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A GEOSPATIAL STUDY OF TRENDS AND PATTERNS OF BIOPHYSICAL TRANSFORMATION IN THE STATE OF UTTARAKHAND, INDIA

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Abstract: *Inevitable process of urbanization is taking place at much faster rate than ever before. It has engulfed all possible regions across the globe in order to meet out the demands of ever-increasing demographic pressure. Urbanization involves anthropogenic activities like construction of roads, railways, bridges, buildings (both residential and commercial) resulting in alteration of landscape. Similar scenario is taking place in the States of India but the most vulnerable ones are the mountainous states located in close vicinity of the mighty Himalayas. One such State is Uttarakhand which is facing the widespread destruction of pristine environment due to various developmental processes taking place as a result of urbanization. The vegetative destruction in order to provide land area for construction of hotels, resorts, ropeways and other constructions. The current unsustainable urbanization has triggered multi-dimensional problems like alteration of micro-climate, vegetation destruction, biodiversity degradation, habitat fragmentation and many more in the study area. The present study analyses trend and pattern of landscape alteration in the light of digital data viz Landsat - 4, 5 (TM) for 1990, 2000, 2010 and Landsat - 8 (OLI) for 2020. The 'change detection' along with 'rate of change of land per year' has been calculated and analyzed for various categories of land use/land cover. In addition to this, built-up expansion during 1990-2020 have also been analyzed and discussed. Lastly, study gives emphasis to bring urbanization process on the lines of sustainability and make an appeal to promote ecological urbanization in the study area.*

Key words: Landscape Alteration, Ecological Urbanization, Impervious Surface, Vegetation Destruction

Introduction

Human beings and the environment are linked to each other through the reciprocal relationship (Mrash, 1864). In this relationship of 'man and nature', overuse of resources has degraded environment and resulted in land transformation (Turner, et. al., 1990). The landscape of the earth is altered either by natural changes or anthropogenic activities (various developmental activities). Talking globally, then developed nations were early destroyers of forest while in developing nations exploitation paced up during the 20th century (Goldewijk, 2001). The ever increasing demographic and developmental pressure increased the demand for food, feed, fuel and raw materials by manifolds. The urbanization and economic globalization have resulted in expansion of grey infrastructure and shrinkage of vegetation cover at the global level (Turner, 1994). Landscape alteration is taking place from time immemorial (Kato and Yamaguchi, 2005). In ancient times, landscape was dominated by vegetation cover or forest cover characterized by the most complex patterns. As soon as, human beings came into scene then landscape alteration took place in the form of agricultural lands, and settlements or built-up. India experienced continuous decline in forest area from 32 percent (1880) to 20 percent (1980) (Rahman, 2007).

In the present scenario, most vulnerable situation is being faced by the States located in the region of the Himalayas of India. One such State is Uttarakhand which have experienced fast pace of urbanization on one hand and deforestation on the other hand. The anthropogenic activities like housing construction, roads & railways construction, industries, markets and buildings (commercial and residential) marked the unsustainable urbanization in the State of Uttarakhand. The present study assesses the scenario of landscape alteration and urbanization over the period of 1990 - 2020 that is 30 years. The study suggests the need of 'ecological urbanization' in order to promote the process of development and urbanization on the lines of sustainability.

Objectives of the Study

- To analyze the trend and pattern of landscape alteration (1990-2020) in the study area.
- To analyze the change detection and land transformation for various categories of land use/land cover (1990-2020) with special reference to built-up expansion in the study area.

Database and Methodology

The digital data in the form of satellite imagery (Landsat-4,5 and Landsat-8) for the years 1990, 2000, 2010 and 2020 have been used to carry out the present research study.

Table 01: Details of Satellite Imagery

Satellite	Sensor	Date	Details				Bands	
			Spatial (meters)	Thermal (meters)	Path	Row	Spectral	Thermal
Landsat -4,5	TM	23/02/1990	30	120	146	40	1-5 & 7	6
Landsat-4, 5	TM	19/02/2000	30	120	146	40	1-5 & 7	6
Landsat-4,5	TM	14/02/2010	30	120	146	40	1-5 & 7	6
Landsat-8	OLI	09/11/2020	30	100	147	40	1-9	10, 11

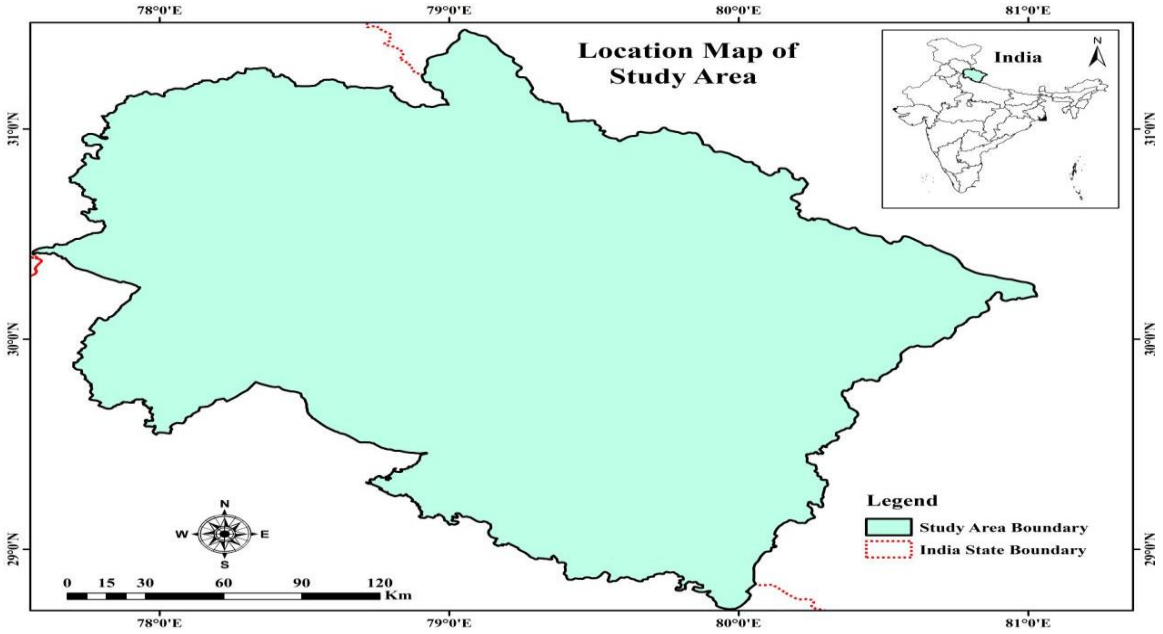
Source: Landsat Manual, Various Issues

Study Area

The State of Uttarakhand is famous as 'land of gods' (*Devbhoomi*) and currently, it is major tourist attraction due to picturesque natural scenic beauty and places of religious importance. Geographically, it is located between 28º44' N - 31º28' N latitude and 77º35' E - 81º01' E longitude. It comprises of 13 districts as administrative units. Though the State of Uttarakhand is well known for pristine forests and region of ecological importance but in last few decades, urbanization process resulted in clearing of large forest stretch in order to fetch land area for

one or the other constructional activity. Under such circumstances, region is facing ecological imbalance, biodiversity loss, problem of habitat fragmentation along with intensification of natural disasters. Demographic pressure (10,086,292, census 2011) has created manifold demands for housing, medical infrastructure, educational institutions, which have given rise to built-up dominated landscape.

Figure 01: Location Map Study Area



Tools of Analysis

'Rate of Change Per Year' is calculated by using the following formula (Chebet, 2013):

$$R = \frac{Y - X}{T}$$

Where, R = rate of change
Y = the area (km^2) of the study area in the final year.
X = the area (km^2) of the study area in the initial year.
T = the time difference in years

RESULTS AND DISCUSSION

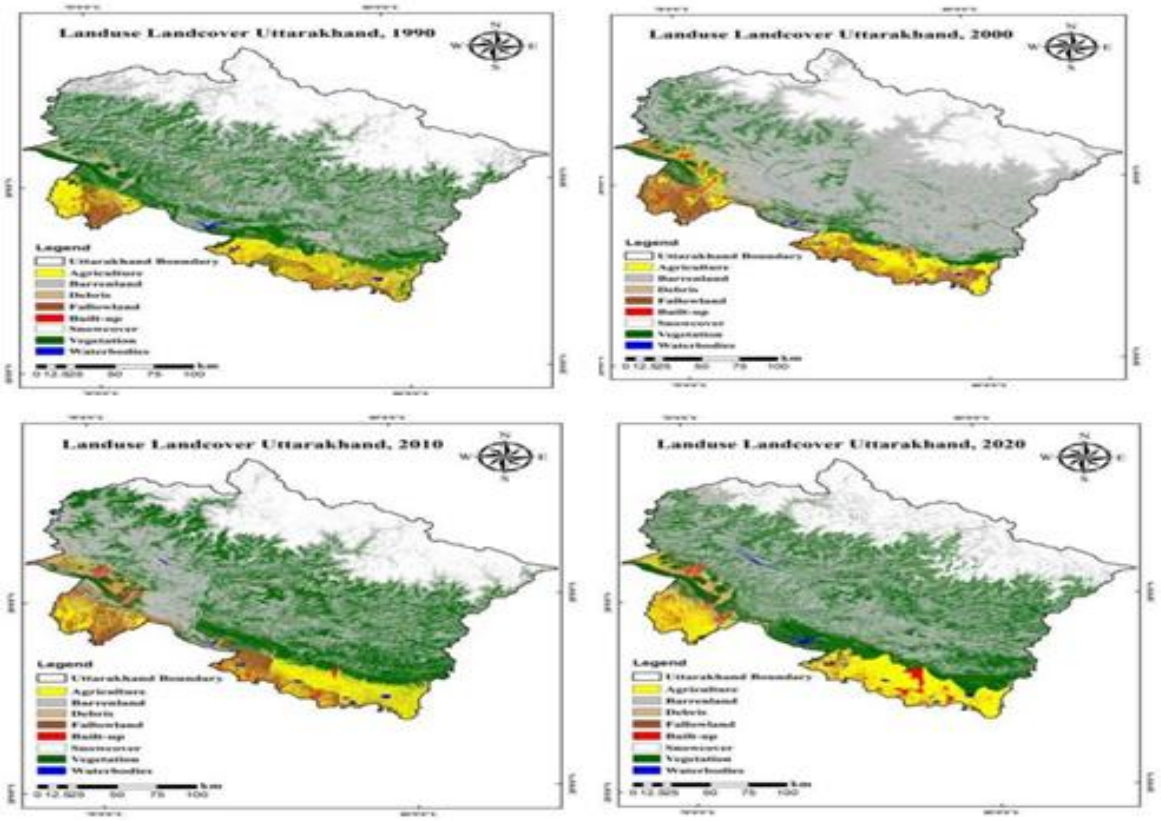
Landscape Alteration

Landscape alteration in the State of Uttarakhand can be understood in terms of land use/ land cover changes over the period of 1990-2020. The classes of land use/land cover taken for the present research study includes fallow land, agriculture land, built-up, snow cover, debris, vegetation, water bodies and barren land. Figure shows the land use/land cover in the study area during the years 1990, 2000, 2010 and 2020.

Table 1 shows fluctuating trend of land use/land cover for the period 1990-2020. The area under the 'fallow land' shows mix trend as land area increases initially from 3.50 percent (1990) to 5.3 percent (2000) then decreases gradually to 4.2 percent (2010) and finally dipping to 1.0 percent (2020). The agriculture land remains more or less constant around 6.8 percent for the years 1990, 2000 and 2010 and increases to 8.6 percent in the year 2020. Built-up shows inclined trend as the land area increases sharply from 0.47 percent (1990) to 1.08 percent (2020) and gradual increase to 1.0 percent (2010) and finally attaining the value of 1.6 percent (2020). The land area under snow cover shows declining trend with sharp decrease from 24.94 percent (1990) to 21.8 percent (2000) and then keeps rolling around 21.5 percent (2010) and 21.4 percent (2020). The 'Debris' show inclined trend with land area increasing

sharply from 1.11 percent (1990) to 2.9 percent (2020). The LULC category of vegetation shows mix trend with sharp decrease initially from 25.60 percent (1990) to 11.24 percent (2000) then increasing to 28.3 percent (2010) and finally attaining the value of 29.8 percent (2020). 'Water bodies' shows inclined trend with marginal increase in land area from 0.28 percent (1990) to 0.5 percent (2020). Barren land shows mix trend with sharp increase initially from 37.37 percent (1990) to 52.92 percent (2000) then decreases to 34.8 percent (2010) and 34.2 percent (2020).

Figure 02: Landscape alteration in the State of Uttarakhand (a) 1990 (b) 2000 (c) 2010 (d) 2020



Source: Landsat Imagery, 1990, 2000, 2010, 2020

Table 02: Uttarakhand, India: Land use/Land Cover Change during 1990-2020

LULC Classes	1990		2000		2010		2020	
	Area		Area		Area		Area	
	Hectare	%age	Hectare	%age	Hectare	%age	Hectare	%age
Fallow Land	187578	3.50	282886	5.3	225123	4.2	52000.2	1.0
Agriculture Land	360575	6.70	327025	6.8	372493	6.8	466132.2	8.6
Built-up	25410.4	0.47	58316.4	1.08	52568	1.0	86773.9	1.6
Snow Cover	1341460	24.94	1172139	21.8	1156050	21.5	1149610	21.4
Debris	59416.5	1.11	71357.6	1.3	159214	3.0	156511	2.9
Vegetation	1377620	25.60	604106	11.24	1520223	28.3	1601177	29.8
Water Bodies	15000.1	0.28	15372	0.29	18909	0.4	25105.7	0.5
Barren Land	2009880	37.37	2845738	52.92	1872360	34.8	1839630	34.2

Source: Calculated and compiled by the authors

Change Detection in Land Use/Land Cover Categories

The 'change detection' analysis shows that agriculture land (-0.62 percent), snow cover (-3.15 percent) and vegetation (-14.39 percent) have experienced negative change during 1990-2000. In other words, land area under the above-mentioned categories have decreased during 1990-2000. The decrease in land area is due to construction of houses (kachcha/pakka houses) in agriculture land. The encroachment of land for development activities like construction of roads is yet another factor responsible for substantial decrease in agriculture land. The fast pace of

urbanization and construction activities related to tourism sector like hotels, resorts, parks have led to speed up the process of deforestation and thus, vast stretches of forest were cleared confirming decrease in vegetation cover during 1990-2000. The decrease in land area under snow cover can be attributed to climate change and global warming which have resulted in shifting of snow line, melting of glaciers and other related impacts.

Table 03: Uttarakhand-'Change detection' land use/land cover categories, 1990-2020

LULC Classes	1990-2000		2000-2010		2010-2020	
	Change in Area		Change in Area		Change in Area	
	Hectares	%age	Hectares	%age	Hectares	%age
Fallow Land	95,308	1.77	-57,763	-1.07	-173,122.8	-3.22
Agriculture Land	-33,550	-0.62	45,468	0.85	93,639.2	1.74
Built-up	32,906	0.61	-5,748.4	-0.11	34,205.9	0.64
Snow Cover	-169,321	-3.15	-221,570	-4.12	-6,440	-0.12
Debris	11,941.1	0.22	11,941.1	0.22	-2,703	-0.05
Vegetation	-773,514	-14.39	916,117	17.04	80,954	1.50
Water Bodies	371.9	0.01	3,537	0.07	6,196.6	0.12
Barren Land	835,858	15.55	-973,378	-18.10	-32,730	-0.61

Source: Calculated and compiled by the authors

The 'change detection' analysis during 2000-2010 shows that scenario of landscape alteration becoming much faster and decrease in land area have been recorded in other land use/land cover categories other than those in 1990-2000. During the period 2000-2010, land area under fallow land (-1.07 percent), built-up (-0.11 percent), snow cover (-4.12 percent) and barren land (-18.10 percent) have decreased considerably. The decrease in fallow land can be explained in terms of agriculture land. The useless fallow land after ploughing and tilling was converted into agriculture land. Similarly, disasters like landslides destroy infrastructure and resulted decrease in land area under built-up. Moreover, age-old buildings are demolished as they can't stand impact of disasters. The activities like afforestation and re-afforestation were carried out which resulted decrease in land area under barren land category. The 'change detection' analysis during 2010-2020 shows entirely different scenario of landscape alteration and land area under categories viz. fallow land (-3.22 percent), snow cover (-0.12 percent), debris (-0.05 percent) and barren land (-0.61 percent). The land area under debris have experienced decreased due to one or the other reason.

Rate of Change Per Year of Land For Land Use/Land Cover Categories

The 'rate of change per year' of land during 1990-2000 was negative for agriculture land (-3355 hectares per year), snow cover (-16932.1 hectares per year), vegetation (-77351.4 hectares per year) and positive for fallow land (+9530 hectares per year), built-up (+3290.6 hectares per year), debris (+1194.11 hectares per year), water bodies (+37.19 hectares per year) and barren land (+83585.8 hectares per year). While during 2000-2010, fallow land, built-up and barren land experienced negative 'rate of change per year' of about -5776.3 hectares per year, -5748.4 hectares per year and -97337.8 hectares per year respectively. The 'rate of change per year' got catalyzed for 'snow cover' and there was a loss of land of about -22157 hectares per year. The categories of vegetation and agriculture land experienced positive 'rate of change per year' of about +91611.7 hectares per year and +4546.8 hectares per year. The 'rate of change per year' of land remains same for category 'debris'. During 2010-2020, the 'rate of change per year' of land gained pace for 'fallow land' with loss of -17312.28 hectares per year. On the other hand, loss of land from snow cover and barren land got slow down attaining value of - 644 hectares per year and - 3273 hectares per year. Contrary to this, agriculture land, built-up and water bodies experienced expansion at the rate of +9363.2 hectares per year, +3420 hectares per year and +619.66 hectares per year. Though the vegetation still experienced expansion but at a reduced rate of about +8095.4 hectares per year.

Table 04: Uttarakhand- 'Rate Of Change Per Year' of Land, 1990-2020

LULC Classes	'Rate of Change per year' of Land			
	1990-2000	2000-2010	2010-2020	1990-2020
	Hectares	Hectares	Hectares	Hectares
Fallow Land	+9530.8	-5776.3	-17312.28	-4519.3
Agriculture Land	-3355.0	+4546.8	+9363.92	+29177.6
Built-up	+3290.6	-5748.4	+3420.59	+2045.5
Snow Cover	-16932.1	-22157.0	-644.0	-6395
Debris	+1194.11	+1194.11	-270.3	+3236.5
Vegetation	-77351.4	+91611.7	+8095.4	+7451.9
Water Bodies	+37.19	+353.7	+619.66	+336.9
Barren Land	+83585.8	-97337.8	-3273.0	-5675

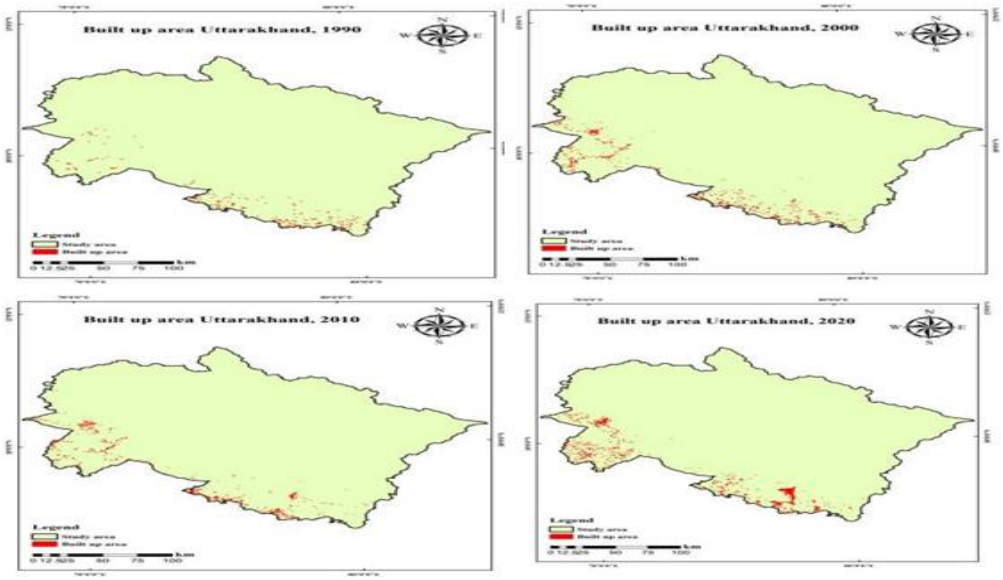
Source: Calculated and compiled by the authors

The overall 'rate of change per year' of land during 1990-2020, the expansion of land took place for agriculture land, built-up, debris, vegetation and water bodies at a rate of about +29177.6 hectares per year, +2045.5 hectares per year, +3236.5 hectares per year, +7451.9 hectares per year, and +336.9 hectares per year respectively. The categories which experienced negative rate of change were fallow land (-4519.3 hectares per year), snow cover (-6395 hectares per year), barren (-5675 hectares per year).

Built-up Expansion

Built-up in simple terms refers to all sort of cultural features like houses, buildings (both residential and commercial), roads, bridges. As per the table 02, built-up coverage in the study area was about 0.47 percent (1990), 1.08 percent (2000), 1.00 percent (2010) and 1.60 percent (2020). Thus, it can be observed that built-up expansion took place at an alarming pace and increased from 0.47 percent (1990) to 1.60 percent (2020). Talking about the 'change detection' (table 03) for built-up then positive growth of 0.61 percent was observed during 1990-2000 while during 2000-2010, built-up experienced negative growth of -0.11 percent due to afforestation or demolition of built-up structures due to natural hazards like landslides. Though the period 2010-2020, the category of built-up experienced alarming growth of 1.74 percent due to construction of houses under various governmental schemes, construction at tourist spots and other developmental processes like road construction. The land transformation took place at different pace during different time period. The 'rate of change of land per year' for built-up was about +3290.6 hectares during 1990-2000 and came down to -5748.4 hectares during 2000-2010. The land transformation again paced during 2010-2020 and +3420.59 hectares of land was gained by built-up category. On a whole, land transformation from other categories of land use/land cover to built-up took place at an alarming rate of +2045.5 hectares annually.

Figure 03: Built-up Expansion, Uttarakhand, 1990-2020



Recommendations/Suggestion

The built-up expansion due to unsustainable urbanization have resulted in 'anti-environmental' development causing unprecedented loss of ecological assets, biodiversity losses and habitat fragmentation. At this vary point, the concept of 'ecological urbanization' comes to rescue. According to this concept, urbanization need to be carried out without disturbing the natural environment in order to promote sustainable urbanization. This concept also helps in mitigating future implications like urban floods, micro-climatic changes (Yadav, 2020) due to present unsustainable urbanization. Now, the question arises that what are the ways through which we can promote 'ecological urbanization'? Answering this question, first we need to make 'green building certification' (LEED/GRIHA) for mega projects like construction of campuses of educational institutions, hospitals, hotels in order to promote 3R (Reduce, Reuse and Recycle) (Yadav et.al., 2020). Constructional activities on agricultural land need to be discouraged in order to ensure good food production. Adoption and promotion of ecotourism in order to cause minimum possible damage to environment and wildlife. In addition to this, use of electric vehicles needs to be promoted in order to minimize vehicular pollution and promote sustainability for one and all.

Conclusion

The unsustainable and unprecedented growth of urbanization in the study area has led to disturbance in ecological balance. The cascading effect of ecologically disturbed surroundings can be seen in the form of intensification and increased frequency of disasters like forest fires, landslides, mud flow. In addition to this, enormous built-up expansion has altered local heat budget in the study area which in lieu have led to change in pattern of snowfall and other prominent activities. Under such circumstances, the community people along with concerned governmental authorities need to opt sustainable and eco-friendly ways of development in order to promote sustainable urbanization, environmentally friendly activities, horticulture and many other practices to restore the ecological balance.

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