Enrich Mountain GeoINTusing Open Source Thermal Satellite Images

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Due to the recent revolution of Geo Intelligence (GeoINT) technology, the products derived from freely downloaded satellite imagery, being an important parameter to provide the information of the associated changes happening over the Earth's surface. From the open sources such as United State Geological Survey (USGS), EARTHDATA sites the registered user, can download coarser to medium scale terrain inputs. In the present study, Landsat satellites operating from 8-14 µm has been used to compute the Land Surface Temperature (LST) for a given terrain in 30m spatial resolution.

Here Landsat data of L5, L7 and L8 sensors have been used to assess the LST for two high relief areas representing perpetual snow covered and vegetation terrain. For the first study area, a part of Karakoram is characterized with permanent snow covered and the impact of LST over the terrain is clearly visible during summer season. It indicates the slow term geo-environmental change i.e., climatic change occurring over the terrain. The Path-Row of the satellite data pertain to 148-35 has been used for the study which ranges from 1991 to 2016.

Similarly the second study area falls in the Uttarakhand state which is characterized with high vegetation terrain. Here sudden LU/LC changes occur due to the pre-monsoon forest fire events which are also reflected in the LST value. The entire state is covered by three Path& Row of Landsat images namely 145-39, 146-39 and 145-40 which varies from the period from 2013 to 2016. Using both single and split window algorithms, LST of the given terrain has been estimated. The models are realised using spatial modeller tool of the ERDAS software.

The result shows that in the Karakoram area, the summer temperature rises relatively higher in non-snow than snow areas leading overall 6%depletion of snow areas. Similarly, LST analysis that during 2016 Forest fire shows that there is sudden rise of temperature (> 200^0C) in April 2016 and that is supported with reported data. Hence open source data and its derived products can enrich existing geospatial database by considering both its static and dynamic terrain attributes.

Key words: Mountain GeoINT, Landsat, Land Surface Temperature

1. Introduction

GEOINT (GEOspatial INTelligence) is defined as the intelligence about the human activity on earth, derived from the analysis of imagery and information. It describes, assesses, and visually depicts physical features and geographically referenced activities on the Earth surface. It is defined as data, information, and knowledge gathered about entities that can be referenced to a particular location or region on the earth's surface. It use a variety of existing spatial skills and disciplines including photogrammetry, cartography, image analysis, remote sensing and terrain analysis etc. The main advantage is that such imagery is freely available and from its intelligence can be extracted by faster ways. These input data use both the Remote Sensing and GIS platforms for the generation of such GEOINT products. Satellite imagery is one of the vital sources for intelligence product creation. The commercial satellites of the IKONOS, Landsat, ASTER, MODIS or SPOT satellites which is freely available had played an important role in gathering information pertain to inaccessible terrain. These data plays a vital role in the fields such as Agricultural, forestry, geology, hydrology, geography, cartography, environment, climatology, oceanography and meteorology etc. An open source can be defined as the software or the data that are freely accessible. Open sources data domains such as United States Geological Survey (USGS), EARTHDATA provides free satellite images that are used to create terrain intelligence required for military planning, military operation as well as civilian applications. These international organizations provide reliable scientific information to describe and understand the unknown terrain. Here the data explorer gives a quick way to view and download the aerial and satellite imagery (pertaining optical and thermal bands) and further users can create area of interest from the available in the data domain.

In the present study, an attempt is made to use open source thermal data for creating GEOINT products pertain to high relief terrains. Due to the continuous and better resolution of Landsat data compared to the other satellites is chosen for the study. Also, procurement of satellite images is time consuming and costly which can be avoided due to open source datasets. Here using thermal bands of Landsat satellites of L5, L7 and L8 sensors the Land surface temperature (LST) over two unique test sites are generated. The LST parameter estimate the temperature of the earth surface and the warmth rising off earth's surface influences the weather and climatic patterns of the globe.LST is determined from thermal emission at wavelengths either in infrared or microwave which lies within the "atmospheric windows". Here both single and split window algorithms are used for the temperature computation over the given terrain. In the present analysis, LST product is derived using the open source satellite images which can used to understand and also evaluate the dynamic changes happening in the high altitude terrain.

The two study areas are as follows: the first is the part of Karakoram region covering Siachen Glacier and the second site is the Uttrakhand state which is vegetated terrain and is frequently affected by the forest fire incidents during pre-monsoon. The first site is characterised by permanent snow covered area and here Normalized Differential Snow Index (NDSI) is used to calculate the change in snow cover. Here the long term snow cover change with respect to LST has been studied using 25 years summer data that starts from June and lasts up to October months though August to September is the predominant months of this season. Also a threshold limit of 0.6 NDSI value has defined that estimate snow cover accurately. Similarly, the second site which experience frequent forest fires which starts from March to May months. Here the severity of forest brunt areas, the fire index is studied using Normalized Difference Vegetation Index (NDVI), Normalized Differential Burn Ratio (NDBR) and also correlated with the rapid change in LST value. These indices are ranges between -1.0 and +1.0, depending on its attribute types. Similarly, NDVI indicate the presence of healthy vegetation on which the severity of forest fire depends.

2. Objectives

Here two objectives have been considered in the study and they are as follows: first to generate the multi spatio-temporal LST products for the defined two sites and the second is find the association of the LU/LC changes with respect to the LST and their overall impact over the study areas.

3. Study Area and Input Data

The study is carried out over the mountainous sites to estimate the terrain dynamics due to LST changes. A part of Karakoram is selected, where Siachen glacier is present. The Karakoram is a large mountain range spanning the borders of, India, Pakistan and China and is the most heavily glaciated part of the world outside the Polar Regions. The study area lies in between 35^0 54' N and 75^0 31' E and Landsat scene having Path Row 148-35 is selected as study site for the first site covering an area of 28,297 km^2 (Fig.1). Here the focus is to find out the snow cover area change due to LST, one of the dynamic terrain attributes.

Similarly the second test site is located in Uttarakhand where the rapid LST changes happen due to forest fire events. The study area lies in between 28^0 43' N to $31^0$27' N and 77^0 34' E to 81^0 02' E covering 54,036 sq.km. Three Landsat scenes having Path and Row such as 146-39,145-39,145-40 (Fig.1) are considered for the study. The area experiences an average summer temperatures of about 30^0C (about 86^0F) and winter temperatures of about 18°C (about 64°F). Mainly the study areas were densely forested and experiences sever forest fires events.

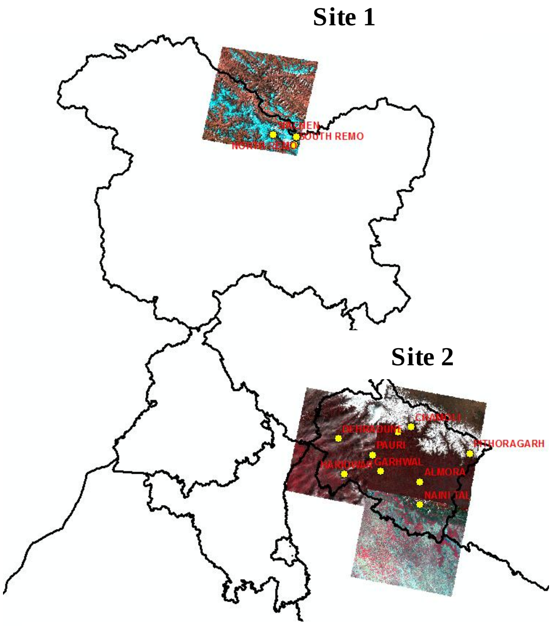

Fig.1: Location map of the two Study Areas

The Landsat images have been acquired for the study areas from USGS, Earth explorer. The Landsat 5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper Plus (ETM+) and in case of Landsat 8, both Operational Land Imager (OLI)and Thermal Infrared Sensor (TIRS) data with 30 m resolution has been used. For Karakoram region, total 42 data covering June, July, August, September, and October months (describing summer season) from 1991 to 2016 has been used to find out the net snow cover change happening in this area. Although, August and September are the best period to study the influence of summer however the prolonged months are considered for getting the cloud free scene for this region is the utmost challenging task. For Utharakhand region, Satellite data pertaining to March, April, May months from 2013 to 2016 years depicting the pre event, during and post events are used for the study.

Methodology

In this study, the Landsat data downloaded from the USGS sites after generating authorized user login and password are used for the LST estimation. RGB composites (Bands of 2345 or 3456) are made to get the general information of the terrain. Models are created to prepare different thematic layers such as LST, NDSI, NDVI and NDBR. Model tools of ERDAS and ArcGIS software are used for the advanced computation purpose. For both test sites the LST is estimated for all the data accrued from USGS site. In the Karakoram area, automatic snow cover area extracted by defining threshold of NDSI value (≥ 0.6) for snow area using published literature as well as matching the threshold value with RGB image and once the snow cover area is extracted it compared with the LST value. Similarly, for the Utharakhand region, the indices such as NDVI and NDBR are computed to find out its association with the rapid LULC changes and also correlated with that of increase in LST value. The process flow adopted in the study is mentioned in Fig.2. Here the spatio-temporal analysis of the LST with respect to snow bound areas of Karakoram and vegetated area of Utharakhand has been studied.

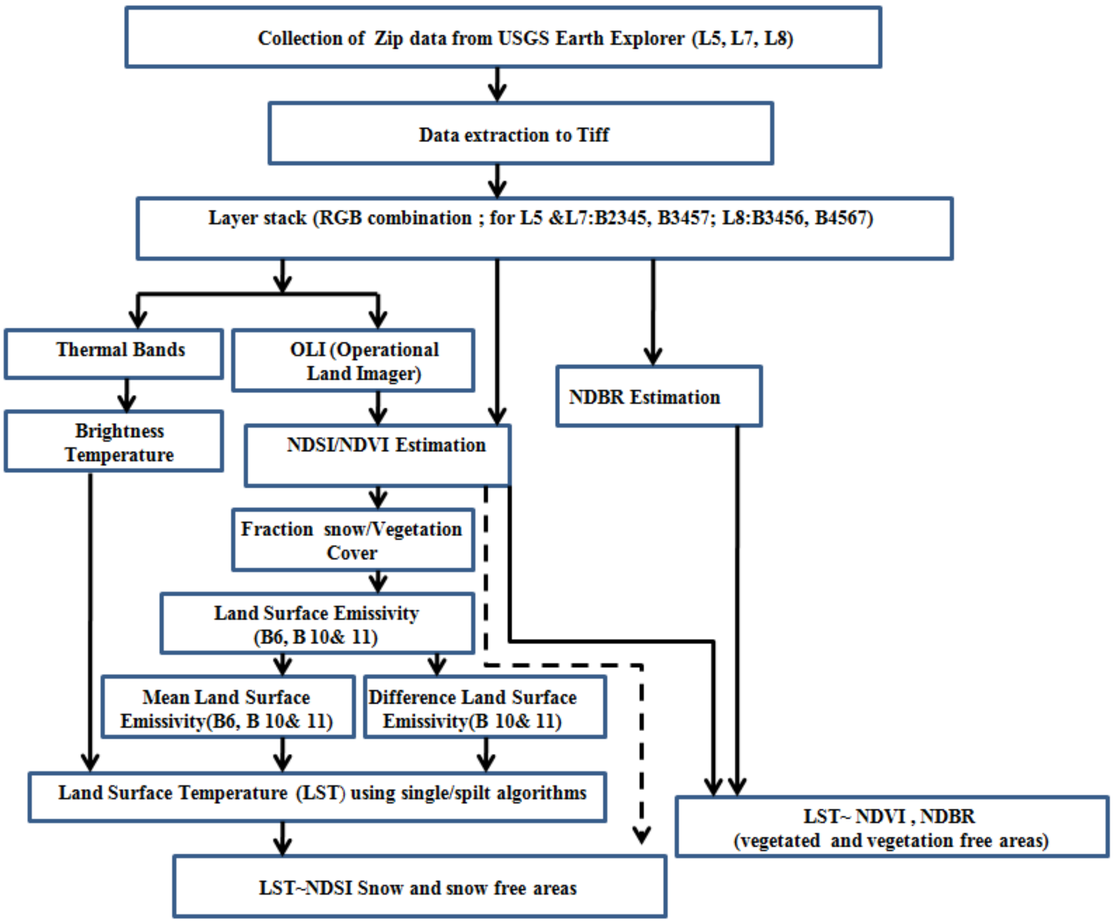

Fig.2: Process flow adopted in the study area

RESULT &DISSCUSSION

The results and discussion for both the test sites are discussed separately.

Test site1: Karakoram Area

This part of study area also covers the Siachen Glacier. In part of Karakoram covering 28,297 sq km where an average of 41% is snow covered or glaciated and the remaining 59% is non-snow. The estimated snow cover changes based on NDSI parameter from 1991 to 2016 is depicted shown in Fig 3. Comparing the RGB image with respect to NDSI, it has been found that the threshold value could able to discriminate the snow boundary accurately. Taking a threshold of 0.6 in NDSI images, it could differentiate the snow from non-snow areas and which is validated with the RGB image. In Fig.3, the cyan colour depicts the snow bound areas over the study site and the NDSI image shows a clear-cut decrease in the snow bound areas from 1991 to 2016. During the summer season in 1991 the snow cover area is approximately 14,662 km^2, while in 2016 the area becomes 12,950 km^2.

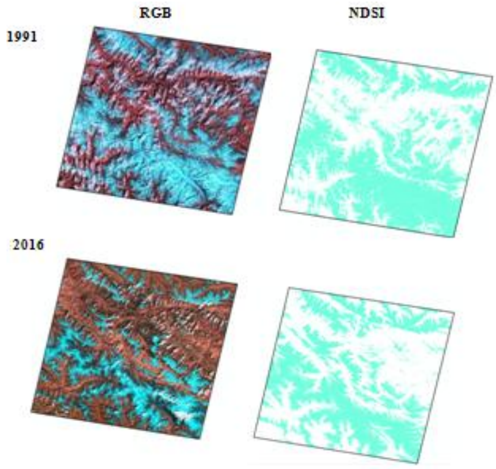

Fig 3: Temporal Variation of snow area for Karakoram

Over 25 years the snow area shows decrease trend with loss of 1711 km^2 .The changes in snow cover area are not following any particular trend, it’s fluctuating every year (Fig.4). Because the snow cover is also highly depend upon local climatic conditions. The quantitative analysis shows decrease in the snow cover area of 12% within the last 25 years.

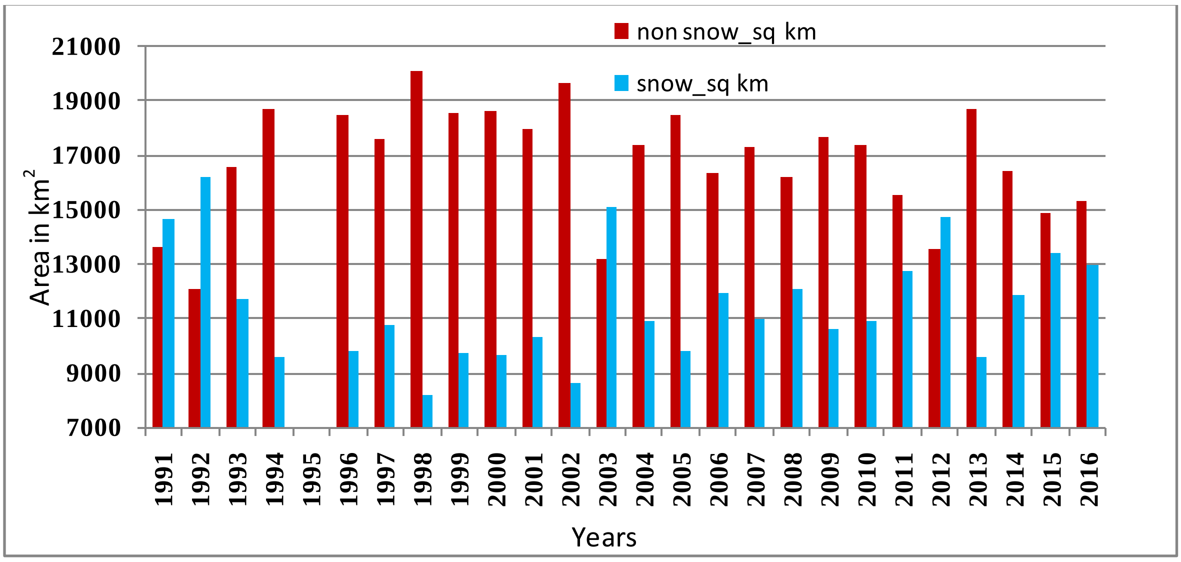

Fig 4: Variation of areal extent of Snow and Non snow areas

In the study area LST image of 1991 year shows a minimum value of 221^0 k to maximum of 314^0 k. In the same summer period during 2016 the maximum range goes up to 372^0 k and minimum value of LST becomes 244^0 k. In the year 1991 the LST image shows mainly the average surface temperature is below 273^0 k which shows yellow colour in the map. While the 2016 LST image clearly shows the maximum area experiences average temperature more than 283^0 k, which marked as red colour in the map (Fig.5).

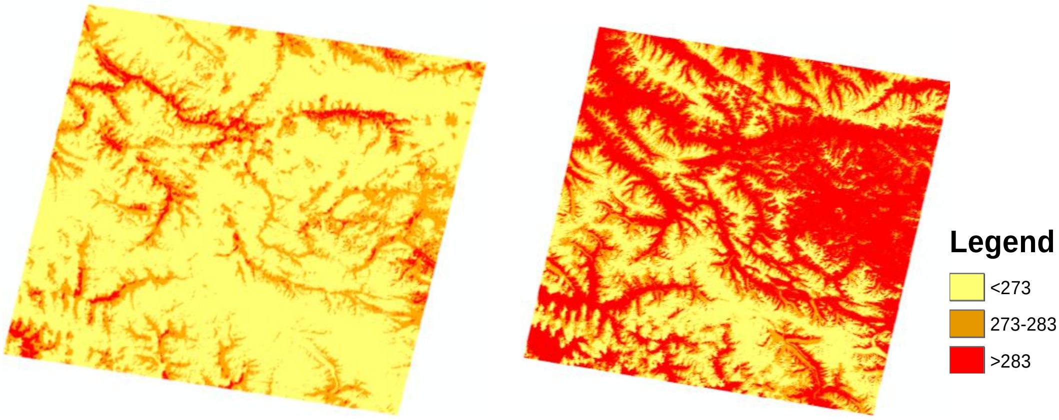

Fig 5: LST changes for the year 1991 and 2016 study area

LST estimated from the satellite images gives a clarifying explanation for the decrease in the snow cover area over the terrain. It gives a clear idea that in the year gap of 25 years the terrain undergoes vast climatic changes with increase in the surface temperature (Fig.6).

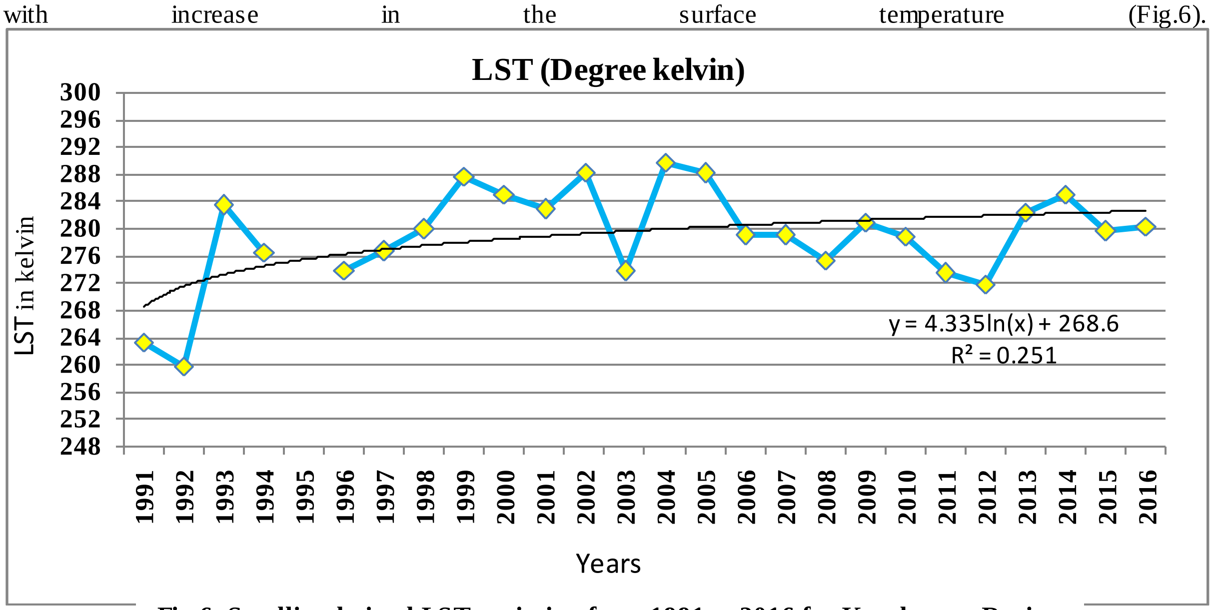

Fig 6: Satellite derived LST variation from 1991 to 2016 for Karakoram Region

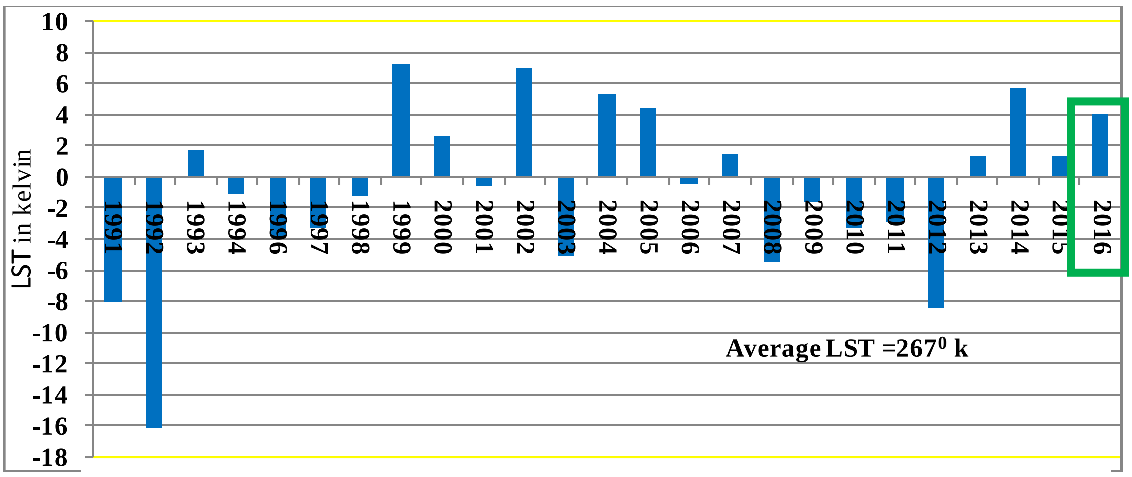

Fig 7a: Average LST variation of Snow area of Karakoram Region

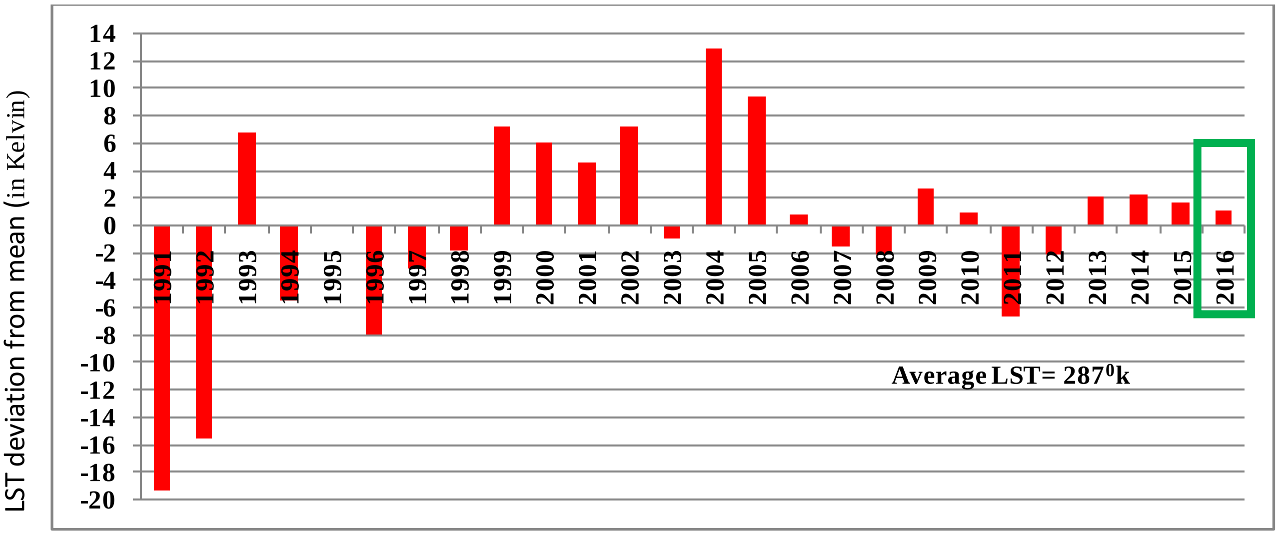

Fig 7b: Average LST variation of Non-snow area of Karakoram Region

The estimated value shows that the terrain experiences considerable increase in LST during last 25 years. The LST range over the area is changing year to year. It is not following any specific trend. According to the study, the terrain shows an average LST of 279 ^{o} k. During the summer season of 1991 the estimated LST was 263 ^{o} k and in 2016 it becomes 280 ^{o} k. When we consider only snow bound area, the average LST is 267 ^{o} k. In 1991 the LST vale over snow area is259 ^{o} k and in 2016 value becomes 271 ^{o} k. In the year 2016the LST becomes 4 ^{o} k more than the average vale over the snow bound area (Fig.7a & b). Considering the Non-snow area of the karakoram region the average LST is 278 ^{o} k. In 1991 the temperature over non-snow area is 268 ^{o} k and increased to 288 ^{o} k in 2016.From the analysis the study area experiences a decrease in snow bound area with increase surface temperature of 0.69 ^{o} k LST per year.

The second test site, Utharakhand falls in three scenes of Landsat images with path and row 145-39 shows 38% vegetated area over a total area of 3,087 sq km, in 145-40 scene the vegetated area is 85% of the total area of 32,202 sq km and 146-39 scene has a total area of 30,733 sq km in that the vegetated part constitutes 69% of the total area. The NDVI images are used to delineate the vegetated part over the study site from 2013 to 2016.The analysis shows that 2013 to 2016 all three scenes the vegetated area is decreased during the month of April.Howerver, for the year 2013, 2015 the cloud free April data is not available.

According to published reports the Pauri area which falls in the scene 146-39 has severely affected the forest fire during 2016. In the analysis during the April month this scene shows 86% vegetation in 2014 to a sudden decrease to 41 % in 2016 while comparing April data. The burned area estimated from the NDBR images of the same scene gives a clear view of increase in burned area in the year 2016. (Fig.8).Burned area was 14% in 2014 and it increased to 28% of total area in 2016.The decrease of 45% of vegetation cover over the total area is caused by an increase of burning during the period.

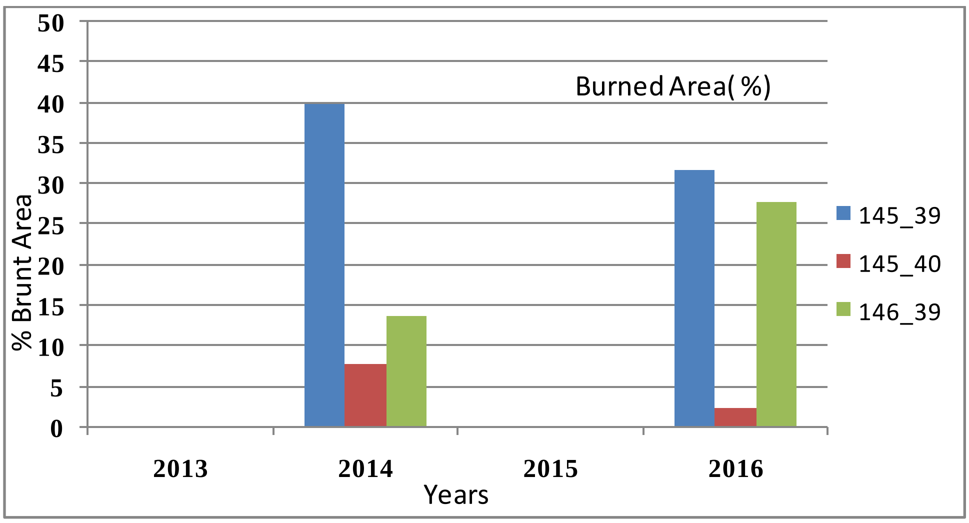

Fig 8: Percentage of burned area for 2014 and 2016

Similarly the LST estimated for the three scenes in April month, 146-39 scene shows an increase trend in the LST form 2013 to 2016 (Fig.9). In the 146-39 scene the maximum value of LST is estimated 120^0 c in 2014 and it become 240^0c in 2016.Compiring all the scenes from 2013 to 2016, scene with path and row 145-40 shows the least LST value. And highest is reported in the year 2016 in the scene 146-39.It is matching with the published report, that the maximum severity of forest fire occurred in the Pauri area which falls in the same scene. The NDVI shows a decrease in 45% of vegetated area over the total area and the NDBR shows a 14% increase in the burned area. The estimated LST value shows that the LST is increased during the period. Some areas show the LST value maximum up $240^{o\ c}$.

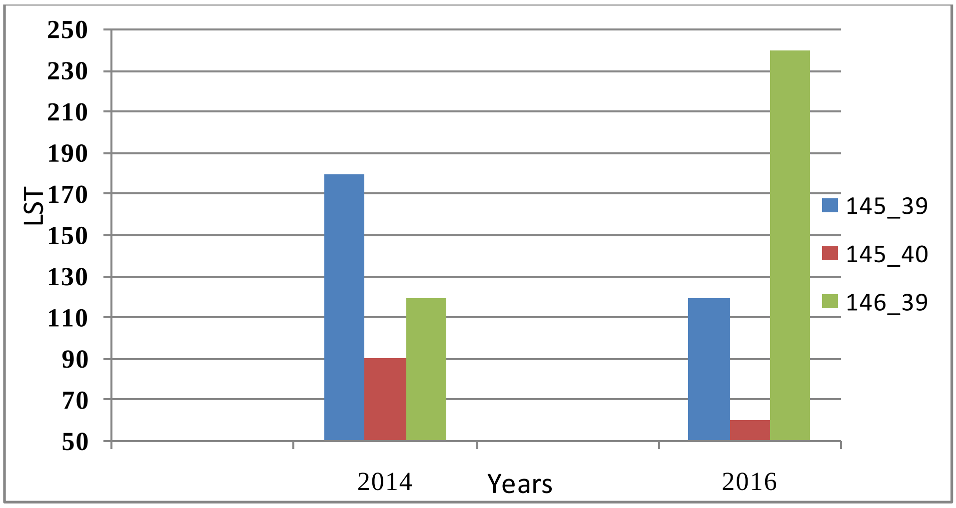

Fig 9: Maximum LST for 2014 and 2016

When comparing the three scenes from 2013 to 2016, 145-40 shows the least affected area in forest fires. Were the vegetated area is not reduced drastically throughout the years. The severity is peak in the scene 146-39.where the NDVI image gives the vegetation is decreased to 45% with increase in burned area of 14%.The LST reach the maximum of 240^o in some areas. It will only possible during forest fire. According to the study the decrease of 45% of vegetated part of the area is because of the forest fire during 2016.

CONCLUSION

The paper discusses about the application of open source data and in Geo-intelligence support. Main focus on the use of open source data derived LST images to estimate the change in LU/LC pattern of the terrain. Two test site of high altitude mountain range is considered in the study. The first site is glaciated part of Karakoram and Second is vegetated part of Utharakhand. The study made use of the beneficial spatial and spectral resolution of the Landsat images for two test sites. Three different indices NDVI, NDBR, NDSI were compared with LST data to obtain the LU/LC change. According to the analysis in the Karakoram area, the snow bound area derived from the NDSI indices shows the reduction of 6%snow covered area from 1991 to 2016 with an average increase of 0.69^o k LST per year. In the Utharakhand region comparative study is done over three scenes of Landsat images with Path & Row145-39,145-40,146-39.The result shows that in the scene 146-39from 2014 to 2016, 45% of the vegetation cover is reduced with increase in the burned area of 14% of the total area. The LST reaches maximum of 240^o c in the same period. It indicate the particular scene is severely affected by forest fire in 2016 and the same validated with which is matching with the published reports. Hence in the absence of high resolution satellite data the open source data and its derived data products can provide the insitu geo-environmental condition and also are very useful for the support of Geo-intelligence over the terrain.

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