The Land Use Pattern of National Capital Region Delhi Using Geo-informatics

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Abstract This paper presents the identified four satellite towns around Delhi mega city, namely Gurgaon, Ghaziabad and Gautam Budh Nagar included Noida and Greater Noida, which are well populated and connected with urban core Delhi. Furthermore, the population growth and its impact on Land Use Changes of Delhi and its surrounding towns were considered for the study. The rates of growth of these cities were analyzed through census and multi temporal high-resolution satellite data. The decadal growth rate of Delhi and Gurgaon was more than 50 per cent during 1941-81, and 26.83 and 44.25 in 2011. Similarly in Ghaziabad it was more than 60 per cent during 1951-2011 whereas the Gautam Budh Nagar, shows the rapid growth, 237.10, 269.10, 80.80 and 116.70 during 1981-2011. The impact of this growth has shown in the form of land use changes. The built-up land increased by 8.10 km² per annum in Delhi, 0.92 km² in Gurgaon, 4.80 km² in Ghaziabad and 13.03 km² in Gautam Budh Nagar whereas, the agricultural land, decline by 7.35 km², 0.86 km², 5.45 km² and 11.60 km² per annum in this cities. The decadal rate of population growth and land use changes is higher in Gautam Budh Nagar, followed by Delhi, Ghaziabad and Gurgaon. The findings of this study would provide insight to the planners and policy makers for the management of urban land in the field of growth related problems of the city regions.

Keywords: Population Growth, Land Use Change, built-up land, Multi-Temporal Satellite Data, GIS, NCR

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1. Introduction

The impact of growth of cities in the change of urban environment especially in the study of land use and land cover change has drawn attention from scholars in the field of urban studies. The global urban population has multiplied more than ten times in the past century; from 224 million in 1900 to 2.9 billion in 1999 [1]. According to United Nations estimates, the population living in urban areas exceeded 50 percent of the world total in 2006 and approach 60 percent in 2020 [25]. While the world’s urban population is expected to increase by almost 2 billion over the next 30 years, the world’s rural population is actually expected to decline slightly falling from 3.3 billion in 2003 to 3.2 billion in 2030. Thus, all future population growth for the foreseeable future is expected to be absorbed in urban areas. Most, if not virtually all of this growth, is taking place in the developing countries [2].

The rapid spatial expansion of urban areas due to growth of population and economic activities is increasing additional demand on natural resources thereby causing land use changes especially in megacities. High rates of urban expansion around the world have been shown to lead to the loss of agricultural lands [3,4,26,27,28], reduce wildlife habitat [5,6], and alter regional hydrology and climate [7,8,9]. The speed of growth of urban areas around the world, but especially in developing countries, also stretches the capacity of local and regional governments and institutions to provide sufficient infrastructure and services for their residents [10,11,12]. These impacts of urbanization are related to the spatial extent and density of urban areas [13,14,30]. In the fast developing countries like India, there is a mass migration of people from rural to urban and also from smaller to bigger urban areas and then to metropolises like Delhi, Bangalore, Mumbai etc. The process of urbanization in India gained momentum with the start of industrial revolution way back in 1970s followed by globalization in 1990s. Forests were cleared, grasslands ploughed or razed, wetlands drained and croplands encroached upon under the influence of expanding cities, yet never as fast as in the last decade [15,28,29,31]. In 1991, there were 23 metropolitan cities in India, which increased to 35 in 2001 and 53 in 2011 [16].

As has been observed in the rest of the world, India had similar impacts of urbanization and land use land cover (LULC) change. Land use which is a highly dynamic entity in nature is one of the key parameters to quantify development. Therefore, the role of techniques such Global Positioning System, satellite remote sensing, aerial photography and Geographical Information System becomes important. Satellite Remote Sensing have been
used to monitor urban growth and dynamics in hundreds of areas throughout the world over the last decades [17-22]. Timely and accurate information on existing LULC pattern, its distribution and changes over time is a prerequisite for planning, utilization and formulation of policies and programs for making any developmental plan. More often than not in developing countries, government data proves to be insufficient, inaccurate, obsolete or simply non-existent [23,24]. In such a case where only a few authentic data sources are available in hand, use of satellite imageries proves to be the best solution. Therefore the present study is focused at preparing a multi-temporal GIS database for LULC change and to assess the spatial and temporal changes in and around of Delhi NCR between 1971 and 2020 using remote sensing and GIS techniques. Primary aim of the study is to quantify the changes in various LULC classes of four five decades and to analyze rate of change and the driving forces of changes. The study briefly describes the location, followed by the database and the methodology. The LULC results and their interpretations along with comparative assessments for different years of the study areas are discussed in the result section. The next section provides the findings and final conclusions of the study.

1.1. Location of the Study

The study is focus on the capital city Delhi and its surrounding three major cities of NCR namely Gurgaon, Ghaziabad and Gautam Budh Nagar (included Noida and Greater Noida) in the states of Haryana, and Uttar Pradesh. Delhi, located between the 28°24'17" and 28°53’00”N latitudes and 76°45’30” and 77°13’20”E longitudes, Gurgaon, located within coordinates of latitudes 28°24’N and 28°30’30” N and longitudes 76°59’15”E and 77°7’ E, Ghaziabad located latitude 28°40’ North and Longitude 77°25’ East, and Gautam Buddha Nagar district is situated in the Doab of Ganga and Yamuna rivers between the parallels of 28° 6’ to 28° 40’ north latitude and 77°17’ to 77°42’ East longitudes. As per the census of India 2011, the decadal population growth is much higher in Gautam Budh Nagar, followed by Ghaziabad, Gurgaon and Delhi.

1.2. Objective of the Study

The purpose of the study is to evaluate the impact of the rapid growth of population on the land use/land cover change. To see the spatial pattern of land use/ land cover changes last four to five decades. It is also interesting to investigate the land transformation of the different category of land in Delhi and its surrounding towns. Based on satellite remote sensing data, to assess the rate of the urban growth and land use change over the past few decades as well as discuss the driving forces of changes in recent trends of development (undesirable mixed land use of various types).

2. Database and Methodology

To find out the spatial growth of the cities, we used IRS-1D (LISS-III), IRS PAN sharpened LISS-III & PAN merged data, MSS, TM, ETM+, Google earth pro data and other data like Census of India 1981-2011, and guide map 1:20,000 scale. The image data are rectified with Survey of India map, toposheets: 1:63360, 1:50, 000, 1:25,000 scale, and registered in Universal Transverse Mercator (UTM) zone 45’N. The visual image classification system has been applied to classify the images in different land use categories. The limited ground truth verification was carried out during the study. Some major land use classes have been identified; urban (built-up), agricultural land, forest area, water body, and open field, etc. The past, current and possible future land-use dynamics of the cities have been described and analyzed.

To understand the complexity of dynamics of land use changes, spatial pattern of the city’s growth and population growth, a few indicators are examined. The indicators land use, roads, railway network and the agricultural area-crop and fallow land, were captured from map sheets and imagery and each of the layers were digitized. The extension of agriculture land of the last four decades was determined by computing the areas from the digitized map sheets, imagery and compared it with the areas of different time periods. The land use categories and their description are shown in Table 1.

| Land use class          | General description/Subclass                          |
|-------------------------|------------------------------------------------------|
| Built-up Land           | Include Dense, Moderate, Sparse as well as Rural settlements, Industrial, Institutional, Commercial, Recreational, Transportation and utilities. |
| Agricultural Land       | Cropland, Fallow land                                |
| Forest                  | Trees, green cover, Plantation                       |
| Wasteland               | Scrub land, Water logged, hills / barren rock        |
| Water Bodies            | River, Pond, tank/lakes                              |
| Transport Network       | Railway, Metro Rail, Expressway, National Highway, Major and Minor Road |

3. Results and Discussion

3.1. Demographic Structure of the Study Areas

India, with 1,220,200,000 (1.22 billion) people is the second most populous country in the world. The figures show that India represents almost 17.31 per cent of the world's population, which means one out of six people on this planet live in India (census of India, 2011). In 2011, the population of India was 1.21 billion wherein 2001-1.02 billion, and 1947-350 million. For the first time since Independence, the absolute increase in population is more in urban areas than in rural areas. The rural population of India was 68.84 per cent whereas Urban Population is 31.16 per cent. The level of urbanization increased from 27.81 per cent in 2001 to 31.16 per cent in 2011. The proportion of rural population declined from 72.19 per cent to 68.84 per cent.

The total population of Delhi was nearly 0.4 million in 1901, which increased slowly and reached 1.74 million in 1951 (4.35 times in half-century) and 13.78 million in 2001(census of India, 2001) implying about 34.45 times increase in one century. The population of Delhi, as of 1st March 2011, was 16.78 million as against 13.85 million on 1st March 2001. According to Census 2011, about 97.50 per cent of the population of Delhi lives in urban
areas and the remaining 2.5 per cent in rural fringe areas. The growth in the urban area during 2001-2011 was observed at 20.44 per cent. This pace of urbanization reduced the number of villages in Delhi from 300 in 1961 to 165 in 2001 and 112 in 2011. The number of urbanized villages increased from 20 in 1961 to 135 in 2011. The number of census towns increased from 3 in 1971 to 29 in 1991 and 110 in 2011. The decadal growth rate of the population during 2001-2011 was recorded at 21.2 per cent. This is a peculiar feature of Census 2011, as in all censuses since 1951, the decadal growth rate of the population was more than 50 per cent and 47 per cent in 2001 (Table 2, Figure 1).

The growth of population encouraged the urban population, along with the time the urban population continue increased (Table 7). In 1951, there were 304 villages in Delhi, but in 2011 it reduced to stand 105, the rural area also reduced sharply along with rural population and it’s almost around 300 km². The district-wise census data shows that the Central district and New Delhi are fully urbanized, whereas North-East, East, West and South districts are more than 99 per cent urban. The other districts like North, North-west, and Southwest are 98, 94, and 93 per cent urbanized respectively.

The satellite of Delhi, *Gurgaon* has been a small but important urban centre in the neighborhood of Delhi. A district headquarters; its importance lay in providing space for the defense and wireless station during the British period. The airport later turned to be an important international airport for Delhi. Table-2 shows that the city had a small population of 4765 in 1901. The population grew at the rate of 1.46 per cent during 1901-1911. It faced a decline during 1911-1921 (-6.48 per cent) in line with the rest of India, a period when epidemics took a heavy toll of India’s population. In the subsequent decades of 1931 and 1941, its rate of growth had been higher than national average. Subsequent migration of people after partition resulted in a sharp increase in population, reflected in the next two decades (Table 2). Population grew by 87.35 per cent during 1941-1951 and by 103.45 per cent in 1951-1961. The location of Gurgaon vis-à-vis Delhi has always been a positive factor in attracting people and industrial activity, resulting in higher growth rate than the national average.

The *Ghaziabad*, known as old industrial city, has very close proximity to Delhi. After independence the Ghaziabad town grows slowly and smoothly. The beginning of 20th century shows the slow decadal growth rate and in 1911 to 1921 the decadal growth rate was 9.19, whereas in 1921 to 1931, it was 52.56 and 1931-1941, it was 26.57 respectively. The decadal growth rate drastically changes after independence, and reached on 60.35 in 1941-1951, 65.35 in 1951-1961, 88.06 in 1961-1971, 132.10 in 1971-1981, 64.66 in 1981-1991, 113.20 in 1991-2001 and 70.27 in 2001-2011 respectively (Table 2, Figure 1).

### Table 2. Urban Population and Decadal Growth Rate of NCR Cities

| Year | Delhi | Gurgaon | Ghaziabad | Gautam Budh Nagar |
|------|-------|---------|-----------|------------------|
| 1901 | 2.14  | 4765    | 11275     | 24707            |
| 1911 | 2.38  | 5461    | 11304     | 21172            |
| 1921 | 3.04  | 5107    | 12343     | 24381            |
| 1931 | 4.47  | 7208    | 18831     | 23834            |
| 1941 | 6.95  | 9935    | 23834     | 32827            |
| 1951 | 14.37 | 18613   | 32827     | 275815           |
| 1961 | 23.59 | 37868   | 275815    | 454156           |
| 1971 | 36.47 | 57151   | 37868     | 968256           |
| 1981 | 57.68 | 89115   | 57151     | 1648643          |
| 1991 | 84.72 | 121486  | 89115     | 248557           |
| 2001 | 129.06| 173542  | 121486    | 449415           |
| 2011 | 163.69| 248557  | 173542    | 974309           |

**Sources:** Economic Survey of Delhi, District Gazetteers, and Census of India, Govt. of India.

![Decadal Growth Rate of Urban Population (in percent)](image_url)
After independence the population growth was too high due to partition of the country in 1947, the most of the people moved from Pakistan and settled in and around of Delhi. The development of medical facilities and decline of the mortality rate are reason to immediately change the demographic structure of Ghaziabad.

The cities like Noida, Greater Noida are the attraction of Delhi neighborhoods and an industrial, commercial, IT hub of northern India. The both cities come under Gautam Budh Nagar district. The population of the district of Gautam Budh Nagar was 1,105,292 in 2001 and growing by 49.11 per cent during the last decade of 2001-2011 and it’s become 1,648,115 at 2011 censuses. In 2011, the decadal growth rate is 49.11 per cent in the district whereas 1.63 per cent is found in rural area and 120.29 per cent in urban area (Table 2, Figure 1). The proportion of urban population increased from 40.0 per cent in 2001 to 59.1 per cent in 2011. Highest (580.11 per cent) decadal variation 2001-2011 is found in Gautam Buddha Nagar Tehsil. The area of the district is 1,282.0 square kilometer. The density of population in the district is 1,286 compare to rural areas of the district the population density is 616.

4. Dynamics of Land Use Land Cover

The demographic structure has brought with it the areal growth and spatial transformation of the city. As there has been a sharp spurt in the population of the city in the last 20 to 30 years, there has been a parallel increase and growth in its built up area. The need to accommodate the growing population has caused this increase in area. The growth in its area has brought with the change in the nature of land use with the growing limits of the city. This has brought the encroachment of the peripheral villages. Consequently, there has been landscape change in the city. A considerable change in land use has occurred during the last few decades. The change may be in a specific area or the entire region. The change from rural to urban land use is so fast that the resultant need and complex uses coupled with the shortage of land have led to speculation and increase in land values.

4.1. Land Use Land Cover Analysis: Delhi

In 1985, Built-up land covered 298 km² areas which are almost 20 per cent of the study area, where agricultural land 49.12 per cent or 729 km², 209 km² area covered by forest, 215.98 km² area under scrub, waste and barren land, and water bodies stand with 32 or 2.16 per cent of the area. During this period, the cropped area covered by 704.97 or 47.50 per cent, whereas fallow land 1.61 per cent area, forest 10.46 per cent or 155.30 km², and plantation 3.62 per cent or 53.72 km² area, respectively. The population growth not only effected the cropped land and fallow land but it was also affected the forest, degraded land, barren or wasteland, and even scrub land.

In 1998, after 13 years there is a massive change observed in this area and built-up land rapidly increased to reach 31.88 per cent or 473 km², where the major impact of this expansion shown in agricultural land which shrinks from 729 km² to 572 km² almost 38 per cent, and forest slightly increased 209 to 211 km² or 14 per cent to 14.25 per cent, waste-barren and scrub land are least effected and it stands 13.23 per cent (earlier in 14.56 per cent) of the area, where water bodies have no major changes and it still stands on 2.16 to 2.10 per cent respectively (Table 3, Figure 2A to 2D). The spatial expansion of built-up land; that is high density stands on 11.73 per cent, medium density 6.89, low-density 11.61 per cent, and most of the expansion based on the agricultural land; that’s fallow and cropped area. During this period the expansion of high density, as well as low density, are almost equal and it shows that the people who migrated from a different state to search for a job, career opportunities, education are settled in that area of Delhi, where house rent is low or the area who is not much developed.

In 2008, after 10 years of gap, there is a major change seen in built-up land, and it covered 46.67 per cent or 692.50 km², where 372 km² or 25.07 per cent high density, 160.57 km² or 10.82 medium, and 126.17 km² or 8.50 per cent low-density area, and this expansion is in the cost of agricultural land; which shrunk from 38.54 to 32.74 per cent, forest; 14.25 to 10.38 per cent and waste-barren-scrub land; 13.23 to 8.19 per cent, respectively. The change which has taken place during this period is mainly based on fallow land, cropped land, forest, barren and scrub land. The fallow and cropped land shrinks from 37 to 30 per cent, forest decline from 14.25 to 10.38 per cent and degraded-waste-barren and scrub land shrink from 13.23 to 8.19 per cent area respectively (Table 3, Figure 2A to 2D).

In 2018, the rate of growth was slow, and the urban built-up area reached in 773.59 km² or 52.13 per cent, in which high density built-up increased from 372 to 461 or 25 to 31.45 per cent, medium-density built-up area from 160.57 to 181 km² or 10.82 to 12.19 per cent and low density continue in decreasing trend and almost 2 per cent area. In the other side, the agricultural area shrinks from 485.91 to 412.41 km². During this period the massive positive changes observed in the forest area, which has extended from 153.96 km² to 197.34 km² area, which is almost 13.29 per cent of the study area. Other categories like scrub, waste, barren land decline from 121.55 to 74.23 km² which has almost 5 per cent of the study area (Table 3, Figure 2A to 2D). The land-use categories like barren, degraded, scrub, fallow which has continued shrink along with the time due to expansion of the built-up area.

| Year/LULC Category | 1985 | 1998 | 2008 | 2018 | Growth km² per annum |
|-------------------|------|------|------|------|---------------------|
| Built Up Land     | 298  | 20.08| 472.98| 31.88| 692.50              |
| Agricultural Land | 729  | 49.12| 572   | 38.54| 485.91              |
| Forest            | 209.02| 14.08| 211.42| 14.25| 153.96              |
| Barren & Scrub Land | 215.98| 14.56| 196.31| 13.23| 121.55              |
| Water Bodies      | 32   | 2.16 | 31.29 | 2.10 | 30.08               |
| Total Area        | 1484 | 100  | 1484  | 100  | 1484                |

Sources: result based on multi temporal Image Data analysis.
Figure 2A. Land Use Land Cover Map of Delhi, 2018

Figure 2B. Land Use Land Cover Map of Delhi, 2008
Figure 2C. Land Use Land Cover Map of Delhi, 1998

Figure 2D. Land Use Land Cover Map of Delhi, 1985
The rate of increase of the built-up area has been higher between 1998-2008 (21.92 km² per annum) by the addition of 219.52 km² compared to 1985-98 period (13.46 km² per annum) during which 174.98 km² was added and 81.09 km² added in 2008-2018 (less than 8.11 km² per annum). There was 9.55 per cent decline in barren-scrub-wasteland (from 215.98 km² to 74.23 km²), rapidly during 1998-2008 than in the first and last decades (Table 3, Figure 2C, 2D). The process of urban sprawl is clearly brought out in Figure 2D (urban land-use change 1985-2018, & land use 2018).

4.2. Land Use Land Cover Analysis: Gurgaon

The statistics reveal that out of the 126.77 km² as total study area of Gurgaon city region, nearly 81 per cent was under agriculture in 1971. It has reduced to 50.67 per cent in 1993, 26.5 per cent in 2002 and 14.92 in 2019. The rate of decline has been higher during the last decade. In 1971-93 around 38.43 km² of agricultural land was lost, 1993-2002 around 30.65 km² and 2002-2019 around 14.67 km² land converted in other categories (Table 4, Figure 3A to 3E).

The area under built-up land category increased substantially from 11.36 km² (8.96 per cent) in 1971 to 99.97 km² (78.86 per cent) in 2019. The built up area has been expanded higher between 1993-2002 (3.6 km² per annum) by an addition of 33.06 km² compared to 1971-1993 (1.81 km² per annum) added 39.78 km² and in 2002-2019 (less than 0.93 km² per annum) by added 15.77 km². There was 33 per cent decline in wasteland (from 7.48 km² to 5.01 km²), more rapidly during the last decade than in the first two decades. Other land uses have reduced by 25 per cent from 1971 to 2002 (from 5.26 km² to 3.97 km²) with the rate of decline from 10 per cent during 1993-2002, as compared to 15 per cent during 1971-1993 and 3.97 km² to 3.14, during 2002 to 2019 (Table 4).

Table 4. Comparison of areas under different land uses

| Land use class | 1971 | 1993 | 2002 | 2019 | Percentage of Changes |
|----------------|------|------|------|------|-----------------------|
|                | Area (sqkm) | per cent | Area (sqkm) | per cent | Area (sqkm) | per cent | Area (sqkm) | per cent | 1971-1993 | 1993-2002 | 2002-2019 |
| Built-up land  | 11.36 | 8.96  | 51.14 | 40.34  | 84.2 | 66.42  | 99.97 | 78.86  | 50   | 50   | 50   |
| Agricultural land | 102.67 | 80.99 | 64.24 | 50.67  | 33.59 | 26.50  | 18.92 | 14.92  | 48.30 | 46.35 | 46.51 |
| Waste land     | 7.48  | 5.90  | 6.97  | 5.50   | 5.01 | 3.95   | 4.74  | 3.74   | 0.65  | 2.96  | 0.86 |
| Others         | 5.26  | 4.15  | 4.42  | 3.49   | 3.97 | 3.13   | 3.14  | 2.48   | 1.05  | 0.69  | 2.63 |
| Total          | 126.77| 100   | 126.77| 100    | 126.77| 100   | 126.77| 100   | 100   | 100   | 100   |

Sources: Map sheet 1971, IRS(IB) 1993, IRS(1D) 2002, IRS 1D PAN Merged data of 2002, & Google earth 2019.

Figure 3A. Urban Growth Pattern Map of Gurgaon, 2019
Figure 3B. Land Use Land Cover Map of Gurgaon, 2019

Figure 3C. Land Use Land Cover Map of Gurgaon, 2002
Figure 3A to 3E depict land use pattern in and around Gurgaon in 1971, 1993, 2002 and 2019 and shows the land use changes during the last decade (2002-2019) which is still continuing. This can be attributed to rapid
outsourcing of economic activities and increase in the
demand for residential and commercial purpose.

4.3. Land Use Land Cover Analysis: Ghaziabad

A considerable change in land use has occurred during
the last few decades. The change from rural to urban land
is fast. The shortage of land has led to speculation and an
increase in land values (Table 5, Figure 4A and 4B). The
growing difference between the demand and supply of
house sites has increased in last two three decades, and
conversion of agricultural land to other categories of
land increase for residential and industrial purposes.
Simultaneous to the population increase, there has been a
contiguous growth and expansion of the area of Ghaziabad.
This has been largely due to the influx of huge population
in the city. This influx has been generated by the multiple
job generations in the city and has been accompanied by
the huge range of housing offered by the private developers.

![Figure 4A. Land Use Land Cover Map of Ghaziabd, 2020](source)

![Figure 4B. Land Use Land Cover Map of Ghaziabd, 2005](source)
The areal increase of the city has resulted into the transformed landscape. The land use transformation in the city has been immense. The most drastic has been the transformation of agricultural land into the built-up area and the resultant changes are revealed by the explicit differences in the land use transformation over the years depicted in Table 5. Table 5 reveals that three subcategories of land-use have undergone substantial changes. The maximum change has occurred in the agricultural land, which has declined, from 878.23 km² of the total land in 2005 to 796.39 km² in 2020. Next in order is the ‘Built-up land’, which has increased from 188.64 km² to 260.74 km² during the above period. The significant changes occurred is the conversion of agricultural land to built-up land. Figure 4A & 4B shows the spatial changes of the city during last two decade. In 2005 the built-up area was around 188.64 km², out of that 104 km² under high density built up, and 30.28 km² medium density and 40.42 km² for industrial uses, but after 15 years it was reached on 260.74 km², out of that 149.52 km² high density, 58.13 km² medium density, 8.48 km² low density and 10.91 km² village, as well as 34.24 km² industrial used.

Figure 4A &4B show that the changes of land from one activity to other during 2005 to 2020. The large agro and plain area encroached by commercial, industrial and built-up land during this period, which was around 13.05 per cent of total change. The rate of growth of built up land was almost 6.11 km² per annum, whereas agro land shrink by 5.45 km² per annum during this period. The other land like transportation, water bodies and forest has not shown any major changes in last 15 years. The forest slightly increased from 0.92 per cent to 1.65 per cent, whereas water bodies 0.55 per cent to 0.65 per cent and transport network are stable on 8.03 per cent, during 15 years.

The statistics reveal that out of the 1179 km² total area of Ghaziabad region, nearly 74.48 per cent was under agriculture in 2005. It has reduced to (67.54 per cent) in 2020, whereas built up area increased from 16 per cent to 22.11 per cent, high density 8.82 to 12.68, medium density 2.56 to 4.93, Village 1.18 to 0.87 and industrial area 3.42 to 2.90 per cent during the above period.

The Table 5, reveals that the built-up area increased by 6.11 per cent (72.10 km²), out of that high density increased 3.86 per cent, medium density 2.36, forest area 0.72 per cent (8.53 km²) and water bodies 0.10 per cent (1.21 km²), other categories like village decline by 0.30 per cent, and industrial decline by 0.52 per cent respectively. The major impact of population growth are shown in the term of areal expansion of built up land on the cost of agricultural land which has shrink by 6.94 per cent (81.84 km²). Figure 4A&4B, depict land use pattern in and around of Ghaziabad in 2005 and 2020. This can be attributed to rapid outsourcing of economic activities and increase in the demand for residential and commercial purpose.

4.4. Land Use Land Cover Analysis: Gautam Budh Nagar

The research reveals that the study area has experienced significant changes over the time periods. During 2010 to 2020 the high density built up land increased by 30 per cent whereas, the medium density showed the increase of 43.26 per cent but the low density shown less decline of only 2.78 per cent. It is also observed that three sub-categories of land use have been undergone the substantial changes. The maximum change occurred in the agricultural land. The statistics reveal that out of the 1442 km² of total area, nearly 43 per cent was under agriculture in 2010, whereas in 2020, it has reduced to 35 per cent only. During 2010-2020 around 116.16 km² of agricultural land was lost (Table 6, Figure 5A & 5B). It indicates a threat to the conversion of the rich agricultural land into non-agriculture (built-up area) in the region (Figure 5A & 5B). The agricultural land like crop land decline by 20.17 per cent whereas fallow land decline by 15.47 per cent, other land like plantation decreased by 6.25 per cent, forest 13.34 per cent during these periods.

The high density urban built up land grow much more during 2010 to 2020 and the crop land, forest and water bodies decline during the same periods. The last decade, built up land witness 24.45 per cent growth. The area under ‘built up land’ category increased substantially from 486.8 km² (33.75 per cent) in 2010 to 130.34 km² (42 per cent) in 2020. The rate of growth of built up area has been higher during 2010-2020 (13 km² per annum) by an addition of 130.34 km² additional land area. In this time periods, 18.72 per cent agricultural land decline (from 620.02 km² to 503.86 km²), other categories of land have also shrink like forest 10.87 per cent, water bodies 0.90 per cent (from 33.16 km² to 29.68 km² and 160.06 to 158.62 km²) respectively (Table 6).

Figure 5A & 5B, depict land use pattern in and around of Gautam Budh Nagar in 2010 and 2020 and shows the land use changes of the last decade, which is still continuing. This can be attributed to rapid growth of economic activities and increase in the demand for residential, commercial and other purpose of land in the city. The villages in Gautam Budh Nagar can broadly be classified into three categories based on the process of their transformation: Rural – dominated with agricultural land and primary activities; transitional semi rural to semi urban village – dominated with built up land and territory activities.

### Table 5. Comparison of changes areas under different land uses

| L U Categories | Ghaziabad | 2020 | per cent | 2005 | per cent | Changes 2005-2020 | per cent | Per annum |
|---------------|-----------|------|----------|------|----------|-------------------|----------|-----------|
| Built Up      | 260.74    | 22.11| 188.64   | 16   | 72.10    | 6.11              | 4.80     |
| Agricultural land | 796.39   | 67.54| 878.23   | 74.48| -81.84   | 6.94              | 5.45     |
| Forest        | 19.44     | 1.65 | 10.91    | 0.92 | 8.53     | 0.72              | 0.56     |
| Water Bodies  | 7.75      | 0.65 | 6.54     | 0.55 | 1.21     | 0.10              | --       |
| Transport     | 94.68     | 8.03 | 94.68    | 8.03 | 0        | 0                 | --       |
| Total         | 1179      |      | 1179     |      | 168.58   | 14.29             | 11.23    |

Sources: Map sheets 1971, & Google earth 2005, 2020.
Table 6. Comparison of changes areas under different land uses

| Land Use LandCover Gautam Budh Nagar | area(in sq.km) 2010 | Area (in sq.km) 2020 | Changes during 2010-2020 | Per cent 2010 | Per cent 2020 | Decadal Growth per cent |
|--------------------------------------|---------------------|----------------------|--------------------------|---------------|---------------|-------------------------|
| Built up land                        | 486.8               | 605.63               | 130.34                   | 33.75         | 42            | 24.45                   |
| Agricultural Land                   | 620.02              | 503.86               | -116.16                  | 42.99         | 34.94         | -18.72                  |
| Forest                              | 33.16               | 29.68                | -3.48                    | 2.30          | 2.05          | -10.87                  |
| Water Bodies                        | 160.06              | 158.62               | -1.44                    | 11.10         | 11            | -0.90                   |
| Transport Network                   | 141.96              | 144.21               | 3.53                     | 9.84          | 10            | 1.62                    |
| **Total**                            | **1442**            | **1442**             | **254.95**               | **99.98**     | **99.99**     | **-4.42**               |

Sources: Map sheets 1991, & Google earth 2010, 2020.

Figure 5A. Land Use Land Cover Map of Gautam Budh Nagar, 2020
5. Comparative Analysis and Major Findings

The land use pattern of NCR, namely; Delhi, Gurgaon, Ghaziabad, and Gautam Budh Nagar including Noida, Greater Noida were broadly discussed. The data reveals that the population growth was much higher (Table 7, Figure 6) in Gautam Budh Nagar compared to other cities. The decadal population growth was much higher during 1981 onwards in Gautam Budh Nagar, followed by Ghaziabad, Gurgaon and Delhi. The Gurgaon city population was much higher during 1951 to 1981, and in 1961 it was on highest, but after that it decline. The impact of above growth shown in the land use changes during 1971 to 2001, after that the rate of land use changes decline in the city (Table 8, Figure 7).
Table 7. Decadal Urban Growth (Population) Rate of NCR

| City              | 2011  | 2001  | 1991  | 1981  |
|-------------------|-------|-------|-------|-------|
| Delhi             | 21.21 | 47.02 | 51.45 | 53.00 |
| Gurgaon           | 44.25 | 42.85 | 36.32 | 55.93 |
| Ghaziabad         | 70.27 | 113.20| 64.66 | 132.10|
| Gautam Budh Nagar | 116.7 | 80.8  | 269.1 | 237.1 |

Sources: Census of India 2011, District Census Handbook Abstract.

The other cities like Gautam Budh Nagar, and Ghaziabad have shown rapid land use changes over the time periods. The Gautam Budh Nagar was the high rate of decadal changes due to demographics changes as well as development of physical infrastructures, whereas Ghaziabad have shown moderate changes due to old industrial city. The Gautam Budh Nagar included Noida, and Greater Noida has a hub of industrial, commercial, IT and residential multi story buildings and provides world class urban facilities. The most of the people attract towards this city due to close proximity to Delhi and well infrastructure as well as effective transport corridor developed in last two decades. The pace of development of these three cities shown that the Gurgaon shows slow rate of growth in term of land use change as well population growth, whereas Ghaziabad shows moderate growth rate and Gautam Budh Nagar have high rate changes during last three decades. The urban decadal
growth rate of Delhi was much higher till 1991, after that it shows lower growth, simultaneously the other three cities show higher growth rate during these periods. The impact of this growth shown in the form of land use changes and last decades the changes was higher than Gurgaon and Ghaziabad.

The process of urban sprawl is clearly brought out in Figure 2A, 3A, 4A, & Figure 5A (urban land-use change and Land Use Pattern) and these figures highlight the following:

- Major conversion of agricultural land into urban built-up: commercial, residential and institutional land. The built-up area is largely added in peripheral areas rather than along transit.
- Table 7, Figure 6 shows that the rapid growth of population and urbanization, along with economic reform and development of physical infrastructure especially the transport system has triggered the land use changes.
- Table 8, Figure 7 shows that the impact of the mega city Delhi on its surroundings satellite cities. Till 1951-91 the urban growth rate was higher in Delhi, but afterward the satellite cities grow faster than Delhi.
- The development of infrastructure and migration of people from a different state made it highly populated region and the explosive population growth (Table 7, Table 8, & Figure 1, Figure 6), created many problems, among them, the land use is prominent, which is challenging for the sustainability of urban ecology and environment of this region.
- The increase in population size has simultaneously led to the areal growth and spatial changes in the city thus, altering the landscape. Robust implantation strategies are required for sustainable intervention.

The capital city Delhi attracts people because of good infrastructure, opportunities, connectivity, and development. The development of smooth transport connectivity and close proximity to Delhi, its surrounding towns are second choice for people and investors. The city Gurgaon is about 15 miles from the national capital, New Delhi, and has witnessed rapid changes in the last 3-4 decades. Due to closeness to airport and the good infrastructures it attracts FDI and consequently the land value increased in the city. Outsourcing required workplaces for thousands of white-collar employees. In New Delhi, rents are exorbitant and space is limited, and Gurgaon as an alternative. It did have advantages: it was close to New Delhi airport and Maruti-Suzuki automobile plant opened in the 1980s. But Gurgaon still seemed remote and DLF a major company took a risk to locate there.

Gurgaon, a shadow of Delhi is a natural attraction for people from India and abroad for residential and investment purpose. It might be a sleeping city-for some people who prefer to reside here and who work in Delhi. Gurgaon, where there is no any micro level plan and city growth depends on the builder and developers of the area. The location plays a major role to attract the people. The absence of local government helped Gurgaon become a leader of India’s growth boom. But that absence had also created a dysfunctional city. No one was planning at a micro level; every developer pursued his own agenda as more islands sprouted and state agencies struggled to keep pace with growth. This time the growth of Gurgaon seems to be little slower.

As far as Gautam Budh Nagar, its new district and Noida and Greater Noida are come under this district. There is an ample scope of development and world class infrastructure developed here that why multinational company, industrialist and common people attract towards this city. The close proximity to the capital city as well as good transport communication from Delhi, make it second choice city of NCR. The old Industrial City of NCR, Ghaziabad has not grown as much as expected by the people, somewhere may be the reason that establishment of Gautam Budh Nagar, and rapid development of Noida and Greater Noida in term of infrastructure and other convenience. The development of Gautam Budh Nagar- Noida and Greater Noida provide an alternate option in front of the people, administrator, foreign Investors, and other to opt him instead of Ghaziabad.

The Old industrial city Ghaziabad is not in position to provide world class infrastructure which attracts Indian as well as foreign investors. The satellite cities grow much faster than the core city Delhi, hence the people, investors, industrialists prefer to move towards satellite cities where the infrastructure are well and good as well as the connectivity between Delhi to surrounding city are well established. The success story of the satellite towns lies with the connectivity aspects with the urban core. This shown that, there is a positive relation between the decadal growth of population and the rate of land use land cover changes. The result reveal that the significant changes in land use land cover with the decline in crop, fallow land, vegetation and water bodies. Ghaziabad is second choice after Noida, and Delhi is epicenter of all activities, but due to high crowd, expensive living and lifestyle, as well as smooth transport corridor force the people to live in satellite towns like Gautam Budh Nagar, Gurgaon and Ghaziabad.

6. Conclusion

This paper presents the spatial pattern of growth of 4 major satellite towns around Mega city Delhi. The satellite towns which are well populated and connected with core city Delhi were considered for the study (Figure 6). According to UN Habitat, satellite towns are one such spatial category associated with secondary cities surrounding the large urban metropolitan region [25]. Majorly, the expansion and development of core city are sprawling along the transport corridors connected to these towns (Figure 2A-D, 3A-E, 4A-B, & Figure 5A-B). Here in the current scenario, the satellite towns act as a catalyst and a supporting hub for production, trade, transport, and transfer of good and services.

The results of the current analysis highlight the significant changes in land use land cover with the decline in green vegetation area, fallow and crop land, and water bodies (Table 8). The rapid population growth and urbanization has also resulted in increased pollution, decreased water percolation into ground, and urban heat
island phenomenon [32]. The result revealed that the population growth and land use change are higher in Gautam Buddh Nagar, including Noida and Greater Noida, followed by Ghaziabad, Gurgaon and Delhi (Figure 6). It is evident form the above analysis that the population growth and changing economy have led to unprecedented rates of urbanization thus acting as a driver of land use change and changes the morphology of the cities. Thus, the study spanning last four decades provide an insight to the land use land cover changes that have taken place in Delhi and it surrounding satellite towns and there is an urgent need to look into the unplanned urban expansion not only the core city, but it surrounding satellite towns. Rampant spatial urban growth needs to be checked in the future and encourage the vertical stratification through high rise buildings could possibly be one of the solutions to the city’s urban distress.

**Competing Interests**

Author declare that they have no competing interests.

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