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Rezayee, Asadullah
Amity Institute of Geoinformatics & Remote Sensing (Alumni), Amity University

Praveen Kumar Rai
Department of Geography, Khwaja Moinuddin Chishti Language University

Prasad, Ritika
Department of Geography, University of Lucknow

Singh, Ashutosh
Department of Geography, Pachhunga University College, Mizoram University

他

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Assessment of Wakhan Corridor Glaciers and Glacier Lakes in Afghanistan from 1994-2019 Using Earth Observation Data

Asadullah Rezayee[1],** Praveen Kumar Rai[2], Ritika Prasad[3], Ashutosh Singh[4], Prafull Singh[5], Rahul Kumar Misra[6], Bratati De[7]

[1]Amity Institute of Geoinformatics & Remote Sensing (Alumni), Amity University, Noida, India and 6th District Faizabad, Badakhshan, Afghanistan
[2]Department of Geography, Khwaja Moinuddin Chishti Language University, Lucknow, India
[3]Department of Geography, University of Lucknow, Lucknow, India
[4]Department of Geography, Pachhunga University College, Mizoram University, Aizawl, India
[5]Department of Geology, Central University of South Bihar, Gaya, Bihar
[6]Rahul Kumar Misra, Khwaja Moinuddin Chishti Language University, Lucknow, India
[7]Swastik Edustart - GIS and Remote Sensing Institute, New Delhi, India

**Author to whom correspondence should be addressed:
E-mail: rai.vns82@gmail.com

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Abstract: Glaciers holds an important place in maintaining the ecological balance, moreover it is the major source of fresh water. Snow and ice cover are extremely important in the Himalayan region. It not only monitors the region's climatic conditions, but it also controls the local people's day-to-day livelihood structure. Snow and glaciers are two of the most important land covers on the earth's surface. As a result, it is critical to examine, monitor, and map these land covers on a regular basis. Thus, in the present study an effort has been made to study the Wakhan corridor glaciers in Afghanistan from 1994-2019. Landsat satellite images were used to monitor the glacier change as well as to delineate the glaciers lake. Various GIS techniques are used to complete the research like band rationing, on screen digitization, statistical analysis. During the study, it was clearly identified that the snow line as the accumulation zone in this part is receding, with the melting of glaciers there has been increase in the numbers of glacial lakes is a warn of a danger in the coming days. In this study, glacier inventory were calculated followed by estimation of accumulation area ratio (AAR) of each glacier. Thus, multi-temporal Landsat images were used to estimate change in glacial area and accumulation area ratio (AAR) respectively. The estimated AAR was used to assess the glacial retreat. A total of 64 lakes were identified using this and the areas of each of these lakes were calculated in ArcGIS desktop software. Majority of these lakes are lateral moraine glacial lake.

Keywords: Glaciers, Climate Change, GIS and Remote Sensing, Glacier lakes, Glacier Inventory

1. Introduction

During the recent decades, the world has been warming and the temperature has been rising, mostly it influences the cryosphere and water flow of the major rivers and their tributaries, it indicates the retreats and negative mass balance in glaciers which are having the most significant role in climate change[1)]. As the glaciers are retreating, it is creating an intensive influence on the lower parts of the glaciers, retreating of the glaciers lead the formation of glaciers lake on higher altitude, by raising the heat, these lakes start expanding and will create a severe disaster which known as glaciers lake outburst flood (GLOF)[2,3,4)] such an environmental disaster could claim many catastrophes and disasters[5)]. Investigation and monitoring of these calamities need 100 million EURO per year, so monitoring of the glaciers is an important phenomenon as they are sensitive against the heat raising[6)].

The glacier melting recognizes water security as "the reliable availability of an acceptable quantity and quality of water for health, livelihoods and production, coupled with an acceptable level of water-related risks”[28]. The focus here is on the most important impacts related to vanishing glacier and the resulting consequences to be faced with conditions of a warming world[28,29]. The retention and depletion of snow and ice have a strongly stabilizing effect in the hydrological system[30,29].

In the scope of the glacier study, the land cover composition on the glacier surface is defined through classification of the snow and ice types on the surface of the glaciers. To investigate the change in glacier extent and surface composition, an evaluation of a time series of specific years is conducted[31]. The present study is thus an initiative to monitor the Wakhan corridors glaciers in Afghanistan, the largest and longest of glaciers in Afghanistan are formed in the entrance of Wakhan corridor on the left bank of Darya-ye Panj river, along the north face. Where the mountain peaks are having more than 6000 m height, and at least 15 glaciers of the north-facing are having more than 10km length. The largest of these glaciers in their area are almost 75-100km^2. In the Wakhan corridor, there are 9 peaks in the central part which ranges more than 6000m height. The more extensive glaciers in their area are formed here because of the high altitude and mean annual precipitation of less than 100mm[7]. Glaciers melt water from Wakhan corridor feeds the Pamir, Wakhan, and Panj rivers and their tributaries which flow into the major (Amu Daria) river of Afghanistan, Tajikistan, Uzbekistan, and Turkmenistan. A slight change in these glaciers may have a huge impact in the low-lying areas[8].

Glacier melting will trigger a higher loss of biodiversity, lower economic growth, and more acute food and water shortages in the future.
Thus, the present study was conducted to accomplish the following objectives:

i. To identify the glacier inventory using the optical remote sensing data.
ii. To identify the glaciers lakes of study area.

2. Study area

The Wakhan corridor is in the northeast parts of Afghanistan located between Pamir mountains form north and the Karakoram range to the south, as a narrow strip extended to China from east and separated Tajikistan from Pakistan and Kashmir, and from west it has border with Ishkashim district. It is about 350km long and 13-65km wide, Pamir and Panj river appeals from the Zarkul lakes on top of these high mountains and forms the Amu Darya where the Lake of Zarkul is the origin of the Amu River. The Wakhan corridor is extended to the east west about 25km and it is part of the Silk Road. In antiquity, a trade way was passed through this corridor and, connected to the East, South, and Central Asia. Pamir river has been formed the northern border there. The study is parts of this area which is between 36° 30' 00" to 37° 10' 00" North latitude and 72° 20' 00" to 73° 20' 00" East longitude with 1417. 16sq.km area, glaciers of this part are mostly located on north-facing slopes at different ranges (less than 13° at the endpoint of the glaciers and greater than 47° at the higher altitude (Fig. 1).

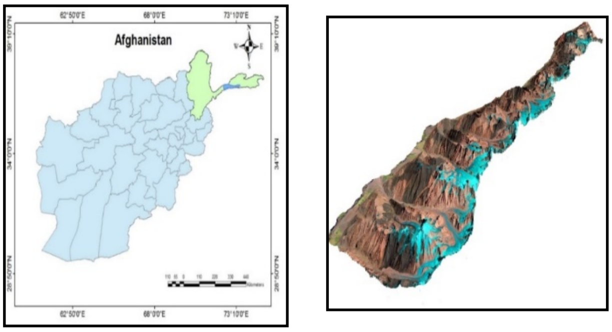


Figure 1: Location of the study area in Landsat 8 OLI data of 2019

3. Data Sources and Methodology

Delineation of glacier boundaries were carried out using the following satellite data which were downloaded from the website of United States Geological Survey (USGS); Earth Explorer (http://earthexplorer.usgs.gov/). (Table 1). Universal transverse projection (UTM) system was followed using WGS-84 datum.

i. Landsat 5 and 8 were used for temporal change of glacier.
ii. Alaska Satellite Facility was used for digital elevation model
iii. Google earth was used for glaciers lake extraction and correlation data with ArcGIS output.

Table 1: Details of Landsat’s and Alaska satellite Facility data

S.no	Satellite	Sensor	Date of pass	Resolution (m)
1	Landsat 5	TM	01/09/1994	30
2	Landsat 5	TM	04/09/2001	30
3	Landsat 5	TM	26/09/2009	30
4	Landsat 8	OLI	29/09/2016	30

Source-USGS Earth Explorer

Using standard image characteristics such as tone, texture, pattern, shape, size, location and association etc. the visual interpretation was carried out for extraction of glaciers in the study area. The identification of glacier on satellite data was interpreted by using reflectance characteristics of snow and glacier ice, shape of valley occupied by glacier, the flow lines of ice movement and the rough texture of the debris on the ablation zone.

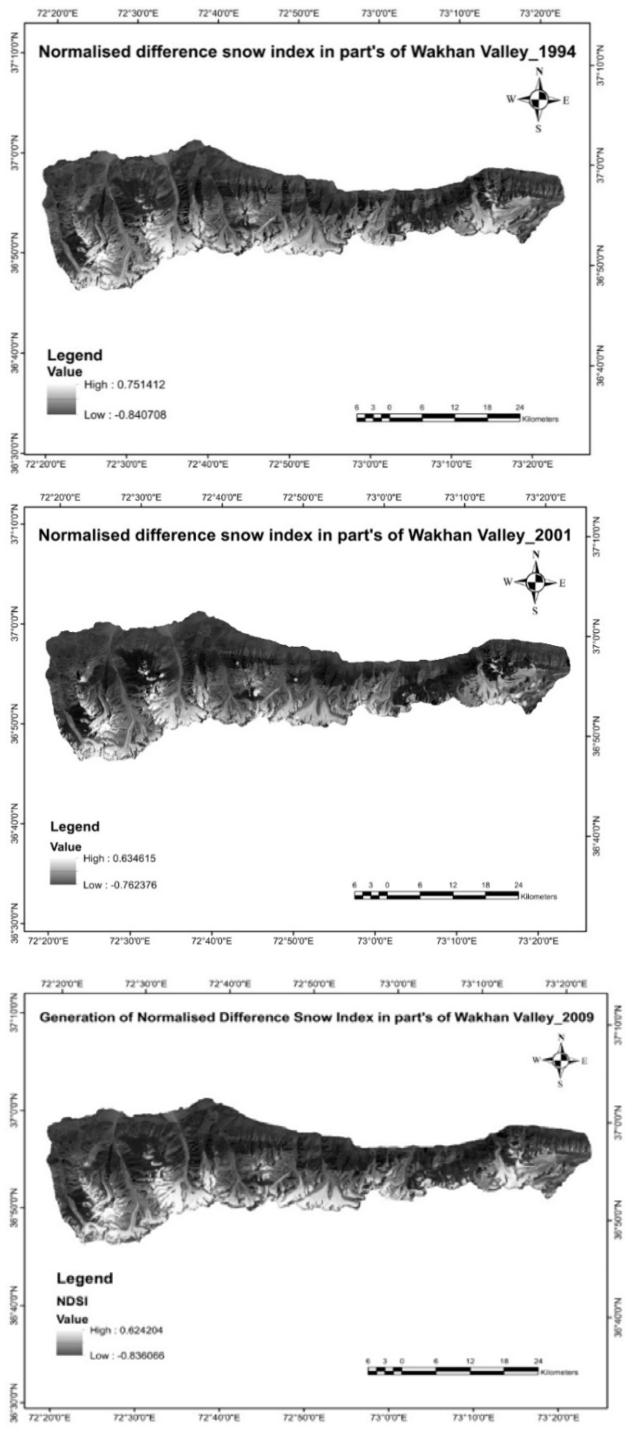
For studying the glaciers lakes, it needs higher spatial resolution for temporal data. But in this paper, Google Earth as data source for one date (05/08/2009) is used because glacial lakes in the study area were small in size so, with the free cost satellite data (Landsat's) the output would not be a good result. Due to the high altitude region, complex topography, lack of road network, low temperature, absence of site station measurement it's difficult to get accurate and temporal information about these glaciers[9]. Local climate includes the valley wind, slope wind, glacier wind whereas glacio geomorphic parameters include slope, aspect, altitude, debris cover, areal extent, depth of ice, size of the valley, etc[30].

Digital image of remote sensing for September 1994 (Landsat 5 TM), September 2001 (Landsat 5 TM), September 2009 (Landsat 5 TM), September 2016 (Landsat 8 OLI) and September 2019 (Landsat 8 OLI), thirty and fifteen meters spatial resolution are freely available in https://earthexplorer.usgs.gov/ were downloaded (To identify the glaciers attribute and inventory) the image should be cloud-free, but for the freely available data this ideal requirement often difficult to meet, therefore images has been selected for different years rather than particular years[27]. The month of September was used because the minimum amount of snow would be present in the area and actual glacier will be easily identified. Data were already being geometrically rectified and referenced, visible near-infrared, and SWIR bands were stacked for glaciers mapping to carried out false-color composite (FCC), Universal Transverse Mercator projection (UTM) was followed with WGS-84_1984 datum. ASTER DEM was used to verify the extracted glacial terminus from the Landsat data of different time periods.

For identifying the glaciers health and their change, accumulation and ablation of each glacier digitized separately, for different time series from September 1994- September 2019 to get their area, perimeter, length, retreat, accumulation area ratio, depth, and mass balance of the glaciers. Debris cover of glaciers are needed more attention to identify and differentiate from surrounding rocky area and outcrops [10]. NDSI and band ratio (TM4/TM5 & TM4/TM6) were effective for this issue to differentiate the glaciers from surrounding. Elements of visual interpretation like tone, texture, shape, size, pattern, texture were used with standard images characteristics to differentiate the glacier from surrounding features then manual digitization has been applied

4. Result and Discussion

The standard false-color composite was used with the band 2, band 3, band 4, band 5, band 6, band 7 for Landsat 8 Oli and band 1, band 2, band 3, band 4, band 5, band 7 for Landsat 5 TM as RGB to differentiate the glaciers with their surrounding free land features. the snout of the glaciers was delineated from the frontal parts of glaciers where streams observed on satellite images, however, it was identified by FCC images also, but for better results, we compared the output with NDSI (normalized difference snow index) of each data separately. NDSI used with (bands 4 - bands 6)/ (bands 4+bands 6), here the value with greater than 0 represents as snow area and <=0 is indicated free land surface (Fig 2a to d).



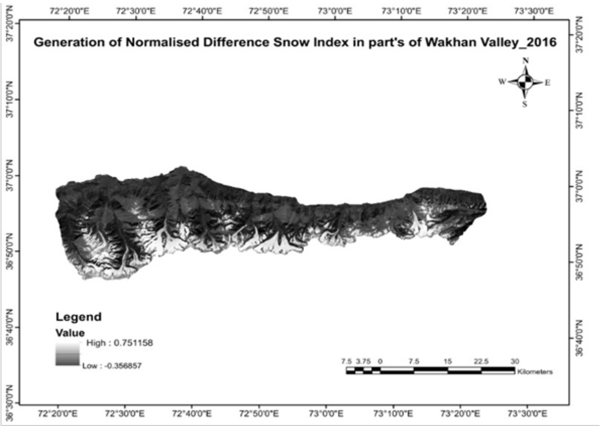
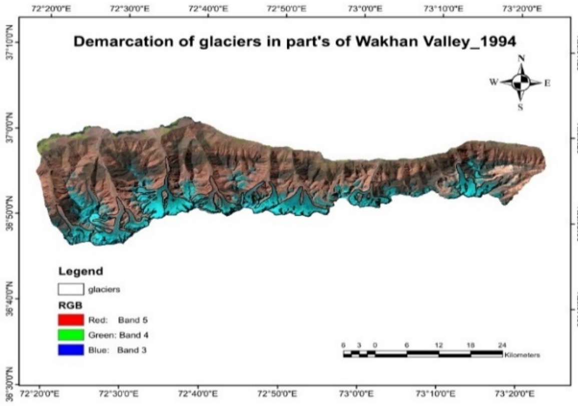
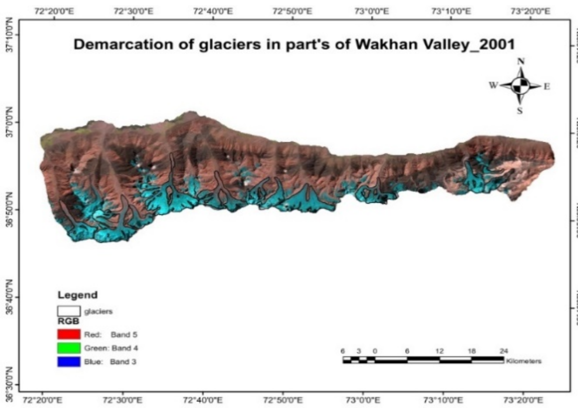
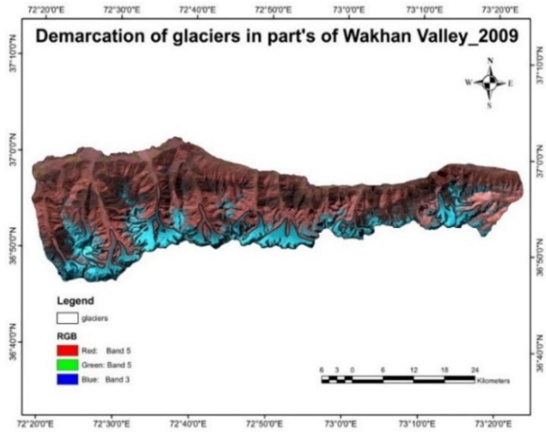
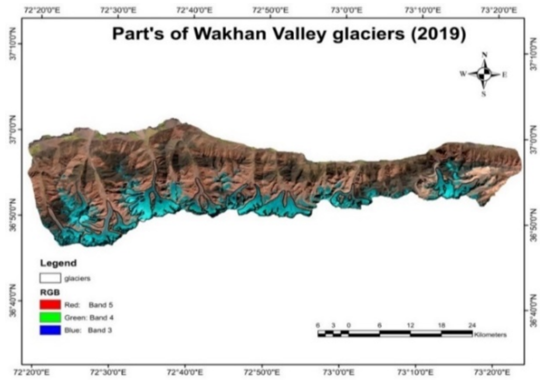


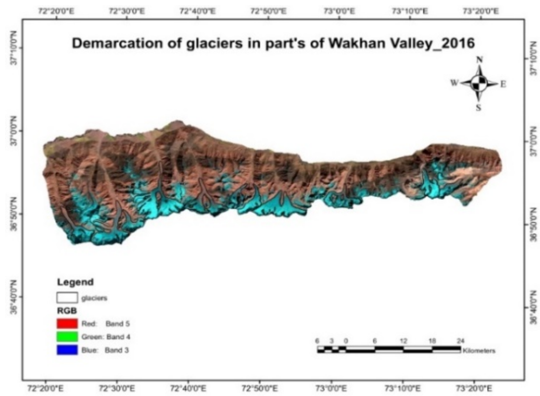
Figure 2 (a to d): Extraction of the normalized difference snow index (NDSI) for study area for September 1994, 2001, 2009 and 2016 respectively











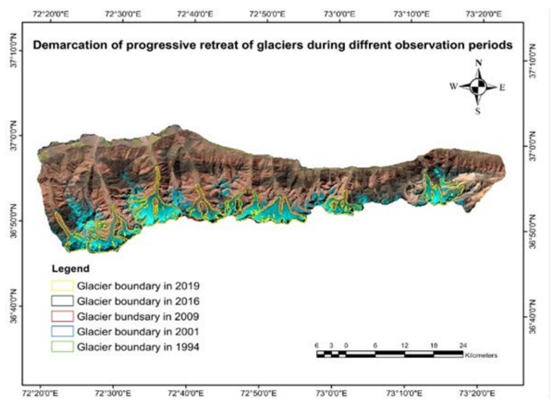


Figure 3 (a to e): Demarcation of the glaciers terminous boundaries for the year 1994, 2001, 2009, 2016 and 2019 resppectively

Accumulation area ratio (AAR) is the ratio between the area of accumulation and total glacier area. The specific mass balance calculated through the AAR. Retreat or advance of glaciers is the result of long term changes in mass balance of glaciers. There is a parameter known as AAR (Accumulation Area Ratio) which is used for determining mass balance of the glaciers at reconnaissance level. The thickness of the glaciers was identified using the H= -11.32+53.21F 0.3 formula[11,12] where H represents the mean glacier thickness, F shows the glacier area in sq.km. specific mass balance of the glacier was calculated applying AAR formula b=243.01*X-120.187 where b is the specific mass balance in water equivalent (cm) and X represents the AAR[13,14,15,16,17,18]. Fig. 3a to e show the glacier boundaries delineated from 1994 to 2019 using remote sensing data of different time period. Fig. 4 shows the overlapping of demarcated glacier terminus boundaries in different time period as shown over the Landsat 8 OLI data of year 2019.

The lakes which their source of water is from present or past alpine glaciers or continental ice sheets are known as glacier lakes[19]. A glacier lake can form inside/surrounding of the glacier (lateral marine dam glacier), in front of a glacier (proglacial), below the glaciers (subglacial), within glacier (in-glacial), on the surface of the glacier (supra-glacial) and can also be built by moraine of the glaciers (moraine-dammed glacier). All these lakes are a good source for drinking water but in some case, they can act as a natural disaster also, which is known as glaciers lake outburst flood (GLOF).

Due to climate change in recent decades' changes affected the glaciers on thinning, retreating and down wasting, thus the result could be increase in number and enlarge the glaciers lakes on the region[20]. Other different changes may occur in glaciers lake due to tectonic movement, triggering uplift or subsidence and development of stream[21, 22]. The detection of glacial lakes plays an important role in predicting risk assessment and hazardous catastrophe, so with the help of remote sensing data it is possible to know their details in any high altitude topographic region, where it can be difficult for labor and, needs more budget and time[20].

To delineate the glaciers lake on the study area less snow coverage of different periods of Landsat's data was downloaded from earth explorer site, which is freely available. To extract each glaciers lake geometry, the NDWI (NIR-SWIR/NIR+SWIR) was performed on the satellite data, but as the spatial resolution of Landsat data is 15m and 30m and the lakes of our study area are smaller in size, in this case it was not possible to generate their characteristics for a temporal date on Landsat's satellite images the created maps are highlighted in Fig 5. To solve this issue, the Google Earth data were used and in this study it is found that each lakes of the glaciers were digitized separately for the date of September 2009 and, the digitized data overlaid on Landsat's FCC image as, there size were in a small scale we represented them as point data to indicates the glaciers lakes delineation of the study area as shown in Fig 5.

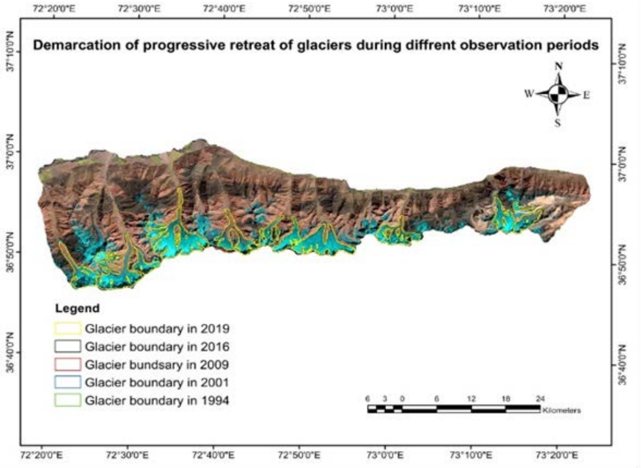


Figure 4: Overlapping of extracted glacial terminus boundaries during 1994 to 2019.

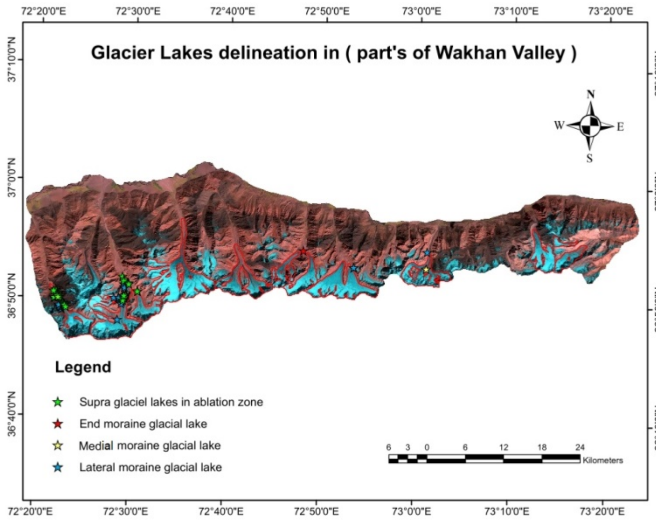


Figure 5: Glacier lakes inventory using Google earth data for the date of 2019

The lakes visualized using optical bands of Landsat satellite and Google earth pro are enlisted in Table no. 2. A total of of 64 lakes were identified using this and the areas of each of these lakes were calculated in ArcGIS desktop software. The glacier ID 10, 11 and 12 glaciers are more affected of global warming and temperature raising, so more glaciers lakes are prominent in these three glaciers. Majority of these lakes are lateral moraine glacial lake (Fig. 6). The lakes visualized using optical bands of Landsat satellite and Google earth pro are listed in Table no. 2. A total of 64 lakes were identified using this and the area of each of these lakes were calculated in ArcGIS desktop software. The glacier ID 10,11 and 12 are more affected of global warming and temperature raising, so more glaciers lakes are prominent in these three glaciers. Majority of these lakes are lateral moraine glacial lake (Fig. 6).

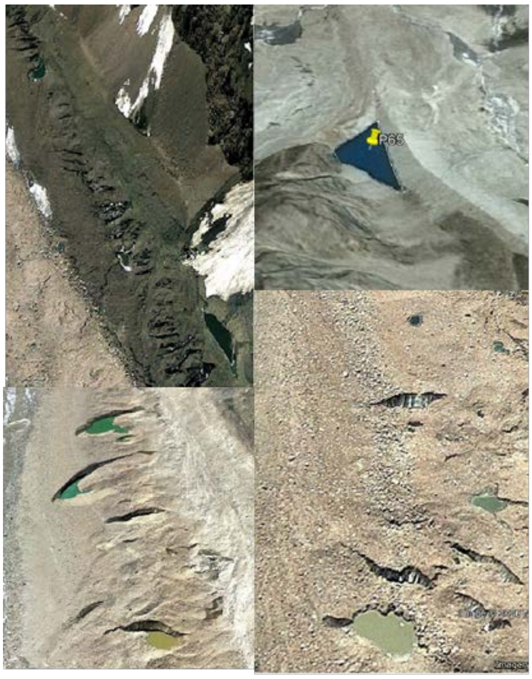


Figure 6: Location of few glacial lakes as identified through the Google Earth data

Morphometric parameters were also calculated from the created data. Morphometric parameters help in making an in-depth study of the glacial activity. With the help of Landsat images as well as on screen digitization of Google earth image, the parameters calculated are enlisted in the table number 3. The upper part of the glaciers which is known as accumulation of the glaciers separated by Equilibrium Line Altitude ELA, which is an imaginary line between accumulation and ablation of the glaciers is generated from FCC images[23]. After calculating the glaciers area in ArcGIS the accumulation area separated from ablation by subtracting the area of an accumulation from the area of the glaciers, the result would be the ablation area, the details are highlighted in fig 4. Length of the glaciers was measured individually form the highest point of the accumulation area along the central line to the snout point by line feature in ArcGIS. Delineation of the glacial terminus boundaries extracted from Landsat TM and OLI for the date of 1994, 2001, 2009, 2016, 2019 satellite images, and the changes were easily calculated and represented in the Table 3. Snout position coordinates was extracted by overlying the glaciers boundary outputs on Google earth. The ablation area of the glaciers was differentiated by the bright reddish color from surrounding features. Many more parameters of the glaciers were also calculated, like perimeter, accumulation area ration, mass balance, thickness, volume, lengths, and width[24,25,26].

5. Conclusion

This study has been shown that using remote sensing and GIS technology are effective and important to monitor and assess the health and changes of the glaciers. This study has clearly indicated that glaciers in parts of Wakhan valley are retreating and shrining, here12 glaciers in parts of Wakhan valley was chosen and the data of Landsat for the date of September 1994 to September 2019 free cloud satellite images have been used for extraction of different glacier morphometries. Chosen the month of September for the study area is the best date to show the lowest amount of seasonal snow cover and, represent the real glaciers area. Changes are obvious in different geometry of these glaciers, as from September 1994-2019 it showed 2.904% area losses for the 12 chosen glaciers. Length of these glaciers have retreated from 18 – 700m, similar in their mass balance which are mostly in negative mass balance and, thickness of these glaciers are shrinking at various scale as, the glaciers number 9 showed the lowest thinning which is 0.130m and, the glacier number 12 had loosed its thickness at the higher range, that is 42m. However, from the date of 2001-2009 the glaciers of the study area are showed slightly advancing also, for instance, the ID12 glacier showed 1.104sq.km. and the ID 1 glacier represented 0.989sq.km area gain. The appearance of 65 glacial lakes on various parts of these glaciers in different categories for the year 2009 and 2019 are indicated the change and negative mass balance in this region. The most prominent glacial lakes type of this area are the supra glacier lake in the ablation zone (30 lakes) contained 39165.865sqm area, the second types of glacial lakes are lesser in size but more in their numbers, these lakes are the lateral moraine glacier lakes which had (34 lakes) and 23874.015 sq.km area. This study disclosed an extensive change in different parameters and characteristics of these glaciers from 1994-2019. Hence assessing and monitoring of these glaciers is a crucial task for predicting the multi types of natural disaster and water resource with more advance equipment and technology on the ground and areal study like higher resolution of passive satellite data and, active remote sensing (RADAR) which data could be achieved in any time and any weather condition.

Table 2: Glacier lakes inventory using Google earth data of 2019

Point Name	Latitude	Longitude	Lakes Area in sqm	Glacial lakes Type
L1	36°50'40.57"N	72°22'2.68"E	112.409	Supra glacier lake in ablation zone
L2	36°50'33.75"N	72°22'6.15"E	320.388	Supra glacier lake in ablation zone
L3	36°50'24.98"N	72°22'15.37"E	837.016	Supra glacier lake in ablation zone
L4	36°50'22.25"N	72°22'13.60"E	180.399	Supra glacier lake in ablation zone
L5	36°50'17.32"N	72°22'16.80"E	62.534	Supra glacier lake in ablation zone
L6	36°50'16.22"N	72°22'17.37"E	136.911	Supra glacier lake in ablation zone
L7	36°50'15.34"N	72°22'17.71"E	105.803	Supra glacier lake in ablation zone
L8	36°50'8.46"N	72°22'14.73"E	155.155	Supra glacier lake in ablation zone
L9	36°50'2.64"N	72°22'29.19"E	1023.178	Supra glacier lake in ablation zone
L10	36°50'2.32"N	72°22'28.39"E	280.477	Supra glacier lake in ablation zone
L11	36°49'34.47"N	72°22'50.04"E	71.948	Supra glacier lake in ablation zone
L12	36°49'32.81"N	72°22'51.59"E	383.575	Supra glacier lake in ablation zone
L13	36°49'28.59"N	72°22'55.75"E	160.611	Supra glacier lake in ablation zone
L14	36°49'26.98"N	72°22'55.01"E	97.715	Supra glacier lake in ablation zone
L15	36°49'24.80"N	72°22'58.75"E	462.251	Supra glacier lake in ablation zone
L16	36°49'22.12"N	72°23'0.01"E	14.545	Supra glacier lake in ablation zone
L17	36°49'12.30"N	72°23'8.52"E	33.224	Supra glacier lake in ablation zone
L18	36°49'1.73"N	72°22'42.40"E	430.593	Lateral moraine glacial lake
L19	36°49'10.22"N	72°22'38.10"E	29.282	Lateral moraine glacial lake
L20	36°49'10.52"N	72°22'35.02"E	125.569	Lateral moraine glacial lake
L21	36°49'13.17"N	72°22'29.86"E	811.976	Lateral moraine glacial lake
L22	36°49'20.55"N	72°22'26.00"E	619.406	Lateral moraine glacial lake
L23	36°49'22.77"N	72°22'23.43"E	104.472	Lateral moraine glacial lake
L24	36°49'56.65"N	72°21'56.32"E	365.909	Supra glacier lake in ablation zone
L25	36°49'59.89"N	72°21'54.38"E	530.753	Supra glacier lake in ablation zone
L26	36°50'33.85"N	72°21'49.69"E	164.237	Supra glacier lake in ablation zone
L27	36°50'1.19"N	72°22'19.04"E	1447.234	Supra glacier lake in ablation zone
L28	36°51'52.53"N	72°29'4.17"E	2479.833	Supra glacier lake in ablation zone
L29	36°51'38.01"N	72°29'12.96"E	5474.627	Supra glacier lake in ablation zone
L30	36°51'29.95"N	72°29'12.02"E	1178.641	Lateral moraine glacial lake
L31	36°51'15.15"N	72°29'11.57"E	101.403	Lateral moraine glacial lake
L32	36°50'59.93"N	72°29'16.33"E	193.912	Lateral moraine glacial lake
L33	36°50'56.28"N	72°29'17.56"E	307.049	Medial moraine glacial lake
L34	36°50'30.07"N	72°29'28.52"E	264.439	Medial moraine glacial lake
L35	36°50'23.70"N	72°29'26.82"E	1199.271	Medial moraine glacial lake
L36	36°50'22.10"N	72°29'25.88"E	103.022	Medial moraine glacial lake
L37	36°50'19.83"N	72°29'24.26"E	198.927	Medial moraine glacial lake
L38	36°50'17.14"N	72°29'23.25"E	366.719	Medial moraine glacial lake
L39	36°50'9.71"N	72°29'19.66"E	1041.533	Medial moraine glacial lake
L40	36°50'5.05"N	72°29'17.02"E	395.929	Medial moraine glacial lake
L41	36°50'2.43"N	72°29'15.00"E	218.040	Supra glacier lake in ablation zone
L42	36°49'52.45"N	72°29'9.13"E	312.331	Supra glacier lake in ablation zone
L43	36°49'51.45"N	72°29'7.52"E	409.178	Lateral moraine glacial lake
L44	36°49'45.26"N	72°29'1.20"E	642.581	Lateral moraine glacial lake
L45	36°49'47.92"N	72°28'58.80"E	1610.048	Lateral moraine glacial lake
L46	36°49'34.50"N	72°28'57.36"E	1812.973	Lateral moraine glacial lake
L47	36°48'13.83"N	72°28'36.24"E	961.935	Lateral moraine glacial lake
L48	36°50'4.83"N	72°28'38.59"E	353.825	Lateral moraine glacial lake
L49	36°50'5.23"N	72°28'11.11"E	128.555	Supra glacier lake in ablation zone
L50	36°50'15.71"N	72°29'14.93"E	509.072	Lateral moraine glacial lake
L51	36°50'4.34"N	72°28'43.29"E	803.039	Lateral moraine glacial lake

L52	36°53'4.70"N	72°53'22.13"E	536.463	Lateral moraine glacial lake
L53	36°53'5.39"N	72°53'22.16"E	6488.208	Lateral moraine glacial lake
L54	36°53'4.93"N	73° 1'0.07"E	804.001	Lateral moraine glacial lake
L55	36°54'30.23"N	73° 1'5.12"E	628.950	Lateral moraine glacial lake
L56	36°54'50.71"N	72°40'45.34"E	126.591	Lateral moraine glacial lake
L57	36°53'57.40"N	72°41'1.73"E	87.115	Lateral moraine glacial lake
L58	36°52'42.23"N	72°41'22.64"E	46.994	Lateral moraine glacial lake
L59	36°52'43.69"N	72°41'23.96"E	356.487	Lateral moraine glacial lake
L60	36°52'44.37"N	72°41'23.90"E	224.412	Lateral moraine glacial lake
L61	36°51'20.20"N	72°29'41.87"E	509.890	Supra glacier lake in ablation zone
L62	36°51'15.23"N	72°29'44.14"E	249.554	Supra glacier lake in ablation zone
L63	36°50'40.22"N	72°30'41.15"E	22797.458	Supra glacier lake in ablation zone
L64	36°50'39.50"N	72°30'39.03"E	49.307	Supra glacier lake in ablation zone

Table 3: Morphometric parameters of 12 selected glaciers from September 1994-2019

Glaciers	Perimeter (m)`	Snout position (m)	ELA Position	Area (Sq.km)	Accumulation Area (sq.km)	Ablation Area (sq.km)	AAR (sq.km)	Thickness (m)	Specific mass balance (cm)	Length (m)	Year
G1	16478.667	4551	5120.000	8.939	1.168	7.771	0.131	91.334	-88.442	6561	2019
	17125.284	4515	4908.000	8.869	5.057	3.812	0.570	91.093	18.364	6674	2016
	16861.271	4536	4789.000	8.890	4.492	4.398	0.505	91.165	2.604	6699	2009
	19012.049	4426	4787.000	9.879	4.502	5.377	0.456	94.460	-9.448	6480	2001
	17064.084	4517	4787.000	9.334	5.042	4.293	0.540	92.677	11.062	7081	1994
G2	10261.087	4708	5223.000	2.295	1.062	1.234	0.462	56.953	-7.804	3938	2019
	10340.028	4708	5095.000	2.416	1.309	1.107	0.542	58.011	11.441	3956	2016
	10340.028	4708	5087.000	2.416	1.365	1.051	0.565	58.011	17.100	3956	2009
	10705.247	4661	5069.000	2.792	1.494	1.298	0.535	61.084	9.875	4138	2001
	10261.315	4705	5068.000	2.511	1.537	0.973	0.612	58.813	28.637	3956	1994
G3	28630.899	4576	5044.000	13.195	5.635	7.560	0.427	104.056	-16.408	7266	2019
	28748.597	4565	5029.000	13.790	6.779	7.011	0.492	105.593	-0.724	7290	2016
	28679.747	4564	4989.000	13.834	7.868	5.966	0.569	105.705	18.020	7365	2009
	28414.803	4560	4966.000	13.779	8.569	5.210	0.622	105.566	30.939	7534	2001
	28667.525	4518	4980.000	14.116	8.891	5.225	0.630	106.416	32.871	7935	1994
G4	41756.466	4193	4854.000	16.745	6.881	9.864	0.411	112.605	-20.325	5638	2019
	44108.226	4190	4858.000	17.341	8.910	8.431	0.514	113.911	4.677	5702	2016
	44157.892	4180	4854.000	17.361	9.550	7.811	0.550	113.955	13.485	5742	2009
	43488.387	4177	4824.000	17.284	8.652	8.632	0.501	113.788	1.461	5749	2001
	44098.957	4147	4799.000	17.506	9.166	8.340	0.524	114.268	7.052	5804	1994
G5	49063.050	4398	4960.000	27.936	7.390	20.546	0.265	133.172	-55.902	7524	2019
	49262.817	4365	4865.000	29.031	12.009	17.022	0.414	134.848	-19.665	7809	2016
	48038.080	4358	4848.000	29.199	14.002	15.197	0.480	135.101	-3.656	7848	2009
	48625.953	4342	4810.000	29.541	15.619	13.922	0.529	135.613	8.299	7991	2001
	47733.640	4335	4827.000	30.426	15.004	15.422	0.493	136.920	-0.350	8177	1994
G6	23397.099	4058	4993.000	10.382	5.549	4.833	0.535	96.048	9.703	8419	2019
	21318.424	4034	4985.000	11.081	6.291	4.790	0.568	98.168	17.780	8471	2016
	23906.066	4104	4974.000	11.983	7.497	4.486	0.626	100.768	31.854	8396	2009
	23343.723	3997	4964.000	11.812	7.082	4.730	0.600	100.287	25.514	8493	2001
	24759.035	4013	4945.000	12.211	8.189	4.022	0.671	101.403	42.779	8568	1994
G7	29540.311	4097	4924.000	9.262	3.338	5.924	0.360	92.434	-32.605	6914	2019
	30645.825	4076	4888.000	10.138	4.187	5.951	0.413	95.285	-19.831	6994	2016
	30591.799	4062	4885.000	10.133	4.134	5.999	0.408	95.271	-21.046	7033	2009
	30750.706	4052	4850.000	10.273	4.619	5.655	0.450	95.710	-10.938	7125	2001

	31039.207	4043	4850.000	10.603	4.628	5.976	0.436	96.731	-14.128	7151	1994
G8	44338.843	4093	4740.000	19.920	5.936	13.984	0.298	119.231	-47.776	8994	2019
	45703.641	3925	4702.000	22.588	7.943	14.646	0.352	124.248	-34.739	8972	2016
	48429.311	3928	4688.000	23.775	12.752	11.022	0.536	126.346	10.160	8956	2009
	54119.915	3905	4697.000	25.588	10.736	14.852	0.420	129.416	-18.230	9140	2001
	54691.248	3930	4482.000	24.989	13.344	11.645	0.534	128.420	9.582	9051	1994
G9	90123.298	3219	5207.000	45.132	21.298	23.834	0.472	155.535	-5.510	12485	2019
	90238.818	3220	4831.000	45.195	0.001	45.194	0.000	155.605	-120.18	12513	2016
	90570.032	3188	5052.000	45.061	32.505	12.555	0.721	155.455	55.114	12675	2009
	92003.189	3177	5006.000	45.210	32.822	12.388	0.726	155.621	56.236	12770	2001
	89384.763	3128	5010.000	45.249	33.438	11.811	0.739	155.664	59.394	12923	1994
G10	20158.846	4433	4834.000	8.696	4.743	3.953	0.545	90.488	12.364	5560	2019
	20720.126	4436	4831.000	10.505	5.057	5.448	0.481	96.428	-3.209	5485	2016
	20499.660	4435	4883.000	10.634	5.293	5.341	0.498	96.823	0.771	9333	2009
	20813.777	4436	4834.000	11.028	5.171	5.857	0.469	98.011	-6.231	5496	2001
	66405.284	4227	4832.000	11.332	5.783	5.549	0.510	98.906	3.826	5543	1994
G11	69836.756	4203	4793.000	35.014	16.941	18.073	0.484	143.300	-2.608	12394	2019
	65553.350	4211	4784.000	35.918	19.876	16.042	0.553	144.487	14.287	12405	2016
	65791.802	4198	4829.000	36.129	20.405	15.724	0.565	144.761	17.061	5461	2009
	67522.542	4194	4787.000	37.519	19.034	18.485	0.507	146.539	3.096	6480	2001
	54691.248	4111	4781.000	24.989	20.348	4.641	0.814	128.420	77.687	12881	1994
G12	32791.975	4240	4980.000	17.181	7.862	9.319	0.458	113.565	-8.985	9397	2019
	31487.183	4246	4885.000	17.348	9.030	8.318	0.521	113.927	6.303	9329	2016
	31524.657	4261	4787.000	17.563	9.932	7.631	0.566	114.390	17.240	12435	2009
	32656.236	4222	4861.000	18.667	10.040	8.626	0.538	116.710	10.524	9696	2001
	89384.763	4224	4865.000	17.852	10.822	7.030	0.606	115.008	27.125	9952	1994

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