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Estimation and Study of Forest Loss and Gain Using Spatial Dataset across Districts of Uttarakhand

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Original Research Article

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ABSTRACT

Aims: To study and estimate the forest cover loss and gain across the 13 districts of Uttarakhand.
Place and Duration of Study: Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, between September 2021 and December 2021.
Methodology: We extracted forest cover time-series data from the year 2001 to the year 2020 from Hensen Global Forest Change Dataset. This data was then mapped to the shapefile created in ARC-GIS containing all 13 districts as a Feature Collection, which was then used to individually classify each region and to estimate the size of the loss of tree cover precisely over the district boundary.
Results: Our study shows forest loss of about (21,05,71,646 square meters) and forest gain of (6,00,79,072 square meters) cumulatively in all the districts of Uttarakhand from the year 2001 to 2020 at a spatial resolution of 30 meters where trees were identified as canopies greater than 5 meters in height.
Conclusion: Among the districts of Uttarakhand Udham Singh Nagar, Nainital, and Champawat alone contribute to the total tree cover loss area of 15061.7513801 ha. which is about 71.5 % of Uttarakhand's total tree cover loss. These regions require monitoring and controlling deforestation and more detailed studies like this are required to analyze and prevent the causes of such great-scale deforestation. Analyzing districts apart from those mentioned above, it is observed that the amount of tree cover loss is greater than the reforestation.

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Keywords: Global forest watch; masking; shapefiles; feature collection.

1. INTRODUCTION

Uttarakhand has an area of (534,933x106 square meters), of which 86% is slope and mountain region and about 65% is covered by forest. A large portion of the northern part of the state is covered by high Himalayan peaks and glaciers. In the first half of the nineteenth century, the growing demand for roads, railways and other physical infrastructure was giving rise to concerns over indiscriminate logging, particularly in the Himalayas. The State lost (21,05,71,646 square meters) of tree cover from 2001 to 2020. Human and natural aggravations occurring frequently have led to changes in forest cover. Natural aggravation like forest fires in Uttarakhand have been customary and historic elements. Consistent fires in Uttarakhand Forest makes the extraordinary loss to the forest biological system. In recent years, various factors like clearing, consuming, logging, increased alongside horticultural practices and extending metropolitan areas and activities, have brought about broad degradation to the forest around the world. All these signs are also visible in Uttarakhand which is for the most part is a slope region with immense forest cover areas. A study which caters to both afforestation and deforestation is needed for better administration and quantitative analysis of forest cover so that the critical environment balance can be maintained. Our study proposes a methodology that can provide an estimated size of deforestation and afforestation and better administration of forest cover.

The presented study focuses on all the 13 districts of Uttarakhand. To individually classify each region and to estimate the size of the loss of tree cover precisely over the district boundary, a shapefile was used to map the geometry of the district regions. The shapefile is a geospatial digital vector storage format for storing geographic location. It mainly contains the geometry data. The shapefile format can spatially describe vector features like points, lines, and polygons [1]. For classification, tree cover loss was characterized as a stand-substitution aggravation or the total removal of tree cover canopy from the same pixel region in comparison to the previous pixel data. For the tree cover addition, it was characterized as the opposite of tree cover loss, or the emerging of a tree cover canopy. Higher resolution (30.92 m) land cover characterization and monitoring permits detection of land change at the scale of most human activity and offers the increased flexibility of environmental model parameterization needed for global change studies [2]. However, there are many challenges to deal with before developing such datasets such as including unavailability of consistent global coverage of satellite data, the sheer volume of data, unavailability of timely and accurate training and validation data, difficulties in preparing image mosaics, and high-performance computing requirements [2] Therefore, providing an accurate estimation on area loss can be very difficult, because a lot depends upon the quality of image taken by the satellite as different variables like a shadow and overcast cloud cover can block the presentation of the dataset for that locale.

This study purposes an assessment that can characterize the tree cover loss space of various districts of Uttarakhand district over the period ranging from 2001 to 2020.

2. METHODOLOGY

The predominantly mountainous state of Uttarakhand covers an area of 53,483 sq km, which is 1.63% of the geographical area of the country, the State lies between 28°43' N to 31°28' N latitude and 77°34' E to81°03' E longitude and shares borders with Himachal Pradesh in north & Uttar Pradesh in the south It also shares international borders with Nepal and China [3]. As the State lies in the Himalayan range, the climate and vegetation vary greatly with altitude, from glaciers at the highest elevations to subtropical forests at the lower elevations [3]. Ice and bare rocks cover the higher elevations [3]. Table 1 List the Land Use Statistics, Source: [4], GOI, (2014-15).

Uttarakhand is rich in forest resources. As per the Champion & Seth Classification of Forest Types (1968) [4], the forests in Uttarakhand belong to nine Forest Type Groups, which are further divided into 43 Forest Types. Physiographically, the State can be divided into three zones namely, the Himalayas, the Shivalik, and the Terai region [3]. The human and livestock population is largely dependent on forests due to the agrarian economy and pastoralism [3].

The State has 13 districts; most of them are hill districts and district-wise forest cover distribution is as mentioned in the Table 2, Source: [3].

Table 1. Land Use Statistics (Uttarakhand)

Land use types	Area (in 000' ha)	Percentage
Georaphical Area	5348	
Reporting area for land utilization	5993	100
Forests	3800	63.41
Not available for land cultivation	452	7.54
Permanent pastures and other grazing lands	192	3.21
Land under misc. tree crops and groves	388	6.47
Culturable wasteland	317	5.29

Table 2. District-wise forest cover in Uttarakhand (in sq. km)

District	Geographical Area (Sq. km)	Total Forest cover (Sq. km)
Almora	3144	1719.14
Bageshwar	2241	1262.69
Chamoli	8030	2709.43
Champawat	1766	1225.55
Dehradun	3088	1608.69
Garhwal	5329	3394.99
Haridwar	2360	584.25
Nainital	451	3041.56
Pithoragarh	7090	2079.8
Rudraprayag	1984	1142.17
Tehri Garhwal	3642	2065.98
Udam Singh Nagar	2542	431.79
Uttarkashi	8016	3036

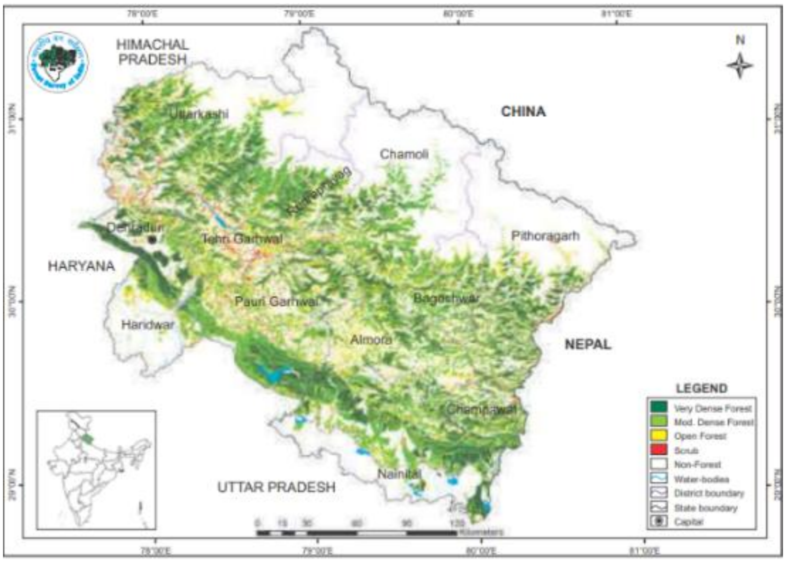

Fig. 1. Forest Cover Map of Uttarakhand
Source: [3], GOI, (2014-15)

A forest cover map of Uttarakhand is shown in Fig. 1:

shapefiles are used for defining the geometric region on the map. Shapefiles were developed using ArcCatalog, after defining the attributes and then the shapefiles Coordinate System was defined. Later Shapefile is imported to google earth engine for analysis. Fig. 2. shows the shapefile containing districts of Uttarakhand boundaries.

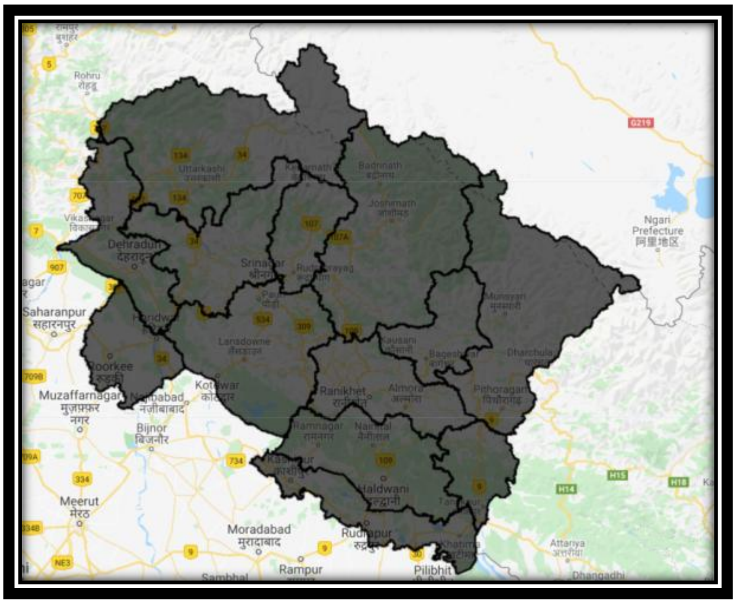

Fig. 2. Uttarakhand District shapefile with district boundaries

2.1 Spatial Dataset

The database was taken from google earth engine which is freely available. The data was generated from time-series analysis of over 655000 Landsat 7 images, by scientists at the University of Maryland but with significant support from Google, with the actual database generated using their Google Earth Engine [5]. In this database to identify the tree canopy, threshold value range for tree detection was 5 meters in height [5,6].

In this analysis the bands first_b30, first_b40, first_b50, last_b30, last_b40, last_b50 are bit-masked for detecting forest cover gain. These represent the 3rd, 4th, 5th and 7th band of the Landsat satellite spectral band. Median is calculated for each individual above mentioned band from group of images collected during the study period i.e., 2001-2020. Table. 3 shows the band spectrum of dataset used.

2.2 Pre-Processing Dataset and Literature Review

The temporal accuracy (delay) of deforestation detection depends on the temporal separation between the available cloud-free observations. The strategy included first pre-handling all Landsat scenes for the years altogether, rectifying and normalizing them so all were comparable regardless of adjustment or climatic conditions. Then change in the pixel value from all legitimate observations for every pixel, including features identified with normal greenness, and patterns in that greenness through time.

Earth perception from space has become more significant because of the huge effect that cutting-edge human progress is having on the Earth. More than 7 billion individuals are putting tireless strain on our planet, and the forest, unquestionably are the most affected. Forty years prior, the United States of America was the main source of earth observation data, but today there are many countries having their satellites in space providing image data [5,6].

In 1972 Landsat 1 was the main regular satellite fit for imaging the earth at a degree of spatial detail, fit for estimating any kind of quantitative changes in the forest. Speaking of today there are many satellites circling the globe that can give reasonable samples for the spatial data [5].

Screening of forest cover across the districts of Uttarakhand begins with the computation expected to make a band that shows pixels where the map information shows both forest loss and forest gain. Every scene is cautiously color adjusted so that the tones and their corresponding values match. The two information mosaics dated 2002 and 2020 were first compared exhaustively. Region of interest (forest loss and recovery) were analyzed and compared with the Global Forest Watch database. Global Forest Watch makes the best available data about forests online for free,

Table 3. Band Spectrum of Hensen Dataset

Name	Wavelength	Description
first_b30	0.63-0.69µm	Landsat 7 band 3 (red) cloud-free image composite.
first_b40	0.77-0.90µm	Landsat 7 band 4 (NIR) cloud-free image composite.
first_b50	1.55-1.75µm	Landsat 7 band 5 (SWIR) cloud-free image composite.
first_b70	2.09-2.35µm	Landsat 7 band 7 (SWIR) cloud-free image composite.
last_b30	0.63-0.69µm	Landsat 7 band 3 (red) cloud-free image composite.
last_b40	0.77-0.90µm	Landsat 7 band 4 (NIR) cloud-free image composite.
last_b50	1.55-1.75µm	Landsat 7 band 5 (SWIR) cloud-free image composite.
last_b70	2.09-2.35µm	Landsat 7 band 7 (SWIR) cloud-free image composite.

creating unprecedented transparency about what is happening in forests worldwide. Better information supports smarter decisions about how to manage and protect forests for current and future generations, [3]. GFW data is accessed daily by governments, companies, civil society organizations, journalists, and everyday people who care about their local forests [3]. Results of our study analyzed for contrasts which could demonstrate (i) regions wrongly marked as deforested and (ii) areas of deforestation that were not identified by the forest loss each year. Special care needs to be taken to bar the region from the examination that had changed from non-forest cover to plains, which can happen because of occasional changes and horticultural practices yet which don't address deforestation. Data for such regions was removed from the study.

The four commonly used broadband vegetation indices (VI) were initially examined, namely the normalized difference vegetation index (NDVI) [7], enhanced vegetation index (EVI) [8], normalized difference moisture index (NDMI), also known as normalized difference water index [9] and normalized burn ratio (NBR) [10]. It was observed that NDMI shows high sensitivity (most clear signal) in response to deforestation events in the study area, with signal change magnitude most visibly larger than ephemeral noise [11] NDMI was calculated as follows:

$$NDMI = \frac{\text{NIR}-\text{SWIR1}}{\text{NIR}+\text{SWIR1}} \tag{1}$$

According to Schultz et al. [12] who used LTS for deforestation detection across tropical forest sites in Brazil, Ethiopia, and Vietnam, “wetness”-related VI(Vegetative Index) such as NDMI (the SWIR band used is sensitive to canopy water content) performed better than “greenness”-related VI such as NDVI and EVI (the red band used is sensitive to pigment content). They attributed the lower accuracy of the greenness VI to their inability to properly isolate the change signal from noise in LTS [13]. Therefore, NDMI was chosen for deforestation detection in this study.

Fig. 3. shows a false color image that utilizes 3 bands, Landsat band 5, 4, and 3 after removing noise and smoothening the image pixels. This combination of band is required to display the green vegetation, soil and ice for further analysis and for visual purpose.

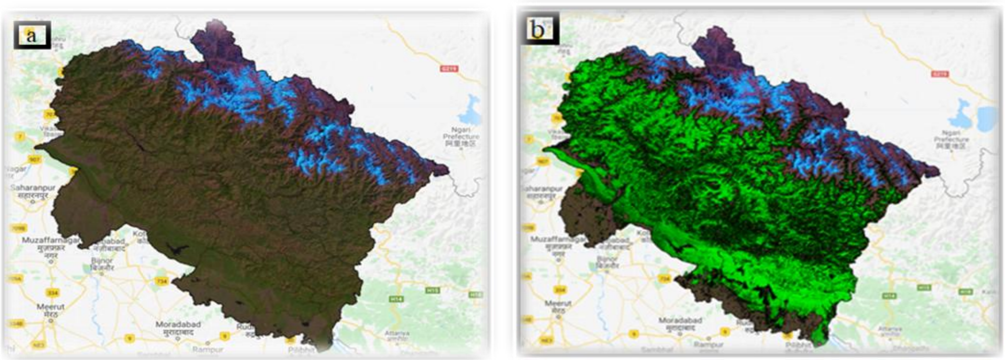

Fig. 3. [a] Year 2020 false-colour composite of the Uttarakhand and [b] The Year 2000 tree cover, stretched and masked

Median composite is needed over the new recent-value composite for analysis, but some portions of the picture need to be masked. Masking pixels in a picture makes those pixels straightforward/transparent and bars them from the analysis. Every pixel in each band of a picture has a mask. Those with a value of 0 or underneath will be straightforward/transparent. Those with a value over 0 will be used in analysis. Region of interest was masked by masking an image with itself.

3. RESULTS AND DISCUSSION

Spatial patterns of forest cover change over the years 2001 to 2020 were measured. The mechanisms causing forest loss were quantified over time as the proportional change in tree canopy cover removal representing tree cover loss of each district individually. The color composite of tree cover is green, forest loss is red. Below are 13 Bar Graphs Fig. 4 to Fig. 16 of every district of Uttarakhand depicting forest loss

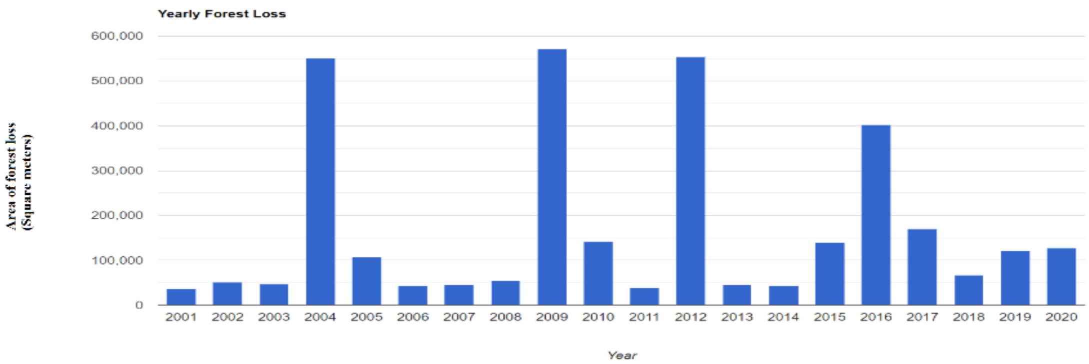

Fig. 4. Almora district Cumulative Forest Cover Change for year 2000-2020

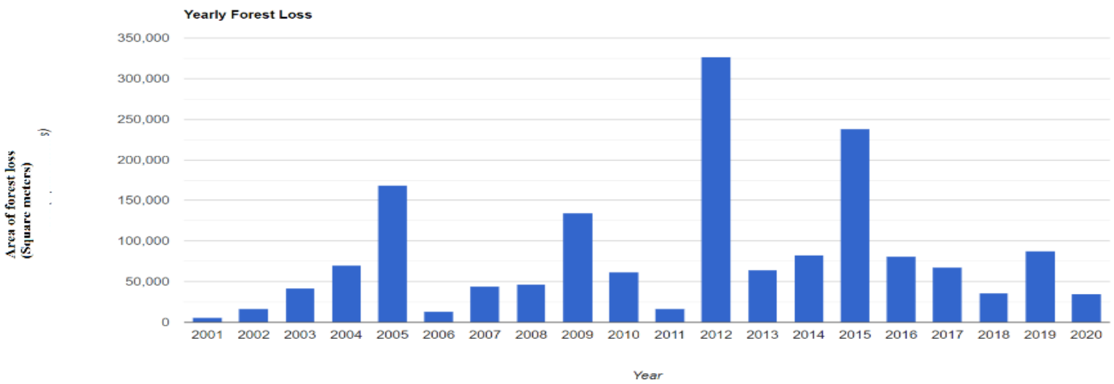

Fig. 5. Bageshwar district Cumulative Forest Cover Change for year 2000-2020

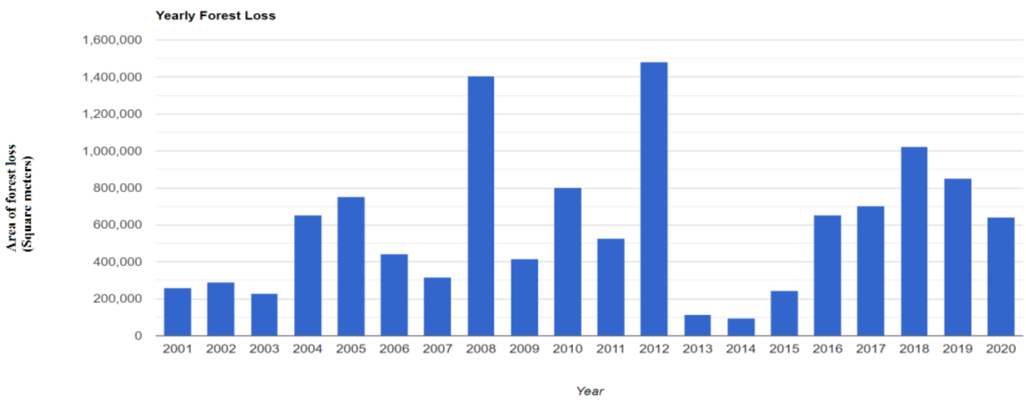

Fig. 6. Champawat district Cumulative Forest Cover Change for year 2000-2020

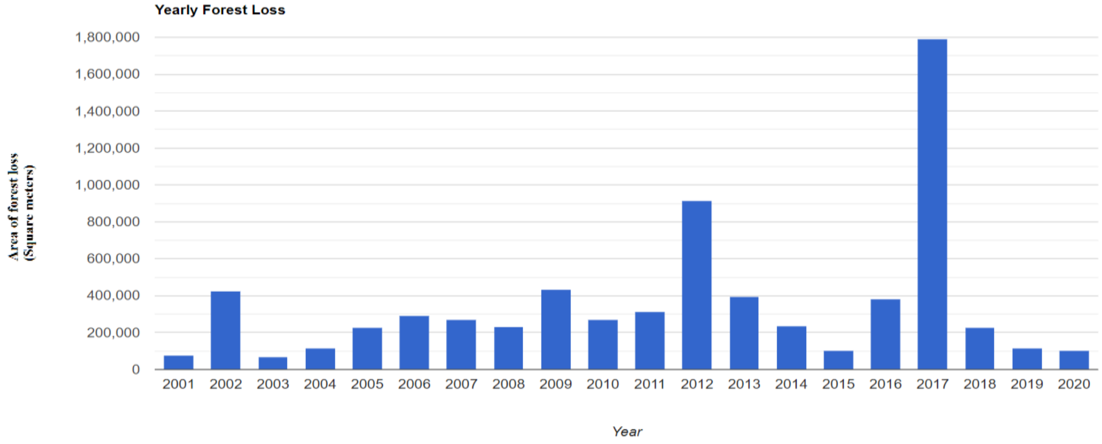

Fig. 7. Dehradun district Cumulative Forest Cover Change for year 2000-2020

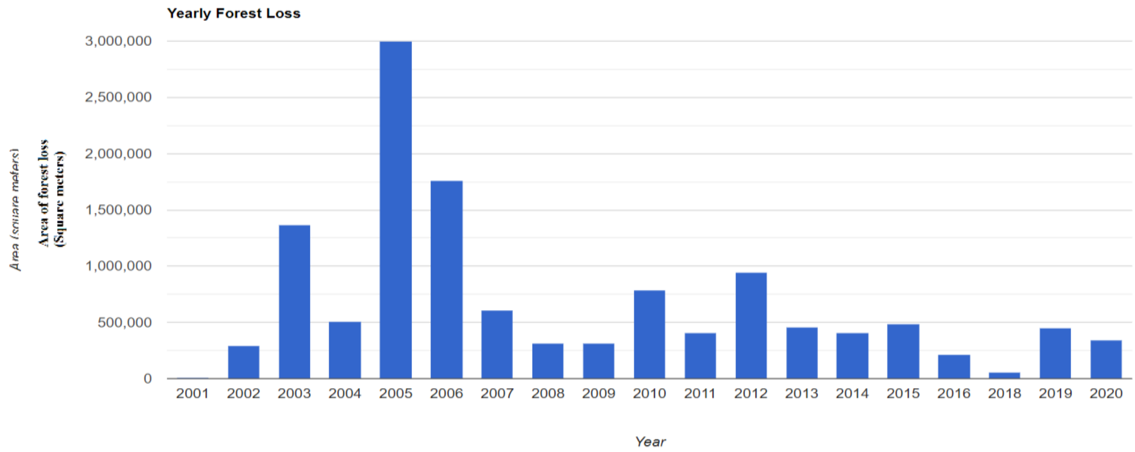

Fig. 8. Haridwar district Cumulative Forest Cover Change for year 2000-2020

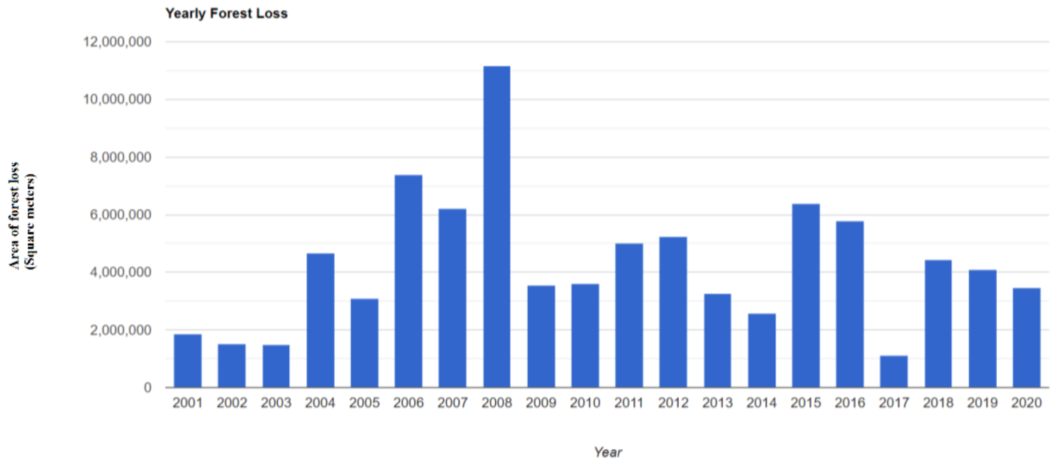

Fig. 9. Nainital district Cumulative Forest Cover Change for year 2000-2020

every year from year 2001 to 2020. Every bar is an observation of one year. Further analysis with the previous year data also reveals the forest gain in any previously marked deforested area.

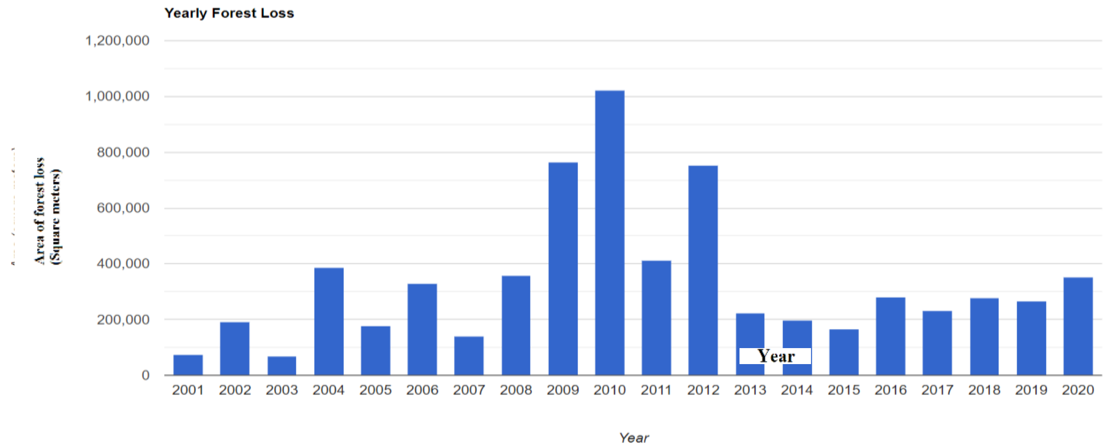

Fig. 10. Pauri Garhwal district Cumulative Forest Cover Change for year 2000-2020

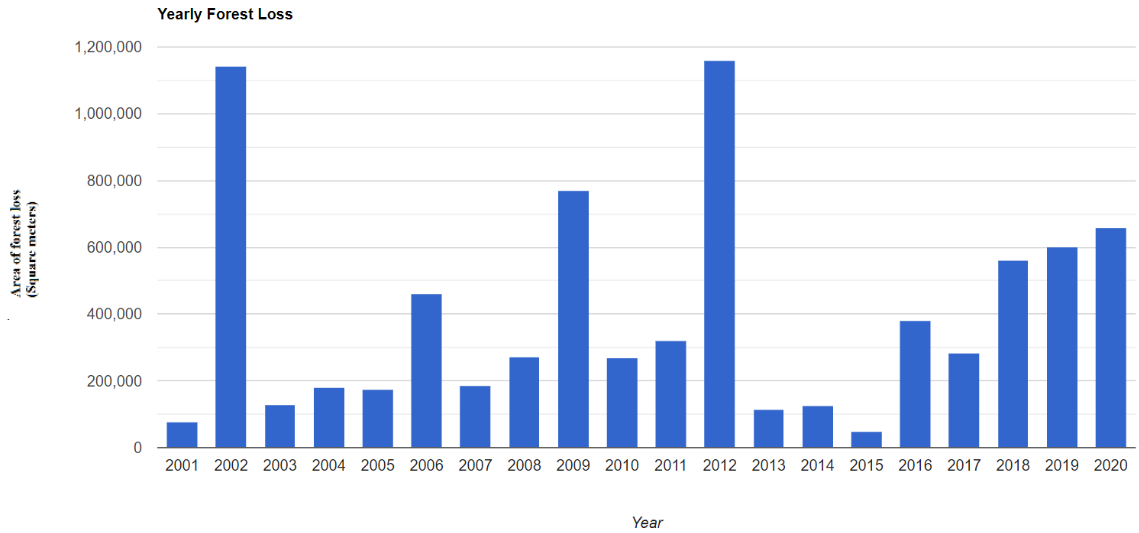

Fig. 11. Tehri Garhwal district Cumulative Forest Cover Change for year 2000-2020

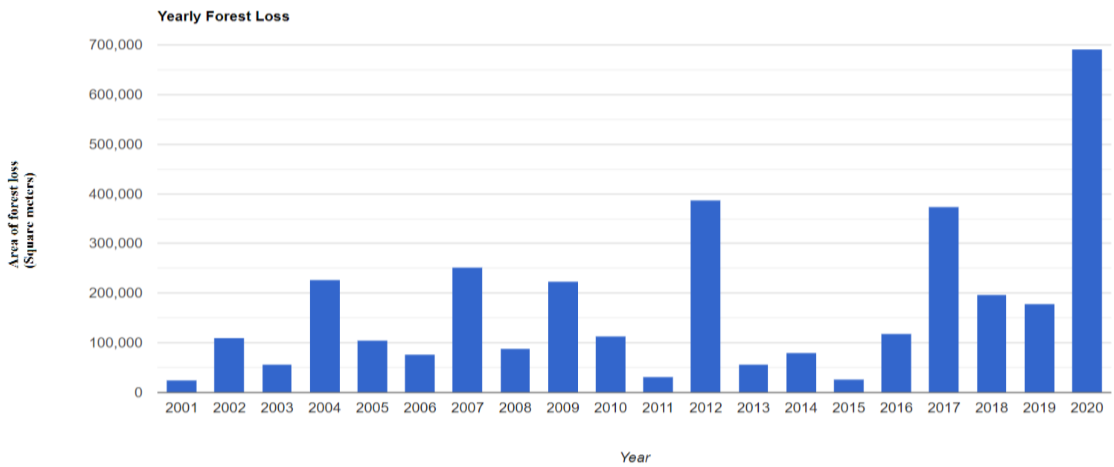

Fig. 12. Pithoragarh district Cumulative Forest Cover Change for year 2000-2020

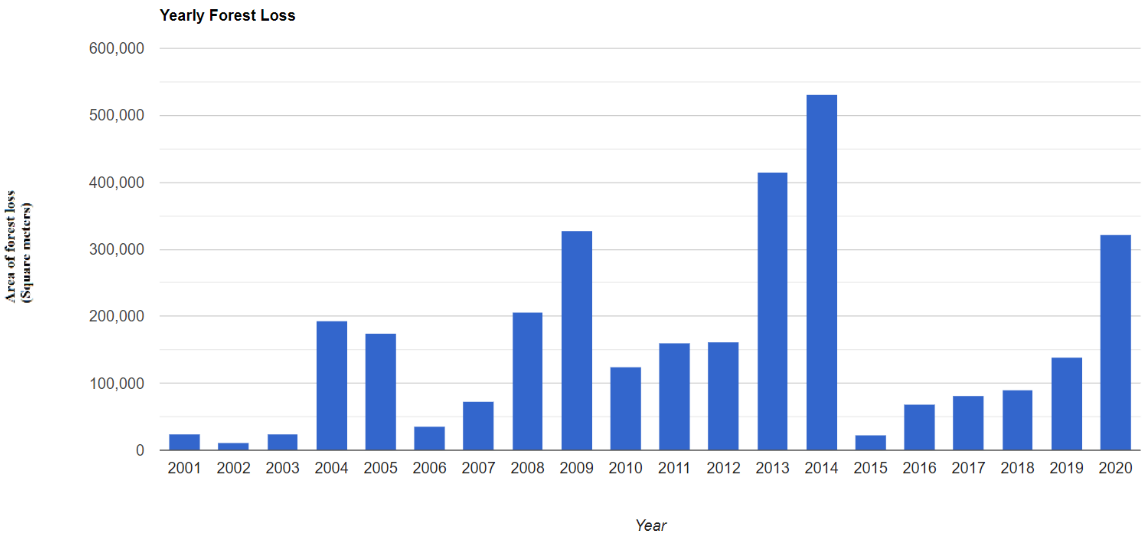

Fig. 13. Rudraprayag district Cumulative Forest Cover Change for year 2000-2020

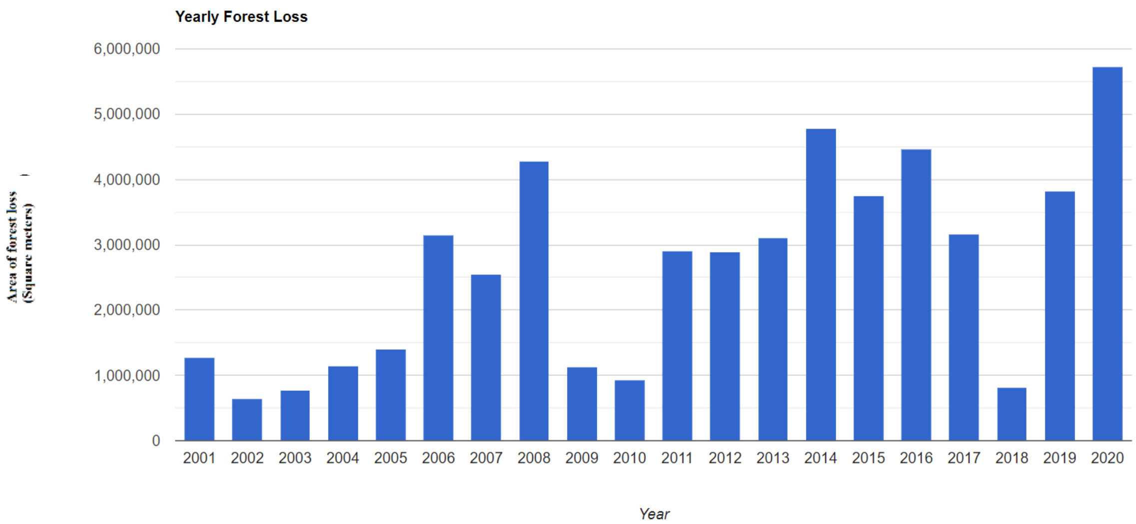

Fig. 14. Udam Singh Nagar district Cumulative Forest Cover Change for year 2000-2020

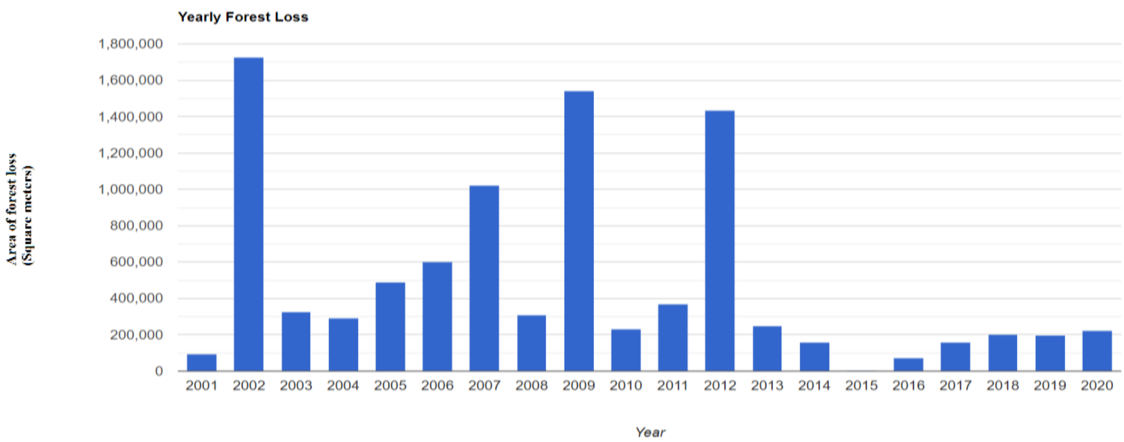

Fig. 15. Uttarkashi district Cumulative Forest Cover Change for year 2000-2020

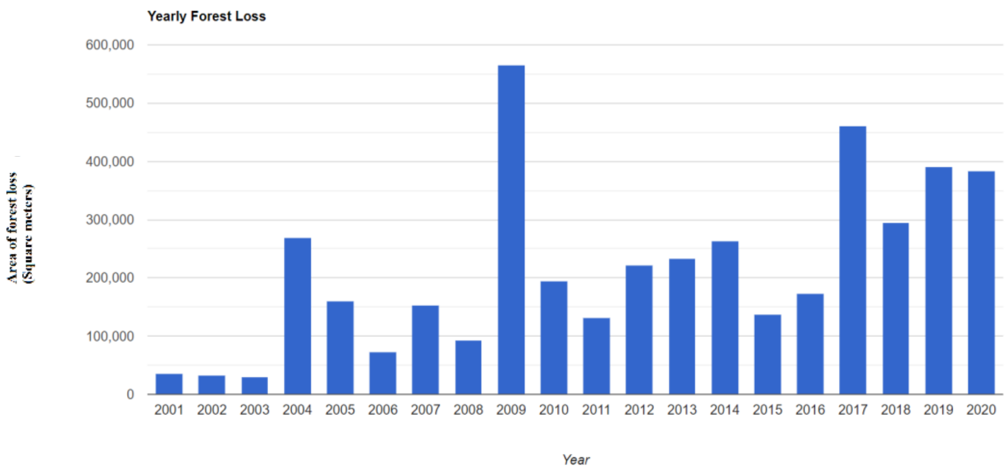

Fig. 16. Chamoli district Cumulative Forest Cover Change for year 2000-2020

As the graph in results from our study show the most significant Forest loss was observed in U.S.N, Nainital and Champawat District of Uttarakhand. In U.S.N. the forest cover loss was assessed to be around 52726425.893 meter square or 5272.640ha. also, around 1276.04ha of forest gain was observed. Where the peak loss for Udam Singh Nagar as observed from the histogram is in the year 2020 Significant contribution of forest loss was also observed in year 2006, 2008, 2014, 2015, 2016, 2019 as well. A similar trend of total Forest cover loss was observed in Nainital area where it is assessed to be around 85985787.398meter square or 8598.75ha and approx. around 3434.46ha of reforestation. Where the peak loss as observed from the histogram is in the year 2008. In Similar manner Champawat is assessed to lost around 11905300.509meter square or 1190.5300ha, what's more around 520.781ha. of forest gain and highest forest cover loss in the year 2012 was observed. These trends can be seen in rest of the 10 districts as well.

4. RESULT COMPARISON

Global Forest Watch being an open-source web application to monitor global forests in near real-time with initiative from the World Resources Institute, with partners including Google, USAID, the University of Maryland, Esri, Vizzuality and many other academic, non-profit, public, and private organizations [5]. Global Forest Watch (GFW) provides data and tools for monitoring forests, it allows anyone to access near real-time information about where and how forests are changing around the world. GFW along with Google earth engine's set of tools were used for computing evaluation [14].

Fig. 17 to Fig. 29 depict graph plot comparison between our study and GFW.

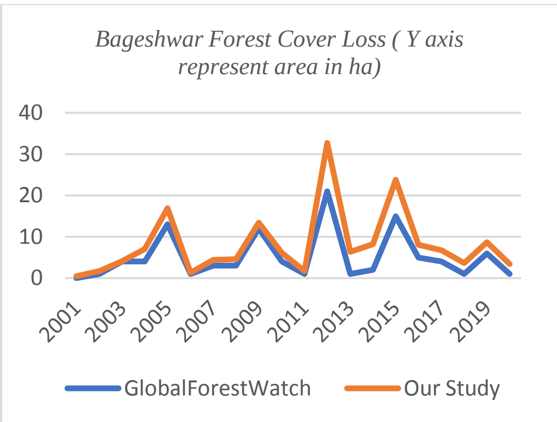

Fig. 17. Plot of our study versus Global Forest Watch for Bageshwar region

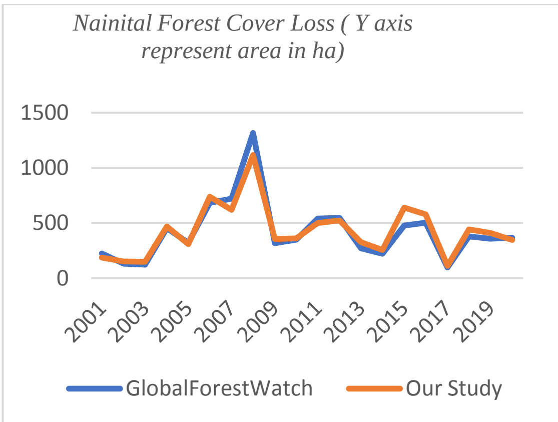

Fig. 18. Plot of our study versus Global Forest Watch for Nainital region

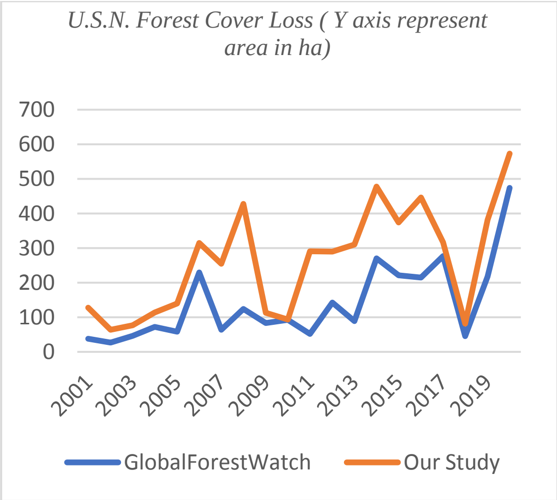

Fig. 19. Plot of our study versus Global Forest Watch for U.S.N. region.

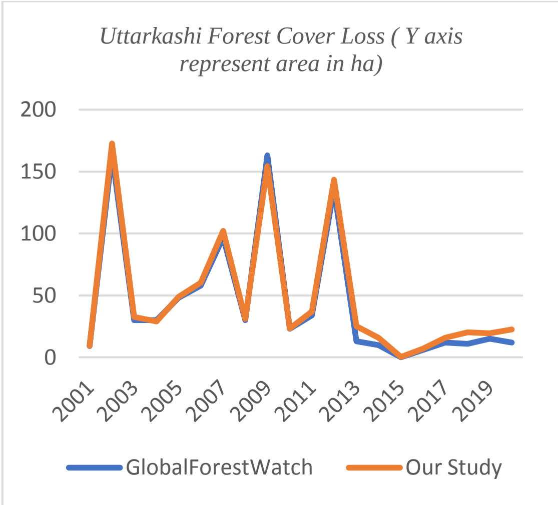

Fig. 20. Plot of our study versus Global Forest Watch for Uttarkashi region.

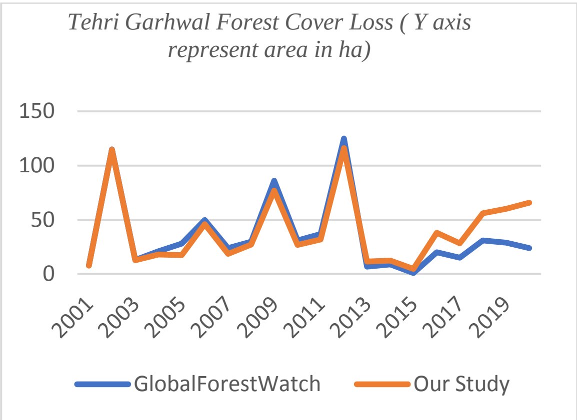

Fig. 21. Plot of our study versus Global Forest Watch for Tehri Garhwal region.

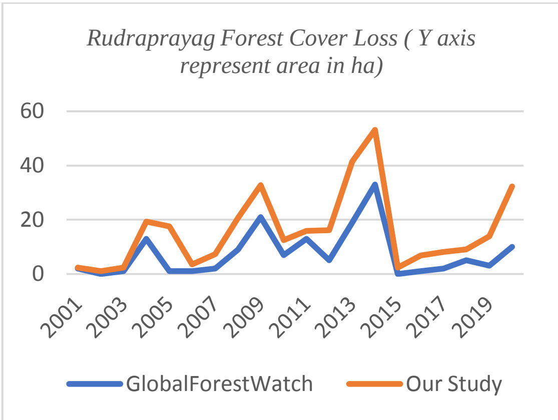

Fig. 22. Plot of our study versus Global Forest Watch for Rudraprayag region.

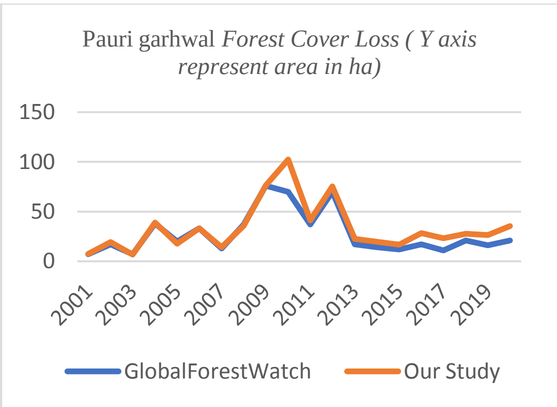

Fig. 23. Plot of our study versus Global Forest Watch for Pauri garhwal region

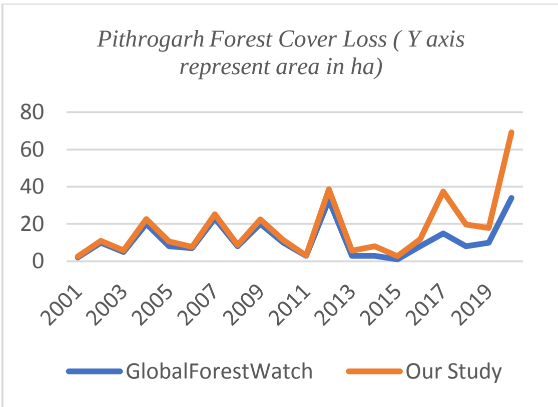

Fig. 24. Plot of our study versus Global Forest Watch for Pithrogarh region

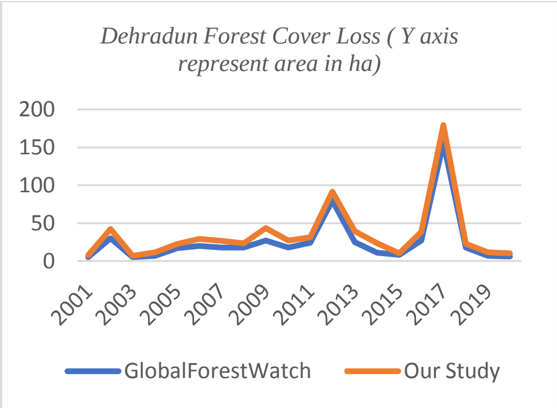

Fig. 25. Plot of our study versus Global Forest Watch for Dehradun region

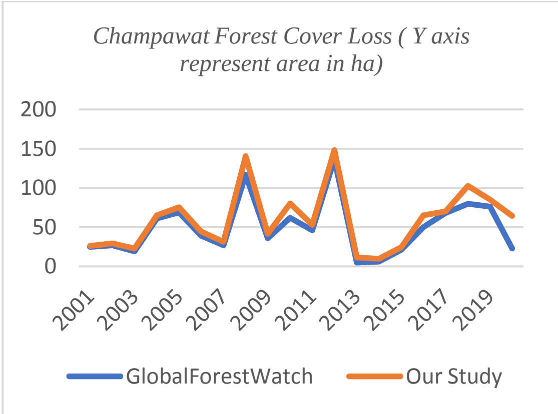

Fig. 36. Plot of our study versus Global Forest Watch for Champawat region

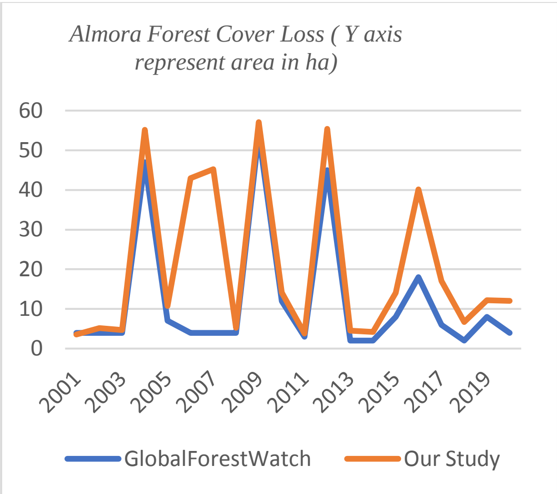

Fig. 47. Plot of our study versus Global Forest Watch for Almora region

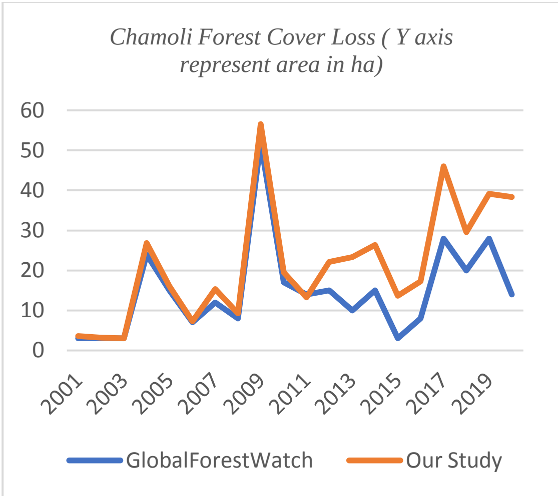

Fig. 58. Plot of our study versus Global Forest Watch for Chamoli region

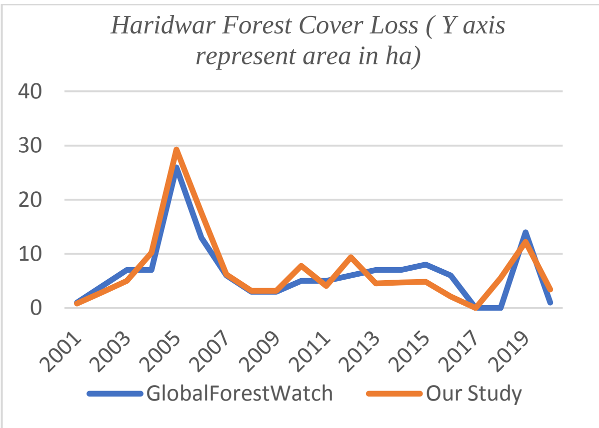

Fig. 29. Plot of our study versus Global Forest Watch for Haridwar region

5. CONCLUSION

Based on 20 years of Landsat data we performed our analysis on spatial patterns to estimate the tree cover loss in Uttarakhand and its districts. The outcome from this forest loss and gain study can be utilized in prioritizing the region (hot spots) that are of central issue, that is the districts that are having the highest count of tree cover loss driven by human or regular causes [15,16]. This study gauges and exhibits the problem area for forest cover loss, and verifies the result with the result of Global Forest Watch, however, it doesn't investigate factors influencing forest loss. The goal of our study centers around featuring the regions with tree cover loss, yet this study can be extended to classify deforestation based on categories that are influencing the tree cover loss. Overall forest loss around worldwide is an issue every developed and underdeveloped nation is presented with and similar are the conditions in Uttarakhand and its districts (Chakraborty et al. 2017).

As the graph in results from our study show Udam Singh Nagar, Nainital, and Champawat districts of Uttarakhand alone contribute to the total tree cover loss area of 15061.7513801 ha. which is about 71.5 % of Uttarakhand's total tree cover loss. These regions are in need of monitoring and controlling deforestation and more detail studies like this are required to analyze and prevent the causes of such great scale deforestation. Analyzing districts apart from those mention above, it is observed that the amount of tree cover loss is greater than the reforestation.

This study utilizes freely available dense Landsat Time Series (LTS) data for deforestation detection in all the districts of Uttarakhand, at annual time scales. Results from this will be useful for forest management and in Land Use Land Cover (LULC) classification. It will also be very useful for the local community affected by the consequences of deforestation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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