

GLACIER CHANGE ESTIMATION USING LANDSAT TM DATA

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ABSTRACT:

The Mongolian territory includes various ecosystems as, taiga forest, high mountains, width steppe and gobi desert, through North to South. The glacier is most important land cover type to keep the freshwater resources and as indicator of the climatic temporal variability. In this paper have been included some results research work on integrating of glacier observation data and satellite imagery from the space. The remotely sensed data has an advantage of real estimation of the glacier condition spatially and temporally. The results of climatic and hydrologic scientists showed that during last several decades the glacier is melting due to global warming and we have tried to approve this result using Landsat TM data of 1990s and beginning of 2000s of some mountains of Western Mongolia.

The results were obtained by utilizing the all bands of Landsat TM data and the NDSI (normalized difference snow index) images as input to a maximum likelihood classification approach. Also we have used the SRTM/DEM in order to calculate the area of the glaciers.

1. INTRODUCTION

By the geographical position and “ecotone” formation whole territory of Mongolia was selected as main part of study areas in Northeastern Asia. In Mongolia located Altai, Khangai and Khuvsgul high mountains and formulated permanent snow and ice. As mentioned the glacier is most important land cover type to keep the freshwater resources and as indicator of the climatic temporal variability.

Since the middle of the last century, the global climate is changing drastically and as a result the current climate experiences more frequent extremes in Mongolia causing big losses amongst animal and land degradation. Also the National Program on Climate Change mentioned that for every increase of 3 degrees in air temperature, there will be a 10 percent reduction in carbon (C) and nitrogen (N) contents of the plant-soil ecosystem, a 3-10 percent reduction in pasture vegetation and a biomass reduction of 21.5 percent¹. Nowadays, the air temperature has already increased by 1.9 degrees². The global warming factor could strongly influence to melt the permanent snow and ice on top of higher mountain system in Western Mongolia at the same time to decrease fresh water resources.

In order to estimate glacier area we have used the Landsat TM data from different period and applied NDSI (normalized difference snow index) calculation method and maximum likelihood classification approach. Also the

SRTM/DEM data have been used for 3 dimensional processing and for calculation of the glaciers area.

2. THE STUDY AREA AND DATA

There have been used Uvs lake hydrology data of 1970-2002 and meteorological data observed at Ulaangom and other stations, located in the basin.

For estimation of glacier area dynamics have been used Landsat of 3 different time period data for glacier massifs as Kharkhiraa, Turgen Tsambagarav, Munkhkhairkhan and Sair Mts. The Landsat TM and ETM+ scenes were selected from 141-144 paths and 26-27 rows and obtained on following dates.

- 16 September 1990 (used for only Munkhkhairkhan Mt. Noted with in Table 1)
- 25 June 1992
- 10 Sep., 2000 /Kadota and Davaa, 2003/
- 08 August 2002

3. METHODS

For mapping the glacier area from the satellite image we have applied several approaches such as,

- To identify spectral characteristics of glacier in each Landsat band
- To apply bands combination method for glacier extraction
- To apply both supervised and unsupervised classification methods
- To calculated normalized difference snow index
- To analyze three dimensional view of images

¹ National Program on Climate Change, 2000

² L. Natsagdorj – Assessment of Climate factors to Mongolian pasture degradation, 2006

- To compare calculated areas

In order to distinguish snow from similarly bright soil, rock and cloud we have calculated NDSI (normalized difference snow index) by following formulae:

$$NDSI = \frac{(TM 2 - TM 5)}{(TM 2 + TM 5)} \quad (1)$$

where: TM2, TM5- Landsat TM band data

In Fig. 1 shows Landsat TM data fragments of 2 mountains in different periods.

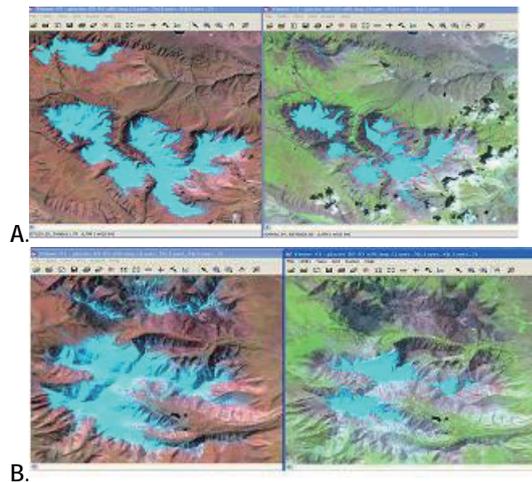


Fig. 1. Landsat TM, ETM+ images of glaciers in 1990 and 2002 (A – Tsambagarav, B – Sair mountain)

4. RESULTS AND DISCUSSION

On the background of the paleoclimate data, more precise climatic chronology has been given by the research on reconstruction of climate data with tree ring indices.

One (Khalzan Khamar) of the tree ring chronology sites were selected in the Altai Mountains. It has permanent snow fields, ice and permafrost and located near the timberline where temperature appears to be limiting factor for growth. Similar fluctuations have been derived from the tree-ring width indices record, taken from the sample of the Turgen Mountain. Reconstructed with 5 year moving average of tree ring width indices ($r=0.60$) of the Turgen and instrumental, annual temperature at Ulaangom station were well correlated and show that highest temperatures are in last decades.

Melting of the ice masses in the mountains, the end of pediment formation on the lower mountain slopes and the slow regeneration of plant cover owing to rising temperatures and increased precipitation all lead to a relative quick rise in lake level, since the basins filled up with both rainwater and melt water from the rapidly melting glaciers. Therefore, pretty good relationship exists between 5 year moving average of tree ring width indices and annual average of water level of the Uvs lake for the period of 1970-2002.

Reconstructed with 5 year moving average of tree ring width indices ($r=0.76$) of the Turgen and observed water level of the Uvs lake were well correlated and show that highest water levels are observed in the last decade.

It is obvious that dynamics of the water balance elements of the Uvs Lake were following water level fluctuations. However, it is possible to estimate water balance elements in last 40 years.

Spectral characteristic of glacier

The maximum, minimum and mean spectral values of each of land cover class were calculated from high resolution Landsat images, based on that spectral reflectance of each land cover types is different in each wave length of electromagnetic radiation .

On Landsat ETM+ data the glacier spectral values accounted as 255, 145-255, 191-255, 116-217, 20-31 and 3-18 in each spectral bands 1-5 and 7 respectively. The calculated spectral values of land cover classes used as a reference value for glacier classification.

Also for identification of glacier have been used band combination method and the glacier was extracted in each 3,2,1 and 4,3,2 and 5,4,3 combinations of bands as showed in Fig. 2.

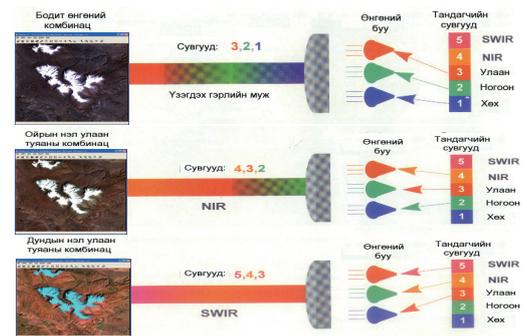


Fig. 2 Landsat ETM+ data combination (Tsambagarav mountain)

For extraction of glacier area we have used the NDSI (normalized difference snow index) calculation to distinguish snow from similarly bright soil, rock and cloud from entire images.

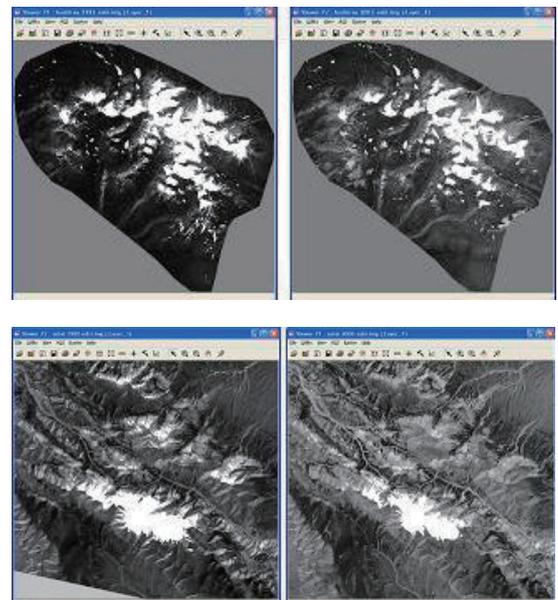


Fig. 3 NDSI images of Kharkhiraa and Sutai mountains

Also the SRTM/DEM data have used for 3 dimensional processing and identification of the glaciers area.

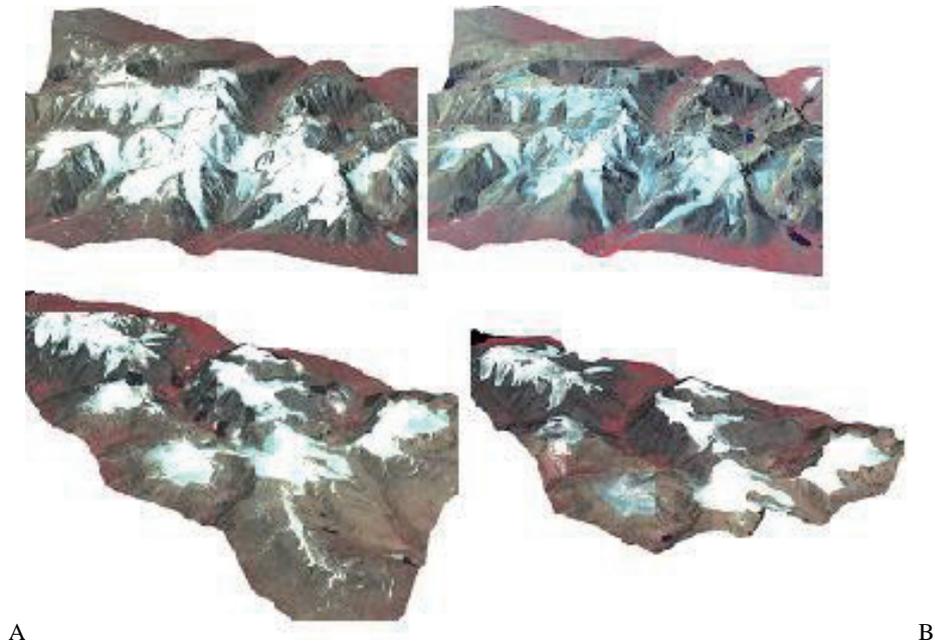


Fig. 4 Three Dimensional Landsat images (A – Kharkhiraa, B – Tsambagarav mountains)

Reason of reduction of evaporation from water surface area of the lake can be the decrease in water temperature due to the increase in melt water, draining to the Uvs Lake primarily in the form of underground flow. Retreat of Kharkhiraa and Turgen glaciers is drastically increasing since 1940s. Kharkhiraa, Turgen, Kharkhiraa, Tsambagarav and Tavanbogd glacier areas were 50.13, 43.02, 105.09 and 88.88 sq.km, estimated from topographic map, scaled as 1:100 000 and compiled in 1940s. Areas of the Kharkhiraa, Turgen, Munkhkhairkhan, Tsambagarav and Sair glaciers were decreasing by 45.5, 33.7, 25.8, 21.4 and 42.5 percent since 1992 till 2002, respectively (Table 1).

Glacier massif	1940-th topo map	25 June 1992	10 Sep 2000	8 Aug. 2002
Kharkhiraa	43.02	57.37	36.08	31.29
Turgen	50.13	51.03	34.74	33.83
Munkhkhairkhan	-	36.96*	-	27.42
Tsambagarav	105.09	90.98	74.8	71.52
Sair	-	11.51	-	6.62

Table 1. Changes in glacier areas

Retreat of glaciers is intensified in last decades and many of glacier peaks got ice free especially in very dry year 2002. We have analyzed Landsat TM, ETM+ data from 1992, 2002 and compared their massif changes (Fig. 5).

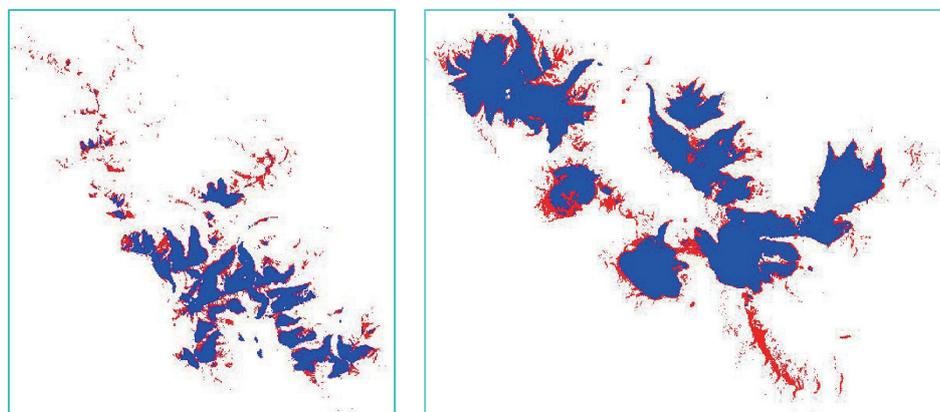


Fig. 5 Comparison of Turgen and Tsambagarav mountains glacier massif in 1992 (red) and 2002 (blue)

5. CONCLUSIONS

Comprehensive investigation focusing on glacier mass balance, ground and surface water interaction, dating and the environment changes are desired in the near future.

Compilation of glacier inventory is important issue, using remote sensing and ground observation data, especially vertical air photographs, which are basic information for development of hydro-climate-glacier and integrated water resource management studies.

For satellite data application on glacier mapping we still need fresher (2005 and 2006) and higher resolution satellite (ASTER, IKONOS) imageries.

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