

Land Use Fragmentation Analysis Using Remote Sensing and Fragstats

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Abstract This study presents the results of a set of landscape metrics derived from remotely sensed data aiming to characterize the historical trends of landscape changes in the Allahabad district in the period 1990–2010. However, the identified trends in landscape changes and its effects in the region have potential policy implications. The land use and land cover were estimated from sensors viz. for the period 1990 (LANDSAT TM), 2000 (LANDSAT ETM⁺) and 2010 (IRS 1D LISS III) through the maximum likelihood classification (MLC) method. The land use land cover change was quantified with the help of ERDAS imagine 9.1. Further, landscape level and class level metrics were derived from the classified satellite images in FRAGSTATS 3.3. Total four metrics for landscape level viz. total area (TA), number of patch (NP), patch density (PD), area mean (AREA MN) and four metrics for class level viz. core area (CA), number of patch (NP), patch density (PD) and percentage of land (PLAND), respectively to uncover the influence of land use change which can be correlated to the degree of urbanization, development and water quality. The different class level metrics of study area has revealed internal exchange of four land use classes given as agricultural land (65.32 % in 1990, 67.13 % in 2000, 68.1 % in 2010), builtup area (9.98 % in 1990, 11.63 % in 2000, 13.36 % in 2010), cultivable land (4.42 % in 1990, 3.47 % in 2000, 2.1 % in 2010) forest (6.03 % in 1990, 4.47 % in 2000, 5.6 % in 2010), and water body (5.89 % in 1990, 5.82 % in 2000, 5.35 % in 2010). The study showed that the notable changes had occurred in the last 20 years in this landscape, hence there is need of appropriate measures to mitigate these negative impacts of changes.

Keywords Landscape pattern · Fragmentation · LISS III · LANDSAT · Ecological metrics

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1 Introduction

Growing concerns over the recent urban and rural developmental activities, changing landscape scenario and the loss of biodiversity has made it an imperative for land managers to seek for better ways of managing the landscape and to be able to analyze positive and negative factors that influence the land use and land cover change pattern and its change dynamics. Land use land cover change is a continuous process which is altered by several ways with respect to time and space. The natural and socio-economic factors and their utilization by man in time have greatly affected historical land use and land cover pattern. Therefore, the accurate information pertinent to land use land cover is essential for the selection, planning and implementation of land use programmes which can be used to meet the increasing demands for basic human needs and their welfare (Zubair 2006). Rapid population increment and industrial sprawl has made land a scarce resource, mainly in urban and urbanizing areas which are undergoing to large-scale land transformation changes which alters the natural ecosystem in different way at temporal and spatial scale (Morley and Karr 2002). Change in land use land cover also aggravates the soil erosion, creates strong environmental impacts, effects on agricultural production, infrastructure and water quality (Lal 1998; Pimentel et al. 1995). The productive agricultural land and essential forest, neither of which can resist nor deflect the overwhelming land use and land cover but accelerate its change and alteration on the basis of necessity and sustainable development. This growth is an indicator of socio-economic development and generally has a negative environmental impact on the region. Agricultural practices, forest cutting, urban and industrial expansion, road development, military training, alteration of water way and other human activities have significant impact on land cover (Dale et al. 1998). Today one of the greatest challenge in front of human lies in the question of ‘how to minimize the negative impacts of land use land cover change by applying both appropriate and cost-effective technology respectively?’. The landscapes metrics is a special feature that provide the ability of quantifying land use and land cover pattern distribution. There are variety of landscape metrics to allow quantitative assessment of a landscape and its level of fragmentation (McGarigal and Marks 1995).

The analysis of landscape level and class level metrics (Szabó et al. 2012) has provided a strong conceptual and theoretical basis for understanding landscape structure, function and change. The landscape metrics mainly focus on the three characteristics of landscape (Forman and Godron 1986; Turner 1989). (1) Structure: the spatial relationships among the distinctive ecosystems or elements present—more specifically, the distribution of energy, materials, and species in relation to the sizes, shapes, numbers, kinds, and configurations of the ecosystems. (2) Function: the interactions among the spatial elements, that is, the flow of energy, materials, and species among the component of ecosystems. (3) Change: the alteration in the structure and function of the ‘Ecological Mosaic’ over time. The landscape level metrics is a special feature of land use that provide

significance ability to quantify the landscape patterns and the interactions among patch density, number of patches, total area, and large patch index within a landscape mosaic and also represent the patterns and interaction change over time. The class level metrics comprising with different metrics viz. core area, number of patches, patch density, percentage of landscape and largest patch index, some of these metrics quantify the landscape composition and while others quantify landscape configuration. It is also known that composition and configuration can affect ecological processes independently and interactively. So it is necessary to understand each metrics of landscape.

2 Study Area

This study area Allahabad district is situated at (24°47'N and 25°47'N to 81°19'E and 82°21'E) and it covers an area 5,246 km². It lies in the northern-central part of the densely populated eastern region of state Uttar Pradesh, in between the Gangetic plain and adjoining Vindhyan plateau of India. River Ganga and Yamuna flowing through the district (Fig. 1 location map of the study area). Geologically the district presents a greater complexity, the whole Trans-Ganga tracts, the greater portion of 'doab' are composed of gangetic alluvium. The Trans Yamuna region is mainly quartzitic in nature and consisting denudational hills. Administratively the district comprised of eight tehils and twenty blocks. The mineral products that are commonly found in the district are glass sand, building stone, kankar, brick earth and reh. Building stone is extracted either by blasting or by splitting the chief quarries. Bricks and pottery, earth-material is available in the alluvial tract of the district and is locally used for the manufacture of bricks and earthenware.

3 Materials and Methods

Total fourteen Survey of India (SOI) topographical sheet at 1:50,000 scales were used 63—G/10, G/11, G/12, G/14, G/15, G/16, H/13, K/2, K/3, K/4, L/1, K/6, K/7, K/8, and L/5 and satellite images of Landsat TM, 1990, ETM⁺ 2000 (<http://www.usgs.gov/pubprod/aerial.html#satellite>) and 2010 were used.

3.1 Classification of Satellite Data

According to Lu and Weng (2007), the major steps of image classification may include a suitable classification system, selection of suitable classification approaches, post-classification processing and accuracy assessment. These images were first geometrically and radiometrically corrected ERDAS IMAGINE 9.1

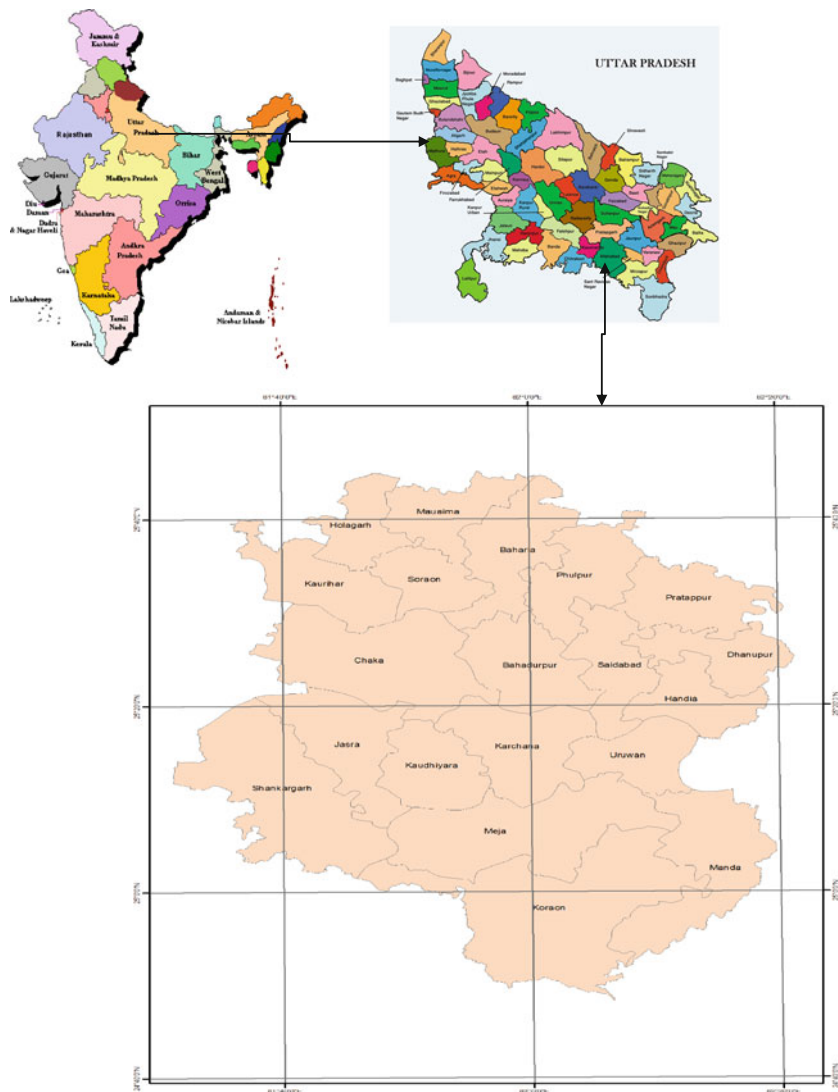


Fig. 1 Study area location map

tool (ERDAS Field Guide 1999). The automatic atmospheric calibration was performed on each image separately. The Anderson et al. (1976) classification method was used as classification scheme. Afterwards, the Maximum Likelihood Classification tool is considered for image classification of year 2010 as it is taking account of both the variances and covariances of the class signatures and assigning each cell to one of the classes represented in the signature file. The algorithm used by the Maximum Likelihood Classification tool is based on Bayes' theorem and

the equation used in MLC classification as shown in the Eq. 4. The image of year 1990 and 2000 was classified using Isodata clustering approach (unsupervised method). The random sampling method was used for the accuracy assessment. The Google image, ancillary data and field data was employed for the accuracy assessment.

In the study following Eqs. 1, 2, and 3 were used e.g.:

$$\% \text{ Cover Change} = \frac{Area_{i \text{ year } x} - Area_{i \text{ year } (x+1)}}{\sum_{i=1}^n Area_{i \text{ year } x}} \times 100 \quad (1)$$

$$\% \text{ Cover Coverage} = \frac{Area_{i \text{ year } x}}{\sum_{i=1}^n Area_{i \text{ year } x}} \times 100 \quad (2)$$

$$\text{Change area} = Area_{i \text{ year } (x+1)} - Area_{i \text{ year } x} \quad (3)$$

where $Area_{i \text{ year } x}$ area of is cover i at the first date; $Area_{i \text{ year } (x+1)}$ is area of cover i at the second date; $\sum_{i=1}^n Area_{i \text{ year } x}$ is total cover area at the first date; t_{years} is period in years between the first and second scene acquisition dates.

$$D = \ln(a_c) - [0.5 \ln(|cov_c|)] - [0.5(\mathbf{X} - \mathbf{M}_c)\mathbf{T}(cov_c - 1)(\mathbf{X} - \mathbf{M}_c)] \quad (4)$$

where, D is weighted distance; c is a particular class; X is the measurement vector of the particular pixel; M_c is the mean vector of the sample of class; a_c is percent probability that any particular pixel is a member of class c; (Defaults to 1.0); Cov_c is the covariance matrix of the pixels in the sample of class c; $|Cov_c|$ is determinant of Cov_c ; $Cov_c - 1$ is inverse of Cov_c ; \ln is natural logarithm function; T = transposition function.

3.2 Fragmentation Analysis

A spatial pattern analysis program i.e., FRAGSTATS3.3 offers a comprehensive choice of landscape metrics and have been used to quantify landscape structure. It is implemented by decision maker and ecologists to analyze landscape fragmentation and to describe the characteristics and components of those landscapes. These statistics facilitates the comparison of landscapes and the evaluation of processes. The advantage of FRAGSTATS is that the calculations are implemented in a fully integrated fashion in a GIS and consequently easy to apply to digital map. The three indices have been taken into account for the ecological metrics analysis viz. patch density (PD), mean patch size (MPS) and percentage of landscape (PLAND). The number of patche per 100 ha, mean patch size (MPS)

means the area occupied by a particular patch type divided by the number of patches of that type (McGarigal and Marks 1995) and percentage of landscape (PLAND) (McGarigal and Marks 1995) measure of landscape composition. The representative equations for all the three indices are shown by following Eqs. 5, 6, and 7.

$$PD = \frac{n_i}{A}(10,000)(100) \quad (5)$$

where n_i is number of patches in the landscape of patch type (class) i ; A is total landscape area (m^2).

$$MPS = \frac{A}{N} \left(\frac{1}{10,000} \right) \quad (6)$$

where N is total number of patches in the landscapes, excluding any background patches

$$PLAND = \frac{\sum_{j=1}^n a_{ij}}{A} (100) = P_i \quad (7)$$

P_i is proportion of the landscape occupied by patch type (class) i ; a_{ij} is area (m^2) of patch ij .

4 Result and Discussion

4.1 Land Use and Land Cover Distribution

The study area has been classified into different land use classes shown in Fig. 2. The overall accuracy for the classified images was arrived 80.39, 85.36 and 88.10 % respectively of years 1990, 2000, and 2010. According to Anderson et al. (1976), the accuracy of classified images should >84 % for better results. On the basis of analysis the result showed that the buildup area was 555.89 km^2 in 1990 and it increases 647.80 km^2 in 2000 and it further increases to 744.16 km^2 in 2010 respectively. This may be attributed to an increase in urban population. As the population of the district shows the increasing trend of population in the region. The area of agriculture land showed nominal increment from 3,638.40 km^2 in 1990 to 3,739.22 km^2 in 2000 and 3,793.25 km^2 in 2010, which means that the area remained same for agriculture. Cultivable area decreased from 246.19 km^2 in 1990 to 193.28 km^2 in 2000 and it further decreased to 116.97 km^2 in 2010 (Table 1). This decrease in cultivable area may be due to either urban pressure or nominal conversion into agriculture land. The difference in land use classes are given in (Table 2) which shows change in area which indicates that in the year 2000/1990

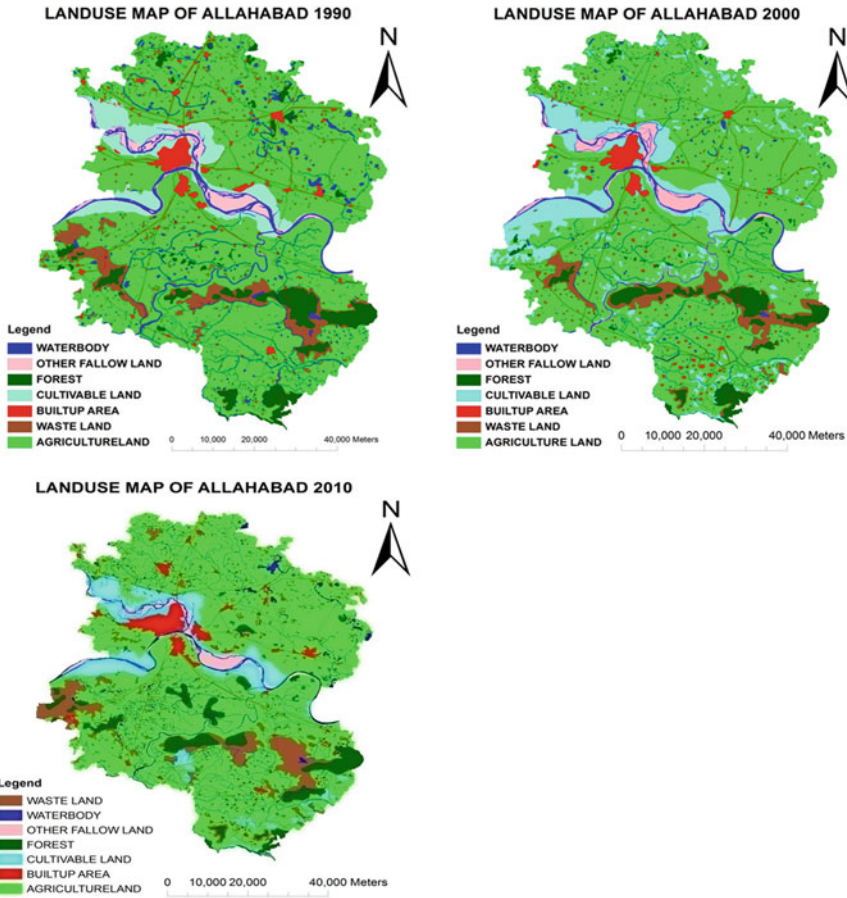


Fig. 2 Unsupervised and supervised classified satellite images of year 1990, 2000, and 2010

the forest is -86.89 km^2 while in the 2010/2000 its area is increased by 62.94 km^2 , however in overall analysis it showed 2010/1990 it reduced -23.95 km^2 respectively indicates that the fluctuations in forest cover area could be due to social and economic influence. Built up area change 2000/1990 are 91.91, in 2010/2000 are 96.36 and in 2010/1990 increase in 188.3 km^2 indicates that the built up area continuously increased over the study period.

The change area of cultivable land in 2000/1990 was -52.91 , in 2010/2000 was -76.31 and in 2010/1990 was -129.2 km^2 . It indicates a slight decline of cultivable land due to urbanization. It indicates that this change may be due to agricultural and built-up area expansion. The agriculture area in 2000/1990 is

Table 1 Area of different land use classes in km² for the year 1990–2000–2010

Land use land cover distribution						
Land use land cover categories	1990		2000		2010	
	Area (km ²)	Area (%)	Area (km ²)	Area (%)	Area (km ²)	Area (%)
Forest	335.87	6.03	248.98	4.47	311.92	5.6
Waste land	279.62	5.02	234.50	4.21	179.91	3.23
Built up area	555.89	9.98	647.80	11.63	744.16	13.36
Cultivable land	246.19	4.42	193.28	3.47	116.97	2.1
Agriculture land	3,638.40	65.32	3,739.22	67.13	3,793.25	68.1
Water body	328.08	5.89	324.18	5.82	298.00	5.35
Other fallow land	186.04	3.34	182.14	3.27	125.88	2.26
Total	5,570.09	100	5,570.09	100	5,570.09	100

Table 2 Difference in area of different land use classes during 1990–2000–2010 (positive values shows decrease while negative values shows increase)

Land use classes	Land use and land covers change (area in km ²)		
	1990–2000	2000–2010	1990–2010
Forest	–86.89	62.94	–23.95
Waste land	–45.12	–54.59	–99.97
Built up area	91.91	96.36	188.3
Cultivable land	–52.91	–76.31	–129.2
Agriculture land	100.8	54.03	154.9
Water body	–3.9	–26.18	–30.08
Other fallow land	–3.9	–56.26	–60.16

100.8 km², while reduced in 2010/2000 is 54.3 km² and however it further showed increment in 2010/1990 is 154.9 km² respectively. Water body area in 2000/1990 is –3.9, while in 2010/2000 its area is reduced by –26.18; however in 2010/1990 again it shows reduction by –30.08 km² respectively, which indicates that the change in water body area could be due loss of surface water body.

4.2 Landscape Level Metrics

Landscape metrics were characterized for the landscape fragmentation patterns which reveals the configuration and composition pattern of the landscape element such as in the form of class, patch and landscape metrics. The spatial characteristics of patch, class of patches or entire landscape also quantifying and exploring with the help of ecological process by landscape metrics (Narumalani et al. 2004). The landscape level metrics analysis analyses the following parameters i.e. total

area (TA), number of patches (NP), patch density (PD), and Area mean. PD metrics is an important measure to show the health of an ecosystem. If the NP increases while the area under the class decreases, it represents fragmentation or dissection. Anthropogenic and natural activities affect the spatial structure of landscape such as urbanization and industrialization due to anthropogenic activities while the natural activities like flood and drought etc. The nature of these change experienced by each land use land cover varies.

The landscape can undergo in different type of transformation, the result after the change process analysis are given in Table 3 shows that the total area 499,182.5 ha in 1990, 498,818.6 ha in 2000 and 550,046.2 ha in 2010. The number of patches per unit area has increased from 3,301 ha in 1990 to 42,394 ha in 2000 and further it decreases by 4,646 ha in 2010 respectively in twenty block of study area. The increase in number of patches in the first decade shows that the landscape is more fragmented while in the second decade it shows that the landscape gets less fragmentation. The maximum number of patches (582 in year 2010) found in Koraon block. Kaurihar and Soraon have number of patches 240, 134 in 2000 means these areas are fragmented during the year 2000. While low number of patches i.e. 54 was present in Dhanupur means this area has less developmental activities. PD increases from 12.755 in 1990 to 386.142 in 2000 and after one decade it rapidly decreases to 19.821 in 2010. These values indicate that the landscape fragmentation was at higher pace during the year from 1990 to 2000 while it was less fragmented during the year in 2000–2010. These change in values of mean area indicates that the forest is less fragmented in 2000 than in 1990 and again it is more fragmented in 2010. Two decades of natural conditions or human activities had less impact on forest landscape and thus fragmentation was less in 2000. While in 2010, human pressure or natural conditions may played a major role in the decrease of forest mean area.

4.3 Class Level Metrics

The class level metrics has a spatial feature to represent each land use land cover classes. The importance of class level metric analysis is to assess the transformation types which affect the spatial pattern of the landscape. In the present study we calculated the core area (CA), number of patches (NP), patch density (PD), and percentage of landscape (PLAND), and Area mean of land use classes. The class level metric analysis shows that CA of agriculture land (Table 4) from 345,595.3 ha in 1990 to 363,219.9 ha in 2000 which further decreases 334,817.4 ha in 2010. Out of twenty blocks the maximum core area of agricultural land was found in Koraon block 43, 684.5 in 1990, 43,683.94 in 2000 and 42,928.23 in 2010.ha, while minimum core area of agricultural land was reported in Kaundhiyera (1990) and Soraon (2010) 7,759.75 and 8,065.66 ha respectively. The overall study reveals that the year 2000 comprises the maximum core area in two decades. The number of patches of agricultural land decreases from 550 in

Table 3 Landscape level metric analyses during 1990–2000–2010

Block	Land fragmentation classes											
	TA			NP			PD			Area mean		
	1990	2000	2010	1990	2000	2010	1990	2000	2010	1990	2000	2010
Bahadur Pur (A)	19,675.54	24,451.57	24,451.85	103	105	154	0.5235	0.4294	0.6298	182.4716	232.8659	136.2284
Baheriya (B)	25,656.46	25,656.46	25,657.66	182	167	223	0.7094	0.6509	0.8691	137.2189	152.5269	113.9818
Chaka (C)	44,671.8	44,671.8	44,673.11	296	230	284	0.6626	0.5149	0.6357	10.2493	193.8678	144.8997
Dhanupur (D)	16,597.84	16,597.84	16,596.41	54	54	120	0.3253	0.3253	0.723	306.9854	307.1328	138.303
Handia (E)	16,791.73	16,791.73	16,792.56	94	107	181	0.5598	0.6372	1.0779	173.0862	154.8885	92.2627
Holagarh (F)	14,455.04	14,455.04	14,454.18	164	125	195	1.1346	0.8648	1.3491	86.3075	114.5474	182.8897
Jasra (G)	26,610.2	26,610.2	26,609	166	207	441	0.6238	0.7779	1.6573	156.5568	128.4638	59.351
Karchhana (H)	27,806.32	27,806.32	27,805.85	122	242	148	0.4387	0.8703	0.5323	212.6537	114.1218	181.7698
Kaundhiyara (I)	21,944.88	21,944.88	21,943.26	190	103	292	0.8658	0.4694	1.3307	104.3583	211.8577	69.7837
Kaurihar (J)	19,763.02	18,762.01	19,761.9	110	240	270	0.5566	0.6509	1.3663	114.1218	103.2439	72.7601
Koraon (K)	66,121.86	66,121.86	66,123.05	433	382	582	0.6549	0.5777	0.8802	152.1393	147.761	113.6001
Manda (L)	35,354.4	35,354.4	35,354.04	253	225	306	0.7156	0.6364	0.8655	138.6052	140.6936	115.4479
Mau Aima (M)	17,310.67	17,510.47	17,309.64	165	190	207	0.9532	0.3253	1.1959	104.3914	69.7837	83.6107
Meja (N)	26,610.2	46,091.37	46,090.87	198	209	359	0.6509	0.4534	0.7789	182.8897	185.3426	128.1778
Phulpur (O)	23,072.12	23,072.12	23,073.38	212	126	239	0.9189	0.5461	1.0358	108.6951	182.8897	96.5325
Pratappur (P)	21,702.91	21,641.35	21,706.54	110	100	178	0.5068	0.4621	0.82	196.8082	194.6931	121.9431
Saidabad (Q)	19,369.24	19,369.24	19,369.22	126	82	121	0.6505	0.4234	0.6247	151.0637	235.2959	157.2086
Shankargarh (R)	50,873.17	50,873.17	50,870.54	302	218	319	0.5936	0.4285	1.205	166.7587	232.7424	82.1304
Soraon (S)	14,096.19	35,354.4	14,094.56	82	134	186	0.5817	0.3253	1.3197	162.2836	103.2439	73.0113
Urwa (T)	17,309.13	17,309.29	17,308.58	137	186	160	0.7915	1.0746	0.9244	122.6177	93.0607	105.7192
Total	499,182.5	498,818.6	5,500,046	3,301	3376	4,646	12.755	386.142	19,821	2,673.25	3,229.23	2,086.722

1990 to 508 in 2000 and while it increases 799 in 2010. Out of twenty blocks NP was more in Chaka (2010), Kaundhiyera (2010) block 89 and 84 respectively. The low NP of agricultural land was found in Dhanupur (2000), Pratappur (2000) block 7 and 9 respectively, the low NP in the year 2000 shows less fragmentation of agricultural land compared to 2010. The PD was 2.18 in year 1990 of agricultural land which decrease to 1.78 in year 2000, and again increases to 3.18 in 2010. Maximum PD was found in Soraon (2010) 0.39 and Kaundhiyera (2010) 0.38 while minimum in Dhanupur and Pratappur (2000) 0.04 and 0.04 respectively. PLAND in two decade's study was found maximum in Dhanupur (1990) 93.85 and Handia (2000) 87.48, while it was minimum in Chaka (2010) 4.88 and Kaundhiyera (1990) 35.36 out of twenty block. The Area mean of agriculture land firstly increased from 14,588.2 ha in 1990 to 17,742.5 ha in 2000 and then decreased to 11,036 ha in 2010, the maximum area occupied by Dhanupur (2000) and Pratappur (2000) was 2,212 and 2,099 ha respectively. The minimum in Chaka (2010) and Kaundhiyera (2010) was 24.58 and 101.7 ha respectively.

The CA of built up area (Table 5) decreases from 25,483.8 ha in 1990 to 24,783.5 ha in 2000 and it again increases from 24,783.5 to 38,045.7 ha in 2010. Out of the twenty block maximum CA was found in Chaka (2000) 8,485.91 ha and Bahadur Pur (2010) 3490.648 ha while minimum CA was found in Bahadurpur (1990) was 270.97 and 274.7842 ha in Kaurihar (1990). The two decade's study, showed that the year 2010 has more CA 38,045.7 ha compared to 25,483.8 ha in year 1990 of builtup area. The NP increased from 741 in 1990 to 775 in 2000; it again increased to 1863 in 2010. Shankargarh (2010) and Jasra (2010) block have more NP 240 and 212 respectively. The result indicates that the year 2010 is fragmented as compared to previous decades. The PD has decreased from 3.4 ha in 1990 to 3.21 ha and in 2000 it further increased to 7.26 ha in 2010. PD in Holagarh (2010) 0.78 and Mau (2010) 0.56 are found at maximum but a minimum in Bahadurpur (1990) was 0.07, Urwa (2000) and Shankargarh (1990) were 0.07. The lowest PD was observed in Meja 0.5 in year 2000.

The PLAND also decreased from 95.07 ha in 1990 to 80.89 ha in 2000, while again increased 146.6 ha in 2010. The maximum value of PLAND was found in Soraon (2010) 15.63 ha and Chaka (2000) 18.99 ha while minimum is 1.37 ha in Bahadurpur (1990) and 1.048 ha in Meja (2000). The Area mean of built-up area increases from 689.5 ha in 1990 to 799.9 ha in 2000 and again decreases to 611.32 in 2010. Out of twenty blocks the maximum Area mean contained by Chaka 292.6 ha in 2000 and minimum in Soraon (2000) and Jasra (2010) with 6.64 and 7.55 ha respectively.

The CA for cultivable area (Table 6) decreases from 18,699.62 ha in 1990 to 14,696.69 ha in 2000 and remains to 14,696.69 ha in 2010. The maximum CA is investigated in Jasra (2000) 7,983.1 ha and Kaundhiyera (2000) 9,530.8 ha, while minimum CA was found in Dhanupur (1990) 0.0812 ha. The NP of cultivable area was found 217 in 1990 and it increases to 422 in 2000 but further it shows reduction to 311 in 2010. Out of twenty blocks maximum NP was found in Koraon (2000) 65 and minimum 1 in Bahadurpur, Dhanupur and Kaurihar (1990) respectively. The PD also decreases in two decades study period from 0.29 in 1990

Table 4 Class level metric analysis for core area, number of patch, patch density, percentage of land, and area mean (ha) during 1990–2000–2010 of agricultural land

Block	Agricultural land														
	CA			NP			PD			PLAND			Area mean		
	1990	2000	2010	1990	2000	2010	1990	2000	2010	1990	2000	2010	1990	2000	2010
Bahadur Pur	16,155.5	11,958.76	12,634.11	19	33	22	0.1	0.14	0.09	82.11	48,9079	51,6693	850.3	362.4	574.3
Baheriya	20,398.2	20,714.49	21,247.24	18	21	23	0.07	0.08	0.09	79.505	80,7379	82,8105	1,133	986.4	923.8
Chaka	22,155.6	22,183.85	2,183.255	32	50	89	0.07	0.11	0.2	49.596	49,6596	4,8872	692.4	443.7	24.53
Dhanupur	15,577.7	15,487.09	14,741	12	7	13	0.07	0.04	0.08	93.854	93,3079	88,8204	1,298	2,212	1,134
Handia	13,742.1	14,690.27	13,543.53	19	11	34	0.11	0.07	0.2	81.838	87,4852	80,652	723.3	1,335	398.3
Holagarh	11,807.4	12,470.88	11,921.49	35	13	18	0.24	0.09	0.12	81.684	86,2736	82,4778	337.4	959.3	662.3
Jasra	17,887.7	15,330.65	15,788.18	27	46	69	0.1	0.17	0.26	67.221	57,6119	59,334	662.5	333.3	228.8
Karchhana	18,965.9	18,862.48	17,300.68	28	37	29	0.1	0.13	0.1	68.207	67,8352	62,2196	677.4	509.8	596.6
Kaundhiyara	7,759.75	7,817.744	8,540.327	14	11	84	0.06	0.05	0.38	35.36	35,6244	38,92	554.3	710.7	101.7
Kaurihar	16,217.8	16,627.24	14,996.7	22	21	43	0.11	0.11	0.22	82.061	84,1331	75,8869	737.2	791.8	348.8
Koraon	43,684.5	43,683.94	42,928.23	75	68	64	0.11	0.1	0.1	66.067	66,0658	64,9217	582.5	642.4	670.8
Manda	23,611.8	22,724.64	19,595.75	45	37	46	0.13	0.1	0.13	66.786	64,2767	55,4272	524.7	614.2	426
Mau Aima	13,363.3	0.00	13,862.91	33	0.00	25	0.19	0	0.14	77.197	0.00	80,0878	404.9	476	554.5
Meja	8,860.87	27,120.54	24,476.51	0.00	27	37	0	0.06	0.08	0.00	58,8408	53,1049	576	1,004	661.5
Phulpur	17,037.9	19,516.09	18,494.75	34	17	30	0.15	0.07	0.13	73.846	84,5873	80,1562	756	1,148	616.5
Pratappur	18,974.7	18,890.17	18,457.07	10	9	13	0.05	0.04	0.06	87.429	87,0398	85.03	1,897	2,099	1,420
Saidabad	14,794.2	15,223.11	13,934.71	27	15	30	0.14	0.08	0.15	76.38	78,5943	71,9425	547.9	1,015	464.5
Shankargarh	30,585.3	29,527.64	28,814.85	58	37	45	0.11	0.07	0.09	60.121	58,0417	56,6435	527.3	798	640.3
Soraon	8,736.07	16,627.24	8,065.66	15	21	55	0.11	0.11	0.39	61.975	84,1331	57,2253	582.4	791.8	146.6
Urwa	14,139.9	13,763.09	13,290.45	27	27	30	0.16	0.16	0.17	81.638	79,5127	76,7853	523.7	509.7	443
Total	345,595.3	363,219.9	334,817.4	550	508	799	2.18	1.78	3.18	1,291.23	1,352.66	1,309.0	14,588.2	17,742.5	11,036.83

Table 5 Class level metric analysis for core area, number of patch, patch density, percentage of landscape and area mean (ha) during 1990–2000–2010 of built up area

Block	Built-up area														
	CA			NP			PD			PLAND			Area mean		
	1990	2000	2010	1990	2000	2010	1990	2000	2010	1990	2000	2010	1990	2000	2010
Bahadur Pur	270.9666	1,103.6041	3,490.648	13	22	39	0.07	0.09	0.16	1.3772	4.5134	14.276	20.84	50.16	89.5
Baheriya	1,189.459	768.7134	1,031.654	71	70	47	0.28	0.27	0.18	4.6361	2.9962	4.0208	16.75	10.98	21.95
Chaka	8,054.434	8,485.9007	6,201.948	42	29	35	0.09	0.06	0.08	18.03	18.996	13.883	191.8	292.6	177.2
Dhanupur	294.3594	528.3686	678.3259	24	21	55	0.14	0.13	0.33	1.7735	3.1834	4.0872	12.27	25.16	12.33
Handia	992.0822	732.9744	1,662.001	29	14	43	0.17	0.08	0.26	5.9082	4.3651	9.8972	34.21	52.36	38.65
Holagarh	774.5616	610.1622	1,031.766	72	71	113	0.5	0.49	0.78	5.3584	4.2211	7.1382	10.76	8.594	9.131
Jasra	877.3925	741.0157	1,600.609	32	37	212	0.12	0.14	0.8	3.2972	2.7847	6.0153	27.42	20.03	7.55
Karchhana	1,038.218	643.6269	1,153.048	22	54	44	0.08	0.19	0.16	3.7337	2.3147	4.1468	47.19	11.92	26.21
Kaundhiyara	1,178.087	1,155.4256	1,734.415	42	31	83	0.19	0.14	0.38	5.3684	5.2651	7.9041	28.05	37.27	20.9
Kaurihar	274.7842	505.1383	911.2621	14	76	118	0.07	0.38	0.6	1.3904	2.556	4.6112	19.63	6.647	7.723
Koraon	1,766.075	2,966.7431	3,347.436	92	52	153	0.14	0.08	0.23	2.6709	4.4868	5.0624	19.2	57.05	21.88
Manda	538.8467	777.6482	1,530.366	38	34	88	0.11	0.1	0.25	1.5241	2.1996	4.3287	14.18	22.87	17.39
Mau Aima	1,351.34	0.00	1,494.744	64	0.00	97	0.37	0	0.56	7.8064	0.00	8.6353	21.11	21.65	15.41
Meja	483.67	483.1263	1,315.519	0.00	23	153	0.23	0.05	0.33	0.00	1.0482	2.8542	22.76	21.01	8.598
Phulpur	1,738.621	1,283.1113	1,768.924	35	27	109	0.15	0.12	0.47	7.5356	5.5613	7.6665	23.67	47.52	16.23
Pratappur	1,035.375	861.4724	1,462.684	40	38	74	0.18	0.18	0.34	4.7707	3.9694	6.7384	25.88	22.67	19.77
Saidabad	1,179.143	1,051.7013	1,741.372	38	30	49	0.2	0.15	0.25	6.0877	5.4298	8.9904	31.03	35.06	35.54
Shankargath	1,243.149	1241.2805	2,770.244	36	58	240	0.07	0.11	0.47	2.4436	2.44	5.4457	34.53	21.4	11.54
Soraon	1,234.62	505.1383	2,203.516	20	76	66	0.14	0.38	0.47	8.7585	2.556	15.634	61.73	6.647	33.39
Urwa	451.611	338.3834	915.2139	17	12	45	0.1	0.07	0.26	2.6091	1.9549	5.2876	26.57	28.2	20.34
Total	25,483.8	24,783.5	38,045.7	741	775	1,863	3.4	3.21	7.26	95.07	80.89	146.6	689.5	799.9	611.32

to 0.27 in 2000 and 0.22 in 2010, while the block Holagarh (2000) and Kaundhiyara (1990) has maximum 0.17 PD and Dhanupur (1990), Kaurihar (1990) and Baheriya (2010) contained minimum PD 0.01. But in two decades study period the year 1990 contained more 0.29 PD. The PLAND also decreases from 105.73 in 1990 to 41.606 in 2000 and further increases 350.22 in 2010. But the maximum value was found in Urwa (1990) 81.69 and minimum in Mau (1990) 0.001. In the two decades study reveal that PLAND was high in the year 1990 in cultivable land. The Area mean of cultivable land found in increasing order from 1,567.69 ha in 1990 to 2,037.17 ha in 2000 and it further increases from 2,037.17 to 3,312.62 ha in 2010. The maximum Area mean are 804.7 ha in Chaka (2010) and Jasra (2010) 506 ha. But the minimum Area mean are in Saidabad (1990) and Phulpur (2010) 0.045 and 0.1 ha respectively.

The CA of forest area (Table 7) shows increase from 65,311.38 ha in 1990 to 78,226.87 ha in 2000 but rapid decrease of 37,260.71 ha in 2010. Out of the twenty blocks the maximum CA are Koraon (1990) 11,982 ha and Karchhana (1990) 9,146 ha but the minimum are Mau, Phulpur and Chaka (2010) 0.223, 0.39 and 0.167 respectively. This result indicates that developmental activity and human pressure put a great impact in forest area reduction over the last two decades. The NP of forest area decreased from 250 in 1990 to 158 in 2000 and further it continues reduction to 141 in 2010. The maximum NP were found in Koraon 22 (1990) and Handia 17 (1990) and minimum in Dhanupur (2010) 1 and Saidabad 1 (1990) PD of forest area in 1990 was 1.512 and increases 4.53 in 2000, it then decreases 1.61 in 2010. The maximum PD was found in Chaka (2010) 0.98 and Urwa (2000) 0.987. The minimum PD in Saidabad 0.005 (1990) and 0.007 in Meja (2010) was obtained. The value of PLAND drastically decreases from 1,333.72 ha in 1990 to 43.10 ha in 2000 and further increases 95.39 ha in 2010. Out of twenty block the maximum PLAND 18.15 ha in Manda (1990), 18.12 ha in Koraon (1990) and 10.26 ha in Karchhana (2010) but the minimum PLAND was found at 0.016 ha in Holagarh (2000) and 0.054 ha Bahadurpur (2000). The Area mean accounts in 1990 is 8,048.71 ha which decreases to 3,131.77 ha in 2000 and goes on to increase in 2010. The maximum Area mean reported out of twenty in Jasra (1990) and Holagarh (1990) 891.5 and 788.7 ha respectively.

The CA of water body (Table 8) decrease from 34,568.5 ha in 1990 to 22,580.5 ha in 2000 and gradually increases to 37,287.5 in 2010. The CA was maximum in Chaka block (2010) 11106 ha and Koraon (1990) 3,730 ha. After two decades study revealed that the CA was found maximum in year 2010 compare to year 1990. The NP of water body was 1,071 in 1990 and it decreases 982 in 2000 and further increases 1,234 in 2010. The maximum NP was found 176 in Koraon block 1990 and minimum 7 in Holagarh in 2000. The PD in 1990 was 3.91 in 1990 and decreases 3.55 in 2000 and further increases to 4.67 in 2010. The PLAND decreases from 40.65 in 1990 to 22.66 in 2000 and increases to 31.47 in 2010. In two decades the data showed that PLAND was high in 1990 and low in 2000. But out of twenty block the value of PLAND was found higher in Meja (1990) 13.12 ha and Urwa (1990) 10.52 ha but minimum was 1.72 in Holagarh (2000), Dhanupur 0.95 in 2000. The Area mean of water body also increases from

Table 6 Class level metric analysis for core area, number of patch, patch density, percentage of landscape and area mean (ha) during 1990–2000–2010 of cultivable area

Block	Cultivable land														
	CA			NP			PD			PLAND			Area mean		
	1990	2000	2010	1990	2000	2010	1990	2000	2010	1990	2000	2010	1990	2000	2010
Bahadur Pur	0.1625	7,232.193	3,126.355	1	7	36	0.01	0.03	0.15	8	29.578	12.786	0.163	103.3	86.84
Baheriya	1,100.599	2,358.937	187.9631	9	16	3	0.04	0.06	0.01	4.29	9.1943	0.7326	122.3	147.4	62.65
Chaka	7,010.611	7,066.494	2,116	54	44	25	0.12	0.1	0.06	15.69	15.819	45.03	129.8	160.6	804.7
Dhanupur	0.0812	410.3487	0.00	1	6	0.00	0.01	0.04	0	5.08	2.4723	0.00	0.081	68.39	76.5
Handia	28.3475	603.0144	123.2864	5	10	6	0.03	0.06	0.04	0.169	3.5911	0.7342	5.67	60.3	20.55
Holagarh	0.1625	796.4924	0.00	2	24	0.00	0.01	0.17	0.00	0.001	5.5101	0.00	0.081	33.19	56.8
Jasra	3,974.014	7,983.118	5,566.202	9	20	11	0.03	0.08	0.04	14.93	30	20.919	441.6	399.2	506
Karchhana	3,136.585	5,079.812	3,839.245	16	38	10	0.06	0.14	0.04	11.28	18.269	13.807	196	133.7	383.9
Kaundhiyara	9,209.94	9,530.779	7,997.867	37	7	17	0.17	0.03	0.08	41.97	43.431	36.448	248.9	136.2	470.5
Kaurihar	0.1625	832.3938	0.5566	1	17	10	0.01	0.09	0.05	8.09	4.2119	0.0028	0.163	48.96	0.056
Koraon	1.3808	2,554.932	1,910.244	15	65	57	0.02	0.1	0.09	0.002	3.864	2.8889	0.092	39.31	33.51
Manda	0.8935	1,754.785	1,524.856	8	25	36	0.02	0.07	0.1	0.003	4.9634	4.3131	0.112	70.19	42.36
Mau Aima	0.2437	0.00	0.3896	3	0.00	5	0.02	0	0.03	0.001	0.00	0.0023	0.081	9.36	0.078
Meja	.00	1,032.695	1,945.588	0.00	20	34	0	0.04	0.07	0.00	2.2405	4.2212	0.087	51.63	57.22
Phulpur	0.4874	1,536.858	0.5009	6	16	5	0.03	0.07	0.02	0.002	6.6611	0.0022	0.97	96.05	0.1
Pratappur	0.00	1,733.666	0.4453	0.00	16	5	0	0.07	0.02	0.00	7.9882	0.0021	0.67	108.4	0.089
Saidabad	1,412.097	2,206.071	2,486.768	8	10	8	0.04	0.05	0.04	7.29	11.39	12.839	0.045	220.6	310.8
Shankargarth	1,086.384	10,847.84	1,406.189	6	32	37	0.01	0.06	0.07	2.136	21.323	2.7642	181.1	33.9	38.01
Soraon	2,061.247	832.3938	2,192.161	11	17	8	0.08	0.09	0.06	14.62	4.2119	15.553	187.4	48.96	274
Urwa	14,139.89	810.3818	703.6511	27	12	8	0.16	0.07	0.05	81.69	4.6818	4.0653	52.37	67.53	87.96
Total	18,699.62	14,696.69	14,696.69	217	422	311	0.29	0.27	0.22	105.73	41.606	350.22	4,028.99	6,497.424	6,522.351

Table 7 Class level metric analysis for core area, number of patch, patch density, percentage of landscape and area mean (ha) during 1990–2000–2010 of forest area

Block	Forest														
	CA			NP			PD			PLAND			Area mean		
	1990	2000	2010	1990	2000	2010	1990	2000	2010	1990	2000	2010	1990	2000	2010
Bahadur Pur	1,766	1,678	709.4	12	7	3	0.035	0.066	0.012	4.78	0.054	2.901	233.6	345	236.5
Baheriya	1,796	1,694	1,417	13	9	13	0.057	0.076	0.051	5.76	0.077	5.524	134.7	534.7	109
Chaka	1,895	1,754	0.167	15	10	2	0.068	0.034	0.98	6.76	0.061	2.67	430.1	345	0.084
Dhanupur	1,806	1,795	252	13	5	1	0.077	0.067	0.006	3.87	0.033	1.518	465.8	324.8	252
Handia	3,975	3,684	200.4	17	7	3	0.055	0.05	0.018	6.78	0.034	1.194	654.7	675	66.81
Holagarh	1,782	1,587	2,600	15	4	4	0.068	0.056	0.08	8.65	0.016	1.56	788.7	0.074	44.98
Jasra	1,597	1,398	2,654	16	6	7	0.046	0.034	0.05	5.56	4.088	3.45	891.5	21.45	78.97
Karchhana	9,146	8,432	2,882	13	8	12	0.054	0.076	0.043	4.87	1.45	10.36	734.7	0.195	240.1
Kaundhiyara	6,179	5,798	230.8	17	14	10	0.077	0.045	0.046	5.67	2.56	1.052	376.7	69.08	23.08
Kaurihar	882.2	7,864	2,133	12	10	15	0.061	0.065	0.076	4.464	5.45	10.79	73.52	46.15	142.2
Koraon	11,982	10,654	5,520	22	16	15	0.033	0.032	0.023	18.12	2.54	8.347	544.6	54.56	368
Manda	6,416	5,698	7,069	12	9	9	0.034	0.012	0.026	18.15	2.76	2.56	534.7	55.87	785.4
Mau Aima	1,048	9,876	0.223	4	6	3	0.023	0.56	0.017	6.055	4.76	3.67	262	46.1	0.074
Meja	1,046	8,976	6,189	13	11	3	0.567	0.734	0.007	7.67	4.87	13.43	324.8	13.99	2,063
Phulpur	1,765	1,597	0.39	10	6	2	0.043	0.875	0.009	7.65	3.78	6.45	463.7	34.1	0.195
Pratappur	34.85	126	138.1	5	4	2	0.023	0.018	0.009	0.161	0.056	0.636	6.969	0.122	69.07
Saidabad	80.33	56.87	369.2	1	6	8	0.005	0.076	0.041	0.415	0.766	1.906	80.33	25.88	46.15
Shankargarth	3,247	1,929	4,140	12	12	15	0.024	0.024	0.03	6.383	3.792	8.139	270.6	160.7	276
Soraon	2,356	1,765	0.334	13	3	4	0.086	0.65	0.028	5.08	2.86	4.87	324	134	0.084
Urwa	6,512	1,865	755.7	15	5	10	0.076	0.987	0.058	6.876	3.098	4.366	453	345	75.57
Total	65,311.38	78,226.87	37,260.71	250	158	141	1.512	4.53	1.61	133.72	43.10	1.61	8,048.71	3,231.77	4,877.26

1,345.44 ha in 1990 to 593.5 ha in 2000 and further increases 613.38 ha in 2010. Out of twenty block the maximum Area mean occupied by Chaka (2010) and Bahadurpur (2000) 137.1 and 87.23 ha respectively.

4.4 Class Level Metric Analysis

The results from class level metric analysis are discussed in this section.

Percentage of landscape (PLAND) is a unique technique which revealed landscape composition, the different landscape have different land use pattern with unique attributes like residential land use has high patch density and agriculture land use has high mean patch size (Weng 2007). The PLAND of built-up area of selected blocks are positively related to the developmental activities like commercial, transportation, industrial development and human intervention. In this study topographical factors have great impact on the change of PLAND of cultivable land. The PLAND of forest and agriculture land are found to have decreased. The PLAND of water body and built-up area also change in two decades showing in Fig. 3.

The area mean of class level metrics denote the average patch size of all patch belonged to the same land use type in landscape (Fig. 4) The area mean of urban land use type (built-up) is high compared to rural land use type (agriculture, forest and water body). The change in area mean of agriculture gradually decreases in two decades while the built up and cultivable land is positively correlated with the degree of human intervention and commercial practices. The PD is expressed by the number of patch per 100 ha. PD of any particular type of landscape denotes the current condition of all land use type metrics showing Fig. 5. The change of PD of different land use type like agriculture, built up, cultivable, forest and water body have different values compared to each year differently which revealed that the fragmentation of landscape has occurred due to human intervention and developmental activity. PD of overall twenty blocks among the five landscapes like forest area has more PD than built up, cultivable, agriculture and water body. The unusual high PD of forest area at Baheriya and Soraon block are due to road, household and commercial extension. The PD of forest and agriculture area has increased whilst the PD of built-up, cultivable and water body decreases in previous two decades gradually.

The NP provides clear information about the class level metrics high value indicates more fragmentation in particular area. The NP of agriculture and forest land is more as compared to cultivable, built-up and water body. That revealed the change in NP which is highly correlated with the human intervention showing in Fig. 6. The core area of the twenty blocks has greatly influenced in the past two decades which reveal the continuous change of class level metrics. Among the five class showing in Fig. 7, the agriculture and cultivable land have more CA compare to built-up, forest and water body in current time.

Table 8 Class level metric analysis for core area, number of patch, patch density, percentage of landscape and area mean (ha) during 1990–2000–2010 of water body

Block	Water body														
	CA			NP			PD			PLAND			AREA MEAN		
	1990	2000	2010	1990	2000	2010	1990	2000	2010	1990	2000	2010	1990	2000	2010
Bahadur Pur	1,660	959.5	1,018	36	11	39	0.183	0.045	0.16	8.435	3.924	4.162	46.1	87.23	26.09
Baheriya	1,077	790.6	1,327	29	46	110	0.113	0.179	0.429	4.197	3.081	5.17	37.13	17.19	12.06
Chaka	3,210	2,722	11,106	34	35	81	0.076	0.078	0.181	7.186	6.092	24.86	94.42	77.76	137.1
Dhanupur	692.6	159.1	917.6	13	17	23	0.078	0.102	0.139	4.173	0.959	5.529	53.28	9.36	39.9
Handia	1,467	449.1	1,151	35	27	32	0.208	0.161	0.191	8.739	2.675	6.855	41.93	16.63	35.97
Holagarh	895.3	249.4	605.1	21	7	46	0.145	0.048	0.318	6.194	1.726	4.186	42.64	35.63	13.15
Jasra	1,932	1,906	2,213	56	54	111	0.21	0.203	0.417	7.26	7.163	8.318	34.5	35.3	19.94
Karchhana	2,474	1,458	1,727	36	46	45	0.13	0.165	0.162	8.896	5.244	6.21	68.71	31.7	38.37
Kaundhiyara	1,537	1,140	1,307	24	17	63	0.109	0.078	0.287	7.006	5.194	5.955	64.06	67.04	20.74
Kaurihar	1,675	1,077	1,527	36	51	68	0.182	0.258	0.344	8.477	5.451	7.729	46.54	21.12	22.46
Koraon	3,730	2,449	2,857	176	152	139	0.266	0.23	0.21	5.642	3.703	4.321	21.19	16.11	20.56
Manda	1,962	1,264	1,621	124	98	48	0.351	0.277	0.136	5.551	3.575	4.586	15.83	12.9	33.78
Mau Aima	982	1,344	582.1	37	79	46	0.214	0.432	0.266	5.673	2.75	3.363	26.54	13.67	12.65
Meja	1,982	1,423	1,866	12	94	100	0.033	0.204	0.217	13.1205	3.088	4.049	544.6	15.14	18.66
Phulpur	1,733	658.7	1,915	76	50	49	0.329	0.217	0.212	7.51	2.855	8.301	54.76	13.17	39.09
Pratappur	989	155.8	793.5	19	36	29	0.088	0.166	0.134	4.557	0.718	3.656	52.05	4.328	27.36
Saidabad	1,238	592.9	488.9	41	15	20	0.212	0.077	0.103	6.389	3.061	2.524	30.18	39.53	24.44
Shankargarh	2,580	1,325	2,272	155	57	97	0.305	0.112	0.191	5.072	2.604	4.467	16.65	23.24	23.43
Soraon	931.6	1,077	765.3	29	51	50	0.206	0.258	0.355	6.609	5.451	5.43	32.12	21.12	15.31
Urwa	1,821	1,380	1,228	82	39	38	0.474	0.225	0.22	10.52	7.974	7.095	22.21	35.39	32.32
Total	34,568.5	22,580.5	37,287.5	1,071	982	1,234	3.912	3.515	4.672	40.65	22.66	31.67	1,345.44	593.5	613.38

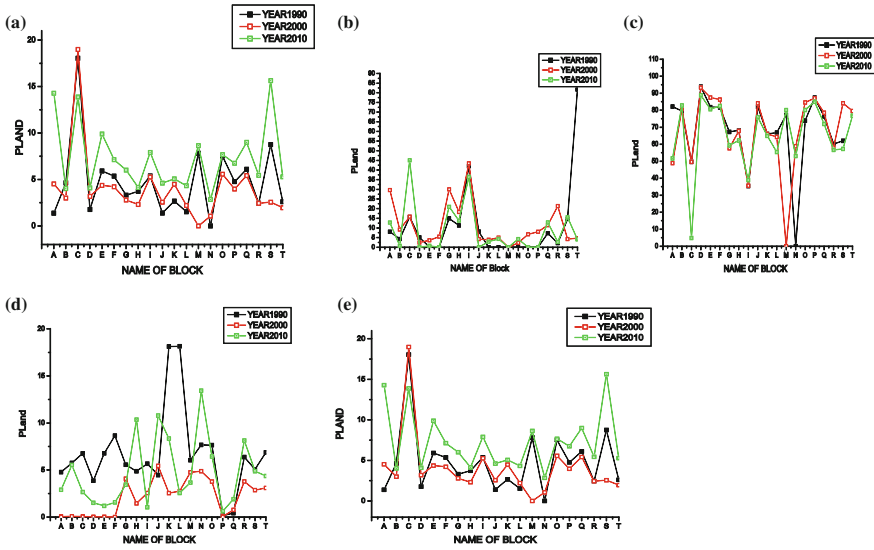


Fig. 3 Change of class level percentage of landscape (PLAND) of different land use class of a built-up, b cultivable, c agriculture, d forest and, e water body

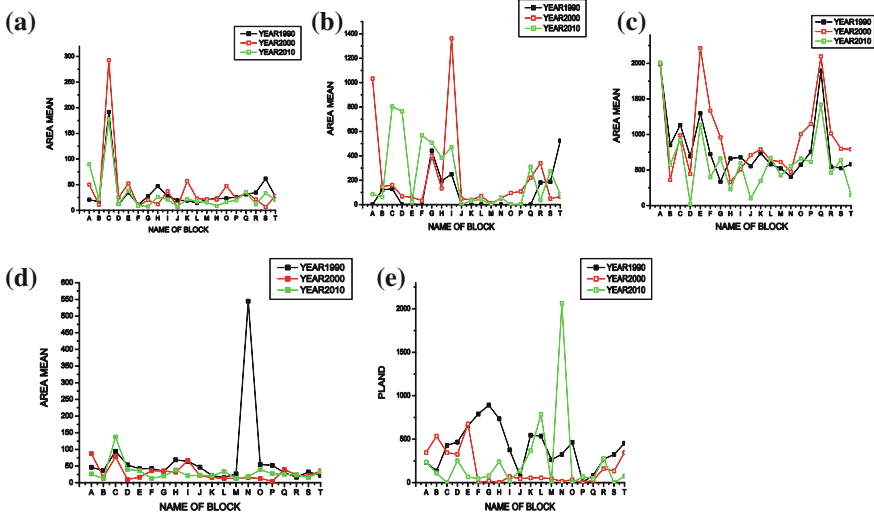


Fig. 4 Change of class level: area mean (Area Mean) of different land use class of a built up, b cultivable, c agriculture, d forest and, e water body

The patterns of change of class level metrics are more complicated. Generally, the results of built-up area and agriculture area are similar with metric outputs. This indicates a positive relationship to the degree of human intervention and

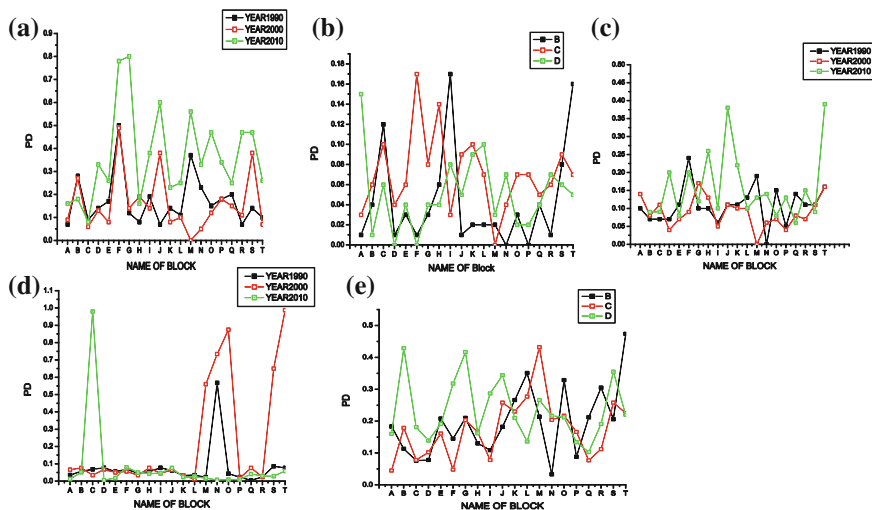


Fig. 5 Change of class level: patch density (PD) of different land use class of **a** built up, **b** cultivable, **c** agriculture, **d** forest and, **e** water body

developmental activity due to population pressure. The cultivable, forest and water body has also affected by human intervention.

4.5 Land Fragmented Class Analysis

Figure 8 shows the changes of landscape pattern both spatially and temporally through two decades. In the graph vertical axis represents the value of class and the horizontal axis represents the name of twenty blocks. TA mainly comprises of the overall area which is going through different processes of land use change. The TA value of land fragmented class when compared to previous two decades reduced and converted into many land use class with respect to the degree of human interference, as shown in Fig. 8a. The area mean shown in Fig. 8b presents gradual decrease within the last two decades indicating a fragmented area mean. Temporally, area mean in most of the blocks of land fragmented class is previously seen as decreasing and then it increases, which reveals the reciprocally changed area mean that highly correlates to the degree of human interference and developmental activity

PD at high value are indicating a fragmented landscape (Fig. 8c), which is directly or indirectly effected by the topographical or anthropogenic activity. Theoretically the observed changes of PD indicating positive relationship to the degree of commercial transportation (road construction) and residential expansions. Temporally, PD has increased through time in most of the blocks, indicating an increasing fragmentation of land fragmented class. The high value of number of

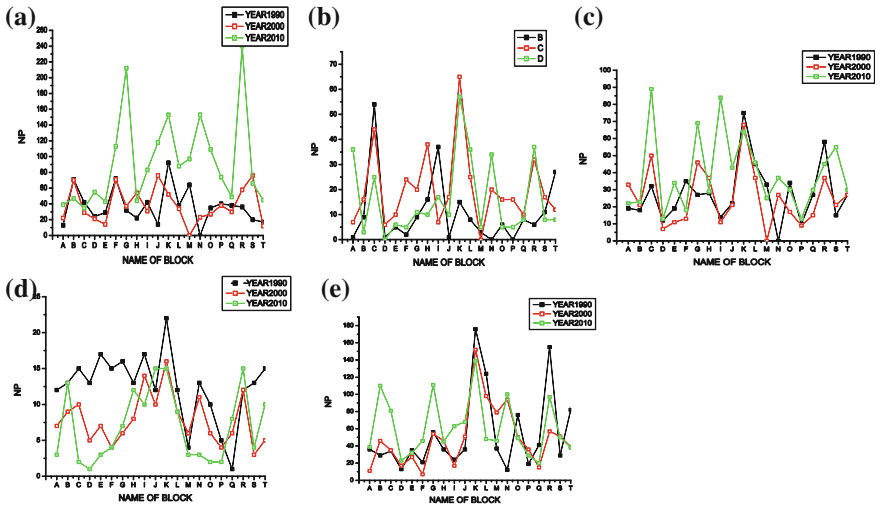


Fig. 6 Change of class level: number of patch of different land use class of **a** built up, **b** cultivable land, **c** agriculture, **d** forest and, **e** water body

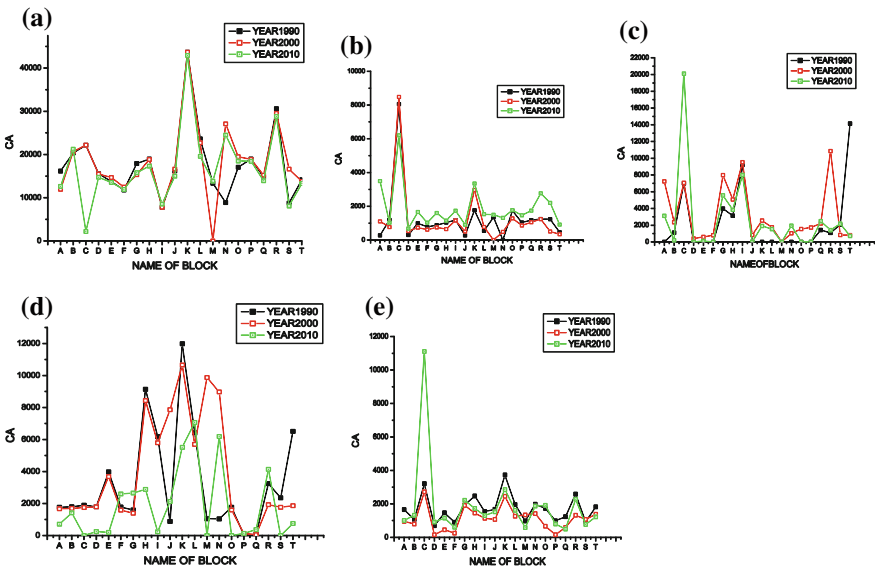


Fig. 7 Change of class level: core area of different land use class of **a** built up, **b** cultivable, **c** agriculture, **d** forest and, **e** water body

patch in a particular landscape denotes the most fragmentation. Thus the NP has significant information of current land use practice. Overall study of twenty blocks reveals that increase of NP value frequently in the current year which represents

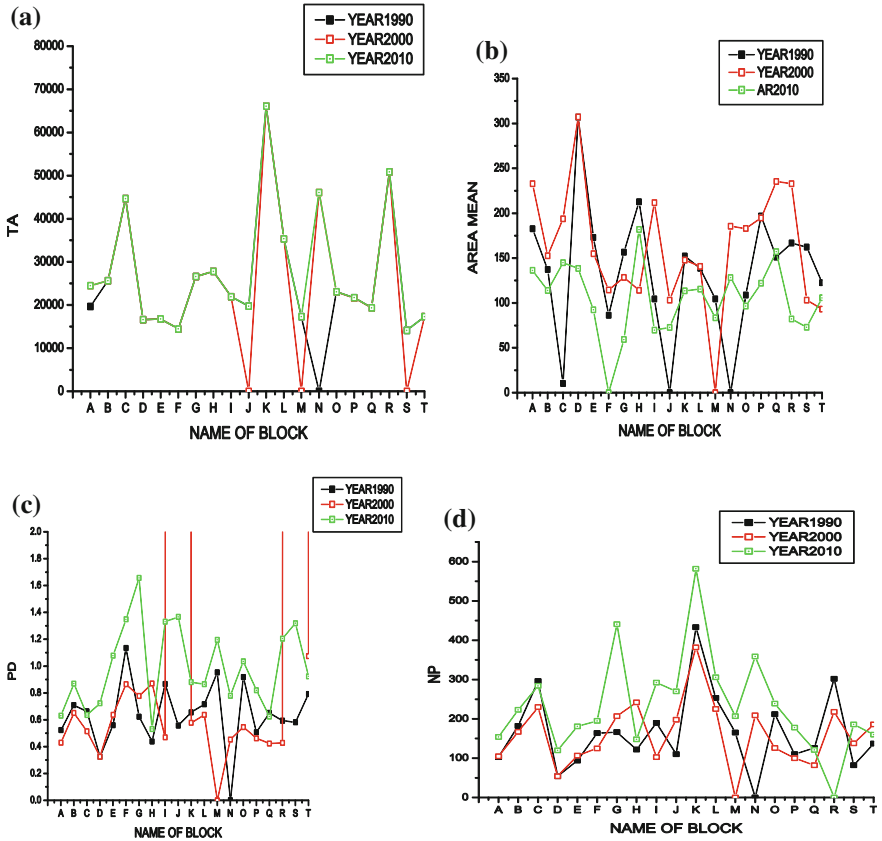


Fig. 8 a Total area. b Area mean. c Patch density and, d Number of patches in different land fragmented class

explicit information of fragmentation of landscape due to human intervention and developmental activity.

4.6 Estimating Effects on Water Quality

Rapidly growing countries, and particularly those emerging from rural to urban, frequently lack the resources to adequately monitor and forecast the impacts of land development on biologic, hydrologic, and social resources. Urbanization has significantly changed natural landscapes everywhere (Forney et al. 2001). Urban growth and fragmentation caused by urban sprawl have been extensively studied (Herold et al. 2002; Gonzalez-Abraham et al. 2007). Landscape structure is one of the most important factors influencing nutrient and organic matter runoff in

watersheds (Turner et al. 2003; Wickham et al. 2003; Uemaa et al. 2007). Therefore there is increasing demand for indicators and methods that make it possible to evaluate the landscape factors influencing water quality in freshwater management (Griffith 2002). Several studies have attempted to determine the relationship between land use/land cover structure and water quality but most studies have largely relied on compositional landscape metrics (Kearns et al. 2005). It is, however, clearly important to understand not only the total area of sources and sinks in the landscape, but also their spatial arrangement relative to flowpaths. The importance of the spatial arrangement of land cover within watersheds on water quality has been studied by Jones et al. (2001), King et al. (2005), Xiao and Ji (2007), Uemaa et al. (2005, 2007).

The groundwater after analysis showed that the areas which are more urbanized and fragmented have elevated concentration of different ions in the water. Three sites, namely Koran, Bahariya and Karchhana, were found to have elevated fluoride in analyzed groundwater samples. Similarly, Urwa, Holagarh and Soraon had positive value of fluoride so water is not suitable for drinking. The fluoride in pre-monsoon found that Koraon, Chaka (Naini) and Bahariya had values of fluoride of 1.096–1.291 mg/l and Jasra, and Bahadurpur had moderate values of fluoride (Singh et al. 2002). The domestic pollution is the major source of pollution in Yamuna River. About 85 % of the total pollution in the river is caused by the domestic sources. About 3 km upstream from confluence with Ganga River at Grand Trunk Road Bridge called Naini Bridge near Gau Ghat (MoEF 2006). This location depicts the Yamuna River water quality before its confluence with river Ganga. The domestic pollution is mainly caused by the urban centers. The organic pollution and microbial contamination reflect increasing trend up to Allahabad. The yearly average from 1999–2005 showed that the Dissolved oxygen was highest during year 1999 and 2000 (8 mg/l) afterwards it showed decreasing trend (6.5 mg/l). During the year 2004 and 2005 Biochemical oxygen demands was higher as compared to previous years. Chemical oxygen demand at Allahabad it ranged between 5 and 18 mg/l. These results showed that the Yamuna River quality is deteriorating due to organic pollution and this may also be attributed to landscape fragmentation.

According to Singh et al. 2002, heavy metal analysis in the <20- μ m-fraction of stream sediments appears to be an adequate method for the environmental assessment of urbanization activities on alluvial rivers. In their study they sampled during the pre-monsoon season at Delhi, Agra, Kanpur, Allahabad and Varanasi in 1993 and at Lucknow in 1995. These wide ranges are attributed to differential behavior of heavy metals rich urban effluents draining into rivers of the Ganga Plain. Stream sediments from Allahabad are classified into Sediment Pollution Index (SPI) natural sediments. To understand the impact of urbanization activities on stream sediment quality, the Pollution Load Index (PLI) given by Tomlison et al. (1980) was calculated for each urban centre. Allahabad 1.13 this PLI values show direct linear relationship with urban centre population.

5 Conclusion

The results of our study are partially validated. This study presents the results of a set of landscape metrics derived from remotely sensed data aiming to characterize the historical trends of landscape changes in the Allahabad district in the period 1990–2010. However, the identified trends in landscape changes in the region have potential policy implications in the region. The present study clearly reveals the impact and influence of the action taken during prolonged phase of land use/cover monitoring followed by a relatively short phase of passive management of twenty block of study area of Allahabad region during past two decades. The study is taken up to characterize the landscape pattern using land use/cover, landscape metrics and class level ecological metric analysis type that affect pattern of landscape changes. The landscape metric analysis indicates that from the year 1990 to 2000 periods the fragmentation of landscape was slightly low because the natural and climate condition are probably good, while from the year 2000 to 2010 it deteriorates which indicates that it could be due to human induced disturbance and development to gain more luxurious life, this still needs to be validated. The study on landscape and class level metrics helps for land management officer, forest management officer and policy makers in assessing and quantifying the extent to which the land use/cover is affecting the landscape and thus provide a complete perspective of change. Since most of changes are occurred in this area are due to human intervention and thus study over the fragmentation pattern will help to understand the spatial landscape transform processes which are also important for the ecological system and services. Landscape metric and landscape transformation analysis showed that over the time spatial configuration and composition of the landscape has changed a lot which leads to the environmental degradation. This study demonstrates the probable use of remote sensing, GIS and FRAGSTAT in assessing spatial structure and change in landscape.

Acknowledgments This research works is supported by K. Banerjee Centre of Atmospheric and Ocean Studies, IIDS, Nehru Science Centre University. Authors also thanks to the Landsat (<http://www.usgs.gov/pubprod/aerial.html#satellite>) programme for providing the satellite data. Authors are also thankful to the University Grant Commission, Delhi, for providing the financial grant for this research [Grant No. F. No. 42-74/2013 (SR)].

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