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Spatio-Temporal Change of Vegetation Line in the Gori Ganga Watershed, Kumaun Himalaya by Using Remote Sensing and GIS Techniques

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ABSTRACT

Present research paper is an attempt to examine the dynamics of vegetation line by using Normalized Difference Vegetation Index (NDVI) method in Gori Ganga watershed, Kumaun Himalaya, Uttarakhand (India). For the study of detect vegetation line shifting used of Landsat-5,8 and Cartosat-1 satellite imageries of three different time periods, i.e., Landsat-5 Thematic Mapper (TM) of 1990, Landsat-5 (TM) of 1999 and Landsat-8 (OLI and TIRS) of 2016 and Cartosat-1 of 2008. Geographical distribution of vegetation line average height reveals that in 1990 about 4294.97 m, 1999 about 4394.51 m and in 2016 about 4758.55 m which is change from non-vegetation to vegetation area. During 1990-1999 about 150.67 km^2 areas and during 1999-2016 about 434.03 km^2 area of the Gori Ganga watershed was converted from non-vegetation cover to vegetation cover area. These data suggest that due to global warming about 463.58 m vegetation line average height and 584.70 km^2 vegetation area of Gori Ganga watershed has been shifted into non-vegetation cover to vegetation cover area at an average rate of 17.83 m/year and 22.49 km^2/year during 1990 to 2016.

KEYWORDS: Spatio-Temporal Change, NDVI, Vegetation Line Dynamics, Remote Sensing and GIS

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1. INTRODUCTION

The global climate change is predicted to increase level of weather extremes and variability and high altitude ecosystems are particularly sensitive (Patz et al., 2005). In many parts of the globe effects on the plant and vegetation communities due to global warming such as boundary shift in timberlines (Wardle and Coleman 1992; Kullman 2001), advances in phenological patterns (Cayan et al. 2001; Sparks et al. 2009), extended growing period (Menzel and Fabian, 1999), pathogens and insect infestation on forests (Lazarus et al. 2004; Uniyal and Uniyal 2009) were more frequent in recent past. Erratic climatic conditions exert a remarkable effect on plant communities and extremeness of an event for particular community depends on its rarity and the deviation from the normal conditions (Adhikari et al., 2011). Although, tree species are adapted for the climatic conditions at this elevation zone, extreme climatic events and sharp variation in the inter-annual climatic conditions may lead to change in their resistance and adaptability, as well as strategies during the growth period (Beniston et al., 1997).

NDVI is a common and widely used index and it is an important vegetation index, widely applied in research on global environmental and climatic change (Bhandari et al., 2012). Vegetation dynamics is defined as the change in vegetation with time according to an appropriate scale of abundance, while changes caused by external factors such as human interventions are considered secondary factors (Miles, 1979). This approach has already proven to be relevant to many requirements of vegetation status monitoring including assessment and monitoring of changes in canopy biophysical properties such as Vegetation Fraction (*VF*), Leaf Area Index (LAI), fraction of absorbed photo synthetically active radiation, and net primary production (Holben 1986, Myneni et al. 1995, 1997). There are three basic approaches for estimating vegetation fraction from satellite data: spectral, mixture and analysis (Ustin et al., 1996). John (2004) mentioned that in natural forest management, it is necessary to understand and consider the factors and conditions that control the changes and dynamics of the forest to achieve the desired management outcomes. Understanding natural forest dynamics in a particular region should be the foundation of every management action (Abdelsalam, 2004).

2. METHODOLOGY

The present work out the study of vegetation index and vegetation line, remotely sensed data are extremely valuable for examine the dynamic of vegetation line height in Gori Ganga watershed. To determine vegetation line shifting Landsat-5 (TM) for the year 1990 and 1999, Landsat-8 (OLI and TIRS) for the year 2016 and Cartosat-1 Satellite images for the year 2008 were used from www.USGS.com, website and Global Land Cover Facility (GLCF). Use of first image in present study was the date 18^{th} November 1990, second image is the date 15^{th} November 1999 and third image is the date 28^{th} November 2016 based on Landsat-5 and Landsat-8 at 30 m resolution. Use of Cartosat-1 image Digital Elevation Model (DEM) was deriving the average height of vegetation line. DEM image helped in understanding the process of dynamics of vegetation in the watershed over the last 26 years (1990-2016).

3. STUDY AREA

The study area, viz., the Gori Ganga watershed lies Kumaun Himalaya Uttarakhand extends between 29045'0''N to 30035'47''N latitudes and 79059'33''E to 80029'25''E longitude, and encompasses an area of 2191.63 km2 in Figure 1. The altitude of the Gori Ganga watershed varies between 626 m and 6639 m. The Gori Ganga watershed has 168 villages and total population is about 40616 (2011).

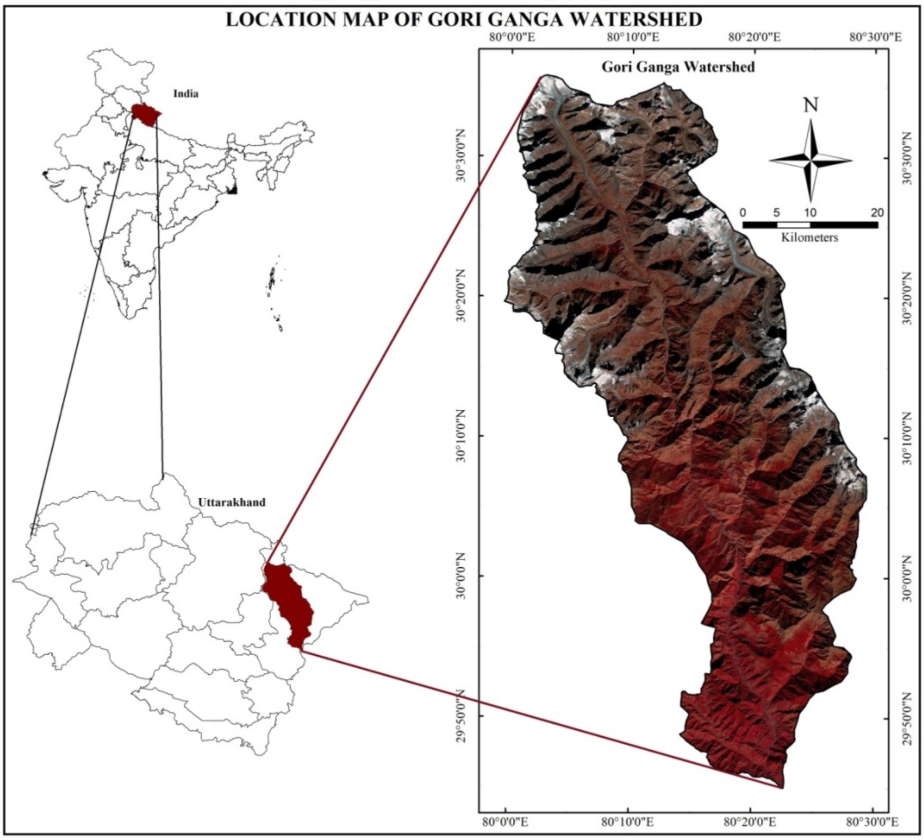

Figure 1: Geographical location and extension of the study area, Viz., Gori Ganga watershed, Kumaun Himalaya, Uttarakhand.

4. RESULT AND DISCUSSION

The results obtained through the analysis of NDVI imagery are diagrammatically illustrated in Figure 2. Figure 3 and Figure 4 depicts vegetation line average height in 1990 to 2016 and which are registered in Table 1, while Figure 5 depicts dynamics of vegetation line. Figure 7 depicts the geographical distribution of vegetation line shifting in different years (A) 1990-1999, (B) 1999-2016 and (C) 1990-2016 which are registered in Table 2 and diagrammatically illustrated in Figure 6. Figure 8 depicts total amount of vegetation line cover area dynamics in between (A) 1990-1999, (B) 1999-2016 and (C) 1990-2016 in the Gori Ganga watershed which are registered in Table 3 and diagrammatically illustrated in Figure 7. A brief account of these results it's discussed in the following paragraphs.

5. NORMALIZED DIFFERENCE VEGETATION INDEX (NDVI)

NDVI has found wide application in vegetative studies as it has been used to estimate yields, pasture performance, and grassland carrying capacities, among others. It is often directly related to other ground parameters such as percent of ground cover, photosynthetic activity of the plant, surface water, leaf area index and the amount of biomass. Since we know the behavior of plants across the electromagnetic spectrum, we can derive NDVI information by focusing on the satellite bands that are most sensitive to vegetation information (near-infrared and red). Theoretically, NDVI values are represented as a ratio ranging in value from -1 to 1 but in practice extreme negative values represent water, values around zero represent bare soil and values over 6 represent dense green vegetation. For the NDVI raster data of the 1990, 1999, and 2016 was calculated in Arc GIS 10.2.2 software using the equation Normalized Difference Vegetation Index (NDVI) = NIR-Red/NIR+Red. Where NIR (Near Infrared) = Band 4 (Landsat-5) and Band 5 (Landsat-8), RED = Band 3 (Landsat-5) and Band 4 (Landsat-8). Using NDVI was delineating the upper limit of vegetation. Use of threshold value of NDVI ranging from 0.2 to 0.4 is use to map out vegetation line respectively (www.earthobservatory.nasa.gov). Figure 2 depicts geographical distribution of NDVI values (>0.2) in the Gori Ganga watershed in 1990, 1999 and 2016.

6. DELINEATIONS OF VEGETATION LINE AVERAGE HEIGHT

The upper limit of vegetation line in the watershed was delineate for different years after calculation NDVI imagery and displaying values on the screen of Arc GIS. To estimate vegetation line height, the vegetation line of both the years were overlaid on the DEM data and then a point shape file has been created in arc-catalogue and keeping the snapping mode on, the digitization was done, over the vegetation line of both year and then the digitized points were masked by the mask function from DEM data, so, that each point bear some height and then those points were exported into the Microsoft excel sheet and the average height have been estimated. The vegetation area are digitized and extracted by using vegetation line and study area boundary with using tracing tool. It reflects the spatial characteristics of vegetation dynamics.

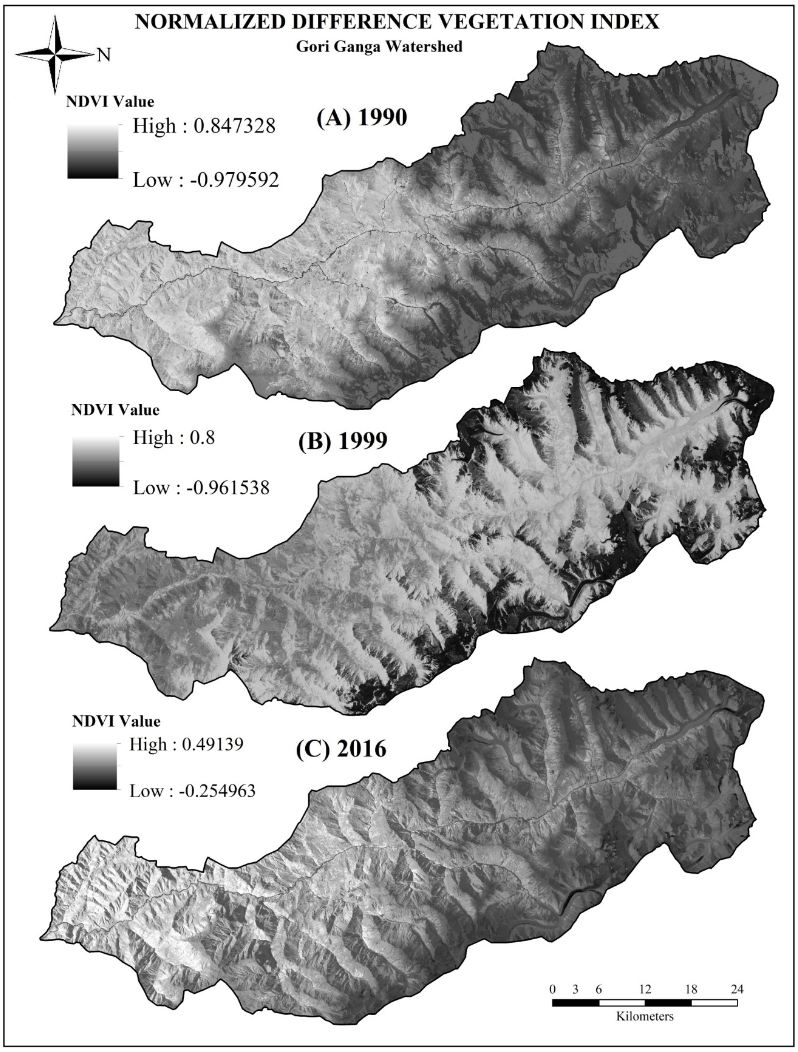

Figure 2: Geographical distribution NDVI values (>0.2) in different years in the Gori Ganga watershed in (A) 1990, (B) 1999 and (C) 2016 (*based on used NDVI techniques and Landsat-5 and 8, Satellite imageries*).

The extraction of vegetation line for the year 1990, 1999 and 2016 is depicts by Figure 4 (A), (B) and (C), and registered in Table-1 which is diagrammatically illustrated in Figure 3. For the determine the average height of vegetation line in the Gori Ganga watershed, DEM was overlaid on these vegetation line maps and by taking maximum height of vegetation line (at 13492 different places in 1990, 3917 places in 1999 and 19970 places in 2016) throughout the Gori Ganga watershed, the average height of vegetation line was worked out which is depicts in Figure 4 for different years. Figure 5 depicts dynamics of vegetation line. A brief description of vegetation line of different years is presented in the following paragraphs.

Table-1: Average height of vegetation lines in 1990, 1999 and 2016 in Gori Ganga watershed *(Based on Cartosat-1, Satellite image).*

Year	Average height of vegetation lines (in m)
1990	4294.97 (sd ± 307.13 m)
1999	4394.51 (sd ± 325.79 m)
2016	4758.55 (sd ± 533.88 m)

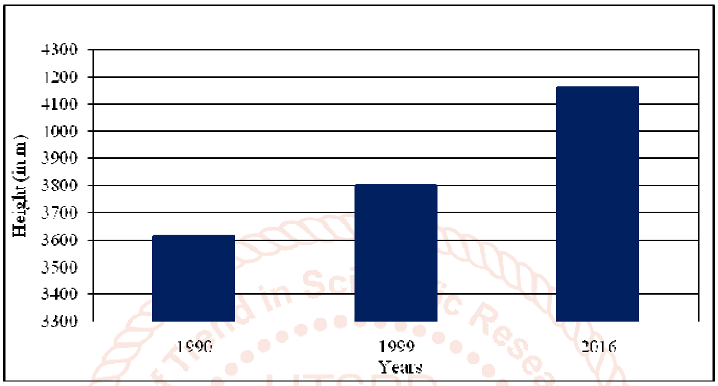

Figure 3: Average height of vegetation line in 1990, 1999 and 2016 in Gori Ganga watershed *(based on Cartosat-1, Satellite image).*

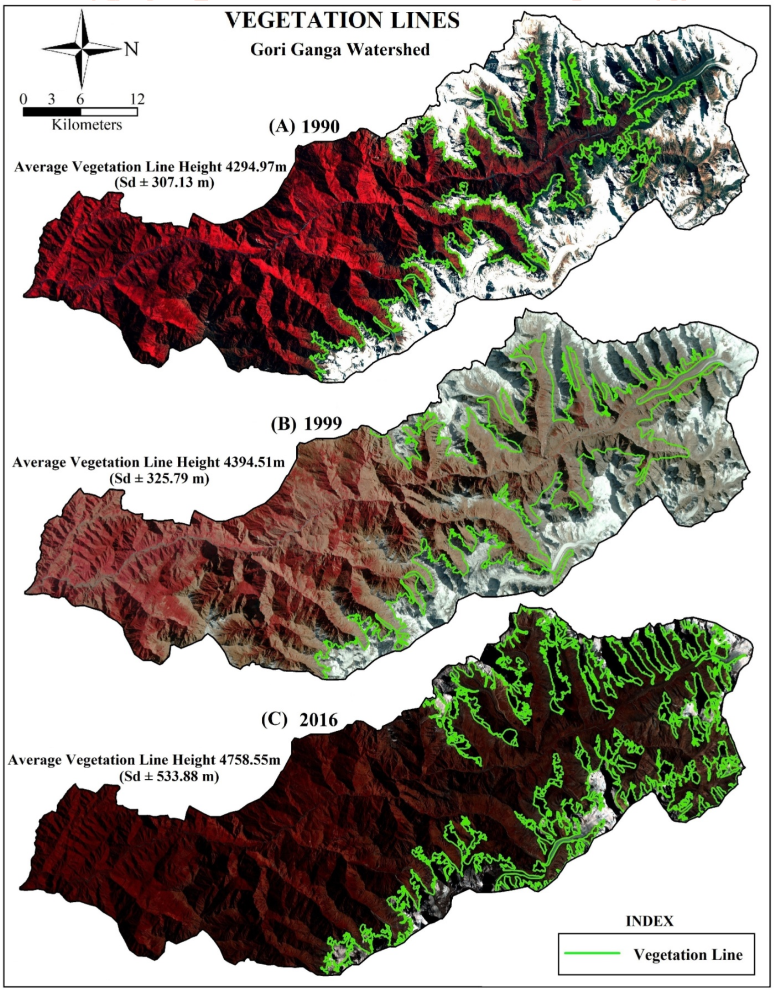

Figure 4: Vegetation lines in different years at the Gori Ganga watershed (A) 1999, (B) 1999 and (C) 2016 *(based on Landset-5, 8 and Cartosat-1, Satellite imageries).*

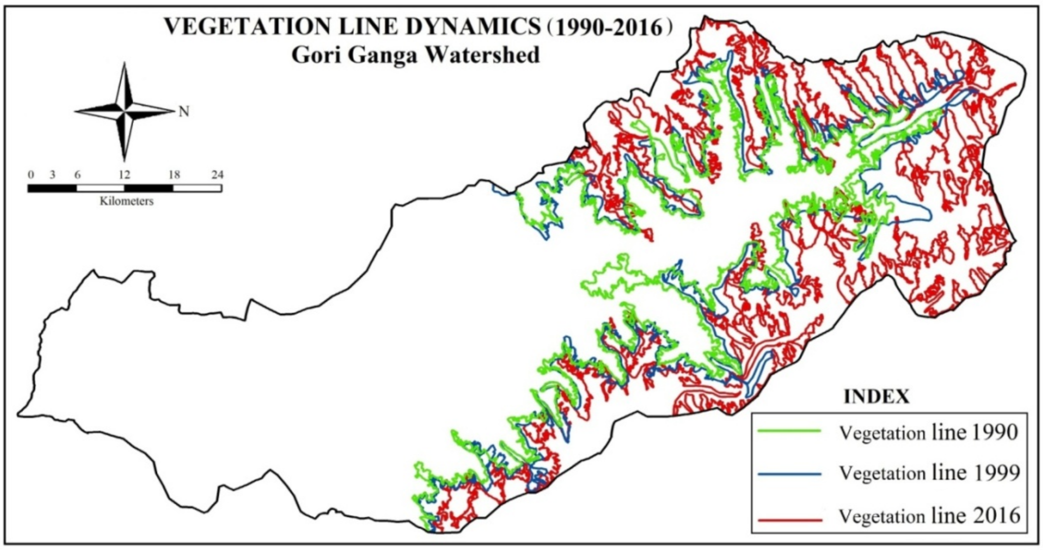

Figure 5: Vegetation line in different years at the Gori Ganga watershed from 1990-2016 *(based on Landset-5, 8 and Cartosat-1, Satellite imageries).*

6.1. Vegetation Line in 1990
Figure 4 (A) depicts the spatial distribution of the vegetation line of the Gori Ganga watershed in 1990 which reveals that the average height of vegetation line in the study area was 4294.97 m ± sd 307.13 m (Table-1 and Fig. 3).

6.2. Vegetation Line in 1999
Figure 4 (B) depicts the spatial distribution of the vegetation line of the Gori Ganga watershed for the year 1999. It reveals that the average height of the vegetation line in the study area was 4394.51 m ± sd 325.79 m (Table-1 and Fig. 3).

6.3. Vegetation Line in 2016
Figure 4 (C) depicts the spatial distribution of the vegetation line of the Gori Ganga watershed for the year 2016. The map reveals that the average height of vegetation line in the study area was 4758.55 m ± sd 533.88 m (Table-1 and Fig. 3).

7. NATURE OF CHANGES IN VEGETATION LINE
The main objective of this review is to describe the configuration of vegetation lines and their spatial distribution in the Himalayan region, in particular the Gori Ganga watershed, identify the relationship between the vegetation line and climatic conditions and the response of vegetation growth and regeneration to climate change. Under this section the nature of vegetation line of the Gori Ganga watershed is defined in term of vegetation line changes pattern and vegetation line change rate and trend. The fundamental objective of present chapter is to define nature, pattern, rate and trend of vegetation line.

7.1. Vegetation Line Changes Pattern
Based on Figure 4 and Figure 5, the area of changes in the average height of the vegetation line over several years, the total displacement from 1990 to 2016 during the 26 years was worked out depicts Figure 6, Figure 7 and Figure 8 which is presented in Table-2 and Table-3. Table-2 and Figure 6 reveal that the vegetation line was shifted upward about 99.54 m during 1990 to 1999 and 364.04 m during 1999-2016 in the Gori Ganga watershed. These data suggest that during 26 years (during 1990-2016), the vegetation line in the Gori Ganga watershed has been shifted about 463.58 m upward due to global warming and climate change. Table-3 and Figure 7 reveals that during 1990 to 1999 about 150.67 km2 areas at an average rate of 16.74 km2/year and during 1999 to 2011 about 434.03 km2 area at an average rate of 25.53 km2/year in the Gori Ganga watershed was converted from non-vegetation to vegetation area respectively. During the last 26 years (1990-2016) due to global warming about 584.70 km2 area of the Gori Ganga has been converted from non-vegetation to vegetation area at an average rate 22.49 km2/year. Figure 8 depicts vegetation line shifting area in the Gori Ganga watershed.

7.2. Vegetation Line Changes Rate and Trend
Based on vegetation line average height (Table-1) during periods i.e. 1990, 1999 and 2016, amount of shift of vegetation line was worked out and results are presented on Table-2 and Figure 6. Table-2 reveals that during 9 years (from 1990-1999) the vegetation line of the Gori Ganga watershed was shifted upward at the rate of 11.06

m/year. During 17 years (from 1999-2016) the rate of vegetation line shifting 21.42 m/year of the watershed was changed from vegetation cover area to non vegetation cover area. Based on these data the vegetation line in the Gori Ganga watershed was shifted 463.58 m and at an average rate of 17.83 m/year during the last 26 years (from 1990-2016) presented on Figure 6. The pattern of 26 years vegetation line average height studies in three different time period in 1990, 1999 and 2016 reveals that there is strong positive trend of vegetation cover with global warming. Which means as the temperature is rising due to global warming the vegetation line average height is increasing.

Table-2: Amount and rate of vegetation line dynamics in different periods in the Gori Ganga watershed (*based on Landset-5, 8 and Cartoset-1, Satellite images*).

Year	Period in years	Dynamics of vegetation line	
		amount	Rate
1990-1999	9	99.54 m	11.06 m/year
1999-2016	17	364.04 m	21.42 m/year
1990-2016	26	463.58 m	17.83 m/year

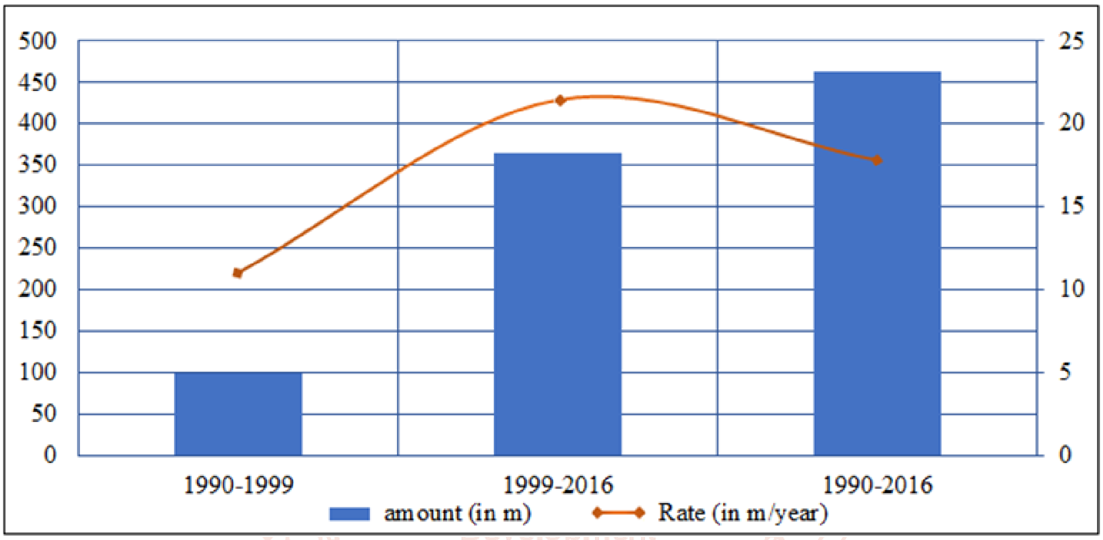

Figure 6: Dynamics of vegetation line in different periods in Gori Ganga watershed (*based on Landset-5, 8 and Cartoset-1, Satellite images*).

Table-3: Amount of upward shift of vegetation cover area in different time periods in the Gori Ganga watershed (*based on Landset-5, 8 and Cartoset-1, Satellite images*).

Year	Period in years	Upward shift of vegetation cover area	
		Area (km^2)	Rate
1990-1999	9	150.67	16.74 km^2/year
1999-2016	17	434.03	25.53 km^2/year
1990-2016	26	584.70	22.49 km^2/year

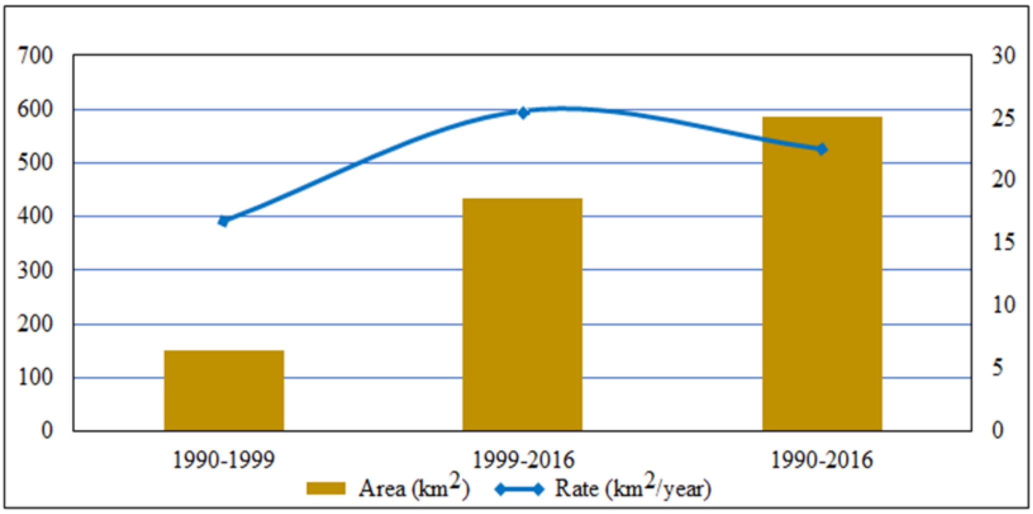

Figure 7: Area of Upward Shifting of vegetation line in different periods in Gori Ganga watershed (*based on Landset-5, 8 and Cartoset-1, Satellite images*).

8. CONCLUSION

The fundamental objectives of this chapter is to study vegetation line dynamics in the Gori Ganga watershed, which also includes the study of their patterns, rate and trends using remote sensing and GIS techniques. Based on the previous study following can be concluded.

A. The vegetation line average height in the study area shifted 99.54 m upward at the rate of 11.06 m/year during 1990-1999 and about 364.04 m above at the rate of 21.42 m/year during 1990-2016.
B. On an average the last two decades (1990 to 2016) the vegetation line in the Gori Ganga watershed has been shifted 463.58 m at an average rate of 17.83 m/year upward due to global warming and climate change.
C. During 1990-1999 about 150.67 km^2 areas at an average rate of 16.74 km^2/year and during 1999-2016 about 434.03 km^2 areas at an average rate 25.53 km^2/year of the Gori Ganga Watershed was converted from non vegetation to vegetation area respectively.
D. On an average, during the last 26 years (1990-2016) due to global warming and climate change 584.70 km^2 area of the Gori Ganga watershed has been converted from non vegetation to vegetation area at an average rate 22.49 km^2/year.
E. This study is based on remote sensing data, i.e. Landsat-5 (TM), Landsat-8 (OLI and TIRS) and Cartosat-1 satellite imageries using GIS techniques and has demonstrates that the remote sensing and GIS techniques are very useful for the study of determination and dynamics of vegetation lines.

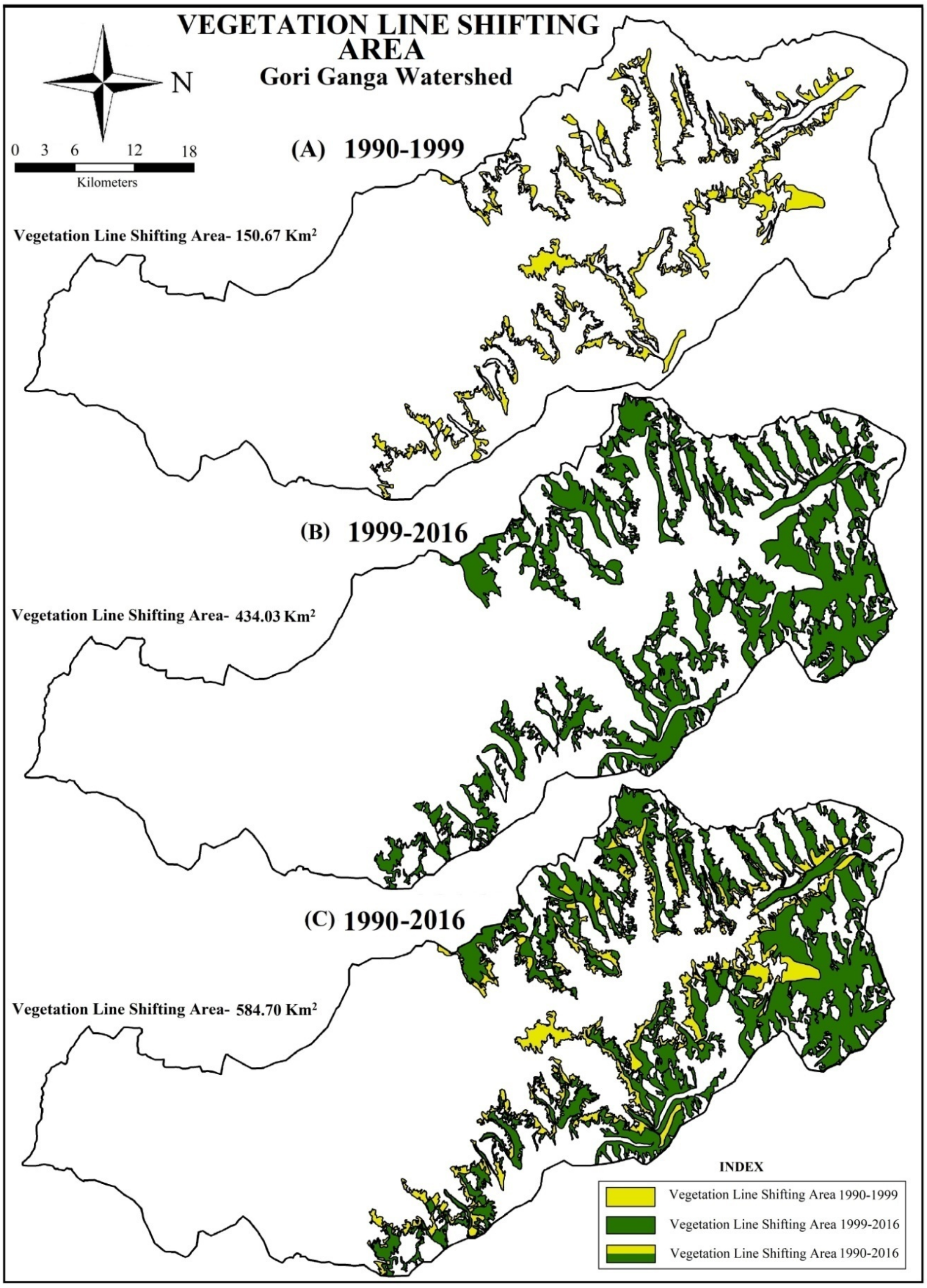

Figure 8: Vegetation line shifting area in different years at the Gori Ganga watershed (A) 1990-1999, (B) 1999-2016 and (C) 1990-2016 ***(based on Cartosat-1, Satellite image).***

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