Permafrost Mapping of Bhaga Basin, Himachal Pradesh

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Contents

1 Abstract

The Bhaga basin in the Himalayas is a potential zone for the existence of permafrost. The Himalayas being young mountain ranges, poses challenges in keeping track of the impacts due to climate change. Permafrost is a good indicator of climate impacts. However, this being a subsurface feature makes it difficult to be identified or keep track of. Indicator variables of Land Surface Temperature and Rock Glaciers are used for the identification of potential region with permafrost. With the rock glaciers and Landsurface temperature mapped over the years between 2015-19, the intersection map between rock glaciers and LST map of region less than 0 degree celsius is obtained. This Intersection map gives us a region with higher confidence level of the presence of rock glacier

2 Introduction

Permafrost is a subsurface layer of soil that remains frozen (at a temperature less than or equal to 0 celcius) for a period of more than two consecutive years. Such permafrost conditions are generally found at higher altitudes or the poles of the Earth, though it's not necessary for permafrost zones to be always covered in snow. Permafrost generally comprises soil, sand, rocks, and organic matter frozen together.

The increasing temperatures of Earth are causing the thawing of permafrost. This trend is increasing in the current time due to global warming and the heating up of polar zones.

When frozen, the permafrost ground is well-bound and is considered harder than concrete, but the thawing of this permafrost could cause the ground to become weak in slope stability and increase the chances of landslides. This can also weaken the man-made structures in permafrost regions, as they are majorly constructed on frozen soil. The Chamoli disaster and Uttarkashi avalanche in 2022 are the recent incidents that explain this phenomenon in the Himalayas.

The organic matter present in permafrost is undecomposed as it is preserved at such a low temperature. But due to thawing, all this organic matter gets exposed to higher temperatures and decomposes, releasing carbon dioxide, methane, and other greenhouse gasses into the atmosphere. So another major impact of permafrost thawing can be this cyclic effect of permafrost thawing, emission of greenhouse gasses from the decomposing organic material, further increase in temperature, and further thawing of permafrost.

Another negative impact of permafrost thawing is that the ancient microbes preserved in the frozen soil also get thawed. These bacteria and viruses, as old as nearly 4,00,000 years, might challenge the evolved immune systems of animals and humans on the Earth, causing major outbreaks of diseases.

Because of all the above impacts, permafrost studies and their trends are really important for mankind and permafrost being one of the ECVs (Essential Climatic Variables), its thawing pattern gives an insight into the extent of global warming on Earth.

3 Literature Review

3.1 Modelling Permafrost Distribution Using Geoinformatics in the Alaknanda Valley, Uttarakhand, India

The paper points out the importance of permafrost mapping as an underresearched parameter for climate change and disasters in the Himalayan region due to the thawing of permafrost. The paper explores the permafrost mapping of the Alakanda Valley using different predicting variables: MAAT(Mean Annual Air Temperature), Land Surface Temperature(LST),Snow Cover, Potential Incoming Solar Radiation and Aspects. A comparison is drawn between these models. The presence of RockGlacier was used as a parameter to confirm the presence of permafrost in the region. A statistical relation is built between the relic and active rock glacier and the occurrence of permafrost. Based on the above benchmark, a logistic regression run on a test sample revealed the MAAT-based model to be most accurate in predicting permafrost as its receiver operative characteristic curve had covered the most area. The Permafrost Zonation Index (Gruber) was used to check the correctness of the model.

3.2 Manual for Mapping Rock Glaciers in Google Earth

The manual gave brief instructions on identifying rock glaciers using 3D imaging on the Google Earth Pro platform. It first starts with a walk-through

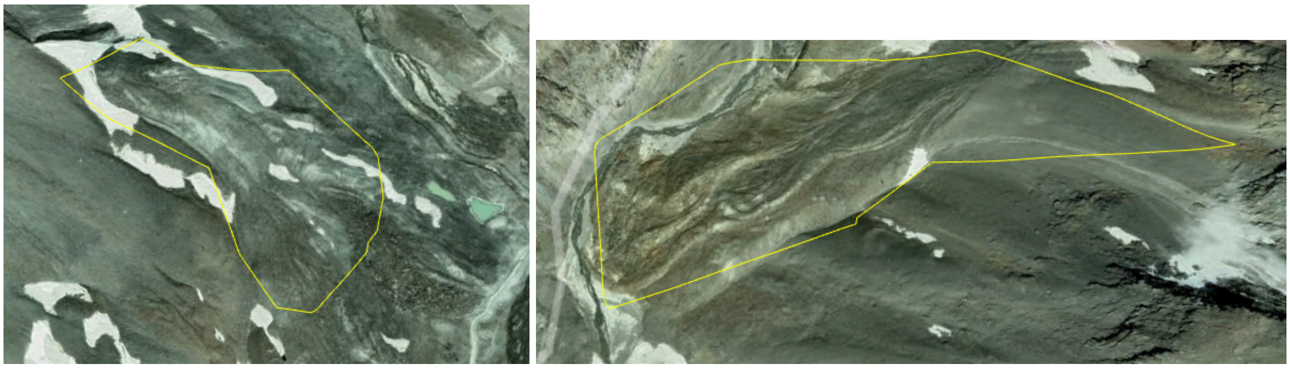

Figure 1: Rockglaciers in Bhaga Basin outlined using Google Earth Pro

of the work environment in Google Earth. Rock Glaciers are distinctive landforms with landmasses that seem to flow, characterised by horizontal and vertical ridges. The Rock Glaciers are to be visually identified and given characterised to be active/passive, outline visibility, type of boundary (glacier/slopey), steep or of a gentle slope, and on basis of snow cover. The rock glaciers are then outline with polygon and the and saves in "My places". As its a visual identification, two or more member could independently identify the rock glaciers, the common ones are of high confidence and thus considered.

4 Methodology

4.1 Identification of Rock Glaciers

The identification of rock glaciers were done on visual basis. This was done on Google Earth pro. The shape file for Bhaga Basin was clipped from the Asia Basin map from hydroshed.org. The shape file was then added to the QGIS project and exported as kml file. The boundary for the basin was marked on the google earth map using this kml file.

As ablation period for the Himalayan glaciers are from March to July, the snow cover is expected to be at lowest in months of August, September and October. Identification of rock glaciers would be easy on these months and hence chosen for six years 2015-2019. Two of the members were involved in the identification of rockglaciers independently during the months of August, September and October. The common one were then considered and its

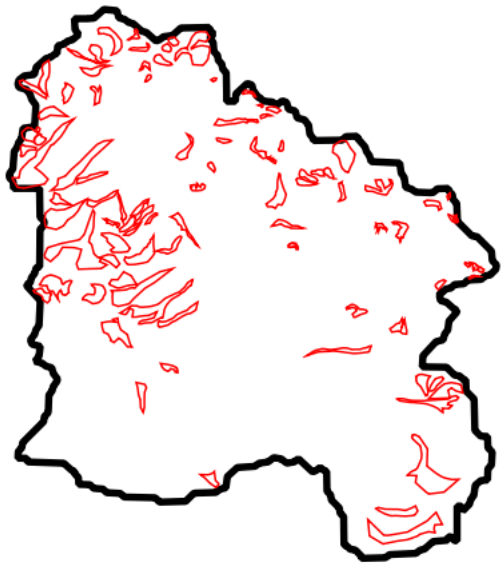

Figure 2: Map of Rock Glaciers identified in Bhaga Basin

boundary marked with both the members involved. A total of 80 rock glaciers were identified covering an area of 14 sq. km.

4.2 Mapping of LST

For LST mapping satellite images from Landsat-8 and Landsat-9 from collection 2 level 1 were obtained from USGS Earth Explorer. Images of band 10 along with their respective mtl.txt file were downloaded. The band 10 images were obtained from e.m. waves of 10.8 micrometer to be used for thermal infrared imaging. The band 10 images were converted into Land Surface Temperature using Semiautomatic Classification Pluggin. Using Raster calculator a map for region with temperature less than or equal to 0 degree celsius was obtained. The intersection of rockglacier and map of region with temperature less than 0 degree. The total rock glacier data is assumed to remain constant in the years in which the data have been collected. centigrade gives a region with probable permafrost. A further intersection map for probable permafrost region on consecutive years were also drawn. Of these intersection layers "raster layer unique value report" was generated

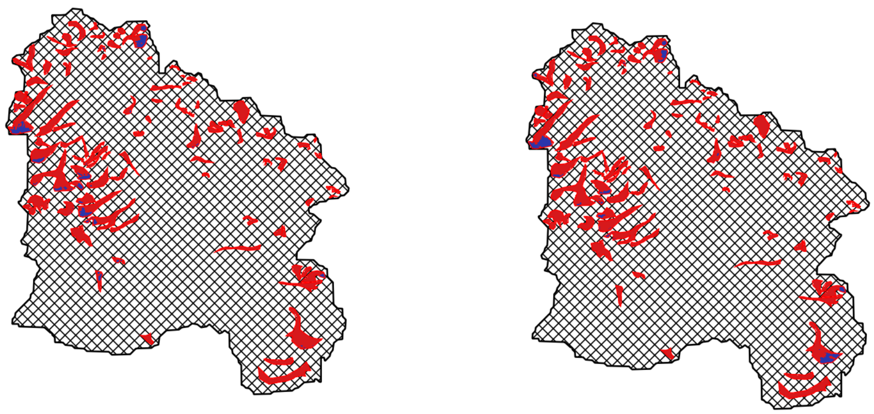

Figure 3: Potential Permafrost 2015(left) 2016(right)

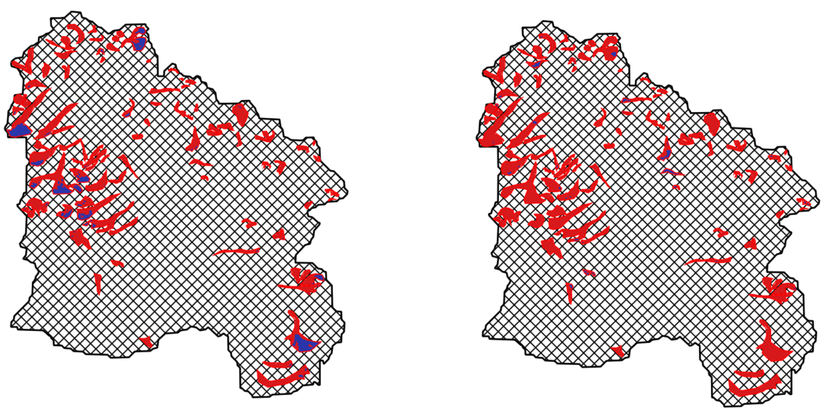

Figure 4: Potential Permafrost 2017(left) 2018(right)

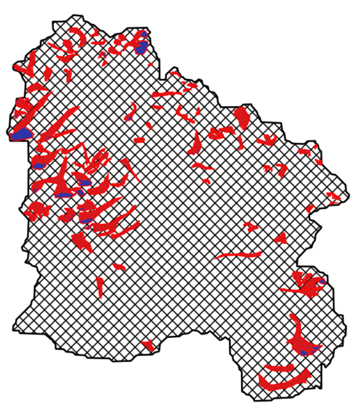

Figure 5: Potential Permafrost 2019 (blue:$\leq$ °0 C,red: greater than°0)

Table 1: Potential permafrost area over the dates with low snow cover

Date	Area from LST ($\leq$ °0 C)in sq.m	Permafrost Intersection in area sq.m
30/8/2015	226097100	5567400
14/8/2015	1444707000	143286300
15/9/2015	156730500	22249800
1/10/2015	772364700	121250700
17/10/2015	603493200	106072200
16/8/2016	80520300	10302300
1/9/2016	1516419900	146666700
17/9/2016	469157400	72292500
3/10/2016	229765500	48598200
19/10/2016	453509100	94956300
19/8/2017	1671427800	72292500
3/8/2017	1563993900	150152400
4/9/2017	308747700	49971600
20/9/2017	26026200	26026200
6/10/2017	348455700	75033900
22/10/2017	537982200	537982200
6/8/2018	1210437000	136828800
22/8/2018	6573600	75841200
7/9/2018	1520342100	149967000
23/9/2018	1671427800	153216000
9/10/2018	1671427800	153216000
25/10/2018	1288521900	148074300
19/8/2019	1564881300	144018000
10/9/2019	104935500	16001100
26/9/2019	137643300	21069900
12/10/2019	879230700	131501700
28/10/2019	788607900	126211500

Table 2: Annual Permafrost area

Year	Area of Region with high confidence level of permafrost
2015	11095200
2016	9755100
2017	23867100
2018	5889600
2019	14916600

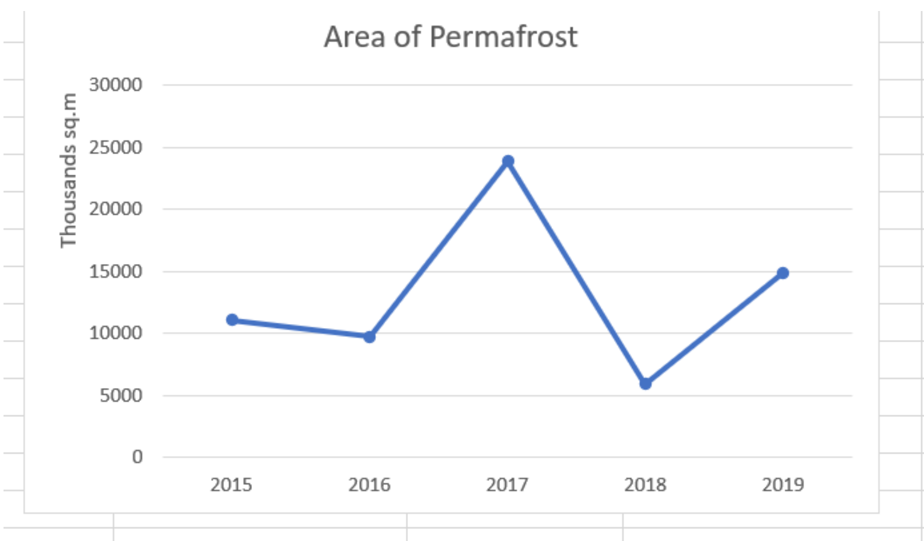

Figure 6: Annual Permafrost variation

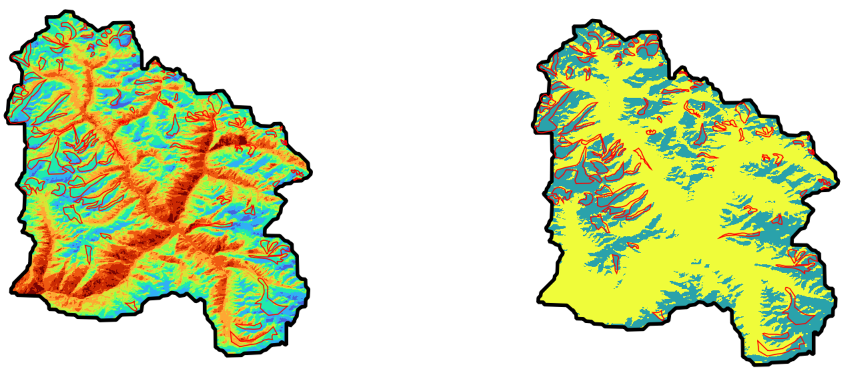

Figure 7: LST map of Bhaga Basin on 17/10/2015(left)
Map showing regions ≤ °0 C in green and above 0 centigrade in yellow(right)

from which the permafrost area were obtained.

5 Result

The potential permafrost region are obtained from the intersection area of rock glaciers and region with LST ≤ °0 C of the chosen dates. Further intersection of these area is done over a year plot the annual variation of permafrost over the Bhaga Basin. Figure 3,4 and 5 shows the area with LST ≤ °0 C and within the rock glacier boundary. Table 1 list the variation of permafrost area over the ablation period of the basin. An intersection mapping to get annual permafrost variation was done as the result is displayed in Table 2 and Figure 6.

6 Discussion

The permaforst region is gradually decreasing due to global warming over the glaciers on rest of the world. However the Himalayan Glacier has seen unusual increase in glacial cover over the past decade on it western region. This anomaly is caused by the Western Disturbances causing precipitation over the Himalayan glacier and adding up to the accumulation of Glacier. A similar trend is also observed in the permafrost, with an anomalous trend in annual permafrost area mapped.

Reference:

1. Pandey, A. C., Ghosh, T., Parida, B. R., Dwivedi, C. S., & Tiwari, R. K. (2022). Modeling Permafrost Distribution Using Geoinformatics in the Alaknanda Valley, Uttarakhand, India. *Sustainability (Switzerland)*, *14*(23). https://doi.org/10.3390/su142315731
2. Schmid, M. O., Baral, P., Gruber, S., Shahi, S., Shrestha, T., Stumm, D., & Wester, P. (2015). Assessment of permafrost distribution maps in the Hindu Kush Himalayan region using rock glaciers mapped in Google Earth. *Cryosphere*, *9*(6), 2089–2099. https://doi.org/10.5194/tc-9-2089-2015