Remote Sensing based Study of Retreat of and Accompanying Increase in Supra-glacial Moraine Cover over a Himalayan Glacier

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Glaciers are prime reserves of freshwater and amass about 75% of the world's freshwater. As a major consequence of global warming, glaciers all over the world have been experiencing recession at varying intensities. Owing to this high sensitivity of glaciers for changes in the climatic environment, they are considered as excellent indicators of prevailing climatic changes in a region. Thus mapping and monitoring of glaciers has great significance. Remote sensing is perhaps the only effective tool for comprehensive and repetitive study of mountain glaciers in a cost effective manner.

`Mapping of glaciers through remote sensing data can be carried out using visual demarcation, segmentation of ratio images via thresholds, NDSI (Normalised Difference Snow Index) based algorithms and digital image classification. Each has some merits and demerits. Demarcation of snow covered areas through visual interpretation is extremely tedious and time consuming. Segmentation of ratio images is used for segregation of land cover including snow, ice, ice-mixed-debris, and debris. Digital image classification using statistical classifiers are also being used for snow and glacier cover mapping.

In this paper, recent recession of a Himalayan glacier from 1976 to 2004 has been studied. Three remote sensing images one each from IRS-1C LISS-III (date of acquisition: 13th September, 2001), IRS-P6 AWiFS (date of acquisition: 7th September, 2004), TERRA ASTER (date of acquisition: 8th September, 2004) images and Survey of India topographical maps (year of preparation: 1976) of Samudratapu glacier, Chenab basin, Himalayas, have been procured. In a rugged terrain such as Himalayas with highly undulating surface and steep slopes, the radiance reaching the sensor greatly depend on the orientation (slope and aspect) of the target. Therefore, for the optimal recognition of the classes for their effective mapping, the digital numbers have to be converted into topographically corrected reflectance images. The C-correction method, generally reported to be the best amongst the various other methods of topographic correction, has been used in the present work for topographic normalization.

Supervised classification of topographically-corrected reflectance images enabled the mapping of various land cover classes such as snow, ice, ice-mixed-debris, moraine, valley-rock, and water in the glacier terrain, together with the extent of the glacier. Since the extent of glacier, mapped from remote sensing images and topographic map varies in time, thus their inter-comparison highlights the varying recessional trends of the glacier in recent past.

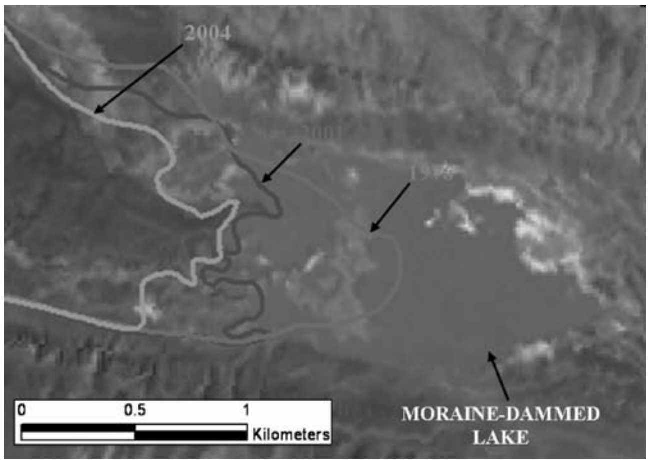

FIGURE 1. Change detection of glacier snout. The position of glacier snout has been mapped in years 1976 (S.O.I toposheets), 2001 (IRS-1C LISS-III image) and 2004 (IRS-P6 AWiFS image).

Analysis of the results reveals that from 1976-2004 the glacier has receded by about 756.23 m with an average rate of 27 m/yr (Figure 1). An overall depletion in the areal extent is also observed during the said period, reducing the glacier area from 110 km^2 to 96 km^2 with the overall deglaciation amounting to 12.34% of the total area covered by the glacier. Interestingly, the glacier retreat has also been accompanied by a marked increase in the extent of moraine cover over the glacier, which has increased from 7.52 km^2 to 13.27 km^2 i.e. about 76% increase in just three years (2001-2004).

Thus, the rates at which various surface characteristics of the glacier are changing warrants their effective mapping and monitoring since they might profoundly influence the glacier mass balance, response of the glacier towards climatic fluctuations and also the triggering of various glacier-related hazards. The study highlights the potential of advanced image processing techniques in precise mapping and monitoring of varying glacier extents in time using remote sensing data.