TEMPORAL MONITORING OF GLACIER CHANGE IN DHAULIGANGA BASIN, KUMAUN HIMALAYA USING GEO-SPATIAL TECHNIQUES

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ABSTRACT:

Present study is based on the change in surface area of the glaciers in downstream area of Dhauliganga basin, Pithoragarh district, Uttarakhand. For this study, Survey of India toposheets (surveyed in 1963) have been used for preparation of initial boundary of glaciers. Total 11 glaciers have been selected for the study in downstream valley. RGI (Randolph Glacier Inventory) data version 60. (15_RGI 60.SouthAsiaEast) from GLIMS, released July 28 2017, used for measuring temporal change in surface area. Landsat 8 OLI/TIRS image of 06 November 2016 has used to measure present area of glaciers. ASTER GDEM was used for automatic extraction of basin boundary by hydro-processing methods. Glacier boundaries were manually digitised from the Landsat image for better accuracy. The total glacier area was 69.35 km^2 (1963), 48.10 km^2 (2001) and 34.35 (2016) as determined from SOI toposheet, GLIMS and the Landsat image of 2016 respectively. Total vacated area by the retreat and melting of glaciers from 1963 to 2016 is 35 km^2, which accounts to a total loss of 50 % from the total glaciated area. Google Earth imagery was also considered for marking the actual position of glacier outlines. Ice walls in topographic maps are also considered as the part of glacier but in present satellite image they are free from ice.

1. INTRODUCTION

The Glaciers are the world's primary source of fresh water. Glaciers of Himalaya contributing a varying scale of the overall runoff in south Asian countries. Himalayan glaciers are considered as the third pole environment of the Earth and the water tower of Asia. In general glaciers all around the world are receding, but Himalayan glaciers are receding much faster as compared to glaciers in other parts of the globe. Mountain glaciers constitute one of the most important components of the earth's natural system (Slaymaker and Kelly, 2007). Current knowledge on the behaviour of glaciers in the Himalayan region is limited (Bolch et al. 2012). Long term monitoring of glaciers provides a comprehensive overview of glacier dynamics in the context of climate change. Most previous studies were based on terminus monitoring for the Indian Himalayan region (Kulkarni et al.2007; Kulkarni and Rathore, 2005). Remote sensing methods have supported improve estimates of glacier area changes (Bhambri et al., 2010; Bolch, 2007). It is evident that due to rise in temperature, glacier melting, ice sheets showed a rise in sea level (IPCC, 2007). Historical instrumental weather records from north-eastern Himalaya have shown an increase in temperature 1.60C over the past century and the weak trend in monsoonal precipitation (Bhutiyani and Others, 2007, 2009). Himalayan glaciers have been in a general trend of recession since the 1950s (Bhambri and Bolch, 2009).

So, regular monitoring of a large number of the Himalayan glacier is important for improving our knowledge of glacier response to climate change. Although field observations are highly recommended, a few numbers of glaciers can be investigated owing to time and by logistic support in the remote mountainous region. Multitemporal and multispectral satellite data provide an abundant potential for mapping and monitoring the large spatial coverage of glaciers at regular temporal intervals, as they allow automated/semi-automated glacier mapping (Paul and others, 2009; Racoviteanu and others, 2009).

Most of the glacier change studies based on the satellite data with the comparison of 1960s topographic maps. Satellite remote sensing has a great potential to monitor glaciers due to their synoptic view, repetitive coverage and up-to-dateness. Remote sensing appears to be the only means of monitoring the retreat if it is to be carried out for a large number of Himalayan glaciers, where field methods are difficult to implement due to rough weather and terrain conditions [4]. The verification of remote sensing studies with the field data is also very important. Glaciers from Eastern Dhauliganga basin have been monitored by remote sensing methods as well as field investigations. The Meloa glacier (GLIMS ID: G080466E30214N) is divided into 2 parts, one part as highly debris-covered area and second upper part is some ablation and accumulation zone. The portion of the upper part is divided by height free from ice. The snout of Sona glacier (G080452E30235N) is too high and showing the hanging type of glacier. These two and rest of one Chipa (G080500E30180N) have been monitored by ground verifications.

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2. STUDY AREA

The present study of glacier area monitoring is based on upper Dhauliganga river basin of Pithoragarh district,
Kumaun region of Uttarakhand. Dhauliganga river is one of a tributary of Mahakali basin of Kumaun Himalaya. The study area lies between latitude 29° 55' to 30° 35' N and longitude 80° 15' E to 80° 45' E. Left side of this river, Mahakali catchment and in south Goriganga catchment are formed the headword region of Mahakali river. The total geographical area of the basin is 1365.21 km^2.

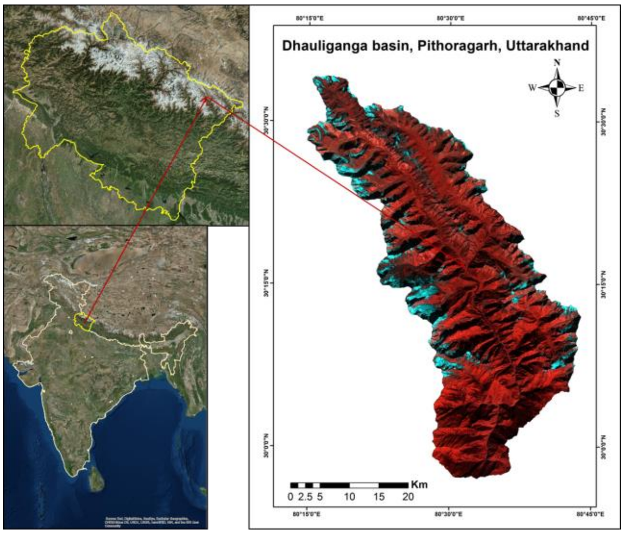


Figure 1. Study Area: Eastern Dhauliganga basin, Pithoragarh district, Kumaun Himalaya, Uttarakhand.

The headward region of Dhauliganga river basin originates with two glacier-fed tributaries namely Darma Yangti (Left) and Lissar Yangti River. These both tributaries supply almost 80% of the glacierized water of Dhauliganga basin. Dhauliganga River originates from Govan Khana glacier. It joins with Kali River at Tawaghat. The total length of the river is 91 km. The towns situated in the valley are Siphu, Tidang, Dantu, Dugtu, Nagling, Baling, New Sobla etc.

3. METHODOLOGY

3.1 Data Sources

In this study, ASTER GDEM, 30 meters have been used for hydro-processing like catchment delineation and Landsat 8 OLI/TIRS image of date 06 November 2016 were downloaded from USGS website and used to measure the present areal extent of glaciers. Survey of India topographical sheets (surveyed in 1963) have been used as a base for initial glacier boundary. Randolph Glacier Inventory (RGI) is a global inventory of glacier outlines (1999-2001) used for measuring glacier extent in 2001. It is supplemental to the GLIMS (Global Land Ice Measurements from Space) database and is a map of glaciers for one time and a collection of useful attributes. RGI (Randolph Glacier Inventory) data version 60. (15_RGI 60.SouthAsiaEast) released July 28, 2017, used to measure temporal change. This data is made available from GLIMSView (www.glims.org). GLIMS glacier outlines have a limit for precise boundary delineation for glacier area change. These outlines are prepared from ASTER data on a global scale, so they can provide overestimation in glacier area as compared to high-resolution imagery like Google Earth and Sentinel 2A (MSI). However, for showing a decadal change in glacier area, GLIMS outlines may become an asset for the glacier inventory data. Landsat 8 OLI image, 30 meters spatial resolution, dated 06 November 2016 used to delineate present glacier outlines for measuring total loss in glacier area from 1963 to 2016.
Use decimal numbering for headings and subheadings

3.2 Glacier Mapping

Glaciers mapping in a watershed, primarily provide a basic idea of surface water available in the basin for perennial water supply in the river. From May to September (sometimes October) summer season in the northern hemisphere when all seasonal snow has melt and glaciers are fully exposed in their actual positions. In ablation season (May-September), cloud conditions are very high and a few satellite images come under the cloud-free area. September and sometimes October, cloud-free satellite images can be identified for glacier mapping. At this time, no seasonal snow cover on the glacier surface and snout is easily marked in satellite data. Glaciers mapped from SOI toposheet (1963), provide a base for the initial stage of glacier condition for Mark footnotes in the text with a number (1); use the same number for a second footnote of the paper and so on. Place the study. All glaciers are mapped by the conventional method by digitizing for better accuracy. However, this method is time-consuming than semi-automated methods of mapping but suitable for small and less number of glacier mapping. Landsat 8 OLI image provides information about the present glacier extent in the downstream area of the basin. GLIMS glacier outlines also be used for decadal change in glacier and was overlapped on the present glacier outlines that provided continuous loss in glacier area and extent change from 1963 to 2016.

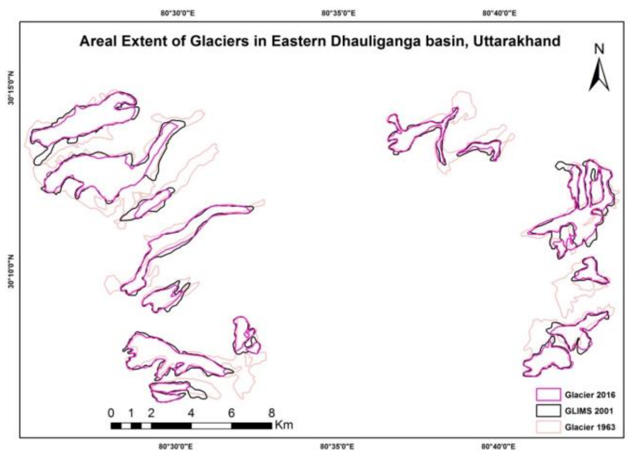
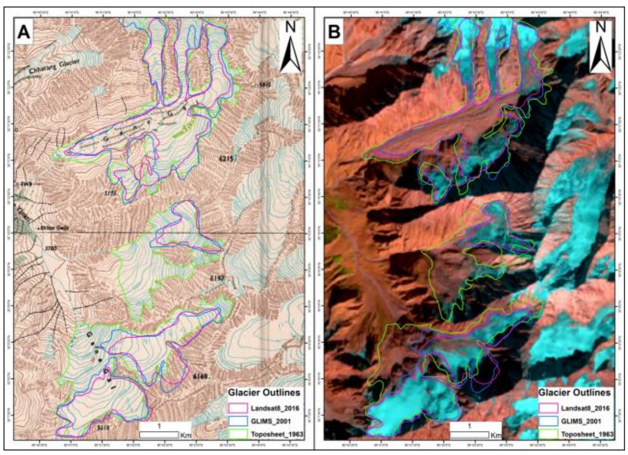


Figure 2. Glacier area change from 1963-2016. Glacier outlines are mapped from Survey of India toposheet (1963), GLIMS boundary (2001) and Landsat 8 OLI image of raw DNs. (2016).



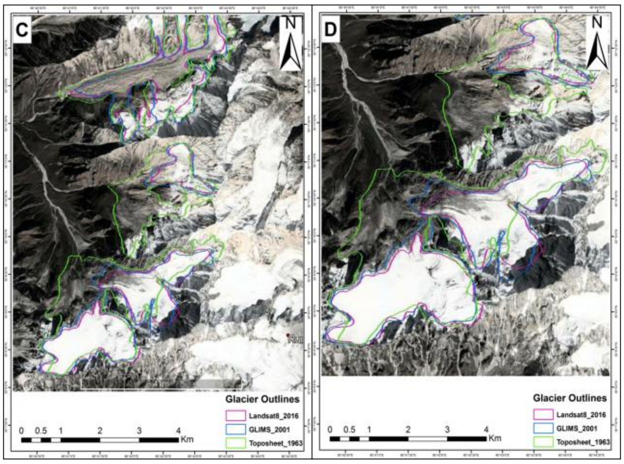


Figure 3 & 4. Loss in glacier area shown from different images: (A) SOI toposheets surveyed in 1963, (B) Landsat 8 OLI image, 06 Nov. 2016, (C) Google Earth image (13/10/2017), (D) High resolution Google Earth image, (13/10/2017).

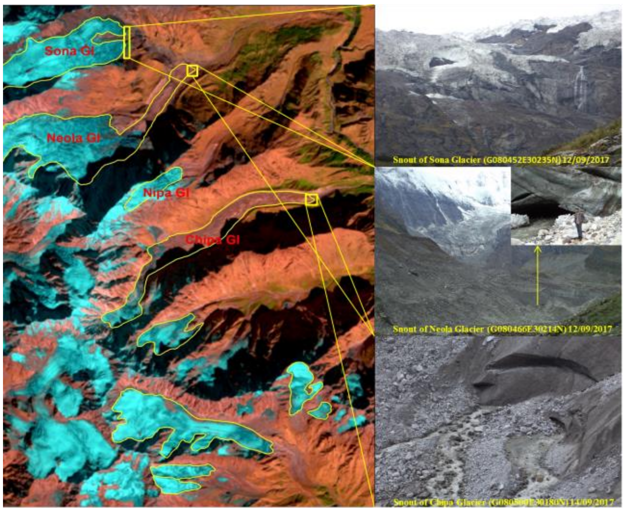


Figure 5. Map showing snout positions of Sona, Neola and Chipa glacier, photographs by Dhanendra Kr. Singh

4. RESULTS

Glaciers of the upstream side are receding slowly as compared to the downstream region. In the downstream region, glaciers are showing fast dynamics. Their frontal part is vacating more to the glaciers of an upward region. The total glacier area in 1963 was 69.35 Sq.km, 44.89 sq.km in 2001 and 34.35 in 2016. A loss in the glaciated area reduced to 35.29 Sq.km. from 1963-2016. The loss may be occurred due to human accessibility and changes in the meteorological phenomenon.

Table: 1 Glacier area change during 1963-2016 (area in Sq.km).

S.N.	GLIMS ID	1963	2001	2016
1	G080452E30235N	9.46	6.85	5.43
2	G080466E30214N	14.75	9.62	5.43
3	G080485E30197N	3.44	1.53	0.84
4	G080500E30180N	5.36	4.44	4.19
5	G080494E30155N	2.06	1.77	0.71
6	G080496E30128N	8.51	5.58	2.08
7	G080501E30114N	2.05	1.20	0.88
8	G080692E30128N	6.24	2.37	2.08
9	G080714E30167N	3.38	1.13	0.88
10	G080710E30190N	7.30	6.8	5.88
11	G080659E30223N	6.80	3.59	2.89

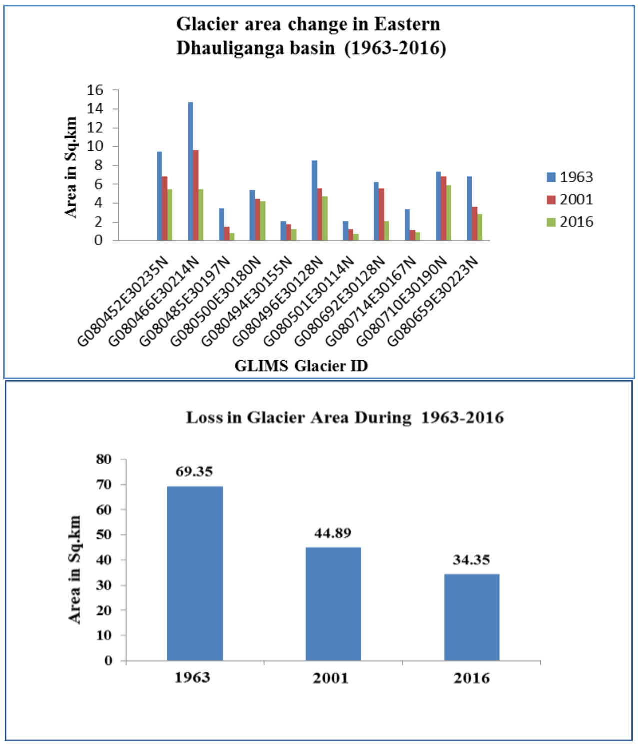


Figure 6&7. Observed Change in glaciers of Eastern Dhauliganga basin.

5. DISCUSSION

Glacier area change from 1963-2016 shows areal as well as the frontal extent of glacier due to may rise in temperature or other human accessions. It is widely accepted that the rise in temperature is a major cause for glacier melting. But in sometimes microclimatic conditions are also responsible for the warming in small areas. However, glacier area shown by SOI toposheets may some error in the preparation of toposheets from aerial photographs surveyed in 1963 because at that time instruments were not as sophisticated as much today. In that time surveying was widely done through Plain Table and other levelling instruments like Dumpy level and Sextant. These instruments produced levelling problems in undulating hilly

terrain. Valley walls covered by snow were considered under the glacier area in toposheets but present day in satellite data they are free from snow and ice. So, this can also be led error in results. GLIMS outlines are considered as a global inventory of glaciers, broadly used by researchers in the world. These outlines are prepared from ASTER satellite images by semi-automatic glacier mapping methods but presenting shift in present glacier boundary of the snout and ablation areas. This shift may be due to the effect of the high-resolution difference in satellite data. We have overlapped GLIMS outlines on Landsat 8 OLI data and checked shift in lateral moraine side of the glaciers. So, this problem may also affect the final results of the study. The intersection has among outlines are due to GLIMS boundaries which are prepared from ASTER imagery worldwide automatically, different resolutions gave rise to change in visual interpretation. Recent Landsat 8 image has been precisely interpreted for seeing a change from GLIMS data to present Landsat image.
Microclimate is widely affected by deforestation, changing land use pattern. Small glaciers near villages are a major source for fresh water supply for the people. This 53 years period of glacier monitoring provides primary investigation for areal extent of glaciers. This study provides an overview to study some other parameters for enhancing our knowledge and a better understanding of glaciological investigations.

6. MAPPING UNCERTAINTY

Glacier outlines have been derived from different resolutions like Survey of India toposheet on 1:50000 scale, GLIMS and Landsat 8 OLI data. For precise mapping, manual delineation has done from toposheet and Landsat 8 OLI data. Mapping uncertainty has estimated as ± 2.059 % from Landsat 8 and the GLIMS boundary has already provided glacier area in the attribute table data. GLIMS boundaries have been delineated from ASTER data and are compared with Landsat 8 OLI by manual methods. Toposheet data may have some errors when surveyed because that time instruments were not so precise and sophisticated.

7. CONCLUSION

Glacier monitoring in the study area primarily provides alarming information for the health of glaciers. Mapping of glacier area and retreat of snout may provide basic knowledge of glacier dynamics. However, this study is not enough to estimate the glacier dynamics with reference to climate change. The further study like mass balance, volume and ice thickness estimation, glacier velocity, and melt runoff are such parameters which provide extensive information for the study of glaciers and ice sheets. This study is an attempt to assessing the basic idea of glacier mapping and to prepare for other investigations.

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