P: ISSN NO.: 2394-0344 RNI No.UPBIL/2016/67980 VOL-2* ISSUE-5* August- 2017
E: ISSN NO.: 2455-0817 *Remarking An Analisation*

Snow Cover Change in Uttarkashi District (Uttarakhand) between 2000 and 2015 and Its Impact on Local Livelihood Structure

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Abstract

In the Himalayan region snow and ice cover plays a very vital role. It not only monitors the climatic condition of the region but it also dictates the day to day livelihood structure of the local people. Snow cover and glaciers are one of the most sensitive landcover over the earth surface. Thus time to time assessment, monitoring as well as mapping of these land covers is very essential. Thus in the present study an effort has been made to study the snow cover change of Uttarkashi district between 2000 and 2015 taking Landsat ETM+ and Landsat 8 images using geoinformatic techniques like supervised classification and normalized difference snow index(NDSI) with the help of Erdas imagine 9.1 and Arc GIS 10.1 software. An effort is also made to find out the impact of these changes on the livelihood structure of the local people.

Keywords: Snow Cover, Local Livelihood structure, Global warming, Geoinformatic techniques, Supervised classification, NDSI.

Introduction

There is a huge hue and cry all over the world regarding global warming and climate change. Global warming is the century scale rise of the global temperature. According to the IPCC 5th assessment report (AR5) 2013, in the period from 1880 to 2012, the global average surface temperature has increased to 0.85ºC (0.65 to 1.06ºc). As per a climatic model projection during 21st century, the global surface temperature may rise a further 0.3 to 1.7ºC in the lowest emission scenario and 2.6 to 4.8º C in the highest emission scenario. With the rise in the global temperature the snow covered area is retreating. Glacier/ snow cover are considered to be very important part of the earth surface because most of the freshwater is trapped in them. But due to global warming and climate change most of the glaciers in the world have receded during the last 100 years. Presently 10% of the earth's landmass is covered with snow, out of which 84.16% is in the Antartic, 13.9% in Greenland, 0.77% in the Himalayas, 0.51% in North America, 0.37% in Africa, 0.15% in South America and 0.06% in Europe. All of these snow covered area are in the process of recession. Snow cover/ Glacier are thus the most sensitive part of the earth surface and time to time assessment and monitoring of these land cover is very essential. Assessment, mapping and monitoring of the Himalayan glaciers are even more important as the region is having maximum concentration of snow cover, with 9.04% area with glacier and 30-40% additional snow covered area (Shiva Vandana). Himalayan glaciers are called the' third pole' as it is the origination point of many greatest rivers which caters most of the part of Asia. But in spite of having so much importance still very less work has been done on the Himalayan glacier. Thus the present study is an effort to find out the changes of the area covered by snow in Uttarkashi district, which is a part of the Garhwal Himalaya.

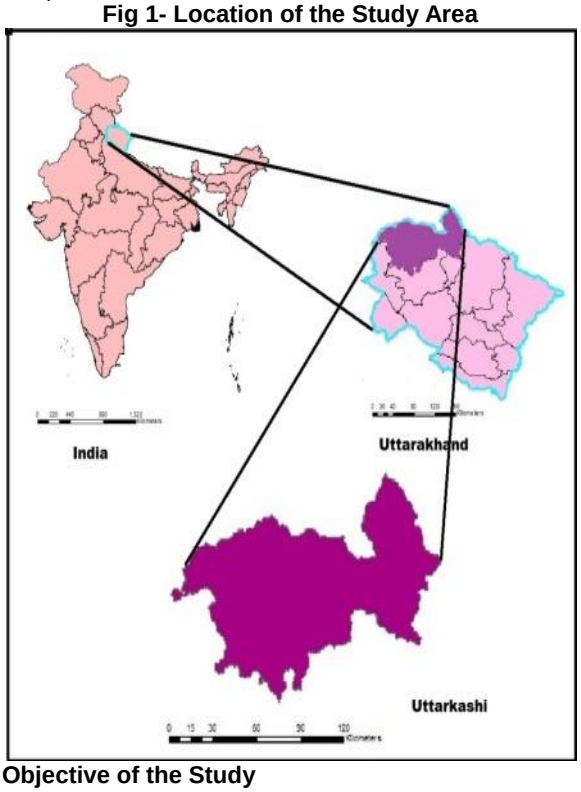
Study Area

Uttarkashi is a border district of Uttarakhand, It is situated between 78º 26" E and 30º 44"N with an elevation of 1150 Mts above sea level on the bank of Bhagirathi river. District Uttarkashi has an area of 8016 sq. km where a population of 330,086 resides in it.

It is considered as a pious place for the people following Hinduism as two of the most sacred rivers of India i.e Ganga and Yamuna originates from this place. Ganga (Bhagirathi) originates from Gangotri glacier and Yamuna originates from Yamunotri glacier. Both these glaciers have an

important impact on the local livelihood structure of Uttarkashi. A slight change in the glacial activity hampers the daily livelihood of the people residing in this place.

Fig 1- Location of the Study Area



Objective of the Study

The present study was started keeping in mind the importance of snow cover/ glacier on the local livelihood and how the change in the snow cover area is affecting the day to day life of the local people. Uttarkashi district has its own significance as it is having two of the most important glaciers i. e Gangotri and Yamonotri from where two of the sacred rivers of India originate i.e Ganga and Yamuna respectively. A small change of these glaciers can have a huge impact over the low lying areas. Thus the main objective of the present study is to find out the kind of snow cover change happening in this part of the Himalaya and how it is affecting the local livelihood structure. The work is done using geoinformatic techniques, two technique has been used to find the snow cover change- One is by classifying the images to get the required classes and second is by finding out the normalized difference snow index (NDSI)

Snow cover change can be assessed with the help of classification technique in GIS platform using optical bands of landsat images and with the help of NDSI which uses optical as well as mid infrared bands of landsat.

In the recent time the NDSI is widely used for snow cover mapping at large scale(Dozier J. 1989). There have been plenty of studies on snow cover mapping and monitoring using NDSI like Sibandze Phila et. al (2014) used normalized difference principle snow index(NDPSI) for distinguishing snow from related land cover types and they have found an accuracy of 84.9% in snow cover mapping using this technique. NDSI is preferred over other snow identification method such as the Relative spectral mixture analysis (RMESMA) (Shreve et. al). Xiao et. al(2000) used Normalized difference snow/Ice index(NDSII) using reflectance values of red and mid infra red spectral bands of landsat TM. The three visible bands (TM1,2,3) of landsat TM is useful spectral band for identifying snow and ice cover (Bresjo Bronge and Bronge 1999, Sidjak and Wheate 1999). For instance in using landsat TM data and ground radiometer measurements to classify ice and snow type in the eastern Antartic, Bresjo Bronge and Bronge(1999) found that the TM3/TM4 ratio is a simple tool for distinguishing between blue ice and snow of various characters and the TM3/TM5 ratio is useful tool for quantifying snow grain size variations. Basnet Smriti et. al has also used the NSDI technique to monitor the seasonal snow cover in Sikkim Himalayas between 2004-2008. Besides the NSDI technique image classification and eventually overlapping technique also helps in identifying the locational change of any landcover. Though very less studies has been done to monitor snow cover change using this technique. Thus in this study an effort has been made to use both these techniques to find out the snow cover change of Uttarkashi district between 2000 and 2015.

Methodology Used

The present work was started by downloading Landsat images for the year 2000 and 2015 online from www.USGS.com website. For 2000 landsat TM image was downloaded and for the year 2015 landsat 8 images was taken. For both the years the images of 19th february was selected as the month is quite cloudless and maximum snow cover can be seen in this month.

The images were then resampled and required bands were layerstacked in Erdas imagine 9.1 software. After layerstacking FCC images were generated. The FCC images were then classified, the Maximum Likelihood (MLH) supervised classification algorithm was applied to classify the study area, whereas, Post Classification Comparison (PCC) approach was adopted to find out the locational change of the snow cover.

To validate the snow cover change the NDSI technique was used. To find out the NDSI visible band and mid infrared band were selected as snow and ice cover have very high spectral reflectance values in visible band but low spectral reflectance in mid infrared band. The band characteristics of landsat TM and landsat 8 are listed in the tables below:

Table 1- Band Characteristics of Landsat TM

Band No.	Band Name	Wavelenght	GSD(m)
1	Blue	0.45-0.52	30
2	Green	0.52-0.60	30
3	Red	0.63-0.69	30
4	NIR	0.77-0.90	30
5	SWIR	1.55-1.75	30
6	Thermal	10.40-12.50	120
7	SWIR2	2.09-2.35	30

Source-https://landsat.usgs.gov/what-are-band-designations-landsat-satellites

Table 2- Band Characteristics of Landsat 8(OLI)

Band No.	Band Name	Wavelenght	GSD(m)
1	New Deep Blue	0.43-0.45	30
2	Blue	0.45-0.51	30
3	Green	0.53-0.59	30
4	Red	0.64-0.67	30
5	NIR	0.85-0.88	30
6	SWIR2	1.57-1.65	30
7	SWIR3	2.11-2.29	30
8	PAN	0.50-0.68	15
9	SWIR	1.36-1.38	30

Source-https://landsat.usgs.gov/what-are-band-designations-landsat-satellites

As already stated the underlying idea of using optical sensors to map snow is that snow has a distinctive spectral signature. Its reflectance is very high in the visible wavelength and it drops steeply in SWIR and remains low for longer wavelength. Therefore the ratio between green and SWIR (short wave infra red) reflectance is called NDSI (Wang et. al). Thus for landsat TM we used the formula:

NDSI= Band2-Band5/Band2+Band5

And for landsat 8 the NDSI is calculated using the formula:

NDSI=Band3-Band6/Band3+Band6

To know about the impact of the snow cover change on the local livelihood a village level survey was conducted. Systematic random sampling technique was adopted, in which all the villages of the six blocks of Uttarkashi district was arranged in ascending order based on the total area covered by each village and every 10^{th} village among the list was selected as the sample village for survey.

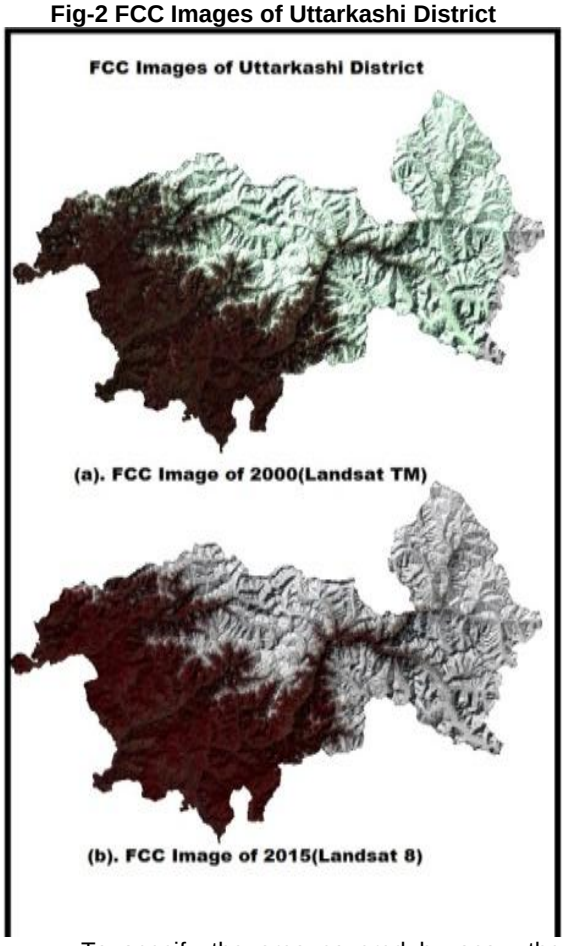
Results

Snow cover holds an important part in the land cover pattern of the Himalayan region. In an assessment of about 200,000 glaciers since the mid nineteenth century in the world, it has been found that about two thirds of the current glacial melting is due to human influence on the climate (Connor Steve). It is estimated that the glacial melting a century before was directly the result of the natural calamities in the climate, but the present melting is primarily caused by anthropogenic global warming resulting from industrial greenhouse gases.

Extensive literature shows that the ongoing loss of mass from glaciers is caused primarily by warming over those glaciers and this warming is, in turn being caused primarily by the CO2 concentration in the atmosphere. (Burkhat et. al)

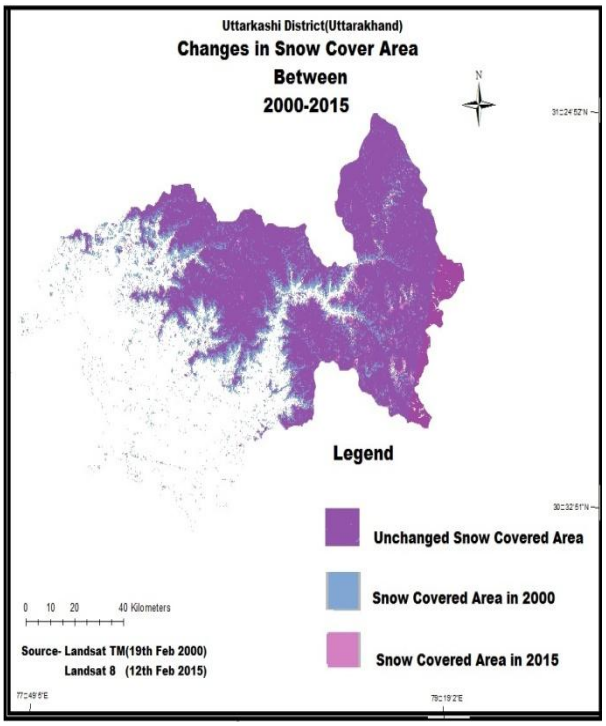
Even in the present study it is found that the area under snow cover is declining in Uttarkashi District. The point was validated using geoinformatic techniques. Landsat images for the year 2000 and 2015 were downloaded from USGS website and the required bands were layerstacked to produce the FCC (False Color Combination) images as shown in fig 2.

Fig-2 FCC Images of Uttarkashi District



To specify the area covered by snow the FCC images were classified using supervised classification technique, the Maximum Likelihood (MLH) supervised classification algorithm was applied to classify the study area. Classification is the process of sorting pixels into a finite number of individual classes, or categories of data based on their data file values. If a pixel satisfies a certain set of criteria, then the pixel is assigned to the class that corresponds to those criteria. The maximum likelihood technique for supervised classification was selected as it is based on the hypothesis that the distribution of pixels values in each class is approximately described by a normal distribution whose variables are digital values in every spectral band of the image. Generally majority of the training pixels of a class have similar values and thus found to be located in a tight cluster over the space. As the distance from the centre of the cluster increases, the number of training pixels of corresponding value decreases. MXL classifier evaluates both the variance and covariance of the category and the spectral response pattern when classifying unknown pixel. In the post classification stage both the classified images were overlapped to find out the location change of this specific class (Fig 3).

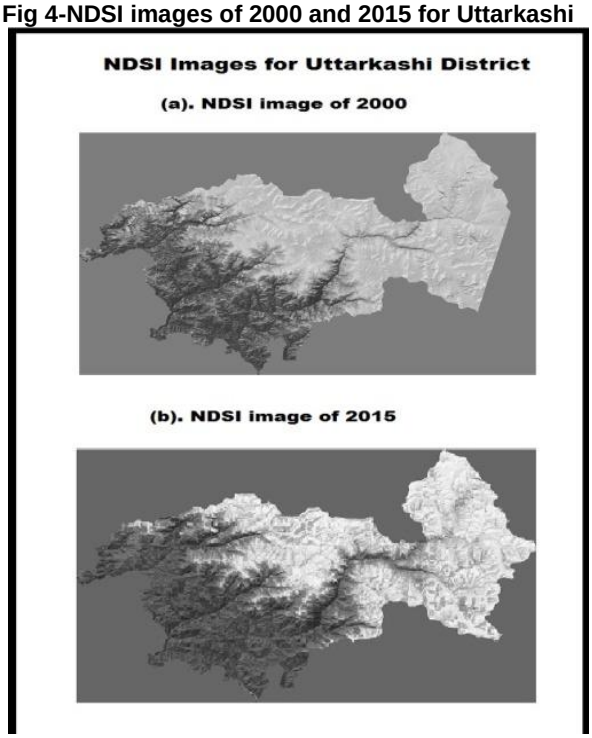
Fig 3- Changes in Snow Covered Area between 2000 and 2015



From the map it is clear that the snowline is receding. Most of the snow covered area seen in the year 2000 has been converted into barren rocky surfaces.

To know more about the receding snow cover the NDSI technique is also being used. NDSI is actually a ratio between visible band and SWIR band of landsat image. We prepared the following NDSI images (Fig 4) of 2000 and 2015 by rationing visible and SWIR bands:

Fig 4-NDSI images of 2000 and 2015 for Uttarkashi



The very bright areas in the mountain area of Uttarkashi have large values of NDSI are likely to be snow/ice cover. In both these NDSI images we can find that the bright white area as seen in the image of 2000 has receded quite a certain extent in 2015. Many of the snow covered area are found to have either converted into barren rocky or is being replaced by vegetation.

Discussion

Various literatures on glacier melt have proved that almost every glacier over the earth surface is melting. In one of its assessments a controversial statement made by IPCC was “Glaciers in the Himalaya are receding faster than in any part of the world. If the present rate continues the likelihood of them disappearing by the year 2035 and perhaps sooner is very high if the Earth keeps warming at the current rate (Kulkarni V. Anil et al, 2014). There are many causes associated with glacier melt but the global warming due to rise of Carbon dioxide and other green house gases are considered to be the main culprits. The green house gases are produced and released due to anthropogenic activities but whatever be the reason behind glacier melt has got an adverse impact over the livelihood of the people both in local as well as global scale.

For centuries the local livelihood structure is related with the snow. Water comes from the snow melt; the snowfall also provides moisture to the land. The moisture from the snow melt is good for the production of many crops. It is good for the pastures too. Less snowfall means less moisture for the crops, the less snowfall is affecting winter crops like wheat, manduwa(a kind of local flour), potatoes ,pulses and apples in Uttarkashi as during the winter season the air lack moisture and the soil gets very dry, in that situation only the snow fall gives the soil the required moisture.

As per said by the local residents the duration of snowfall in Uttarkashi has also shortened. Earlier they used to get snowfall from November itself and it lasted till the mid February. But in the recent time snowfall can be seen only for one or two months. The shorter period of snowfall prevents the snow from turning into ice crystals. Therefore more of the snow cover gets melted with the coming of the summer. The rise in temperature and the resultant climate change also accelerates rainfall activities. As per the local people the amount of rainfall has increased in the recent time. The type of rainfall is very erratic, the period of heavy rainfall and lesser snowfall have a very dangerous consequence in the form of disaster. One such major disaster was seen in the year 2013, In June 2013 there was a very heavy rainfall; the rainfall impregnated the rivers of the area. Besides the high temperature accelerated the melting of the glaciers; both heavy rainfall and snow melt gave rise to floods and eventually landslip and landslides. The 2013 disaster has devastated the local economy; almost every village became a prey of this disaster. In June 2013 disaster 1930 houses were slightly damaged, 186 houses were totally damaged and 467 houses were severely damaged. There was a loss of 339 hectares of agricultural land, 12 people were

killed and 20 were severely injured (DMMC, Dehradun). Many roads and bridges were cut down. Its losses are yet to be recovered; there are many villages where the repair work is still under process. Such incidents makes it clear the Himalayan region is very sensitive, a small change in temperature, rainfall or snowfall can have a severe consequence for itself as well as for the low lying places.

Conclusion

There is no doubt that the snow cover/ glacier is very sensitive part of the earth surface, thus a small change in the global climate can bring a huge change on the snow cover. In the present study it was found that the snow cover area of Uttarkashi have changed in last 15 years(2000-2015) and the change is affecting the local livelihood structure, Due to less snowfall there is less moisture on the ground which is hampering the growth of some ethnic crops. Rise in temperature is accelerating snow melt and heavy rainfall is swelling the rivers and eventually leading to disasters like heavy flood, glacial lake outburst etc. The recurring disasters are hampering the growth and development of this region.

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