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A Study of Snow Cover Change and its Impact on local livelihood in Uttarkashi District: An Analytical Approach

Dr. Rajender Singh, Department of Geography, Shivaji College, University of Delhi,
prajenders@yahoo.com
Dr. Parveen Bano, Department of Computer Science, PDM University, Bahadurgarh,
parveen.bano1@gmail.com
Dr..Anjali Yadav, Department of Geography, Swami Shraddhanand College, University of Delhi,
anjali.dse@gmail.com

Abstract

Snow and ice cover are extremely important in the Himalayan region. It not only monitors the region's climatic conditions, but it also regulates the local people's day-to-day livelihood structure. Snow and glaciers are two of the most vulnerable landcovers on the earth’s surface. As a result, it is critical to examine, monitor, and map these land covers on a regular basis. Thus, in the present study an effort has been made to study the snow cover change of Uttarkashi district between 2000 and 2021 using Landsat 5 and Landsat 8 images respectively using techniques like band rationing. Band rationing is the technique of ratioing two bands to define a particular landcover. In band ratioing the band with maximum absorption and maximum reflectance are taken and an average of both are found out, moreover in the present work the output is converted to polygon and an overlay analysis was done to find out the change of snow-covered area. Besides this in this paper an effort was also done to find out the impact of snow cover change on local livelihood structure.

Keywords- Snow cover, Local livelihood, NDSI, Overlay analysis.

Introduction

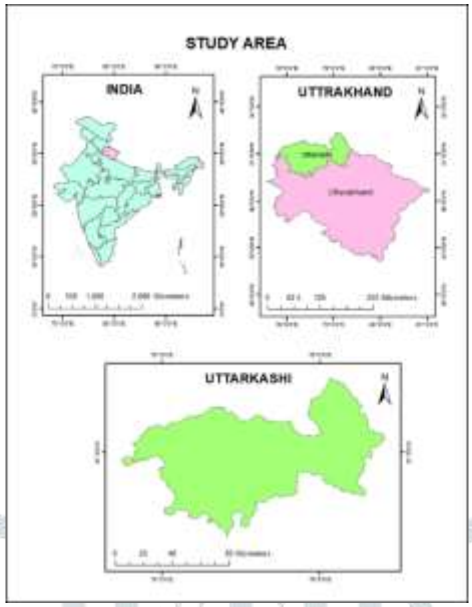
There is a huge hue and cry all over the world regarding global warming and climate change. Global warming is the century scale rise of the global temperature. According to the IPCC 5th assessment report (AR5) 2013, in the period from 1880 to 2012, the global average surface temperature has increased 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 receding. 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 areas 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. Uttarkashi town is itself the district headquarter; it has an area of about 12.02 Sq. Km where a population of 18220 approx (2011 census) resides in.

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 Yamunotri 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.

Generally, Snow cover change is 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 5 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 TM4/TM6 ratio is a simple tool for distinguishing between blue ice and snow of various characters and the TM4/TM6 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.The normalized difference snow index (NDSI) is an index that is related to the presence of snow in a pixel and is more accurate description of snow detection as compared to fractional snow cover (FSC). Snow typically has very high visible (VIS) reflectance and very low reflectance in the shortwave infrared (SWIR), a characteristic used to detect snow by distinguishing between snow and most cloud types. Snow cover is detected using the NDSI ratio of the difference in VIS and SWIR reflectance; NDSI=((band4-band6)/(band4+band6)). A pixel with NSDI>0.0 is considered to have some snow present. A pixel with NDSI<=0.0 is a snow free land surface (Riggs et.al.,2016). Besides the NSDI technique image classification and eventually overlapping technique also helps in identifying the locational change of any landcover. Though very less studies have 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 2021.

Methodology used:

The present work was started by downloading Landsat images for the year 2000 and 2021 online from www.USGS.com website. For 2000 Landsat 5 image was downloaded and for the year 2021 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 work is done using Geoinformatic techniques, two techniques has been used to find the snow cover change- one is by band rationing visible and short-wave infrared and another by converting the image into polygon defining the changes in different years (Fig 2).

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 5 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	CIRRUS	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 Visible and SWIR (short wave infra red) reflectance is called NDSI (Wang et. al). Thus for landsat 5 the formula has been used:

NDSI= Band3-Band5/Band3+Band5

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

NDSI=Band4-Band6/Band4+Band6 (Riggs et al., 2016)

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 10th village among the list was selected as the sample village for survey. The detail work is highlighted in the methodology chart in Fig. 2

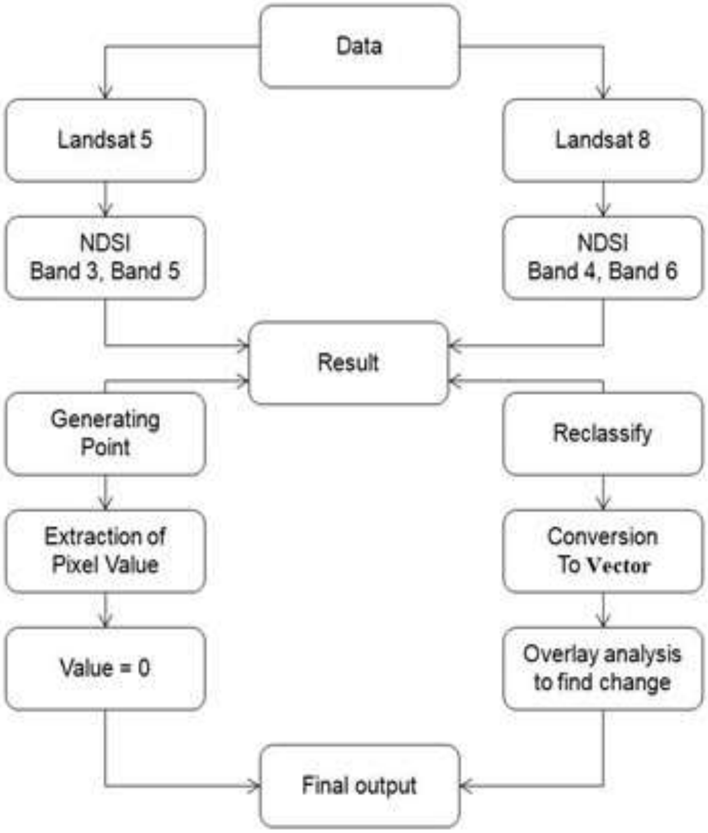


Fig 2- Methodology Chart

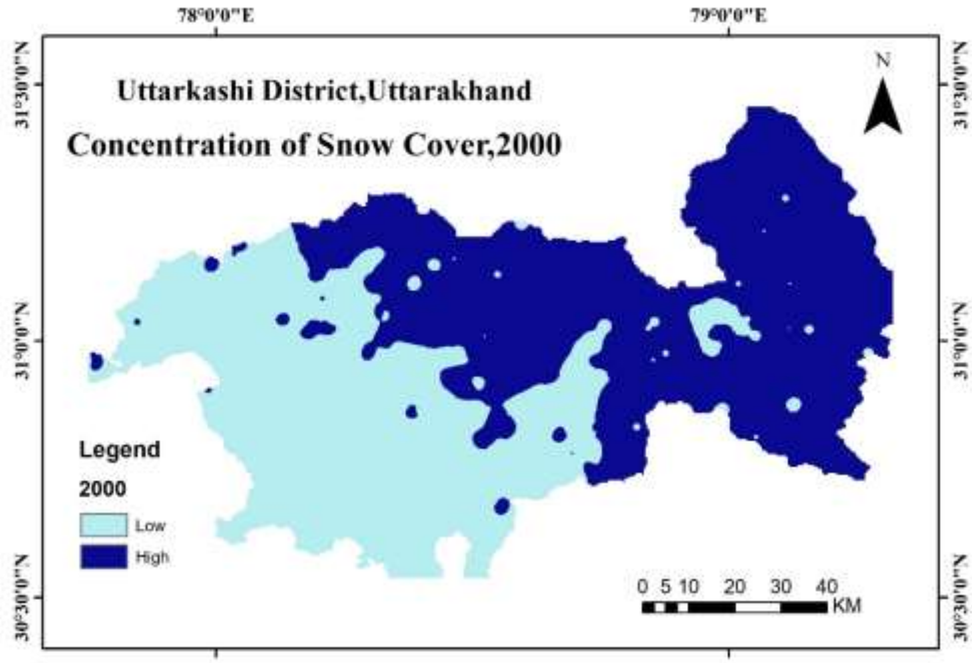
Results

In the Himalayan area, snow cover plays a crucial role in the land cover pattern. According to a study of approximately 200,000 glaciers around the world since the mid-nineteenth century, about two-thirds of present glacial melting is related to human climate change (Connor Steve). Glacial melting a century ago was thought to have been caused by natural tragedies in the climate, while current melting is mostly caused by anthropogenic global warming produced by industrial greenhouse emissions.

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)To specify the area covered by snow NDSI technique was used. NDSI is an index where a ratio is done between VIS and SWIR. A pixel with NDSI>0.0 is considered to have snow(Fig 3)

Further changes were analyzed by converting the raster image into polygon, it is done by reclassifying the images and converting it into polygon.

Fig 3- Changes in Snow covered area between 2000 and 2021



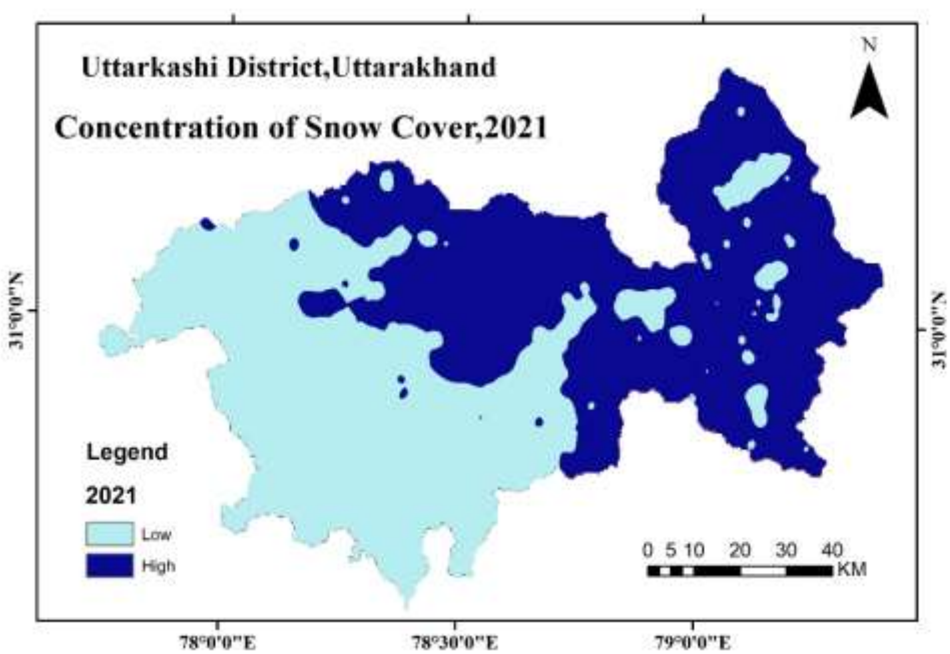
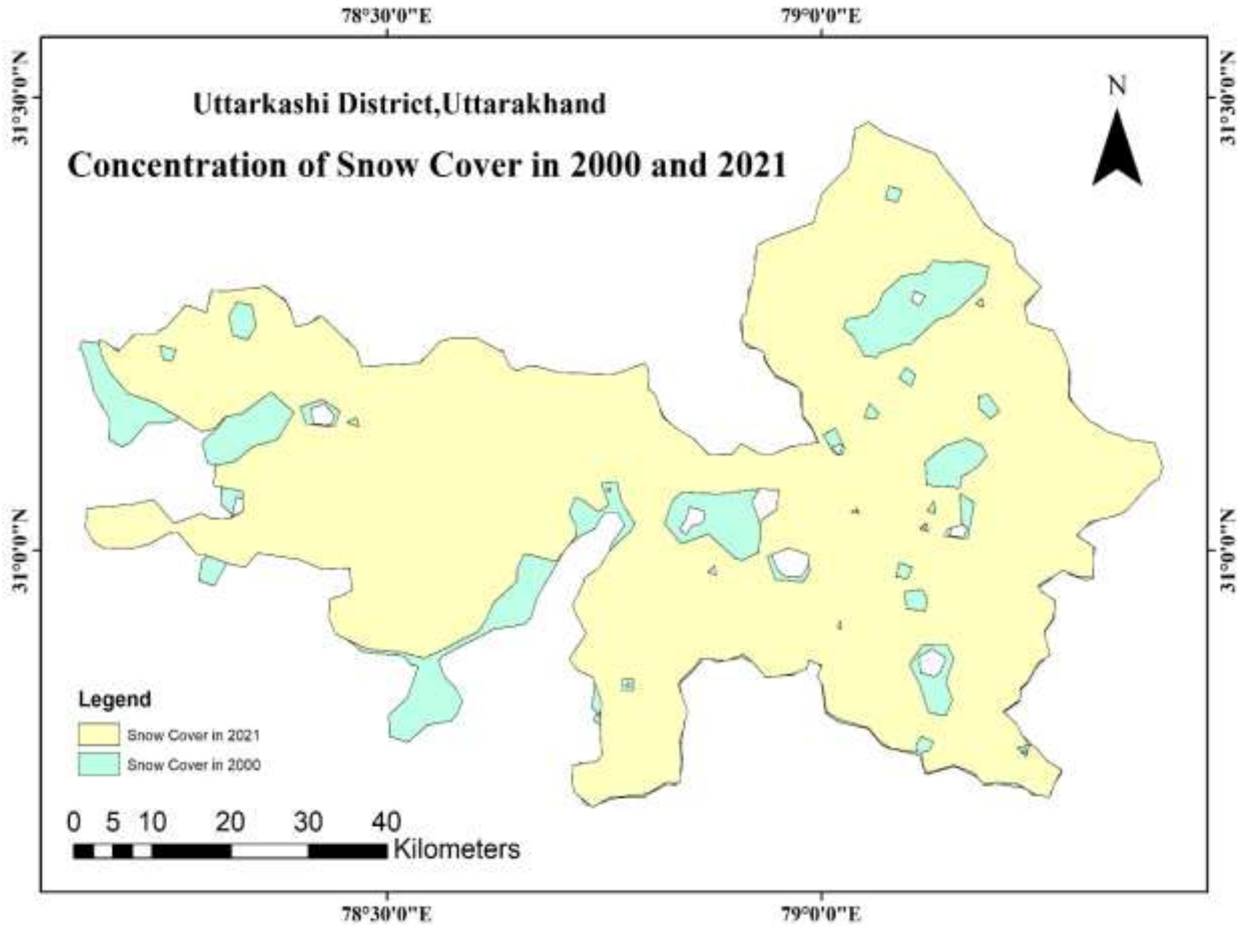
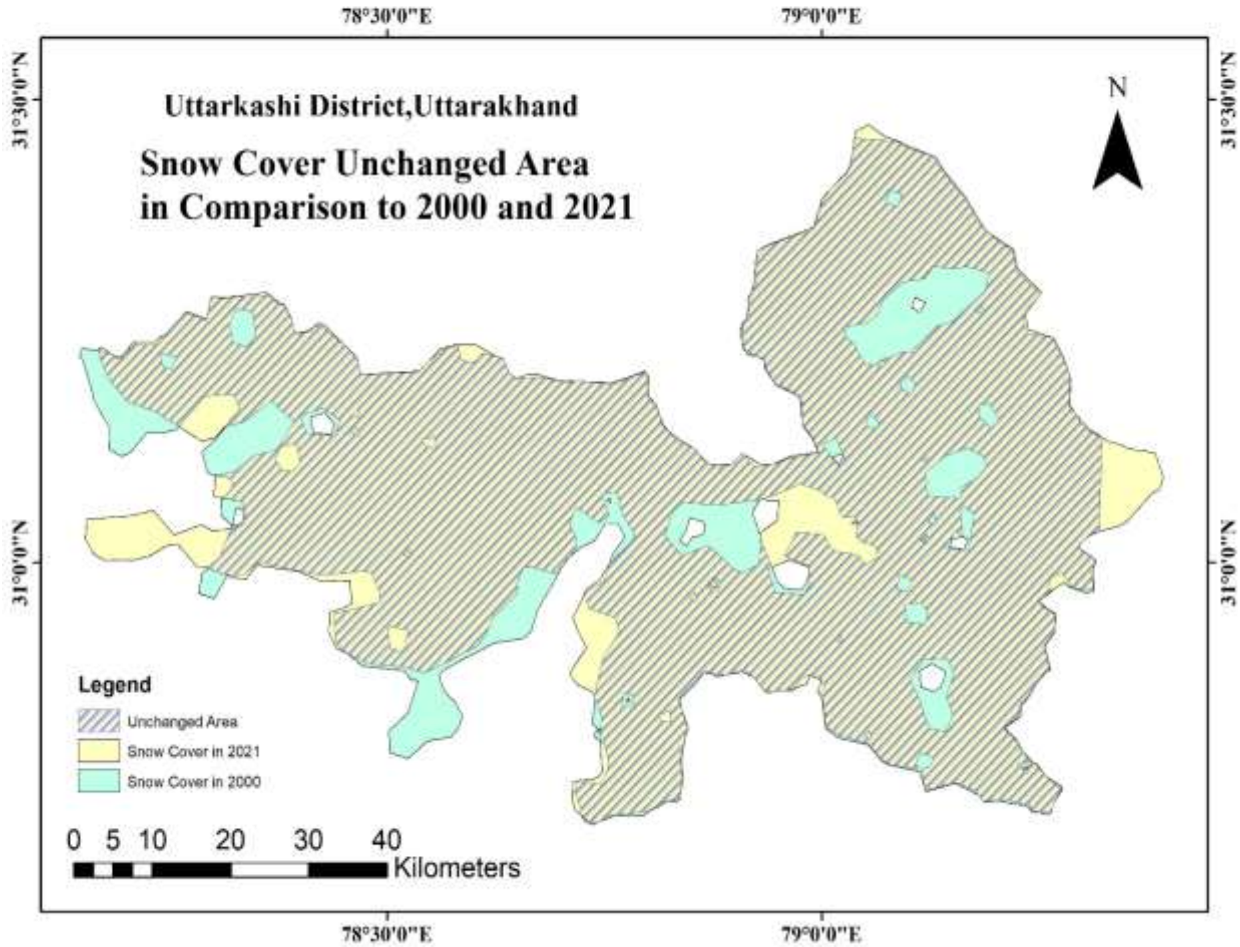


Fig 4- Concentration of snow cover between 2000 and 2021



An effort was also made to find out the unchanged area from 2000 to 2021 as well using the polygon itself.

Fig 5- Snow cover unchanged area in comparison to 2000 and 2021



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 awas b 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 2021 by rationing visible and SWIR bands.

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 2021. 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 demonstrated 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 related 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,it has got an adverse impact over the livelihood of the people both in local as well as global scale.

The local livelihood system has been linked to the snow for ages. Snowmelt supplies water, while snowfall also delivers moisture to the ground. The moisture from the melting snow is beneficial to the growth of many crops. It's also beneficial to the pastures. Less snowfall means less moisture for the crops; in Uttarkashi, less snowfall is affecting winter crops such as wheat, manduwa (a type of local flour), potatoes, pulses, and apples, as the air lacks moisture during the winter season and the soil becomes extremely dry; in this situation, only snowfall provides the required moisture to the soil.

Local locals claim that the duration of snowfall in Uttarkashi has also decreased. They used to have snowfall starting in November and lasting until mid-February. However, in recent years, snowfall has only lasted one or two months. The shorter snowfall period stops the snow from forming ice crystals. As a result, as summer approaches, more of the snow cover melts. 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 a particularly vulnerable feature of the earth's surface, and that even modest changes in global climate can have a substantial impact on the snow cover. The current study discovered that the snow cover area of Uttarkashi has altered over the last 21 years (2000-2021), and that this change is wreaking havoc on the local economy. Because there is less snowfall, there is less moisture on the ground, which hinders the growth of certain 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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