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URBAN LANDSCAPE DYNAMICS FOR QUANTIFYING THE CHANGING PATTERN OF URBANISATION IN DELHI

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ABSTRACT

Ongoing rapid pace of population growth and accelerating urbanisation have transformed urban and rural landscapes in the National Capital Region of India. To understand the changing ecology of Indian urban systems, it is essential to quantify the spatial and temporal patterns of urbanisation with the way it is transforming the characteristics of sub-urban and rural areas.

The current paper uses Urban Landscape Analysis Tool (ULAT) to compute the changing patterns of urban sprawl in Delhi, India. Classified images having three classes namely Urban, Water and Others are utilised to extract the degree of urbanisation, which in turn reclassified into urban sub-classes called built-up, sub-urban built-up, rural built-up, open land and water. Area corresponds to each urban sub-class when plotted temporally provides significant information about the nature and type of urban sprawl. This paper also helps to identify the name of different sub-urban and rural areas changed and became the part of urban ecosystem in last two decades in Delhi.

Keywords: Urbanisation, GIS, Remote Sensing, Urban, Land Use Land Cover, ULAT. etc.

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Introduction

The world has seen a rapid surge in urban population as a consequence of urban revolution in the 1990s. Urbanisation is not a recent phenomenon but an incessant process characterised by the remarkable increase of urban inhabitants- from a yearly average of 57 million between 1990 and 2000 to 77 million between 2010 and 2015. The fast-paced urbanisation in many developing countries seems to have been escorted by irrationally high levels of concentration of urban population in metro cities. Currently in Asia, the urban centres of Karachi, Jakarta, Osaka, Shanghai, Mumbai, Seoul, Manila and Beijing are home to 20 million population each while in New Delhi and Tokyo this figure is expected to approach 40 million populations in the coming decade.

Urbanisation has been often delineated in phrases of its various patterns, process, causes and their consequences. The entire civilisation was in rural settlements before the development process started (Baker, W.L. 1989). Gradually, needs and requirements of human beings increased and rural settlements started acquiring urban character. Most of the rural settlements have already changed and merged into urban areas with changed characteristics in terms of pucca houses, pucca roads, availability of infrastructure, etc. Such changed villages are called urban villages while the others remained the rural villages (López, et al., 2001). Urban growth monitoring is of prime importance to achieve the much desired dream of sustainable human society existence (Barredo et al., 2003, Fang, S. et al., 2005).

In 1981, Dehli had 369 settlements consisting of 111 urban and 258 rural villages. Since more than one decade, urban villages are becoming slum pockets which have necessitated the development in terms of lying of infrastructure, construction of roads, public and semi-public buildings and parks, etc. Similarly, it is also necessary to formulate strategies for the development of different types of suburban settlements and neighbouring villages.

Due to socio-economic changes and transformations in the society (Anuj Tiwari and Dr. Kamal Jain, 2014), "previously all the settlements were rural, but later slowly they are transformed into suburban and then urban settlements. In a super metropolitan city, the changes and transformations are more, than in a metropolitan city and other urban centres. Currently, in Delhi, there are 369 settlements with a break-up of 11 urban villages and 258 rural villages. It is expected that the number will keep on increasing and by the end of this century, it may go up to 160 villages. Accordingly, number of rural villages will come down to the figure of 209 villages.

Due to deficient expansion of rural areas, a substantial amount of people is relocating to suburban or urban localities of Delhi region after selling their properties to real State companies/ construction firms constructing different noxious and nuisance industries and warehouses. This rapidly transforming land activity became the primary reason of degrading environment. Fits can be controlled up to some extent if a proper expansion scheme is prepared for these villages and implemented under the supervision of pollution control and monitoring authority.

The shift from rural to urban dominated region is an asset in one way whereas a liability in other. People are now interested in the secondary and tertiary sectors of employment against the customary agricultural activities. A stark contrast can be seen between the highly modernised urban stretches and the remotely settled rural areas. Possibly, this can be reason behind the increase in the rate of urban growth in Delhi, especially in the central part of the city with highly concentrated urban settlements.

Population Explosion in Delhi Region: Population of Delhi has increased rapidly in last 10 years. From the figure of 400,000 in the year 1901, the population of Delhi has increased to around 18,686,902 in the year 2016. According to 2011 census of India, population of Delhi was around 16,753,235.There has been tremendous development in transport, education and other facilities offered by the government and other agencies in Delhi. A detailed graph is presented in Figure 1 depicting the growth rate of India and Delhi from 1951 to 2011.The population of Delhi is expected to rise 40 per cent by the year 2020. Better roads and good living standards in Delhi have attracted people from all over India. Not only locals but tourists from all over the world have made their way to the capital of India.

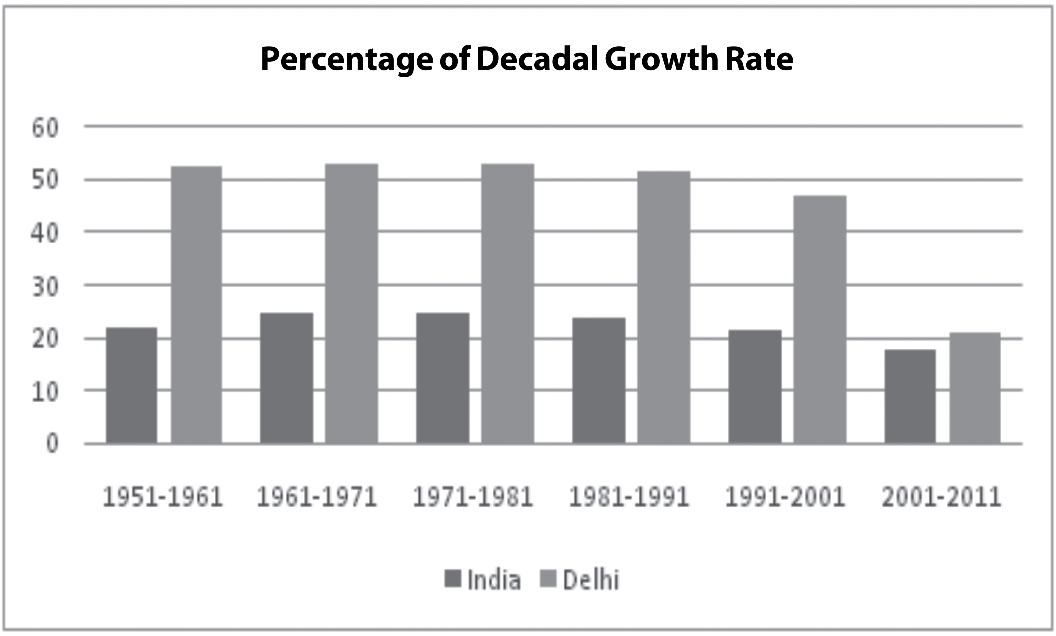

Figure 1: Growth Rate of India & Delhi from 1951 to 2011

Industrial growth and rampant urbanisation have been emanated in an exponential increase in Delhi population in past 10 years. Due to availability of affordable housing in the metro city in comparison to the national capital, the growth has been increased because of the immigration of people from New Delhi. The dream city of Delhi attracts people from all over India as offices of major multinational companies are set up here. Thus, a large number of Delhi populations are migratory.

Study Area

Delhi is the capital city of India. It is situated on the banks of river Yamuna and lies in between 28° 24' 17" N to 28° 53' 00" N latitudes and 76° 45' 30" E to 77° 21' 30" E longitudes. Its geographical boundaries touch on three sides by Haryana and to the east, across the river Yamuna by Uttar Pradesh. Besides its long history the city is popular for Akshardham Temple, the largest Hindu temple and Jama Masjid, the principal mosque. The geographical area of the city is about 1483 km². Monsoon season starts from July and lasts up to September. In summer season, temperature reaches up to 45°C or higher. The location map of study area is shown in Figure 2.

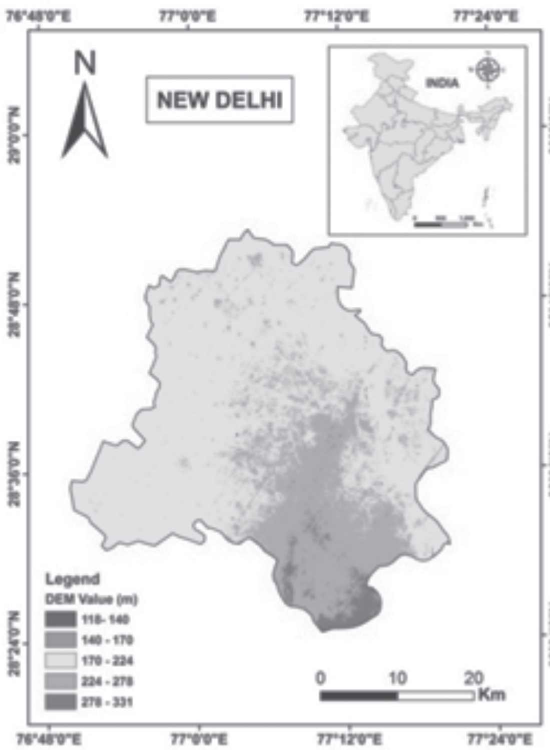

Figure 2: Study Area of Delhi Region

Landsat and Resourcesat Satellite Data: As shown in Figure 3, the current study uses three satellite images for 2001, 2011 and 2015. 2001 and 2015 image is selected from Landsat satellite mission (Landsat 7 and Landsat 8) and downloaded from US Geological Survey (USGS) Global Visualisation Web Portal. 2011 image is selected from Resourcesat satellite mission and downloaded from Bhuvan, Indian Data Distribution Portal. The collected satellite imageries are co-registered and projected to UTM zone 43 North projections with WGS-84 datum. The specifications of Landsat TM, ETM+ and LISS images are shown in Table 2 (Zhuang, X et al., 1991).

Table 1: Specifications of Landsat TM, ETM+ and LISS Images

Satellite	Sensor	Path	Row	Acquisition Date	Time (GMT)	Resolution (m)
Landsat 7	ETM	146	40	02-Apr-2001	05:08:56	30/120
Resourcesat-1	LISS-III	-	-	22-Apr-2011	05:08:32	0.000225 Deg
Landsat 8	OLI/TIRS	146	40	21-May-2015	05:18:27	30/100

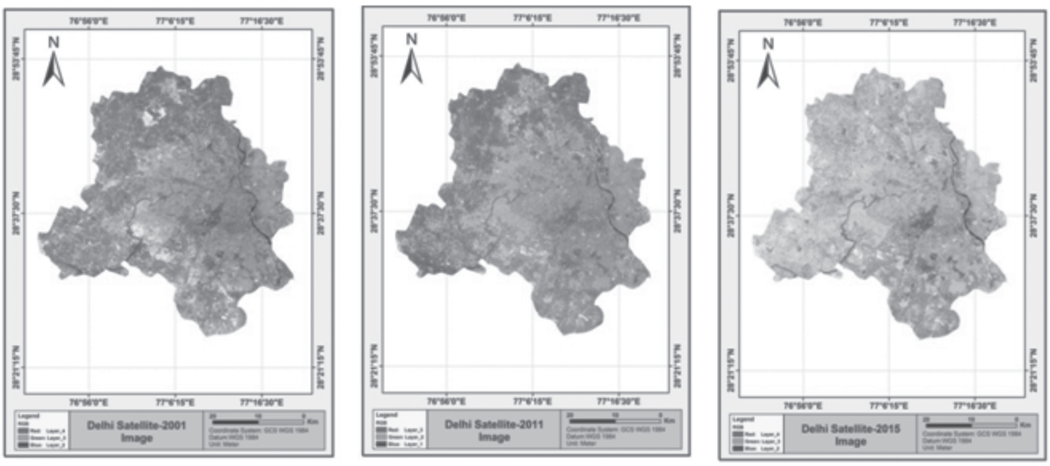

Figure 3: Delhi Satellite Images for 2001, 2011 and 2015

Methodology

Maximum Likelihood Classification: Current study implements one of the most popular supervised classification methods, Maximum likelihood with a set of optical remote sensing imagery (Benediktsson et al., 1990). Classifier can generate most accurate classification results with bunch of accurate training datasets (Asmala, 2012). Maximum likelihood classifier is based on Bayesian probability theory (Hord, 1982). Once classifier receives training data, it computes means and variances for each band of each class, which are described by the mean vector and covariance matrix and treating them in nature of Gaussian (Shi, Wenzhong, and Qunming Wang, 2015). From this information, the statistical probability is computed for a given pixel value being a member of a particular land use and land cover classes (Raymond Bonnett and Campbell, 2002). Not only mean and variance but defining membership-variability of brightness values in each class also plays an important role while classifying the dataset (De Wulf, R., 2002; Merugu Suresh and Kamal Jain, 2015; Verhoeye. J). Now for every unknown pixel as per the equation1, distance is calculated using the mean of a class and the probability of occurrence of that pixel in the class, class having minimum distance to the pixel is assigned to the designated class (Merugu Suresh and Kamal Jain, 2016 & 2017; Niroumand et al., 2012).

$$D_{Max}\left(m_{ij}\right) = \ln P(W_1) - \frac{1}{2}\ln|Cov_c| - \frac{1}{2}\sum_j^{nb}(m_{ij} - k_j)Cov_c^{-1}(m_{ij} - k_j) \text{ ----- (1)}$$

Where:

$i = i^{th}$ class,

x = n-dimensional data (where n is the number of bands),

$P(w_i)$ = Probability that a class occurs in the image and is assumed same for all classes, $|Cov_c|$ = Determinant of the covariance matrix of the data in a class,

Cov_c^{-1} = Inverse of covariance matrix of a class,

m_{ij} = Mean vector of a class i and band j.

Equation (1) assumes that probability values are same for each class, and different input bands shows normal distributions. If this is not the case, Parallelepiped or Minimum distance method can be used for classification with better accuracy and computation time.

Urban Landscape Analysis Tool (ULAT): Urban Landscape Analysis Tool (ULAT) was developed by Centre for Land Use Education and Research (CLEAR), University of Connecticut. It is best suited to compute the changing patterns of urban sprawl. Classified Images having three classes namely Urban, Water and Others are the input for ULAT, which in turn reclassified into urban sub classes called built-up, sub urban built-up, rural built-up, open land and water (Table 2). Area corresponds to each urban sub-class, when plotted temporally provides significant information about the nature and type of urban sprawl.

Results and Discussion

Land Use Land Cover Mapping: Landsat OLI/TIRs images are used for land use and land cover mapping. Satellite images for the study area are classified into four different classes i.e. water, impervious surface, green space and other. A brief description of areas included in each class is shown in Table 2.

Table 2: Description of Land Cover Classes

Category	Description
Water	Including all water bodies (e.g. sea, lake, river and ponds).
Urban	Including buildings, roads and all other impervious surfaces such as parking lots, airports, tennis courts and sidewalks.
Green Space and Others	Including all healthy vegetation cover (e.g. forest and grass) based on vegetation index and Others class include all lands not classified as green space, impervious surface and water.

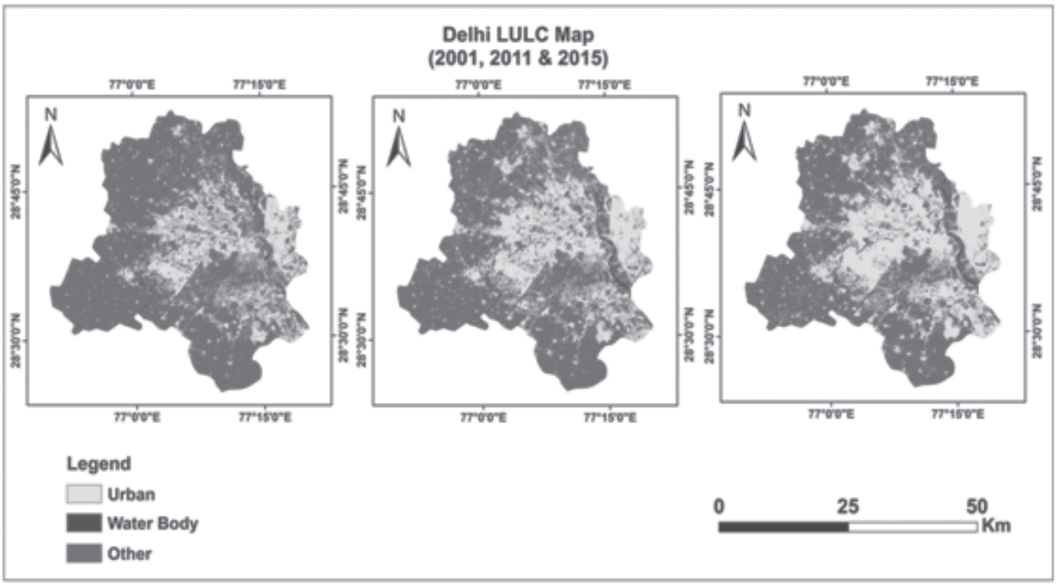

Figure 3: Delhi Land Use and Land Cover for 2001, 2011 and 2015

Table 3: Accuracy Assessment for LULC Classification for 2001 Imagery

Class Name (2001)	Producer's Accuracy	User's Accuracy	Overall Accuracy	Overall Kappa
Other	81.82%	88.52%		
Waterbody	76.09%	92.11%	92.91	0.8732
Urban	83.93%	88.68%		

Table 4: Accuracy Assessment for LULC Classification for 2011 Imagery

Class Name (2011)	Producer's Accuracy	User's Accuracy	Overall Accuracy	Overall Kappa
Other	70.00%	87.50%		
Waterbody	80.00%	94.12%	91.60%	0.9085
Urban	85.92%	85.92%		

Table 5: Accuracy Assessment for LULC Classification for 2015 Imagery

Class Name (2015)	Producer's Accuracy	User's Accuracy	Overall Accuracy	Overall Kappa
Other	90.48%	82.61%		
Waterbody	86.67%	90.70%	94.98%	0.8931
Urban	95.35%	91.11%		

Table 6: Land Use Land Cover Classification Statistics between 2001, 2011 and 2015

S. No	LULC Class	Year 2001 Area (sq km)	Percentage of Area	Year 2011 Area (sq km)	Percentage of Area	Year 2015 Area (sq km)	Percentage of Area
1.	Urban	404.09	26.89%	556.33	37.04%	600.61	39.97%
2.	Waterbody	17.74	01.18%	11.43	00.76%	15.56	01.03%
3.	Vegetation	1080.75	71.93%	934.32	62.20%	886.46	60.00%
	Total Area	1502.58	1502.58	1502.58			

Land use land cover status for the year 2001, 2011 and 2015 are presented in Table 7. Land use land cover status of Delhi for 2001 reveals that total 26.89 per cent of area about 404.09 sq km belongs to urban built-up area, 71.93 per cent (1080.75 sq km) belongs to vegetation and other features, and 01.18 per cent (17.74 sq km) belongs to waterbody. Accuracy assessment results obtained for individual land use land cover classes (2001) are summarised in Table 4. Overall classification accuracy (92.19 per cent) and overall kappa coefficient (0.8732) justifies degree of satisfaction in results.

While land use land cover results for the year 2011 shows that total 37.04 per cent of area about 556.33 sq km belongs to urban built-up area, 62.20 per cent (934.32 sq km) belongs to vegetation and other features, and 00.76 per cent (11.43 sq km) belongs to waterbody. Accuracy assessment results obtained for individual land use land cover classes (2011) are summarised in Table 5. Overall classification accuracy (91.60 per cent) and overall kappa coefficient (0.9085) justifies degree of satisfaction in results.

Lastly, land use land cover status for the 2015 presented in Table 6 describes that the total 39.97 per cent of area about 600.61 sq km belongs to urban built-up area, 60.00 per cent (886.46 sq km) belongs to vegetation and other features, and 01.03% (15.56 sq km) belongs to waterbody. Accuracy assessment results obtained for individual land use land cover classes (2011) are summarised in Table 6. Overall classification accuracy (94.98 per cent) and overall kappa coefficient (0.8931) justifies degree of satisfaction in results.

Urban Landscape Analysis: Land cover mapping of Delhi from 2001 to 2015 demonstrates a persistent increasing trend of impervious surfaces that comprises rural built-up, urban built-up and sub-urban built up areas. As shown in Table 8, it is observed that the total urban area increased up to 46026.83 Ha in 2015 from 26850.40 Ha in 2001. Suburban built-up boundaries are combining with rapidly increasing urban area and total suburban area has started decreasing from 15616.10 Ha in 2011 to 12744.61 Ha in 2015. Rural built-up area which was 1444.20 Ha in 2001 has also decreased and reached up to 1293.273 Ha in 2011. The rapid rate of rural-urban transformation affected rural boundaries and in 2015 only 1289.56 Ha is left as rural. Similar pattern of transformations can be observed in open land which often changes its nature from vegetation land to rural, suburban and urban land. Area belonging to waterbodies is decreased and in 2015 only 1548.04 Ha water surface area is found in comparison to 1754.56 Ha in 2001. Regional visual analysis depicts that total 34 suburban areas are changed into urban areas, 53 rural areas are transforming toward suburban areas while in 30 rural centres on the outskirts of city, no change is observed. All of these changes are summarised in Tables 9, 10 and 11. A detailed map with the locations of these urban, suburban and rural centres is also presented in the Figures 4 & 5. Similar pattern is observed for open land which is utilised for different land use transposes.

Table 8: Impact of Urbanisation (Separately in Urban, Suburban and Rural Areas)

S. No.	Class	Area in 2001 (Ha)	Area in 2011 (Ha)	Area in 2015 (Ha)
1.	Urban built-up	26850.4	43421.81	46026.83
2.	Suburban built-up	12115.08	15616.1	12744.61
3.	Rural built-up	1444.208	1293.273	1289.565
4.	Urbanized open land	9015.818	13092.19	9306.36
5.	Captured open land	2695.298	4026.898	3664.958
6.	Rural open land	96862.52	71579.48	75674.41
7.	Water	1754.86	1143.67	1548.047

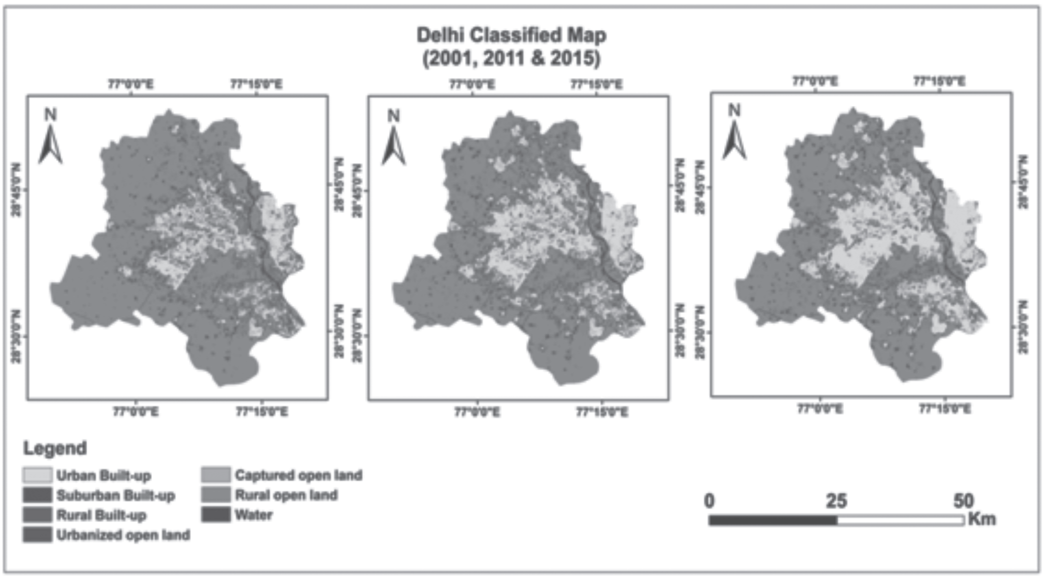

Figure 4: Rural to Suburban and Suburban to Urban Transformation in Delhi

Table 8: Suburban Areas Transformed into Urban Area

S. No.	Rural to suburban village	S. No.	Rural to suburban village
01	Malikpur	28	Zindpur
02	Shikarpur	29	Majra Dabas
03	Daulatpur	30	Naya Bans
04	Kanganheri	31	Tiggipur
05	Badusarai	32	Sungerpur
06	Pandwala	33	Jaunti
07	Paprawat	34	Jat Khor
08	Khera Dabar	35	Punjab Khor
09	Jaffarpur Kalan	36	Holambi Khurd
10	Mundhela Khurd	37	Kanjhawala
11	Hari Dass Enclave	38	Tikri Khurd
12	Dasghara	39	Mungeshpur
13	Todapur	40	Lampur
14	Shahpur Jat	41	Jharera
15	Katwaria Sarai	42	Kotla
16	Mandi	43	Samashpur
17	Ambedkar Colony	44	Chatesar
18	Ruchi Vihar	45	Raota
19	Nangal Dewat	46	Ghummanhera
20	Bamnoli	47	Kushak No 2
21	Sector 24 Dwarka	48	Goyla Khurd
22	Sector 29 Dwarka	49	Sector 17 Dwarka
23	Tajpur Kalan	50	Khampur
24	Akbarpur Majra	51	Savada Ghewra
25	Palla	52	Gobhna
26	Khushak No 3	53	Ranhola Extension
27	Hiranki		

Table 9: Rural Areas (Villages) not Showing Urbanisation Trend

S. No.	Rural Villages (Remain Rural)	S. No.	Rural Villages (Remain Rural)
1	Isherheri	16	Janti Khyud
2	Gobhna	17	Jhingola
3	Sarangpur	18	Luksar
4	Asola	19	Kharkhari Nahar
5	Mandi	20	Hasanpur
6	Kankar Khera	21	Daryapur
7	Garhi	22	Jhuljhuli
8	Chandpur Kalan	23	Pandwalan Khurd
9	Asalatpur Khawad	24	Rewla Khanpur
10	Bhim Basti	25	Kharkhari Jatmal
11	Basant Nagar	26	Sherpur Extension
12	Munirpur	27	Galibpur
13	Sawada	28	Kazipur
14	Garhi Rindhala	29	Qutabfarh
15	Chandpur village	30	Bakargarh

From the results and discussions, it has been determined that 53 villages have been converted into development areas and 30 villages into suburban villages. Many areas have fine potential for housing and infrastructure development like Mehrauli, Bijwasan, Chhatarpur and Matiala.

Mehrauli is located near Gurgaon in the South-West district of New Delhi. It has good connectivity to both Gurgaon and Faridabad with availability of land. Land pooling in this area will impact its real estate demand to a great extent.

Mehrauli, Bijwasan and Chhatarpur are located close to Gurgaon and IGI Airport. They are even accessible by the Metrorail. The demand for residential and commercial real estate will be high in this area once they are developed using land pooling method. Ghitorni in West Delhi is located on AH-1 towards Mathura and Agra. It has good connectivity and is located beside the Central Ridge Reserve Forest. With many industrial areas around, this area will see surge in residential real estate after development through land pooling.

Conclusion

The study with the help of Urban Landscape Analysis Tool in Geographic Information System (GIS) and Remote Sensing is a useful tool for urban land transformation. In and around the city of New Delhi, the measurement of land use/ land cover change is useful for future urban planning at local and global level. Finally, with proper management and planning it can be restricted and directed in a desirable and sustainable way, protecting fertile agriculture lands, although urban expansion cannot be stopped. The work analysed the process and pattern of urbanisation in New Delhi from 1995 to 2015 in both quantitative and qualitative domains. Two land cover maps were prepared for each year and used as an input to ULAT tool.

The study demonstrated that built-up area has increased by 417 Ha in from 1995 and by 6,633 Ha during 2015. The expansion of built up in the city has been majorly due to extension development accounting for 56 and 60 per cent of total development respectively in the two phases of study. The urbanised area and urban footprint map statistics show that urban-sub-urban built-up area increased by 285Ha and 6,889Ha during the two time periods complemented with a decrease of 9,786 Ha and 3,135 Ha in rural open lands. Development of sub-cities of Bwana and Narela in northern part and Dwarka in south-western New Delhi under urban expansion plans of DDA account for extension-associated development in second time period. The study clearly illustrated how urbanisation is taking over the rural lands of New Delhi.

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