Bhaga	1	77.1734381	32.8676592	3.04	3.58	-0.54
2	Chenab	Bhaga	2	77.2802048	32.8407203	6.47	5.84	+0.63
3	**Chenab**	**Bhaga**	**6**	**77.329889**	**32.719406**	**10.94**	**9.92**	**+1.02**
4	Chenab	Bhaga	7	77.3410855	32.7033073	0.80	1.17	-0.37
5	Chenab	Bhaga	8	77.3473933	32.7005791	5.30	5.47	-0.17
6	**Chenab**	**Bhaga**	**11**	**77.305895**	**32.627195**	**10.40**	**11.21**	**-0.81**
7	Chenab	Bhaga	22	76.9821489	32.8673090	0.54	0.62	-0.08
8	Chenab	Bhaga	23	76.9986103	32.8960560	2.08	2.26	-0.18
9	Chenab	Bhaga	30	77.1459159	32.9309155	2.00	2.29	-0.29
10	Chenab	Bhaga	34	77.1555991	32.9327311	1.73	2.50	-0.77
11	Chenab	Bhaga	36	77.2000277	32.9032892	2.10	1.91	+0.19
12	Chenab	Bhaga	41	77.1950523	32.7583121	6.37	6.85	-0.48
13	Chenab	Bhaga	63	76.9827844	32.8681563	0.40	0.31	+0.09
14	Chenab	Bhaga	66	77.3821191	32.5777717	2.09	2.25	-0.16
15	Chenab	Bhaga	102	77.1624154	32.8714300	0.79	1.63	-0.84
16	Chenab	Bhaga	104	77.3004205	32.7691328	0.43	0.41	+0.02
17	Chenab	Bhaga	105	77.3269190	32.7606612	1.08	0.71	+0.37
18	Chenab	Bhaga	119	77.1058292	32.7438304	0.95	0.56	+0.39
19	Chenab	Bhaga	120	77.1086478	32.7438304	0.24	0.30	-0.06
20	Chenab	Bhaga	121	77.1826116	32.7946623	0.61	0.56	+0.05
21	Chenab	Bhaga	122	77.0164731	32.7095532	1.74	0.21	+1.53
22	Chenab	Bhaga	123	77.0010069	32.6946456	0.38	0.31	+0.07
23	Chenab	Bhaga	128	77.3416623	32.7044059	1.55	1.87	-0.32
24	Chenab	Bhaga	208	77.2032165	32.8254725	0.64	0.27	+0.37
25	Chenab	Bhaga	209	77.2062295	32.8216820	0.85	1.19	-0.34
26	Chenab	Bhaga	214	77.1885404	32.7398455	0.50	1.22	-0.72
27	Chenab	Bhaga	216	77.2301390	32.7608392	1.08	1.14	-0.06
28	Chenab	Bhaga	218	77.2176011	32.7826104	3.02	3.60	-0.58
29	Chenab	Bhaga	220	77.2278306	32.8128799	0.77	0.57	+0.20

30	Chenab	Bhaga	231	77.2697041	32.6748078	2.08	2.81	-0.73
31	Chenab	Bhaga	233	77.3167519	32.6367293	0.44	0.56	-0.12
32	Chenab	Bhaga	107SG	77.3028921	32.7167426	0.30	0.21	+0.09
33	Chenab	Bhaga	112SG	77.3471881	32.6209900	0.19	0.31	-0.12
34	Chenab	Bhaga	113SG	77.3429714	32.6209104	0.19	0.21	-0.02
35	Chenab	Bhaga	114SG	77.3334239	32.6209900	0.34	0.35	-0.01
36	Chenab	Bhaga	115G	77.3265021	32.6176484	0.68	0.32	+0.36
37	Chenab	Bhaga	116SG	77.2950835	32.5205182	0.46	1.04	-0.58
38	Chenab	Bhaga	117SG	77.2966446	32.5143377	0.21	0.41	-0.20
39	Chenab	Bhaga	118SG	77.2956235	32.5123889	0.15	0.37	-0.22
40	Chenab	Bhaga	59SG	77.3023523	32.7214583	0.77	0.71	+0.06
41	Chenab	Bhaga	62SG	77.3044038	32.7151116	0.41	0.30	+0.11
42	Chenab	Bhaga	64SG	77.3374816	32.6199557	0.44	0.56	-0.12
43	Chenab	Bhaga	67SG	77.2926637	32.5048696	0.20	0.41	-0.21
44	Chenab	Bhaga	300	76.9941332	32.7114221	0.31	-------	-------
45	Chenab	Bhaga	301	77.0710510	32.6680222	0.18	-------	-------
46	Chenab	Bhaga	302	77.0661123	32.6719943	0.39	-------	-------
47	Chenab	Bhaga	303HWL	77.2555422	32.7532433	1.30	-------	-------
48	Chenab	Bhaga	304	77.3037621	32.7706422	0.29	-------	-------
49	Chenab	Bhaga	305	77.3011820	32.768754	0.50	-------	-------
50	Chenab	Bhaga	306	77.305525	32.7196820	0.29	-------	-------
51	Chenab	Bhaga	308SG	77.3023221	32.4937310	0.38	-------	-------

SG-Supra Glacier

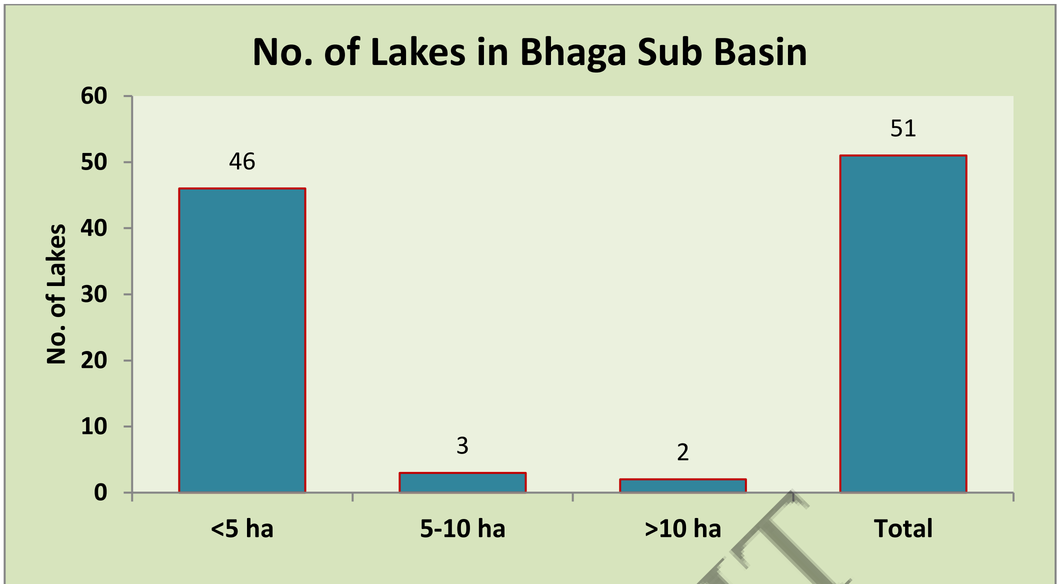


Fig.10.1.1.2 Distribution of lakes in Bhaga sub basin (2019)

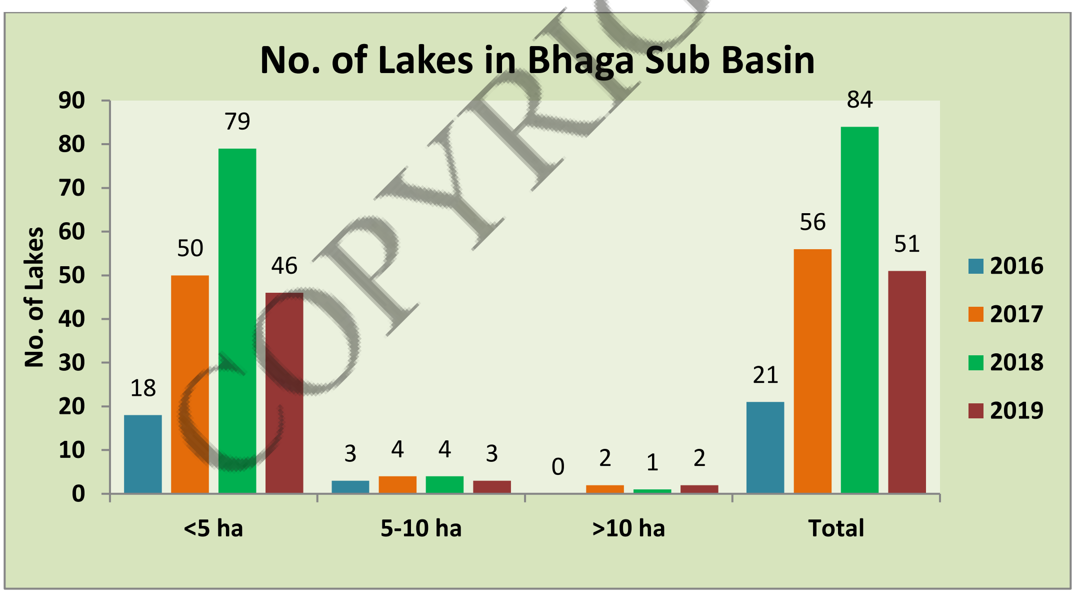


Fig.10.1.1.3 Distribution of lakes in Bhaga sub basin in 2016, 2017, 2018 & 2019

10.1.2 Inventory of lakes in Chandra Sub Basin

From the analysis of satellite data of IRS-RS2-L3 for 08 September 2019 in Chandra basin (Fig.10.1.2.1), a total of 52 lakes could be mapped in comparison to 64 lakes mapped in 2018, 23 in 2016 and 46 in 2017 reflecting an increase trend in the basin (Fig.10.1.2.3). Further it is found that out of these 52 lakes, maximum number of lakes i.e. 47 lakes are the small one with area less than 5ha, 03 lakes fall within the areal range of 5-10h and 02 lakes with ids 1 (98.68ha) and 3 (162.07) are such which have the area more than 10ha and shows an increasing in its area by 3.65ha in 2019 i.e. the area has increase from 95.03ha(2018) to 98.68ha(2019).Likewise the lake with id 3 shows an increase of 1.09 ha i.e the area has increased from 160.99ha(2018) to 162.07ha(2019)(Table 10.1.2.1.& Fig10.1.2.2). Further the lake with id 1(at the snout of Geepang Gath Glacier) seems to be quite deep one having a large water column ,where as the water column n the other lake with id 3 (at the snout of Samudri Tapu Glacier) appears to be shallow one based on its tone and texture(Fig10.1.2a& 10.1.2b.). The remaining 18lakes which could be seen temporally with that of 2018 data shows that 12 lakes have increased in their aerial extent and 06 lakes have been reduced in aerial extent. The remaining lakes which could not be compared with that of 2018 data are either new one or could not be mapped during 2019 because of cloud cover in the satellite data and thus forms the base line data for their monitoring during next ablation season. (Table 10.1.2.1)

Fig.10.1.2a Geepang Gath Glacier

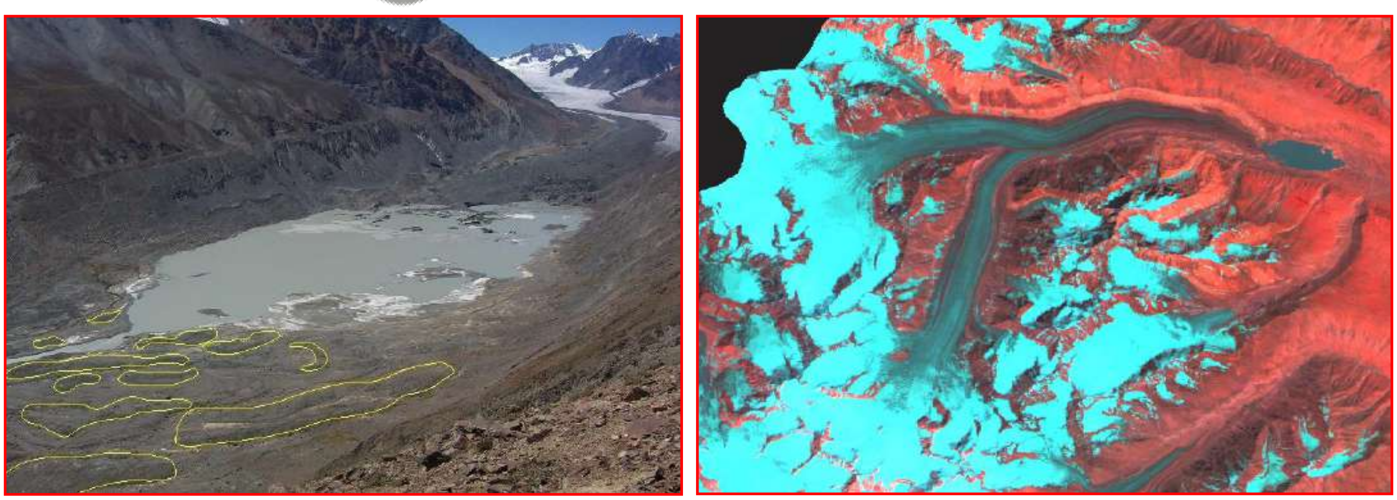
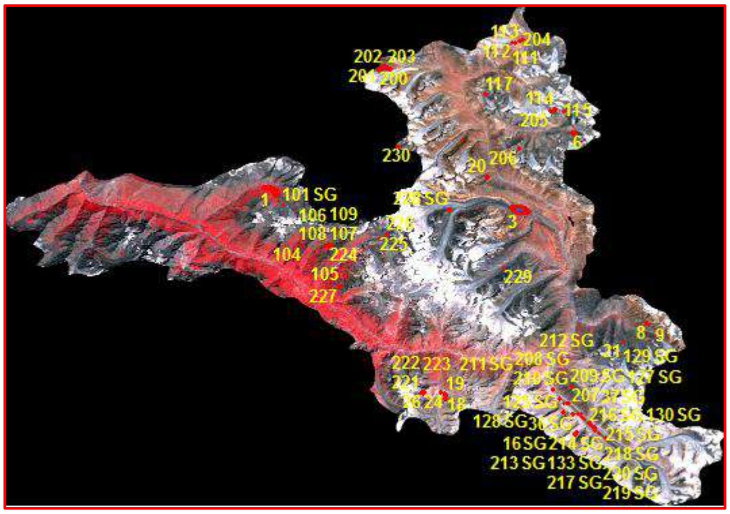
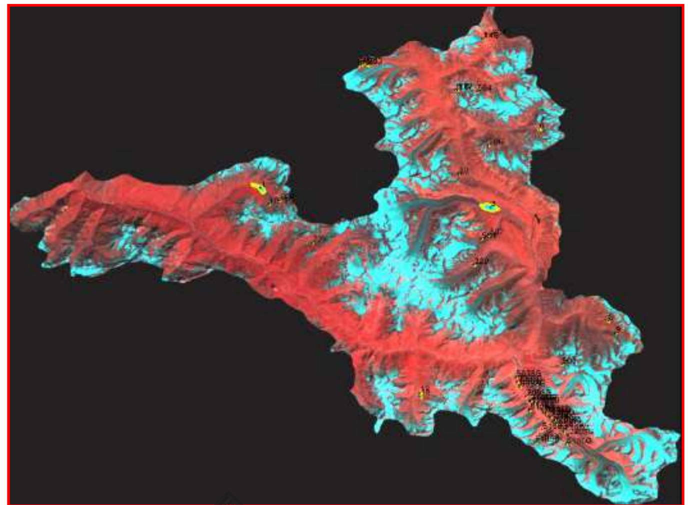


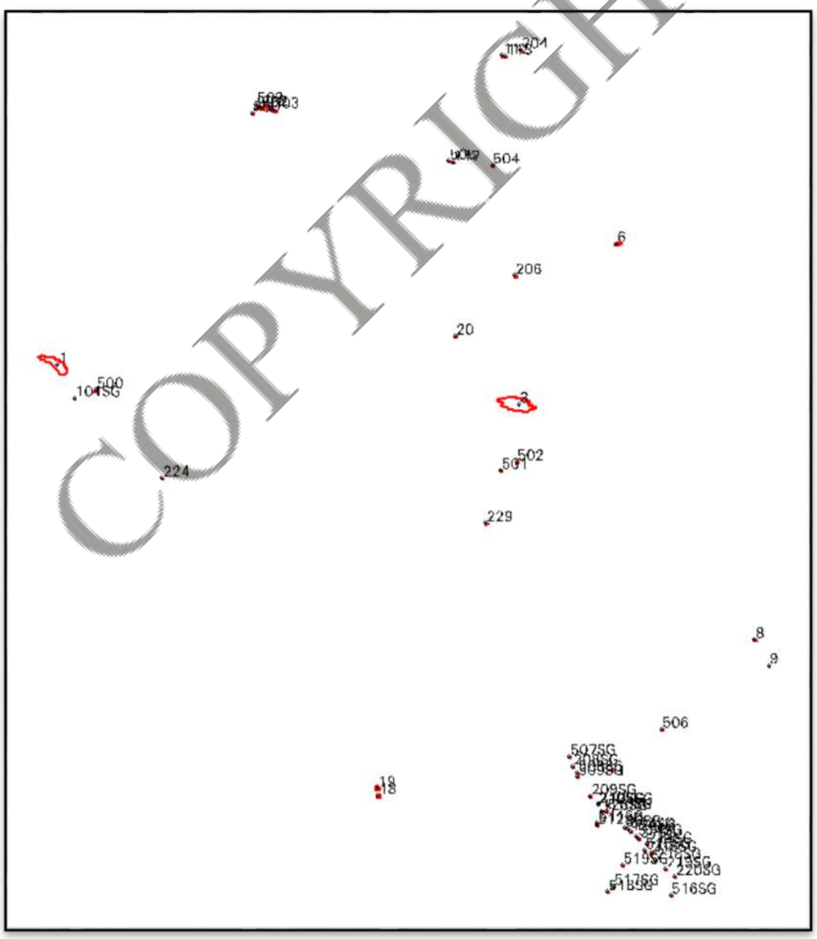
Fig.10.1.2b Samudri Tapu Glacier



IRS-R2-L3-95-48-27-August-2018



IRS-R2-L3-95-48-08 September 2019



Lake Inventory in Chandra Sub Basin based on IRS-R2-L3-95-48- 08 September 2019

Fig. 10.1.2.1

Table10.1.2.1: Aerial extent of lakes in Chandra Sub Basin

Sr. No.	Name of the Basin	Name of Sub-Basin	Lake id Number	Longitude	Latitude	Area (hectare in 2019)	Area (hectare in 2018)	Change in Area w.r.t. 2018
1	Chenab	Chandra	1	77.223534	32.5207017	98.68	95.03	+3.65
2	Chenab	Chandra	3	77.548075	32.4941692	162.07	160.99	+1.09
3	Chenab	Chandra	6	77.6166762	32.6008379	6.96	6.62	+0.34
4	Chenab	Chandra	8	77.7145066	32.3391710	2.29	2.37	-0.29
5	Chenab	Chandra	9	77.7248201	32.3226695	0.44	0.31	+0.13
6	Chenab	Chandra	18	77.4489006	32.2364558	3.02	3.11	-0.09
7	Chenab	Chandra	19	77.4474254	32.2418035	6.61	7.13	-0.52
8	Chenab	Chandra	20	77.5032971	32.5392512	0.81	0.61	+0.20
9	Chenab	Chandra	36SG	77.6235746	32.2188532	0.34	------	------
10	Chenab	Chandra	37SG	77.6340152	32.2112348	0.49	------	------
11	Chenab	Chandra	101SG	77.2341110	32.5020629	0.20	------	------
12	Chenab	Chandra	112	77.5362728	32.7241884	0.43	0.76	-0.33
13	Chenab	Chandra	113	77.5397679	32.7229727	0.21	0.35	-0.14
14	Chenab	Chandra	117	77.5011656	32.6535101	1.04	0.81	+0.23
15	Chenab	Chandra	125SG	77.6112134	32.2335527	0.55	------	------
16	Chenab	Chandra	126SG	77.6070921	32.2294317	0.44	------	------
17	Chenab	Chandra	129SG	77.6276931	32.21611.15	0.43	------	------
18	Chenab	Chandra	200	77.3598405	32.6857553	1.19	1.03	+0.16
19	Chenab	Chandra	202	77.3656129	32.6891942	1.91	0.86	+1.05
20	Chenab	Chandra	203	77.3727363	32.6885801	7.38	6.86	+0.52
21	Chenab	Chandra	204	77.5496952	32.7277944	0.70	0.65	+0.05
22	Chenab	Chandra	206	77.5450016	32.5787442	0.74	0.70	+0.04
23	Chenab	Chandra	208SG			0.59	------	------
24	Chenab	Chandra	209SG	77.5995435	32.2395945	0.75	------	------
25	Chenab	Chandra	210SG	77.6053725	32.2338917	0.65	------	------
26	Chenab	Chandra	214SG	77.639357	32.2078451	0.41	------	------
27	Chenab	Chandra	216SG	77.6425917	32.2020357	1.31	------	------
28	Chenab	Chandra	218SG	77.6454823	32.1972238	0.24	------	------
29	Chenab	Chandra	219SG	77.6528238	32.1917338	0.19	------	------
30	Chenab	Chandra	220SG	77.6594839	32.1866559	0.20	------	------

31	Chenab	Chandra	224	77.2958323	32.4456611	0.78	1.31	-0.53
32	Chenab	Chandra	229	77.5245107	32.4154285	0.75	0.74	+0.01
33	Chenab	Chandra	500	77.2493457	32.5074423	2.88	------	------
34	Chenab	Chandra	501	77.5360823	32.4543345	0.75	------	------
35	Chenab	Chandra	502	77.5471918	32.4599619	1.55	------	------
36	Chenab	Chandra	503	77.3628227	32.6956134	0.39	------	------
37	Chenab	Chandra	504	77.5299323	32.6556422	0.74	------	------
38	Chenab	Chandra	505	77.4992445	32.6582535	0.30	------	------
39	Chenab	Chandra	506	77.6498267	32.2836842	0.63	------	------
40	Chenab	Chandra	507SG	77.5847734	32.2656922	0.45	------	------
41	Chenab	Chandra	508SG	77.590457	32.2548458	0.26	------	------
42	Chenab	Chandra	509SG	77.5903321	32.252332	0.44	------	------
43	Chenab	Chandra	510SG	77.6105944	32.2297711	0.29	------	------
44	Chenab	Chandra	511SG	77.6044857	32.2218748	0.43	------	------
45	Chenab	Chandra	512SG	77.6040722	32.2200920	0.20	------	------
46	Chenab	Chandra	513SG	77.6266611	32.2175522	0.19	------	------
47	Chenab	Chandra	514SG	77.6321591	32.2128867	0.41	------	------
48	Chenab	Chandra	515SG	77.6380622	32.2040241	0.28	------	------
49	Chenab	Chandra	516SG	77.6562619	32.1743520	0.57	------	------
50	Chenab	Chandra	517SG	77.6155910	32.1800320	0.35	------	------
51	Chenab	Chandra	518SG	77.6114723	32.17652505	0.25	------	------
52	Chenab	Chandra	519SG	77.6221622	32.1940912	0.82	------	------

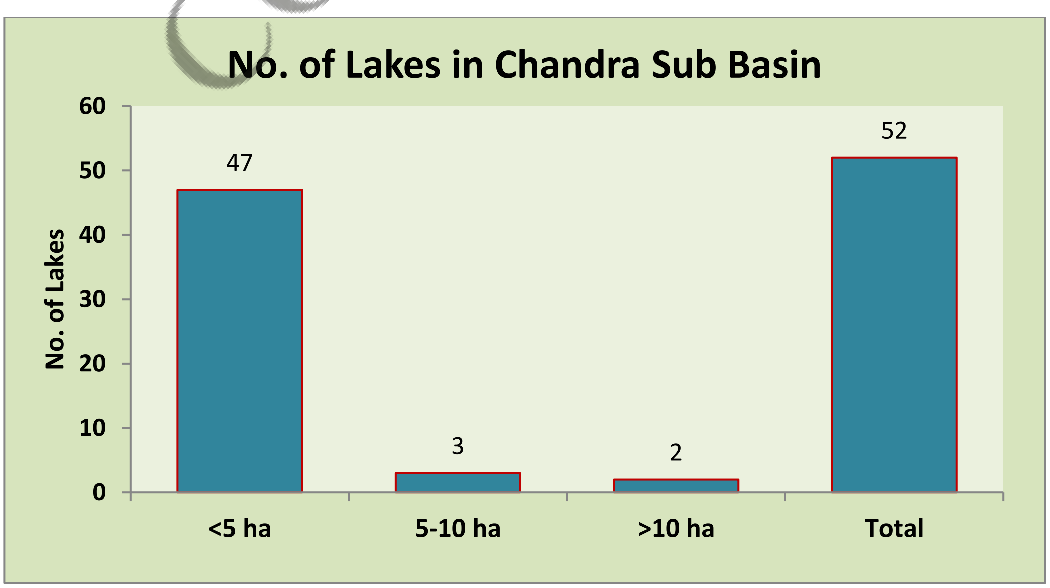


Fig.10.1.2.2 Distribution of lakes in Chandra sub basin

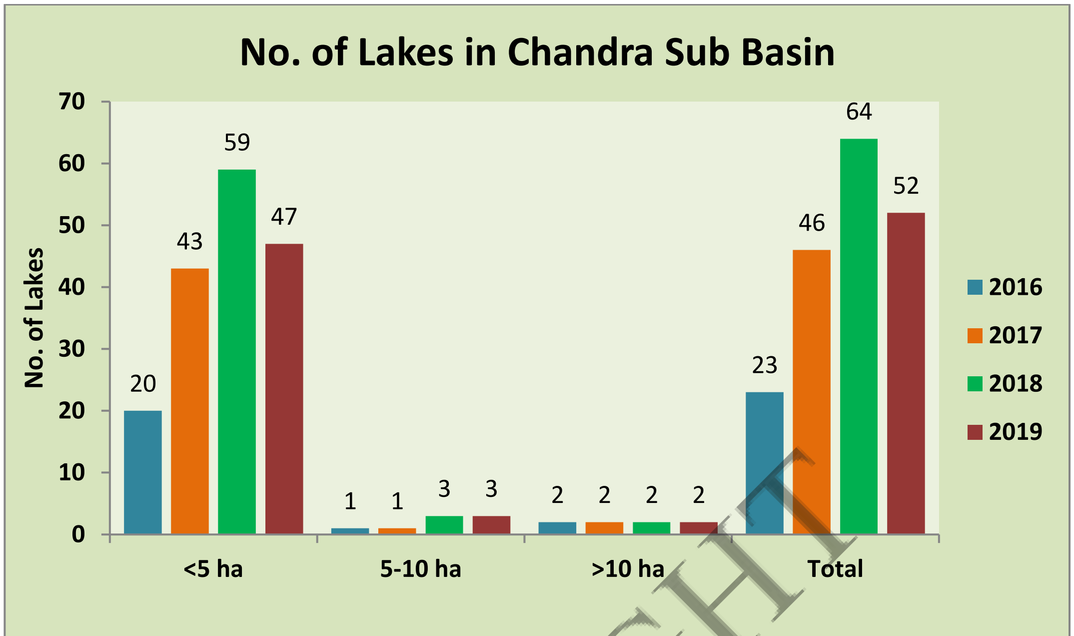
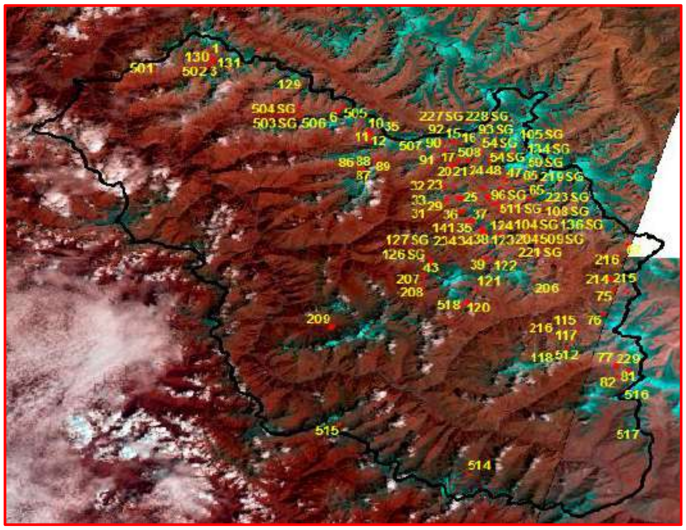


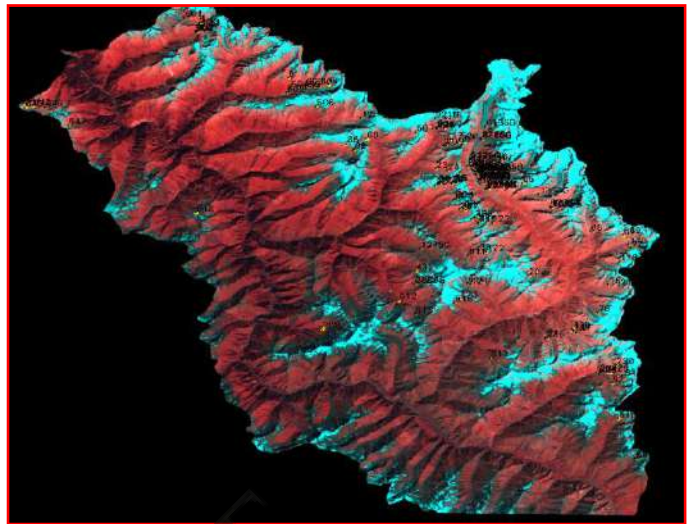
Fig.10.1.2.3 Distribution of lakes in Chandra sub basin in 2016, 2017, 2018 & 2019

10.1.3 Inventory of lakes in Miyar Sub Basin:

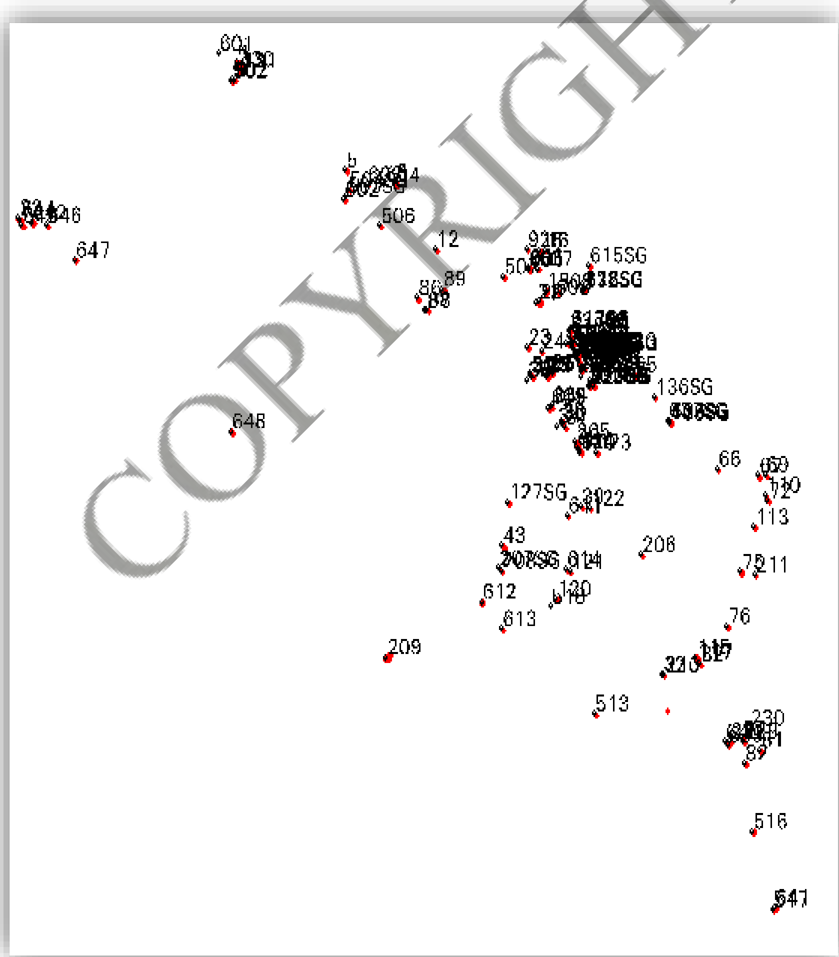
From the analysis of satellite data of IRS-RS2-L3 f or 10 September 2019 in Miyar sub basin(Fig.10.1.3.1), a total of 139 lakes could be delineated in comparison to 106 lakes that were mapped in 2018, 118 in 2017 and 89in 2016 (Fig.10.1.3.3) out of which about 95% lakes i.e. 133 lakes are small one with area less than 5ha, about 3% lakes i.e. 5 lakes are within the areal range of 5-10ha and about 0.7% i,e, 1 lake is having area more than 10ha (Fig 10.1.3.2 &Table 10.1.3.1). The lakes with ids 1,6 and 43 with area 5-10ha does show an increase in their water spread in comparison to 2018 and the lake with id 209 with area more than 10ha shows an increase of 0.91ha i.e. the area has increased from 15.06ha(2018) to 15.97ha(2019) respectively (Table10.1.3.1). Further 60 lakes when seen temporally w.r.t. 2018 shows an increase in their water spread, whereas 19 lakes are showing a reduction in their water spread w.r.t. 2018.The lakes that could not be compared forms the base line data for next year monitoring.



L8_148-37_27-Aug-2018



IRS-RS2-L3-94-47-10 September 2019



Lake Inventory in Miyar Sub Basin based on IRS-R2-L3-94-47-10 September 2019

Fig 10.1.3.1

Table 10.1.3.1: Aerial extent of lakes in Miyar Sub Basin

Sr. No.	Name of the Basin	Name of Sub-Basin	Lake id Number	Longitude	Latitude	Area (hectare) in 2019	Area (hectare) in 2018	Change in Area w.r.t. 2018
1	Chenab	Miyar	1	76.3623530	33.3106575	9.58	9.20	+0.38
2	Chenab	Miyar	2	76.36096	33.30837	0.83	-----	-----
3	Chenab	Miyar	3	76.3594376	33.2971373	1.23	0.54	+0.69
4	Chenab	Miyar	5	76.48876	33.22744	1.59	-----	-----
5	Chenab	Miyar	6	76.5467061	33.2165954	8.07	6.82	+1.25
6	Chenab	Miyar	12	76.5932141	33.1636157	0.50	0.37	+0.13
7	Chenab	Miyar	15	76.7145045	33.1627599	1.40	1.27	+0.13
8	Chenab	Miyar	16	76.7204277	33.1633411	0.59	0.45	+0.14
9	Chenab	Miyar	17	76.7204894	33.1311872	3.40	3.27	+0.13
10	Chenab	Miyar	20	76.7140102	33.1221609	3.42	3.12	+0.30
11	Chenab	Miyar	21	76.7110532	33.1220358	1.92	1.95	-0.03
12	Chenab	Miyar	23	76.6999142	33.0857256	2.06	1.72	+0.34
13	Chenab	Miyar	24	76.7152662	33.0830997	0.75	0.88	-0.13
14	Chenab	Miyar	25	76.7284912	33.0652837	1.42	1.09	+0.33
15	Chenab	Miyar	26	76.7265716	33.0661253	0.69	0.36	+0.33
16	Chenab	Miyar	27	76.7238636	33.0647208	0.93	0.27	+0.66
17	Chenab	Miyar	28	76.7228677	33.0632925	1.05	0.64	+0.41
18	Chenab	Miyar	29	76.7212703	33.0653836	1.68	1.08	+0.60
19	Chenab	Miyar	30	76.7036078	33.0646230	0.39	0.26	+0.13
20	Chenab	Miyar	31	76.7034069	33.0638577	0.40	0.39	+0.01
21	Chenab	Miyar	33	76.6992814	33.0603560	0.49	0.55	-0.06
22	Chenab	Miyar	34	76.7344619	33.0237122	0.55	0.53	+0.02
23	Chenab	Miyar	35	76.5943242	33.1773590	2.03	1.98	+0.05
24	Chenab	Miyar	36	76.7405276	33.0260143	2.36	1.89	+0.47
25	Chenab	Miyar	37	76.7425815	33.0224057	2.61	2.28	+0.33
26	Chenab	Miyar	38	76.7565693	33.0074921	1.93	1.79	+0.14
27	Chenab	Miyar	39	76.7623514	32.9600391	1.45	1.07	+0.38
28	Chenab	Miyar	43	76.6716658	32.9284154	5.55	4.65	+0.90
29	Chenab	Miyar	47	76.791825	33.0965142	2.35	1.63	+0.72
30	Chenab	Miyar	48	76.7855275	33.0988296	1.67	0.56	+1.11
31	Chenab	Miyar	65	76.8235672	33.0646188	1.86	2.45	-0.59
32	Chenab	Miyar	66	76.92132	32.99102	0.59	-----	-----
33	Chenab	Miyar	67	76.9674401	32.9843397	1.93	1.81	+0.12

34	Chenab	Miyar	69	76.97692	32.98651	0.80	-----	-----
35	Chenab	Miyar	72	76.97959	32.96582	0.35	-----	-----
36	Chenab	Miyar	75	76.9464866	32.9054413	1.78	1.41	+0.37
37	Chenab	Miyar	76	76.9308664	32.8625122	2.87	3.10	-0.23
38	Chenab	Miyar	77	76.9491922	32.7732177	4.20	4.14	+0.06
39	Chenab	Miyar	81	76.9693927	32.7646784	1.50	1.47	+0.03
40	Chenab	Miyar	82	76.9519285	32.7539505	3.21	2.30	+0.91
41	Chenab	Miyar	86	76.5731816	33.1248329	1.58	1.16	+0.42
42	Chenab	Miyar	87	76.5818615	33.1142932	0.39	0.35	+0.04
43	Chenab	Miyar	88	76.5837484	33.1153683	1.04	0.75	+0.29
44	Chenab	Miyar	89	76.6017412	33.1323820	5.19	5.14	+0.05
45	Chenab	Miyar	90	76.7006510	33.1482199	0.69	0.55	+0.14
46	Chenab	Miyar	91	76.7022969	33.1492747	0.44	0.44	-----
47	Chenab	Miyar	92	76.6988565	33.1637202	0.70	0.55	+0.15
48	Chenab	Miyar	110	76.97692	32.97047	0.49	-----	-----
49	Chenab	Miyar	113	76.96355	32.94499	1.04	-----	-----
50	Chenab	Miyar	115	76.8953694	32.8379181	1.12	0.45	+0.67
51	Chenab	Miyar	117	76.8965961	32.8368553	0.80	0.74	+0.06
52	Chenab	Miyar	120	76.7331695	32.8846419	1.77	2.01	-0.24
53	Chenab	Miyar	121	76.7491529	32.9057715	1.04	1.17	-0.13
54	Chenab	Miyar	122	76.7725513	32.9585396	1.38	1.44	-0.06
55	Chenab	Miyar	123	76.7803846	33.0029633	1.14	0.90	+0.24
56	Chenab	Miyar	124	76.7607400	33.0040120	0.99	1.35	-0.36
57	Chenab	Miyar	130	76.3641748	33.3056947	0.59	0.63	-0.04
58	Chenab	Miyar	131	76.3671806	33.3045421	1.62	1.17	+0.45
59	Chenab	Miyar	141	76.7246900	33.0383767	1.31	1.00	+0.31
60	Chenab	Miyar	205	76.7555374	33.0116097	0.28	0.26	+0.02
61	Chenab	Miyar	206	76.8325407	32.9196064	2.20	1.71	+0.49
62	Chenab	Miyar	209	76.537524	32.840664	15.97	15.06	+0.91
63	Chenab	Miyar	211	76.96415	32.90701	0.64	-----	-----
64	Chenab	Miyar	216	76.8590770	32.8241365	0.29	0.20	+0.09
65	Chenab	Miyar	229	76.9503296	32.7710886	1.62	2.76	-1.14
66	Chenab	Miyar	230	76.95831	32.78562	0.70	-----	-----
67	Chenab	Miyar	231	76.93533	32.77497	0.34	-----	-----
68	Chenab	Miyar	234	76.7287715	33.0417467	0.34	0.54	-0.20
69	Chenab	Miyar	502	76.3570250	33.2971668	0.69	0.65	+0.04

70	Chenab	Miyar	506	76.5293669	33.1817595	1.37	1.44	-0.07
71	Chenab	Miyar	507	76.6718507	33.1424568	2.08	1.98	+0.10
72	Chenab	Miyar	508	76.7351277	33.1301765	0.96	0.82	+0.14
73	Chenab	Miyar	513	76.77845	32.79691	0.69	-----	-----
74	Chenab	Miyar	516	76.9629503	32.7080620	4.83	0.81	+4.02
75	Chenab	Miyar	517	76.9860716	32.6395203	0.39	0.46	-0.07
76	Chenab	Miyar	518	76.7267929	32.8782080	0.54	0.66	-0.12
77	Chenab	Miyar	105SG	76.7817659	33.0834581	0.90	0.43	+0.47
78	Chenab	Miyar	108SG	76.8633748	33.0284909	0.59	0.65	-0.06
79	Chenab	Miyar	127SG	76.677643	32.9629000	0.30	0.36	-0.06
80	Chenab	Miyar	132SG	76.76529	33.13287	0.24	-----	-----
81	Chenab	Miyar	134SG	76.7591422	33.0806861	0.44	0.44	
82	Chenab	Miyar	136SG	76.8472727	33.0469035	0.48	0.45	+0.03
83	Chenab	Miyar	207SG	76.66701	32.91218	0.55	-----	-----
84	Chenab	Miyar	208SG	76.67032	32.91029	0.24	-----	-----
85	Chenab	Miyar	221SG	76.7736082	33.0548636	0.44	0.36	+0.08
86	Chenab	Miyar	223SG	76.7717054	33.0550013	0.48	0.46	+0.02
87	Chenab	Miyar	225SG	76.7557505	33.0820066	0.29	0.27	+0.02
88	Chenab	Miyar	227SG	76.7485602	33.0997936	0.35	0.27	+0.08
89	Chenab	Miyar	228SG	76.7656332	33.1327447	0.62	0.38	+0.24
90	Chenab	Miyar	503SG	76.4903797	33.2060554	0.20	0.45	-0.25
91	Chenab	Miyar	504SG	76.4927591	33.2099974	0.79	0.35	+0.44
92	Chenab	Miyar	55SG	76.7644747	33.0696841	0.98	0.44	+0.54
93	Chenab	Miyar	59SG	76.7631306	33.0632568	0.54	0.44	+0.10
94	Chenab	Miyar	96SG	76.7561220	33.0841594	0.45	1.55	-1.10
95	Chenab	Miyar	601	76.34043	33.31922	0.19	-----	-----
96	Chenab	Miyar	602	76.48694	33.20436	0.29	-----	-----
97	Chenab	Miyar	603	76.51392	33.21591	0.39	-----	-----
98	Chenab	Miyar	604	76.53462	33.21581	0.45	-----	-----
99	Chenab	Miyar	605	76.70181	33.14946	0.29	-----	-----
100	Chenab	Miyar	606	76.70174	33.15041	0.24	-----	-----
101	Chenab	Miyar	607	76.71243	33.14954	0.25	-----	-----
102	Chenab	Miyar	608	76.73218	33.12696	0.30	-----	-----
103	Chenab	Miyar	609	76.72738	33.04081	0.54	-----	-----
104	Chenab	Miyar	610	76.76186	33.00431	0.25	-----	-----
105	Chenab	Miyar	611	76.74691	32.95412	0.39	-----	-----

106	Chenab	Miyar	612	76.64748	32.88571	5.19	-----	-----
107	Chenab	Miyar	613	76.67081	32.86408	0.43	-----	-----
108	Chenab	Miyar	615SG	76.77148	33.15265	0.30	-----	-----
109	Chenab	Miyar	616SG	76.76643	33.1328	0.20	-----	-----
110	Chenab	Miyar	617SG	76.75014	33.10263	0.20	-----	-----
111	Chenab	Miyar	618SG	76.74921	33.09658	0.14	-----	-----
112	Chenab	Miyar	620SG	76.75291	33.09061	0.14	-----	-----
113	Chenab	Miyar	621SG	76.75177	33.08705	0.14	-----	-----
114	Chenab	Miyar	622SG	76.74601	33.09082	0.59	-----	-----
115	Chenab	Miyar	623SG	76.76337	33.08527	0.29	-----	-----
116	Chenab	Miyar	624SG	76.76586	33.08349	0.19	-----	-----
117	Chenab	Miyar	625SG	76.76529	33.083	0.15	-----	-----
118	Chenab	Miyar	626SG	76.76003	33.08371	0.19	-----	-----
119	Chenab	Miyar	627SG	76.75654	33.08036	0.24	-----	-----
120	Chenab	Miyar	628SG	76.75739	33.07915	0.34	-----	-----
121	Chenab	Miyar	629SG	76.7596	33.07666	0.40	-----	-----
122	Chenab	Miyar	630SG	76.76479	33.07168	0.68	-----	-----
123	Chenab	Miyar	631SG	76.76458	33.07069	0.54	-----	-----
124	Chenab	Miyar	632SG	76.76323	33.07154	0.44	-----	-----
125	Chenab	Miyar	633SG	76.77276	33.05809	0.24	-----	-----
126	Chenab	Miyar	634SG	76.77319	33.06165	0.24	-----	-----
127	Chenab	Miyar	635SG	76.78308	33.0825	0.30	-----	-----
128	Chenab	Miyar	636SG	76.86663	33.02902	0.24	-----	-----
129	Chenab	Miyar	637SG	76.86354	33.02959	0.49	-----	-----
130	Chenab	Miyar	639	76.93334	32.77254	0.29	-----	-----
131	Chenab	Miyar	640	76.92988	32.77445	0.29	-----	-----
132	Chenab	Miyar	641	76.98702	32.64323	0.29	-----	
133	Chenab	Miyar	642	76.1238	33.18392	0.80	-----	-----
134	Chenab	Miyar	643	76.11231	33.18162	2.73	-----	-----
135	Chenab	Miyar	644	76.11067	33.18704	0.69	-----	-----
136	Chenab	Miyar	646	76.14119	33.18179	0.74	-----	-----
137	Chenab	Miyar	648	76.35672	33.01969	4.66	-----	-----
138	Chenab	Miyar	649SG	76.76178	33.07264	0.24	-----	-----
139	Chenab	Miyar	650SG	76.76288	33.07091	0.68	-----	-----

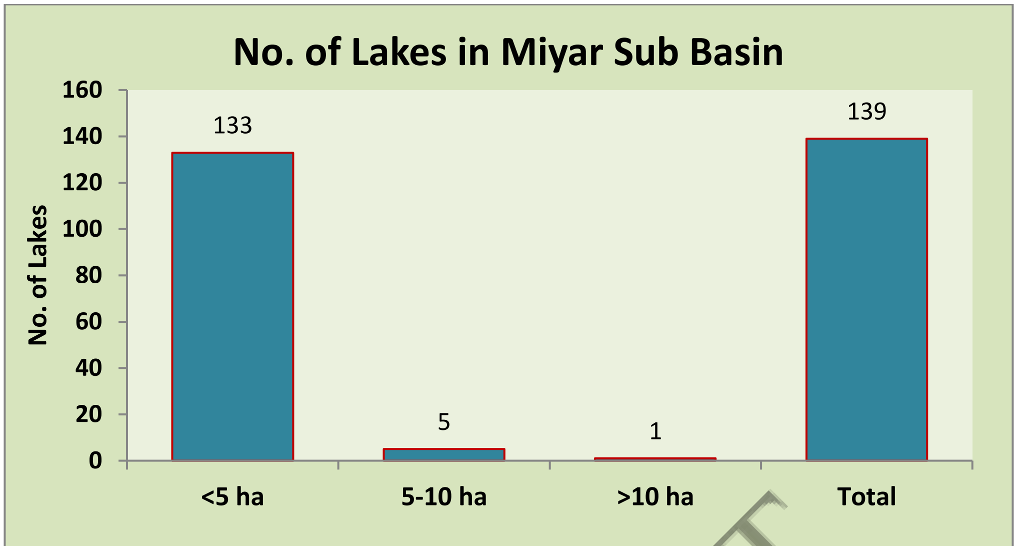


Fig.10.1.3.2 Distribution of lakes in Miyar sub basin

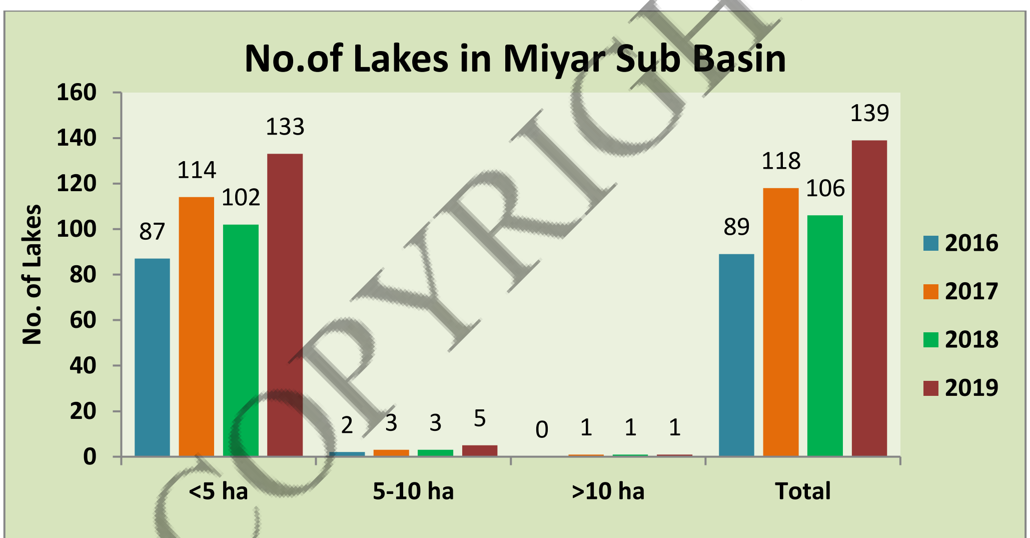


Fig.10.1.3.3 Distribution of lakes in Miyar sub basin in 2016, 2017, 2018 & 2019

As a whole the Chenab basin which mainly originates from the Himachal Himalaya reveals the presence of total of 242 lakes in 2019 comprising majority of the lakes (226) i.e. about 93% as the small lakes with area <5ha, 11 lakes i.e. about 4% are having area between 5-10ha and about 2% i.e. 5 lakes are the big one with area more than 10ha. Further when seen temporally w.r.t to the preceding years, it has been found that a reduction of about 4% in total number of lakes could be seen with that of 2018(254), whereas an increase of about 10% w.r.t 2017(220) and 81% with that of 2016(133) could be seen. The analysis further reveals an overall increase of about 374% with that of 51 lakes mapped in Chenab basin during 2001 (Randhawa et.al.2005). Further, the comparative analysis of the lakes mapped in 2019 reveals that out of the total 242 lakes mapped in 2019, total 5

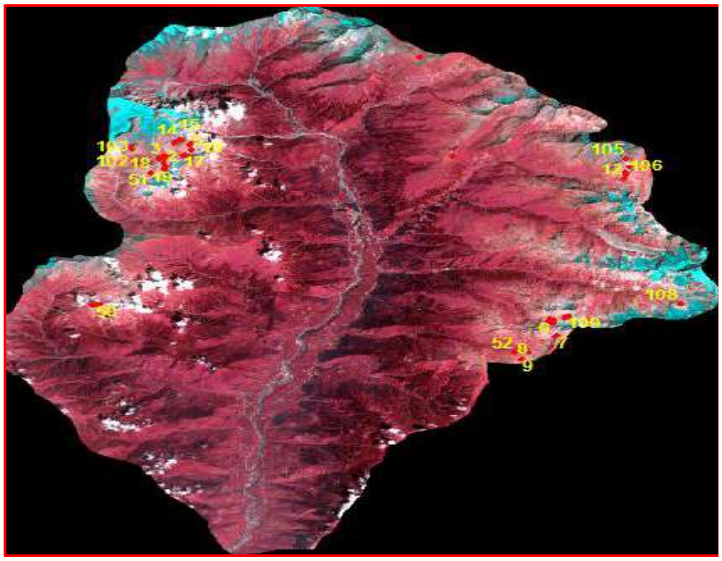
(2019) are the big one with area more than 10ha in comparison to 04 lakes (2018), 11 lakes are having area between 5-10ha in comparison to 10(2018) and 226 are the small one in comparison to 240(2018) respectively.

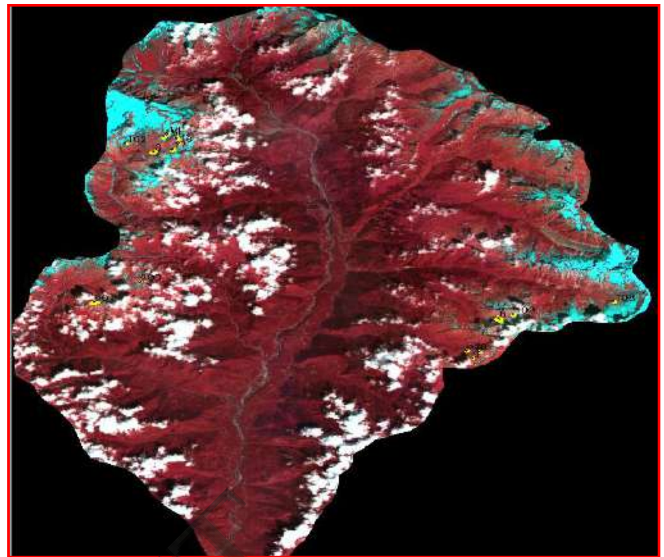
10.2 Inventory of lakes in Beas Basin:

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

10.2.1 Inventory of lakes in Upper Beas Sub Basin:

The interpretation of IRS-LISS III of 08 September 2019 reveals the presence of total 15 lakes in comparison to the 23 lakes(2018) in the Upper Beas Basin upstream of Bhuntar (Fig 10.2.1.1) and the variation is mainly due to the presence of cloud cover in the satellite data as result of which maximum information could not be derived. When compared with the past data, it is found that total number of lakes has increased from 9 in 2015, 17 in 2016 to 25 in 2017 and decreased to 23 in 2018 and further 15 in 2019(Fig.10.2.1.3). Further analysis of the 15 lakes mapped in 2019 reveals that out of 15 lakes, 10 lakes are the small one with area less than 5ha and 02 lakes having area between 5-10 ha and 01 lake with area more than 10ha i.e. the lake with id 6 that has shown a reduction in its area during 2018(9.82ha) further shown an increase in its area in 2019(10.47ha)as a result of which this lake has been counted in the category of the lakes with area >10ha.(Table 10.2.1 & Fig.10.2.1.2). Temporal analysis of the common lakes reveals that there are 3 lakes which shows an increase in their water spread in 2019 than 2018 and11 lakes shows a reduction in their water spread in 2019, whereas 1 lake that could not be seen temporally in 2019, forms the base line data for their monitoring during next ablation season (Table10.2.1).





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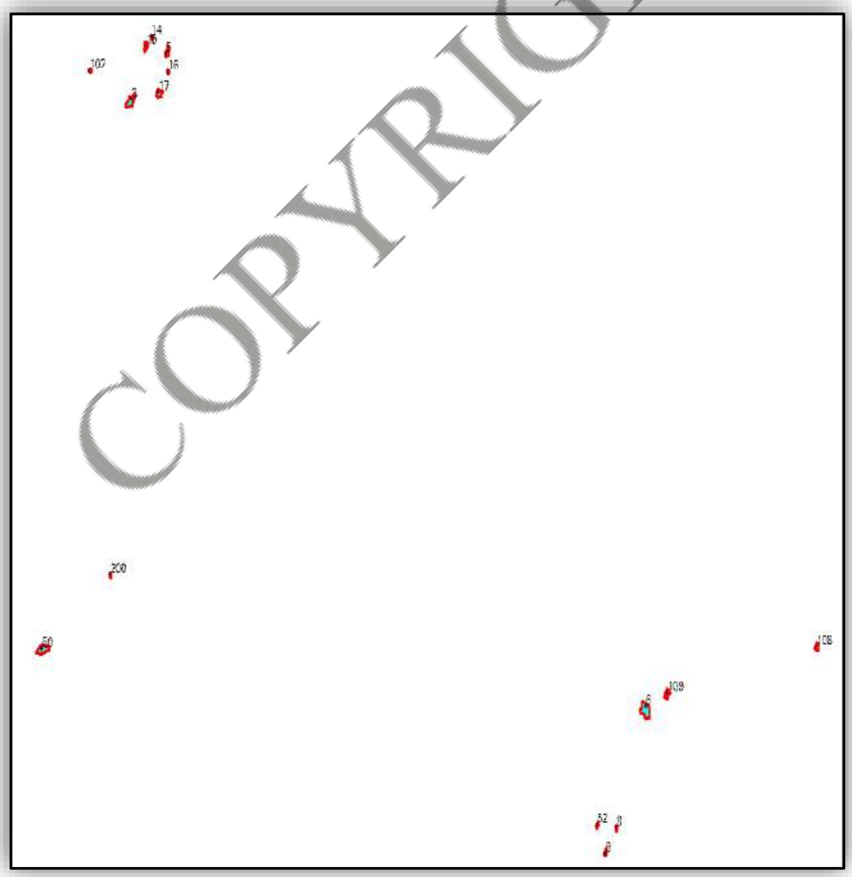


Lake Inventory in Beas Sub Basin based on IRS-R2-L3-95-48-08 September 2019
Fig 10.2.1

Table10.2.1: Aerial extent of lakes in Upper Beas Sub Basin

Sr. No.	Name of the Basin	Name of Sub-Basin	Lake id Number	Longitude	Latitude	Area (hectare)in 2019	Area (hectare) in 2018	Change in Area w.r.t. 2018
1	Beas	Beas	3	77.0785080	32.2888665	6.33	6.14	+0.19
2	Beas	Beas	5	77.0940456	32.2991803	2.14	2.15	-0.01
3	**Beas**	**Beas**	**6**	**77.298311**	**32.153582**	**10.47**	**9.82**	**+0.65**
4	Beas	Beas	8	77.2857210	32.1267930	0.72	0.68	+0.04
5	Beas	Beas	9	77.2814348	32.1215691	1.62	1.64	-0.02
6	Beas	Beas	14	77.0881520	32.3034665	0.79	3.50	-2.71
7	Beas	Beas	15	77.0853392	32.3010555	2.39	2.57	-0.18
8	Beas	Beas	16	77.0949832	32.2951619	0.55	0.63	-0.08
9	Beas	Beas	17	77.0906970	32.2905408	3.32	3.87	-0.55
10	Beas	Beas	50	77.0401997	32.1671105	6.98	8.06	-1.08
11	Beas	Beas	52	77.2774661	32.1276311	0.99	1.23	-0.24
12	Beas	Beas	102	77.0617649	32.2951619	0.44	0.62	-0.18
13	Beas	Beas	108	77.3710440	32.1676462	1.69	1.91	-0.30
14	Beas	Beas	109	77.3068843	32.1565288	2.82	4.73	-1.91
15	Beas	Beas	200	77.07013	32.18694	0.62	------	------

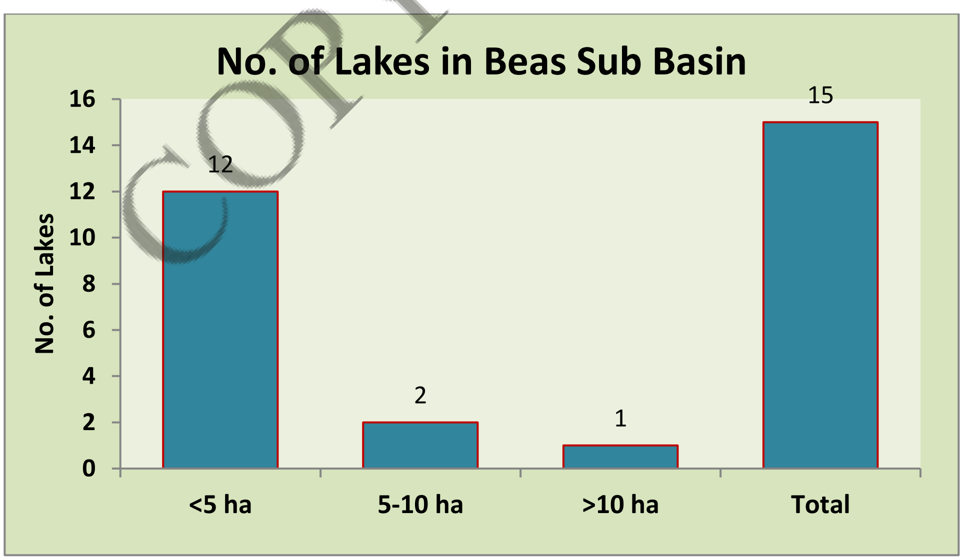


Fig.10.2.1.2. Distribution of lakes in Beas sub basin (2019)

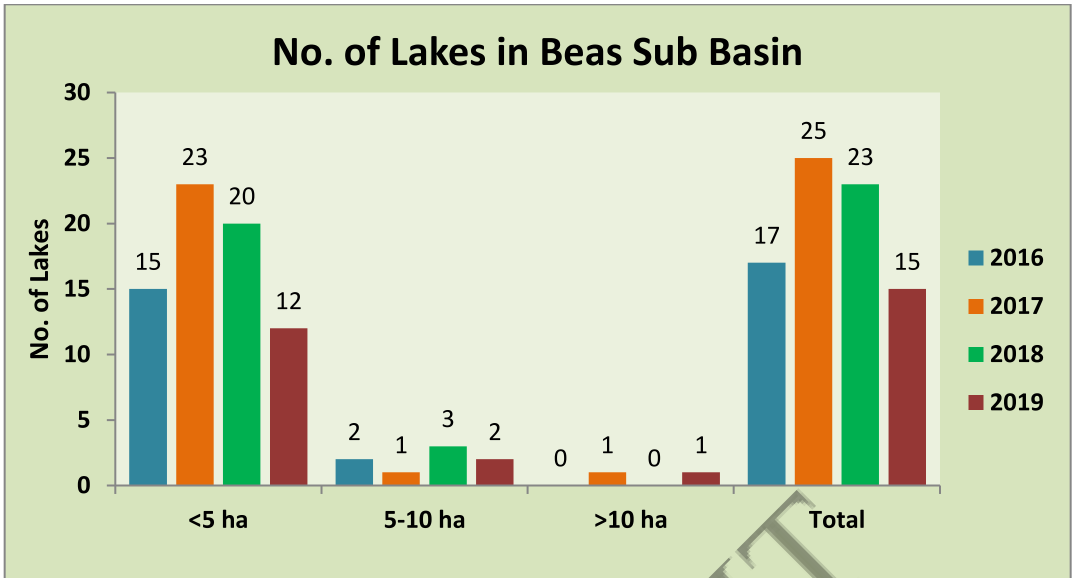
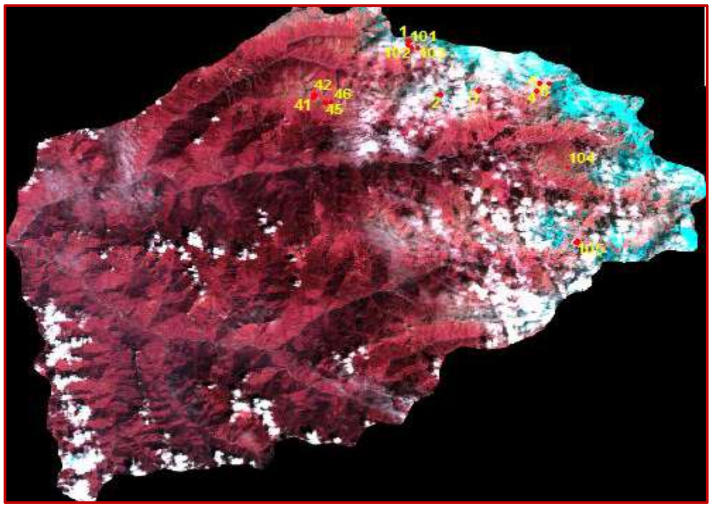


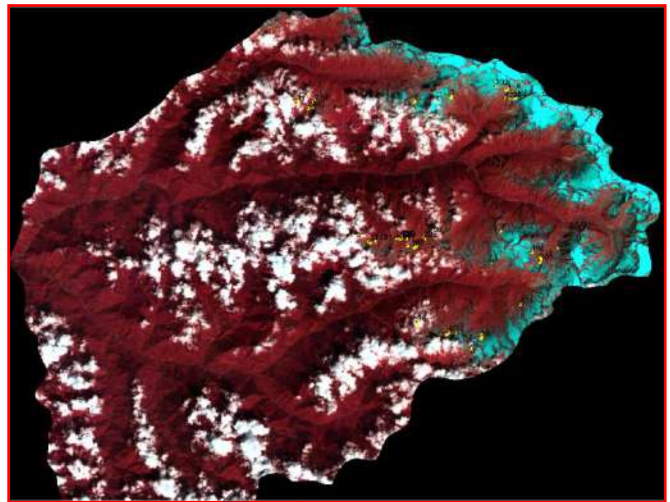
Fig.10.2.1.3. Distribution of lakes in Beas sub basin in 2016, 2017, 2018 & 2019

10.2.2 Inventory of lakes in Jiwa sub basin:

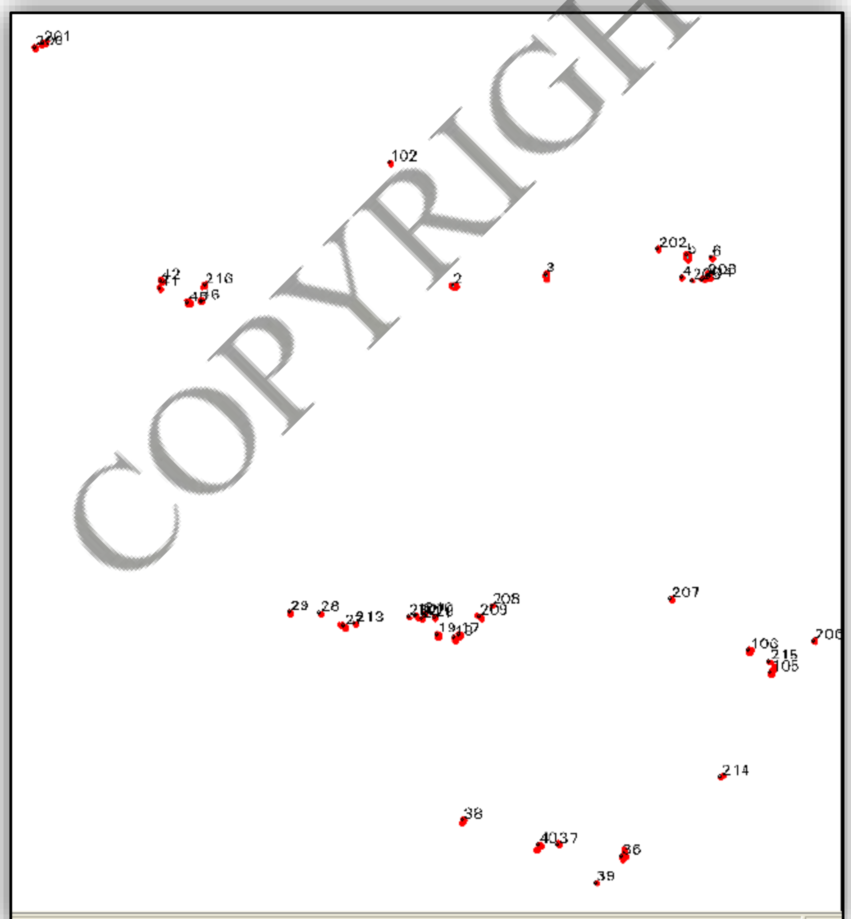
Jiwa sub basin which falls on the southeastern part of the Beas River and comprises of the Jiwa and Sainj as two major tributaries of the Beas basin. From the analysis of the IRS-LISS-III satellite data of 08 September 2019 (Fig.10.2.2.1), a total of 41 lakes could be mapped in comparison to the 15 lakes that could be mapped in 2018, 32 lakes (2017) and 20(2016) (Fig.10.2.2.3) and the variation in two numbers is mainly due to the data quality as a result of which the catchment is not fully exposed . Further all these 41 lakes mapped in 2019 falls in the category of lakes with area less than 5 ha. Besides this, no lake could be mapped in 2017 and 2018 which has the area more than 10ha (Fig10.2.2.2 & Table10.2.2).Further analysis of the data obtained, it is found that out of only 11 lakes could be seen temporally w.r.t 2018 and found that 07 lakes are showing an increase in their water spread whereas 04 lakes have shown decrease in their water spread and the remaining 30 lakes forms the base line data for their monitoring during next ablation season.



IRS-R2-L3-95-48-27-Aug-2018



IRS-R2-L3-95-48-08 Sept.2019



Lake Inventory in Jiwa Sub Basin based on IRS-R2-L3-95-48-08 Sept2019

Fig 10.2.2.1

Table 10.2.2: Aerial extent of lakes in Jiwa Sub Basin

Sr. No.	Name of the Basin	Name of Sub-Basin	Lake id Number	Longitude	Latitude	Area (hectare) in 2019	Area (hectare) in 2018	Change in Area w.r.t. 2018
1	Beas	Jiwa	2	77.5601291	31.8393207	3.21	2.65	+0.56
2	Beas	Jiwa	3	77.5915536	31.8423923	3.80	2.33	+1.47
3	Beas	Jiwa	4	77.6377454	31.8421560	0.49	0.51	-0.02
4	Beas	Jiwa	5	77.6393993	31.8485354	4.19	3.26	+0.93
5	Beas	Jiwa	6	77.6481415	31.8475903	0.73	0.86	-0.13
6	Beas	Jiwa	17	77.56344	31.73425	1.89	------	------
7	Beas	Jiwa	18	77.56149	31.73343	1.77	------	------
8	Beas	Jiwa	19	77.55565	31.73425	2.28	------	------
9	Beas	Jiwa	20	77.55488	31.73951	1.10	------	------
10	Beas	Jiwa	27	77.52403	31.73684	2.64	------	------
11	Beas	Jiwa	28	77.51589	31.74099	0.51	------	------
12	Beas	Jiwa	29	77.50548	31.74118	0.71	------	------
13	Beas	Jiwa	36	77.61846	31.66558	4.75	------	------
14	Beas	Jiwa	37	77.597	31.66911	1.29	------	------
15	Beas	Jiwa	38	77.56463	31.67671	2.09	------	------
16	Beas	Jiwa	39	77.60982	31.65739	0.63	------	------
17	Beas	Jiwa	40	77.59025	31.66914	2.45	------	------
18	Beas	Jiwa	41	77.4610117	31.8376668	1.57	1.64	-0.07
19	Beas	Jiwa	42	77.4613661	31.8403839	2.90	2.57	+0.33
20	Beas	Jiwa	45	77.4701083	31.8337682	2.15	1.51	+0.64
21	Beas	Jiwa	46	77.4748338	31.8336501	1.29	1.04	+0.25
22	Beas	Jiwa	102	77.5388643	31.8773610	0.64	0.70	-0.06
23	Beas	Jiwa	105	77.6683430	31.7192930	3.98	3.15	+0.83
24	Beas	Jiwa	106	77.66206	31.72928	2.07	------	------
25	Beas	Jiwa	107	77.54848	31.74019	0.90	------	------
26	Beas	Jiwa	200	77.41849	31.9162	1.07		
27	Beas	Jiwa	201	77.42128	31.91743	3.40	------	------
28	Beas	Jiwa	202	77.63114	31.85369	0.70	------	------
29	Beas	Jiwa	203	77.64787	31.84541	2.90	------	------
30	Beas	Jiwa	204	77.64636	31.84444	1.00	------	------
31	Beas	Jiwa	206	77.6426	31.84385	0.75	------	------
32	Beas	Jiwa	207	77.68402	31.73232	0.64	------	------

33	Beas	Jiwa	208	77.63529	31.74531	0.34	------	------
34	Beas	Jiwa	209	77.57422	31.74335	1.72	------	------
35	Beas	Jiwa	210	77.57	31.73991	0.41	------	------
36	Beas	Jiwa	211	77.55124	31.7406	0.49	------	------
37	Beas	Jiwa	212	77.55056	31.73921	0.35	------	------
38	Beas	Jiwa	213	77.54618	31.73984	0.91	------	------
39	Beas	Jiwa	214	77.5278	31.73771	1.29	------	------
40	Beas	Jiwa	215	77.65226	31.69013	0.43	------	------
41	Beas	Jiwa	216	77.66881	31.7259	2.05	------	------

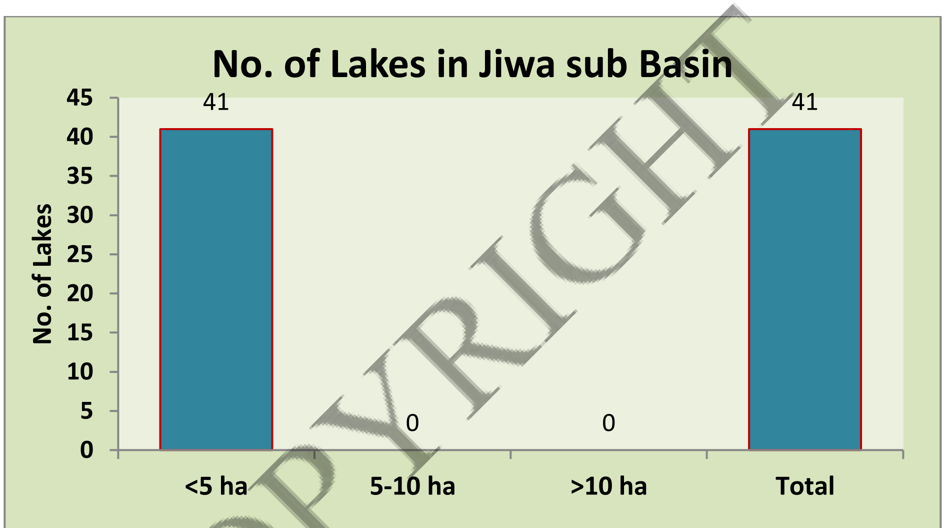


Fig.10.2.2.2 Distribution of lakes in Jiwa sub basin (2019)

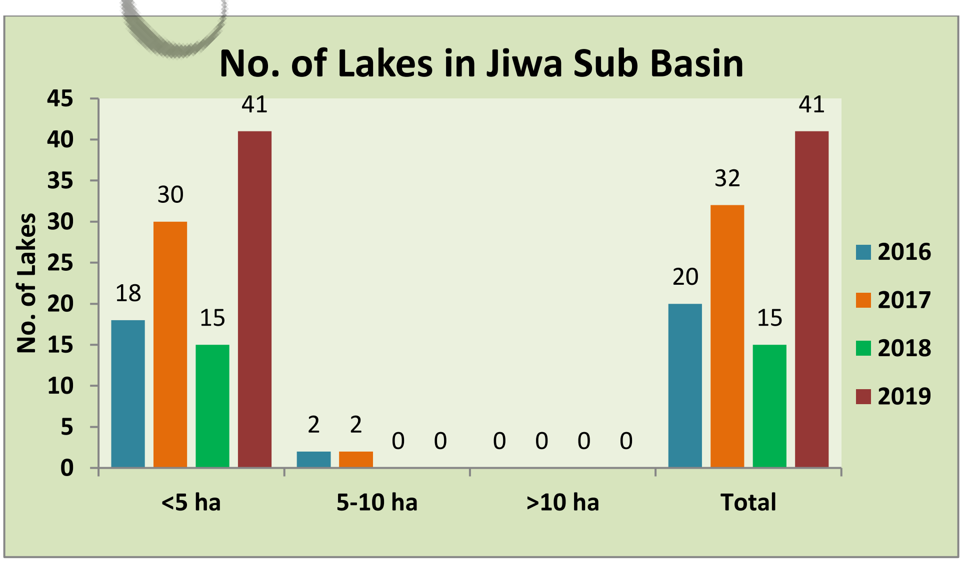
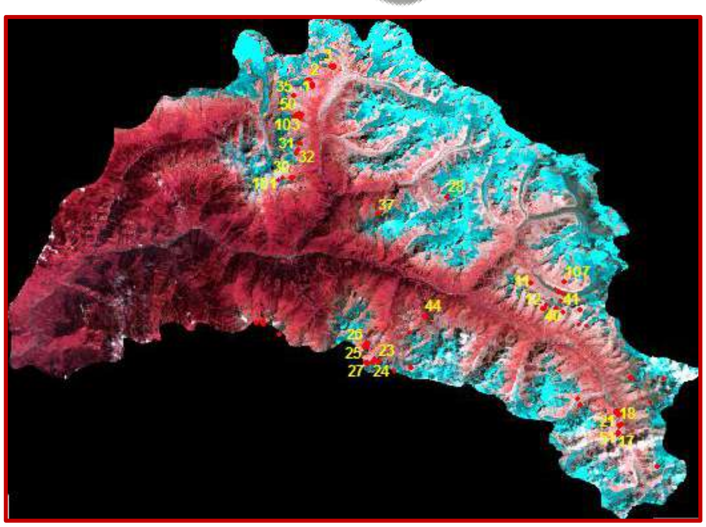


Fig.10.2.2.3 Distribution of lakes in Jiwa sub basin in 2016, 2017, 2018 & 2019

10.2.3 Inventory of lakes in Parvati sub basin:

Parvati is another major tributary of Beas Basin that joins the Beas River on its left bank near Bhuntar in Kullu district. Based on the satellite data analysis for 08 September 2019, a total of 37 lakes could be mapped in 2019(Fig.10.2.3.1) in comparison to the 27 lakes were mapped in 2018, 44(2017) and 26(2016) respectively (Fig10.2.3.3) and the variation in two numbers is mainly due to the data quality as a result of which complete information of the catchment was not available resulting to have variation in the number of lakes mapped. Further out of these 37 lakes mapped on 08 September 2019, 03 lakes with id (21,26&50) are the lakes which have the area more than 10ha and out of which one lake with id(21) indicates an increase in its area by about 1.42 ha, lakes with id 26 shows an increase by 1.39 ha and the lake with id 50 shows a decrease in its area about 1.47 ha respectively w.r.t. 2018 and thus number of lakes with area more than 10ha does not show any change in 2018& 2019 i.e. the number remains the same (3 lakes). Besides this, the lakes with id (3 &30) having area between 5-10ha also shows an increase and decrease in its area by w.r.t 2018. Further analysis reveal that there are 30 lakes out of 37 lakes mapped in 2019 are the small one having area less than 5ha in comparison to 27 lakes mapped in 2018 and 39 lakes as mapped in 2017 and thus it can be inferred that there is variation in the small category lakes during 2017& 2018, whereas the big category lakes are more or less same. Further out of these 37 lakes mapped , 16 lakes could be compared temporally with respect to 2018 which indicates that 10 lakes are showing an increase in their area w.r.t 2018, whereas 06 lakes are showing a reduction in their area w.r.t 2018 (Fig10.2.3.2 & Table10.2.3).



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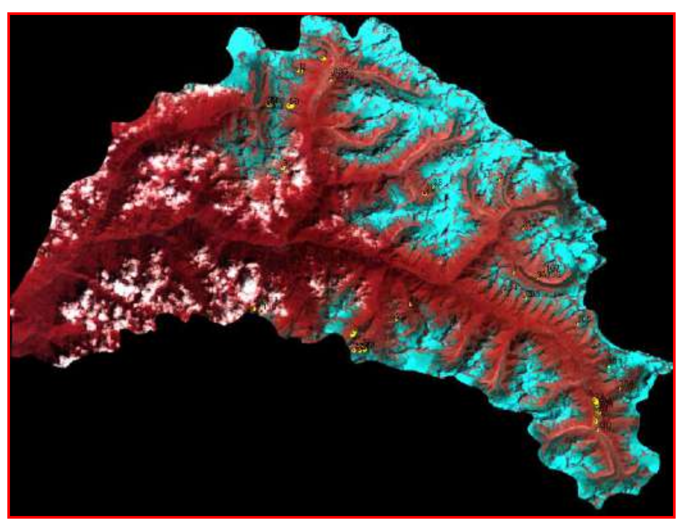
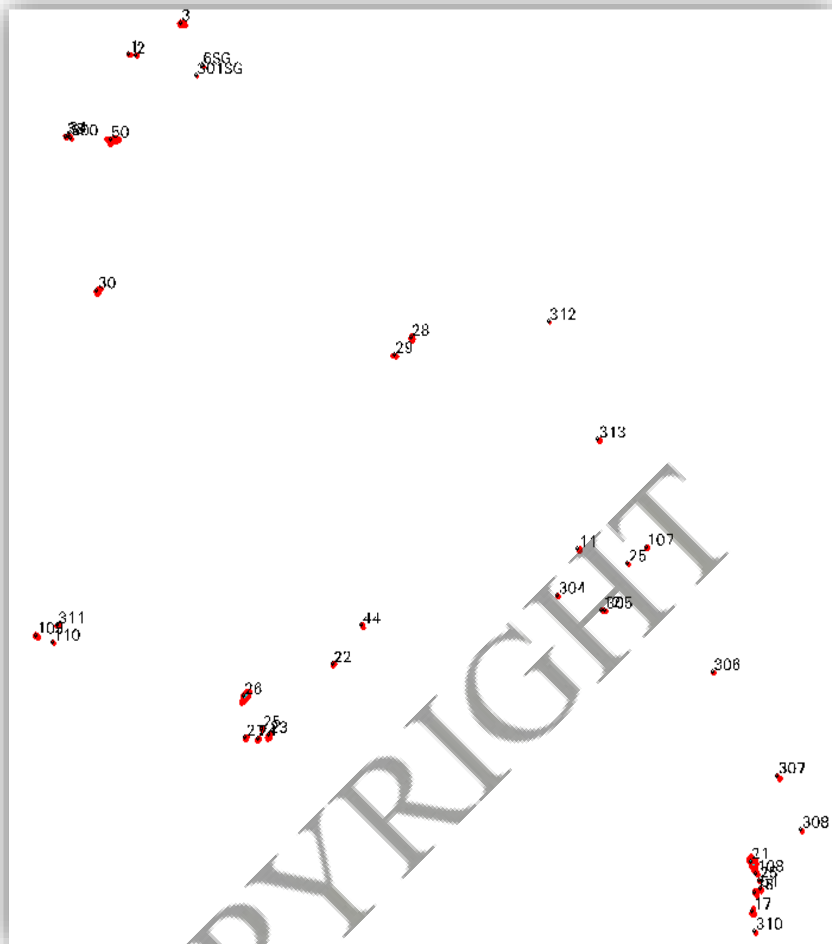


IRS-R2-L3-95-48-08 September 2019



Lake Inventory in Parvati Sub Basin based on IRS-R2-L3-95-48-08 September 2019
Fig. 10.2.3.1

Table10.2.3: Aerial extent of lakes in Parvati Sub Basin

Sr. No.	Name of the Basin	Name of Sub-Basin	Lake id Number	Longitude	Latitude	Area (hectare) in 2019	Area (hectare) in 2018	Change in Area w.r.t. 2018
1	Beas	Parvati	1	77.4646484	32.1640219	1.04	0.98	+0.06
2	Beas	Parvati	2	77.4684949	32.1640608	0.95	0.83	+0.12
3	Beas	Parvati	3	77.4923514	32.1762999	6.29	7.11	-0.82
4	Beas	Parvati	6SG	77.5038	32.16298	0.25	-----	-----
5	Beas	Parvati	11	77.6987450	31.9686629	1.31	1.52	-0.21
6	Beas	Parvati	12	77.7113338	31.9447288	0.91	1.63	-0.72
7	Beas	Parvati	17	77.7892753	31.8258349	3.79	2.77	+1.02
8	Beas	Parvati	18	77.7901301	31.8329840	2.42	1.80	+0.62
9	Beas	Parvati	21	77.789042	31.8441740	14.56	13.14	+1.42

10	Beas	Parvati	22	77.57205	31.92668	1.00	-----	-----
11	Beas	Parvati	23	77.5375777	31.8954616	4.44	3.36	+1.08
12	Beas	Parvati	24	77.5319827	31.8945291	1.95	1.35	+0.60
13	Beas	Parvati	26	77.524988	31.9103816	15.21	13.82	+1.39
14	Beas	Parvati	27	77.5254552	31.8948399	2.13	2.59	-0.46
15	Beas	Parvati	28	77.6117116	32.0519664	3.84	3.27	+0.27
16	Beas	Parvati	29	77.6042	32.04876	1.33	-----	-----
17	Beas	Parvati	30	77.4482859	32.0703881	5.07	4.71	+0.36
18	Beas	Parvati	33	77.43248	32.13504	1.86	-----	-----
19	Beas	Parvati	34	77.43377	32.13547	1.02	-----	-----
20	Beas	Parvati	44	77.58653	31.9387905	1.66	3.71	-2.05
21	Beas	Parvati	50	77.454740	32.1304519	11.83	13.30	-1.47
22	Beas	Parvati	51	77.7932384	31.834072	1.73	1.50	-----
23	Beas	Parvati	107	77.7340246	31.9695954	0.84	0.77	-----
24	Beas	Parvati	108	77.79258	31.84391	1.71	-----	-----
25	Beas	Parvati	109	77.41732	31.938	3.04	-----	-----
26	Beas	Parvati	110	77.42593	31.93517	0.54	-----	-----
27	Beas	Parvati	300	77.43494	32.13449	0.36	-----	-----
28	Beas	Parvati	301SG	77.50058	32.15898	0.18	-----	-----
29	Beas	Parvati	304	77.68939	31.95386	0.46	-----	-----
30	Beas	Parvati	305	77.71411	31.94796	0.29	-----	-----
31	Beas	Parvati	306	77.77019	31.92348	0.40	-----	-----
32	Beas	Parvati	307	77.80377	31.88259	0.24	-----	-----
33	Beas	Parvati	308	77.81619	31.86125	0.50	-----	-----
34	Beas	Parvati	310	77.79184	31.82115	0.75	-----	-----
35	Beas	Parvati	311	77.42839	31.94206	1.80	-----	-----
36	Beas	Parvati	312	77.68477	32.0619	0.20	-----	-----
37	Beas	Parvati	313	77.71054	32.01534	0.89	-----	-----

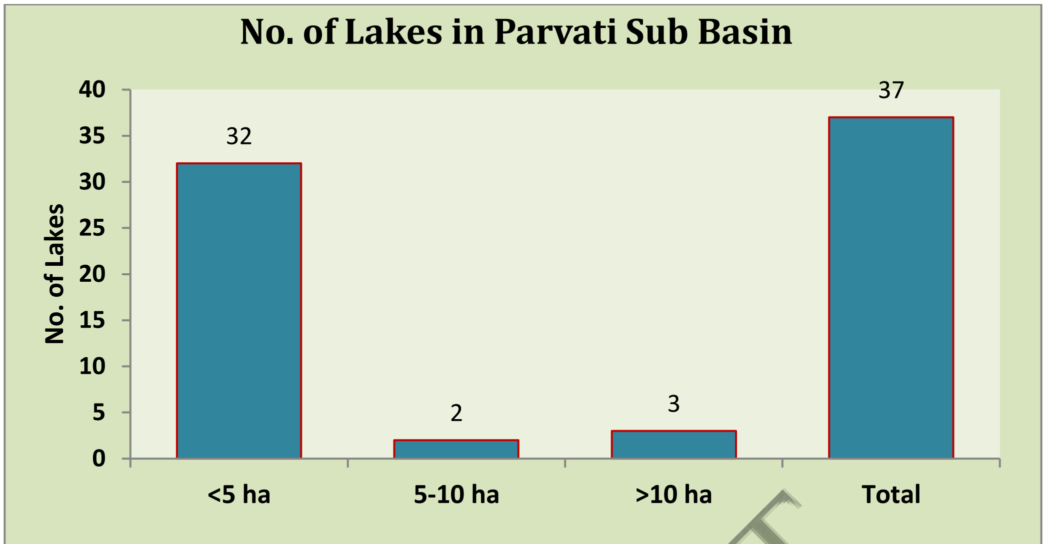


Fig.10.2.3.2 Distribution of lakes in Parvati sub basin

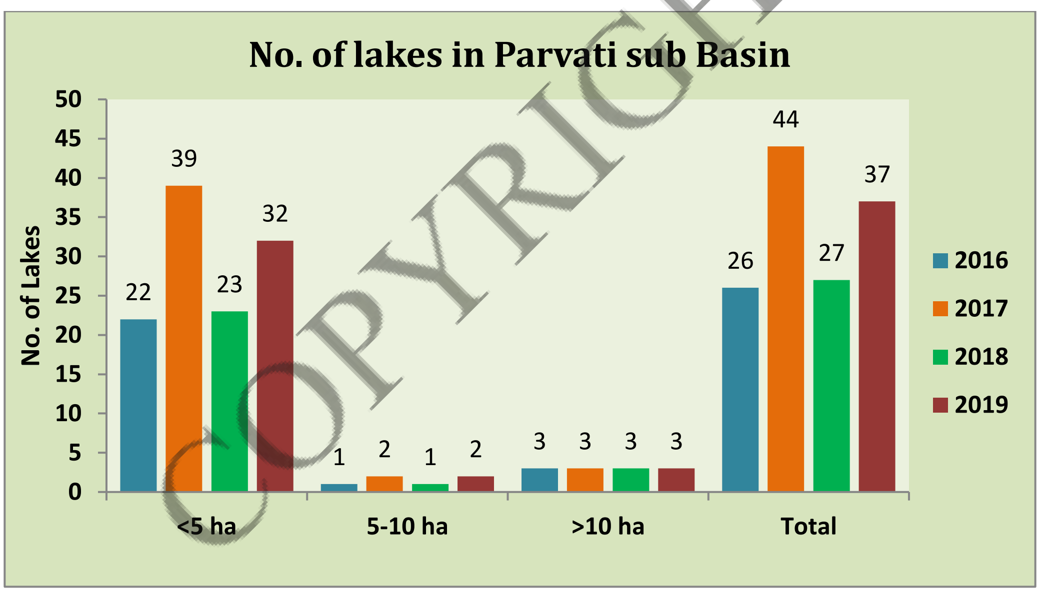
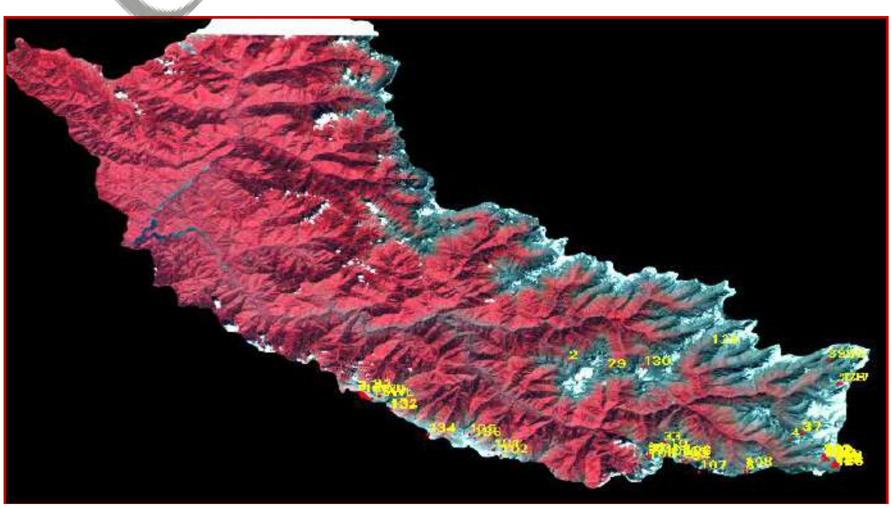


Fig.10.2.3.3 Distribution of lakes in Parvati sub basin in 2016, 2017, 2018 & 2019

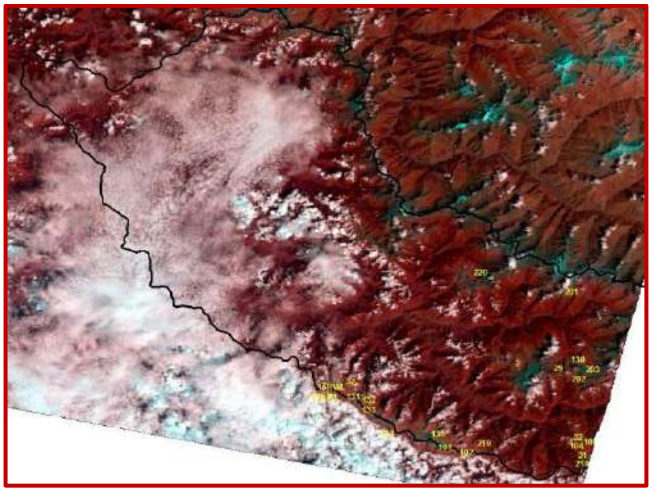
As a whole in the Beas basin, a total of 93 lakes could be delineated in 2019 in comparison to the 65 lakes mapped in 2018, 101 lakes in 2017 and 63 lakes in 2016 respectively, indicating an overall increase of about 43% (2018), a decrease of about 7% in the total number of lakes with respect to 2017 and about 47% increase with respect to 2016. Further analysis of these 93 lakes reveals that 85 lakes (91%) are small one with area less than 5ha in comparison to 58 lakes(2018), 04 lakes are with aerial range between 5-10 hectare in comparison to 4 lakes (2018) and 04 lakes are such which have the area more than 10 hectare in comparison to the 4 lakes of 2018.

10.3 Inventory of lakes in Ravi Basin:

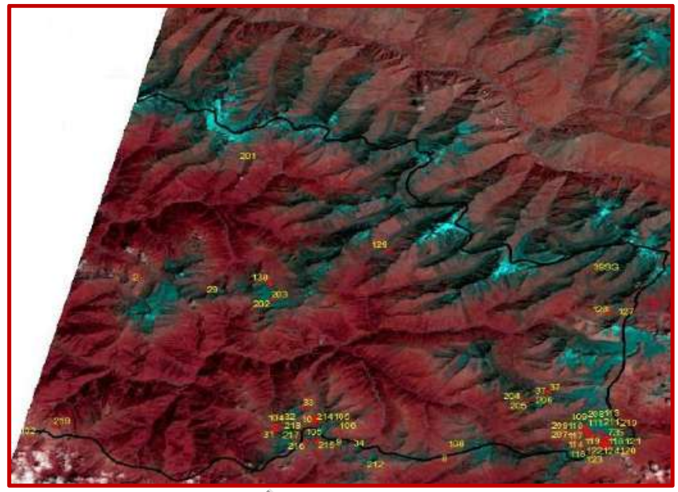
Ravi is another major river that originates from Himachal Himalaya in Bara Bhangal area of Kangra district and flows towards west and enters the Chamba district and then culminates into the Ranjeet Sagar Dam beyond which it enters Punjab and then to Pakistan. On analyzing the IRS-LISS III satellite data for 10 September 2019 a total of 38 lakes could be mapped in 2019 (Fig.10.3.1) against 66 lakes delineated in Ravi basin in 2018 , 28 lakes in 2016 and 54 lakes in 2017 respectively (Fig.10.3.2). The variation in the number of lakes with respect to the preceding years mainly due to the non availability of good quality cloud free satellite data in 2019 as a result of which complete information of the basins could not be derived .Further analysis reveals that out of 38 lakes mapped in 2019, 35 lakes are the small one with area less than 5 ha, 2 lakes comprise of the area within 5-10ha and 1 lake is such which have the area more than10ha in comaprsion to 3 lakes of 2018 (Fig. 10.3.2), in other words, we can say that about 91% lakes delineated in Ravi basin in 2019 are the smaller lakes. Further analysis of lakes with area >10 ha reveals that the lakes with id (10& 31) show an increase in their area by about 0.21ha and 0.22 ha respectively w.r.t 2017 , whereas the lake with id 16HWL is mainly a high altitude wetland shows a decrease of about 23.15ha. Besides this, there are two lakes with id 215 & 220 have the area between 5-10ha in 2018. There are 61 lakes are such which have the area less than 5ha and 43 lakes could be seen temporally out of which 12 lakes are showing an increase in the their spatial extent w.r.t 2017 and 31 lakes are showing decrease in their aerial extent w.r.t 2017 whereas the remaining 18 could not be seen temporally and thus forms the base line date for their monitoring during next ablation season (Fig 10.3.2 &Table 10.3).



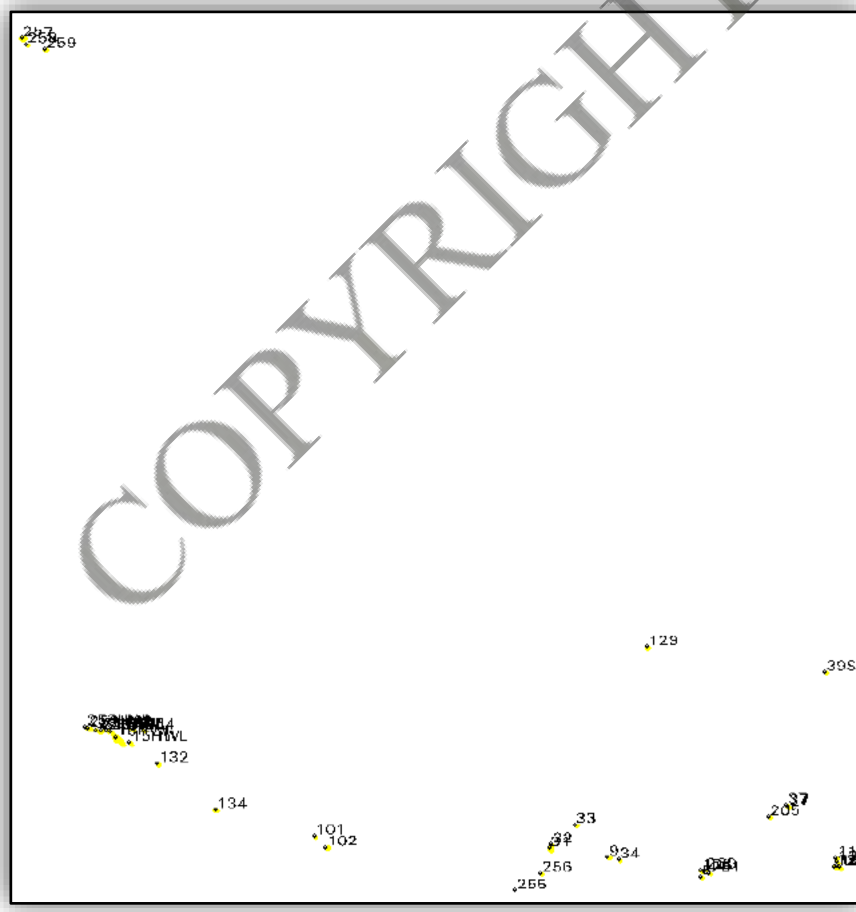
IRS RS2 L3 94-48 10-Sep-2019 Satellite Image of Ravi Basin, District Kullu



L8_148-37_22-Aug-2018



IRS-R2-L3-95-48-27-Aug-2018



Lake Inventory in Ravi Basin based on IRS-R2-L3-94-48-10 September2019

Fig.10.3.1

Table 10.3: Aerial extent of lakes in Ravi Basin

Sr. No.	Name of the Basin	Lake id Number	Longitude	Latitude	Area (hectare) in 2019	Area (hectare) in 2018	Change in Area w.r.t. 2018
1	Ravi	8	76.90039	32.20718	1.09	0.42	+0.67
2	Ravi	9	76.80992	32.22543	2.00	2.7	-0.7
3	Ravi	31	76.75295	32.23393	5.76	**12.38**	-6.62
4	Ravi	32	76.75515	32.2374	2.54	2.06	+0.48
5	Ravi	32	76.3465	32.34509	1.28	0.36	+0.08
6	Ravi	33	76.77783	32.25587	2.74	3.62	-0.88
7	Ravi	34	76.82042	32.22333	0.80	0.82	-0.02
8	Ravi	37	76.98359	32.2738	1.35	1.85	-0.50
9	Ravi	37	76.98497	32.27259	1.87	2.43	-0.56
10	Ravi	101	76.52438	32.24528	1.05	1.91	-0.86
11	Ravi	102	76.53588	32.23473	3.58	2.52	+1.06
12	Ravi	108	76.90013	32.21285	1.42	0.97	+0.45
13	Ravi	118	77.03172	32.22459	1.14	1.18	-0.04
14	Ravi	120	77.03235	32.22064	0.84	0.78	+0.06
15	Ravi	122	77.03075	32.21648	3.29	2.74	+0.55
16	Ravi	123	77.0329	32.21696	0.54	0.62	-0.08
17	Ravi	124	77.03491	32.21585	0.83	0.95	-0.12
18	Ravi	129	76.84848	32.4215	2.39	2.17	+0.22
19	Ravi	132	76.37166	32.31248	4.05	3.98	+0.07
20	Ravi	134	76.42825	32.26945	3.40	4.97	-1.57
21	Ravi	205	76.96666	32.26274	1.11	1.77	-0.66
22	Ravi	254	76.35768	32.34331	1.06	-----	-----
23	Ravi	255	76.72025	32.19435	0.52	-----	-----
24	Ravi	256	76.74473	32.21062	0.50	-----	-----
25	Ravi	257	76.2361	32.988	7.32	-----	-----
26	Ravi	258	76.24054	32.98216	1.09	-----	-----
27	Ravi	259	76.25901	32.97749	2.38	-----	-----
28	Ravi	260	76.90463	32.21336	0.24	-----	-----
29	Ravi	261	76.90863	32.21021	0.39	-----	-----
30	Ravi	15HWL	76.34447	32.33204	3.00	2.79	+0.21
31	Ravi	16HWL	76.33092	32.33679	**29.19**	**11.35**	**+17.84**
32	Ravi	17HWL	76.32602	32.34247	2.30	-----	-----

33	Ravi	250HWL	76.31628	32.34299	3.98	-----	-----
34	Ravi	251HWL	76.31116	32.34236	1.05	-----	-----
35	Ravi	252HWL	76.30389	32.34544	2.77	-----	-----
36	Ravi	253HWL	76.30143	32.34649	0.34	-----	-----
37	Ravi	2HWL	76.32189	32.34299	1.14	-----	-----
38	Ravi	39SG	77.0217	32.39742	0.94	1.08	+0.14

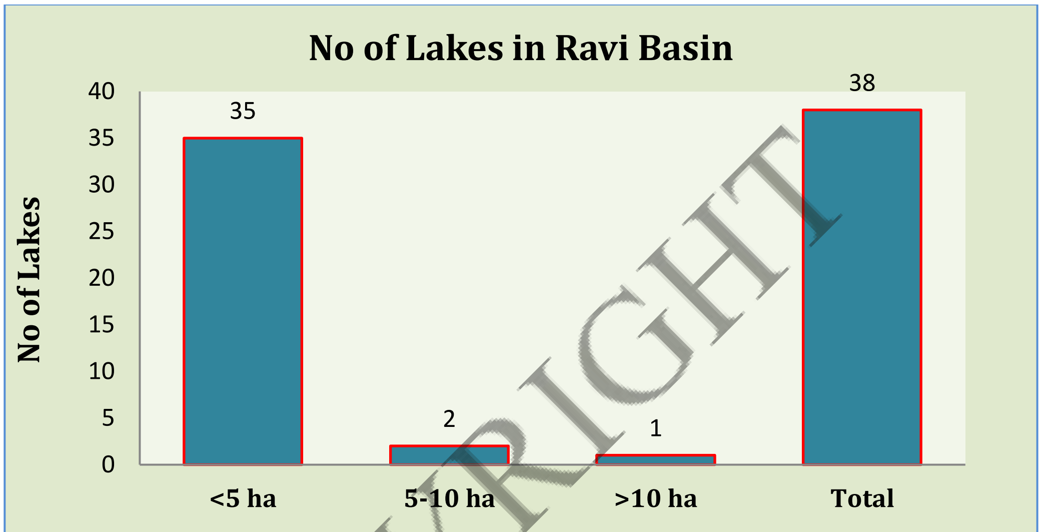


Fig.10.3.2 Distribution of lakes in Ravi basin (2019)

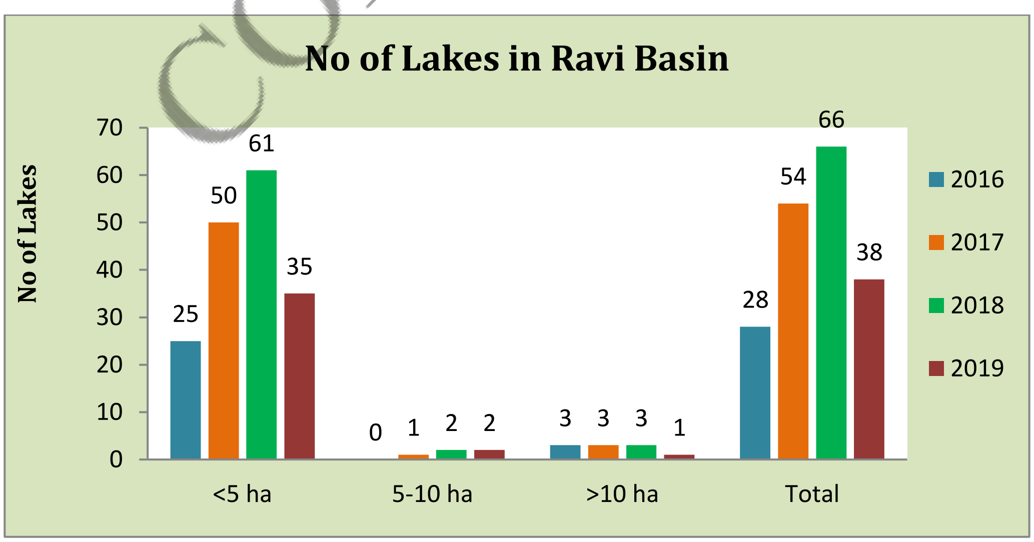


Fig.10.3.3 Distribution of lakes in Ravi basin in 2016, 2017, 2018 & 2019

10.4. Inventory of lakes in Satluj River Basin:

IRS LISS-III Resourcesat 2 satellite data having spatial resolution of 23.5mts have been used for generating a more detailed inventory of glacial lakes/high altitude wetlands in Satluj catchment and was compared with that of the information generated for the year 2018 using LISS-III satellite data. The inventory based on LISS-III satellite data is more detailed one as this sensor has the better spatial resolution (23,5mt) than AWIFS (56mts) and thus gives more information about the terrain. Satellite data for the month of July to October 2019was browsed and good quality cloud free data was selected for the mapping purpose as during this period the glacier surfaces are completely exposed and liable to give more detailed information about the glacier regions. During the year 2019, good quality data could not obtained by virtue of the area under the impact of snow cover for a longer period and the thereafter the cloud cover during the monsoon season. The study area is covered by LISS-III coverage mainly by seven number of scenes within 96-48, 96-49, 97-48, 97-49, 98-48, 99-49 and 100-49path and rows and have been analyzed using visual interpretation techniques and the same methodology adopted for the AWIFS satellite data. As far as data availability is concerned, an attempt has been made to get the best quality data products during August/September, but still in parts the impacts of cloud cover or snow could be seen. Due to non-availability of good quality cloud free data during August/September, the available data during October has also been used in the interpretation purpose wherein the impact of fresh snow could be seen. The study area covered by path – row96-48 of 20 August 2019 (Fig.10.4.4b) shows that the area is not fully exposed but is under the impact of snow cover and partial cloud cover as a result of which not much information could be derived. Likewise 96-49 of 14 October 2019 (Fig10.4.5b) does also show the snow cover impacts resulting to have not much area as fully exposed. The study area covered under path row 97-48 for the period 12 October 2019 (Fig 10.4.6b) and 97-49 for 12October 2019(Fig 10.4.7b) does also show snow cover impacts as a result of which not information is derived. On the extreme eastern part of the study area which is covered by 98-48 for 06 September 2019(Fig.10.4.7b) is partially exposed .Likewise the area covered under path row 99-49 for 22October 2019(Fig.10.4.8b) and 100-49 covered by 10October 2019 (Fig 10.4.9b) does also show the snow cover impacts ,but it has become possible to extract information to some extent. Thus based on the above LISS III satellite data products for the above mentioned path and rows, a total of 562 lakes could be delineated in 2019 (73 in Spiti basin i.e. sub basin 1, 52 in Lower Satluj basin i.e sub basin 2 and 437 in Upper Satluj i.e. sub basin 3) in comparison to the total 769 lakes as mapped in 2018. The difference in the total number of lakes is mainly due to the non-availability of good quality snow free and cloud free data coverage.

Further detailed analysis for 2019 based on different path and rows, it is found that the area being covered under the path-row 96-48, a total of 153(2019) lakes could be mapped against 275 lakes (2018) comprising majority of the lakes (127) as small one with area less than 5ha out of which 65 lakes forms part of the Spiti sub basin, 20 from the Lower Satluj and 42 from the Upper Satluj sub basin respectively. Likewise 17 lakes are within the aerial range of 5-10ha, out of which 6 lakes are from Spiti, 2 lakes from the Lower Satluj and 9 from the Upper Satluj sub basin, whereas 9 lakes are the big one having area more than 10ha comprising 02 from the Spiti, and 07 from the Upper Satluj sub basin respectively (Fig. 10.4.4c). Further analysis based on their classification reveals that out of 153 lakes, only 1 lakes is the high altitude wetland that too from the Spiti sub basin having area more than 10ha(Fig. 10.4.4d). Likewise from the satellite data covering path-row 96-49, a total of 33 lakes could be delineated against 93(2018) lakes out of which 32 lakes are having area less than 5ha and 1 lake having area more than 10ha respectively (Fig. 10.4.5c) comprising 30 from the lower Satluj and 3 lakes from the Upper Satluj basin respectively.(Fig. 10.4.5d) and 1 lakes is high altitude wetland.

Based on the satellite data interpretation covering path row 97-48, a total of 59 lakes could be mapped against the 52(2018) lakes out of which 52 lakes are of area less than 5ha, 04 lakes are within the aerial range of 5-10ha and 3 lakes are having area more than 10ha and all these falls in the upper Satluj sub basin (Fig. 10.4.6c). Likewise from the data interpretation covering 97-49, a total 27 lakes could be mapped in comparison to the 20 lakes as mapped in 2018.Out of these 27 lakes mapped in 2019, 24 lakes are the small one with area less than 5ha, and 02 falling within the aerial range of 5-10ha and 01 lake is with area more than 10ha and all forms a part of the Upper Satluj sub basin (Fig. 10.4.7c).Further out of these 27 lakes, 3 lakes are the high altitude wetlands (Fig. 10.4.7d).

Based on the satellite data interpretation covering path row 98-48, a total of 15 lakes have been mapped forming part of the basin 3 i.e. Upper Satluj basin and all of which are small one with area less than5ha (Fig. 10.4.8c).

Area covered under path row 99-49 and 100-49 mainly falls in Upper Satluj sub basin and based on interpretation in 99-49, a total of 238(2019) lakes have been mapped against the 238(2018) lakes forming part of the Upper Satluj basin. Further, out of which 185 lakes are the small one with area less than 5ha indicating a reduction of about 7% (14) lakes in comparison to 199 lakes(2018) .Likewise 28 lakes as mapped in 2019 are within aerial range 5-10ha indicating an increase of about 47% lakes in comparison to that of 19lakes (2018) within this category and 25 lakes are such which have the area more than 10ha indicating an increase of 5 lakes (25%) (Fig. 10.4.9c). Out of these 238 lakes, 60 lakes are mainly the high altitude wetlands comprising 45 of area less than 5ha, 04 are within the aerial range of 5-10ha and 11 having area more than 10ha (Fig. 10.4.9d). Likewise in 100-49 a total of 37 lakes could be mapped against the 54(2018) out of which 23lakes are having area less than 5ha, 02 are within aerial range 5-10ha and 12 are having area more than 10ha (Fig. 8.10c) and further out of these 8 lakes are mainly the high altitude wetlands (Fig. 10.4.10d).

Based on the further analysis of LISS III satellite data, it has been found that total number of lakes in Upper Satluj basin varies from 443(2016) to 450(2017) to 495(2018) to 437 (2019) thus by indicating a reduction of 6 lakes w.r.t. 2016 and 13 lakes w.r.t. 2017and 58 w.r.t. 2018data or in other words a reduction of about1%, 2%,and about 11% with reference to 2016, 2017 and 2018 database is observed respectively (Fig. 10.4.3) and this variation is mainly due the non-availability of good quality snow free and cloud free data coverage during 2019 in comparison to the receding years in almost all the LISS-III scenes. Likewise in Lower Satluj basin, total number of lakes mapped in 2019 varies from 72 (2016) to 102(2017) to 98(2018) to 52(2019) thus by indicating a decrease of about 27%, 49% and about 46% with reference to 2016, 2017 and 2018 (Fig. 10.4.2) and this large variation is again mainly due to the non-availability of god quality satellite data. Similarly in Spiti basin, the variation in the total number of lakes is from 66(2016) to 90(2017) to 176(2018) to 73(2019) thus by indicating an increase of about 10% w.r.t 2016 and a reduction of about 18% and 58% with reference to 2017 and 2018 respectively (Fig. 10.4.1). Further analysis of these 562 lakes mapped in the entire Satluj basin using LISS-III satellite data reveals that total number of lakes with area more than 10ha varies from 52(2017) to 49(2018)to 51(2019). Likewise based on the analysis for 2019 using LISS-III products, the total number of lakes with area less than 5ha are 458 (2019) in comparison to 663(2018) indicating a reduction of 205 lakes in comparison to 2018 and 73 lakes as that of 531(2017). Likewise the lakes within the aerial range of 5-10 ha has reduced by 06lakes with reference to 2017(59) and 04 lakes as that 2018(57). The large variation in the number of lakes with reference to the preceding years is mainly due to the non-availability of cloud free satellite data covering the entire catchment. Hence these small dimensional lakes/water bodies can be future vulnerable sites and thus needs proper monitoring using higher resolution satellite data for better management. The lakes with 1686 RS to 1688RS are the lakes formed along the river section due to debris coverer along the river course which are the potential vulnerable locations formed due to temporary damming along the stream course and thus needs monitoring.

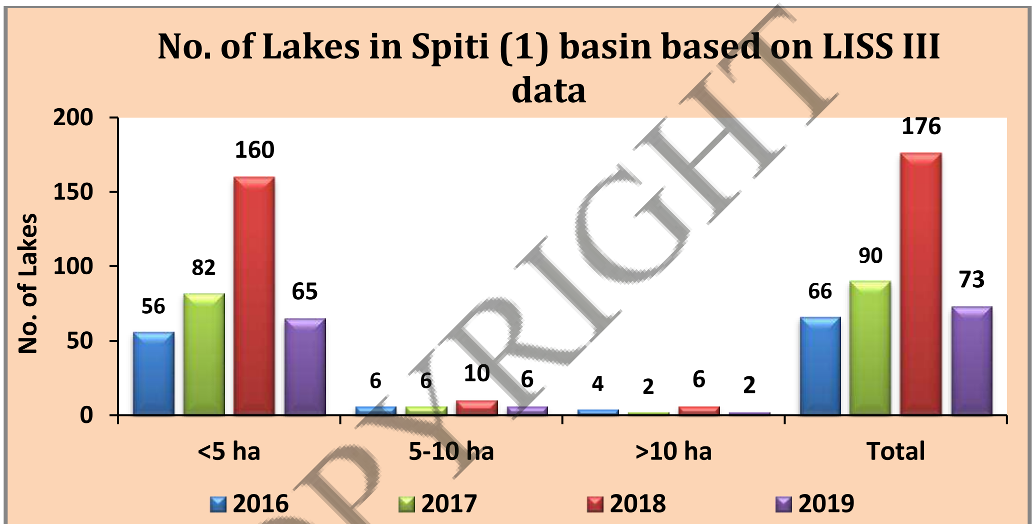


Fig. 10.4.1: No. of Lakes in Up. Satluj (3) basin based on LISS III data

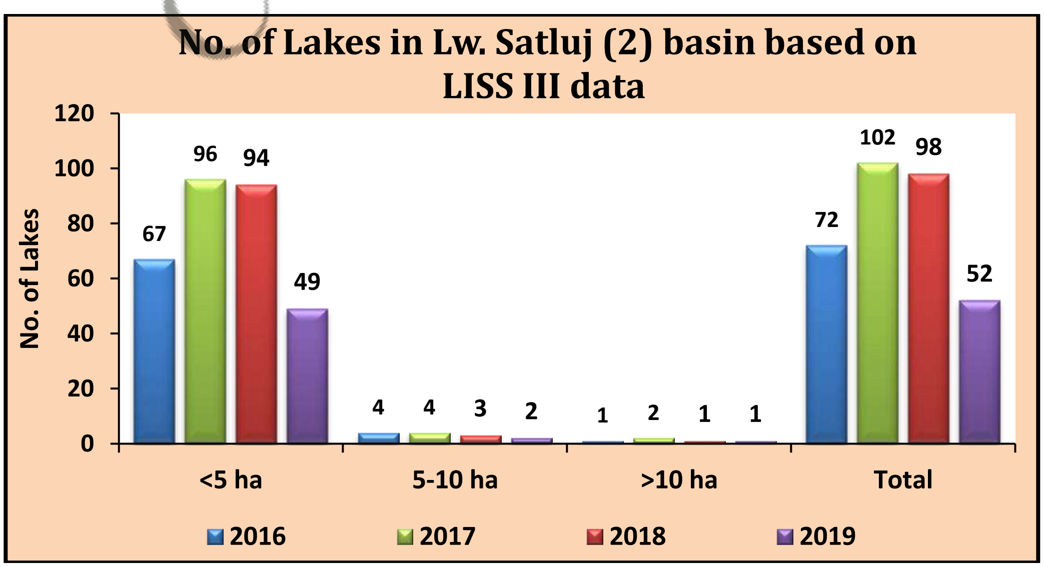


Fig. 10.4.2:No. of Lakes in Lw. Satluj (2) basin based on LISS III data

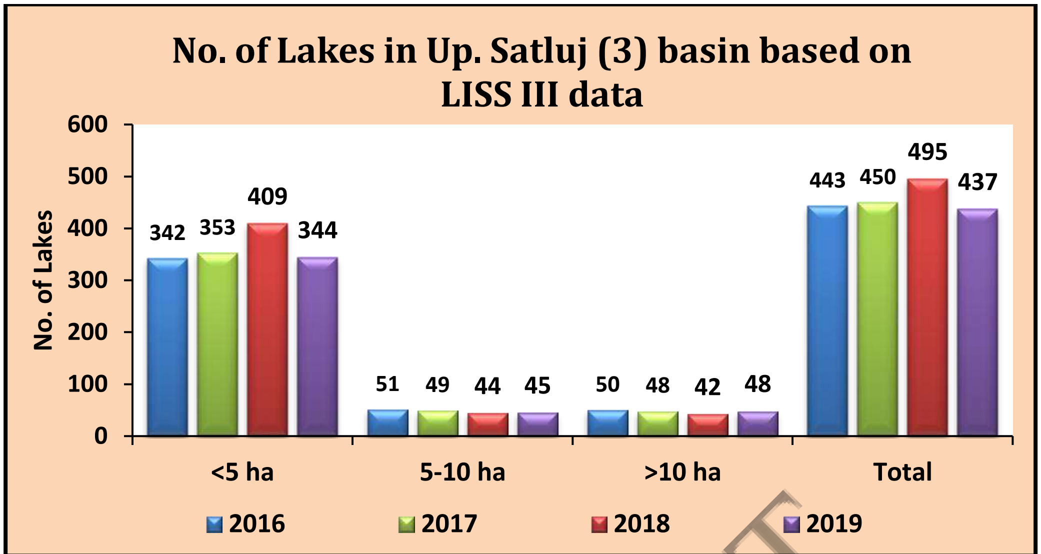


Fig. 10.4.3:No. of Lakes in Spiti (1) basin based on LISS III data

Table 10.4.1: Distribution of Lakes as per satellite data interpretation for the year 2019 using LISS-III sensor

Sr. No.	Lake Id.	Basin No.	Longitude	Latitude	Areal extent (in hectare) 20-Sep-2018	Areal extent (in hectare) 20-Aug-2019	Change in Area w.r.t. 20-Sep-2018
IRS RS2 LISS III 96-48							
1	37	1	78.688548	32.7076	5.5	5.30	-0.20
2	38	1	78.70808102	32.7106	3.8	2.56	-1.24
3	59	3	79.00066502	32.3286	2.3	1.68	-0.62
4	61	1	78.97223827	32.3248	7	7.18	0.18
5	67	3	79.0450196	32.2098	8	7.68	-0.32
6	**67**	**3**	**78.98108706**	**32.3187**	**------**	**24.58**	**------**
7	68	3	79.0283175	32.2236	7.5	6.30	-1.20
8	69	3	79.02123846	32.2076	2.8	2.54	-0.26
9	70	3	79.01172601	32.2148	2.5	1.80	-0.70
10	71	3	79.00708039	32.2245	2.8	2.60	-0.20
11	72	1	78.9848478	32.2255	1.7	2.28	0.58
12	74	1	78.97445046	32.1903	4.9	4.76	-0.14
13	75	1	78.96250459	32.1846	3	3.30	0.30
14	76	3	78.97400802	32.1700	1.6	1.59	-0.01
15	77	3	78.9793173	32.1603	8	9.77	1.77
16	80	1	78.92069404	32.1410	3.3	2.58	-0.72
17	81	1	78.92810491	32.1290	1.3	1.04	-0.26
18	82	3	78.94414334	32.1218	5	4.47	-0.53
19	84	3	78.9525497	32.1189	1.4	1.37	-0.03

20	85	3	78.94878896	32.1064	0.8	1.08	0.28
21	**85**	**3**	**78.16638926**	**31.6612**	**------**	**34.89**	**------**
22	**86**	**3**	**78.94270542**	**32.1067**	**10.6**	**10.10**	**-0.50**
23	**87**	**3**	**78.93341418**	**32.1065**	**10.5**	**10.41**	**-0.09**
24	88	3	78.94768286	32.0917	5.7	5.83	0.13
25	89	3	78.93109137	32.0919	1	0.80	-0.20
26	93	3	78.944807	32.0598	6	6.92	0.92
27	94	3	78.9117457	32.0176	6.1	6.39	0.29
28	95	3	78.9035495	32.0036	1.9	2.21	0.31
29	96	1	78.87766678	32.0194	2.5	1.70	-0.80
30	97	3	78.87565368	32.0169	8.3	5.73	-2.57
31	**99**	**1**	**78.84545717**	**32.0294**	**18.8**	**14.72**	**-4.08**
32	**101**	**3**	**78.84667434**	**31.9923**	**22.8**	**21.10**	**-1.70**
33	103	3	78.86822918	31.9569	3.6	3.85	0.25
34	105	3	78.83764894	31.9781	4.2	1.37	-2.83
35	106	3	78.8387227	31.9806	5.7	5.63	-0.07
36	**122**	**3**	**78.78526677**	**31.9189**	**16.5**	**16.86**	**0.36**
37	131	3	78.70096775	31.9177	0.8	0.71	-0.09
38	152	1	77.91397434	32.1366	3	2.47	-0.53
39	228	2	78.75181688	31.5533	------	6.42	------
40	405	2	78.41899161	31.4039	------	3.14	------
41	552	1	78.69873449	32.7043	5.1	3.90	-1.20
42	570	3	78.92932161	32.0629	1.6	0.92	-0.68
43	586	1	78.69986331	31.9130	5.5	5.56	0.06
44	589	1	78.71741164	31.9011	0.8	1.39	0.59
45	811	1	78.80797447	32.0577	10.3	9.86	-0.44
46	814	1	78.74533443	32.0471	0.7	0.90	0.20
47	816	1	78.74614701	32.0458	0.3	0.32	0.02
48	819	1	78.75566576	32.0444	0.7	0.81	0.11
49	820	1	78.75717483	32.0446	0.6	0.66	0.06
50	821	1	78.75891607	32.0411	2.2	1.76	-0.44
51	822	1	78.7626307	32.0404	0.7	0.65	-0.05
52	825	1	78.77005998	32.0400	0.3	0.55	0.25
53	848	2	78.7398157	31.7094	------	2.23	------
54	854	2	78.61034678	31.5640	------	2.92	------
55	891	2	78.36921715	31.4583	------	1.21	------
56	998	1	78.70693345	32.7075	2.7	1.11	-1.59
57	999	1	78.68224324	32.7063	0.8	1.10	0.30
58	1013	3	79.01847322	32.2762	2.6	3.06	0.46
59	1022	1	78.70308045	32.0356	0.4	0.95	0.55
60	1033	3	78.78477864	31.9052	------	0.52	------

61	1035	1	78.70591376	31.8869	0.5	0.80	0.30
62	1039	2	78.74883041	31.6614	------	0.75	------
63	1049	3	78.735336	31.5180	------	4.14	------
64	1209	2	78.73522539	31.5425	------	1.58	------
65	1213	3	78.73113282	31.5074	------	1.45	------
66	1218	2	78.42894651	31.4935	------	0.21	------
67	1219	2	78.43314968	31.5033	------	1.61	------
68	1220	2	78.43381334	31.5058	------	0.61	------
69	1230	1	78.87392816	32.0308	5.2	5.06	-0.14
70	1231	1	78.75972865	32.0389	0.5	0.45	-0.05
71	1232	1	78.78056543	32.0327	1	0.97	-0.03
72	1234	3	78.81945303	31.9291	1.3	1.45	0.15
73	1237	3	78.82276138	31.9299	0.7	0.73	0.03
74	1238	3	78.82316766	31.9327	0.8	1.26	0.46
75	1259	3	78.81296692	31.9629	4	1.97	-2.03
76	1619	2	78.37496886	31.4487	------	0.81	------
77	1623	2	78.40859428	31.4124	------	0.64	------
78	1624	2	78.42253113	31.4049	------	0.26	------
79	1625	2	78.42363723	31.4040	------	0.63	------
80	1626	2	78.42042954	31.3990	------	0.71	------
81	1628	2	78.43137992	31.4311	------	1.25	------
82	1638	2	78.42513046	31.4895	------	1.64	------
83	1640	2	78.42900181	31.4910	------	1.62	------
84	1646	2	78.74263626	31.6778	------	5.92	------
85	1647	3	78.79484414	31.8798	------	0.64	------
86	1648	3	78.79495475	31.8815	------	0.96	------
87	1652	3	78.82107818	31.9301	0.3	0.45	0.15
88	1653	3	78.82113622	31.9319	1.1	1.31	0.21
89	**1654**	**3**	**78.84098631**	**31.9136**	**18.5**	**22.28**	**3.78**
90	1656	1	78.75264762	32.0425	0.5	0.76	0.26
91	1658	1	78.77934657	32.0340	0.7	0.45	-0.25
92	1660	1	78.7884155	32.0307	0.2	0.20	0.00
93	1663	3	78.93300009	32.0612	1.1	0.47	-0.63
94	1668	1	78.865013	32.0853	1.9	1.64	-0.26
95	1692	1	78.70366008	32.7074	0.4	0.40	0.00
96	1693	1	78.70244337	32.7074	0.5	0.40	-0.10
97	1694	1	78.70171404	32.7052	1.8	1.37	-0.43
98	2100	2	78.71788846	31.5309	------	2.38	------
99	2107	2	78.48930832	31.4008	------	3.19	------
100	2108	2	78.67094811	31.4794	------	0.21	------
101	2109	1	78.69908705	32.7065	------	0.25	------

102	2111	1	78.7534602	32.0443	------	0.52	------
103	2112	1	78.70250003	32.0391	------	0.31	------
104	2113	3	78.8173055	31.9324	------	2.77	------
105	2114	3	78.81498386	31.9337	------	1.80	------
106	2115	3	78.8133587	31.9330	------	0.45	------
107	2116	3	78.8113853	31.9344	------	0.36	------
108	2117	1	78.82862354	31.9298	------	6.27	------
109	2117	1	77.97085782	32.2125	------	0.26	------
110	2118	3	78.36812341	32.3146	------	3.18	------
111	2118	1	78.82763684	31.9297	------	0.34	------
112	2119	3	78.26178093	32.0456	------	1.66	------
113	2119	1	78.82415436	31.9298	------	0.30	------
114	2120	1	78.22836948	32.0904	------	1.74	------
115	2121	3	78.88643815	32.0184	------	1.05	------
116	5045	1	78.90954663	32.3339	3.1	2.44	-0.66
117	5048	1	78.99225866	32.3163	1.3	0.94	-0.36
118	5049	1	78.99330946	32.3171	0.6	0.25	-0.35
119	5052	1	78.99292232	32.2545	1.5	1.83	0.33
120	5056	1	78.98683878	32.2214	0.5	0.42	-0.08
121	5058	3	78.99955892	32.2239	0.4	1.25	0.85
122	5063	1	78.96139849	32.1494	0.4	1.22	0.82
123	5064	3	78.97290193	32.1288	0.2	2.78	2.58
124	5068	3	78.9492314	32.1218	1.3	1.41	0.11
125	5073	1	78.90509804	32.1446	1.3	1.27	-0.03
126	5074	1	78.90987639	32.0984	1	1.17	0.17
127	5075	3	78.92738594	32.0935	0.2	0.45	0.25
128	5077	1	78.80140985	32.0803	0.2	0.31	0.11
129	5078	1	78.80381783	32.0809	1.4	1.05	-0.35
130	5079	1	78.80600553	32.0805	0.3	0.35	0.05
131	5080	1	78.80695354	32.0801	0.6	0.71	0.11
132	5081	1	78.81935054	32.0698	0.8	1.20	0.40
133	5095	3	78.84497457	31.9874	0.2	0.33	0.13
134	6004	1	78.71103043	31.8950	0.2	0.40	0.20
135	6013	3	78.83880976	31.9769	------	1.19	------
136	6014	1	78.83698147	31.9798	0.2	0.30	0.10
137	6015	3	78.68887983	32.7560	0.9	0.39	-0.51
138	6016	1	78.69689905	32.7550	0.5	0.69	0.19
139	6017	1	78.6974521	32.7498	1.6	0.49	-1.11
140	6019	1	78.68998593	32.7308	1.3	0.94	-0.36
141	6020	1	78.69175569	32.7079	------	0.34	------
142	6036	1	78.78120388	32.0319	0.5	0.56	0.06

143	1649SG	1	78.70084503	31.8969	0.5	0.51	0.01
144	1650SG	1	78.71262573	31.8982	1	0.75	-0.25
145	1682RS	1	78.09199131	32.4309	0.5	0.40	-0.10
146	1683RS	1	78.08923021	32.4276	1.3	1.09	-0.21
147	1684RS	1	78.08800305	32.4266	2.1	1.96	-0.14
148	1685RS	1	78.08284899	32.4227	4.1	1.44	-2.66
149	1686RS	1	78.06933856	32.4049	1.6	1.60	0.00
150	1687RS	1	78.0668654	32.4020	17	1.57	-15.43
151	**49HWL**	**1**	**78.71528643**	**32.3283**	**38**	**23.53**	**-14.47**
152	49HWL	1	78.72457767	32.3254	------	7.43	------
153	83(3)	3	78.94834652	32.1196	4.4	4.51	0.11

Sr. No.	Lake Id.	Basin No.	Longitude	Latitude	Areal extent (in hectare) 16-Sep-2018	Areal extent (in hectare) 14-Oct-2019	Change in Area w.r.t. 16-Sep-2018
IRS RS2 LISS III 96-49							
1	168	2	78.7227	31.3627	1.53	1.07	-0.46
2	**173**	**2**	**78.6981**	**31.2234**	**------**	**13.20**	**------**
3	865	3	78.7703	31.3611	0.87	0.67	-0.20
4	866	2	78.7327	31.3592	2.05	2.04	-0.01
5	869	2	78.7008	31.3268	------	1.36	------
6	870	2	78.6956	31.3259	------	1.39	------
7	871	2	78.6628	31.3334	------	1.10	------
8	1048	3	78.7215	31.3669	0.88	0.46	-0.42
9	1269	2	78.7165	31.3402	2.99	2.10	-0.89
10	1270	3	78.7571	31.3643	0.85	0.69	-0.16
11	1272	2	78.7591	31.3225	1.21	1.33	0.12
12	1273	2	78.7578	31.3222	1.15	0.46	-0.69
13	1274	2	78.7559	31.3215	1.56	1.17	-0.39
14	1275	2	78.7550	31.3242	0.79	0.74	-0.05
15	1714	2	78.3264	31.3107	0.53	0.52	-0.01
16	2101	2	78.7441	31.3759	------	0.20	------
17	2102	2	78.7432	31.3750	------	0.88	------
18	2103	2	78.7301	31.3504	------	0.41	------
19	2104	2	78.6686	31.3596	------	0.45	------
20	2105	2	78.6659	31.3538	------	0.40	------
21	2106	2	78.5820	31.3728	------	0.42	------
22	1216SG	2	78.5820	31.3650	0.65	0.43	-0.22
23	1264SG	2	78.6136	31.2491	0.62	0.30	-0.32
24	1265SG	2	78.6148	31.2487	------	0.35	------
25	1310SG	2	78.5555	31.2501	0.42	0.43	0.01

26	171HW	2	78.7967	31.3697	2.27	2.72	0.45
27	582(1)	2	78.3301	31.3152	1.08	0.41	-0.67
28	582(4)	2	78.3302	31.3120	------	0.41	------
29	582(4)	2	78.3282	31.3139	4.5	2.31	-2.19
30	582(5)	2	78.3290	31.3105	0.61	0.40	-0.21
31	582(5)	2	78.3289	31.3113	------	0.21	------
32	582(5)	2	78.3299	31.3104	------	0.46	------
33	630SG	2	78.4755	31.2614	------	0.53	------

Sr. No.	Lake Id.	Basin No.	Longitude	Latitude	Area extent (in hectare) 25-Aug-2018	Areal extent (in hectare) 12-Oct-2019	Change in Area w.r.t. 25-Aug-2018
IRS RS2 LISS III 97-48							
1	**184**	**3**	**79.3935**	**32.3759**	**25.5**	**23.32**	**-2.18**
2	198	3	79.8187	32.0205	1.4	1.16	-0.24
3	199	3	79.8279	32.0179	2.9	3.26	0.36
4	200	3	79.8375	31.9878	2.9	3.74	0.84
5	201	3	79.8466	31.9919	3.9	2.91	-0.99
6	202	3	79.8728	31.9773	8.4	8.32	-0.08
7	203	3	79.8827	31.9695	2.4	3.44	1.04
8	204	3	79.8762	31.9679	3.7	3.65	-0.05
9	207	3	79.8782	31.9557	4.7	3.52	-1.18
10	208	3	79.8573	31.9496	35	1.51	-33.49
11	**209**	**3**	**79.8652**	**31.9255**	**------**	**33.76**	**------**
12	210	3	79.8829	31.9321	3.11	2.41	-0.70
13	211	3	79.9030	31.9272	1.5	0.94	-0.56
14	652	3	79.5944	32.3528	------	4.99	------
15	665	3	79.8908	31.9671	3.7	4.12	0.42
16	806	3	79.4777	32.4215	------	1.15	------
17	885	3	79.2529	32.5067	4.8	2.71	-2.09
18	887	3	79.2871	32.5198	0.3	0.54	0.24
19	890	3	79.2917	32.5131	0.8	1.44	0.64
20	891	3	79.2971	32.5118	1	1.06	0.06
21	**894**	**3**	**79.4171**	**32.3884**	**9.7**	**10.15**	**0.45**
22	895	3	79.4056	32.3506	4.7	3.62	-1.08
23	900	3	79.5905	32.3536	1.2	1.39	0.19
24	1007	3	79.4779	32.4186	------	0.60	------
25	1008	3	79.4717	32.4180	------	0.45	------
26	1014	3	79.6835	32.2540	4.6	5.25	0.65
27	1017	3	79.7062	32.2152	1.6	1.92	0.32
28	1023	3	79.8135	32.0292	1.5	1.25	-0.25

29	1029	3	79.9209	31.9336	1.2	1.36	0.16
30	1728	3	79.5086	32.3824	------	2.24	------
31	1732	3	79.8023	32.1254	1.9	1.86	-0.04
32	1733	3	79.8050	32.1167	2.5	2.35	-0.15
33	1734	3	79.8033	32.1126	0.8	0.60	-0.20
34	1738	3	79.8802	31.9630	2.8	2.40	-0.40
35	1739	3	79.8755	31.9580	1	0.79	-0.21
36	2121	3	79.9072	31.9171	------	1.33	------
37	2122	3	79.8675	31.9668	------	0.31	------
38	2123	3	79.8164	32.0272	------	0.94	------
39	2124	3	79.8013	32.0586	------	0.85	------
40	2125	3	79.7797	32.0626	------	0.24	------
41	2126	3	79.7739	32.0957	------	0.74	------
42	2127	3	79.7751	32.1195	------	0.31	------
43	2128	3	79.6461	32.2872	------	0.89	------
44	2129	3	79.5819	32.3260	------	1.00	------
45	2130	3	79.5735	32.3315	------	0.94	------
46	2131	3	79.5334	32.3705	------	1.85	------
47	2132	3	79.1300	32.4470	------	4.33	------
48	2133	3	79.1303	32.4624	------	2.91	------
49	2134	3	79.1027	32.3542	------	2.20	------
50	2135	3	79.0514	32.3473	------	5.17	------
51	2136	3	78.7926	31.4499	------	7.41	------
52	2141	3	78.7955	31.3699	------	1.50	------
53	6075	3	79.2711	32.5284	0.3	1.86	1.56
54	6079	3	79.7787	32.1189	0.4	0.50	0.10
55	6080	3	79.7859	32.1065	0.4	0.20	-0.20
56	6083	3	79.8114	32.0279	0.8	0.99	0.19
57	6086	3	79.8749	31.9591	0.2	0.30	0.10
58	6089	3	79.9165	31.9250	1.1	0.89	-0.21
59	6090	3	79.8767	31.9400	0.6	0.40	-0.20

Sr. No.	**Lake Id.**	**Basin No.**	**Longitude**	**Latitude**	**Area extent (in hectare) 25-Aug-2018**	**Areal extent (in hectare) 12-Oct-2019**	**Change in Area w.r.t. 25-Aug-2018**
IRS RS2 LISS III 97-49							
1	673	3	79.5699	31.0918	1.8	1.70	-0.10
2	1066	3	79.5147	31.1317	5	5.31	0.31
3	1290	3	79.3197	31.1542	------	0.81	------
4	1291	3	79.3422	31.1530	4.2	3.98	-0.22
5	1292	3	79.3578	31.1502	1	1.52	0.52

6	1293	3	79.3623	31.1496	------	0.41	------
7	1294	3	79.3666	31.1436	4.1	4.44	0.34
8	1295	3	79.4117	31.0604	4	3.99	-0.01
9	1296	3	79.4163	31.0616	------	0.98	------
10	1296	3	79.4148	31.0597	4.8	3.77	-1.03
11	1297	3	79.4382	31.1145	------	0.37	------
12	1301	3	79.4365	31.1085	------	0.45	------
13	1742	3	79.5702	31.0933	0.6	0.81	0.21
14	2137	3	79.6146	31.0594	------	0.39	------
15	2138	3	79.6142	31.0562	------	0.40	------
16	2139	3	79.6073	31.0420	------	0.43	------
17	2140	3	79.7488	31.0136	------	0.71	------
18	6092	3	79.4925	31.1308	1.8	1.26	-0.54
19	6093	3	79.4919	31.0975	1.9	1.62	-0.28
20	7091	3	79.6092	31.0306	1.4	1.40	0.00
21	7092	3	79.6192	31.0352	0.5	0.41	-0.09
22	7094	3	79.6535	31.0716	1.5	0.91	-0.59
23	7095	3	79.6567	31.0735	0.5	0.46	-0.04
24	7096	3	79.7310	31.0284	7.4	7.82	0.42
25	**1063 HWL**	**3**	**79.6010**	**31.3056**	**------**	**44.03**	**------**
26	1743 HWL	3	79.3069	31.2325	4.2	4.06	-0.14
27	6091 HWL	3	79.3018	31.2398	------	0.66	------

Sr. No.	Lake Id.	Basin No.	Longitude	Latitude	Area Extent (in hectare) 06sep2019
IRS RS2 LISS III 98-48					
1	2142	3	79.77324861	32.12014173	0.40
2	2143	3	79.75060127	32.14521108	1.11
3	2144	3	79.76201987	32.13400793	0.55
4	2144	3	79.80015368	32.10998578	0.54
5	2145	3	79.76880639	32.13357704	2.28
6	2145	3	79.8002614	32.10718499	1.40
7	2146	3	79.79681428	32.10567688	1.02
8	2148	3	79.77218704	32.09636251	0.55
9	2149	3	79.8016618	32.07831533	3.58
10	2150	3	79.80898694	32.07422187	2.65
11	2151	3	79.81114139	32.04018151	1.00
12	2152	3	79.80941783	32.02833202	0.85
13	2153	3	79.87954526	31.95141806	0.45
14	2154	3	79.90141296	31.93084304	0.29

15	6079	3	79.77685796	32.1197171	0.55

Sr no	Lake id	Basin no	Longitude	Latitude	(Area extent in Hectare)06-July- 2018 hectare	Area extent (in hectare) 22-Oct-2019	Change in Area w.r.t. 06-July-2018
IRS RS2 LISS III 99-49							
1	98	3	81.4057	30.4656	1.54	0.97	-0.57
2	166	3	81.4306	30.4710	5.47	6.05	0.58
3	172	3	81.7213	30.4476	------	6.34	------
4	173	3	81.6763	30.4476	7.85	7.50	-0.35
5	174	3	81.4338	30.4483	8.13	8.92	0.79
6	**178**	**3**	**81.4320**	**30.4294**	**206.39**	**201.14**	**-5.25**
7	**179**	**3**	**81.7146**	**30.4294**	**25.6**	**24.26**	**-1.34**
8	**181**	**3**	**81.4636**	**30.4304**	**19.28**	**12.39**	**-6.89**
9	**184**	**3**	**81.7235**	**30.4193**	**15.52**	**19.96**	**4.44**
10	185	3	81.7473	30.4084	10.08	8.69	-1.39
11	282	3	81.7233	30.4269	3.62	3.07	-0.55
12	966	3	81.7417	30.4009	3.86	3.55	-0.31
13	968	3	81.6992	30.4546	------	2.64	------
14	969	3	81.6984	30.4303	3.89	3.88	-0.01
15	970	3	81.5142	30.4812	6.22	7.72	1.50
16	971	3	81.5146	30.4766	3.78	3.18	-0.60
17	972	3	81.4931	30.4542	2.35	1.36	-0.99
18	973	3	81.4969	30.4534	0.56	0.43	-0.13
19	975	3	81.4844	30.4962	0.41	0.98	0.57
20	976	3	81.4765	30.4870	1.07	0.46	-0.61
21	977	3	81.4759	30.4819	3.22	2.40	-0.82
22	978	3	81.4573	30.4367	5.15	2.76	-2.39
23	983	3	81.3937	30.4538	3.08	2.89	-0.19
24	989	3	81.4767	30.4260	1.87	1.45	-0.42
25	990	3	81.4805	30.4271	3.21	1.84	-1.37
26	996	3	81.4998	30.4589	2.07	3.20	1.13
27	1102	3	81.4874	30.4790	0.31	0.32	0.01
28	1142	3	81.7751	30.4026	------	0.51	------
29	1143	3	81.8529	30.4021	------	5.23	------
30	1145	3	81.7757	30.4006	------	1.17	------
31	1147	3	81.7763	30.3985	------	3.12	------
32	1148	3	81.7786	30.3981	------	0.60	------
33	1149	3	81.7701	30.3963	------	5.42	------

34	1151	3	81.7844	30.3954	------	2.18	------
35	1152	3	81.7734	30.3941	------	1.27	------
36	1395	3	81.4137	30.4595	1.57	2.71	1.14
37	1443	3	81.7624	30.9885	1.86	1.40	-0.46
38	1445	3	81.7236	31.0696	8.84	7.61	-1.23
39	1446	3	81.7254	31.0566	0.6	0.50	-0.10
40	1447	3	81.7288	31.0513	0.85	0.87	0.02
41	1448	3	81.6862	31.0280	0.75	0.85	0.10
42	1449	3	81.6852	31.0270	0.41	0.52	0.11
43	1453	3	81.5423	31.1171	10.27	9.74	-0.53
44	1454	3	81.5452	31.1020	5.67	6.09	0.42
45	1455	3	81.5509	31.0932	1.53	1.03	-0.50
46	1456	3	81.5558	31.0903	1.41	1.78	0.37
47	1457	3	81.5617	31.0937	1.81	2.32	0.51
48	1458	3	81.5478	31.0786	2.32	1.91	-0.41
49	1459	3	81.5317	31.0950	1.94	1.95	0.01
50	1460	3	81.5299	31.0923	3.01	2.26	-0.75
51	1462	3	81.5200	31.0824	2.24	2.04	-0.20
52	1463	3	81.5147	31.0384	1.62	1.90	0.28
53	1465	3	81.5193	31.0307	1.53	0.46	-1.07
54	1467	3	81.4894	31.0060	1.36	1.26	-0.10
55	1469	3	81.5056	31.0720	1.25	0.92	-0.33
56	1470	3	81.5034	31.1118	8.72	7.82	-0.90
57	1471	3	81.5140	31.0985	4.75	4.23	-0.52
58	1472	3	81.5036	31.0943	6.28	5.60	-0.68
59	1473	3	81.4811	31.0806	3.01	3.24	0.23
60	1475	3	81.4258	31.0839	2.79	3.38	0.59
61	1476	3	81.4246	31.0800	2.25	1.26	-0.99
62	1477	3	81.4078	31.0554	3.81	3.09	-0.72
63	1479	3	81.4169	31.1020	3.36	2.80	-0.56
64	1480	3	81.4131	31.1039	1.37	1.37	0.00
65	1481	3	81.4229	31.1135	2.13	1.16	-0.97
66	1482	3	81.4354	31.1135	5.81	5.41	-0.40
67	1483	3	81.4244	31.1368	6.15	5.48	-0.67
68	1484	3	81.4076	31.1443	1.98	1.91	-0.07
69	1485	3	81.4135	31.1338	1.73	1.97	0.24
70	1486	3	81.4068	31.1252	------	1.46	------
71	1487	3	81.4024	31.1277	4.74	5.79	1.05
72	1488	3	81.3820	31.1388	8.8	8.32	-0.48
73	1493	3	81.2634	31.1245	0.2	0.31	0.11
74	1495	3	81.5561	30.7811	2.78	3.60	0.82

75	1495	3	81.2308	31.0600	------	6.96	------
76	1496	3	81.2065	31.0738	1.11	0.94	-0.17
77	1497	3	81.1960	31.0953	1.11	0.46	-0.65
78	1499	3	81.2272	31.1290	6.5	6.13	-0.37
79	1501	3	81.2309	31.1429	0.51	0.31	-0.20
80	1502	3	81.2321	31.1457	0.51	0.46	-0.05
81	1503	3	81.2348	31.1481	0.51	0.45	-0.06
82	1505	3	81.2251	31.1489	2.68	1.79	-0.89
83	1508	3	81.2153	31.1641	2.71	2.55	-0.16
84	1509	3	81.1996	31.1653	1.23	1.03	-0.20
85	**1510**	**3**	**81.1944**	**31.1824**	**54.38**	**52.93**	**-1.45**
86	1511	3	81.1780	31.1888	2.18	1.67	-0.51
87	**1512**	**3**	**81.1511**	**31.1785**	**24.23**	**21.47**	**-2.76**
88	1513	3	81.1397	31.1688	0.95	1.06	0.11
89	1514	3	81.1111	31.1598	2.83	2.60	-0.23
90	1515	3	81.1148	31.1679	2.38	2.48	0.10
91	1516	3	81.1294	31.1931	0.89	0.91	0.02
92	**1518**	**3**	**81.1472**	**31.1985**	**14**	**12.19**	**-1.81**
93	1519	3	81.1470	31.2038	1.06	0.77	-0.29
94	1520	3	81.1534	31.2081	2.16	1.73	-0.43
95	1524	3	81.1334	31.2210	1.15	0.54	-0.61
96	1525	3	81.1287	31.2177	0.71	3.96	3.25
97	1526	3	81.1447	31.2307	2.81	2.10	-0.71
98	**1527**	**3**	**81.1364**	**31.2343**	**11.43**	**11.37**	**-0.06**
99	1528	3	81.1415	31.2459	10.23	8.82	-1.41
100	1529	3	81.1290	31.2441	4.01	3.38	-0.63
101	1530	3	81.1243	31.2375	4.12	3.60	-0.52
102	1531	3	81.1250	31.2576	0.47	0.31	-0.16
103	1532	3	81.1162	31.2598	4.82	4.75	-0.07
104	1533	3	81.1153	31.2634	2.29	1.63	-0.66
105	1534	3	81.1087	31.2700	4.23	3.93	-0.30
106	1535	3	81.0842	31.2723	1.87	1.77	-0.10
107	1537	3	81.0887	31.2662	7.61	5.38	-2.23
108	1538	3	81.1126	31.2501	------	1.48	------
109	1539	3	81.1018	31.2437	4.1	4.58	0.48
110	1542	3	81.0829	31.2396	5.76	4.25	-1.51
111	1543	3	81.0675	31.2335	2.68	2.88	0.20
112	1545	3	81.0480	31.2899	0.4	0.46	0.06
113	1546	3	81.0464	31.2866	1.61	1.46	-0.15
114	1547	3	81.0322	31.2923	2.52	5.79	3.27
115	**1548**	**3**	**81.0313**	**31.2840**	**19.91**	**17.41**	**-2.50**

116	1549	3	81.0271	31.2767	2.53	2.31	-0.22
117	1550	3	81.0123	31.2949	2.86	3.06	0.20
118	1551	3	81.0109	31.3316	0.71	0.70	-0.01
119	1552	3	81.1323	31.2450	4.51	4.38	-0.13
120	1553	3	81.1347	31.2468	0.62	0.71	0.09
121	1554	3	81.2626	31.1227	1.2	0.92	-0.28
122	1744	3	81.0008	31.2868	0.5	0.75	0.25
123	1745	3	81.0190	31.3754	1.96	2.16	0.20
124	1748	3	81.0173	31.2062	2.88	2.83	-0.05
125	1751	3	81.1366	31.1616	1.11	1.42	0.31
126	1753	3	81.3213	31.1727	0.86	1.00	0.14
127	1754	3	81.3222	31.1602	0.4	0.39	-0.01
128	1754	3	81.4829	31.0389	0.86	0.81	-0.05
129	1755	3	81.3267	31.1385	1.88	2.75	0.87
130	1755	3	81.4657	31.0276	0.66	0.61	-0.05
131	1756	3	81.4582	31.0138	0.31	0.21	-0.10
132	1777	3	81.4661	30.4268	2.33	1.89	-0.44
133	1778	3	81.4680	30.4264	1.11	0.30	-0.81
134	1779	3	81.4702	30.4273	0.67	0.27	-0.40
135	1781	3	81.4837	30.4614	3.27	2.46	-0.81
136	2171	3	81.0849	31.2696	------	0.79	------
137	2172	3	81.1634	31.2218	------	0.50	------
138	2173	3	81.1378	31.1947	------	6.04	------
139	2174	3	81.1724	31.2093	------	3.87	------
140	2175	3	81.3952	31.1685	------	5.04	------
141	2176	3	81.4692	31.0356	------	1.59	------
142	2177	3	81.5187	31.1104	------	1.51	------
143	2178	3	81.6672	31.0259	------	1.98	------
144	2179	3	81.6684	30.9486	------	2.93	------
145	**2180**	**3**	**81.8537**	**31.0055**	------	**23.56**	------
146	2185	3	81.7781	30.3904	------	0.80	------
147	2190	3	80.9514	31.3421	------	0.75	------
148	2191	3	80.9544	31.3186	------	1.97	------
149	2192	3	80.8983	31.3415	------	0.71	------
150	2195	3	81.4111	30.4561	------	2.12	------
151	7029	3	81.4019	30.4767	1.22	1.02	-0.20
152	7035	3	81.4844	30.4645	0.36	0.31	-0.05
153	7037	3	81.4827	30.4627	0.26	0.31	0.05
154	7040	3	81.6998	30.4387	------	0.84	------
155	7042	3	81.7483	30.4041	------	0.30	------
156	7043	3	81.7570	30.4002	------	0.86	------

157	7055	3	81.4873	31.0062	------	0.40	------
158	7060	3	81.3667	31.1253	0.3	0.46	0.16
159	7064	3	81.3127	31.1495	0.76	0.80	0.04
160	7065	3	81.3124	31.1473	1.07	0.60	-0.47
161	7066	3	81.2977	31.1811	2.14	1.94	-0.20
162	7067	3	81.2480	31.1067	0.96	0.79	-0.17
163	7070	3	81.2010	31.1618	0.7	0.20	-0.50
164	7071	3	81.2056	31.1553	0.25	0.21	-0.04
165	7074	3	81.1135	31.2400	1.16	1.47	0.31
166	7075	3	81.0901	31.2416	0.39	0.50	0.11
167	7076	3	81.0903	31.2406	0.4	0.45	0.05
168	7079	3	81.0725	31.2591	0.41	0.46	0.05
169	7080	3	81.0713	31.2733	0.36	0.20	-0.16
170	7081	3	81.0683	31.2761	0.31	0.30	-0.01
171	7082	3	81.0235	31.2812	0.35	1.72	1.37
172	1031HW	3	81.5252	30.7761	1.28	1.71	0.43
173	**1039HW**	**3**	**81.7014**	**30.5141**	**9.76**	**12.16**	**2.40**
174	1074HW	3	81.2297	30.8917	1.12	1.44	0.32
175	1075HW	3	81.2323	30.8911	1.78	2.63	0.85
176	1088HW	3	81.5429	30.8181	0.57	1.38	0.81
177	1090HW	3	81.5415	30.7777	1.49	1.87	0.38
178	**1092HW**	**3**	**81.5656**	**30.7671**	**------**	**14.13**	**------**
179	1136HW	3	81.7787	30.4102	------	7.57	------
180	1139HW	3	81.7965	30.4229	------	2.90	------
181	**1144HW**	**3**	**80.5400**	**31.3991**	**------**	**89.47**	**------**
182	**1349HW**	**3**	**81.5674**	**30.8027**	**322.95**	**335.79**	**12.84**
183	1355HW	3	81.5504	30.7813	------	1.28	------
184	1356HW	3	81.5466	30.7794	------	0.65	------
185	1358HW	3	81.5543	30.7786	------	2.04	------
186	1359HW	3	81.5425	30.7876	------	3.19	------
187	1360HW	3	81.5423	30.7835	------	0.46	------
188	**1363HW**	**3**	**81.5456**	**30.7720**	**------**	**22.24**	**------**
189	**1375HW**	**3**	**81.3609**	**30.7046**	**------**	**28.96**	**------**
190	1376HW	3	81.2378	30.8908	------	2.28	------
191	1378HW	3	81.2317	30.8879	------	0.50	------
192	1380HW	3	81.2296	30.8856	------	3.05	------
193	1381HW	3	81.2151	30.8862	------	4.93	------
194	1383HW	3	81.2112	30.8939	1.08	2.63	1.55
195	1384HW	3	81.2079	30.8943	0.33	1.92	1.59
196	**138HWL**	**3**	**81.2532**	**30.6794**	**25634.8**	**25920.91**	**286.11**
197	1390HW	3	81.1937	30.8972	------	4.21	------

198	**145HWL**	**3**	**81.4814**	**30.6951**	**41233.9**	**41640.43**	**406.53**
199	**1557RS**	**3**	**81.1618**	**30.9143**	**80.87**	**92.85**	**11.98**
200	**1771RS**	**3**	**81.0934**	**30.9247**	**12.22**	**14.99**	**2.77**
201	1772RS	3	81.0999	30.9257	1.05	3.52	2.47
202	1773RS	3	81.1092	30.9239	2.33	2.52	0.19
203	**1774RS**	**3**	**81.1150**	**30.9246**	**11.69**	**12.93**	**1.24**
204	**1776RS**	**3**	**81.1425**	**30.9196**	**2.12**	**13.98**	**11.86**
205	**1782HW**	**3**	**81.7407**	**30.5481**	**29.1**	**30.65**	**1.55**
206	1784HW	3	81.7120	30.5593	2.9	2.68	-0.22
207	1786HW	3	81.7509	30.5414	0.5	1.03	0.53
208	205HWL	3	81.5659	30.7873	4.85	6.38	1.53
209	207HWL	3	81.5493	30.7841	4.8	6.34	1.54
210	208HWL	3	81.5542	30.7834	1.12	2.55	1.43
211	**210HWL**	**3**	**81.5541**	**30.7719**	**59.17**	**63.72**	**4.55**
212	211HWL	3	81.7077	30.5017	2.37	1.99	-0.38
213	2156HW	3	81.5395	30.7928	------	0.46	------
214	2157HW	3	81.5216	30.7921	------	0.41	------
215	2158HW	3	81.5132	30.7957	------	0.77	------
216	2159HW	3	81.5126	30.7930	------	0.25	------
217	2160HW	3	81.5114	30.7951	------	0.30	------
218	2161HW	3	81.5050	30.7982	------	1.32	------
219	2162HW	3	81.5034	30.7978	------	0.51	------
220	2163HW	3	81.5021	30.7979	------	0.20	------
221	2164HW	3	81.5466	30.7916	------	0.65	------
222	2165HW	3	81.5518	30.7813	------	0.30	------
223	2166HW	3	81.5504	30.7800	------	0.35	------
224	**2167HW**	**3**	**81.5896**	**30.7604**	**------**	**214.31**	**------**
225	2168HW	3	81.1853	30.8926	------	2.22	------
226	2169HW	3	81.1882	30.8927	------	2.15	------
227	2170RS	3	81.1056	30.9241	------	2.05	------
228	2188HW	3	81.7354	30.5534	------	1.51	------
229	2189HW	3	81.6821	30.5031	------	1.52	------
230	2196HW	3	81.5218	30.7758	------	0.65	------
231	257HWL	3	81.5695	30.7889	1.35	1.74	0.39
232	385HWL	3	81.5375	30.7777	3.75	5.32	1.57
233	7047HW	3	81.6911	30.5540	0.96	1.40	0.44
234	7088HW	3	81.7648	30.4199	3.88	3.70	-0.18
235	746HWL	3	80.5603	31.3684	------	1.43	------
236	960HWL	3	81.6929	30.4962	2.69	2.65	-0.04
237	961HWL	3	81.6951	30.4966	2.19	2.01	-0.18
238	962HWL	3	81.7016	30.4942	0.94	1.34	0.40

Sr. No.	Lake Id.	Basin No.	Longitude	Latitude	Areal extent (in hectare) 03-Oct-2018	Area extent (in hectare) 10-Oct-2019	Change in Area w.r.t. 03-Oct-2018
RS2 LISS III 100-49							
1	**1128**	**3**	**81.87000**	**30.4258**	**25.14**	**25.00**	**-0.14**
2	**1133**	**3**	**81.86838**	**30.4176**	**15.86**	**16.18**	**0.32**
3	1137	3	81.82013	30.4077	7.43	8.57	1.14
4	1141	3	81.88487	30.4026	5.66	2.30	-3.36
5	1144	3	81.78480	30.4002	6.48	5.23	-1.25
6	**1146**	**3**	**81.86512**	**30.3981**	**8.91**	**10.60**	**1.69**
7	1150	3	81.79152	30.3965	4.98	4.02	-0.96
8	**1153**	**3**	**81.92945**	**30.3808**	**69.2**	**74.10**	**4.90**
9	1154	3	81.79458	30.3921	0.55	0.82	0.27
10	**1155**	**3**	**81.81748**	**30.3897**	**17.47**	**14.27**	**-3.20**
11	**1156**	**3**	**81.89423**	**30.3906**	**11.69**	**11.74**	**0.05**
12	1157	3	81.83804	30.3910	1.57	2.34	0.77
13	1158	3	81.80241	30.3909	2.95	4.12	1.17
14	1159	3	81.81402	30.3918	0.28	0.71	0.43
15	1162	3	81.84761	30.3874	0.44	0.30	-0.14
16	1163	3	81.84364	30.3870	0.22	0.46	0.24
17	**1164**	**3**	**81.84008**	**30.3840**	**14.86**	**16.08**	**1.22**
18	1165	3	81.84680	30.3857	3.54	4.52	0.98
19	1166	3	81.83041	30.3836	0.17	1.08	0.91
20	1167	3	81.82420	30.3823	0.47	0.96	0.49
21	1168	3	81.82980	30.3803	3.54	4.71	1.17
22	1562	3	81.82226	30.3893	1.39	1.69	0.30
23	1564	3	81.84201	30.3789	4.45	3.93	-0.52
24	**1565**	**3**	**81.85372**	**30.4001**	**17.36**	**19.13**	**1.77**
25	2183	3	81.83030	30.3855	------	0.39	------
26	2184	3	81.81453	30.4007	------	0.44	------
27	2186	3	81.80099	30.4197	------	0.60	------
28	7089	3	81.80343	30.4071	0.21	0.26	0.05
29	7090	3	81.84578	30.4095	0.48	0.50	0.02
30	**1093HW**	**3**	**82.15910**	**30.6316**	**5854.36**	**5992.49**	**138.13**
31	**1094HW**	**3**	**82.07237**	**30.5970**	**12.62**	**14.85**	**2.23**
32	**1095HW**	**3**	**82.08336**	**30.5925**	**15.58**	**17.22**	**1.64**
33	1122HW	3	81.81585	30.4386	0.45	0.48	0.03
34	1123HW	3	81.81789	30.4383	0.34	0.55	0.21

35	1124HW	3	81.82023	30.4371	4.66	4.48	-0.18
36	**1566HW**	**3**	**82.03206**	**30.6630**	**18.76**	**10.77**	**-7.99**
37	1787HW	3	82.11553	30.5852	1.97	2.53	0.56

HWL= High Altitude Wetland RS= River Section

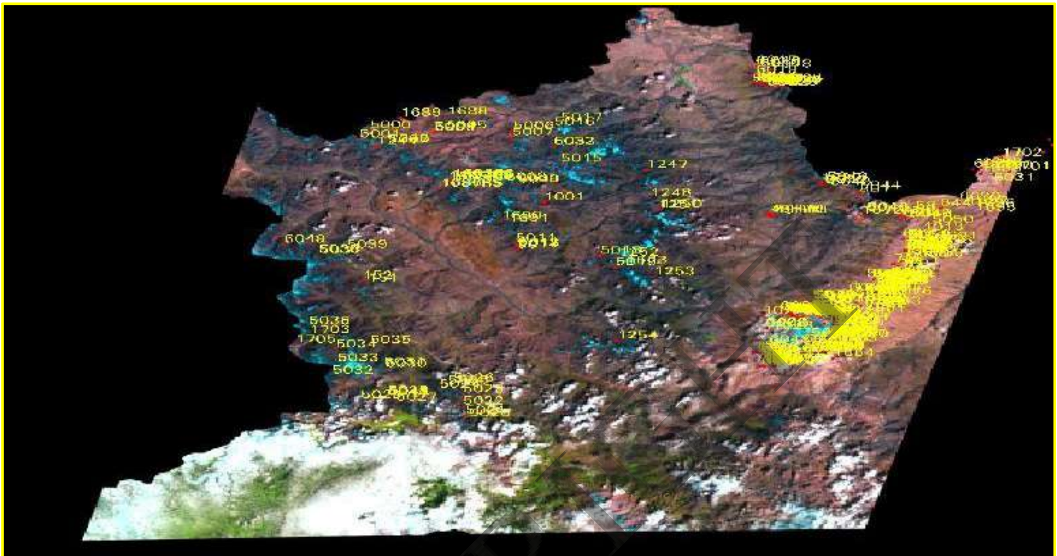


Fig.10.4.4 a: R2 LISS III image 96-48, 01 September 2018 & the Interpreted layer

Fig.10.4.4 b: R2 LISS III image 96-48, 20 August 2019 & the Interpreted layer

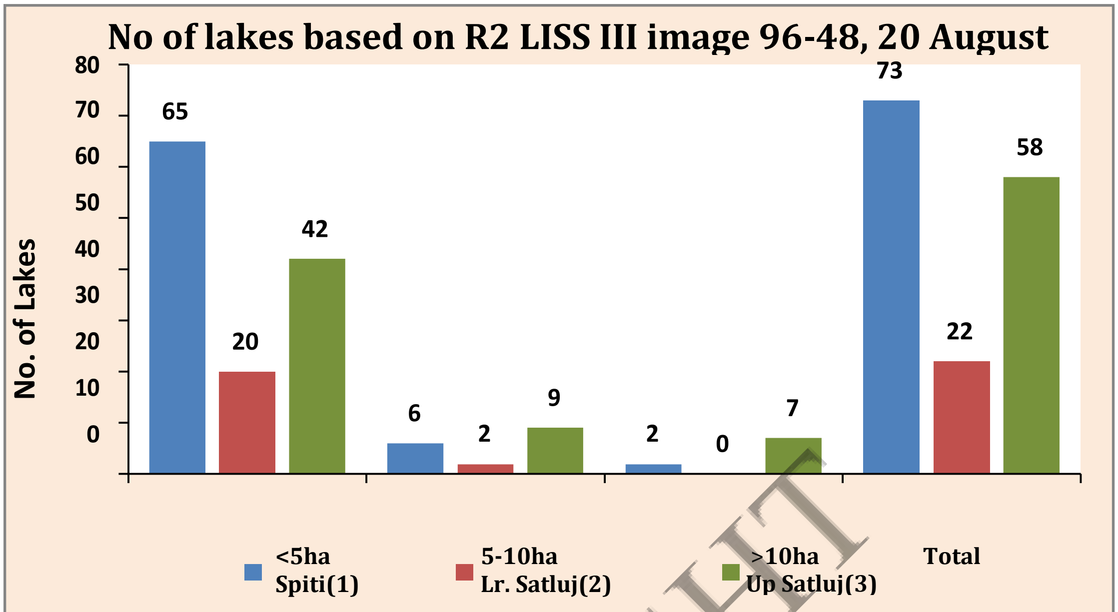


Fig.10.4.4 c: No. of lakes based on R2 LISS III image 96-48, 20August 2019

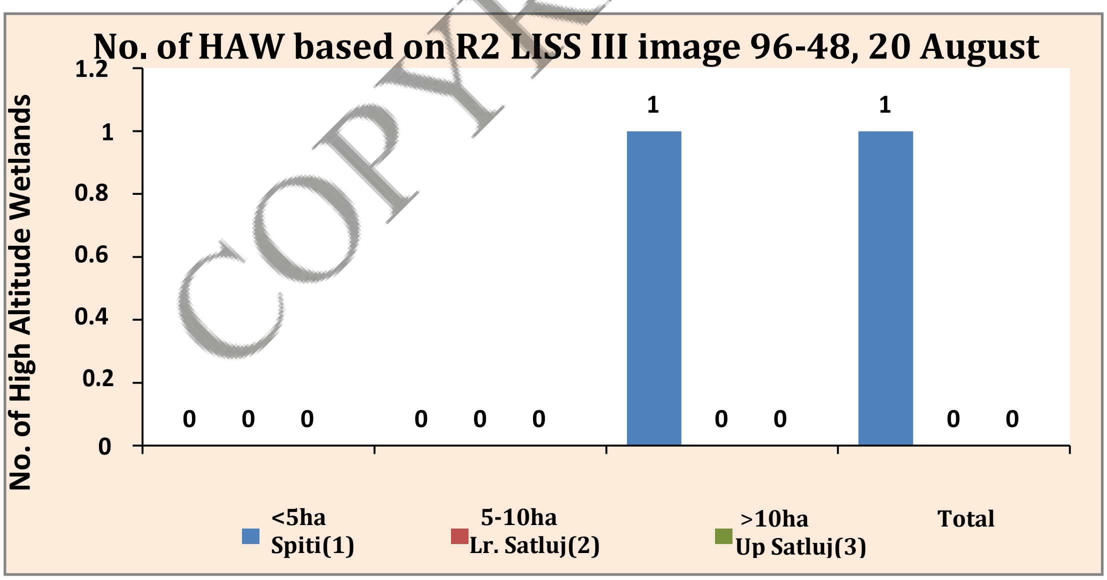


Fig.10.4.4 d : No. of high altitude wetlands based on R2 LISS III image 96-48, 20 August 2019

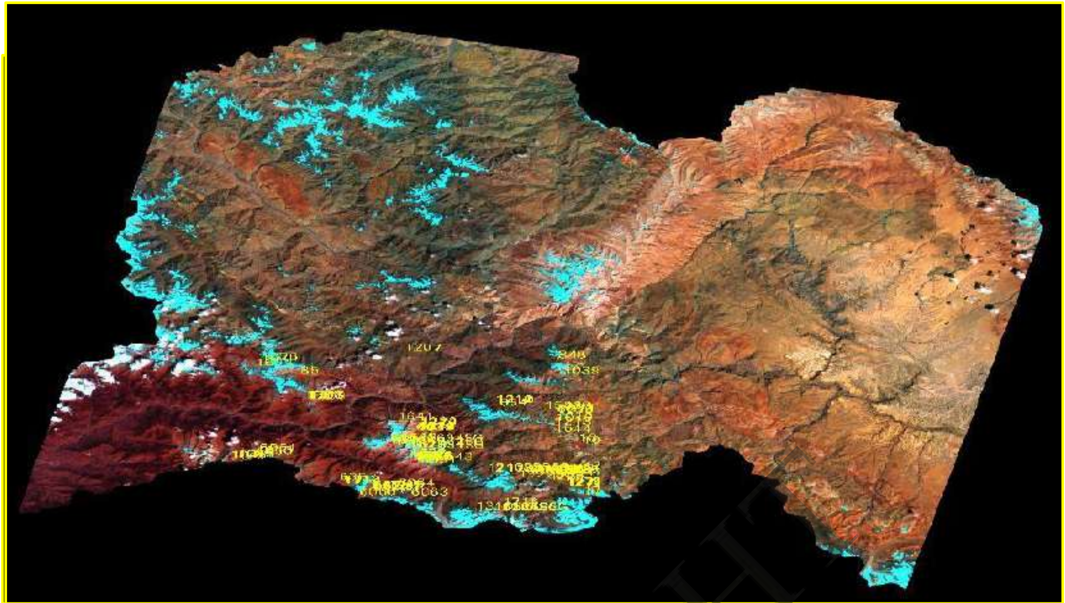


Fig.10.4.5a: Landsat image 146-38, 16 September 2018 & the Interpreted Layer

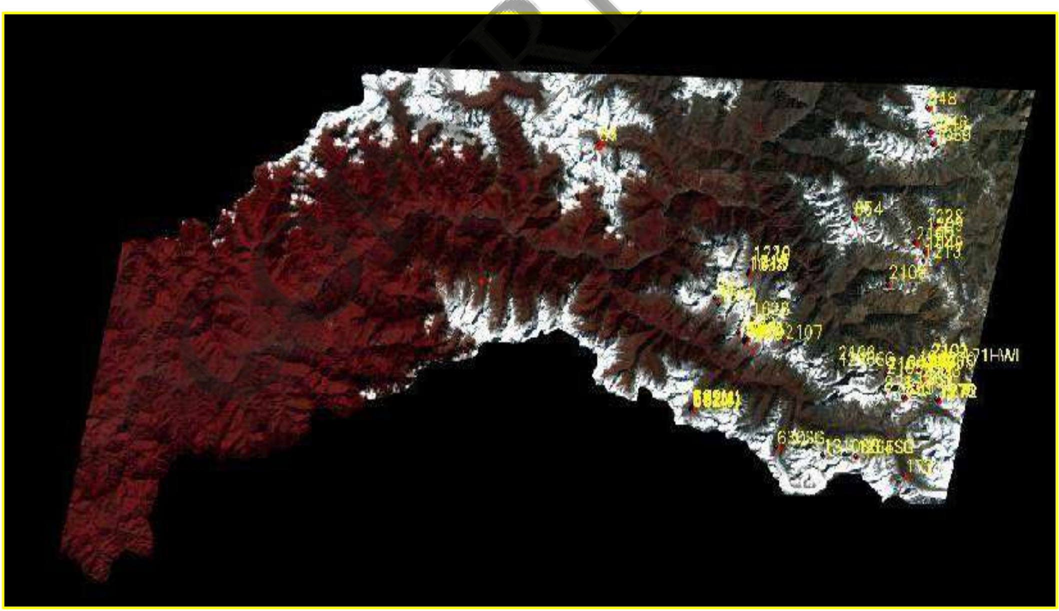


Fig. 10.4.5b: R2 LISS III image 96-49, 14 October 2019 & the Interpreted Layer

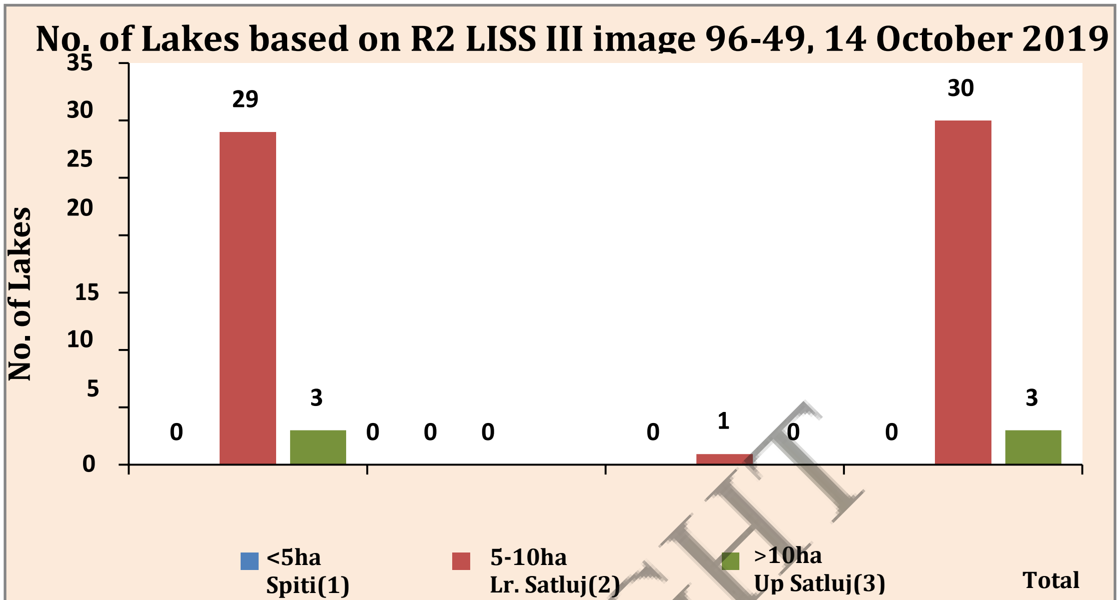


Fig.10.4.5c: No. of lakes based on R2LISS III image 96-49, 14 October 2019

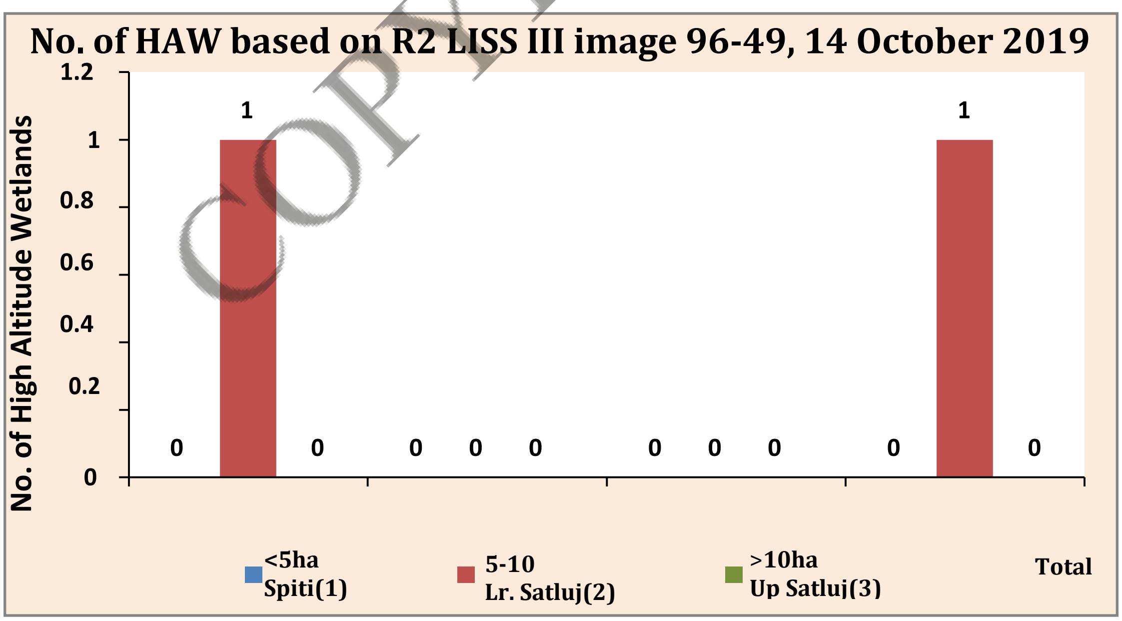


Fig.10.4.5d: No. of high altitude wetlands based on R2 LISS III image 96-49, 14 October 2019

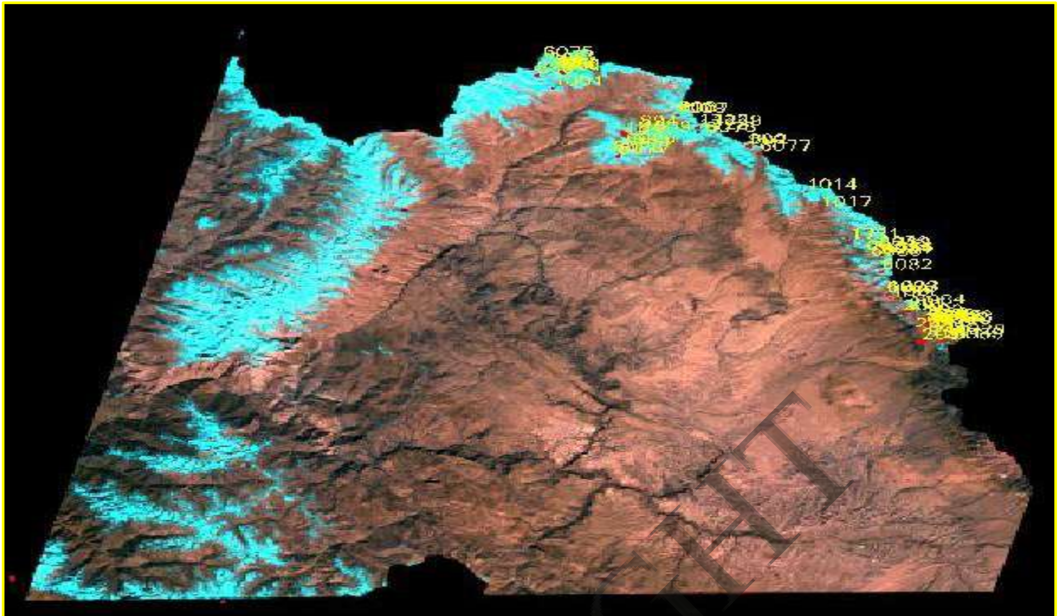


Fig.10.4.6 a: R2 LISS III image 97-48, 25 Aug 2018 & the Interpreted Layer

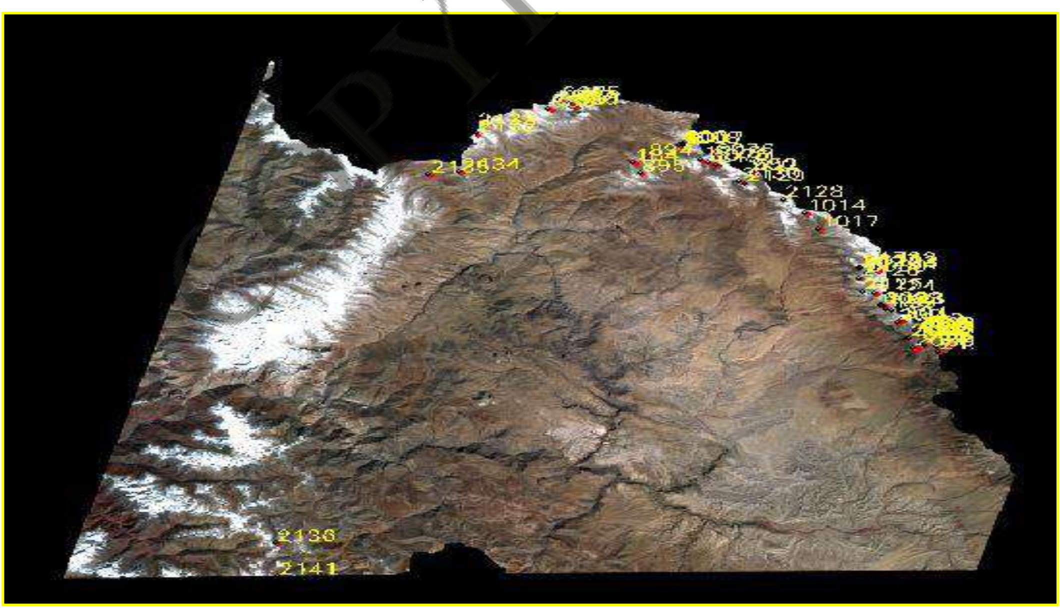


Fig.10.4.6 b: R2-2 LISS III image 97-48, 12 Oct 2019 & the Interpreted Layer

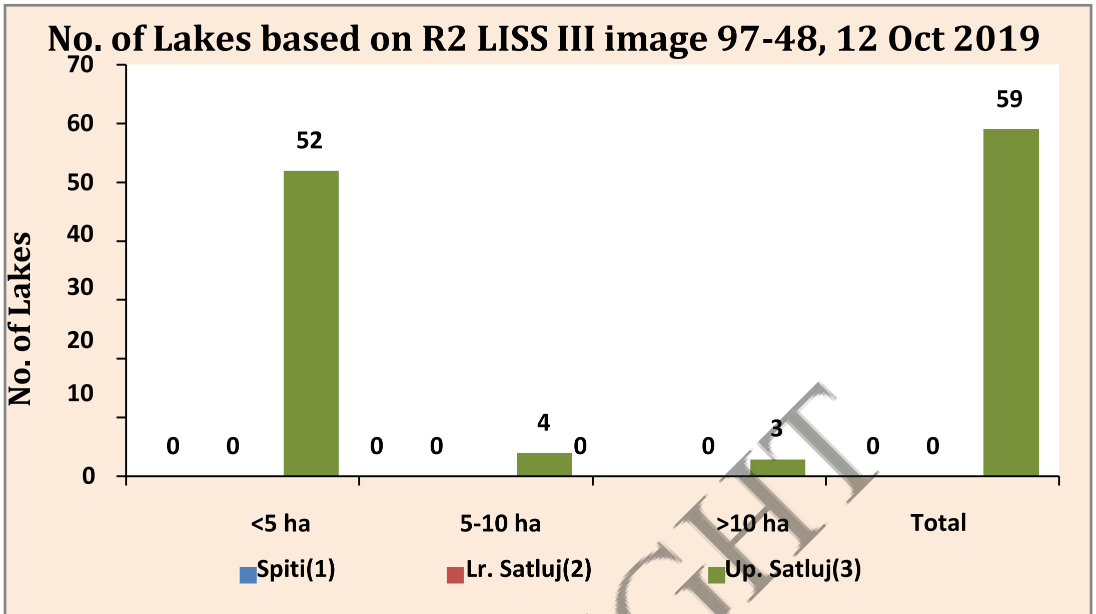


Fig.10.4.6c: No. of lakes based on R2 LISS III image 97-48, 12 Oct 2019

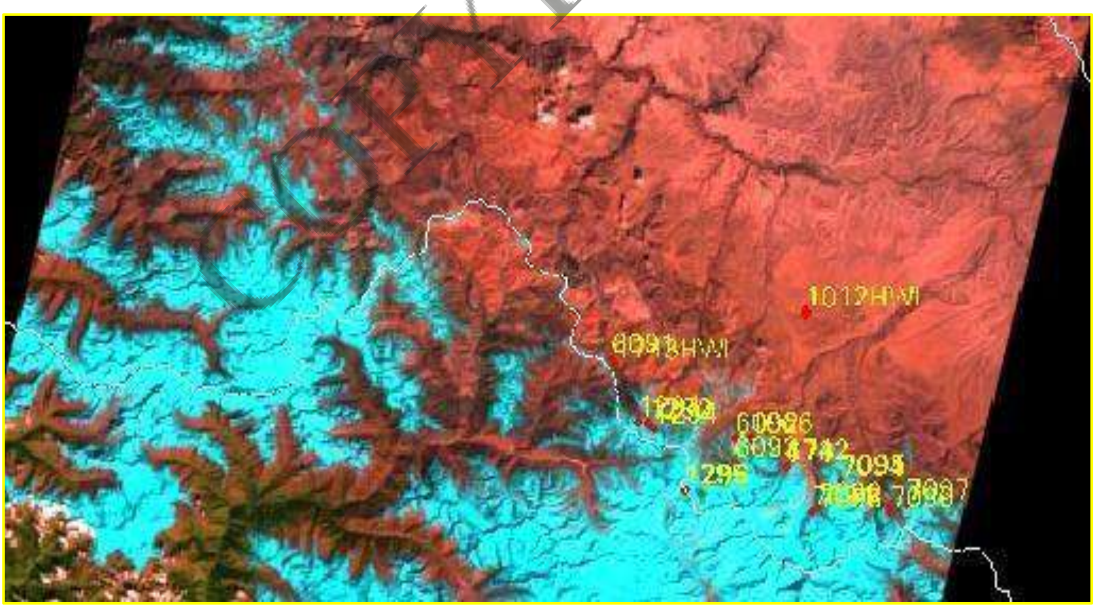


Fig.10.4.7a: R2 LISS III image 97-49, 30 Sep 2018 & the Interpreted Layer

Fig.10.4.7b: R2 LISS III image 97-49, 12 Oct 2019 & the Interpreted Layer

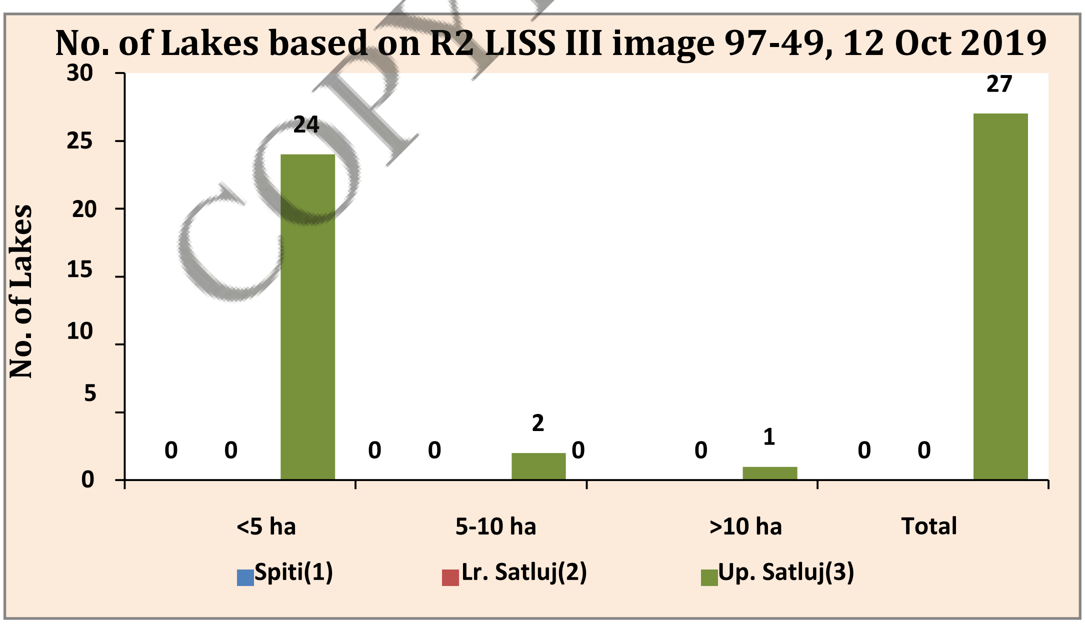


Fig.10.4.7c: No. of lakes based on R2 LISS III image 97-49, 12 Oct 2019

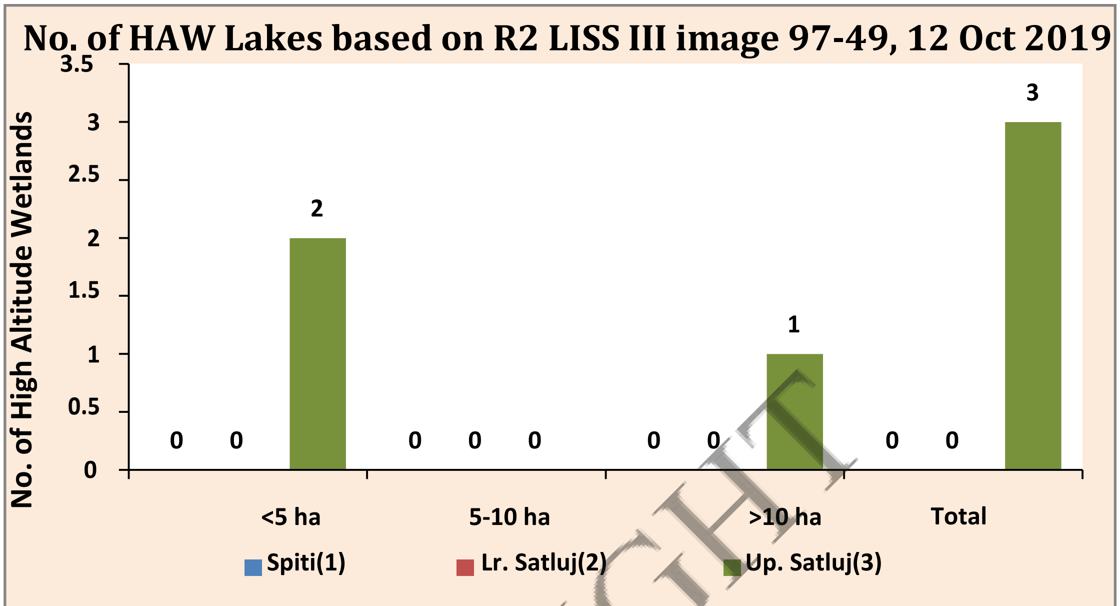


Fig.10.4.7d: No. of high altitude wetlands based on R2 LISS III image 97-49, 12 Oct 2019

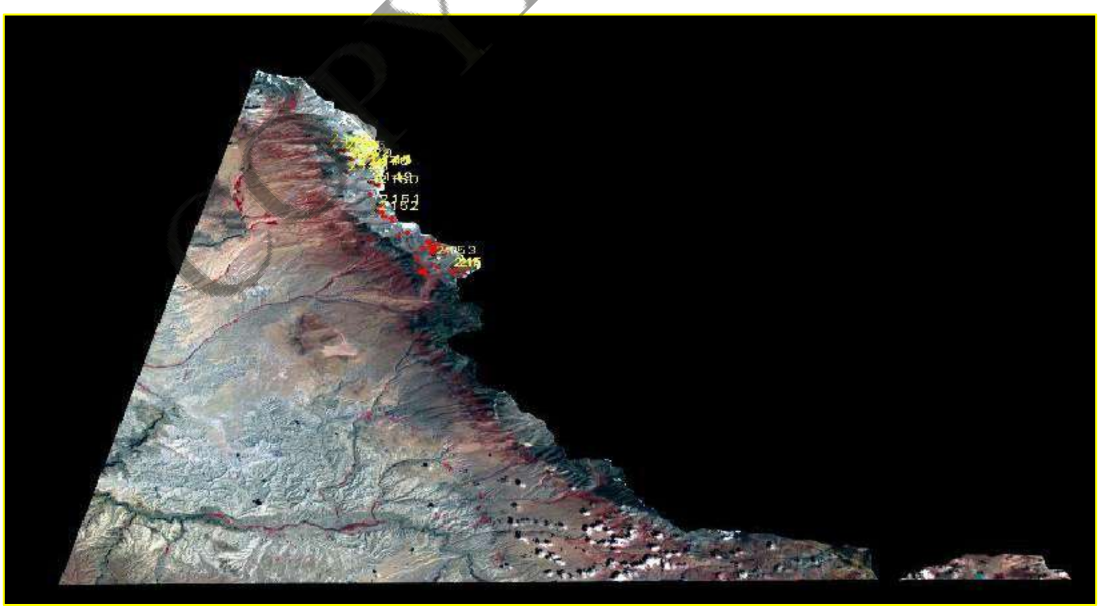


Fig.10.4.8 a: R2 LISS III image 98-48, 06 Sep 2019 & the Interpreted Layer

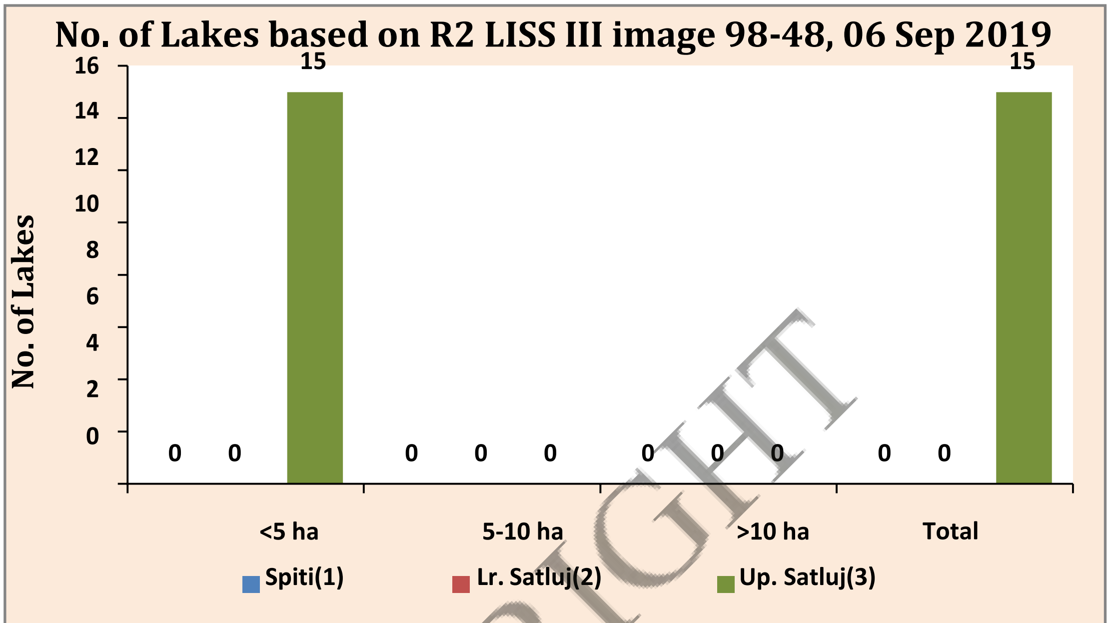


Fig.10.4.8b: No. of lakes based on R2 LISS III image 98-48, 06 Sep 2019

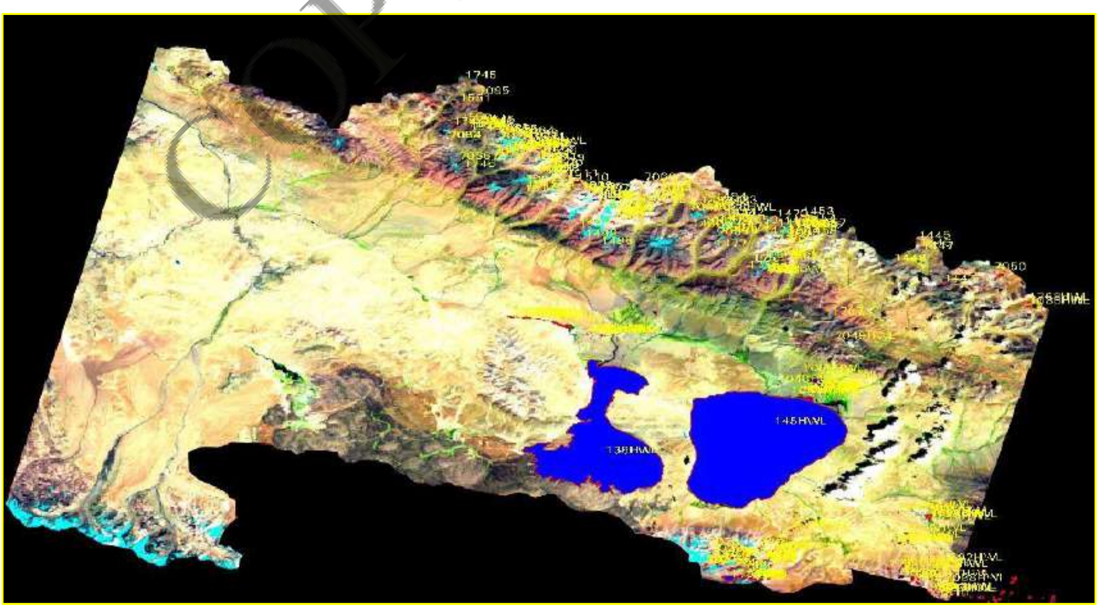


Fig.10.4.9a: R2 LISS III image 99-49, 06 July 2018 & the Interpreted Layer

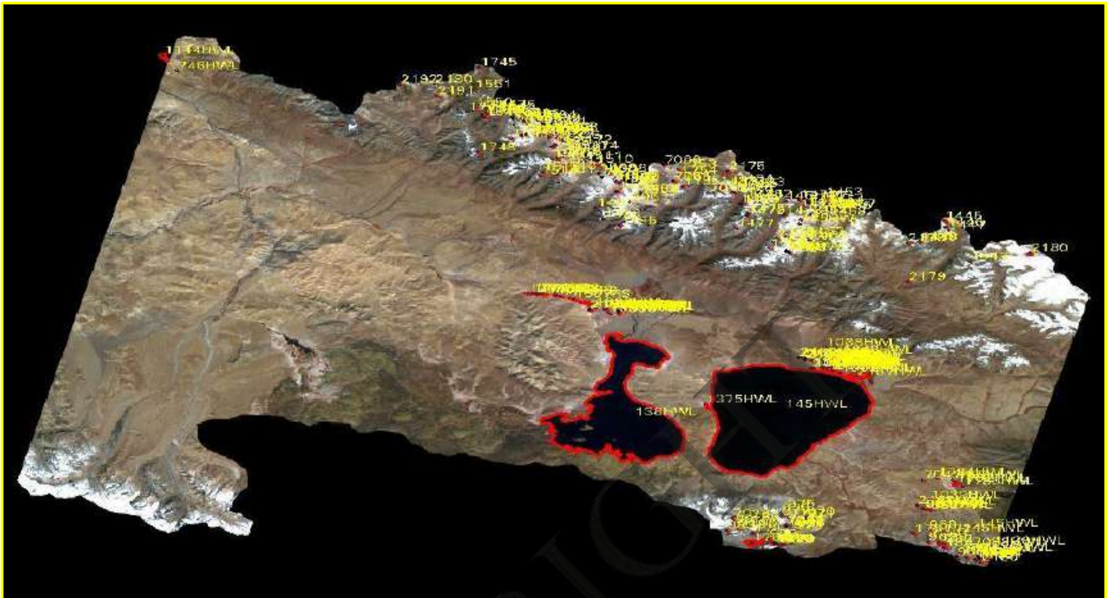


Fig.10.4.9b: R2 LISS III image 99-49, 22 Oct 2019 & the Interpreted Layer

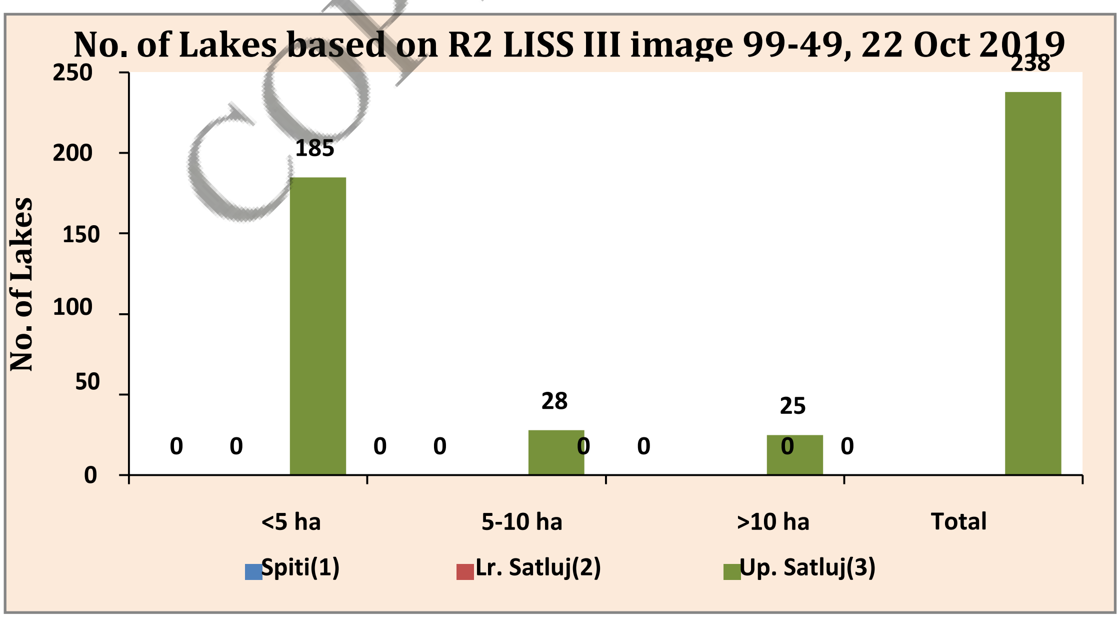


Fig.10.4.9c: No. of lakes based on R2 LISS III image 99-49, 22 Oct 2019

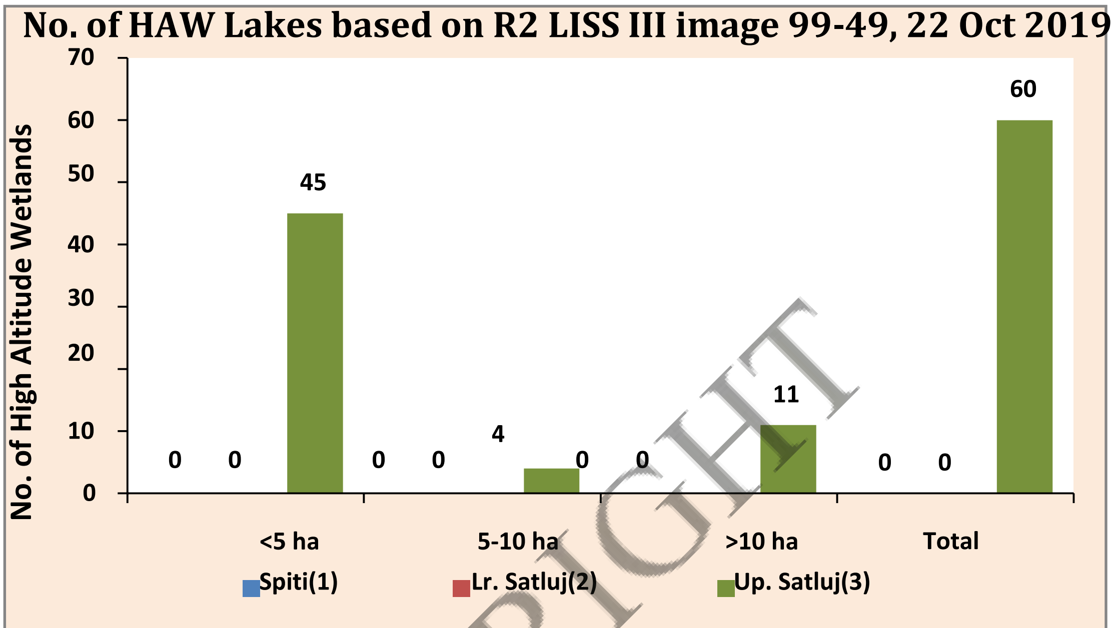


Fig.10.4.9d: No. of high altitude wetlands based on R2 LISS III image 99-49, 22 Oct 2019

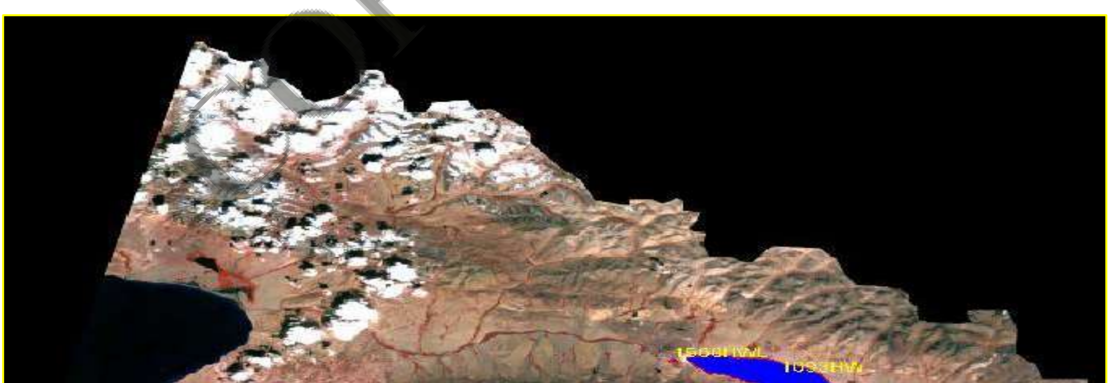


Fig.10.4.10a: R2 LISS III image 100-49, 03Oct 2018& the Interpreted layer

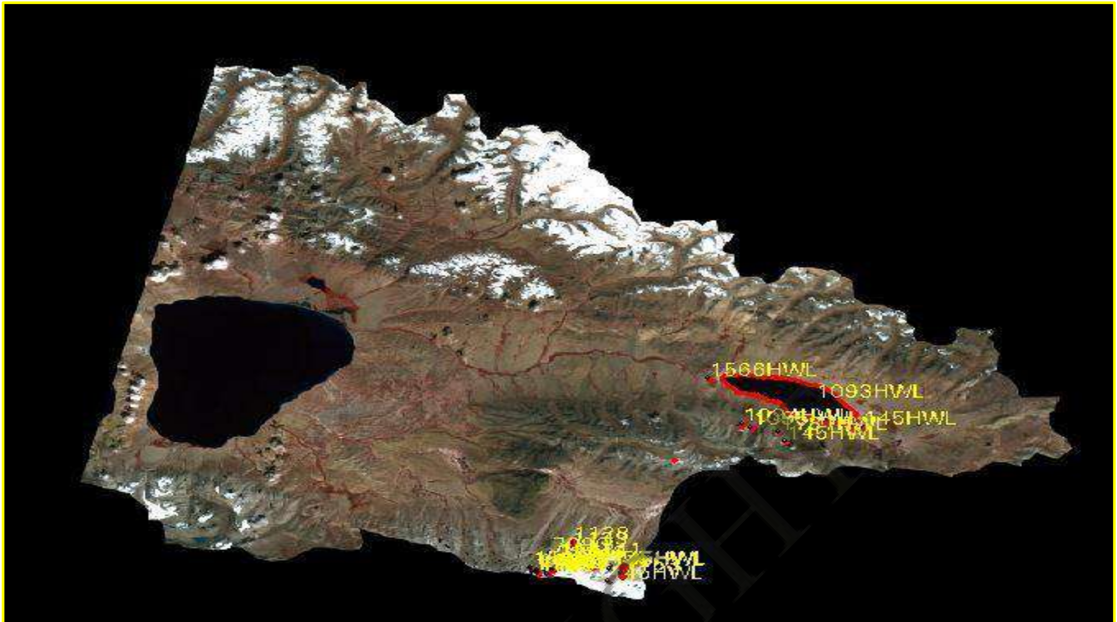


Fig.10.4.10b: R2 LISS III image 100-49, 10 Oct 2019 & the Interpreted layer

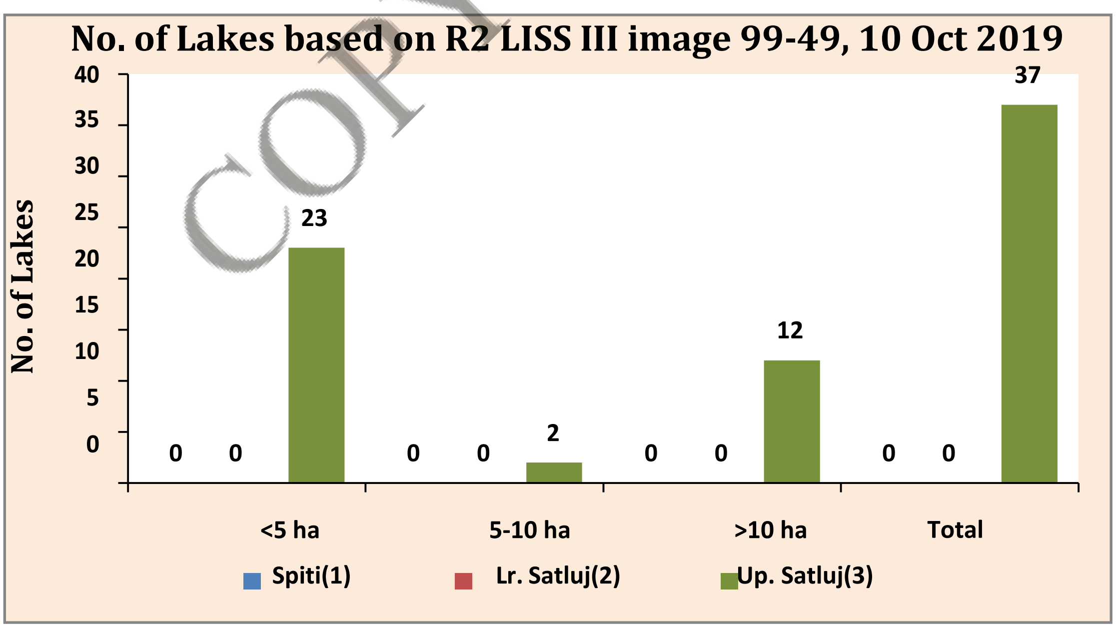


Fig.10.4.10c: No. of lakes based on R2 LISS III image 100-49, 10 Oct 2019

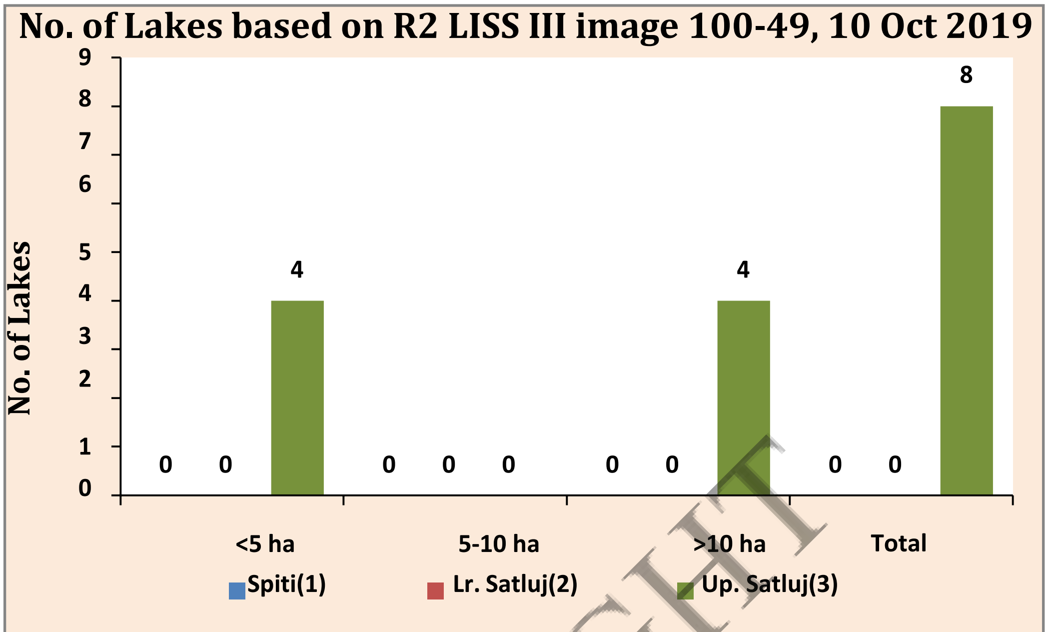


Fig.10.4.10d: No. of lakes based on R2 LISS III image 100-49, 10 Oct 2019

11. Basin wise distribution of lakes:

The comparative analysis based on the results obtained from the analysis of LISS III data products during 2019 have been done with that of results obtained from 2018 for all the total number of lakes and the lakes with area more than 10ha in each basin i.e. Spiti basin (Basin 1), Lower Satluj basin (Basin 2) and Upper Satluj Basin (Basin 3). Based on the LISS-III satellite data analysis (96-48,96-49,97-48,97-49,98- 48,98-49,99-49,100-49 and 146-38) for 2019,a total of 562lakes have been delineated comprising 458 lakes as the small one with area less 5ha, 53 lakes with area 5- 10ha and 51 lakes with area more than 10ha. Maximum number of lakes mapped from LISS III data falls in the path-row96-48(153) and 99-49(238) (Fig 10.4.4C). Further out of 562 lakes mapped, 62 are mainly the high altitude wetlands comprising 1 from Spiti basin, 1 from Lr. Satluj and 60 from the Upper Satluj basin. The comparative analysis based on LISS-III satellite data reveals that total number of lakes varies from 581(2016) to 642(2017) to 769(2018) and 562 (2019) indicating an overall increase of about 10%between 2016-17, and about 19% between 2017-18 and reduction of about 26% between 2018-19 respectively. As far as the big lakes with area more than 10ha are concerned, total number of big lakes varies from 55 (2017) to 49(2018) to 51(2019) indicating a fluctuating trend in the lakes with area >10ha.The total variation in the number of lakes mapped in Upper Satluj basin based on LISSS III data varies from 443(2016) to 450(2017) to 495(2018) to 437(2019), in Lower Satluj basin the number varies from 72(2016) to 102 (2017) to 98(2018) to 52(2019) and in case of Spiti sub basin it varies from 66(2016) to 90(2017) to 176(2018) to 73(2019) (Fig. 9.7) indicating about 1%increase (2016-17) and about 10% (2017-18) and a reduction of about 11% (2018-19) in case of Upper Saltuj basin, 41% increase between (2016-17) and about 2% reduction (2017-18) and a reduction of about 46% (2018-19) in case of Lower Satluj and about 36% increase between 2016-17 and about 95% increase between 2017-18 and a reduction of about 58% (2018-19) in case of Spiti basin could be seen. Further in Spiti basin the lakes with ids 1682RS(0.40ha), 1683RS(1.09ha), 1684RS(1.95ha),1685RS(1.44ha),,1686RS(1.59ha) and 1687RS(1.57ha) are some of the water bodies which have been developed along the nala section coming along the village Chicham just upstream of Kaza on the left bank formed in series. All these water bodies are although small but needs monitoring (Fig. 9.11).Thus from the above analysis, it is clear that although the maximum number of lakes are being formed in the Upper Satluj basin of the study area, but the reduction in the total number of lakes could be seen in all basins which is mainly due to the non-availability of good quality snow free and cloud free LISS III satellite date coverage during 2019.

Thus to summaries based on the results obtained by using AWIFS and LISS III data products, the results obtained using AWIFS indicates an overall reduction of about 16% in total number of lakes mapped in 2019 in comparison to 2018 reflecting 40% reduction in case of Spiti basin, 53% from Lower Satluj and 10% from the Upper Satluj basin and the maximum lakes (89%) of the total229 have been mapped from Upper Satluj, 3% and 7% from Lower Satluj and Spiti basins respectively. In case of the bigger lakes with area >10ha, a reduction of about 55% could also be seen in 2019(31) in comparison to 2018(69) with majority of the lakes (30) forming part of the Upper Satluj basin, 0 from the Lower Satluj basin and 1 from the Spiti basin, out of which 11 are the high altitude wetlands and the remaining 19 are from the glacial origin. Besides this on 5 November 2019, where in total 116 lakes have been mapped, out of which 51 lakes are with area more than 10ha comprising 17 lakes as the high altitude wetlands and the remaining 34 are the lakes from glacial origin as a whole in the entire study area. Likewise LISS-III data indicates a decrease of about 26% in terms of the total number of lakes with about 4% increase in case of the lakes with area more than 10ha. The comparative analysis based on LISS-III satellite data reveals that total number of lakes varies from 581(2016) to 642(2017) to 769(2018) and 562 (2019) indicating an overall increase of about 10% between

2016-17, and about 19% between 2017-18 and reduction of about 26% between 2018-19 respectively. Thus the data base based on AWIFS data product is reflects a complete inventory of lakes in the Satluj catchment with a coarse resolution (56mts) as the data product used covers the complete study area and also free from the impact of clouds as well as not much snow could be seen on 3rd October 2017, whereas the LISS-III data products reflects a more detailed inventory of the lakes with a set of fine resolution(23.5mts) reflecting more detailed information about the lakes with small dimensions.

Table 11.1: Distribution of lakes in different sub basins in Himachal Pradesh based on LISS III satellite data analysis for 2019.

	Name of the basin	No. of lakes with area >10ha	No. of lakes with area between 5-10 ha	No. of lakes with area <5ha	Total No. of lakes
1	**Chenab**	**04(2018)05(2019)**	**10(2018)11(2019)**	**240(2018) 226(2019)**	**254(2018) 242(2019)**
	Bhaga	01(2018)02(2019)	04(2018)03(2019)	79(2018) 46(2019)	84(2018) 51(2019)
	Chandra	02(2018)02(2019)	03(2018)03(2019)	59(2018) 47(2019)	64(2018) 52(2019)
	Miyar	01(2018)01(2019)	03(2018)05(2019)	102(2018) 133(2019)	106(2018) 139(2019)
2	**Beas**	**03(2018) 04(2019)**	**04(2018) 4(2019)**	**58(2018) 85(2019)**	**65(2018) 93(2019)**
	Jiwa	00(2018)00(2019)	00(2018)00(2019)	15(2018) 41(2019)	15(2018)41(2019)
	Parvati	03(2018) 03(2019)	01(2018)02(2019)	23(2018) 32(2019)	27(2018)37(2019)
	Beas	00(2018)01(2019)	03(2018) 02(2019)	20(2018)12(2019)	23(2018)15(2019)
3	**Ravi**	**03(2018) 01(2019)**	**02(2018)02(2019)**	**61(2018)34(2019)**	**66(2018)37(2019)**
4	**Satluj**	**49(2018)51(2019)**	**57(2018) 53(2019)**	**663(2018)458(2019)**	**769(2018)562(2019)**

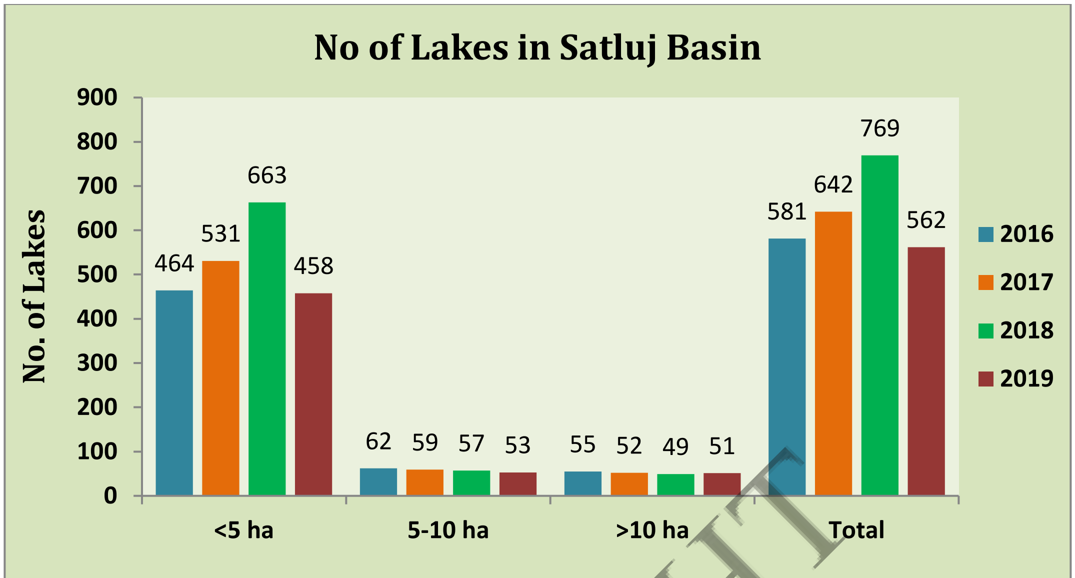


Fig.11.1 Distribution of lakes in Satluj basin

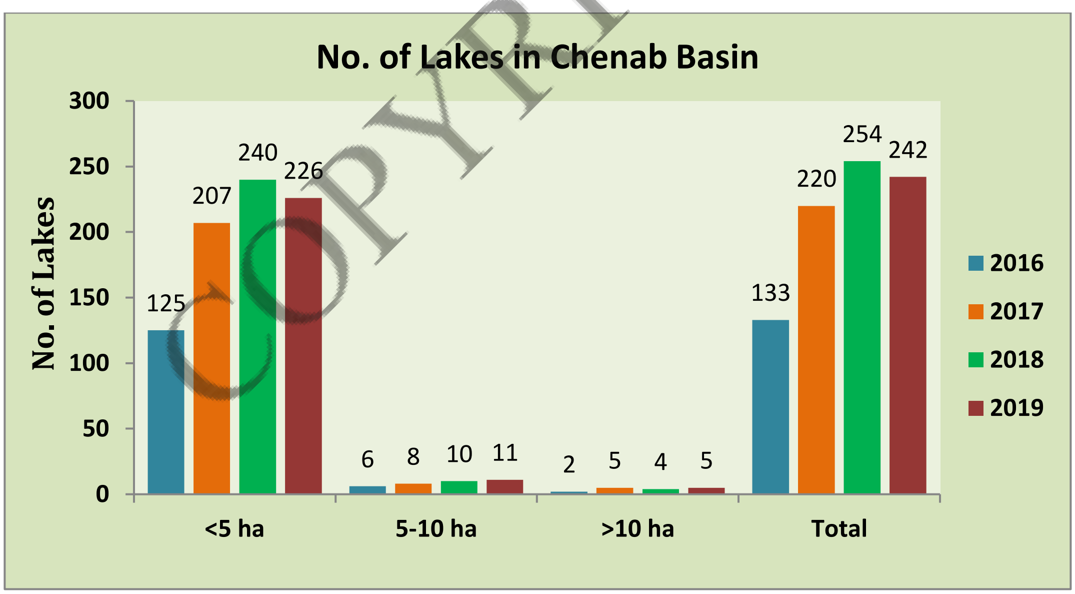


Fig.11.2 Distribution of lakes in Chenab basin

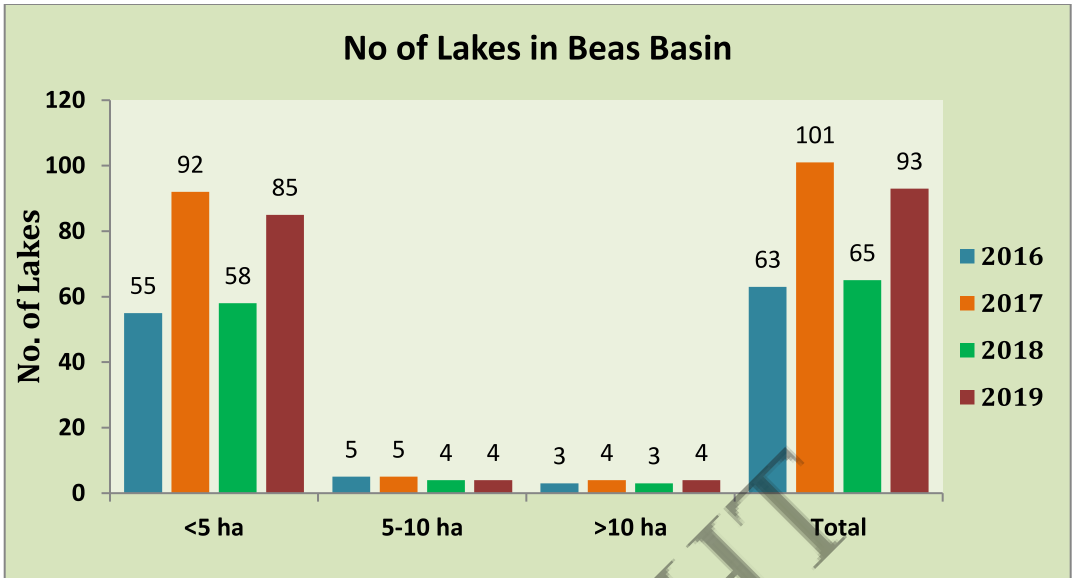


Fig.11.3 Distribution of lakes in Beas basin

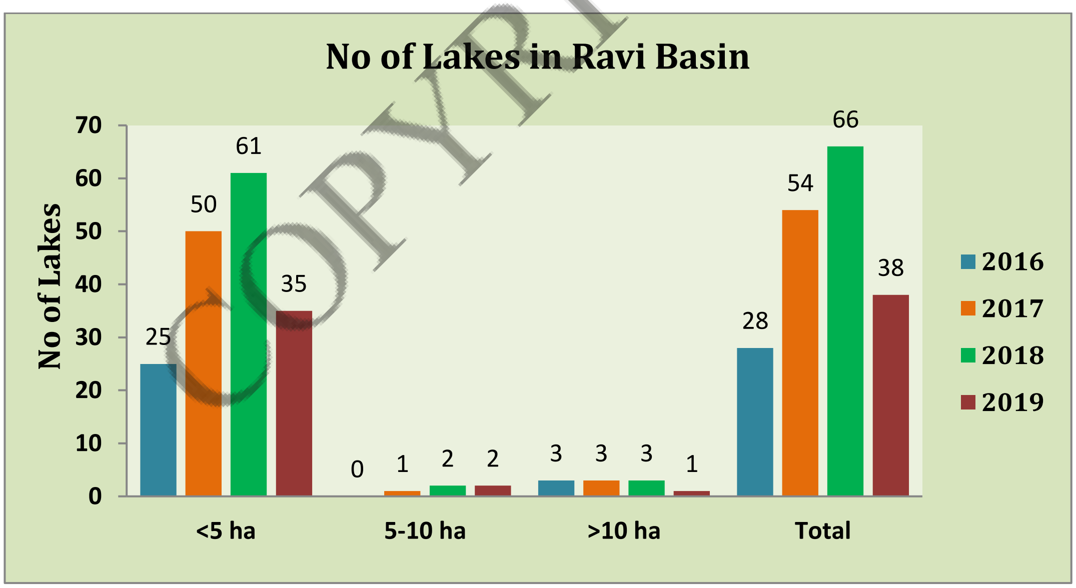


Fig.11.4 Distribution of lakes in Ravi basin

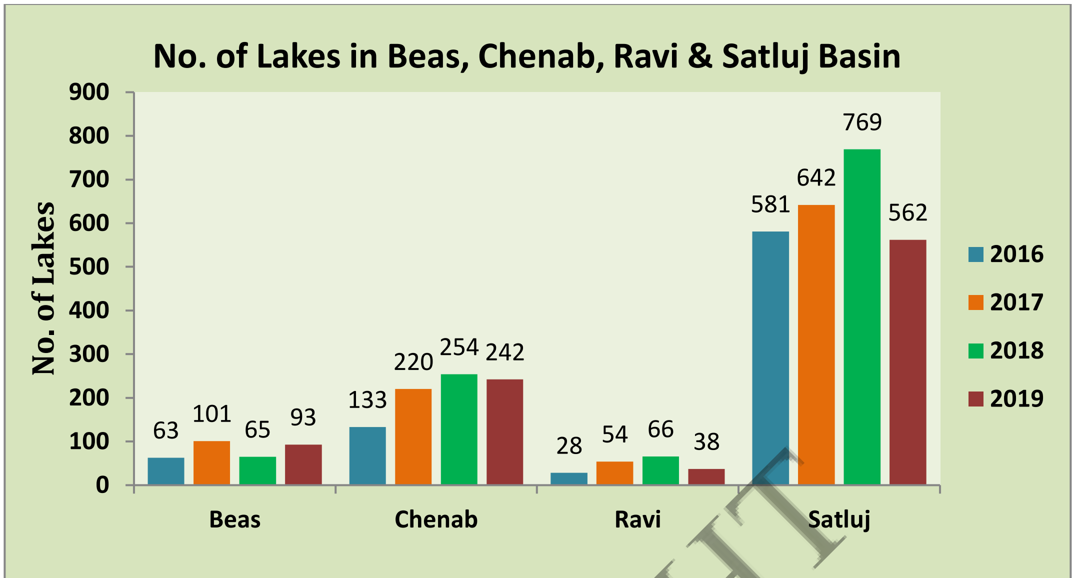


Fig.11.5 Distribution of lakes in Chenab, Beas, Ravi & Satluj basin

12. Distribution of lakes with area more than 10ha

Based on the satellite data interpretation for the year 2019, the study area has been studied to understand the temporal variation of all such lakes with area more than 10ha. In Satluj basin the total number of such lakes has increased from 40(2013) to 42(2015) to 55(2016) to 52(2017) to 49 (2018) to 51 (2019) respectively based on LISS III satellite data . Likewise in other basins, i.e. in Chenab, the number of lakes varies from 3(2013) to 4(2015) to 2(2016), 5(2017) to 4(2018) and 5(2019). In Beas basin the number varies from 2(2013) to 2(2015) to 3(2016)to 4(2017) to3(2018)and 4(2019).In the Ravi basin, the number of lakes varies from 2(2013) to 3(2015) to 3(2016) to 3(2017) and 3(2018)respectively (Table 12.1 & Fig 12.1). The lakes with HWL are mainly the high altitude wetlands in high altitude regions.

Table 12.1: Distribution of lakes with area more than 10ha in different sub basins in Himachal Pradesh based on LISS III satellite data analysis.

Sr. No.	Lake Id.	2015	2016	2017	2018	2019
Bhaga						
1	6	----	6.21	10.23	9.92	10.94
2	11	10.39	7.92	9.84	11.21	10.40
Chandra						
3	1	90.51	90.18	115.51	95.03	98.68
4	3	151.42	131.58	179.64	160.99	162.07
Miyar						
5	209	----	----	16.08	15.06	15.97

Jiwa						
	----	----	----	----	----	----
Parvati						
1	21	12.68	13.81	12.88	13.14	14.56
2	26	13.52	11.28	15.47	13.82	15.21
3	50	----	10.01	14.58	13.30	11.83
Upper Beas						
4	6	----	7.54	10.86	9.82	10.47
Ravi						
1	10	16	12.05	14.42	14.63	???
2	16	30.97	27.28	34.50	11.35	
3	31	11.72	11.2	12.16	12.38	
Satluj						
1	49HWL	23	----	----	38	24.58
2	67	12	13.04	8.06	8	24.58
3	85	----	----	----	----	34.89
4	86	9	10.88	10.11	10.06	10.10
5	87	9	10.06	9.38	10.5	10.41
6	99	19	18.37	17.12	18.8	14.72
7	101	24	24.65	21.37	22.8	21.10
8	122	7	16.16	15.34	16.5	16.86
9	173	3	9.32	7.65	----	13.20
10	184	----	----	----	----	23.32
11	209	33	36.38	----	----	33.76
12	145(HWL)	41584	41646.22	41498.50	41233.9	41640.43
13	179	25	26.26	25.07	25.6	24.26
14	184	27	19.51	19.15	25.5	19.96
15	210(HWL)	57	64.32	59.43	59.17	63.72
16	894	10	----	9.90	9.7	10.15
17	1063HWL	45	39.79	----	----	44.09
18	138(HWL)	26065	26538.79	25891.56	25634.8	25920.91
19	178	205	190.71	204.05	206.39	201.14
20	181	13	13.72	18.07	19.28	12.39
21	1093(HWL)	5515	5676.31	5787.38	5854.36	5992.49
22	1094HWL	16	13.83	12.82	12.62	14.85
23	1128	23	24.45	23.95	25.14	25.00
24	1133	17	15.23	16.09	15.86	16.18
25	1153	63	64.41	66.74	69.2	74.10
26	1155	16	16.38	16.14	17.47	14.27
27	1156(HWL)	11	11.85	11.56	11.69	11.74
28	1164	15	15.12	14.94	14.86	16.08
29	1092HWL	----	14.69	13.63	----	14.13
30	1363HWL	----	28.25	17.77	----	22.24
31	1375HWL	----	47.91	43.26	----	28.96
32	1510	----	54.52	54.37	54.38	52.93
33	1512	----	23.53	23.62	24.23	21.47
34	1518	----	13.78	12.53	14	12.19
35	1527	----	11.17	10.47	11.43	11.37
36	1548	----	17.95	14.62	19.91	17.41
37	1557RS	----	69.88	96.36	80.87	92.85
38	1349HWL	----	352.60	292.13	322.95	335.79
39	1095(HWL)	----	17.26	14.31	15.58	17.22
40	1565	----	16.38	18.11	17.36	19.13
41	1566(HWL)	----	22.81	24.35	18.76	10.77

42	1782(HWL)	----	----	----	29.1	30.65
43	1774RS	----	----	----	11.69	12.93
44	1771RS	----	----	----	12.22	14.99
45	1776RS	----	----	----	----	13.98
46	1654	----	----	----	----	22.28
47	2180	----	----	----	----	23.56
48	1039HWL	----	----	----	----	12.16
49	1144HWL	----	----	----	----	89.47
50	2167HWL	----	----	----	----	214.31
51	1146	----	----	----	----	10.60

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

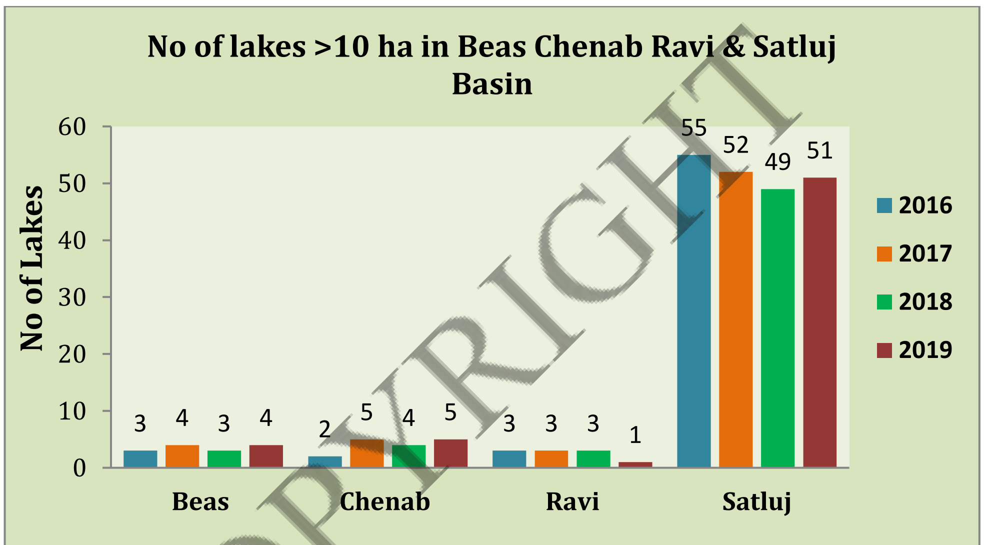


Fig.12.1 Distribution of lakes with area>10 Ha in Chenab, Beas, Ravi& Satluj basin in 2016, 2017, 2018 & 2019

13. Concluding Remarks

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

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

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

Along the course of main Satluj River, few isolated pockets have also been observed which shows accumulated water in the upper catchment of the Tibetan Himalayan Region and within the Spiti basin i.e. sub basin 1. In Spiti basin the lakes with ids 1682RS(0.40ha), 1683RS(1.09ha), 1684RS(1.95ha), 1685RS(1.44ha), 1686RS(1.59ha) and 1687RS(1.57ha) are some of the water bodies which have been developed along the nala section coming along the village Chicham just upstream of Kaza on the left bank formed in series (Fig.13.1). All these water bodies are although small but needs monitoring as this is along the river course and can cause major damage in case if it bursts. Thus the lakes/water bodies coded with abbreviation *RS with their ids* are some of the locations where accumulated water could be seen and these are the permanent features which needs regular monitoring in order to assess any temporal change in their behavior in the time to come.

Fig:13.1:- Accumulation of water along river course in Spiti basin

The Chenab basin comprising mainly of (Chandra, Bhaga, Miyar) as sub basins has a total of 242 lakes(2019) comprising (52lakes in Chandra sub basin, 84 lakes in Bhaga sub basin and 139 in the Miyar sub basin) respectively. Thus the Chenab basin as a whole has 242 (2019) lakes in comparison to 254 lakes (2018),220 (2017),133(2016) , which is about more than four times than the lakes which were identified earlier using 2001 (55) satellite data (Randhawa et.al. 2005) and about 81% increase w.r.t 2016 and about 10% increase with that of 2017 and about 4% decrease with respect to 2018 , which may be due to the data quality in 2019 . When these 242 lakes seen based on their aerial range, it has been found that maximum lakes (226) falls in the category where the area is less than 5 hectare, 11 lakes where area is between 5-10 hectare and only 05 where area is more than 10 hectare indicating increase of 25% in case of bigger lakes i.e. lakes with area more than 10ha and 10% increase in case of the lakes with area between 5-10ha w.r.t 2017(Fig 11.2) and a decrease of about 6% in case of the lakes with area less than 5 ha. Fig.13.2 to 13.6 indicates some of the pictures of the lake formation in different sub basins of Chenab basin as per the satellite image, which needs regular monitoring in order to assess any change in their behavior.

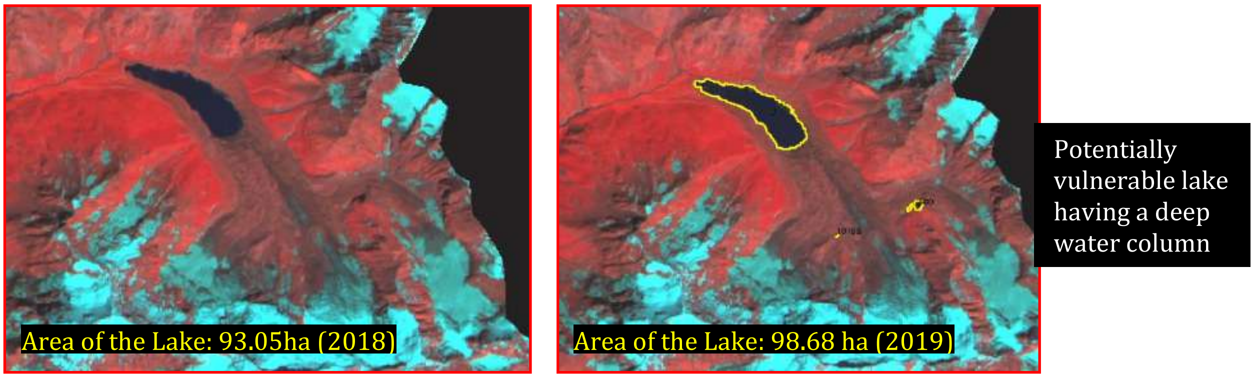


Fig.13.2 Moraine dammed lake formation at Geepang Gath Glacier Snout in Chandra Basin

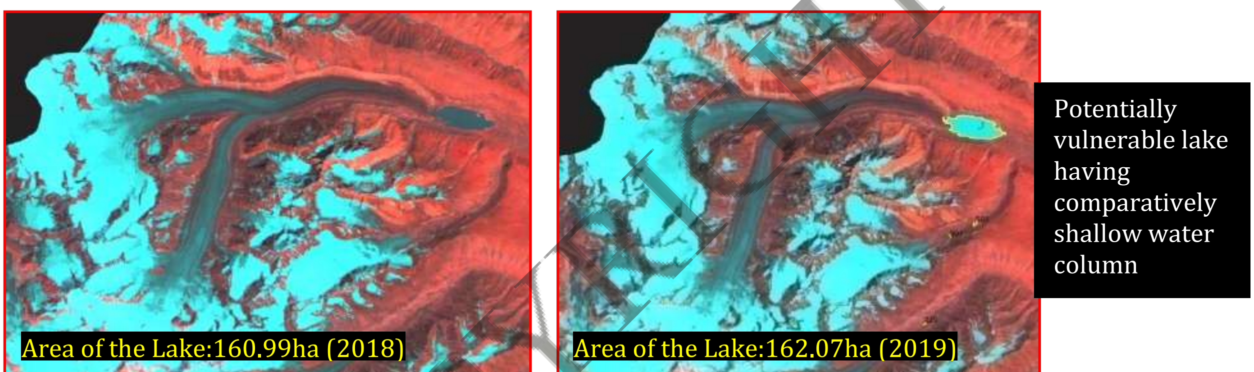


Fig.13.3: Moraine Dammed Lake Formation at the Snout of Samudri Tapu Glacier

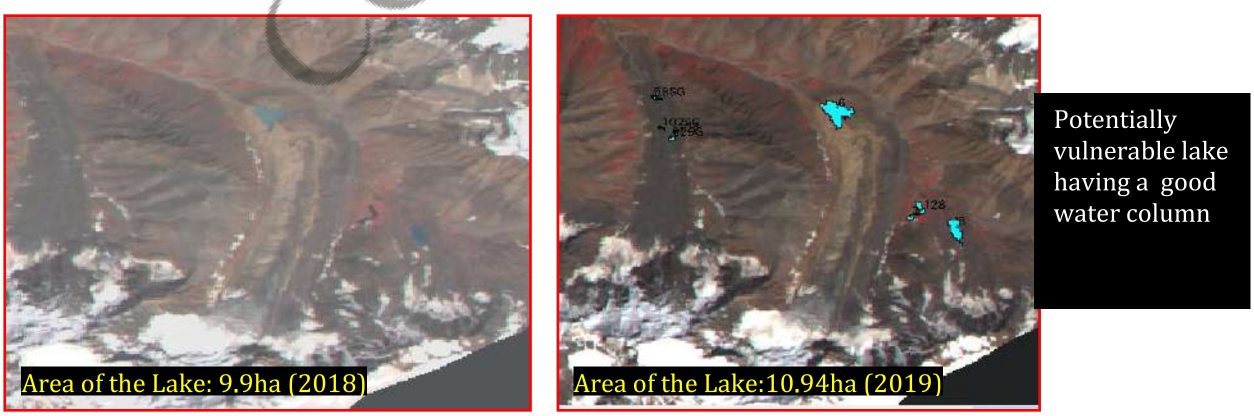


Fig. 13.4: Moraine Dammed Lake Formation at the Glacier Snout in Bhaga Basin

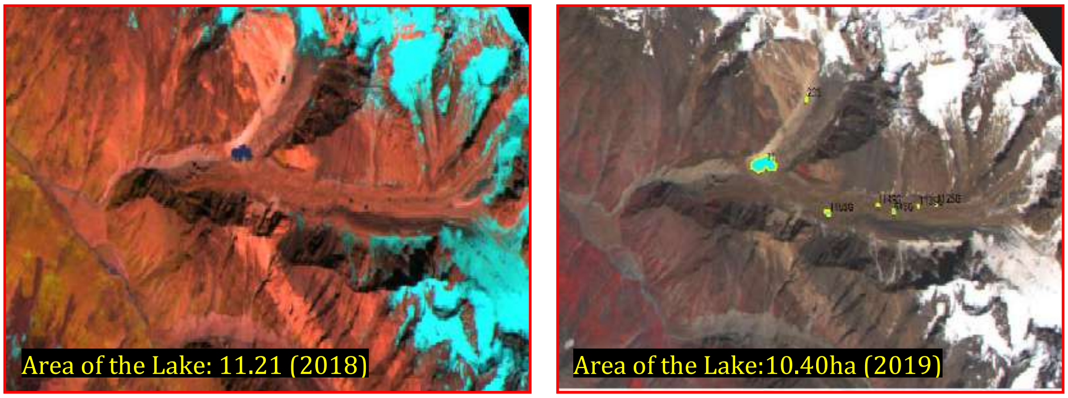
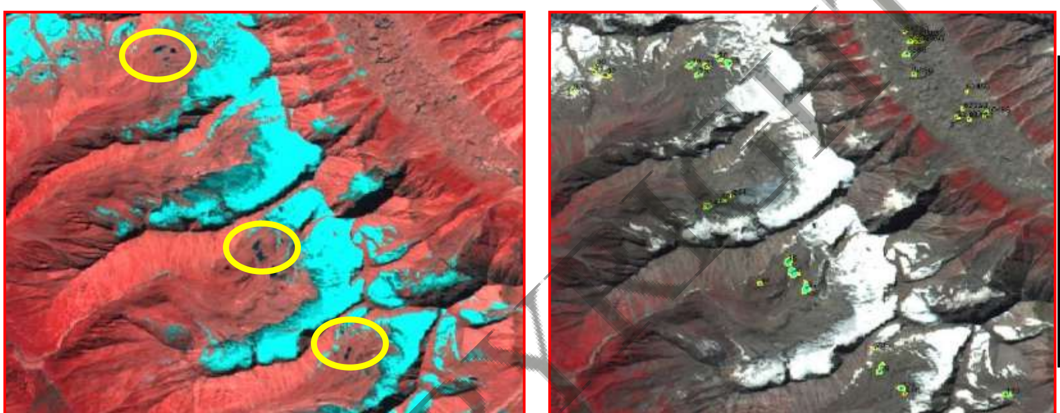


Fig. 13.5: Moraine Dammed Lake Formation at the Glacier Snout in Bhaga Basin



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

Fig. 13.6: Moraine Dammed Lake Formation at the Glacier Snout in Miyar Basin

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

02 lakes are having area between 5-10 hectare and 35 lakes are such which have area less than 5 hectare

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

Based on the above analysis carried out for 2019, it is found that there is a considerable increase in the total number of lakes in each 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 Uttrakhand Himalaya has also been correlated with the bursting of a lake having a total area of about 08 hectare in front of the snout of the Chorabari glaciers that caused widespread damage in the downstream areas besides the heavy rainfall (Dobhal et.al.2013). Thus the magnitude of such lakes as far as the destruction is concerned cannot be overruled. Besides this, the lakes with area >10 hectare and the area between 5-10 hectare can be seen as the potential vulnerable sites for causing damage in case of bursting of any one of them. Thus a proper monitoring of all such lakes is very much essential in the Himalayan region in order to avoid any eventuality like in

Uttrakhand in future, which will not only save the precious human lives but also the public and the Govt. property.

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