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MONITORING RECEDING OF GLACIERS AND IN NORTH-EASTERN PAKISTAN THROUGH GEO-INFORMATICS TECHNIQUES

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Abstract

Pakistan is amongst those countries which are blessed from the wide range of natural features. Pakistan is a land of varied topography, ranging from deep sea to top mountains of the world. Northern area of Pakistan carries the most fascinating mountainous series with snow-clad peaks of varying height. Apart from North and South Pole, Northern Pakistan hosts the greatest masses of glaciated ice in the world. The glaciers are of extreme worth in providing fresh water resources; this important resource is a vital source of water but it has been diminished due to anthropogenic interventions which, as a result, have unbalanced the indigenous eco-system. Monitoring of these glaciers is important to cater the water and power need of a country like Pakistan. By using remote sensing and Geographical Information System (GIS) techniques, this paper is an attempt to address the receding of glaciers and snow cover in the extreme north-eastern districts of Pakistan. Monitoring of melting of glaciers due to climate change in the recent decades has been attempted in this study for Ghanche District. This study is also concerned with observing the spatial change in the snow cover and glaciers of Ghanche District.

Keywords: Receding Glaciers, Climate Change, GIS, Land cover.

1. Introduction

Many studies claim that climate is changing globally which affects different natural entities amongst which glaciers top the list. Due to suspected climate change, glacier retreating significantly increases, especially in case of alpine reserves. GIS and remote sensing is the combination of tools which help in monitoring the glacier and snow cover receding temporally and is considered as a better aid for the geographical and temporal monitoring of different types of land cover. Global warming strongly plays its part in melting permanent snow and ice on top of higher mountain system in Ghanche extreme north-eastern district of Pakistan. There are different remote sensing approaches which help with monitoring of glaciers and snow cover on a frequent basis. For estimating the snow cover in Ghanche district, different satellite images are used with different time periods in which Landsat MSS, Landsat TM and Landsat ETM are the prominent ones, alongwith SRTM Dem data, used for depicting a picture closer to reality.

2. Significance of Study

Alpine glaciers have many benefits in various perspectives; it works as an integral part in a hydrological system and is an excellent source of supplying fresh water for drinking and other purposes. In addition, agro-based economic countries like Pakistan are dependent upon these glaciated masses and snows cover for irrigational and agriculture activities. Temporal monitoring of glaciers helps in obtaining information for the management of water supply and distribution, with that entire monitoring guide in terms of early indication of glacier-associated hazards. Glacier monitoring assists in understanding climate variability and change (Dyurgerov and Meier, 2000).

Depiction of glacial geometrical change is significantly important because of its relation to changes in glacier mass (Krimmel, 1989) and glacier runoff (Fountain and Tangborn, 1985).

3. Study Area

Ghanche is the easternmost district of Pakistan (see Fig. 1). The capital of Ghanche

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district is Khaplu which is considered as one of the coldest places of Pakistan and is famous as the third pole. In the north-east of Ghanche lies Xinjiang (China), Skardu district in the north-west and Astore district to its west is. Ghanche has many peaks over 20,000 feet. This district is famous for wildlife and some beautiful and attractive rivers including Syoke and Saling. The total covered area of this district is 8915 sq.-km.

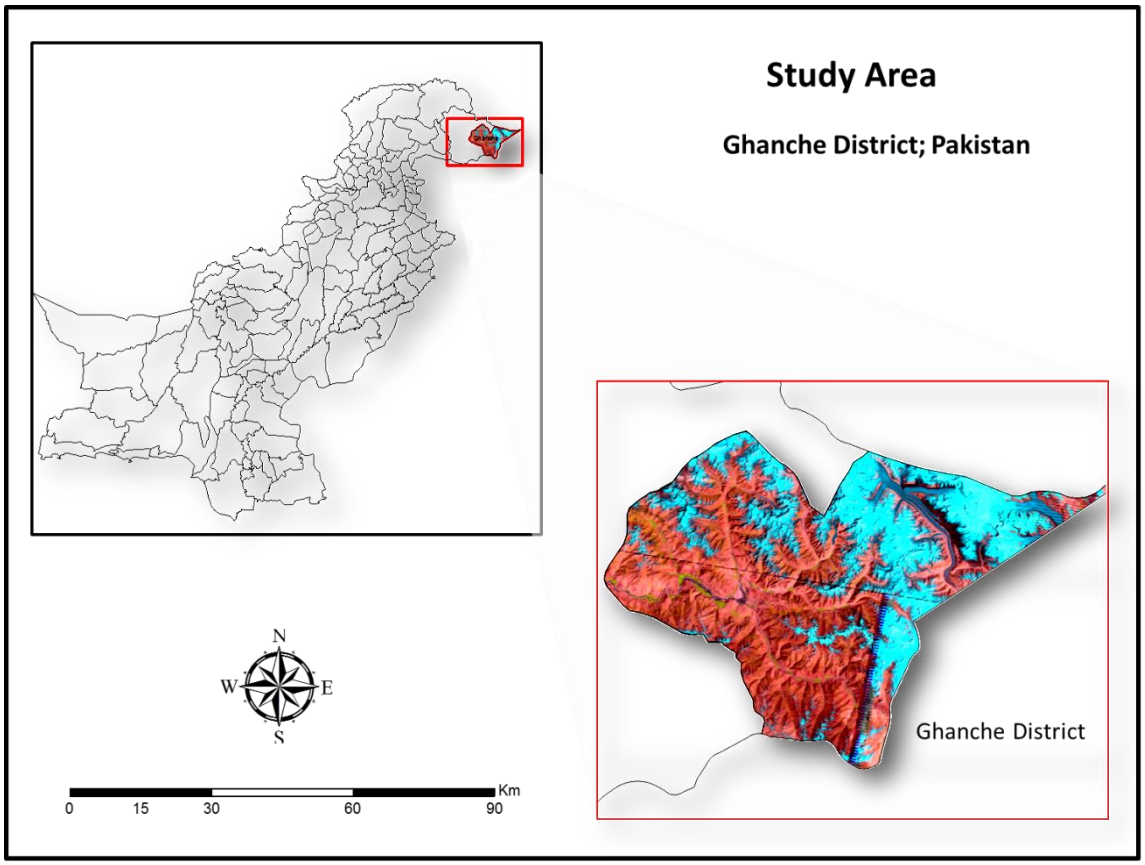

Fig. 1. Study Area.

4. Dataset

This study aims to observe the spatio-temporal change in glacial mass and snow cover in Ghanche district. For this purpose, selected series of remotely sensed data is used which includes the Landsat-3 MSS (1978), Landsat-5 TM (1990), Landsat-7 ETM (2000 and 2010). Furthermore, Digital Evaluation Model (DEM) data (SRTM-90m) is also used for observing the terrain and top snow.

5. Methodology

Temporal maps have been developed for observing spatial changes by considering the availability of data; Landsat imageries of almost 10 years interval are acquired and projected on UTM projection system. For removing the terrain distortion, DEM data of SRTM is used. Glacier examination through DEM is a highly known model of GIS in many other countries. For spatial analysis, aerial photography and other remotely sensed data is utilised in combination with various researchers (Aniya and Naruse, 1986; Allen, 1998). DEM is also used for assessing the glacier volume and its temporal change (Reinhardt and Rentcsh, 1986). In estimating glaciated alpine areas, different GIS software are used to analyse remotely sensed imageries (Klein and Isacks, 1996) with that assisted by assimilating aerial photography to develop regional climate and glacier advance and retreat model (Champoux and Ommanney, 1986). Furthermore, draping of images is done in order to develop the three dimensional model by using Arc Scene (see Fig. 2) for acute investigation of geometrical changes in glaciers and snow cover

pattern for individual years. The glacier geometry data was generated through manual vector digitisation using ArcGIS 9.3. By using the digitised layers, area for different layers is calculated which helps in identifying the changes in geometrical pattern of glaciers and snow-cover for the Ghanche district.1km grid is generated for detecting the per-unit change in glacier and snow cover geometry. A vector layer of Siachen glacier is also developed for the selected years to monitor the net change at Siachen glacier. There are a number of approaches of event-based models (Peuquet and Duan, 1995) and vector topological model (Langran, 1992; Worboys, 1992). Another most common method viz. tagged approach of spatial data layer can be used for representing a specific moment in time (Langran, 1992). In this study, tagged approach and vector topological modelling approach are also used.

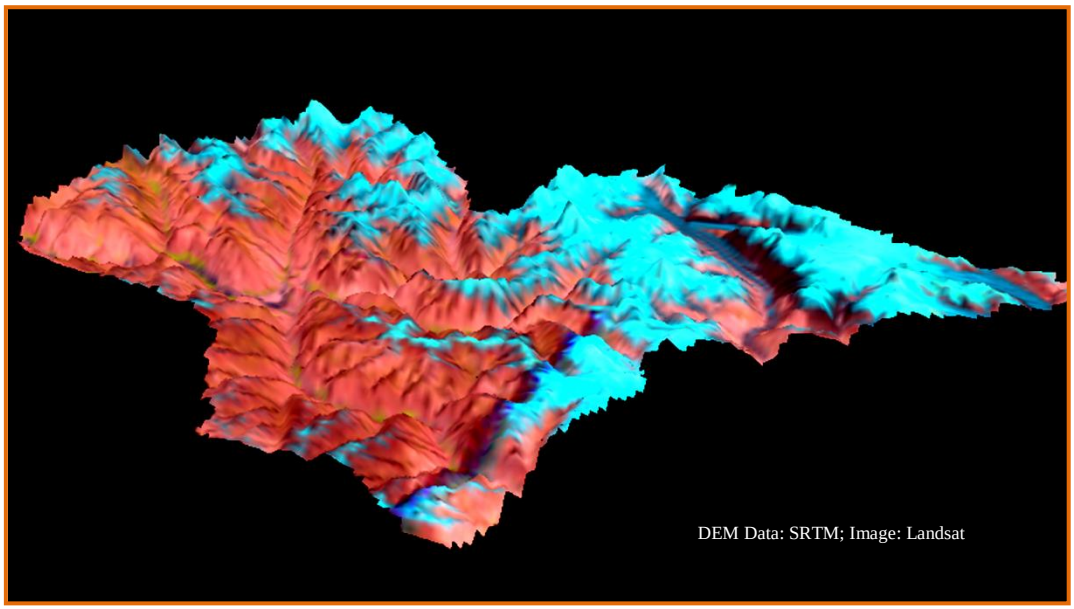

Fig. 2. Three-Dimensional perspective of study area.

6. Results and Discussion

Glaciers and the snow cover of Ghanche district are gradually depleting with the passage of time due to the several factors amongst which the climatic change and global warming are the obvious reasons. From the digitised layers the calculated area for the different years (see Table 1) shows that there is a rapid change regarding the melting of glaciers and snow-cover which leads to flooding and other related disasters. The graphical representation also highlights the declining pattern of snow cover in that extreme north-eastern district of Pakistan (see Fig. 3).

Table 1. Retreated area

Year	Area (Sq.km)
1978	1831.5
1990	1697
2000	1529.5
2010	1451

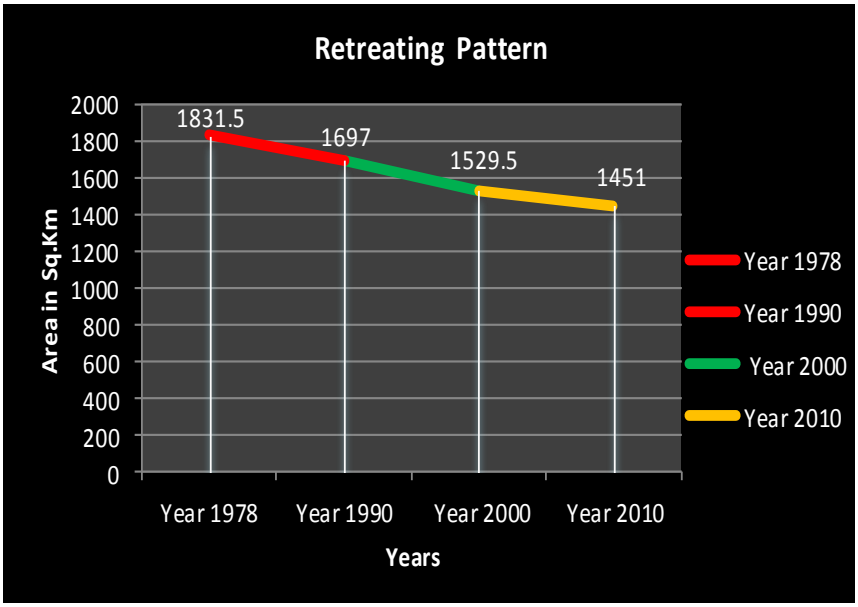

Fig. 3. Retreating pattern.

The set of images are digitised by using ArcGIS for observing the geometrical change from 1978-2010 (see Fig. 4). It is revealed that they're a vital change occur in from 1978-2010 which is almost about 380.5 sq.km.

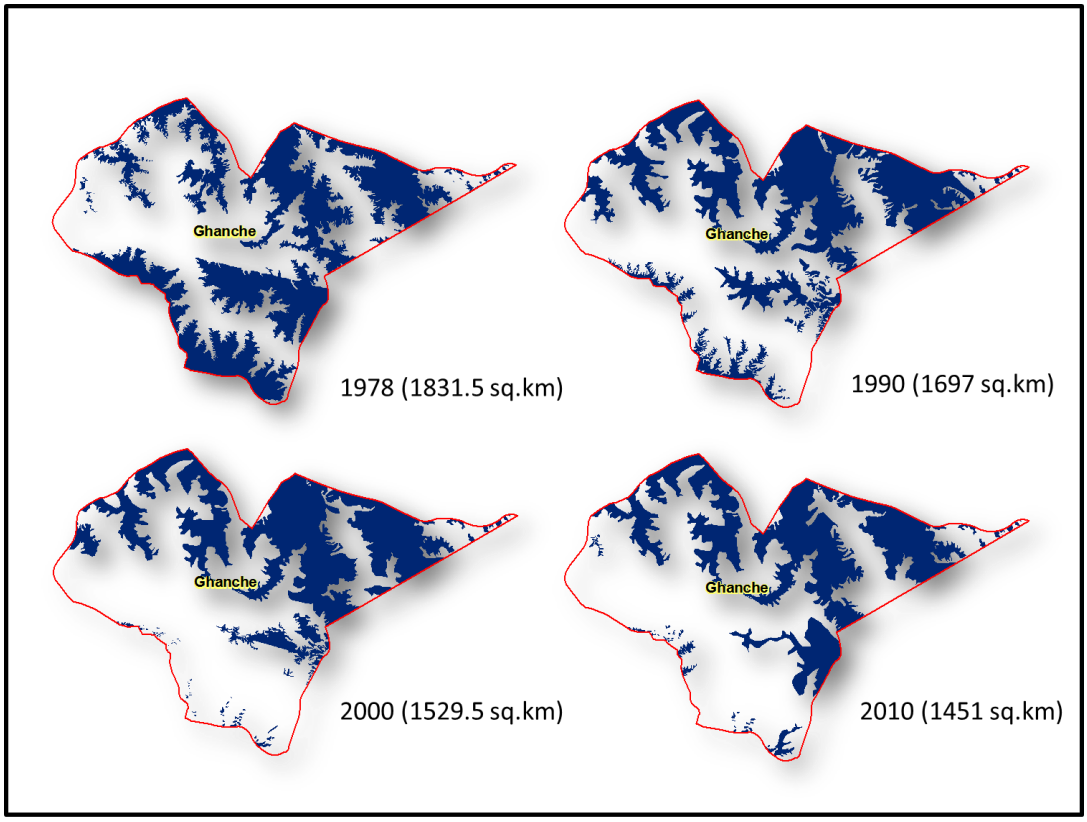

Fig. 4. Temporal Mapping.

When the layers of different years are overlaid, it is noticed that the change rate is quite radical, especially in the southern portion of the Ghanche district (see Figs. 5 and 6).

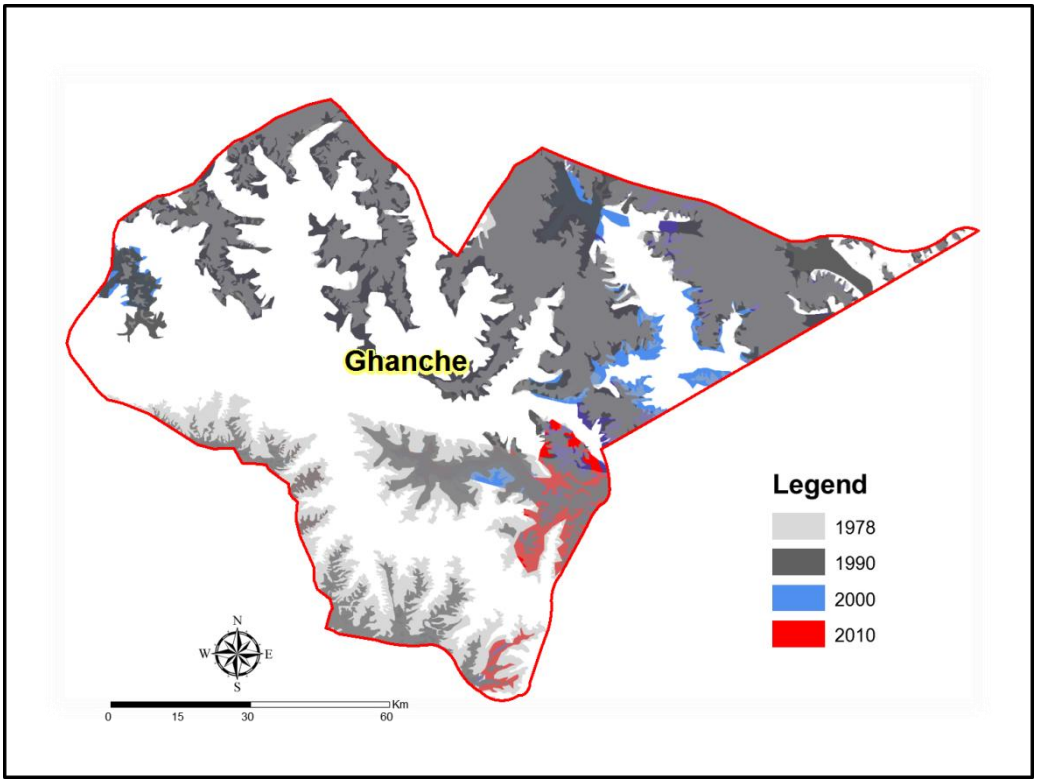

Fig. 5. Overlay Analysis.

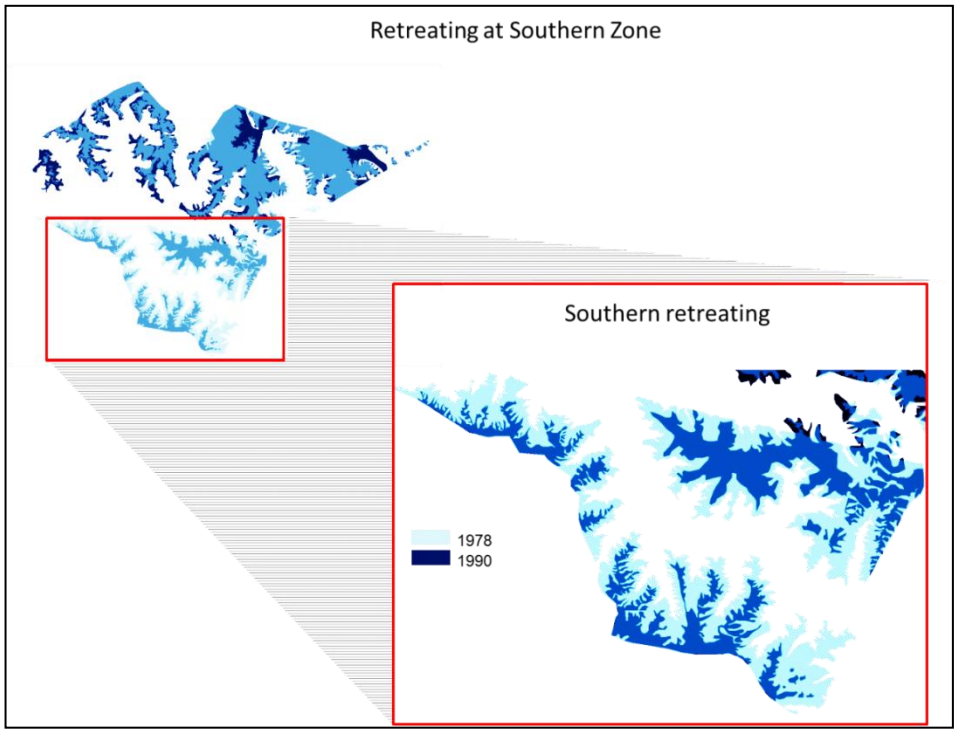

Fig. 6. Retreating at Southern zone.

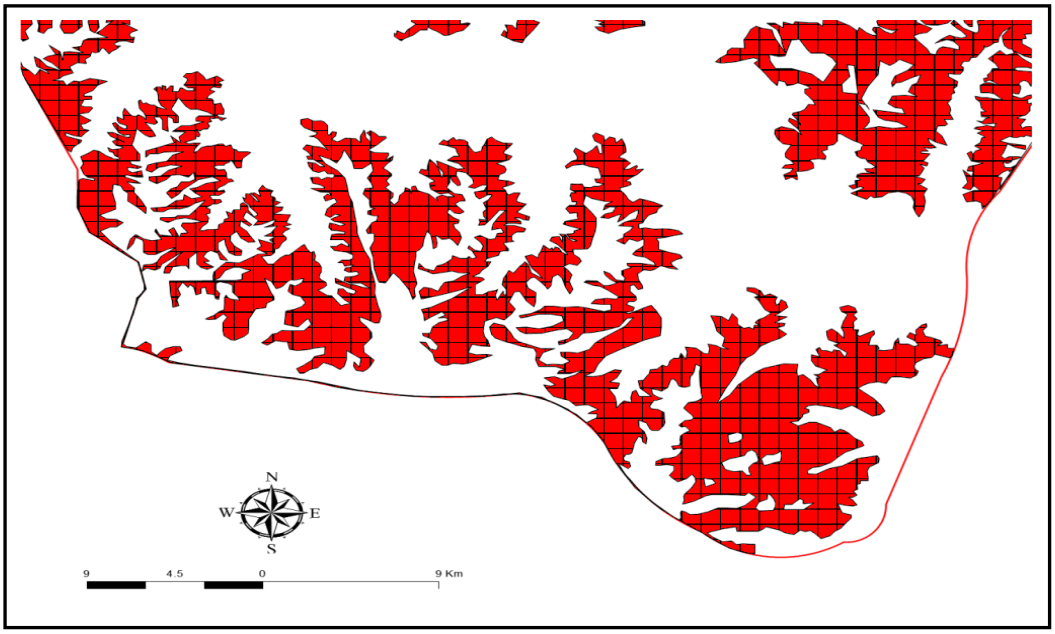

Fig. 7. Map of per-unit (sq.km) Change (1978-1990).

The above figure represents the subtracted values for the span of 1978 to 1990 which not only represents the outer difference; the grid represents the per unit change in almost twelve years. The overlay analysis is also performed in this study to observe the shrinking pattern of snow cover and glaciers (see Fig. 7). The per unit area change in south-eastern zone is maximum between 1978-1990 (see Table 2), which is about 82 units. Between 1978 and 2000, reduction increases to 242 units whilst again jumps to 83 units in between 1978 and 2010.

Table 2. Temporal change in area of south-western zone.

Year	Area/Unit Sq.km
1978	**359**
1990	**177**
2000	**117**
2010	**176**

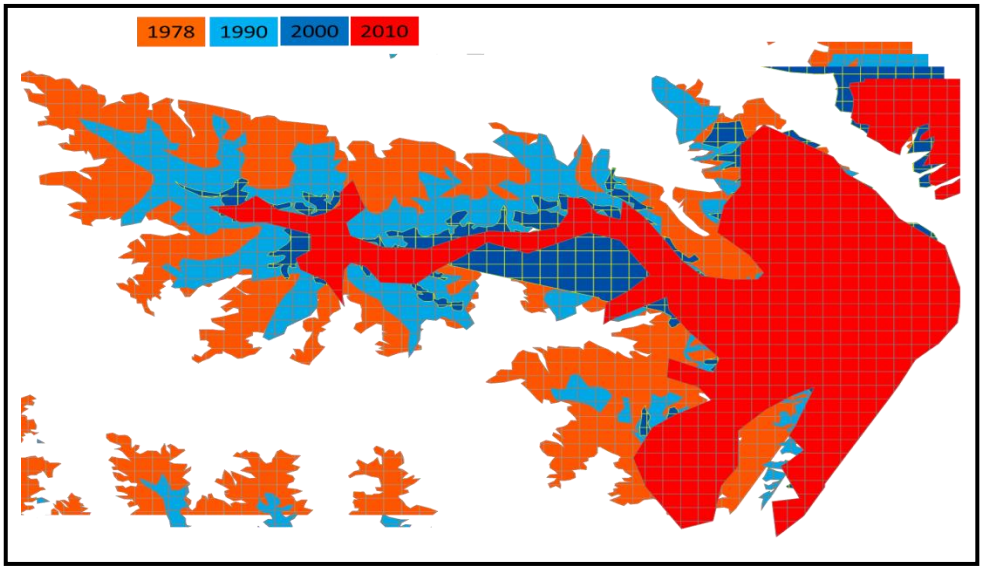

Fig. 8. Map of Overlay Analysis at South-Eastern Zone.

The above figure is showing the shrinking of tail with time; the tail attenuation at south-eastern zone of Ghanche district is quite speedy (see Table 3).

Table 3. Linear tail shrinking.

Years	Linear Tail Shrinking
1978-1990	4km
1978-2000	10 km
1978-2010	11 km

The receding rate at Siachen glacier is also highly significant; the linear tail shrinking in between 1978 and 2010 is also monitored (see Fig. 9). This is about 1.10 km whilst this extent increases by about 0.25 km as compared to 1990.

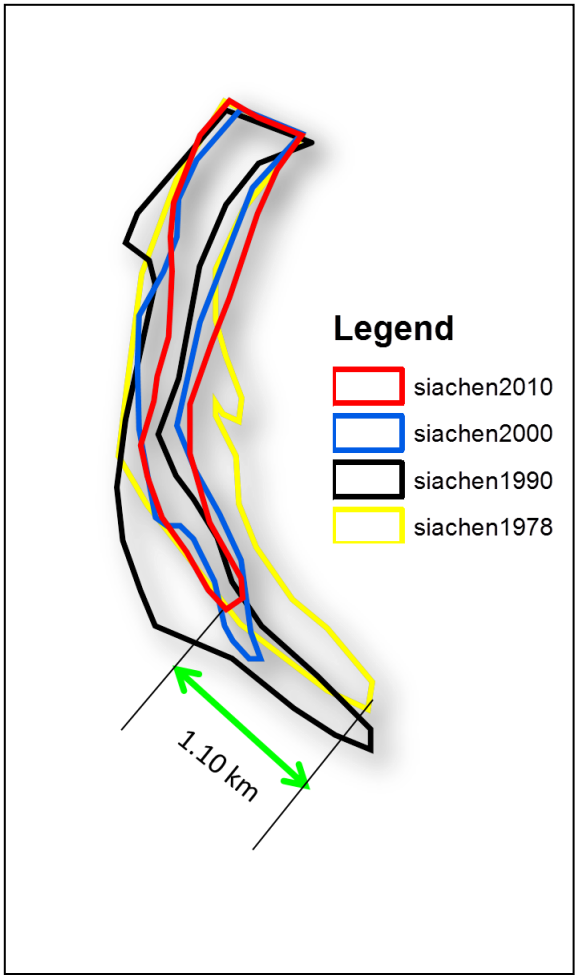

Fig. 9. Temporal Change in Siachen.

7. Conclusion

It has been revealed from this study that the spatial change of snow cover of glaciers is happening from a moderate to a high scale. The total covered area of snow has kept on fluctuating in the stated years. In case of Ghanche district, variability is quite prominent in the southern and south-western zone which requires further scientific investigation. This paper adequately demonstrates GIS techniques for observing temporal change in the glaciers and snow cover. In addition, prior focus is in identifying hot spots in Ghanche District. The snow cover receding in different years has a huge share as compared to glacier retreat. Satellite images play a vital role in monitoring these remote areas. With this, compilation of glacier inventory is also required at regional and local level. Integration of remote sensing in glacier mapping in an extremely efficient manner requires easy availability of high resolution satellite imageries.

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