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RESEARCH ARTICLE

Change Monitoring of Burphu Glacier from 1963 to 2011 using Remote Sensing

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Abstract— Himalayas has one of the largest resources of snow and ice, which act as a freshwater reservoir for all the rivers originating from it. Monitoring of these resources is important for the assessment of availability of water in the Himalayan Rivers. The mapping of Glaciers is very difficult task because of the inaccessibility and remoteness of the terrain. Remote sensing techniques are often the only way to analyze glaciers in remote mountains and to monitor a large number of glaciers in multitemporal manner. This paper presents the results obtained from the analysis of a set of multitemporal Landsat MSS, TM and ETM+images for the monitoring and analysis of Burphu Glacier.

Index Terms— Glacier, glacier retreat, Himalaya, Burphu glacier, satellite images

I. INTRODUCTION

Glaciers are ancient rivers of compressed snow that creep through the landscape, shaping the planet's surface. They are the Earth's largest freshwater reservoir, collectively covering an area the size of South America [Dyurgerov, M.B. and Meier, M.F. 2000]. Snowfields are under increasing pressure due to growing demand for fresh water, industrialization and urbanization. Besides, owing to their high sensitivity to changes in the climatic environment, they are also considered as key indicators of some consequences of global warming. Therefore, it has become very important to monitor. About 15,000 Himalayan glaciers form a unique reservoir which supports perennial rivers such as the Indus, Ganga and Brahmaputra which, in turn, are the lifeline of millions of people. The Gangetic basin alone is home to 500million people, about 10% of the total human population.[IPCC WGII]. Philip and Ravindran (1998) have also mapped glacier landforms of Gangotri glacier using Landsat TM data; they demonstrated that selected digitally processed TM band combination could help to map selected glacial features. The Survey of India has prepared topographic maps of the glaciated terrain of the Himalaya during 1961–1962surveys with limited use of aerial photographs on 1:50,000 scale. After this survey, no revised maps have been published even after the terrain was resurveyed using air photos. Kulkarni et al. (1999) provide an inventory of glaciers in the Satluj river basin that includes the Beas and Spiti sub-basins using Georeferenced IRS-1A and IRS-1B-LISS-II data and Landsat satellites on 1:50,000 scale. Various features such as accumulation area, ablation area, transient snow line/ equilibrium line, moraine-dammed lakes, deglaciated valleys and permanent snowfields were mapped relying on unique repentance characteristics.

II. STUDY AREA

Burphu Glacier originates from three peaks of 5831, 6032 and 5908 m asl and flows towards south-west. As per the inventory details and studies carried out in 1997, length of the glacier was 7.5 km, covering an area of 11.85 sq km with an estimated ice volume of 0.0899 km3 (Bhattacharya et al. 1984). Burphu glacier was first studied in 1963 by Janpangi, and later in 1997 by

Shukla and Siddiqi. Burphu glacier was monitored in August 2011. During the course of recconoitory traverses it was found that the higher reaches of the glacier has got completely detached from the main glacier body. This can be attributed to number of reasons like high gradient, reduced winter precipitation, higher summer ablation or sum total of these factors.

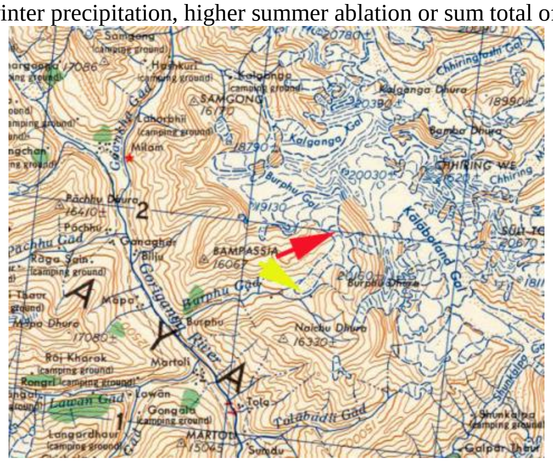

Fig:-1 Model of Burphu glacier

Burphu Glacier is in Uttar Pradesh, India draining into the Goriganga River. The Burphu Gad stream enters the Goriganga a short distance upstream of the proposed hydropower project at Bogudiyar. This project is slated at 370 MW, and will have only a minor dam to divert the water from the river for a short distance before running through turbines and returning to the river. The map of the area is a 1940′s era map with the terminus of the Burphu Glacier indicated by the yellow arrow.

III. DATA SOURCES

The multi-spectral satellite data of Landsat MSS for the year 1963 and 1976, Landsat ETM+ data for the years 2000, 2010 and 2011 have been ETM+ have been procured in the present study.

Table 1.Details of Satellite data

Satellite Data	Data of acquisition	Spatial resolution
Landsat MSS	26/10/1963	79
Landsat MSS	19/11/1976	79
Landsat ETM +	25/05/2000	30
Landsat ETM+	13/11/2010	30
Landsat ETM+	15/08/2011	30

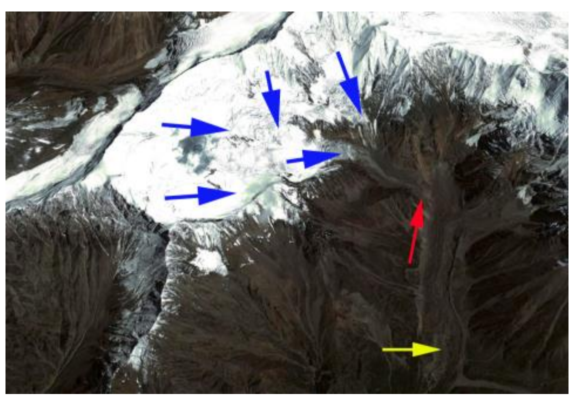

Fig.- 2: 2011 Landsat Image

IV. METHODOLOGY

Phase I: For Landsat MSS data

Landsat MSS data of 1963 and 1976 are classified by both supervised and unsupervised classification techniques. After classification process the data is associated with DEM and finally the glacier area of Burphu glacier main trunk is calculated by measurement techniques using ENVI 4.7.

Phase II: For Landsat ETM+ data

Landsat ETM+ data of Nov 2011 have strips, preprocessing has been done to destripe the Landsat ETM+ data using ENVI 4.7. The spectral distinction does not exist for all the glacial features in any single band thus identification of all features in single band data. The standard FCC of ETM+ 2, 3 and 4 bands (Blue, Green, and Red) may not be sufficient for snow cover type study because of its spectral saturation in two of these bands. Although the ETM+ bands 1 to 3 are found to be useful to detect dusty surface on glacier ,their utility is limited in the higher reaches of many glaciers because of the saturation. However, ETM+ Band 5 and 7, as they do not show detector saturation, are found to be extremely useful for snow mapping [Philip and Ravindran, 1998]. The snow coverage are clearly discriminated from the other features in ETM+ Band 4 irrespective of the amount of saturation. Considering all the above, it is found that despite redundancy in ETM+ bands 5 and 7, a color composite of the bands 4, 5 and 7 (RGB) yields interesting results in discriminating glacial features and the landforms[Philip and Ravindran, 1998]. (Fig. 3).

The terrain of Himalayan glaciers has undulating surface and steep slopes, so the radiance reaching the sensor greatly depends on the orientation (slope and aspect) of the target. The incoming radiance is highly depend on the orientation of the object Therefore, for better recognition of the classes for effective mapping, the DN numbers have to be converted into topographically corrected reflectance images. In a first step the satellite imagery has been topographically normalized by C- correction Method. In second step segmentation of ratio images were calculated using a threshold value of 1. By performing second step we identify the all debris free ice. In order to distinguish snow from similarly bright soil, rock and cloud we have calculated NDSI (normalized difference snow index) by following formulae:

$$NDSI = \frac{(TM2 - TM5)}{(TM2 + TM5)} \quad (1)$$

where: TM2,TM5- Landsat ETM+ band data

Due to the debris cover and dark shadow the manual delineation is very difficult to perform, the solution for that problem has been carried out by combining the images with Digital Elevation model. Now the glacier area was calculated using the combination of satellite images and DEM for the years 1963, 1976, 2000,2010 and 2011 by delineating the glacier boundary. (See Fig 3 FCC of Landsat ETM+ associated with DEM).

V. RESULTS AND DISCUSSIONS

Melt water stream emerging from central feeder disappears under the moraine cover and ice mixed debris (IMD). The right, central and left feeder ice streams are located at about 70, 306 and 610 m upstream of IMD respectively. Jangpangi during his second expedition to Burphu in 1966 writes "inactiveness in the lower part of the Burphu Glacier is unexpected". This could be attributed to the reduced supply of the ice from the accumulation zone.

Evidences of vertical shrinkage can also be seen by comparing the three sets of sub-parallel right and left lateral moraines. The trace of highest lateral moraine is 50 to 60 metres higher than the present day lateral moraine, which suggests that the glacier was 50-60 m thicker than the present. Presence of ice cored lateral moraine at Burphu also indicates the fast degeneration of the glacier.

Glacial signatures of Burphu glacier have been obliterated and modified due to later fluvial action, but there are enough evidences which suggest that during Last Glacial Maximum, Burphu glacier must have come down about 10 km from the current snout position and has its confluence with Goriganga trunk glacier near Burphu village.

The retreat data of the glacier is given in Table-1 and 2

Table-1: Total and annual retreat and area vacated by Burphu glacier.

Period	Retreat (m)	Annual Retreat (m/y)	Area vacated (sq km)	Area vacated sq km/y
1963-2011	3344	69.66	1.44	0.0299

Table-2: Total and annual retreat and area vacated by three snout lobes of Burphu glacier

Parameter		Retreat during 1963-2011
Snout retreat	Left lobe	2516 m
	Central lobe	3344 m
	Right lobe	2870 m
Average	Annual retreat	69.66 m/y
Total area vacated		1.435 sq km^2

The snout position (year 2011) of Burphu glacier was compared with the snout position of 1963. The glacier retreated at an average annual rate of 69.66 m/y. During the period 1963 to 2011, an area of 1.44 km2 has been converted in to Ice Mixed Debris (IMD). It shows that the glacier retreated annually at an average of 29.03 m/y with annual area vacated by the glacier is 0.406 km^2/y during 1963-2011 period.

VI. CONCLUSIONS

Loss in main trunk of glacier area was estimated using high and medium resolution of Landsat ETM+ and MSS data .In this investigation, glacial area loss from 1963 to 2011 was estimated. Burphu glacier must have come down about 10 km from the current snout position between 1963 and 2011.

In the visible bands of Landsat ETM+, the highly reflecting surface of snow and glaciers reach saturation limits and are not useful in discriminating snow types and mapping landforms in these areas. But the TM Bands 4, 5 and 7 in the NIR and SWIR regions are found to be very useful not only in snow mapping but also in identifying various glacial landforms.

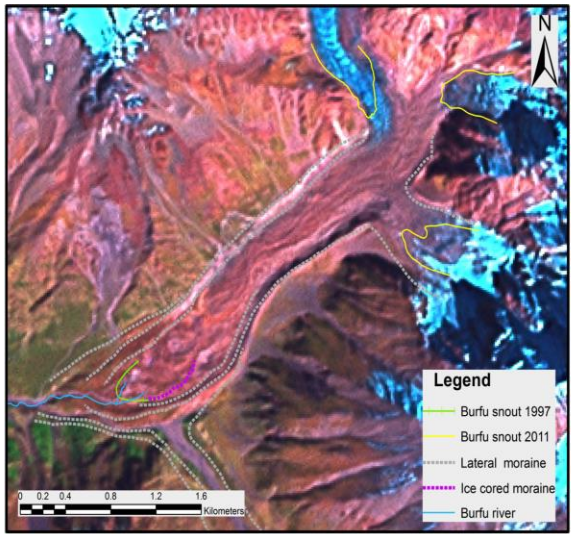

Fig.-3: Time series snout map of Burphu glacier

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