SSRG International Journal of Geo-informatics and Geological Science
ISSN: 2393 – 9206 /doi:10.14445/23939206/IJGGS-V8I1P105

Volume 8 Issue 1, 42-47, Jan-April 2021

Dynamics of Timberline Due to Spatio-Temporal Changes Using GIS and RS in the Gori Ganga Watershed, Kumaun Himalaya, Uttarakhand

D. S. Parihar

Department of Geography, Kumaun University, S. S. J. Campus, Almora, Uttarakhand (India)- 263601.

Received Date: 01 March 2021
Revised Date: 13 April 2021
Accepted Date: 15 April 2021

Abstract - *Present research paper is an attempt to examine the dynamics of timberlines by using the Normalized Difference Vegetation Index (NDVI) in the Gori Ganga watershed, Kumaun Himalaya, Uttarakhand (India). For the study of detect timber lines dynamics used of Landsat-5,8 and Cartosat-1 satellite imageries of three different time periods like Landsat-5 Thematic Mapper (TM) of 1990, Landsat-5 (TM) of 1999 and Landsat-8 Operational Land Imager and Thermal Infrared Sensor (OLI and TIRS) of 2016 and Cartosat-1 of 2008. Geographical distribution of average timberline height reveals that in 1990 about 3516.11 m, in 1999 about 3680.69 m and in 2016 about 4060.58 m which is Change from vegetation to timber area and during 1990-1999 about 197.58 km^2 areas and during 1999-2016 about 463.95 km^2 area of the Gori Ganga watershed was converted from non-timber to timber area. These data suggest that due to global warming, about 544.47 m timberline average height and 661.53 km^2 timber area of Gori Ganga watershed has been shifted into non-timber cover to timber cover area at an average rate of 20.94 m/year and 25.44 km^2/year from 1990 to 2016.*

KEYWORDS: *NDVI, TimberLine Dynamics, Kumaun Himalaya, Remote Sensing, and GIS*

I. INTRODUCTION

The extreme climatic events tend to be much more important to initiate change in forest ecosystems than average climatic conditions (Beniston et al. 1997; Katz and Brown 1992; Innes 1998). Wardle 1974 presents in a broad sense, and the alpine timberlines represent the upper limit of forest on a mountain. Korner 1998a explains the upper limit of natural forests with a steep gradient and increasing stand fragmentation and stiltedness is sometimes called the tree line ecotone or, more commonly, as here, the timberline ecotone. Korner (1998a) defines a tree as an upright woody plant with a dominant above-ground stem that reaches a height of at least 3 m. Therefore, the tree line is defined here as the altitude above which any trees is lower than 3 m (Korner, 2012b). researchers have reported the use of NDVI for vegetation monitoring (Yang et al., 2010), assessing the crop cover (El-Shikha et al., 2007), drought monitoring (Abdelsalam, 2004), and agricultural drought assessment at national (Demirel et al., 2010) and global level vegetation index is a simple and effective measurement parameter, which is used to indicate the earth surface vegetation covers and crops growth status in remote sensing field (Zhang et al., 2009). According to Wardle 1974, in a broad sense, the alpine timberlines represent the upper limit of forest on a mountain. Korner 1998a explains the upper limit of natural forests with a steep gradient and increasing stand fragmentation and stiltedness is sometimes called the tree line ecotone or, more commonly, as here, the timberline ecotone. Korner (1998a) defines a tree as an upright woody plant with a dominant above-ground stem that reaches a height of at least 3m. Therefore, the tree line is defined here as the altitude above which any trees is lower than 3 m (Korner, 2012b).

II. METHODOLOGY

The present work out the study of Normalized Difference Vegetation Index (NDVI), timberline, remotely sensed data are extremely valuable for examining the dynamic of timberline and height in the Gori Ganga watershed. To determine timberline dynamics, Landsat-5 (TM) for the years 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). The use of the first image in the present study was the date 18th November 1990, and the second image is the date 15th November 1999, and the third image is the date 28th November 2016 based on Landsat-5 and 8 at 30 m resolution. The use of Cartosat-1 image Digital Elevation Model (DEM) was deriving the average height of timberline. DEM image helped in understanding the process of dynamics of timberline in the watershed over the last 26 years (1990-2016).

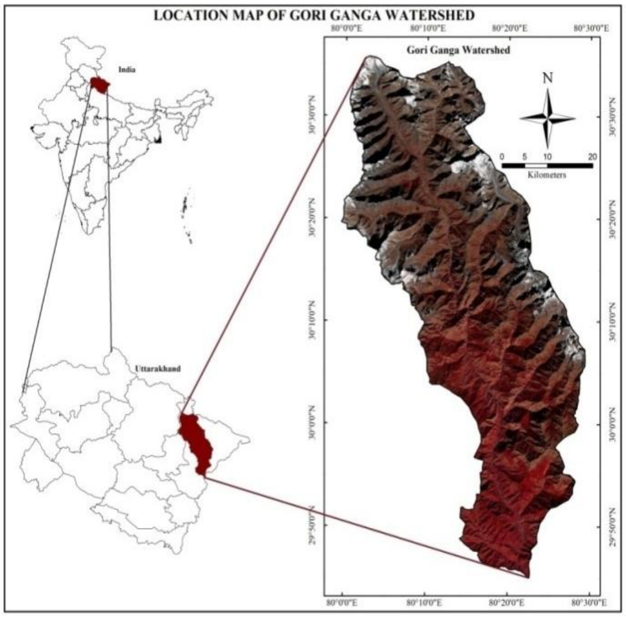

Figure 1: Geographical location and extension of the study area Viz. Gori Ganga watershed, Kumaun Himalaya, Uttarakhand.

III. STUDY AREA

The study area, viz., the Gori Ganga watershed (Kumaun Himalaya) extends between 29045'0''N to 30035'47''N latitudes and 79059'33''E to 80029'25''E longitude and encompasses an area of 2191.93 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 the total population is about 40616 (2011).

IV. RESULT AND DISCUSSION

The results obtained through the analysis of NDVI imagery are diagrammatically illustrated in Figure 2. Figure 3 and Figure 4 depict Timberline average height from 1990 to 2016 and which are registered in Table 1. While Figure 4 and Figure 5 depict dynamics of timberline average height and amount and rate of timber line average height dynamics in 1990, 1999, and 2016 in the Gori Ganga watershed and which are registered in Table 3. Figure 6 depicts the geographical distribution of timberline shifting in different years 1990-1999, 1999-2016, and 1990-2016 which are registered in Table 2. A brief account of these results it's discussed in the following paragraphs.

V. NORMALIZED DIFFERENCE VEGETATION INDEX (NDVI)

NDVI has found a wide application in vegetative studies as it has been used to estimate crop yields, pasture performance, and rangeland 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). The NDVI raster data of 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 the timberline. 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. Figure 2 depicts the geographical distribution of NDVI values (>0.2) in the Gori Ganga watershed in 1990, 1999, and 2016.

VI. DELINEATIONS OF TIMBERLINE AVERAGE HEIGHT

A use threshold value of NDVI ranging from >0.4 is used to map out timberline respectively (www.earthobservatory.nasa.gov). The upper limit of the timberline in the watershed was delineated for different years after calculation NDVI imagery and displaying values on the screen of Arc GIS. To estimate timber line height, the timberline of both the years were overlaid on the DEM data, and then a point shapefile has been created in arc-catalog and keeping the snapping mode on, the digitization was done, over the timberline 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 timber area is digitized and extracted by using timberline and study area boundary using the tracing tool. It reflects the spatial characteristics of timberline dynamics.

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

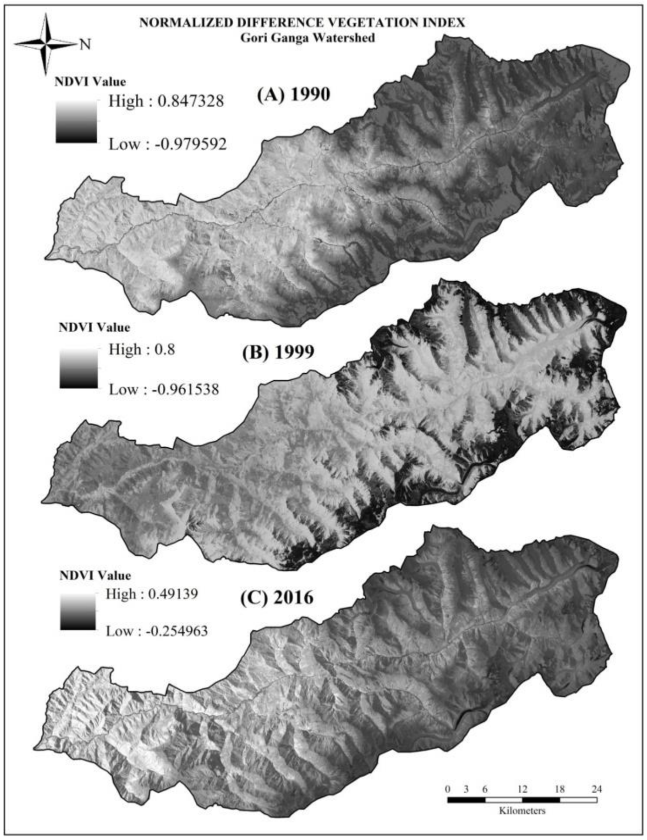

Figure 2: Geographical distribution NDVI values (>0.2) in different years in the Gori Ganga watershed in (A) 1990, (B) 1999, and (C) 2016 (*based on used NDVI techniques and Landsat-5 and 8 Satellite imageries*).

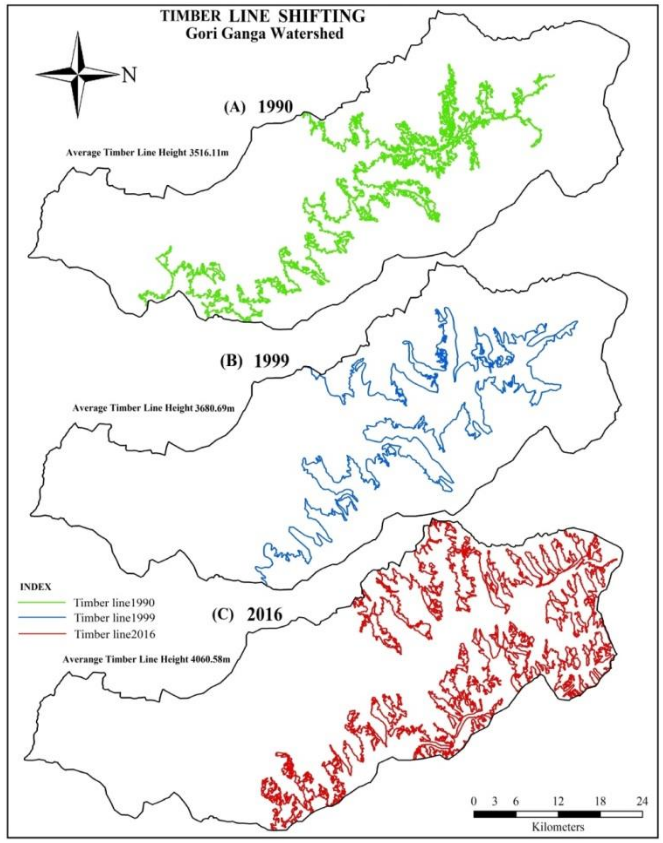

Figure 3: Timberline in different years at the Gori Ganga watershed (A) 1990, (B) 1999, and (C) 2016 *(based on Landsat-5, 8 and Cartosat-1 Satellite imageries).*

A. TimberLine in 1990

Figure 3 (A) depicts the spatial distribution of the timberline of the Gori Ganga watershed in 1990, which reveals that the average height of the timberline in the study area was 3516.11 m ± sd 369.79 m (Table 1 and Figure 4).

B. TimberLine in 1999

Figure 3 (B) depicts the spatial distribution of the timberline of the Gori Ganga watershed for the year 1999. It reveals that the average height of the timberline in the study area was 3680.69 m ± sd 362.36 m (Table 1 and Figure 4).

C. TimberLine in 2016

Figure 3 (C) depicts the spatial distribution of the timberline of the Gori Ganga watershed for the year 2016. The map reveals that the average height of the timberline in the study area was 4060.58 m ± sd 619.27 m (Table 1 and Figure 4).

VII. NATURE OF CHANGES IN TIMBERLINE

The dynamic changes of upward tree growth in the alpine region needed parameters is a long-term process that requires investigations on it. The main objective of this review is to describe the pattern of timberline and their spatial distribution in the Himalayan region, especially the Gori Ganga watershed identify the relationship between the timberline and climatic conditions and the response of tree growth and regeneration to climate change. Li and Chou (1984) estimated the distribution of spruce-fir forests in China and modeled the three-dimensional distribution of spruce forests. They concluded that a decrease of one-degree latitude correlated to a 103 m increase in the elevation of the timberline. Zheng (1995) examined the correlation between coniferous forest vegetation and climatic factors such as temperature and moisture in the southeastern Tibetan Plateau. However, little is known about the spatial distribution of the timberline and its relation to climate across the Tibetan Plateau (Korner, 2012b). Under this section, the nature of the timberline of the Gori Ganga watershed is defined in terms of timberline changes pattern and timberline change rate and trend. The fundamental objective of the present chapter is to define the nature, pattern, rate, and trend of timberline.

A. TimberLine Changes Pattern

Based on Figure 6, the area of timberline average height changes for a different year, the total shift from 1990-2016 during the 26 years was worked out, which is presented in Table 2 and Table 3. The study reveals that from 1990 to 1999, about 197.58 km^2 areas and from 1999 to 2016, about 463.95 km^2 area of the Gori Ganga watershed was converted from non-timber to timber area at an average rate of 21.95 km^2/year and 27.29 km^2/year, respectively. During the last 26 years (1990-2016), due to global warming, about 661.53 km^2 area of the Gori Ganga watershed has been converted from non-timber to timber area at an average rate of 25.44 km^2/year (Figure 6 and Table 2). Table 3 reveals that the timberline was shifted upward about 164.58 m from 1990 to 1999 and 379.89 m in the Gori Ganga watershed. These data suggest that during 26 years (during 1990-2016), the timberline in the Gori Ganga watershed has been shifted about 544.47 m upward due to global warming and climate change.

B. TimberLine Changes Rate and Trend

Based on average timberline height (Table 1 and Figure 3) during periods, i.e., 1990, 1999, and 2016, the amount of shift of timberline was worked out, and results are presented in Table 6. Table 3 reveals that during 9 years (from 1990-1999), the timberline of the Gori Ganga Watershed was shifted upward at the rate of 18.29 m/year, and during 17 years (from 1999-2016), the rate of timberline shifting 22.35 m/year of the watershed was changed from timber cover area to nontimber cover area. Based on these data, the timberline in the Gori Ganga watershed was shifted 544.47 m and at an average rate of 20.94 m/year during the last 26 years (from 1990-2016), presented in Figure 5. The pattern of 26 years timberline average height studies in three different time periods in 1990, 1999, and 2016 reveals that there is a strong positive trend of timber cover with global warming. This means as the temperature is rising due to global warming, the timberline average height is increasing.

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

Year	Average timber height (in m)
1990	3516.11 (sd ±369.79 m)
1999	3680.69 (sd ±362.36 m)
2016	4060.58 (sd ±619.27 m)

Table 2: Amount of upward shift of timber cover area in different periods in the Gori Ganga watershed *(based on Landset-5, 8 and Cartosat-1, Satellite images).*

Year	Period (Years)	The upward shift of timber cover	
		Area in km^2	Rate
1990-1999	9	197.58	21.95 km^2/year
1999-2016	17	463.95	27.29 km^2/year
1990-2016	26	661.53	25.44 km^2/year

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

Year	Period	Dynamics of the timberline	
		Amount (m)	Rate
1990-1999	9 Years	164.59	18.29 m/year
1999-2016	17 Years	379.89	22.35 m/year
1990-2016	26 Years	544.47	20.94 m/year

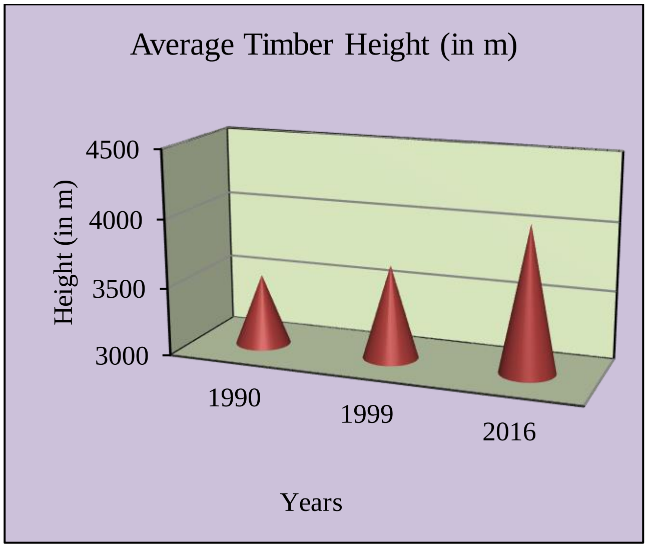

Figure 4: Average height of timberline in 1990, 1999, and 2016 in Gori Ganga watershed *(based on Cartosat-1, Satellite image).*

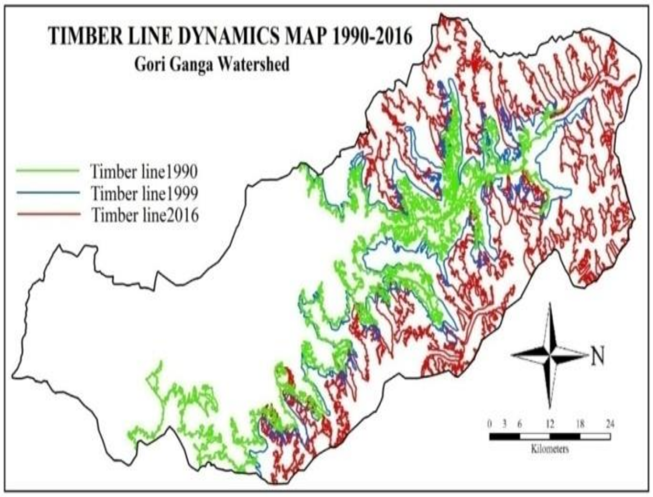

Figure 5: Timberline in different years at the Gori Ganga watershed from 1990- 2016 *(based on Landsat-5, 8 and Cartosat-1, Satellite images).*

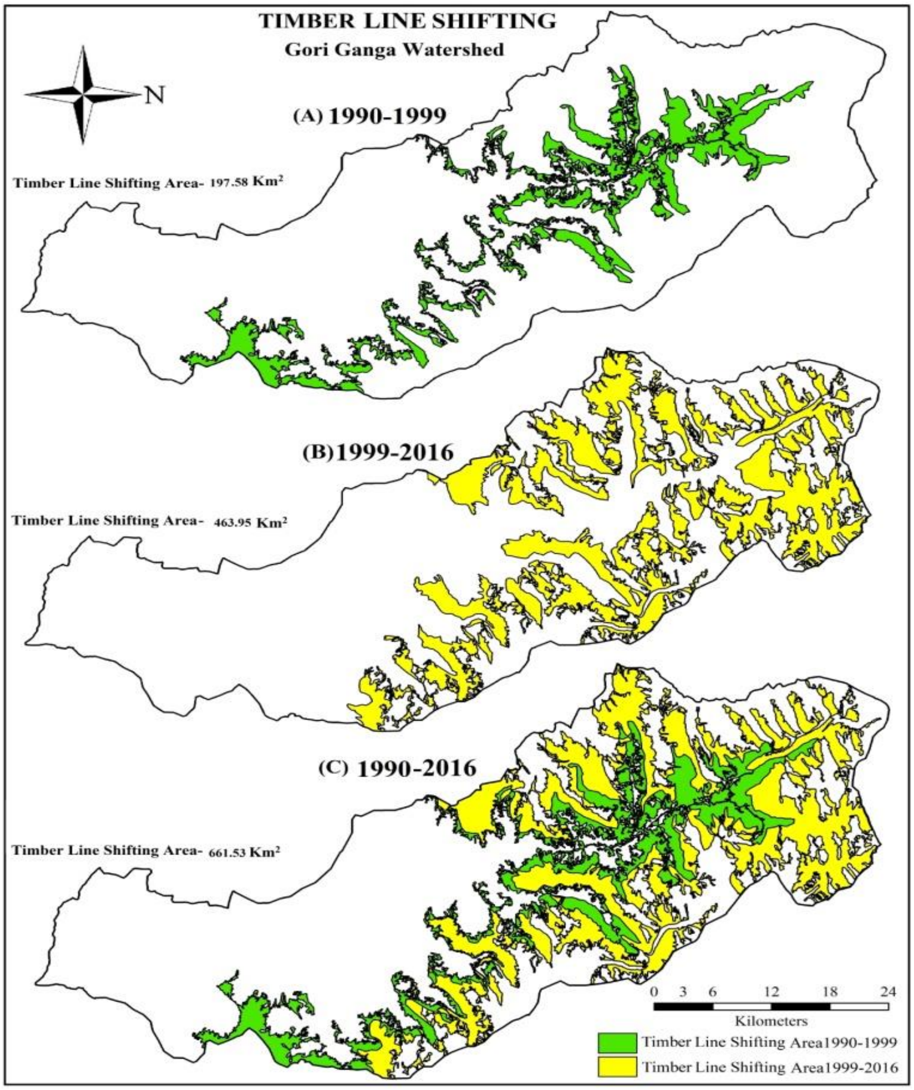

Figure 6: Timberline shifting in different years at the Gori Ganga watershed (A) 1990-1999, (B) 1999-2016, and (C) 1990-2016 *(based on Cartosat-1, Satellite image)*.

VIII. CONCLUSION

The fundamental objective of this chapter is to study timberline 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.

I. The average timberline height in the study area shifted 164.59 m upward at the rate of 18.29 m/year during 1990-1999 and about 379.89 m above at the rate of 22.35 m/year during 1990-2016.

II. On average, in the last two decades (1990 to 2016), the timberline in the Gori Ganga watershed has been shifted 544.47 m at an average rate of 20.94 m/year upward due to global warming and climate change.

III. During 1990-1999 about 197.58 km^2 areas and during 1999-2016, about 463.95 km^2 area of the Gori Ganga watershed was converted from nontimber to timber area at an average rate of 21.95 km^2/year and 27.29 km^2/year, respectively.

IV. On average, during the last 26 years (1990-2016), due to global warming and climate change, 661.53 km^2 area of the Gori Ganga watershed has been converted from non-timber to timber area at an average rate of 25.44 km^2/year.

V. 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 demonstrated that the remote sensing and GIS techniques are very useful for the study of determination and dynamics of timber lines.

REFERENCES

[1] Abdelsalam., The ecological components of the management of natural forest in drylands. Ph.D. Thesis, University of Sudan, Sudan, (2004) 53-69

[2] M. Beniston, H.F. Diaz, and R.S. Bradley., Climate changes at high elevation sites, Climate Change, 36 (3-4) (1997) 233-251.

[3] H. Demirel, C. Ozcinar, and G. Anbarjafari., satellite image contrast enhancement using discrete wavelet transform and singular value decomposition, IEEE geosciences, and remote sensing letters, 7 (2) (2010) 333-337.

[4] D.M. El-Shikha, P. Waller, D. Hunsaker, T. Clarke, and E. Barnes., Ground-based remote sensing for sensing for assessing water and nitrogen status of broccoli, Agriculture water management, 92 (2007) 183-193.

[5] B.N. Holben., Characteristics of maximum value composite images for temporal AVHRR data, International journal of remote sensing, 7 (1986) 1417–1437.

[6] J.L. Innes., The impacts of climatic extremes on forests: an introduction. M. Beniston, J.L. Innes (Editors), The Impacts of climatic variability on forests, Springer- Berlag, Berlin, (1998) 1-18.

[7] R.W. Katz, and B.G. Brown., Extreme events in a changing climate: variability is more important than averages, Climate Change, 21 (3) (1992) 289-302.

[8] C. Korner., A re-assessment of high elevation treeline positions and their explanation, Oecologia, 115 (1998) 445–459.

[9] C. Korner., Treelines will be understood once the functional difference between a tree and a shrub is, AMBIO: A Journal of the human environment, 41 (2012) 197–206.

[10] W. Li, and P. Chou., The geographical distribution of the spruce-fir forest in China and its modeling, Mountain research and development, 4 (1984) 203.

[11] P. Wardle, Alpine timberline, Arctic and alpine environments, J.D., Barry, R.G. Methuen (editor), London, (1974) 371–402.

[12] Y. Yang, J. Zhu, C. Zhao, S. Liu, and Tong., The Spatial continuity study of NDVI based on Kriging and BPNN algorithm, Journal of mathematical and computer modeling, (2010) 77-85.

[13] X. Zhang, Y. Hu, D. Zhuang, Y. Oi, and Ma., NDVI spatial pattern and its differentiation on the Mongolian plateau, Journal of Geographical Sciences, 19 (2009) 403-415.

[14] Y. Zheng., A study on the correlation between mountain forest vegetation and climate in the southeastern part of Qinghai-Tibetan Plateau, Institute of geography, Chinese academy of sciences, 20 (1995) 12–19.