North Asian International Research Journal of Sciences, Engineering & I.T.

IRJIF. I.F. : 3.821

ISSN: 2454-7514 Vol. 3, Issue-7 July-2017

IMPACT ASSESSMENT OF TEMPERATURE VARIATION ON GLACIERS IN ZANSKAR VALLEY, HIMALAYA

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ABSTRACT

Remote Sensing and GIS has become a blooming technology in our digital world which helps us visualize a wide variety of environmental factors affecting our earth in different ways. This technology can also be extended to other extra-terrestrial surfaces that can be remotely sensed through satellite sensors. It not only points out the problem but also provides several steps/techniques to rectify and/or optimize the problem so that to provide a safe survival on earth.

In this study, we deal with the glaciers with respect to climate change in the Zanskar valley using remote sensing and GIS techniques. The satellite data (Landsat 5, 7and 8) were used to map the changes for the years: 1998, 2002, 2006, 2010 and 2014 by comparing the glacier area and temperatures. Several preliminary steps were followed to make the dataset effective for the study. Initially, layer stacking was performed using bands 1 to 3 of Landsat 5 and 7 whose wavelengths lie between 0.45 to 0.69 micrometers and that of Landsat 8 (whose 0.45 to 0.67 micrometers wavelength range belong to bands 2 to 4). Since glaciers can be detected in the wavelength range of 0.45 to 0.69 micrometers, such a bandwidth was selected for the study. This was followed by mosaicking and clipping out of the study area, Zanskar valley. The 'Landsat gap' fill tool was used to remove the scan line present in Landsat data, especially in the years 2006 and 2010. Radiometric correction was then carried out using Landsat Calibration and Dark Object Subtraction (DOS) techniques so as to improve the visualization of the image and the delineation of the glacier boundaries in Geo database (Arc GIS).With the help of Geodatabase, the glacial area was calculated for each year. The glacial temperature characteristics were then determined in order to assess the impact of temperature variation on glaciers in Zanskar valley. This was accomplished through the Band Math operation implemented in the Environment for Visualizing Images (ENVI) software. A prediction model was then formulated till the year 2030 for the assessment of the change in glacial area with respect to temperature. A linear regression model in R (statistical computation) software was derived for this purpose.

***Keywords:** Landsat, Remote Sensing, GIS, Glacier, Zanskar Valley.*

1. INTRODUCTION:

Glaciers are sensitive to climatic conditions and climate change. It is now widely agreed that glaciers act as a very good indicator of climate variations (Houghton et al. 2001, Oerlemans et al. 1998, Vincent 2002). The change in climate due to global warming has caused melting of glaciers, increase in the sea level and many extreme weather events. Glacier length, mass balance and snow melt runoff are some of the glacier parameters that are directly or indirectly related with the climate. Any change in the climate is reflected by the glacier and can be studied by analysing the glacier parameters.

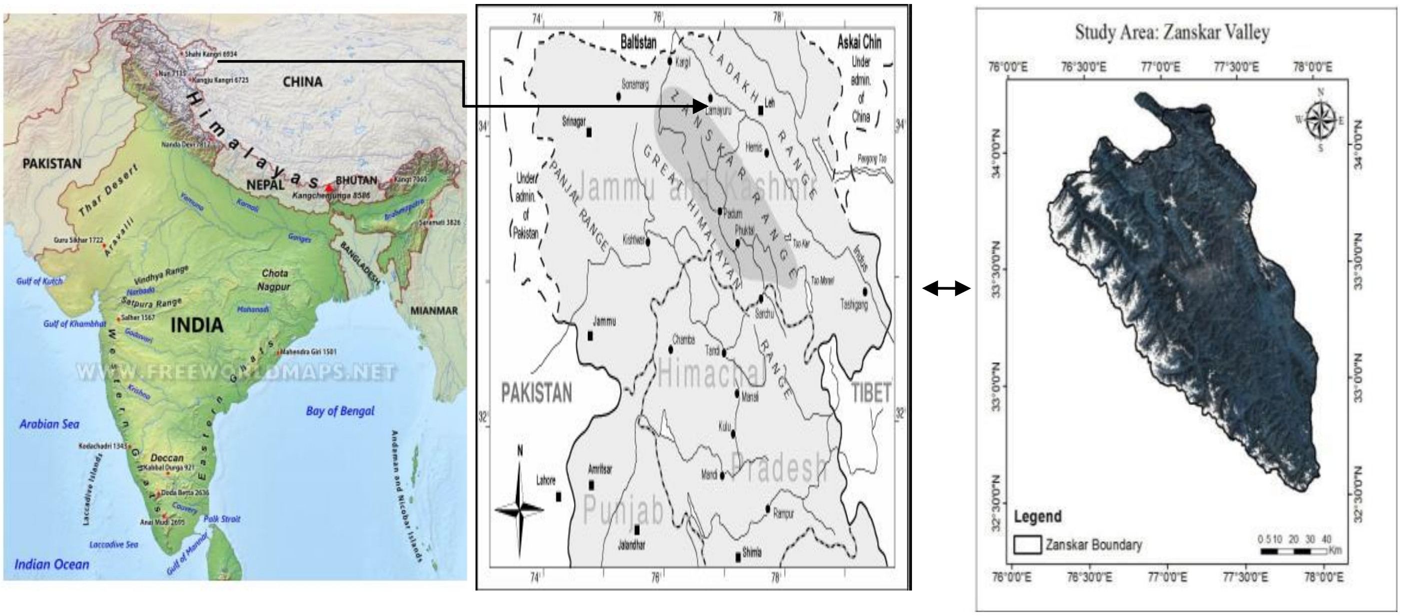
Studies on recent fluctuations of glaciers in Zanskar, southern Ladakh, are extremely rare. Desio (1954) described some exceptional glacier advances in the Karakoram Ladakh region. For Zanskar, the only studies describing recent glacier fluctuations are those from Nathawat et al. (2008) and Pandey et al. (2011). There are some complications to monitoring glaciers in Zanskar, as well as elsewhere in the Himalaya. Particularly, heavy layers of debris in the glaciers' ablation zones make detection and mapping of glacier margins difficult or even impossible (Bishop et al. 2001; Paul et al. 2004; Bolch et al. 2008; Racoviteanu et al. 2008). Bolch et al. (2007) described how it is often impossible to detect a glacier's margin even when one is standing atop the glacier. Yet, if glaciers are to be monitored, they must first be mapped. Thus, while it is possible to effectively map clean-ice glaciers using multispectral imagery (Sidjak and Wheate 1999; Paul et al. 2002; Bolch and Kamp 2006), it is important to develop mapping methods that rely on other methods than just multispectral imagery alone to map the debris-covered glaciers in Zanskar. A morphometric approach, applying topographic parameters, thermal data, and supervised classifiers, has been used to map debris-covered glaciers on Nanga Parbat (Bishop et al. 2001), in the Khumbu Himal (Bolch et al. 2007), and in the Tien Shan (Bolch and Kamp 2006), as well as in other glaciated areas throughout the world (Paul et al. 2004; Shukla et al. 2010; Bhambri et al. 2011). The morphometric approach has never been used to map glaciers in Zanskar. Additionally, glaciers in Zanskar have to date not been systematically studied using modern mapping approaches, and as such, there is currently a paucity of knowledge and literature. Regarding their responses to global climate change.

The surface of the earth has, 97% water, out of which 3% is as snow. From it 1.3% is as glaciers. Out of all the glaciers if 3% of glaciers melt, then there will rise of 50% in sea level. Recently, it has been observed that a change of 2-3 % of volume in the present glacier would result in the sudden rise of mean sea level by 20- 30 m, which in turn would result in the subduction of the 2 % of land area throughout the globe resulting in a huge catastrophic natural event. Though, this alarming situation was formulated there are extensive studies which have studied the behaviour change over the glacier from macro scale levels to compositional change level over the period of the last decade.(Pandey et al.(2013)) The main objective of this study is, to assess the spatial changes of glaciers area over the period of time 1998 to 2014 at a period interval of 4 years are compare the change with temperature fluctuation in Zanskar valley of Himalayan region, For this, various image processing techniques were applied to delineate the glacier's boundary and compared with the manually digitized glacier boundaries, which unfortunately resulted with low accuracy outputs of glacier area extracted from the satellite images due to the cloud cover. Hence, we prefer delineating through the digitizing method, it was used for prediction of the area of glacier using the Linear Regression model. The result shows that there is decrement in area as in future scenario. Temperature change over the period of time was also analysed, tabulated and accordingly the Linear Regression model was applied for the temperature change estimation.

2. STUDY AREA

Zanskar, a sub district/ tehsil of the Kargil district, lies in the eastern half of the Indian state of Jammu and Kashmir. The Zanskar valley lies south west to Zanskar mountain range which separates Zanskar from Ladakh. Geologically, the Zanskar Range is part of the Tethys Himalaya, an approximately 100-km-wide. The average height of the Zanskar mountain range is about 6,000 m. The extends between co-ordinates 32°28'37.007''N - 34°13'55.34''N to 78°8'59.873''E - 76°10'2.907''E. Zanskar valley covers an area of some 7,000 square kilometres, at a height ranging from 3,500 and 7,000 metres. The Valley consists of the area lying along the two main branches of the Zanskar River, Doda and Lungnak (formed by two tributaries Kargyag and Tsarap river). The easiest approach is from Kargil through the Suru valley. These topographical features make access to Zanskar difficult from all sides. Communication with the neighbouring areas is maintained across mountain passes or along the Zanskar river when frozen.

The climate of Zanskar valley is extremely dry and cold. Annual precipitation is only around 100 mm/ year and humidity is very low. In this region, above 3,000 meters elevation, winters are extremely cold. The average January temperature of the valley is − 20 °C which drops as low as − 40 °C.



(Zanskar Valley) (Source: USGS-Landsat 8)

3. OBJECTIVE:

- To understand the long term temperature variation of Zanskar Valley.
- To derive the relationship between glacier area and temperature variation trend.

4. METHODOLOGY

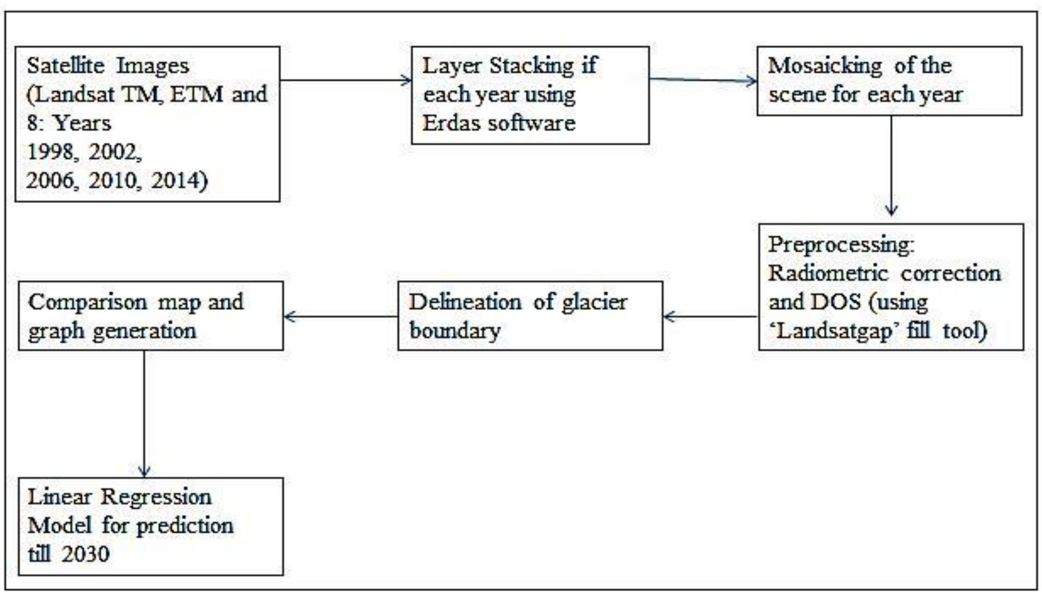


Figure 3.1 Methodology for computing area

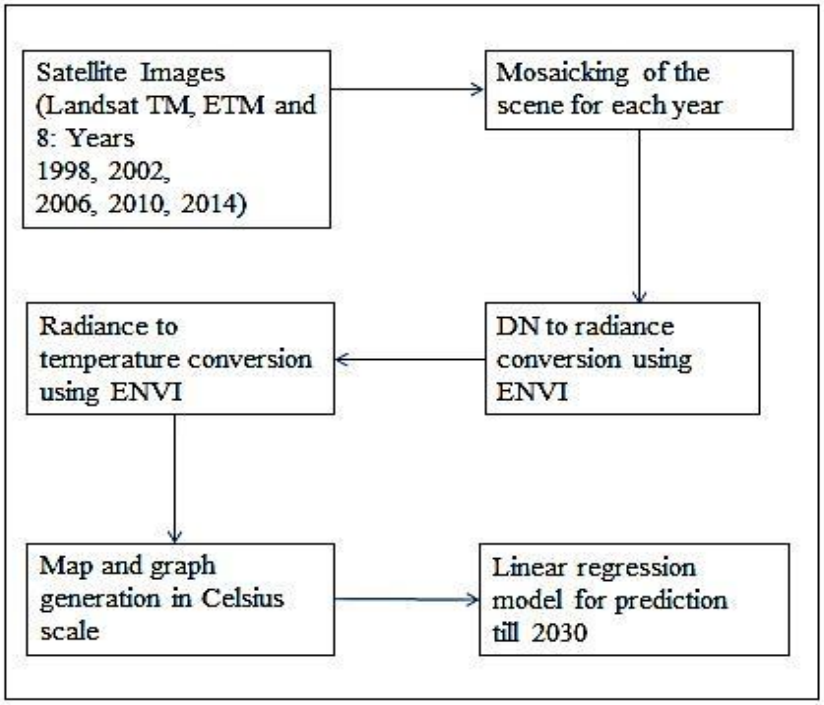


Figure 3.2 Methodology for computing temperature

Area Computation Steps:

The satellite images were first downloaded in TIFF format for various years from the USGS site and then mosaicking was performed. Mosaicking is the process of joining geo-referenced images together to form a larger image or a set of image. The input images must all contain map and projection information, although they need not be in the same projection or have the same cell sizes. It is required to join images and obtain an imagery for a larger area which cannot be covered in a single scene. It was done in ERDAS Imagine. In order to separate out the glacial coverage in the Zanskar valley, the glacier area had to be clipped out from the mosaicked image. As previously mentioned in the introduction, glaciers can be identified and prominently visualized on images using wavelength range 0.45 to 0.67 micrometres. Since, Landsat 5, 7 and 8 datasets were used the corresponding bands containing the required bandwidth of data, were first selected. Bands 1, 2, 3 from Landsat 5 and 7 dataset, and bands 2 to 4 of Landsat 8 were then used for the study. Landsat data for the years 1998,2002,2006 and 2014 were used for delineating the glacier boundary by using Personal Geodatabase in Arc GIS 10. The total area for each year in $km^2$was then calculated using the vector file (polygon type shape file containing glacier boundary).These shape files for each year then served as inputs for generating comparison maps for the years 1998-2002,2002-2006,2006-2010,2010-2014. The comparison map was then classified into three classes: Increase_ area , No change & Decrease_ area .Finally we applied the Linear Regression Model in R software to predict the future scenario of the area.

Temperature Computation Steps:

The downloaded images from USGS site were clipped and converted into Radiance image in Envi software through the given equation:

0.0003342 *(B1) + 0.1	L8
0.05518*(B1) + 1.2378	TM and ETM

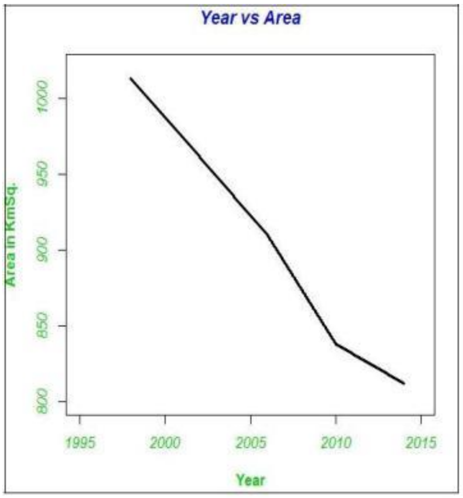
The Radiance image was then converted into temperature in terms of Degree Celsius again using the following (Envi-Band math) formula:

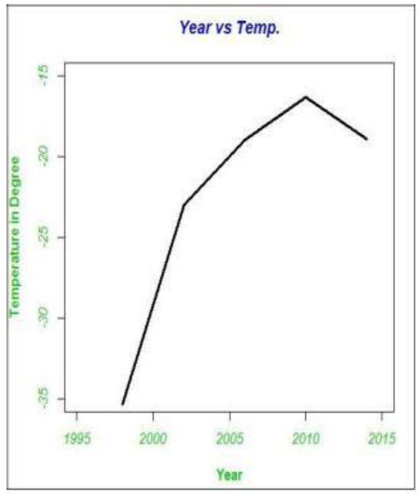
1260.57/alog (((607.7∗0.95)/b1)+1) - 273.15	TM
1282.71/alog (((666.1∗0.95)/b1)+1)- 273.15	ETM
1321.08/alog (((774.89∗0.95)/b1)+1) - 273.1	L8

Note: In the Band Pairing dialog one should match B1 with the thermal band. The temperatures for the years 1998, 2002,2006,2010,2014 were then determined and subsequently the Linear Regression Model was applied in the statistical formulation software R to predict the future Scenario of temperature.

5. RESULTS & DISCUSSION

As per the methodology followed in the previous section, area and temperature were computed from satellite data. Then the area graph was generated in Arc Map (Figure 4.1), which was followed by the temperature graph (Figure 4.2) for the span 1998 –2014. By using the result of both the temperature vs. area map (Figure 4.3) was created which clearly represents the decrease in area as temperature increases.





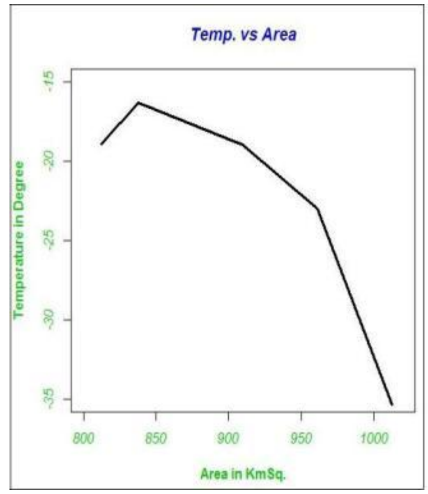
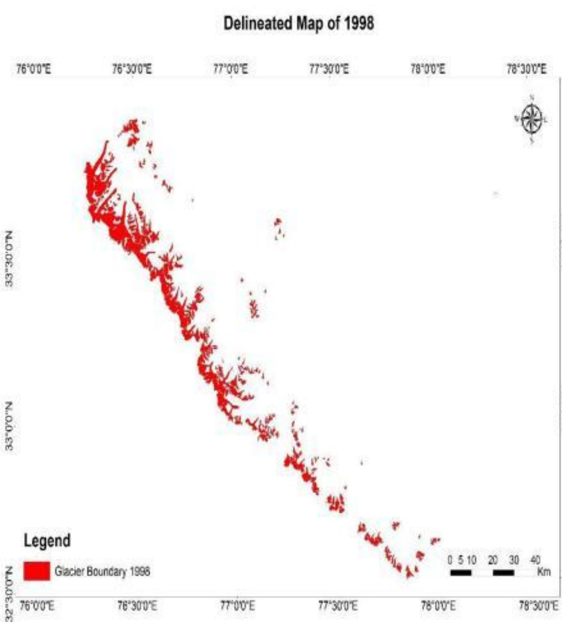


Figure 4.1 Year vs. Area graph Figure 4.2 Year vs. Temperature graph Figure 4.3 Temperature vs. Area graph

Now from Figures 4.4 to 4.8 represents the boundary of glaciers in the following year(1998,2002,2006,2010 and 2014) which are generated by using Landsat 5,7 and 8 satellite images



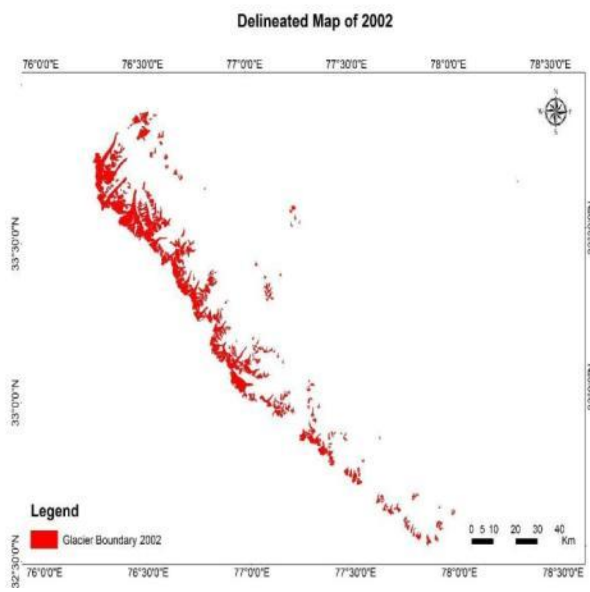
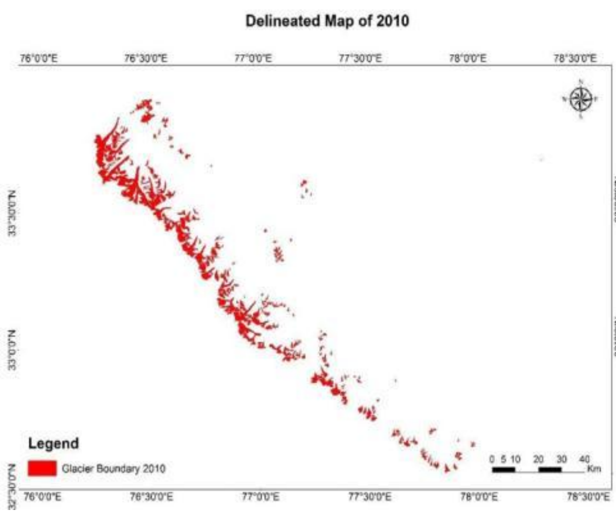


Figure 4.4 Glacier Boundary of 1998 Source: USGS (Landsat 5), Figure 4.5 Glacier Boundary of 2002Source: USGS (Landsat 7)



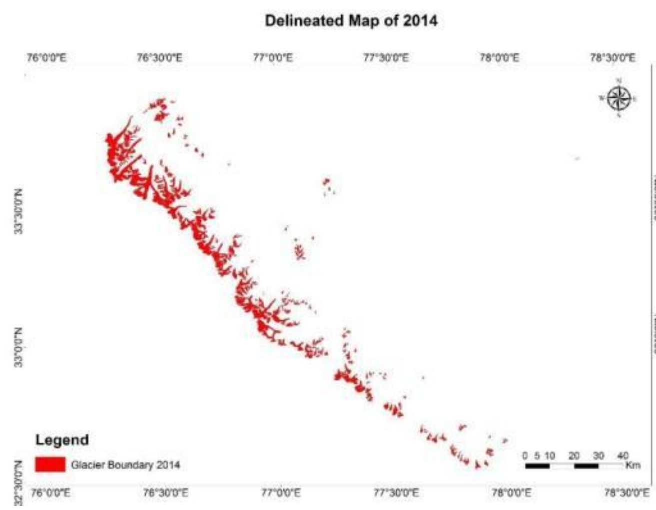
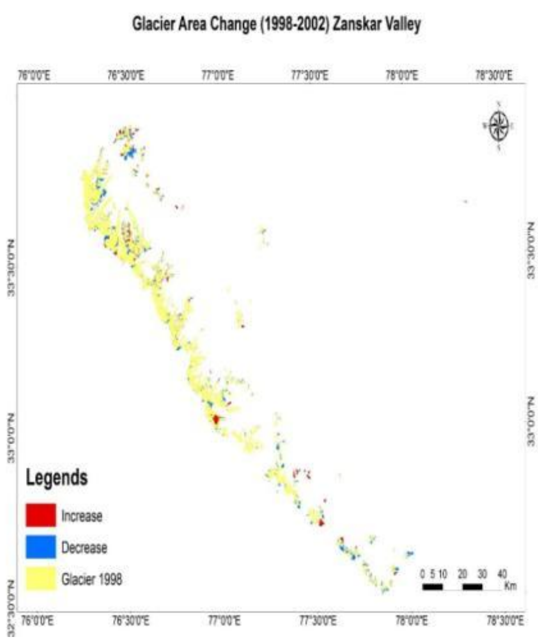


Figure 4.7 Glacier Boundary of 2010 Source: USGS (Landsat 7), Figure 4.8 Glacier Boundary of 2014 Source: USGS (Landsat 8)

The Area distribution change behaviour of glaciers in following years from 1998 - 2014 are prepared by using following sensors (TM, ETM and OLI). Upon observing Figure 4-9 to Figure 4-12 we clearly point out that there is both decrement and increment of the individual units of glaciers because of the spatial shift occurring in the regions of study due to various land erosional activities (like moraines shift, water crevases, heavy rainfall, etc).



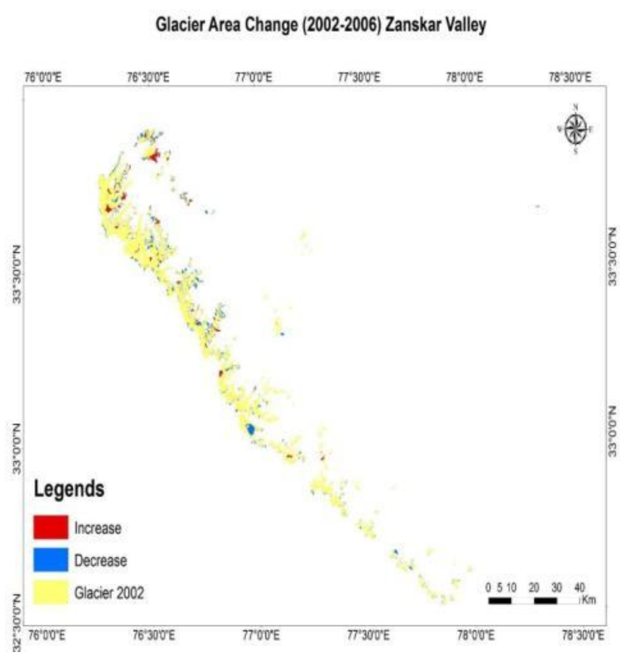
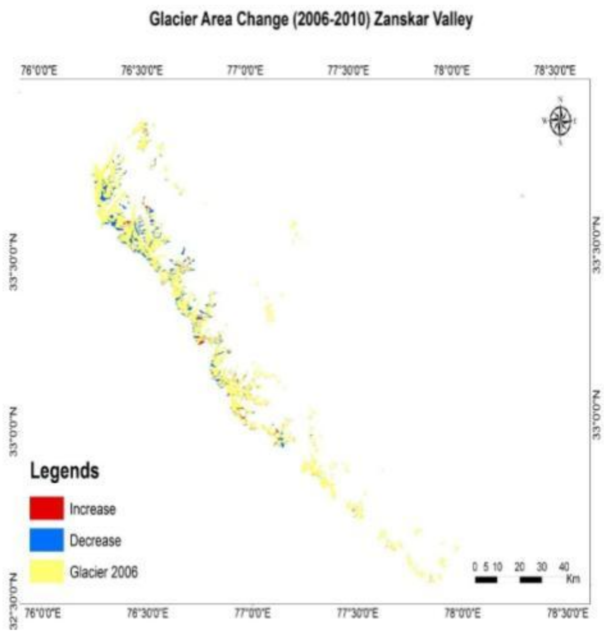


Figure 4.9 Glacier Change Behaviour in Zanskar valley (Period:1998-2002)
Figure 4.10 Glacier Change Behaviour in Zanskar valley (Period:2002-2006)



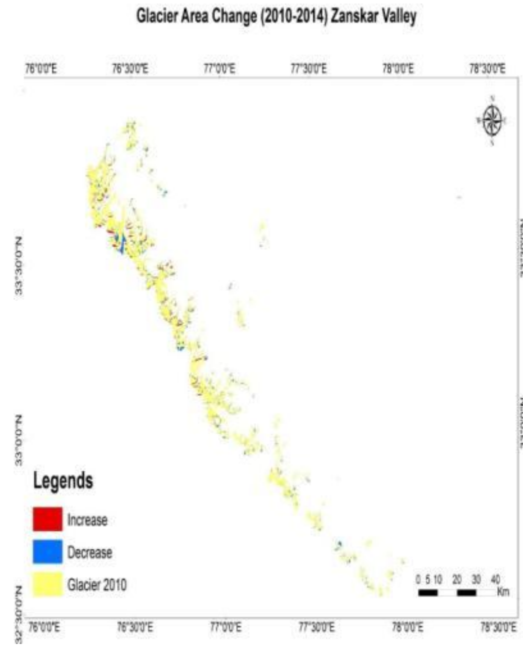
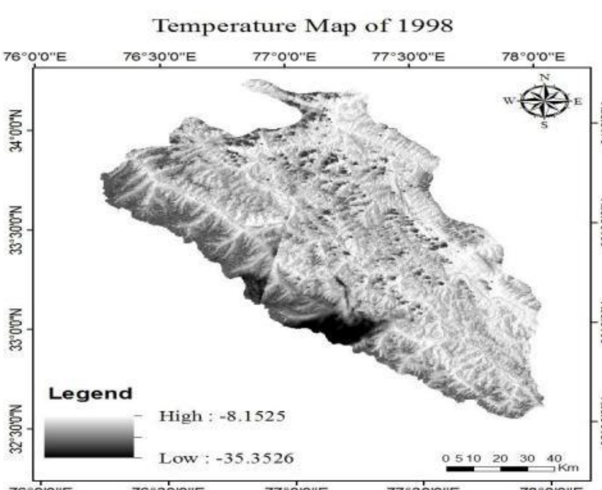


Figure 4.11 Glacier Change Behaviour in Zanskar valley (Period:2006-2010)
Figure 4.12 Glacier Change Behaviour in Zanskar valley (Period: 2010-2014)

The Temperature variation change behaviour of glaciers in following years from 1998-2014 are prepared by using following sensors (TM, ETM and OLI). Upon observing Figure 4.13 to 4.17 we clearly observe that there is a substantial increase of temperature of the glacier through the above mention period of years due to various factors like climate, UV radiation, greenhouse gas, pollution etc.



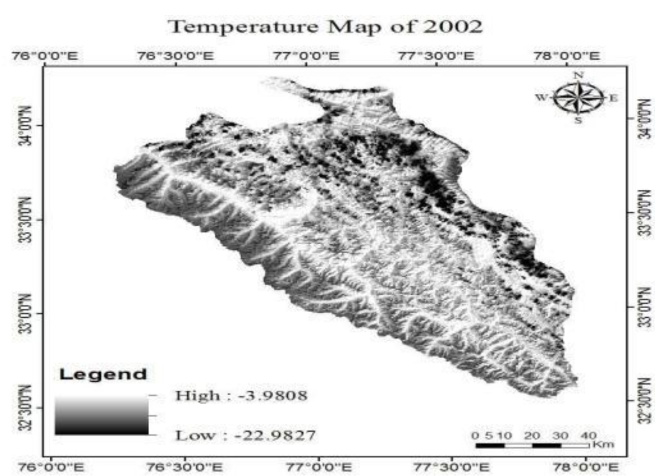
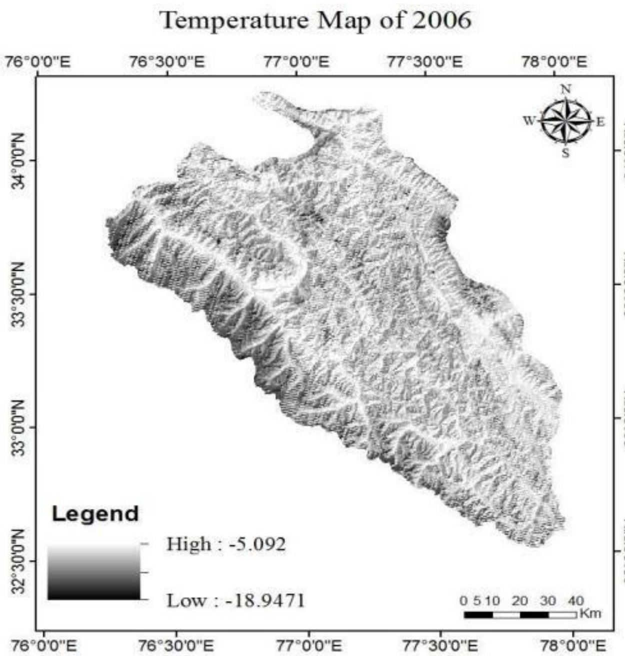


Figure 4.13 Temperature image showing surface temperature for 1998 of Zanskar valley
Figure 4.14 Temperature image showing surface temperature for 2002 of Zanskar valley
(Source: Landsat 5-Band 6) (Source: Landsat 7-Band 6)



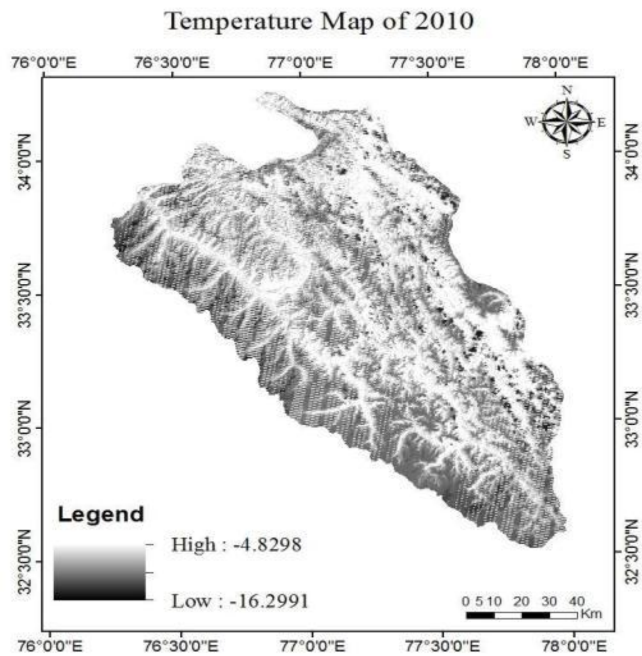


Figure 4.15 Temperature image showing surface temperature for 2006 of Zanskar valley
Figure 4.16 Temperature image showing surface temperature for 2010 of Zanskar valley
Source: Landsat 7- Band 6)

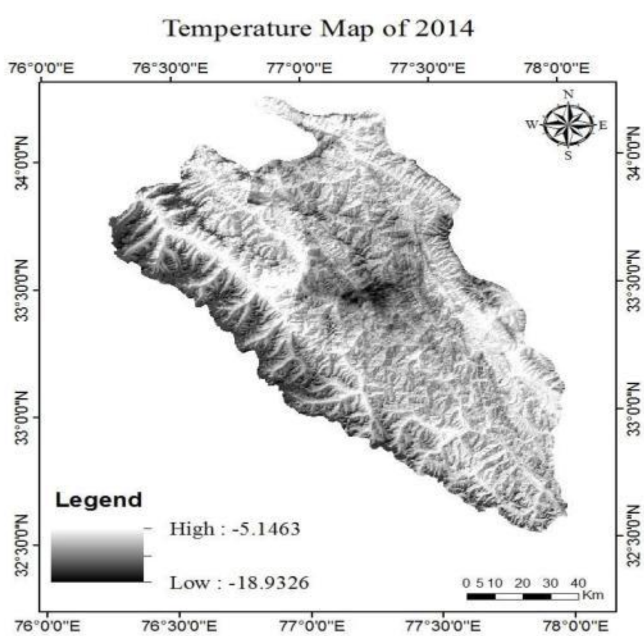


Figure 4.17 Temperature image showing surface temperature for 2014 of Zanskar valley (Source: Landsat 7-Band 6)

The final Figures.4.18 to 4.20 which are the predicted outputs of our study are represented in R windows which are described in Table section briefly.

```
> AY1=coef(M3)[1] + coef(M3)[2]*2018
> AY2=coef(M3)[1] + coef(M3)[2]*2022
> AY3=coef(M3)[1] + coef(M3)[2]*2026
> AY4=coef(M3)[1] + coef(M3)[2]*2030
> AY1
(Intercept)
   748.9831
> AY2
(Intercept)
   696.4045
> AY3
(Intercept)
   643.8259
> AY4
(Intercept)
   591.2472
```

Figure 4. 18 Prediction of Area using Year in R window

```
> AT1=coef(M1)[1] + coef(M1) [2] * -15
> AT2=coef(M1)[1] + coef(M1) [2] * -13
> AT3=coef(M1)[1] + coef(M1) [2] * -11
> AT4=coef(M1)[1] + coef(M1) [2] * -9
> AT5=coef(M1)[1] + coef(M1) [2] * -7
> AT1
(Intercept)
   836.4313
> AT2
(Intercept)
   817.6829
> AT3
(Intercept)
   798.9344
> AT4
(Intercept)
    780.186
> AT5
(Intercept)
   761.4376
```

Figure 4.19 Prediction of Area using Temperature in R window

```
> TY1=coef(M3)[1] + coef(M3)[2]*2018
> TY2=coef(M3)[1] + coef(M3)[2]*2022
> TY3=coef(M3)[1] + coef(M3)[2]*2026
> TY4=coef(M3)[1] + coef(M3)[2]*2030
> TY1
(Intercept)
    -10.639
> TY2
(Intercept)
     -6.686
> TY3
(Intercept)
     -2.733
> TY4
(Intercept)
       1.22
```

Figure 4.20 Prediction of Temperature using Year in R window

Table 4.1 Raw Data in R Software

Data Editor

	Year	Area.KmSq..	Temperature.0C.
1	1998	1013.013	-35.35
2	2002	961.4528	-22.98
3	2006	909.5434	-18.94
4	2010	837.4798	-16.29
5	2014	812.1063	-18.93

According to the result given in table 4.2, we used the Linear Regression model for predicting out the transitions in the area of glacier, According to the following years i.e. 2018, 2022, 2026, 2030 prediction, we observe that, there is substantial decrement in glacier areas as the years proceed.

Table 4.2 Prediction of Area using Year

Input Parameter in Model(Year)	Output Parameter (Area in Km. Sq.)
2018	748
2022	696
2026	643
2030	591

According to the result given in table 4.3,we used the Linear Regression model for predicting out the transitions in the area of glacier, According to the following temperature i.e. -15,-13,-11,-9,-7 prediction, we observe that, there is substantial decrement in glacier areas as the temperature fall out.

Table 4.3 Prediction of Area Using Temperature

Input Parameter in Model(Temperature in Degree)	Output Parameter (Area in Km. Sq.)
-15	836
-13	817
-11	798
-9	780
-7	761

According to the result given in table4. 4,we used the Linear Regression model for predicting out the transitions change in temperature of glacier, According the following years i.e. 2018, 2022, 2026, 2030 prediction, we observe that, there is substantial fall in glacier temperature as the years proceed.

Table 4.4 Prediction of Temperature Using Year

Input Parameter in Model(Year)	Output Parameter(Temperature in Degree)
2018	-10
2022	-6
2026	-2
2030	1

6. CONCLUSION

Remote Sensing and GIS has proved to be a very valuable tool for the application of technology in our digital world which helps us visualize a wide variety of environmental factors affecting our earth in different ways. In this project we examined two major properties of the glacier i.e., the glacial area extent changes through the years & also long-term variations in temperature in the study area Zanskar Valley in the years 1998 to 2002, 2002 to 2006, 2006 to 2010 and 2010 to 2014 at an interval of 4 years. Remotely sensing data has also helped to imply various images processing techniques for the glacial area changes behavior over the study area. The study has proven to be the indicator of the reduction of the glacial extent over the years and also linear increment in the temperature of the glacier has been observed. There is a lateral shift of the glacier towards North-East direction as the slope of the study area is in that direction itself. The melting of glacier as identified in our study is not only disturbing the climatic condition but is also nocuous to the people as well as animal life. If this whole mechanism continues longer then, that day is not far away when there would be no sign of glaciers. Our results have shown that there is a gradual degradation in the glacier area. Global warming plays a very crucial role in the rate of melting of glacier regions. Regional land degradation and human activity can be a cause of such changes occurring in the study region. We see that there is 20 % decrement in the total area of the glacier from the year 1998 – 2014. Subsequently we also observe a linear increment of the glacier temperature from -35 to -18 which proves to be a astounding change of 48 % rise in temperature from the year 1998 – 2014.Finally, in this study we have observed the drastic changes occurred in the glacier and it is now most required to conduct the ground studies over the region for the volumetric analysis and detailed study of the compositional changes occurring in the glaciers so as to prepare a risk zone map and to identify accurately the factors responsible for such changes.

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