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Research Article

Land Use/Land Cover Change Study of District Dehradun, Uttarakhand using Remote Sensing and GIS Technologies

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Abstract The present study illustrates an integrated approach of geospatial technologies, i.e., remote sensing and GIS for assessment of land use/cover dynamics of a district of the Uttarakhand State viz., the Dehradun. Landsat satellite imageries of three different years, i.e., Landsat Thematic Mapper (TM) of 1994, 1999 and 2016 were acquired by USGS Earth Explorer and quantified the land use/cover changes in district Dehradun for a period of more than two decades. Supervised Classification methodology has been employed using Maximum Likelihood Technique in ERDAS 9.3. The images of the study area were categorized into six different land us/land cover classes, viz., vegetation area (in 61.47% area), agricultural land (17.61%), built-up area (6.82%), barren area (5.91%), sediment area (5.67%) and area under water body (2.53%). The results indicate that during the last twenty two years (1994-2016) the vegetation area, built-up area, barren land and sediment area have been increased about 163.67 km^2, 110.78 km^2, 83.69 km^2 and 78.55 km^2, respectively, while the agricultural land and water body have been decreased about 366.78 km^2 and 67.91 km^2, respectively. The approach adopted in this study has clearly demonstrated the potential of remote sensing and GIS techniques in measuring the change pattern of land use/cover.
Keywords *Change detection; Geospatial Technologies; Remote Sensing; GIS; District Dehradun*

1. Introduction

The land is one of the most important natural resources as life and various development activities are based on it. Land cover is a fundamental parameter describing the Earth's surface. This parameter is a considerable variable that impacts on and links many parts of the human and physical environments (Torrens and Alberti, 2000; Barnes et al., 2001). Land use refers to human activities which are directly related to the land (Epstein et al., 2002). Land use involves the management and modification of natural environment or wilderness into built environment such as fields, pastures, and settlements. Land use/land cover (LULC) changes are driven by natural forces or by human land uses. Thus, it involves both the natural and the human dimensions. Information on LU/LC is important to support planning and sustainable management of natural resources and socio-economic development (Rawat et al., 2013a; b; Zubair et al., 2006).

The land is one of the most important natural resources, as life and various development activities are based on it. Land-cover change has been identified as one of the most important drivers of changes in the ecosystem and their services.

Locally, the land cover changes due to an environment or climatic factors determine the vulnerability of people to climatic perturbations and thus affect the decisions on land use by people. Globally, on the other hand, the land cover changes significantly affecting the functioning of Earth's system. Hence, information on land use/land cover is essential for the selection, planning and implementation of land use and can be used to meet the increasing demands for basic human needs and welfare. This information also assists in monitoring the dynamics of land use resulting out of changing demands of increasing population. Changes in land cover by land use patterns, affects biodiversity, water and other processes that come together to affect climate and biosphere. Changes in LU/LC now have become the central component in current strategies for managing of the land use pattern in any area (Abdelhamid et al., 2006; Ye Bai et al., 2008; Lo Yang et al., 2002; Cohen et al., 2006; Heuvelink and Burrough et al., 2002).

LU/LC change detection is very essential for better understanding of landscape dynamic during a known period of time having sustainable management (Kiefer et al., 1987; Zhang et al., 2011) and to asses loss and ecosystem disturbances (Rawat, 2016). LU/LC change is a widespread and accelerating process, mainly driven by natural phenomena and anthropogenic activities, which in turn drive change that would impact natural ecosystem. Timely and precise information about LULC change detection of Earth’s surface is extremely important for understanding relationships and interactions between human and natural phenomena for better management of decision making (Pontius and Malanson et al., 2005; Jokar et al., 2013).

Research conducted in Ethiopia has shown that there were considerable LULC changes in the country during the second half of the 20th. Timely and precise information about LULC change detection of Earth’s surface is extremely important for understanding relationships and interactions between human and natural phenomena for better management of decision making (Krivoruchko and Redlands et al., 2005). Recent LU/LC studies in the Uttarakhand State in Central Himalaya reveals that due to population pressure, towns are growing indiscriminately on the highly fertile agricultural lands (Rawat et al., 2013a;2013b;2013c;2013d; 2014)

The present study aims to demonstrate application of geospatial technologies, i.e., remote sensing and GIS in land use/ land cover study and to define its dynamics since the last few decades.

2. Material and Methodology

2.1. Study Area

The study area, viz., district Dehradun is one of the total thirteen districts of the Uttarakhand state (Figure 1) where the capital of the State –Dehradun lies. District Dehradun, encompassing an area of 3088.50 km^2, extends in between 29^o 57’56.44” N to 31 ^{o}1’127.13” N Latitudes and 77^o 38’19.57” E to 78.1424.53” E Longitudes. The elevation of the district varies in between 288 m to 3096 m from the mean sea level. Attitudinally about one-third part (i.e., 32.43% area) of the district lies in between 600m to 1200m relief region while a small part (3.55% area) lies in the relief zone more than 2400m. The district has 6 development blocks, 6 tehsils and 771 villages with population of 5, 69,578 having a population density of 184 persons/km^2 (SH, 2011)

2.2. Data Process and Data Use

The LANDSAT is a scientific program which is operated by NASA and USGS, which offers the longest global record of Earth's surface. The satellite data used in the present study includes the imagery of LANDSAT-5 "TM", LANDSAT-7 "ETM" And LANDSAT-8 "OLI" & "TIRS" Sensor.

The LANDSAT-5 imagery is of February 1994, LANDSAT-7 imagery is of March 2000, and LANDSAT-8 is of February 2016 with the resolution of 30m nominal and panchromatic resolution is 15m. Map projection used in "UTM" datum "WGS84" and UTM zone is 44.

2.3. Software used

In this study, ERDAS IMAGINE-9.3 remote sensing application with raster graphics editor abilities designed by ERDAS is used. ERDAS IMAGINE is aimed primarily at geospatial raster data processing and allows the user to prepare, display and enhance the digital image for mapping use in GIS or software.

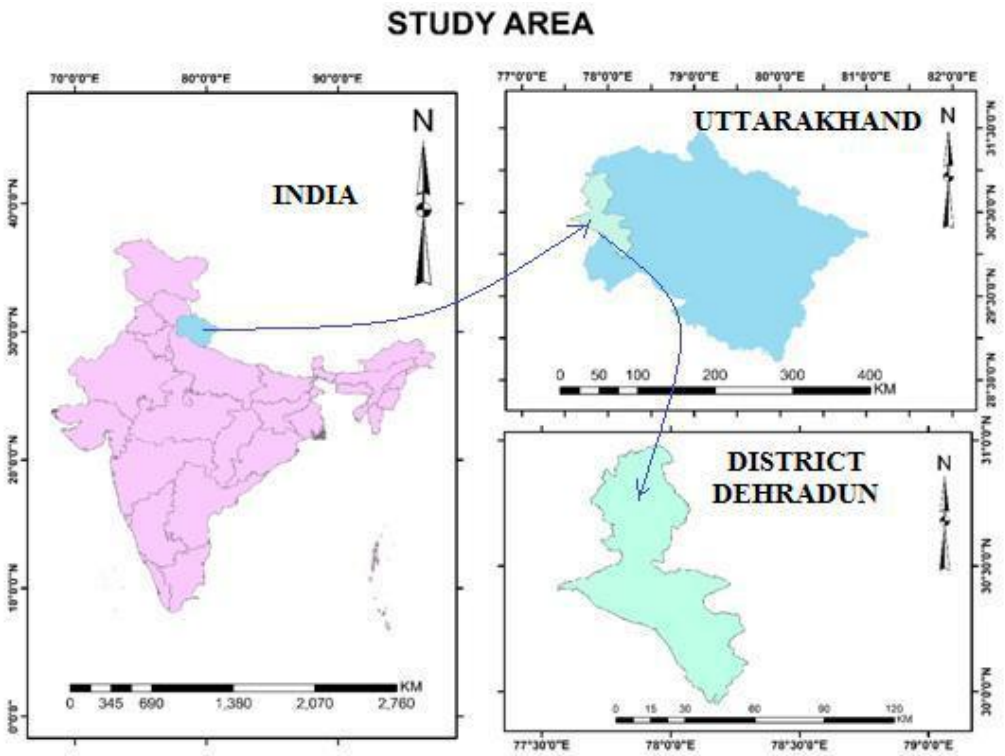

Figure 1: *Location map of the study area, viz., Dehradun District*

2.4. Image Classification

Multispectral classification is the process of sorting pixels into a finite number of individual classes or categories of data, based on their data file values. If a pixel satisfies a certain set of criteria, the pixel is assigned to the class that corresponds to that criterion. This process is also referred to as image segmentation. Depending on the type of information to be extracted from the origin data, classes may be associated with known features on the ground or may simply represent areas that look different to the computer. An example of a classified image is a land cover map, showing vegetation, bare land, pasture, urban and so forth. In this study we have used supervised image classification map, one common application of remotely-sensed images to land management is the creation of maps, vegetation type, or other discrete classes by remote sensing software. The flow chart (Figure 2) illustrates methodology used in this paper which includes data used and different steps of data processing.

2.5. Accuracy Assessment

In the context of information extraction by image analysis, accuracy measures the agreement between a standard assumed to be correct and a classified image of unknown quality (Singh et al., 2013). The accuracy of image classification is most often reported as a percentage correction. The consumer's accuracy (CA) is computed using the number of correctly classified pixels to the total number of pixels assigned to a particular category.

It takes errors of the commission into account by telling the consumer that, for all areas identified as category X, a certain percentage are actually correct. The producer's accuracy (PA) informs the image analyst of the number of pixels correctly classified in a particular category as a percentage of the total number of pixels actually belonging to that category in the image. Producer's accuracy measures errors of the omission.

2.6. Error Matrix

One of the most common means of expressing classification accuracy is the preparation of a classification error matrix. Error matrices compare, on a category by category basis, the relationship between known reference data (ground truth) and the corresponding result of an automated classification. Such matrices are square, with the number of rows and columns equal to the number of categories whose classification accuracy is being assessed. Overall accuracy is computed by dividing the total number of correctly classified pixels by the total number of reference pixels. The accuracies of individual categories can be calculated by dividing the number of correctly classified pixels in each category by either the total number of pixels in the corresponding row and column. Producers accuracies result from dividing the number of correctly classified pixels in each category (on the major diagonal) by the number of training set pixels used for other categories (the column total). User accuracy is computed by dividing the number of correctly classified pixels in each category by the total number of pixels that were classified in that category (the row total).

3. Results and Discussion

3.1. Land use/Land Cover

LULC categories for three different years (i.e., 1994, 2008 and 2016) were assessed using remote sensing and GIS techniques. The results are presented in Figure 3 and Table 1. A brief account of year wise discussion of these results is presented in the following paragraphs.

3.1.1. LULC in 1994- The satellite image of the study area, classification of different LULC of district Dehradun for the year 1994 is presented in Figure 3 (left). In 1994 about 1734.15 km^2 which accounts for 56.17% of the total district area was under vegetation cover, about 910.45 km^2 which accounts for 29.48% was under agricultural land, about 99.76 km^2 which accounts for 3.23% was under built up area, about 98.76 km^2 which accounts for 3.20% was under barren land, about145.98 km^2 which accounts for 4.73% was in water body and the remaining about 98.45 km^2 which accounts for 3.19% of the total district area was under sediment area (Table 1).

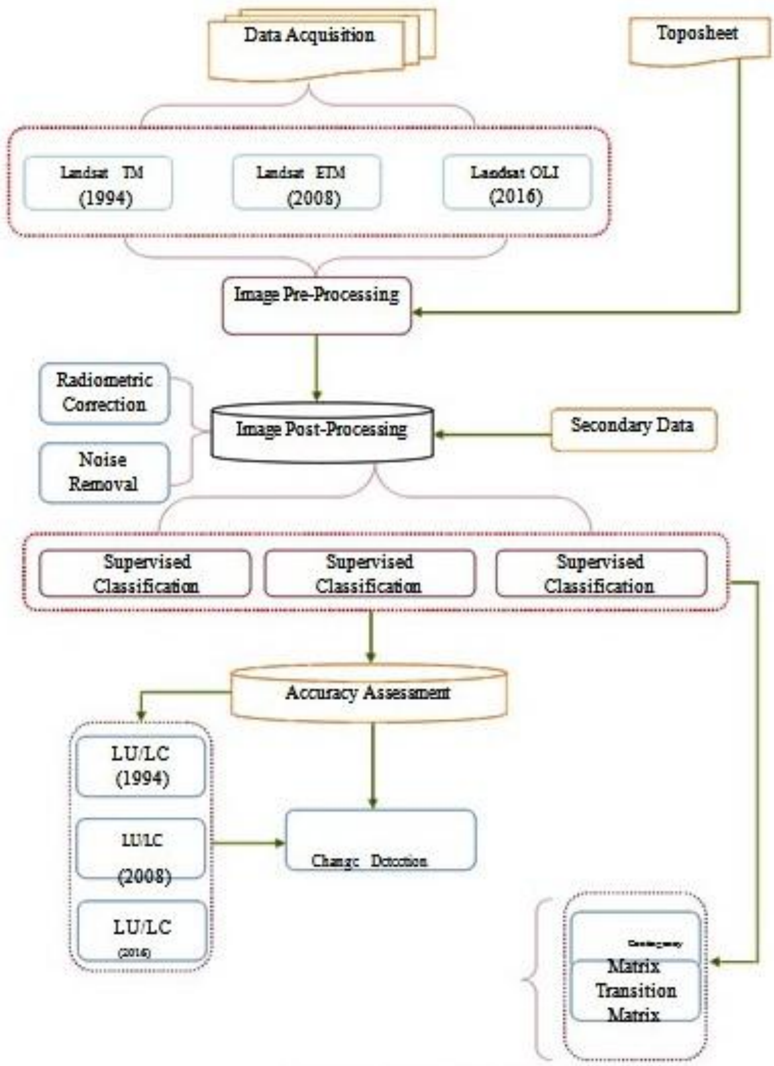

Figure 2: *Methodology Chart*

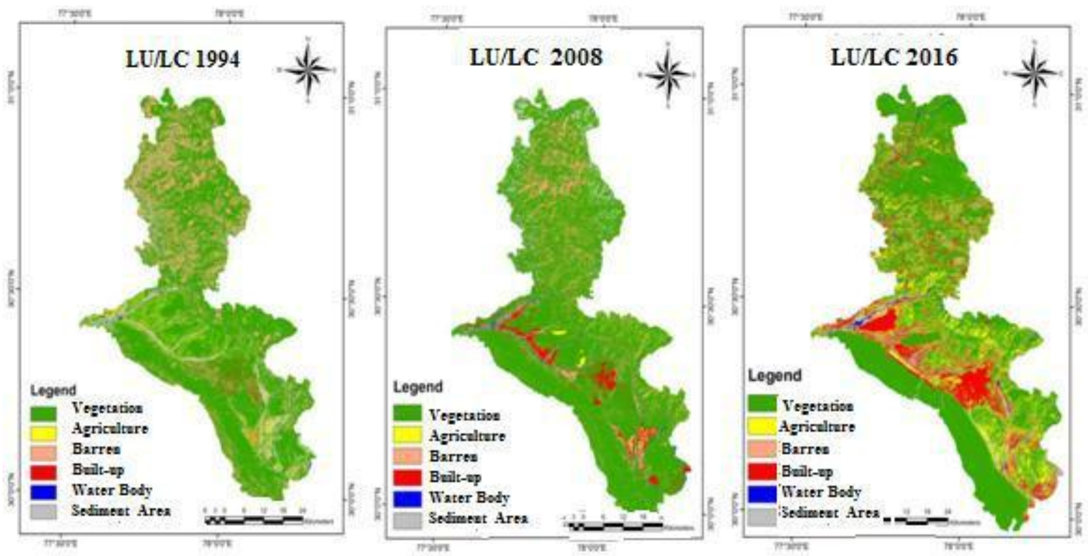

Figure 3: *Land use/Land Cover in 1994, 2008 and 2016 in district Dehradun*

Table 1: *Land use/Land Cover pattern in district Dehradun in 1994*

Land Category	Area(1994)		Area (2008)		Area (2016)	
	in km^2	in %	in km^2	in %	in km^2	in %
Vegetation Cover	1734.15	56.17	1805.89	58.49	1897.82	61.47
Agricultural Area	910.45	29.49	793.59	25.70	543.67	17.61
Barren Land	98.76	3.20	116.09	3.76	182.45	5.91
Built-up Area	99.76	3.23	130.55	4.23	210.54	6.82
Water Body	145.98	4.73	125.46	4.06	78.07	2.53
Sediment Area	98.45	3.19	115.97	3.76	175.00	5.67

3.1.2 LULC in 2008 - Figure 3 *(middle)* depicts the geographical distribution of LULC of district Dehradun for 2008. During 2008 in Dehradun district, the total area under agricultural land was about 793.59 km^2 which accounts for 25.70% of the total district area. Built-up area was 130.55 km^2 which accounts for 4.23%, vegetation area was 1805.89 km^2 which accounts for 58.49%, barren land was 116.09 km^2 which accounts for 3.76%, water body was 125.46 km^2 which account for 4.06% and sediment area was about 115.97 km^2 which accounts for 3.76% of the total district area (Table 1).

3.1.3 LULC in 2016 - Figure 3 *(left)* depicts the geographical distribution of LULC of district Dehradun for 2016. During 2016 in Dehradun district the total distribution of the agriculture area was about 543.67 km^2 which accounts for 17.61% of the total district area, built-up area is 210.54 km^2 which accounts for 6.82%, vegetation area was1897.82 km^2 which accounts for 61.47%, barren land was 182.45 km^2 which accounts for 5.91%, water body was 78.07 km^2 which accounts for 2.53% area of the district (Table 1).

3.2. LULC Change Detection

LULC change detection in district Dehradun was done for three different periods. These are 1994 to 2008, 2008 to 2016 and 1994 to 2016. Results are presented in Figure 4 and Table 2. A brief discussion of these LULC change is presented in the following paragraphs.

3.2.1. Change Detection during 1994-2008 - Figure 4 depicts the status of LULC change in district Dehradun during 1994 to 2008 which reveals that during this period, the vegetation area, built up area, barren land and sediment area have been increased about 71.74 km^2, 30.79 km^2, 17.33 km^2 and 17.52 km^2, respectively; while the agricultural land, and water bodies have decreased about 116.86 km^2 and 20.52 km^2, respectively.

3.2.2. Change Detection During 2008-2016 - Since 1994 to 2008 there has been an increase of 91.93 km^2 of area in vegetation area, 66.36 km^2 in barren land, 79.99 km^2 in built-up area and 59.03 km^2 of area in sediment area, and decrease of about 249.92 km^2 in agricultural area and 47.39 km^2 in water body.

3.2.3. Change Detection During 1994-2016 - Over all during the last 22 years (1994 to 2016), there has been an increase of 163.67 km^2 in vegetation area, 83.69 km^2 in barren land area, 110.78 km^2 in built-up area and 76.55 km^2 in sediment area, and decrease of 366.78 km^2 in agricultural area and 67.91 km^2 in area under water body. From these data, it can be inferred that the built-up and vegetation area is increasing while the water body as well as agriculture area is continuously decreasing in district Dehradun.

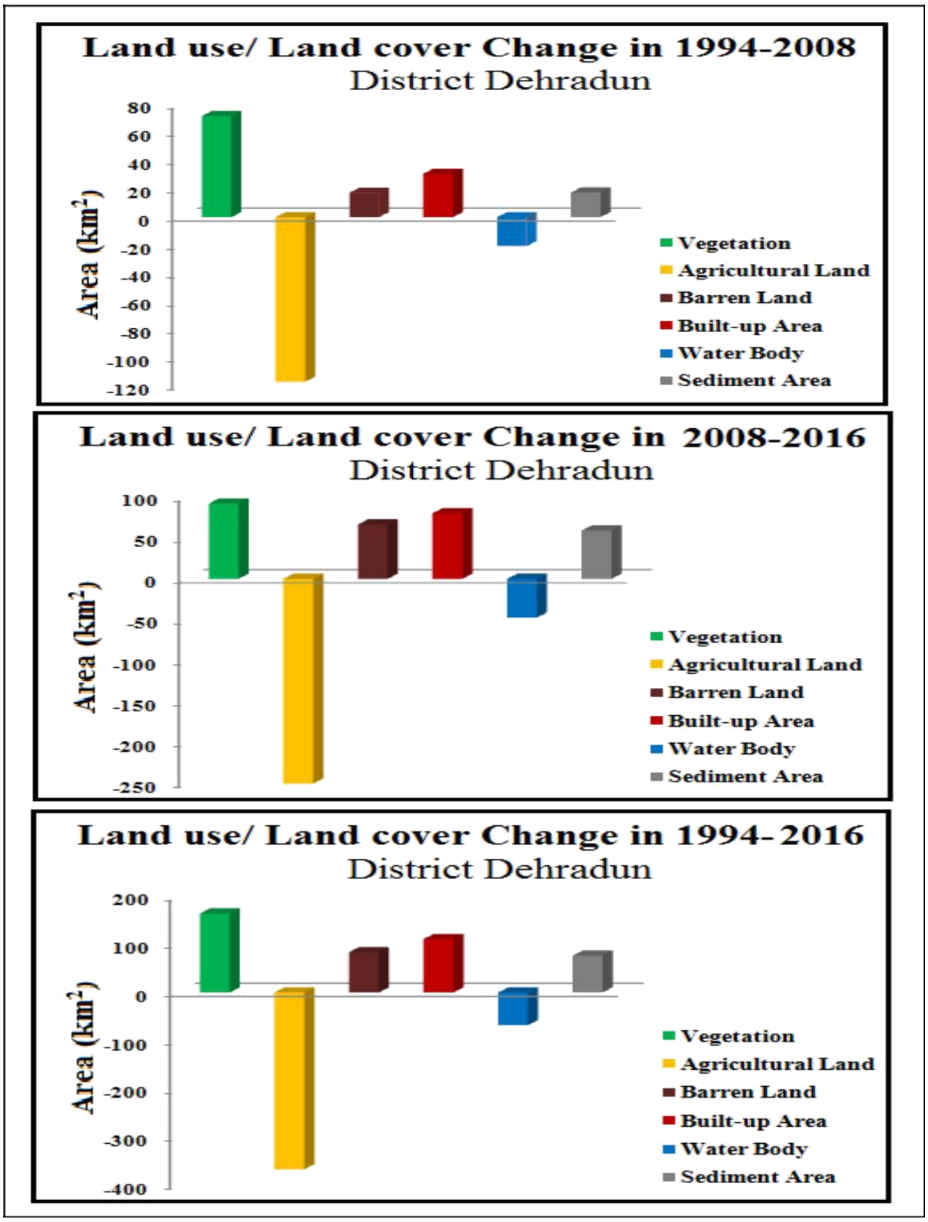

Figure 4: *Bar diagramme showing changes in LU/LC during 1994-2008 (upper), 2008-2018 (middle) and 1994-2016 (lower) in the Dehradun district*

Table 2: *LULC change in district Dehradun during different periods*

Land Category	1994-2008	2008-2016	1994-2016
	km^2	km^2	km^2
Vegetation	71.74	91.93	163.67
Agricultural Land	-116.86	-249.92	-366.78
Barren Land	17.33	66.36	83.69
Built-up Area	30.79	79.99	110.78
Water Body	-20.52	-47.39	-67.91
Sediment Area	17.52	59.03	76.55

3.3. LULC Change Matrix

How much LULC has been changed from one category of land to another category? To define this problem, Change Matrix was calculated for different durations, i.e., 1994-2008 (Table 3), 2008-2016 (Table 4) and 1994-2016 (Table 5). A brief account of these Change Matrices is given in the following paragraphs.

3.3.1. Change Matrix 1994 and 2008 - In district Dehradun, during 1994-2008, about 97.01 km^2 agricultural land area, 2.12 km^2 sediment area and 0.85 km^2 barren land area was converted in to vegetation area; about 12.65 km^2 agricultural land and 0.65 km^2 barren land was converted into agricultural area; about 17.08 km^2 agricultural area and 3.01 km^2 vegetation area was converted in to barren area; 12.67 km^2 vegetation area and 12.77 km^2 agricultural area and 6.21 km^2 barren land area was converted into built-up area; about 1.1 km^2 sediment area was converted into water body; and 21.62 km^2 area of water body was converted in to sediment area (Table 3).

Table 3: *Comparative Matrix between 1994 and 2008*

Category	Vegetation	Agriculture	Barren Land	Built-up	Water Body	Sediment	**1994**
Vegetation	1705.83	12.65	3.01	12.67	0	0	**1734.16**
Agriculture	97.01	783.59	17.08	12.77	0	0	**910.45**
Barren	0.85	0.65	96.36	6.21	0	0	**104.07**
Built-up	0	0.00	0	98.90	0	0	**98.90**
Water Body	0	0.00	0	0.00	124.36	21.62	**145.98**
Sediment	2.12	0.00	0	0.00	1.1	95.30	**98.52**
2008	**1805.81**	**796.89**	**116.45**	**130.55**	**125.46**	**116.92**	

3.3.2. Change Matrix 2008 and 2016 - In district Dehradun, during 1994-2008, about 164.92km^2 agricultural land area and 8.05km^2 barren land area was converted in to vegetation area; about 29.85km^2 vegetation area and 1.25 km^2 barren land area was converted into agricultural land area; about 67.32 agricultural land area and 10.21 agricultural land area was converted into barren land; about 40.25 km^2 forest area , 47.32 km^2 agricultural area and 2.02 km^2 barren land area was converted into built up area; about 70.13 km^2 area of water body was converted into sediment area; and about 13.03 km^2 sediment area was converted into water body (Table 4).

Table 4: *Comparative Matrix between 2008 and 2016*

Category	Vegetation	Agriculture	Barren Land	Built-up	Water Body	Sediment	**2008**
Vegetation	1725.30	29.85	10.21	40.25	0	0	**1805.6**
Agriculture	164.92	512.57	67.32	47.32	0	0	**792.13**
Barren Land	8.05	1.25	105.08	2.02	0	0	**116.40**
Built-up	0	0.00	0	120.45	0	0	**120.45**
Water Body	0	0.00	0	0.00	65.32	70.13	**135.45**
Sediment	0.9	0.00	0	0.00	13.02	101.87	**115.79**
2016	**1899.17**	**543.67**	**182.61**	**210.04**	**78.34**	**172.00**	

3.3.3. Change Matrix 1994 and 2016 - In district Dehradun, over all within the last 22 years (i.e., during 1994-2016) about 237.66 km^2 area of agricultural land, 0.98 km^2 area of barren land and 0.25 km^2 sediment area was converted in to vegetation area; about 10.25 km^2 vegetation area and 0.36

km^2 barren land area was converted into agricultural land; about 76.32 km^2 agricultural land area and 9.21 km^2 vegetation area was converted into barren land area; about 48.32 km^2 vegetation area, about 63.21 km^2 agricultural area and 0.25 km^2 barren land area was converted into built-up area; about 11.25 km^2 sediment area was converted into water body; and about 78.25 km^2 water body area was converted into sediment area (Table 5).

Table 5: *Comparative Matrix between 1994 and 2016*

Category	Vegetation	Agriculture	Barren Land	Built-up	Water Body	Sediment	**1994**
Vegetation	1660.25	10.25	9.21	48.32	0	0	**1728.00**
Agriculture	237.66	533.21	76.32	63.26	0	0	**910.45**
Barren Land	0.98	0.36	97.25	0.25	0	0	**98.84**
Built-up	0	0.00	0	98.65	0	0	**98.65**
Water Body	0	0.00	0	0.00	67.58	78.25	**145.83**
Sediment	0.25	0.00	0	0.00	11.25	87.25	**98.75**
2016	**1899.14**	**543.82**	**182.78**	**210.48**	**78.83**	**165.50**	

4. Conclusions

The study conducted in one of the districts of the Uttarakhand state in the Central Himalaya, viz., Dehradun advocates that multi-temporal satellite data are very useful to detect the changes in LULC quickly and accurately. The study reveals that the major landuse in the Dehradun district are vegetation cover in 61.47% (1897.82 km^2) area, agricultural land in 17.61% (543.67 km^2) area, built-up area 6.82% (210.54 km^2) area, barren land 5.91% (182.45 km^2) area, sediment area 5.67 % (175 km^2) area and water body 2.53 % (78.07 km^2) area. During the last 22 years (1994 to 2016), there has been an increase of about 163.67 km^2 areas in vegetation cover, 83.69 km^2 of area in barren land, 110.78 km^2 in built-up area and 76.55 km^2 in sediment area; and decrease of about 366.78 km^2 in agriculture area and 67.91 km^2 in water body. The study depicts that due to indiscriminate sprawl in built-up area the district, about 48.32 km^2 vegetation areas, 63.21 km^2 agricultural areas and 0.25 km^2 barren land area was converted into built-up area during the last two decades. Thus, increasing population pressure is putting tremendous pressure on the land use and land cover in district Dehradun. The approach adopted in this study has clearly demonstrated the potential of GIS and remote sensing techniques in measuring the change in LULC pattern.

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