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The Study of the Land Cover Pattern in Varanasi District Using GIS and Landscape Metrics

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ABSTRACT

The pattern of land covers and their transformations is one of the main driving forces of environmental as well as socio-economic changes at regional and global levels. In the present, it is a central theme to the sustainable development debate, so understanding land cover transformations with land cover patterns at the landscape level is essential for proper land management and decision improvement in related areas. Varanasi district, in recent decades, has been witnessing significant changes in land cover patterns. In the last 39 years, there is a progressive decline in area under agricultural land, vegetation covers, and water bodies, while built-up land, vacant lands, and sandy area (riverine) have witnessed a prolific growth. At present, Remote Sensing has provided us with a viable tool to assess the land cover pattern and its changes at class-level. The present paper highlights the pattern of land covers and associated class-level transformations in the Varanasi District. This study is based on standard digital classification techniques and class-level landscape metrics.

Key Words : Land cover, Landscape Metrics, Varanasi district

INTRODUCTION

Studies relating to the nature and pattern of land use occurring in the area are of utmost importance to the governments and planning bodies of that area because the growing population rapidly absorbs the agriculture and vacant lots around the towns to meet their residential and commercial needs (Putri *et al.,* 2019). The growing population converts agricultural and vacant land around cities into urban settlements, forest areas into agricultural land, or rural areas into urban areas. As such, land cover is an essential descriptor of the Earth's surface and helps as a series of spatial information and summary data in planning actions or natural resource management decisions at local and national levels (Zwiener *et al.,* 2017). Simultaneously, the land cover also provides biophysical insights related to the changing factors in the environment by indicating the functional relationship between the area, its climate and soil (Wulder *et al.,* 2018). The land cover of any given area is generally described as a set of defined hierarchical classes, indicating the pattern of the major biotic and abiotic combinations that occupy the surface of that area. Thus, spatially explicit land cover data are essential for characterizing anthropogenic activity-induced changes in the region and its climate. Thus land cover change is critically linked to the intersection of natural and human influences that affect the spatial setups and environmental changes in the concerned area.

Presently, remote sensing has become an essential tool to understand the anthropogenic or natural factors and their effects at the local and national levels. Recent developments in the analysis of GIS-based satellite data have revolutionized land cover studies (Mallupattu and Reddy, 2013). GIS-based analysis plays a vital role in timely and accurate change detection to understand land use and land cover. It helps to understand the interactions between human and natural phenomena of the concerned

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region as changes in one affect the other (Sharma *et al.,* 2012). Along with the multi-temporal analysis, remote sensing and GIS-based analysis provide a unique observational capability to understand how the land cover of an area changes (Lo and Choi, 2014; Punithavati and Bhaskaran, 2011).

The study of the structural nature of different land cover classes is also of great importance in the analysis of land cover because the changes in the patches of land cover classes are closely influenced by the physical and socio-economic factors of that area. Therefore, we should also give importance to studying changes in the class-level structure in land cover analysis. FRAGSTATS is a software program developed to understand landscape fragmentation (McGarigal *et al.,* 2002; Paudel andYuan, 2012). Most of these metrics developed in FRAGSTATS are highly correlated to each other, and some of them are redundant, so all these metrics cannot be used for any particular scenario analysis (Turner *et al.,* 2001; Uuemaa *et al.,* 2009; Szabó *et al.,* 2012). These metrics can measure the area of land cover, size, core area, nearest neighbour distance, isolation and linkage in patch, class or landscape level to the respective area (Kumar *et al.,* 2018). The main objective of this study is to conduct a spatio-temporal analysis of the land cover of the Varanasi district and encourage the use of landscape metrics in land cover studies.

Study area:

Varanasi district (25^0 10'N and 25^0 35'N latitudes and 82^0 40'E and 83^0 12'E longitudes) located in the eastern Uttar Pradesh along the left bank of the river Ganga with an area of 153386.10 ha (Fig. 1). The study area is located in the middle Gangetic plain with an extension of old alluvial soil. Its average elevation above mean sea level varies from 90 meters in the west to 70 meters in the east. Total population of Varanasi district is 3676841 persons (Census 2011), which is currently 4261206 based on the estimation.

METHODOLOGY

In the present study, Landsat data (MSS and OLI) have been used. A number of steps *viz.,* image registration, generation of ancillary data layers,

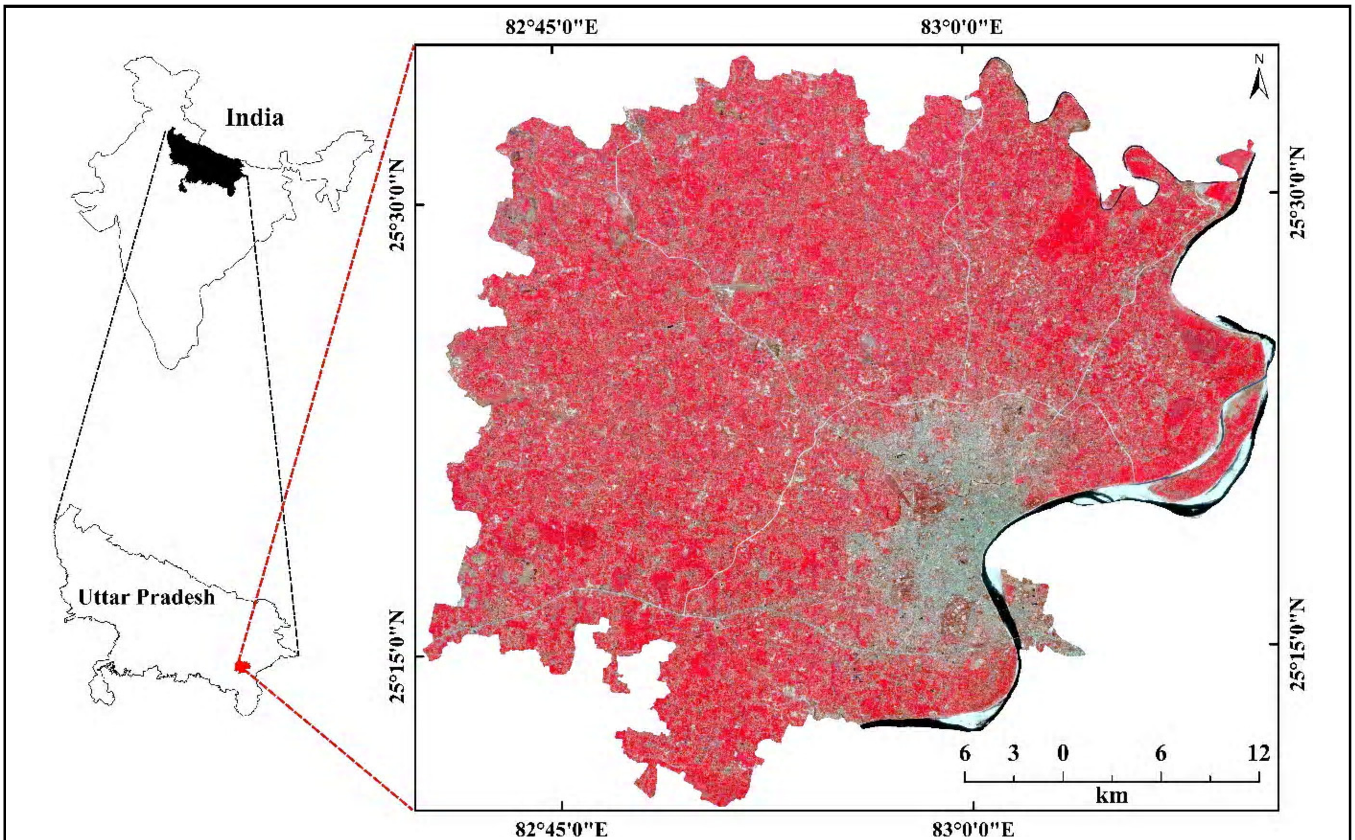

Fig. 1 : Location of Varanasi district

Table 1 : Used landscape metrics

Metrics	Metrics Name	Utility
CA	Class Area	measuring area (ha) of each patch type (Class)
NP	Number of Patches	measuring the number of patches of the corresponding patch type (class)
MPS	Mean Patch Size	measuring average patch size of the corresponding patch type (Class)
PLAND	Percentage of Landscape	Measuring the percentage of the landscape comprised of a particular patch type (Class)

supervised classification by considering six land cover thematic classes, accuracy assessment, tables etc., have been done. All the data processing work has been done on Arc GIS, ERDAS Imagine, and QGIS software. Field checks have been performed with the help of Google Earth real-time data to ascertain the ground truth. After that, final land cover data has been prepared.

After land cover data generation, four landscape metrics have been used to interpret the composition and spatial distribution of classified land cover categories in the study area. The list of used landscape metrics in this study is presented in Table 1.

After obtaining the data of land cover and landscape matrix, the land cover of the study area has been analyzed using both of them in an integrated form.

RESULTS AND DISCUSSION

In this study, six major land cover categories – built-up land, vegetation cover, sandy area (river), vacant land, water body and agricultural land have been classified based on NRSC's six-fold land use/land cover classification scheme. The accuracy of the land cover map (Fig. 2) for the year 1980 is 87.60 per cent, and for the year 2019 is 93.30 percent (Table 2). Table 3 and Fig. 3 show the land cover area and growth rate under each land cover categories in Varanasi district during 1980 and 2019 as base years.

In the year 1980, 74.24 per cent of the total land area came under agricultural land, which came down to 64.55 percent in 2019. The growth rate of agricultural land was -0.35 per cent during the study period (Table 3). In 1980-2019, the maximum transformation of agricultural land occurred into vacant land and the slightest change into the water body (Table 5). The increase in NP of agricultural land and decrease in MPS shows that there has been considerable fragmentation

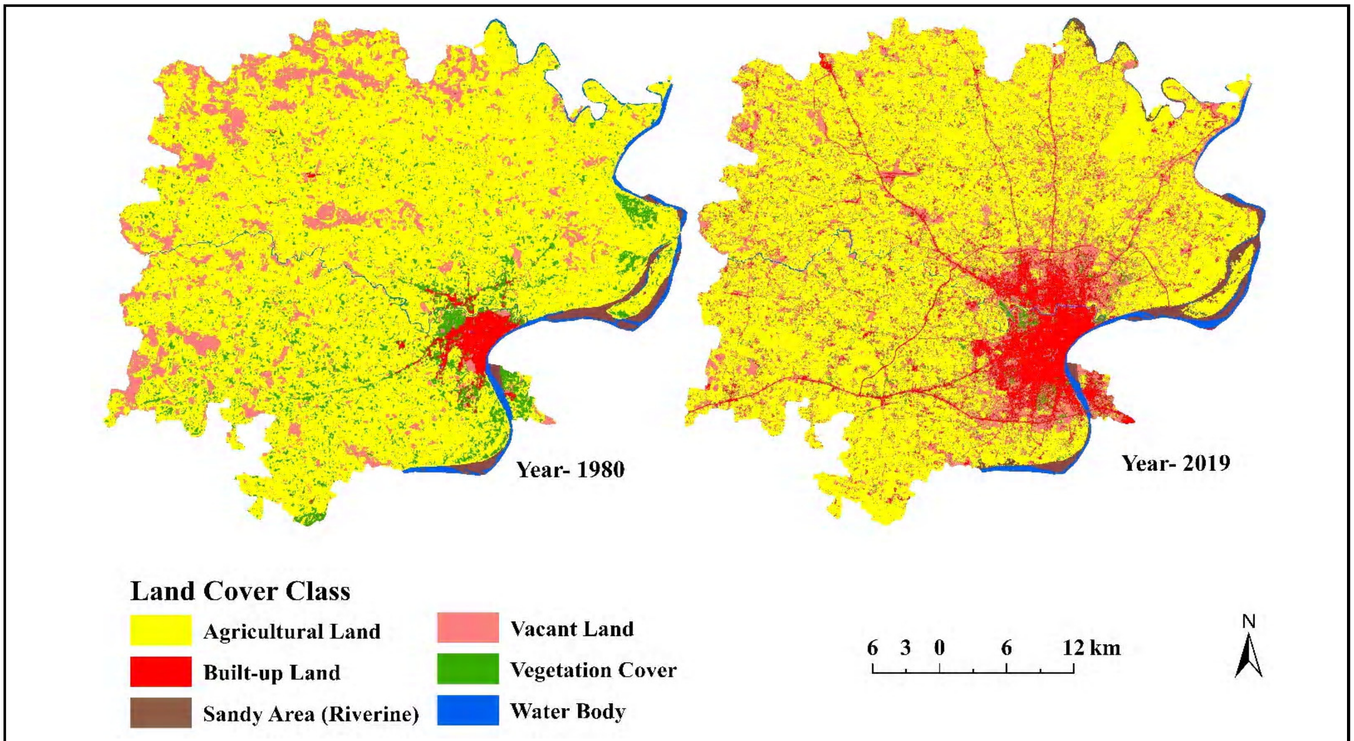

Fig. 2 : Land Cover Map of Varanasi District

Table 2 : Accuracy of classified land cover categories

LULC Category	Year- 1980		Year- 2019	
	Producer's	User's	Producer's	User's
Agricultural Land	88	86	90	90
Built-up Land	93	90	96	96
Sandy Area (Riverine)	98	92	96	94
Vacant Land	97	88	87	84
Vegetation Cover	86	80	90	98
Water Body	86	90	95	94
Overall Accuracy	87.60%		93.30%	
Kappa Value	0. 852		0.92	

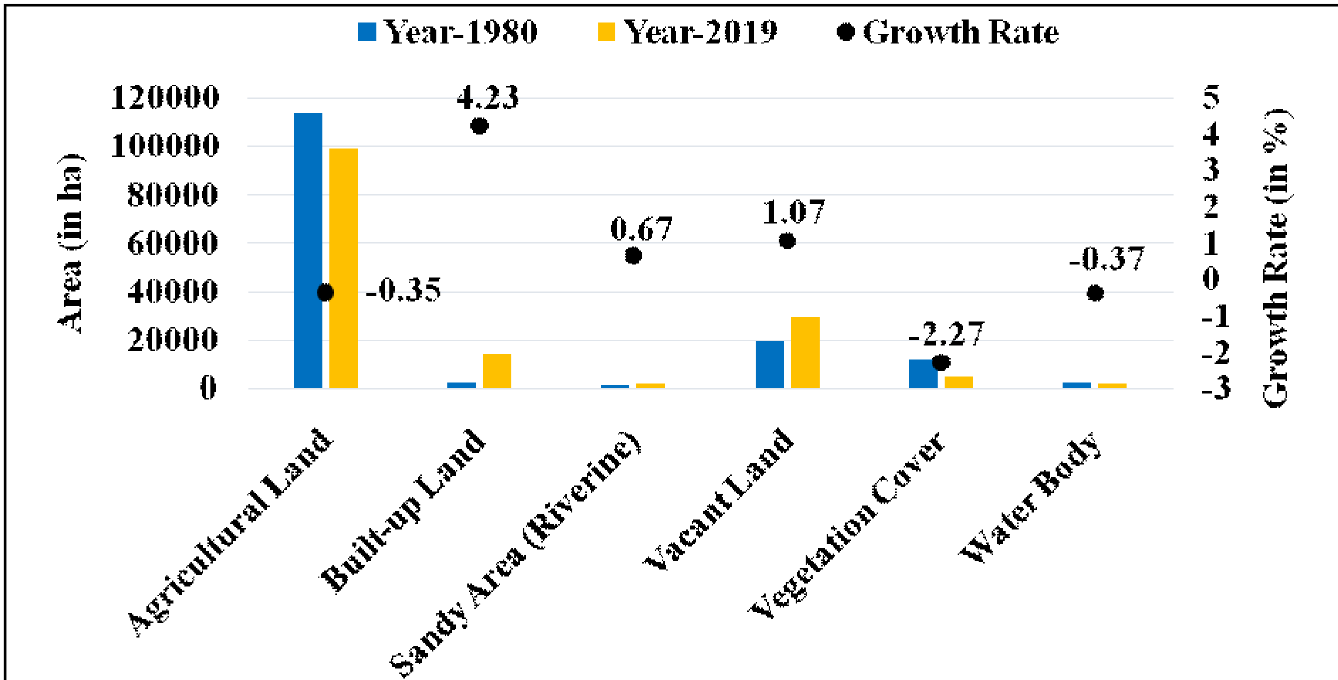

Fig. 3 : Proportional area and growth rate under different land cover categories

of agricultural land from 1980 to 2019. Due to which there has been a decrease in the dominion of agricultural land in the study area. The decrease in the PLAND value confirms this (Table 4).

Built-up land, defined as non-agricultural land use containing buildings, transport and communications, urban utilities, accounted for 1.80 per cent of the total area in 1980 and increased to 9.46 per cent in 2019, with a growth rate of 4.23 per cent (Table 3), which mainly reflects the accumulation of population and increasing urbanization in and around the city of Varanasi. The increasing value of NP and decreasing value of MPS indicate that the built-up land has increased rapidly in the form of small patches. Similarly, increasing values of PLAND indicate that the spatial impact of built-up land has increased faster than other land covers from 1980 to 2019 (Table 4).

The area under sandy area (riverine) has increased from 1967.49 ha to 2567.34 ha in 1980 to 2019, at the growth rate of 0.67 per cent (Table 3). The pattern of NP shows fragmentation, whereas the MPS shows the reduction in the average size of patches of sandy area (riverine). Together, these two show that the sandy area (riverine) increased in the form of small patches. The value of PLAND indicates that the regional dominance of the sandy area has increased (Table 4). From 1980 to 2019, the sandy area (Riverine) land transformed highest into the water body and the least into the vegetation cover (Table 5).

The average growth rate of vacant land was 1.07 per cent. Vacant land increased from 19555.47 ha to

29930.58 ha from the period of 1980 to 2019 (Table 3). The NP increased from 2607 to 25265, and MPS decreased from 7.50 hectares to 1.18 hectares in the last 39 years, showing that the vacant land expanded with a dispersed pattern in the form of small patches. PLAND increased from 12.75 to 19.51 during these 39 years, indicating that the predominancy of vacant land has increased at the landscape level (Table 4). From 1980 to 2019, most vacant land was transformed into agricultural land and the lowest into a sandy area (Table 5).

The vegetation cover has decreased with a growth rate of -2.27 per cent. The vegetation cover was 12436.56 ha in 1980, which was reduced to 4956.66 ha by the end of 2019 (Table 3). During this period, NP increased from 5699 to 17211, and MPS decreased from 2.18 to 0.29, indicating that areas of vegetation cover have undergone rapid fragmentation, and its area has decreased rapidly (Table 4). During these 39 years, most vegetation covers were absorbed by agricultural land, vacant land, and built-land categories, while the water body category absorbed the lowest area of vegetation cover (Table 5).

The water body declined at a rate of -0.37 per cent from 1980 to 2019. In these 39 years, the water body changed from 2776.68 ha to 2398.50 ha (Table 3). During this period, the NP increased from 130 to 569 while the MPS decreased from 21.36 ha to 04.22 ha, indicating that the water body was fragmented at the patch level. As a result, the area of the water body decreased. The PLAND value also decreased from 1.81 to 1.56 in this period (Table 4). Hence it is clear that there has been a decrease in the regional dominancy of the water body. Most of the water body's areas were absorbed by sandy areas, vacant land, and agricultural land, while the lowest absorption was by vegetation cover (Table 5).

Summary and Conclusion:

The present study aptly brings to light the changing pattern of different land cover categories over time in the study area. Among all the classified land cover categories, the agricultural land category covers more than 60 per cent of the total land area in the study area in both the years 1980 and 2019, followed by vacant land and vegetation cover. The Land Transformation analysis shows a phenomenal growth in the built-up area with a growth rate of 4.23 per cent, reflecting the spurt in construction activity mainly due to rising residential needs and rapid expansion of commercial activities in the district. The most rapid reduction occurred under vegetation cover. Apart from this, the areas of agricultural land and water bodies have also decreased during the last 39 years.

Thus a decrease in area under agricultural land encourages an increase in vacant land in some parts, whereas the expansion in built-up land encourages a decrease in agricultural land, vegetation cover, and vacant land in and around urban centers. Moreover, we know

Table 3 : Proportional areas of different land cover classes in study area

Land Cover Class	Year-1980		Year-2019		Growth Rate
	in ha	in %	in ha	in %	
Agricultural Land	113858.19	74.24	98997.37	64.55	-0.35
Built-up Land	2765.16	1.80	14509.17	9.46	4.23
Sandy Area (Riverine)	1967.49	1.28	2567.34	1.67	0.67
Vacant Land	19555.47	12.75	29930.58	19.52	1.07
Vegetation Cover	12436.56	8.11	4956.66	3.23	-2.27
Water Body	2776.68	1.81	2398.50	1.56	-0.37
Total	153359.55	100.00	153359.62	100.00	-

Table 4 : Landscape metrics of different land cover categories

Land Cover Class	Landscape Metrics							
	CA		NP		MPS		PLAND	
	1980	2019	1980	2019	1980	2019	1980	2019
Agricultural Land	113858.19	98997.37	615	3804	185.14	26.02	74.24	64.56
Built-up Land	2765.16	14509.17	572	21112	4.83	0.69	1.80	9.46
Sandy Area (Riverine)	1967.49	2567.34	64	432	30.74	5.94	1.28	1.67
Vacant Land	19555.47	29930.58	2607	25265	7.5	1.18	12.75	19.51
Vegetation Cover	12436.56	4956.66	5699	17211	2.18	0.29	8.11	3.23
Water Body	2776.68	2398.50	130	569	21.36	4.22	1.81	1.56

Table 5 : Land transformation matrix (1980-2019)

	Land Cover	Year- 2019						
		Agricultural Land	Built-up Land	Sandy Area (Riverine)	Vacant Land	Vegetation Cover	Water Body	Grand Total
Year- 1980	Agricultural Land	82014.39	7922.35	562.67	19863.33	3148.40	256.23	113767.38
	Built-up Land	38.76	2602.00	3.81	73.92	30.00	16.16	2764.65
	Sandy Area (Riverine)	193.30	13.98	1320.37	35.06	1.35	400.29	1964.35
	Vacant Land	12013.01	1449.63	34.90	5670.59	276.70	62.35	19507.19
	Vegetation Cover	4347.80	2697.58	134.29	3761.76	1430.45	53.21	12425.10
	Water Body	267.84	85.11	497.34	276.33	24.93	1561.48	2713.03
	Grand Total	98875.11	14770.66	2553.39	29680.99	4911.83	2349.71	153141.69

that the reduction in vegetation cover and water bodies is a cause of environmental concerns which will further affect the living conditions, ecological stability and development of the growing population. Therefore, there is a need for the study of land cover by integrating GIS and landscape metrics with socio-economic data to make the study of land cover more scientific, logical and useful.

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