Cloud Publications
International Journal of Advanced Remote Sensing and GIS
2013, Volume 2, Issue 1, pp. 351-362, Article ID Tech-162
ISSN 2320 - 0243

Research Article **Open Access**

Tracing the Changes in the Pattern of Urban Landscape of Dehradun over Last Two Decades using RS and GIS

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Publication Date: 31 October 2013

Article Link: http://technical.cloud-journals.com/index.php/IJARSG/article/view/Tech-162

Abstract Impact of population explosion is clear on urban landscape of not only metropolitan cities but also on small and medium towns of India. Dehradun, the interim capital of Uttrakhand state, India also witnessed tremendous developments over last two decades. It alters the landscape pattern of the city. In this study, changes in the landscape pattern of Dehradun city and surroundings has been explored using Landsat TM image of 1986 and IRS-1C/1D LISS III image of 1998 and 2011. For this purpose, the calculation of the metrics i.e., percentage of landscape (PLAND), number of patch (NP), mean patch size (MPS) have been carried out with public domain software– *Fragstatsver 4.1*. The results of the study highlights the three fold increase in the built-up area with drastic decrease in river/ water body and open spaces during 1986-2011. The built-up growth was higher between 1986-1998 in comparison to 1998-2011. Also, availability of built-up area available per 1000 persons has increased from 8.5 ha in 1986 to 11.5 ha in 2011. It may be due to the people interest to invest in property as a safe means because of weak economic conditions.
Keywords *Land Use/Land Cover; Urban Landscape; Spatial Metric*

1. Introduction

Landscapes are geographic areas identified by interacting patches or ecosystems and human activities within them [1, 2]. Urban areas have highly fragmented and heterogeneous landscapes shaped by environmental processes and socio-economic drivers [3]. The urban centers are undergoing a constant landscape change due to the pressure of population. Changes in the urban landscape highlight the association of land use/ land cover structure and function. Composition of the urban landscape must be considered explicitly to facilitate the understanding of causes and mechanisms of these changes over the time. A delineation of the landscape into discrete patches serves as a basis for calculating metrics that describe landscape fragmentation, connectivity or human influences [4, 5]. These simple quantitative indices can be used to objectively quantify the structure and pattern of an urban environment by computing them directly from thematic maps [6].

The combination of remote sensing and geographical information system provides opportunities in representing and understanding the changes in complex urban structure. Landscape metrics integrated with the conventional change detection techniques would help in monitoring land use changes [7, 8]. Adopted from landscape ecology, where they are termed landscape metrics [9, 10, 6], recent studies have employed spatial metrics in urban landscape. Analysis results of landscape indices between spatial patterns and processes can be used to inform planners or researchers about landscape functions, which sometimes are difficult or impossible to measure directly [11]. FRAGSTATS is a computer software program designed to compute a wide variety of landscape metrics for categorical map patterns [12].

Nesting on the foot hills of Himalaya, Dehradun city resides in eco-sensitive zone. It has undergone rapid economic development and urbanization over the past decades after becoming the interim capital of newly formed state Uttrakhand in the year 2000. The objectives of this study are twofold: first, quantifying spatial and temporal changes of landscape patterns in Dehradun and surroundings; secondly, anthropogenic influence on the availability of spaces. It may improve our understanding of the patterns of urbanization in the Dehradun and its vicinity as well as provide key information for decision making and management of natural resources. In this study, landscape pattern has been explored through PLAND, MPS and NP spatial metrics. These metrics provide a comprehensive view of landscape pattern including area, compactness/ size and number of patches.

2. Literature Review

The process of global urbanization is accelerating and has potentially large influences on landscape and ecosystem function in cities and surrounding areas [13, 14, 15, 16]. Landscape change associated with urbanization, particularly urban sprawl, has been significant during the last half century and is expected to continue through the next decades [17, 18]. The expansion of urban areas contributes significantly to regional and global environmental change [18, 19, 20, 21]. Quantitatively exploring the causes and effects of urban land-use and land-cover dynamics is important because spatial patterns can be used to assess environmental impacts of various urban planning, policy, and management schemes at landscape and regional levels [16].

Spatial metrics are quantitative measurements to describe spatial heterogeneity. The characterization of urban patterns through indices is not new, although different types of indices are created and used for different purposes [22, 23]. Hundreds of metrics are available on the basis of shape, complexity and interspersion etc. However, some authors have reported that very few of these metrics contain unique information and thus the calculation or reporting of all of them is redundant [9]. The most commonly used metrics for urban studies are class area [23, 24, 25], percentage of landscape [27, 24, 28]; edge density [27, 25, 29, 26], landscape shape index [30, 29], mean patch size [30, 25, 29, 28], number of patches [25, 26], and largest patch index [29, 31]. When applied to multi-scale or multi-temporal datasets, spatial metrics can be used to analyze and describe change in the degree of spatial heterogeneity [27].

3. Study Area

Study area, Dehradun city lies at latitude 30º19’N and longitude 78º20’E. It is one of the most picturesque valleys and one of the most important towns of Uttarakhand state of India. The most striking physical features of the valley is its natural physical features viz. the Himalayan range of mountains in the north, the Shiwalik mountain ranges on the south, river Ganga on the east and river Yamuna on the west. The city is located at an altitude of 696m above mean sea level.

Dehradun is the administrative centre and the interim capital of the newly formed state of Uttarakhand. Dehradun is situated at the Himalayan foot hills in the fertile Doon Valley. It is famous for agriculture products like Basmati rice as well as mango and litchi fruit trees. The valley is well known for its salubrious climate and natural beauty.

A cursory scan on the landscape of the Dehradun City shows that the physical growth of the city is governed by its topography. There has been growth and development of the city because of the establishment of many national institutes. Consequently the road network has been developed to match the growth in-spite of many constraints including terrain conditions. Presence of several places of interest in and around the city attracted tourists from rest of the country.

4. Data Used & Methodology

Data used for this study includes Landsat TM image of 17th April 1986 and IRS-1C/1D LISS III image of 28th October 1998 and 8th October 2011 to trace the changes in the urban landscape over the period of time.

Image-to-image registration has been performed to bring the entire image in the same geometry (projection- UTM and datum- WGS 84) with sub-pixel accuracy. After the registration, all three images were classified into five Land use/ Land Cover (LULC) categories including built-up, forest, green spaces, open spaces and river. The term *green spaces* in the city are used to mean the vegetation cover, which includes trees, shrubs, gardens etc. It excludes other hard paved *open spaces* including stadium, playground, vacant land, fallow/ barren land etc. The term *forest cover* intends to *protected forest* in the vicinity of the city. Vegetation has a different colour from other hard paved open spaces in the multi-spectral image and easier to extract using digital classification techniques.

In this study, supervised classification has been carried out along with the hybrid approach to improve the classification accuracy. Masking for manual editing has been performed on perennial/dry river and forest classes to segregate it from built-up and green spaces within the city respectively. These classified images were input for the further analysis in the *ArcGIS* and *Fragstat software*. The amount of green spaces have been quantified within the 7 buffer zone of 1 km from city center to find the pattern of changes in the green spaces due to influence of population. Also, landscape pattern has been explored through PLAND, MPS and NP spatial metrics.

5. Results and Discussion

5.1. Change in Land use/ Land cover

The pattern of urban growth in Dehradun is influence of the topography and socio-economic structure of people. Here, urban growth includes extension of residential, commercial services, industrial, transportation, communications activities resulting in the expansion of built-up area. Figure 1 shows the classified image of three time period for the study area. Table 1 shows the pattern of urban landscape and its changes during 1986-1998-2011. The built-up area in Dehradun and surroundings was 2837.60 ha, which was 12.83% of the study area in the year 1986. It increased to 4337.58 ha (19.61%) in 1998 and 8244.90 ha (37.27%) in 2011. In the last two decades, built-up area has increased more than three fold. Most of the developments have been taken place on open spaces, and it has shown maximum decrease (4367 ha) in last two decades i.e. 1986-2011. It is also supported by growth rate as built-up increased with a rate of 4.27%; open spaces decreased with a rate of -5.00%. The growth rate of built-up was higher during 1998-2011 in comparison to 1986-1998. Dehradun became the capital of newly formed state of Uttrakhand in the year 2000. This is a major reason for the high growth rate during 1998-2011 apart from the natural growth and rural-urban migration. The extent of built-up has increased with the compactness in the city center. It is contributing significantly in the environmental condition deterioration as well as urban heat island.

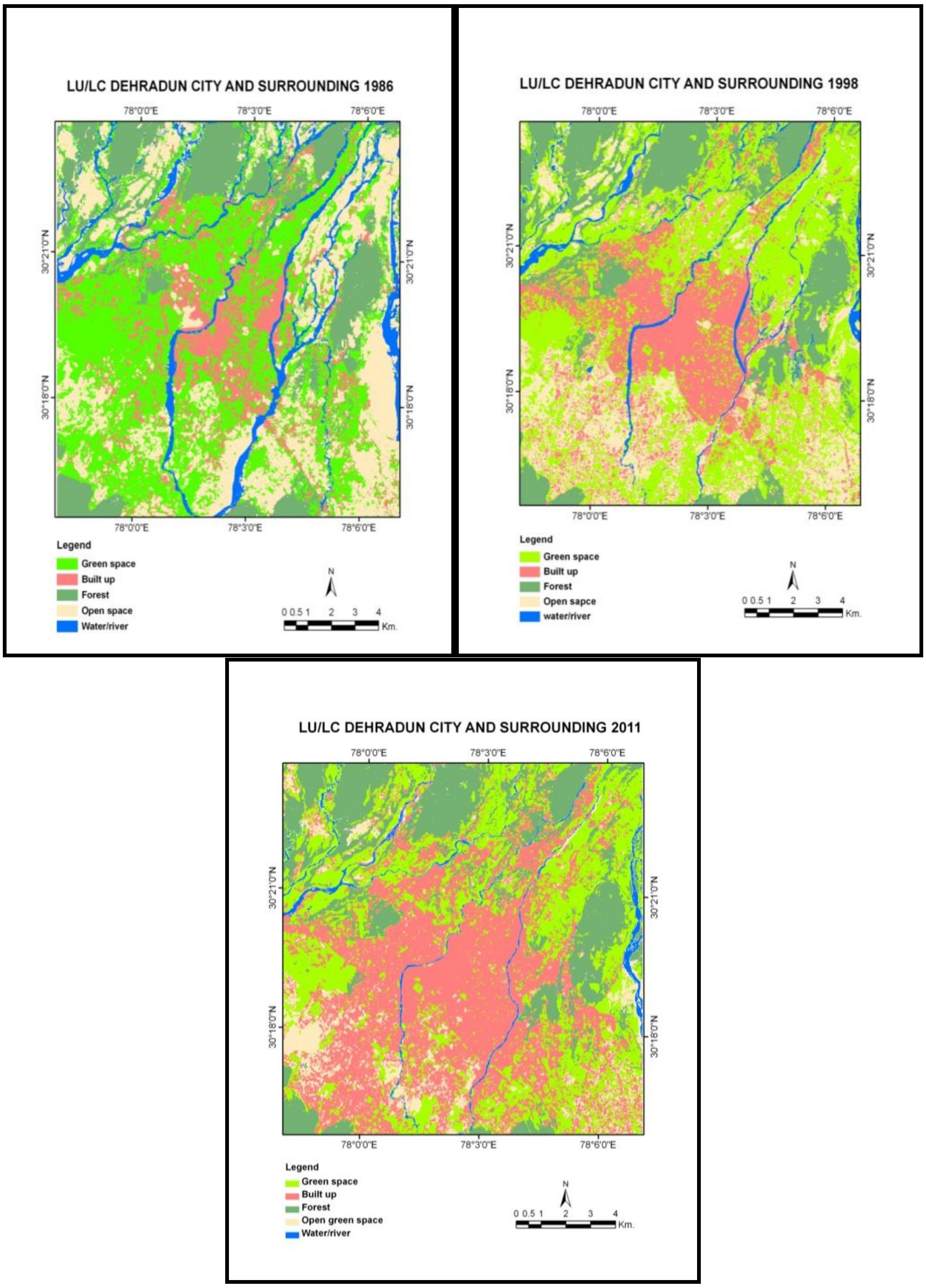


Figure 1: *Classified Image of Dehradun and Its Environment for the Year 1986, 1998 and 2011*

Figure 2 (a) compares the distribution of LULC categories in urban landscape during 1986, 1998 and 2011. The total area under green space in the year 1986, 1998 and 2011 was 8024.95 ha, 8491.98 ha, and 6883.97 ha respectively. Green space exhibits slight increase from 1986 to 1998 with the rate of 0.47%, whereas negative growth was observed during 1998 to 2011 with a rate of -1.61% (Figure 2 (b)). Overall, green spaces observed a decrease over last two decades. Area under forest cover increased slightly about 744.94 ha (3.37%) and 312 ha (1.41%) during 1986-1998 and 1998-2011 respectively.

Protected Forest towards north and south maintains the status of greenery in the vicinity of the Dehradun city.

Table 1: *Statistics Showing the Pattern of Urban Landscape and Its Changes during 1986-1998-2011*

Classification	Y1986		Y1998		Y2011		Y1986-1998		Y1998-2011		Y1986-2011	
/ Year	Area (ha.)	%	Area (ha.)	%	Area (ha.)	%	Changes	%	Change	%	Change	%
Built up	2837.6	12.83	4337.58	19.61	8244.9	37.27	1499.98	6.78	3907.32	17.66	5407.29	24.44
Forest	3578.93	16.18	4323.88	19.55	4635.89	20.96	744.94	3.37	312.01	1.41	1056.96	4.78
Green space	8024.95	36.28	8491.98	38.39	6883.97	31.12	467.03	2.11	-1608.01	-7.27	-1140.98	-5.16
Water/river	1558.62	7.05	925.13	4.18	602.68	2.72	-633.49	-2.86	-322.45	-1.46	-955.94	-4.32
Open space	6120.2	27.67	4041.74	18.27	1752.88	7.92	-2078.46	-9.4	-2288.86	-10.35	-4367.32	-19.74
Total	22120.31	100	22120.31	100	22120.31	100						

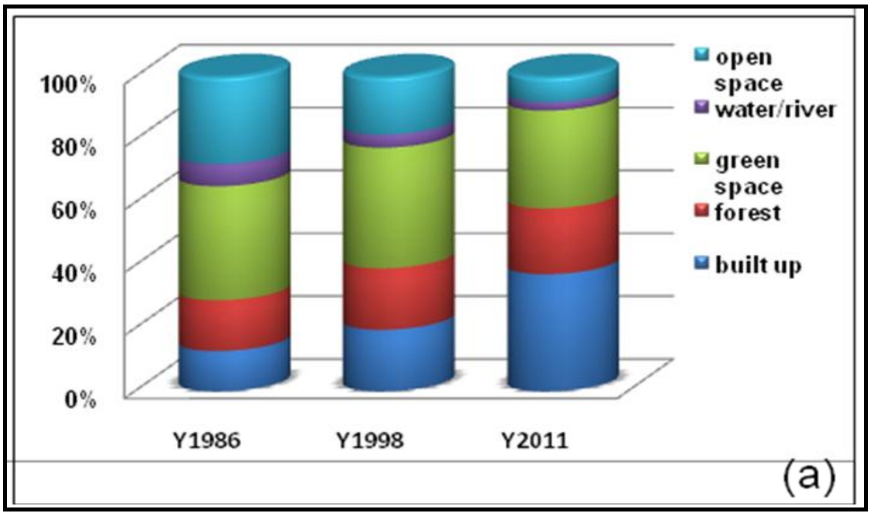


Figure 2 (a): *Comparison of Land Use Pattern during 1986-1998-2011*

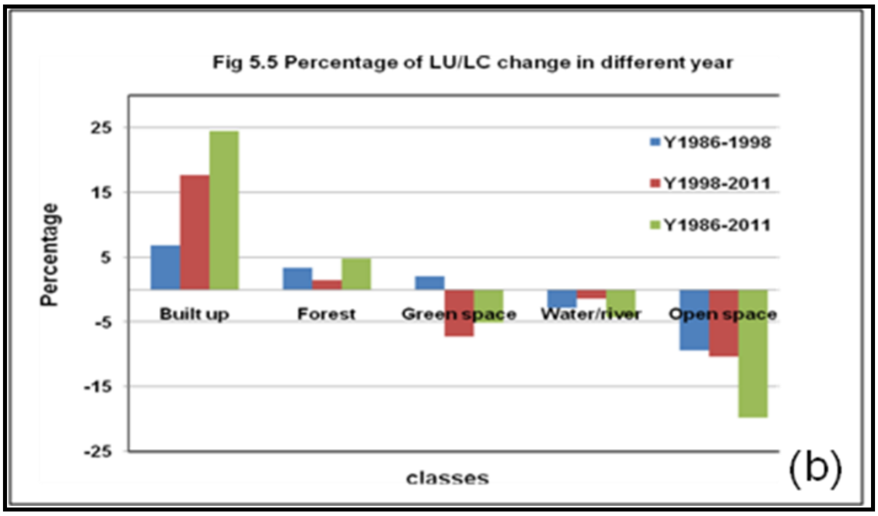


Figure 2 (b): *Percentage of LU/LC Change in Different Year*

The alarming changes have been observed in the river-bed during last two decades as the area under this category is reduced by 955.94 ha, which is about 4% of the study area. The major reason for this is encroachment on the river-bed. Most of the encroachment in the river bed is un-authorized developments with the low standard of living of the people due to a low level of income. It results in the problems of destruction of natural landscape, inadequate open spaces, environmental degradation and lack of appropriate amenities. The rate of encroachments in river bed was higher during 1986-1998 in comparison to 1998-2011. It causes a decrease in the area under riverbeds with a rate of 2.86% during 1986-1998 and 1.46% during 1998-2011.

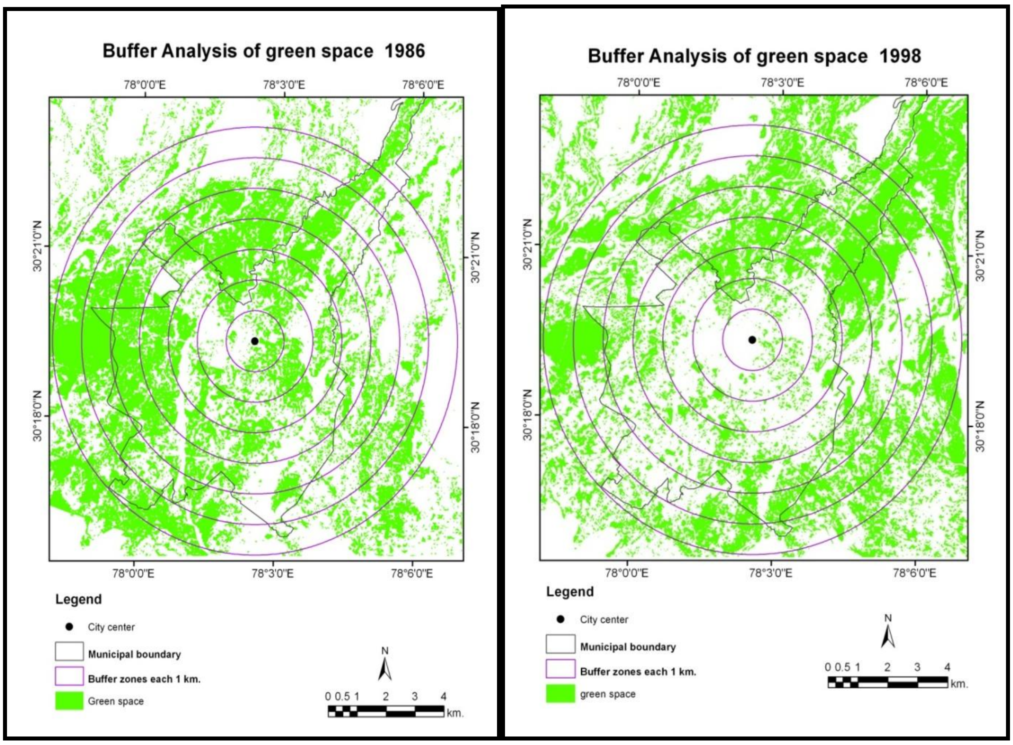
The major obstacle in improving the urban landscape is largely associated with the limitation of plan implementation due to lack of political will and effective administration. In developing countries, where the most rapid urban growth is occurring, urban policy structures are often weaker than those in the developed world because of a lack of expertise, holistic environmental assessments, and scientific support in the decision making process [16].

5.2. Green Spaces within Different Buffer Zones

Due to urban agglomeration, the view of the countryside from the town, a symbol of pre industrial dependence has disappeared and size of cities are increasing at faster rate. The proximity of green spaces has been studied through the seven buffer of 1 km around the city centre (clock tower) to check the quality of urban environment (Figure 3). The statistics derived from the same is given in Table 2 and Table 3. There is a drastic decrease in the percentage of green spaces within 1 km buffer zone, from 34.62% in 1986 to 7.78% in 1998 and 2.81% in 2011. Changes up-to 32% has been observed in the first four buffers during 1986-2011. It highlights compact development pattern up-to 4 km from city center.

Table 2: *Concentration of Green Spaces within 7 Buffer Zones of 1 km from City Center*

	1 km.		2 km.		3 km.		4 km.		5 km.		6 km.		7 km.	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Y1986	108.75	34.62	383.42	40.68	712.48	45.36	1113.77	50.65	1445.76	51.13	1361.61	39.4	1397.51	34.22
Y1998	24.44	7.78	164.33	17.44	443.62	28.24	851.88	38.74	1256.2	44.43	1542.46	44.64	1799.88	44.07
Y2011	8.89	2.81	84.23	8.94	264.25	16.82	447.07	20.33	910.85	32.22	1279.92	37.04	1594.46	39.04



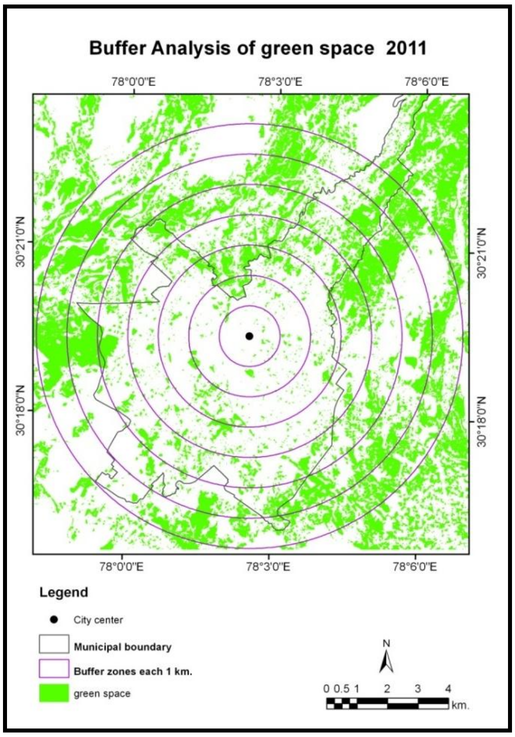


Figure 3: *Distribution of Green Spaces within 7 Buffer Zones of 1 km from City Center for the Year 1986, 1998 and 2011*

The area under the green spaces decreased in the buffer zones up to 5 km during the period 1986 to 1998 and 2011. But there is an increase in the amount of green spaces from 1361.61 ha to 1542.46 ha (buffer zone 5-6 km) and 1397.51 ha to 1799.88 ha (buffer zone 6-7 km) during the year 1986-1998. From 1998 to 2011, amount of green spaces decreased from 1542.46 ha to 1279.92 ha in the buffer zone 5-6 km and 1799.88 ha to 1594.46 ha in the buffer zone 6-7 km from city center. The percentage of green spaces increases with the distance from the city center. Concentration of green spaces, more or less, follows the pattern of municipal boundary. Most of the green spaces are concentrated just outside the municipal boundary.

Table 3: *Changes in the Pattern of Green Spaces from City Center*

Year	1km		2km		3km		4km		5km		6km		7km	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
1986-1998	-84.31	-26.84	-219.09	-23.25	-268.86	-17.12	-261.89	-11.91	-189.57	-6.7	180.85	5.23	402.38	9.85
1998-2011	-15.55	-4.95	-80.1	-8.5	-179.36	-11.42	-404.81	-18.41	-345.35	-12.21	-262.54	-7.6	-205.42	-5.03
1986-2011	-99.86	-31.79	-299.19	-31.75	-448.22	-28.54	-666.7	-30.32	-534.91	-18.92	-81.69	-2.36	196.96	4.82

High changes in the city center exhibits the anthropogenic influence on the structure and availability of green spaces. It is due to the cutting of the roadside trees for road widening, construction activities to meet the demand of increasing population.

5.3. Population vs. Built Up and Green Spaces

As per the Census of India, population of Dehradun urban agglomeration was 293010 in 1981, 367411 in 1991, 560120 in 2001 and 714223 in 2011. This is used to calculate the population growth rate, and further for the projection of population for the year 1986 and 1998. Population of Dehradun city is projected to 332672 in 1986 and 530400 in 1998. While analyzing population growth, population grew at an average annual growth rate of 4.95 % during the period 1986-1998 and growth rate was relatively slow to 2.67 % in 1998-2011. Opposite of this, built up growth was less between 1986-1998 but very high between 1998-2011.

Table 4: *Availability of Built-Up and Green Spaces per Thousand Persons*

Year	Population	Built up Area (ha)	Density Persons/ ha	Built-up/1000 persons (ha)	Green Area	Density Persons/ha	Green Spaces/1000 Persons (ha)
1986	332672	2837.6	117	8.53	8024.95	41	24.12
1998	530400	4337.58	122	8.18	8491.98	62	16.01
2011	714223	8244.9	87	11.54	6883.97	104	9.64

Figure 4 depicts the relationship between population and built-up as well as green spaces. According to this, built-up area increased three fold from 2837 ha in 1986 to 8244.9 ha in 2011. Also, availability of land per 1000 persons increased from 8.53 ha (in 1986) to 11.54 ha (in 2011), as given in Table 4. Increase in land availability per thousand persons indicates towards the less concentration of population within the existing built-up area. This is also an indicator of new developmental activities in the city.

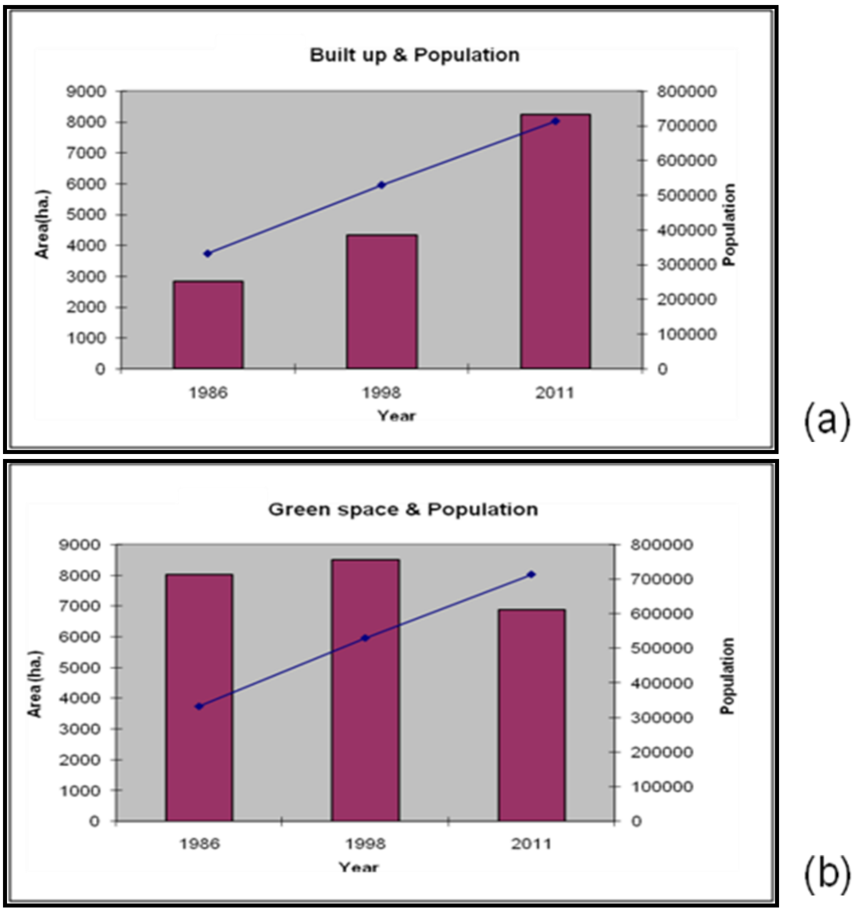


Figure 4: *Comparison of Population Change with the (a) Built-Up (b) Green Spaces*

This has a direct impact on the availability of the green spaces (Figure 2). The area under green spaces in 1986, 1998 and 2011 was 8024.95 ha, 8491.98 ha, and 6883.97 ha respectively. The amounts of green space available per 1000 persons were 24.12 ha in 1986, which get reduced to 16.01 ha in 1998 and further to 9.64 ha in 2011 respectively in the study area. Within the city, most of the green spaces are concentrated in the premises of government institutions.

5.4. Changes in the Pattern of Urban Landscape

Percentage of LU/LC change during 1986, 1998 and 2011 is given in Figure 2 (b). The pattern of urban landscape has also been explored through spatial metrics. The calculation of the metrics i.e., percentage of landscape (PLAND), number of patch (NP), mean patch size (MPS), has been carried out with public domain software– Fragstats version 4.1. Table 5 gives the value of landscape metrics derived for all five LULC categories. It reveals the pattern of urban landscape over the last two decades.

Table 5: *Value of PLAND, NP and MPS Metrics for Different LULC Classes*

	PLAND			NP			MPS		
	Y1986	Y1998	Y2011	Y1986	Y1998	Y2011	Y1986	Y1998	Y2011
Built up	13.32	19.57	36.93	2969	7468	2859	0.99	0.59	2.86
Forest	16.15	19.37	20.95	801	1850	1735	4.45	2.34	2.68
Green space	36.26	37.96	31.07	2458	4290	3145	3.25	1.98	2.19
Water/River	7.00	4.16	2.73	480	2510	731	3.22	0.37	0.83
Open Space	26.81	18.58	8.16	1645	4868	2993	3.59	0.85	0.60

The pattern of urban landscape depicts high degree of fragmentation in the year 1998. Whereas, compactness has been observed in the pattern of 1986 and 2011 built-up as well as green spaces. Decrease in the open spaces is also clear from PLAND and MPS value of the same. Though, PLAND of forest has increased from 1986 to 2011, the low MPS and high NP during the period indicates towards the fragmentation in the forest cover.

6. Conclusion

Remote sensing provides spatially consistent data sets that cover large areas with high spatial, spectral and temporal frequencies to detect, quantify and analyze temporal changes in urban landscape. Spatial metrics are useful for quantifying structure and pattern of urban landscape. It has been found that a combination of remote sensing and spatial metrics leads to an improved understanding and representation of urban dynamics and can help to develop alternative conceptions of urban spatial structure and change, thus supporting the modeling of change processes. The pattern of urban landscapes in Dehradun has been modified from the concentric zone pattern to a patchy urban form with multiple centers of specialized land uses. The development pattern of the city is governed by the topography as well as transportation network. Built-up area in Dehradun increased three fold during 1986-2011 with the increase in the availability of land per 1000 persons. This is due to the change in the status of Dehradun from institutional and tourist city (prior to 2001) to an administrative city (post 2001). This change has witnessed the conversion of fertile agriculture land into vacant open spaces and further its conversion into built-up area. Comparison of PLAND, NP and MPS metrics reveals the dispersed/fragmented development in 1998 with large NP and low MPS value. Built-up area has high value of PLAND and MPS in 2011, which indicates towards the urban agglomeration during last one decade. Thus, there is a need for landscape planning to minimize the impact of urbanization on environments well as to preserve fertile agriculture land.

Acknowledgment

Sawitree Laphawan expresses her sincere gratitude to Center of Space Science and Technology Education in Asia Pacific (CSSTEAP), Dehradun, India for the fellowship to pursue the Post Graduate Diploma Course. Author's area also thankful to Indian Institute of Remote Sensing, Dehradun, India for providing infrastructural support.

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