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Recession of Satopanth and Bagirath Kharak Glacier, Using Multi Temporal Set of Data

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ABSTRACT: The changes in climate variability have led to a rapid retreat of mountain glacier systems which are considered the lifeline of river basins and ecosystems. Scientific studies have shown that 67 % of glaciers are retreating at a startling rate in the Himalayas as a result of various factors including climate change. Glaciers and small ice caps in temperate environments are sensitive indicators of the change in climate. Satopanth and Bhagirath Kharak glaciers are located at the head of the Alaknanda valley in Chamoli District. Retreat of the snouts and area vacated by recession of the glaciers were estimated for 51 years by way of superimposing the Survey of India Toposheets of 1962 on the map .Snouts of the Satopanth and Bhagirath Kharak glaciers recorded continuous recession for the past five decades, with decline in recession of both cases. The retreat rate of Satopanth glacier is 2.88 m/year while Bagirathi Kharak retreat at a rate of 1.21 m/year which is much more less in comparison to Satopanth glacier. Retreat in the length of Satopanth and Bagirathi Kharak glacier was 2.28km and 0.66 km respectively from the period (1962-2013). The total area vacated by the Satopanth and Bhagirath Kharak glaciers during 51years was (0.354 sq. km) and (0.14 sq. km) respectively. This paper presents the results obtained from the analysis from the set of multitemporal satellite data, SOI Toposheets 1962, Satellite data of Landsat 1976, 1990, LISSIII 2000,2010 and CARTOSAT-1& LISS IV 2013 are used in the study.

KEYWORDS: Satopanth, Bhagirath Kharak Glaciers Glacier Retreat, Satellite Data.

INTRODUCTION

Impacts on high mountain systems including glacial retreat are amongst the most directly visible signals of global warming. One of the most important and visible indicators of climate change is the recession of glaciers in many parts of the World including Himalayan glaciers. On a time scale recent glaciations occurred around 20,000 years ago as part of the earth's pale climatic history. Although the recession of glaciers has been suggested by some scientists as a natural phenomena, in the latter half of 20th century. Warmer climate in the future may cause increased melting of glaciers, which will lead to a rise in sea level.. Monitoring of glaciers actuates scientific interest for two main reasons. First, Glaciers change monitoring has been used for climatic change investigation. The surface area and volume of individual glaciers are monitored to estimate future water availability. Second, glaciers in Indian Himalayas, have been recognized as important water storage systems for municipal, industrial and hydroelectric power generation purposes. The present study deals mainly with climatic change and its impact on the Himalayan glaciers. Glaciers all over the world have been shrinking since the last ice age, and they experience melting every year. The increasing temperatures of climate change are speeding up the shrinking process – a concern usually captured in the terms "glacier melt" and "glacier retreat" (S. Swaroop and S. P. Shukla. Changes in glacier melt amounts and patterns, along with other changes in high-altitude hydrology, will affect agricultural production across the region. In the Himalaya, glacier and snow-melt form an important source of water into the North Indian rivers. However, this source of water is not permanent as glacial dimensions change with climate. Along with glacier melt changes, increased temperatures will reduce snow cover throughout the winter but especially in spring, and monsoon patterns will likely change as well. The natural environment, ecosystems with high biodiversity, and human populations that live in these watersheds may experience severe impacts. Although the pace of glacier retreat is slower than was thought at the time of the project's initiation, the phenomenon is occurring.. The river basins are important for Indian economy, as numerous power projects are under operation and construction here. Therefore, changes in glacial extent and their influence on river run-off are important to plan future strategies of power generation.

STUDY AREA

The glaciers are situated at the head of the Alaknanda valley in Chamoli District, Uttarakhand. The major portion of the glaciers falls in the Survey of India topographic map N/6 , 53 N/5, and N/1. The glaciers are located between lat. 30°43′47″–30°43′28″N and long. 79°11′53″–79°29′30″E. The Satopanth and Bhagirath Kharak glaciers are approximately 14.29 and 19.17 km long with an average width of 767–872 m, covering an area of 23.17 and 31.17 sq. km respectively. The Upper Alaknanda watershed covers an area of 234.35 sq. km, out of which 70.70 and 107.22 sq. km are covered by the Satopanth and Bhagirath Kharak sub-watersheds respectively. It lies on the northwest side of Nilkanth, a major peak of the Garhwal division of the Himalayas. It sits below a 2,500 m (8,200 ft) face of the peak. Originating at a height of 7000 meters from the peaks of the Chaukhamba (7068m) and the Badrinath (6974m) mountains, this glacier melts into water at an altitude of 3810 meters. The Narayan Parvat and the foot of Balkun peak, touches the glacier.

DATA USED AND METHODOLOGY

Monitoring of Himalayan glaciers, using conventional methods, is normally a difficult exercise due to the rugged and inaccessible nature of the terrain with the application of remote sensing techniques in mid-seventies now monitoring and mapping of glacier became easier . Extensive work, based on spectral reflectance characteristic of snow and glacier, was done with Multi temporal satellite data .

Table 1: Satellite and topographic data used in the study

Satellite Name	Resolution	Date Of Acquisition
LISS IV data	5.8m	2013
LISS IV & Cartosat Merged data	2.5m	2011
LISS III data	23.5m	2006
AWIFS data	64 m	2012
Landsat MSS data	30 m	1976
Landsat TM data		1990
SOI Toposheets maps at 1:50,000		1962

This investigation has been carried out using data from a number of Indian Remote Sensing satellites. In this study LISS IV (5.8m) Cartosat Merged data(2.5m) , LISS III(23.5m) , Landsat TM (30m) are used for finding retreat and mapping. The oldest information about glacial extent is available on Survey of India topographic maps, surveyed in 1962, using vertical air photographs and limited field investigations. Mapping of glacial extent in 2006,2013 was carried out using LISS-IV images, in the year 2000 LISS-III images are used, for 1976 and 1990 Landsat images were used. Images covering July–September period were selected, because during this period snow cover is at its minimum and glaciers are fully exposed. Glacier boundary was delineated using topographic maps and digitized using Geographic Information System. On satellite images glacial boundary was mapped using standard combinations of bands. Image enhancement technique was used to enhance the difference between glacial and non glacial areas. Ancillary data like basin boundaries, river, Glacier boundary, drainage and spatial frame work parameters (1:50, 000 scale) Survey of India topographic map frames were taken from NRDB database. Elevation values were derived from aster-DEM given in meter.

The present study involves mainly delineation of the terminus portion of the glacier. Hence satellite data devoid of fresh snow at lower altitudes of the glacier were selected. The steps include geo-rectification of maps, Orthorectification, co-registration, interpretation and digitizing the glacier outlines. Subsequently, the Satopanth and Bagirathi Kharak Glacier terminus position was digitized from satellite imageries of 1976, 1990, 1999 and 2010, and 2013. Delineation of the Glacier boundary and terminus from satellite imagery was carried out using standard false color composite (FCC) band combination of SWIR, NIR and green bands for red, green and blue channels respectively. Reflectance of debris/rock in SWIR band was higher than that of ice; therefore, debris cover on the glacier gives a red tone in the aforementioned FCC image. Snow is characterized by a high reflectance in visible spectral region and a rather strong absorption in the SWIR region. Therefore, ratio of visible band/SWIR band can differentiate the snow and non snow covered surfaces. To estimate change in glacial area, the glacier boundaries of two time frame data of glacier extent are overlaid on each other. The two time frame data/glacier boundaries are brought to common scale. While matching the boundary, the scale of the map and image is kept at 1:50,000 because the mapping depends on the scale. Increase or decrease in the evacuated area from glaciers can be measured.

IRS-P6 LISS-III satellite data has been used for preparing geomorphologic map of the study area. The major landforms exposed in this area are of glacial origin. Some landforms of structural, denudation land fluvial origin are also exposed in this area. Under the geomorphic units of glacial origin, the area has glacial terrain and valley glacier. The landforms here include medial moraine and lateral moraine. The geomorphic units of structural origin have highly dissected structural Hills and valleys. The landform of denudation origin has piedmont slope. The landform of fluvial origin has piedmont alluvial plain.Biotite Granite & Tourmaline Granite of Gangotri formation and Vaikrita Group rocks are exposed in this area. The Vaikrita Group mostly composed of migmatites Gneiss and Granite. Change in snout position was ascertain by mapping Satopanth and Bhagirath Kharak glacier from 1962-2013 .The snout of the glacier represent the total health of glacier, the snout is a vital part for the interpretation of glacial extracts . The terminus is identified on satellite data using multiple feature the snout is the originating point of river and river can be easily identified in the image. The peri-glacier area downstream of the snout has distinct geomorphologic set up then the glacier surface. The area vacated was estimated by taking the snout position marked in the Survey of India topographic map (53N/5) of 1962 and comparing it with the present position using set of satellite data. The position of snouts in 1962 was observed at the height of 3726mt with the help of aster DEM, in 1962 the Satopanth and Bagraitah Kharak glacier snout was single but at the steady rate the fragmentation of these two glaciers was started after 1976 .In 1962 the length of Satopanth and Bhagirath Kharak glacier was 14.29 km and 19.17 km respectively. Total decline in the length of Satopanth glacier and Bagirath Kharak glacier 2.28 km and 0.66 km respectively. Rate of Satopanth glacier recession was higher than Bhagirath Kharak glacier.

Table 2: Length of Satopanth Glacier from 1962-2013

Period	Length of Satopanth glacier (km)	Vacated area
1962	14.29	-
1976	13.94	0.35km
1990	12.67	1.27km
2010	12.36	0.31km
2013	12.01	0.35km

Table 3: Length of Bhagirath Kharak Glacier from 1962-2013

Period	Length of Bhagirath Kharak glacier (km)	Vacated area
1962	19.17	
1976	19.00	0.17km
1990	18.81	0.19 km
2010	18.67	0.14 km
2013	18.51	0.16 km

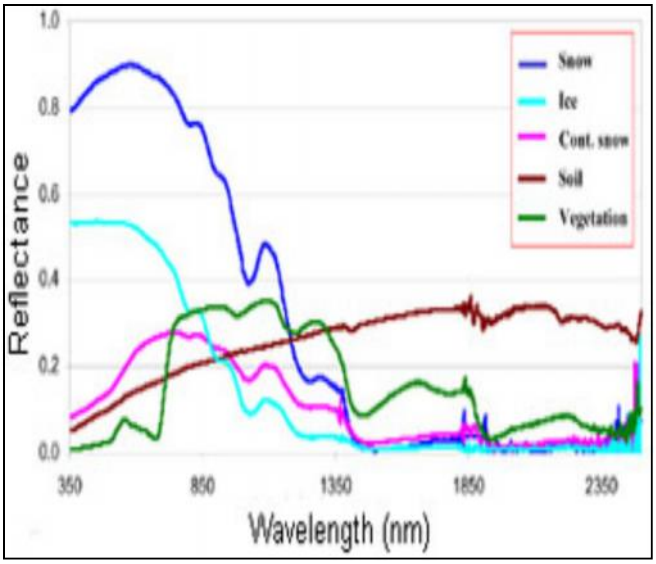

Fig 1: Spectral reflectance of snow, ice contaminated snow, vegetation and soil.

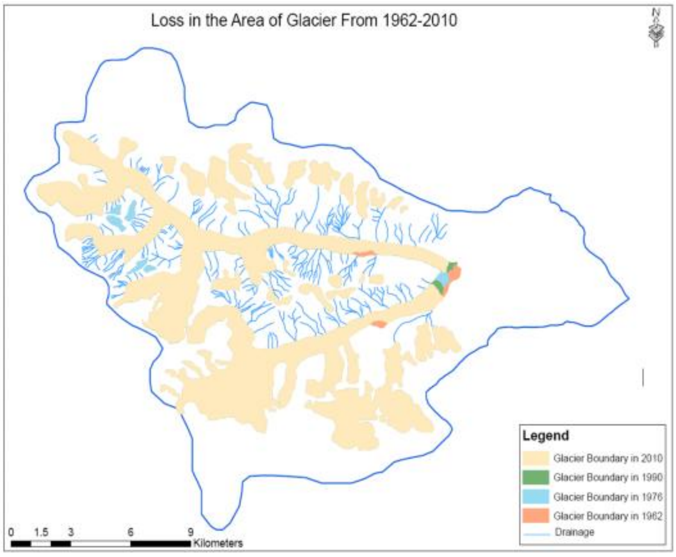

Fig 2:Glacier Boundary of Satopanth and Bagitahi Kharak Glacier from 1962-2010

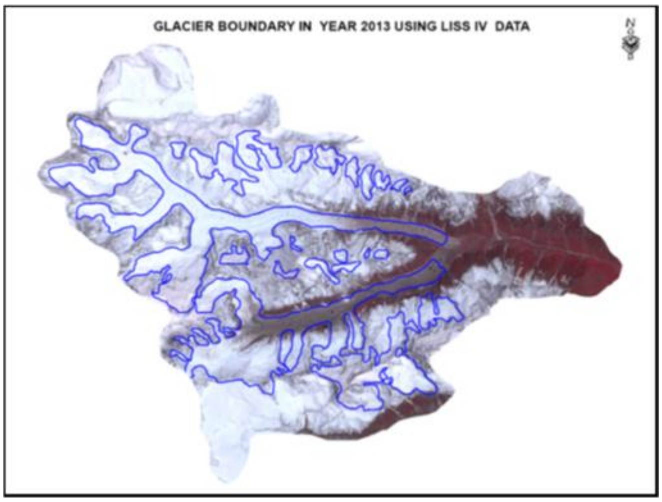

Fig 3:Glacier Boundary of Satopanth and Bagitahi Kharak for the year 2013using LISS IV data

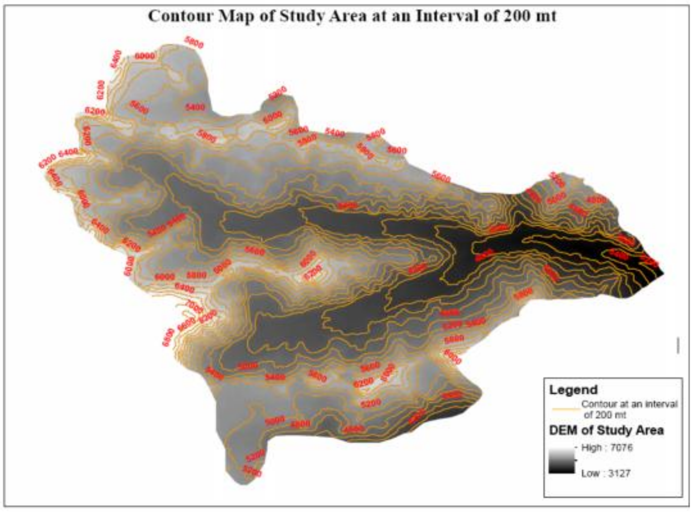

Fig4:Contour Map at an Interval of 200 mt using ASTER DEM

Table 4: Snout Recession of Satopanth and Bagirathi Kharak Glacier Between 1962 And 2013

Period	Snout Position of Satopanth Glacier (using aster DEM)	Snout Position of Bhagirathi Kharak Glacier (using aster DEM)	Retreat of Satopanth glacier	Retreat of Bhagirathi Kharak glacier
1962	3726mt	3726mt	-	-
1976	3827mt	3774mt	101mt	48mt
1990	3836mt	3771mt	9mt	3mt
2006	3872mt	3761mt	36mt	10mt
2013	3873mt	3762mt	1mt	1mt

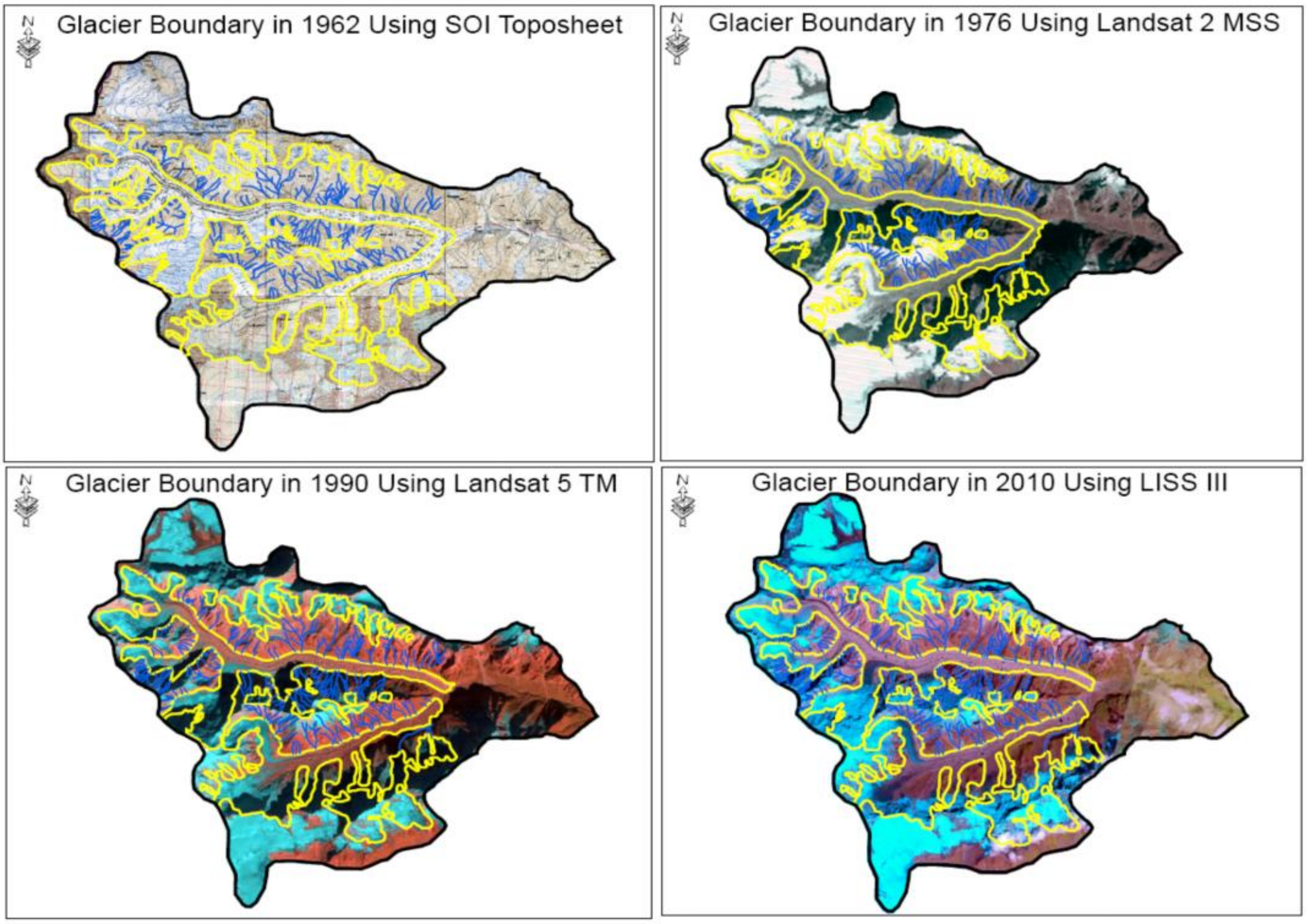

Fig 5: Glacier Retreat of satopanth and bagirath kharak Glacier from 1962 to 2010

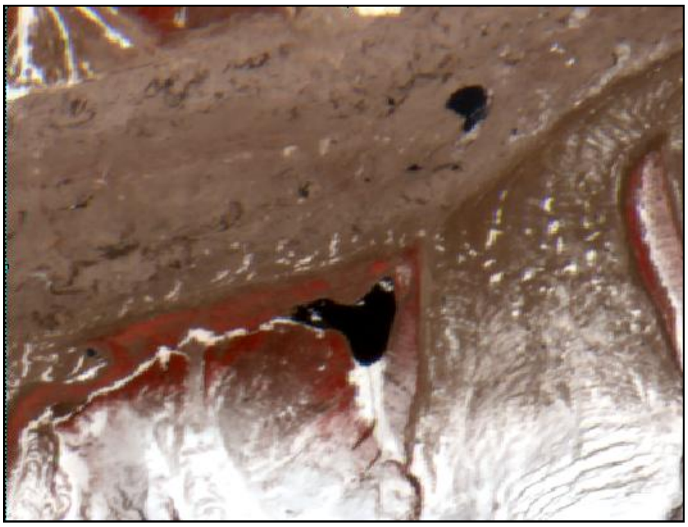

Fig 6 :Satellite imagery LISS-IV sensor showing Satopanth lake near Satopanth galacier

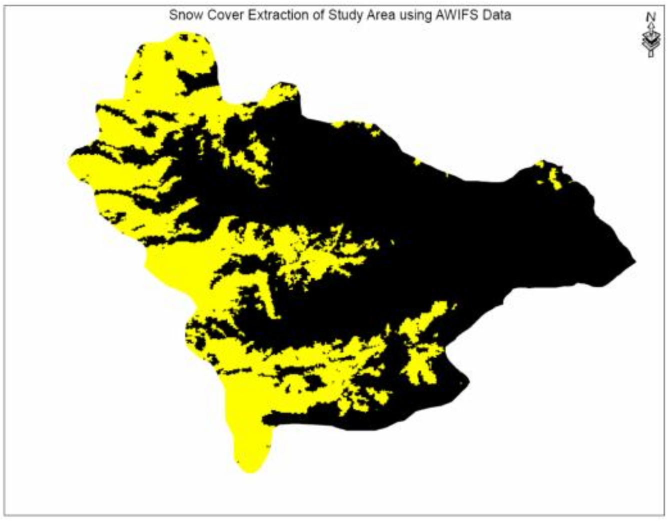

Fig7: Snow Cover Extraction of Study Area using NDSI

Figure 8 :Field Photograph Showing Satopanth Lake Near the Snout of Satopanth Glacier.

Figure 9: Field photograph of terminus region of Satopanth Glacier in year 2011.

Identification and mapping of glacier boundary and terminus is one of the important aspects of estimation of retreat. If glaciers are not covered by debris, identification of snow, ice and rock on satellite images is possible due to substantial difference in spectral reflectance. A satellite imagery of LISS-IV sensor showing glacial boundary of 1962 and 2013 is given in Figure 10. Identification and mapping of glacial terminus in a satellite imagery is normally difficult if glaciers are covered by debris Sometimes a glacial terminus is characterized by a steep ice wall. Depending upon relative positions of the sun and the wall, it can form shadow in downstream, which can be used as a marker for terminus delineation.

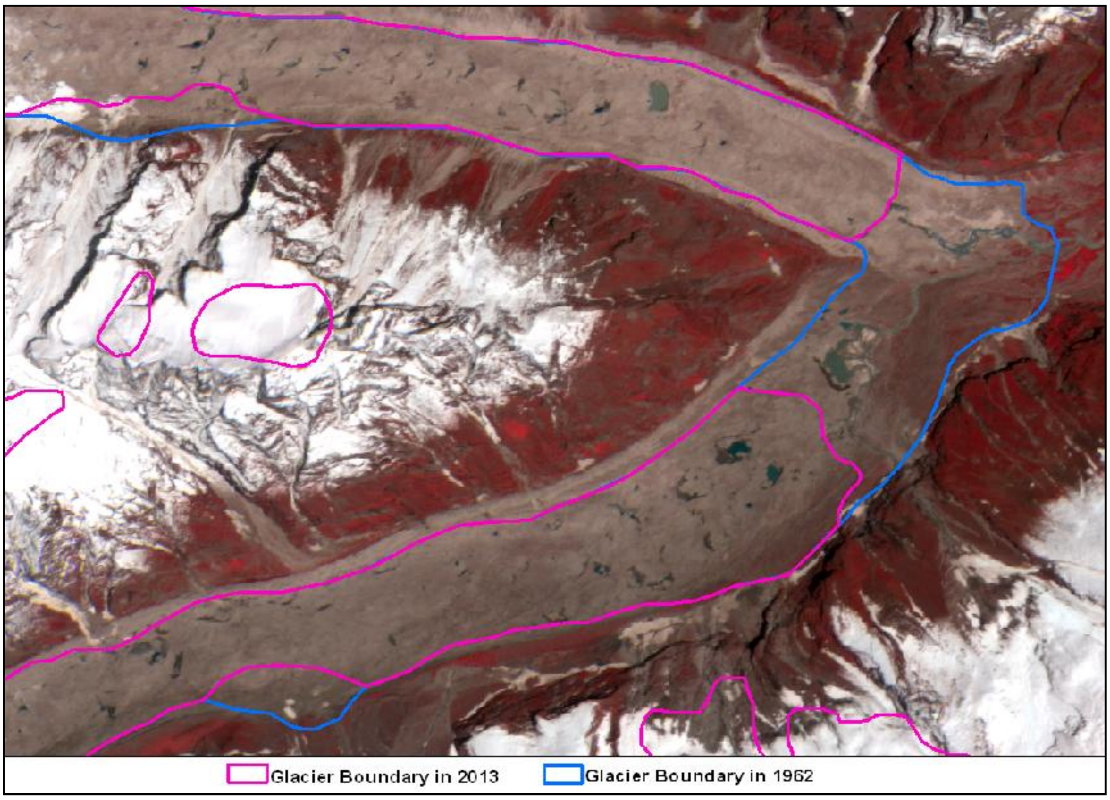

Figure 10. Resourcesat imagery of LISS-IV sensor dated June 2013 showing Glacier Boundary in 1962 and 2013

CONCLUSION

Globally, glaciers are considered to be the sensors of climate change. Any small disparity in the climate will affect the accumulation and ablation rate of glaciers, which in turn affects mass balance of the glaciers. Accurate determination of these glacier changes may be useful in assessing regional hydrological responses in Indian rivers. The retreat of glaciers in the Himalaya has significant impact on the environment, including freshwater supply, diminishing wetlands and unstable stream runoff. Remote sensing offers promise for glacier monitoring in areas lacking traditional glaciological methods. In the study it is observed that Snouts of the Satopanth and Bhagirath Kharak glaciers record continuous recession from 1962 to 2013 which decreased in the year from 1976-1990, recession in the Satopanth glacier is much more higher then Bhagirath Kharak glacier. The retreat rate of Satopanth glacier is 2.88 m/year while Bagirathi Kharak retreat at a rate of 1.21 m/year. Processes of individual glacier also play a pivotal role, in the fluctuation of the rate of glacial melting. The study shows that repetitive space-borne optical data can be used to obtain glacier dynamics of inaccessible terrains of the Indian Himalaya. The lack of in situ meteorological data in many parts of the Indian Himalayan terrain limits better understanding of such environmental changes measured from space. the , larger glaciers are being fragmented into smaller glaciers. In future, if additional global warming takes place, the processes of glacial fragmentation and retreat will increase, which will have a profound effect on availability of water resources in the Himalayan region.

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