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# An assessment of urban growth of Delhi using geospatial techniques

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**Abstract:** The growing population and urbanization are the leading issue faced by the developing countries in the contemporary world. Due to rapid and unplanned urbanization it is imperative to study the urban growth and its pattern in order to properly plan the city's infrastructure in an environmentally substantial way. In the present study, urban growth and pattern of Delhi has been studied using geospatial techniques. Medium resolution satellite data covering two time periods viz., 1992 (Landsat 5) and 2019 (Landsat 8) have been used for the study. Supervised classification using Maximum Likelihood Classifier (MLC) have been used for generating broad urban land use/land cover and FRAGSTATS software for computing class and landscape metrics. It is seen that Delhi city is undergoing urban sprawling with aggregation at the core area and conversion of rural areas into urban patches at the periphery.

**Keywords:** Land Use/ Land Cover (LU/LC), spatial metrics, supervised classification, urban growth, urbanization

## 1. Introduction

Urbanization is a rampant phenomenon at all scales of development around the world. It is considered as an index of transformation from traditional rural economies to modern industrial one. Kingsley Davis has explained urbanization as process of switch from spread out pattern of human settlements to one of concentration in urban centers (Davis, 1962). Cities constantly undergo structural change, improvement and growth; such processes also involve the change in urban relationship with the surrounding environment. In recent years, cities have witnessed rapid urbanization and urban population growth resulting in haphazard sprawling of cities.

According to United Nations Reports (UN, 2018a; UN, 2018b) Delhi will overtake Tokyo as the world's largest city by 2030. Due to rapid growth of population in Delhi, the region is facing many problems associated with housing, waste disposal, air pollution, traffic congestion, shortage of electric power and security. Urban planning is essential because cities are becoming overpopulated and resources are depleting at alarming stage. The level of pollution i.e. air, water and land has increased due to poor environmental management. This has its direct impact on quality of urban environment, affecting efficiency of the people and their productivity in the overall development (Bhatta, 2010). Preservation and protection of the environmentally sensitive areas are mandatory. The study of land use and land cover changes is useful for managing natural resources and monitoring environmental changes (Anas et al., 1998).

The use of geospatial techniques involves visualization, modeling, analysis, computation, manipulation and interpretation of geospatial data using remote sensing, GIS, spatial statistics and GPS. These techniques play an important role in monitoring, quantifying and modeling of spatio- temporal fluctuations in the urban region over a period, identifying the pattern of urban sprawl, and planning for urban development (Coppin et al., 2004).

Delhi being the capital city of India and rapidly undergoing urbanization, there is an urgent need to study the urban growth and its patterns by analysis of spatial and temporal datasets using geospatial techniques. This will help in proper planning of the city and its infrastructure.

## 2. Scope and Objectives

The major scope of the study is to evaluate the urban growth dynamics from 1992 to 2019, which provides vital information on the urban expansion and its impact on the surrounding environment. To realize the scope, the study is divided into 3 main objectives which are listed below:

1. Generation of urban Land Use/ Land Cover map of Delhi using satellite data for two time periods (1992 and 2019)
2. Computation of spatial metrics to describe the urban growth pattern.
3. Change detection analysis of urban land use.

## 3. Study Area

The present study has been carried out within NCT-Delhi, the capital city of India located between the 28º24′17″ and 28º53′00″N latitudes and 76º45′30″ and 77º21′30″E longitudes (Figure 1). The study area covers a geographical area of 1,490 km² and Yamuna river divides the city into two parts east and west. Delhi city is located in northern part of India, bordered by Haryana on the north-west and south, Rajasthan on the south-west and Uttar Pradesh on the east. The Delhi Ridge is a remnant of the Aravalli ranges and functions as the green lung space of the city and protects the city from the hot winds coming from the deserts of Rajasthan to the west. The Delhi ridge is divided into four zones namely The Northern Ridge (The Old Delhi), Central Ridge (The New Delhi), South-Central Ridge (The Mehrauli) and Southern Ridge (The Tughlaqabad). The ridge has many forest and sanctuaries, of which Southern Ridge Forest, Sanjay Van, Jahanpapa City Forest, Rajokri Protected Forest and Mangar Bani Forest are ecologically important areas which needs to be protected. There are many historically significant monuments and heritage sites showing the rich history through their architecture viz., Humayun's Tomb, Lodhi Gardens, Qutub Minar, Safdarjung's Tomb, Jantar Mantar, Red Fort, Jama Masjid etc. which are global tourist spots. There is an urgent need to protect and preserve these culturally rich monuments from unplanned urban growth. Apart from this, Delhi is also the hub of education, employment, business and commerce generating enormous job opportunity for skilled and unskilled personnel. In the Proximity of Delhi, there are satellite towns like Gurugram, Noida, Faridabad and Ghaziabad which are the financial and industrial hubs due to which the city witnesses a large extent of migration from all parts of the country. According to the 2011 census, the population of Delhi city was around 16 million (Census of India, 2011) and the present estimated population is nearly 29 million (World Urbanization Prospects, 2018). The increasing population is one of the major driving elements for urban expansion in the region.

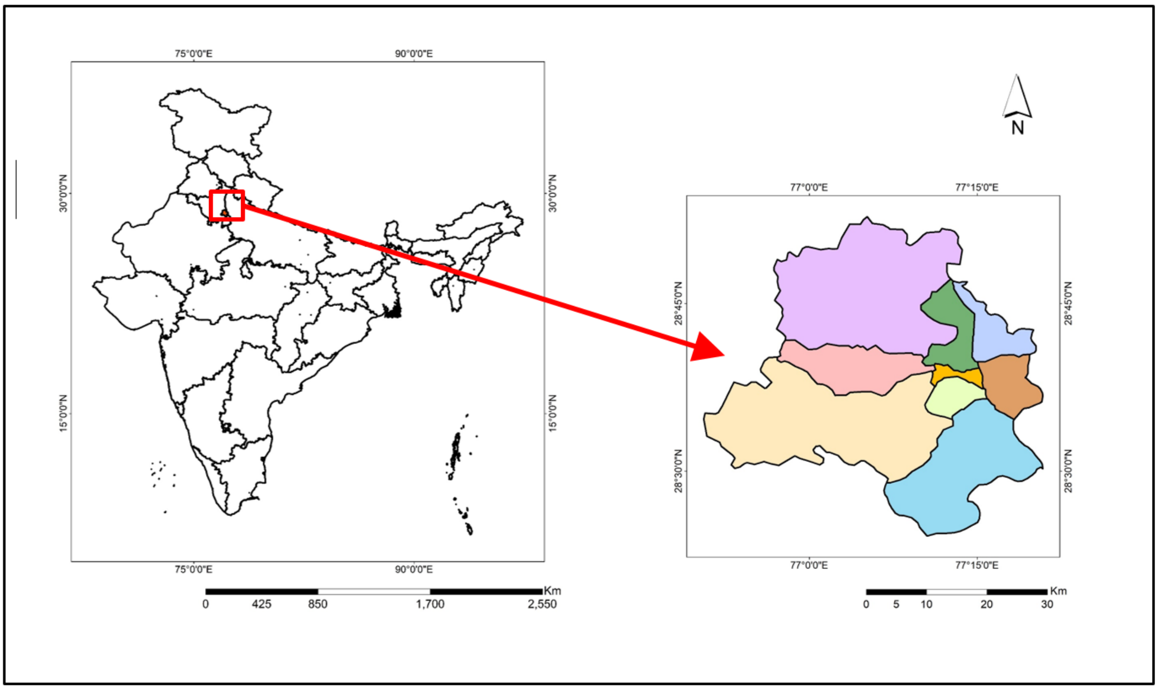


**Figure 1: Study area showing NCT- Delhi**

## 4. Data used

In the present study, two Landsat series satellite imageries have been utilized for LU/LC change detection. Satellite imageries have been downloaded from the USGS website (http://glovis.usgs.gov) for temporal study (1992, 2019). The details of the satellite data used is given in table 1.

**Table 1: Details of satellite data used**

| Satellite Name | Sensor | Spatial resolution (meters) | Acquisition |
|---|---|---|---|
| Landsat 5 | Thematic Mapper (TM) | 30 | April 06, 1992 |
| Landsat 8 | Operational land Imager (OLI) | 30 | May 30, 2019 |

## 5. Methodology

The satellite data has been pre-processed which includes atmospheric correction. The supervised classification using Maximum Likelihood classifier (MLC) has been adopted for generating broad urban land cover classes. The overall methodology adopted for the study is given in figure 2.

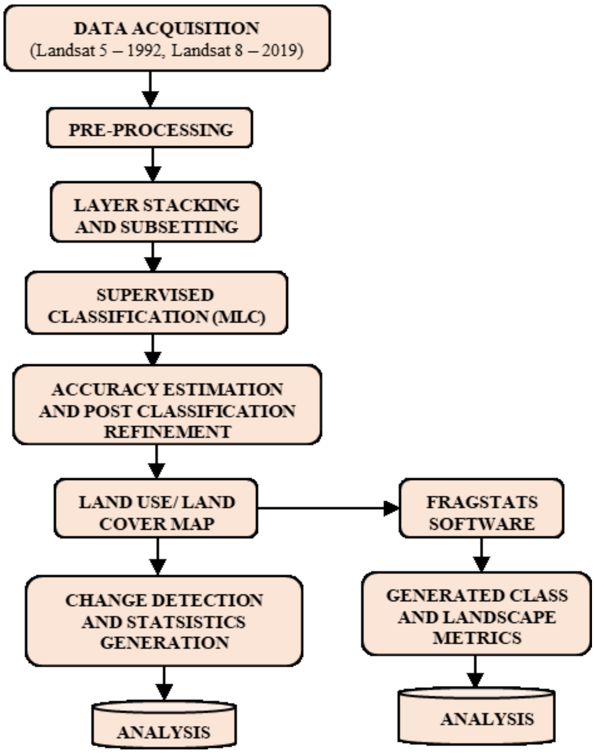


**Figure 2: Methodology flowchart**

Landsat series satellite images of 1992 and 2019 have been used for the generation of LU/LC maps (Figure 3). The classification scheme adopted has the following LU/LC classes viz., urban (built-up and transportation), water, vegetation, scrub land, open land, cultivated land, fallow land.

The broad steps involved are acquisition of temporal datasets (1992 and 2019) from the USGS website, layer stacking, study area extraction and atmospheric correction to improve the accuracy of the classification of imageries. Supervised classification has been adopted for delineating the broad LU/LC classes. Post classification refinement has been carried out to improve the accuracy of classification (Taubenböck et al., 2007). The description for all the land cover used in the study are mentioned in table 2.

**Table 2: Land Use and Land Cover scheme**

| Land cover | Description |
|---|---|
| Built -up | Land cover by building and other man – made structures including transportation (railways, roads and airport) |
| Vegetation | It depicts the vegetation inside the city (parks, gardens, urban green space etc.) |
| Agriculture land<br><br>1. Fallow land<br><br>2.Cultivated land | Land covered with temporary crops followed by harvest period, crop fields and pastures.<br><br>It is agriculture land with no cultivation<br>It is agriculture land with crops |
| Open land | Open lands are the open space land inside the city with no built-up |
| Scrub land | It is an elevated land having natural vegetation with low trees (less than 2 meters tall), bushes etc. |
| Water body | River, lakes, reservoirs |

In order to understand the changing urban landscape pattern, spatial metrics have been used for quantifying and categorizing complex landscape structure into simple and identifiable patterns (Herold et al., 2005). The use of these metrics in landscape studies helped in shifting of environmental ecology from a qualitative to quantitative analysis. This has been carried out using FRAGSTATS, a spatial pattern analysis program which uses the LU/ LC images as the input (Abebe, 2013). Seven metrics have been selected based on the literature review which has the potential to best describe urban growth pattern. They are Class Area (CA), Number of Patches (NP), Patch Density (PD), Largest Patch Index (LPI), Contagion Index (CONT), Shannon's Diversity Index (SHDI) and Landscape Shape Index (LSI). Class Area (CA) is a measure of landscape composition, specifically, how much of the landscape is comprised of a particular patch type. Number of Patches (NP) measure the patches in the landscape. Patch Density (PD) measure the number of patches per unit area. Largest Patch Index (LPI) is the percentage of the landscape comprised of the single largest patch (at the class or landscape level). LPI is the measure of dominance. CONTAG measure the tendency of patch type to be spatially aggregated. Landscape Shape Index (LSI) measures the class aggregation or clumpiness. Shannon's Diversity Index (SHDI) measures the diversity of the landscape. The interpretation of the selected spatial metrics is given in table 3 (McGarigal et al., 2002).

**Table 3: Spatial metrics interpretation table**

| Spatial metrics | Pattern of urban growth |
|---|---|
| Class Area (CA) increases, Number of Patches (NP) increases | Scattered growth of city (Sprawling) |
| Class Area (CA) increases, Number of Patches (NP) decreases | Infilling & Edge expansion (Urban Growth) |
| Patch Density (PD) depends on Number of Patches (NP) (Direct relationship)<br><br>Number of patches decreases, Patch Density decreases<br><br>Number of Patches increases, Patch Density increases | Infilling & edge expansion happens<br><br>Scattered growth happens |
| If Shannon's Diversity Index (SHDI) is 0<br><br>If SHDI > 0 | No Diversity<br><br>Diversity of a particular patch type. |
| If Largest Patch Index (LPI) ≥ 1, without limit<br><br>Largest Patch Index I = 1 | Landscape becomes aggregated<br><br>Landscape pattern is maximum compact (almost square) |
| CONTAG decreases<br><br>CONTAG increases | Landscape pattern is aggregated<br><br>Landscape pattern is clumped |

## 6. Results and discussion

### 6.1 Land Use/ Land Cover (LU/LC) map generation

Supervised classification has been carried out on both the satellite datasets (1992 and 2019) by taking appropriate training signatures for broad LU/LC classes viz., built-up, vegetation, open land, fallow land, cultivated land, water bodies and scrub land. The result of the LU/LC is given in table 4 and the classified outputs are given in figure 4. The classified map of 1992 shows concentration of built-up in the center and eastern part of Delhi, but from the 2019 LU/LC classified map it is seen that the direction of the urban growth is toward the south east, south west and north direction. The prominent reason for this urban spread is due to the presence of emerging technological and industrial hubs like Gurugram, Faridabad, Noida and Ghaziabad.

From the table 4, it is seen that the urban area, which was 338 km$^2$ (23%) in 1992, has increased to 605km$^2$ (41%) in 2019. The open land which was 130km$^2$ in 1992 has decreased to 86km$^2$ in 2019. The agriculture land (fallow and cultivated land) which was 742km$^2$ (50%) in 1992 has decreased to 533km$^2$ (36%) in 2019. There is 14% (209 km$^2$) decrease in the agriculture land from 1992 to 2019, which has been the consequence of conversion of agriculture land into new residential layouts like Dwarka, Rohini, Janakpuri etc.

Marginal changes in area are noticed in the scrub category, because these regions belong to Delhi ridge, which is restricted and preserved by the government authority and forest department, but still has been constantly under the pressures of urban development. The Delhi ridge is the remnant of Aravalli hills which is environmental sensitive region. The ridge has many forest and sanctuaries, of which Southern Ridge Forest, Sanjay Van, Jahanpapa City Forest, Rajokri Protected Forest, Mangar Bani Forest are ecologically important areas which needs to be protected. Minor development has been noticed in vegetation category. The vegetation category represents the greenery inside the city, such as urban green spaces, gardens, parks etc. Thus, an overall 18% increase is observed in the built-up category over 27 years of span.

One of the most important and final step at classification process is accuracy assessment. The aim of accuracy assessment is to quantitively assess how effectively the pixels were sampled into the correct land cover classes. Accuracy estimation has been done for all the classified outputs, with reference to Google Earth imagery. The accuracy assessment of both the classified images were carried out by taking 280 random points which were cross-verified, and the classification accuracy was 85% and 88% for 1992 and 2019 respectively. Post classification refinement was carried to improve the accuracy of LU/LC maps.

**Table 4: Land Use/Land cover Statistics**

| Land Cover | Area in Km$^2$ and % (1992) | Area in Km$^2$ and % (2019) | Change in Km$^2$ (+/ -) |
|---|---|---|---|
| Built-up | 338 km$^2$ 23% | 604 km$^2$ 41% | +266 |
| Cultivated Land | 142 km$^2$ 10% | 121 km$^2$ 8% | -21 |
| Fallow Land | 600 km$^2$ 40% | 412 km$^2$ 27% | -188 |
| Vegetation | 143 km$^2$ 9% | 150 km$^2$ 10% | +7 |
| Scrub Land | 112 km$^2$ 7% | 92 km$^2$ 6% | -20 |
| Open Land | 130 km$^2$ 9% | 86 km$^2$ 6% | -44 |
| Water | 25 km$^2$ 2% | 25 km$^2$ 2% | No change |

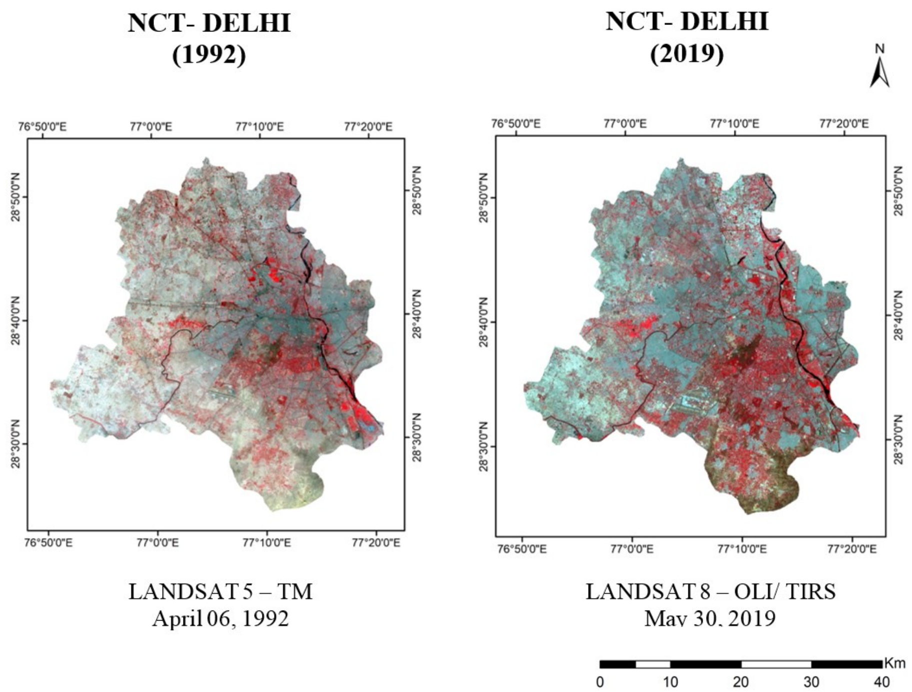


**Figure 3: NCT-Delhi as seen in 1992 and 2019 Satellite images**

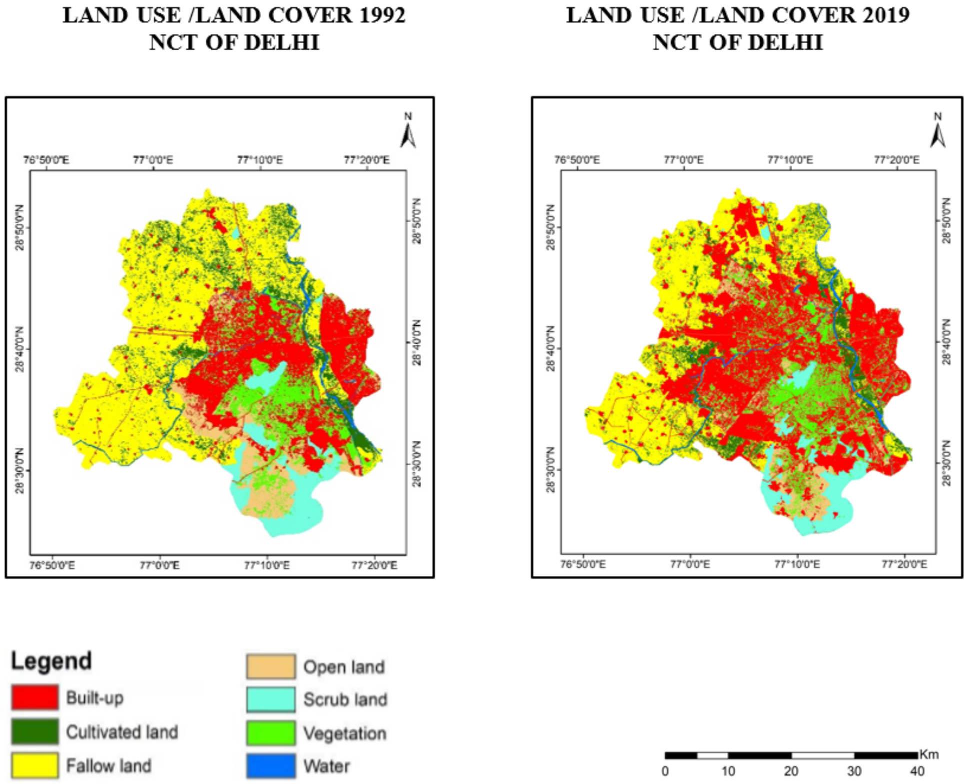


**Figure 4: Classified images of NCT- Delhi**

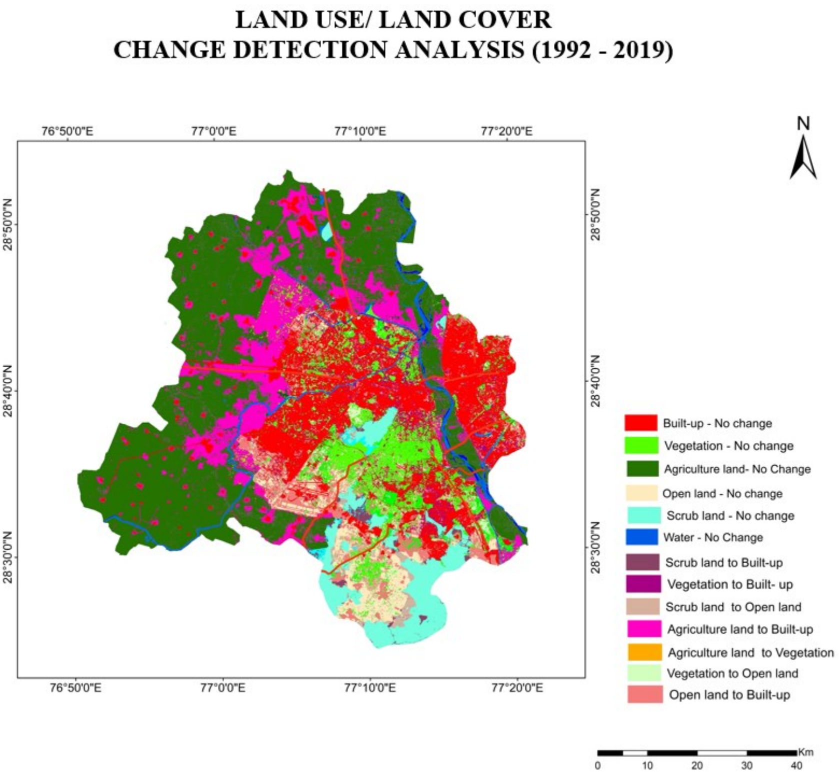


**Figure 5: Map showing Land Use and Land Cover change detection analysis for NCT- Delhi (1992-2019)**

### 6.2 Land Use/Land Cover change detection analysis

Change detection analysis has been carried using the LU/LC outputs (1992-2019) and conversion of land cover classes is given in figure 5. For the change detection analysis cultivated and fallow land has been merged as agriculture land. From the analysis, it is seen that 198km$^2$ agriculture land has been converted into built-up, due to new residential areas like Rohini, Dwarka, Paschim Vihar and Janakpuri. 46 km$^2$ of open land is also converted into built up area and some vegetation areas and scrub land also converted into built-up; further details are given in table 5. From the figure 5, it is seen that, between 1992-2019 high changes in the LU/LC is seen in the north, west and south part of Delhi, however low changes are seen in the scrub land (Delhi Ridge) and slight changes has been seen in the Yamuna floodplain.

**Table 5: Land Use/Land Cover change detection statistics 1992 -2019**

| Class Name | Change in area (km$^2$) |
|---|---|
| Agriculture land to Built-up | 198 |
| Scrub land to Built-up | 13 |
| Vegetation to Built-up | 8 |
| Vegetation to Open land | 3 |
| Open land to Built-up | 46 |
| Agriculture land to Vegetation | 9 |
| Scrub land to Open land | 10 |

### 6.3 Spatial metrics computation

Using the LU/LC classified maps of 1992, and 2019 in FRAGSTATS software, the class and landscape spatial metrics were computed for 7 classes as mentioned in table 2. The class spatial metrics for Built-up area indicated that, the total Class Area (CA) (1992-2019) has increased by 18% while the Number of urban Patches (NP) has increased by 133% between 1992-2019, indicating the scattered growth of the region. The same observation is confirmed from the increase in patch density value by 133.7% between 1992-2020, along with increase in number of patches, which indicates that the urban expansion is undergoing in a scattered manner. Large Patch Index (LPI) has increased 165% between 1992-2019 which indicates aggregation at the urban core area. The class metrics for LU/LC class is given in table 6.

**Table 6: Class metrics for Land Use/Land Cover Classes**

| CLASS NAME | Number of Patches (NP) | | Patch Density (PD) (Number per 100 hectares) | | Largest Patch Index (LPI) (Percent) | |
|---|---|---|---|---|---|---|
| | 1992 | 2019 | 1992 | 2019 | 1992 | 2019 |
| Built-up | 3866 | 9034 | 1.45 | 3.39 | 6.45 | 17.1 |
| Open land | 5507 | 11190 | 2.07 | 4.2 | 1.9 | 0.99 |
| Fallow land | 1835 | 3878 | 0.68 | 1.45 | 11.1 | 8 |
| Cultivated land | 7969 | 6810 | 2.99 | 2.5 | 0.29 | 0.32 |
| Vegetation | 5473 | 9693 | 2.05 | 3.6 | 2.7 | 1.5 |
| Scrub land | 91 | 578 | 0.03 | 0.21 | 8.9 | 1.72 |
| Water | 562 | 1367 | 0.21 | 0.51 | 0.2 | 0.23 |

From the landscape analysis with computation of spatial metric indicators, Contagion value (CONTAG) is decreased resulting in the tendency of patch types to be spatially aggregated, similar observation has been seen from Landscape Shape Index (LSI). The increase in Shannon's Diversity Index (SHDI), the richness in the number of different patches type. The landscape metrics for the LU/LC is given in table 7.

From the analysis of LU/LC map and spatial metrics it is seen that Delhi city is undergoing urban sprawling with aggregation at the core area and conversion of rural areas into urban patches at the periphery.

**Table 7: Landscape metrics for Land Use/Land Cover Classes**

| Landscape Metrics | 1992 | 2019 |
|---|---|---|
| CONTAG | 54.8 | 53.7 |
| SHDI | 1.61 | 1.59 |
| LSI | 60.9 | 80.15 |

## 7. Conclusion

From the study, it is seen that the urban growth has increased by nearly 18% over 27-year span with most of the increase is seen due to the conversion of agriculture land into built-up. The spatial metrics analysis has indicated that the city is sprawling with aggregation at the core. It is evident that the combined approach of using geospatial techniques and spatial metrics has helped in capturing the physical dimension of urban growth and pattern leading to better understanding and representation of the spatio-temporal dynamics of NCT-Delhi.

A proper planning is imperative as the available resources are depleting at an alarming rate due to unplanned urbanization. This has its direct impact on quality of urban environment, affecting efficiency of the people and their productivity in the overall development. Preservation and protection of the environmentally sensitive areas are mandatory. The present study is useful for managing natural resources and monitoring environmental changes and will be helpful in planning of the city and its infrastructure.

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