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Spatiotemporal Analysis of Noida, Greater Noida and Surrounding Areas (India) Using Remote Sensing and GIS Approaches

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ABSTRACT

Spatiotemporal analysis refers to an analysis having both spatial extension and temporal duration. Remote sensing has provided a great tool to quantify changes using satellite data in our area of interest. Population of Indian cities is growing rapidly. That is why human need for shelter is also growing day by day, resulting in fast urbanization. This study uses remote sensing and GIS approaches to delineate the urban growth resulting in decrease of agricultural land. In this study, it is analyzed as to how much change has taken place in a time span of two decades and five years, mainly emphasizing on change and growth of residential, commercial and industrial structures on agricultural land. The use of a time-series of Landsat data to classify the urban footprints since 1986 has enabled detection of spatial and temporal urban sprawl and urban development in the explosively growing large urban agglomerations of the two metropolitan cities of Noida and Greater Noida. In this study, a spatiotemporal analysis using three Landsat scenes of 25 years of time span, aims at the detection of the changes and the urban footprints in Noida and Greater Noida and its surroundings. It is also assessed as to how much urban expansion has taken place during the last 25 years. With the help of socioeconomic data, demographic profile and increase in number of households are also assessed.

Keywords: *Remotely sensed change detection, ratio transformation, geo-spatial and temporal approach, development and environment, urban expansion, Noida, Greater Noida, India*

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1. INTRODUCTION

The rate of urbanization is very fast in developing countries especially in the Asian continent. There are more than 170 urban areas having population of over 750,000 inhabitants in India and China alone (United Nations Population Division, 2001). Once India was called the country of villages, but now India no longer lives in villages because more than 285 million people are living in urban areas [1]. During the last 50 years, the population of India (today 1.21 billion) has grown two-and-a-half times, but the urban population has grown nearly five times. The number of Indian mega cities will increase from the current four (Mumbai, Delhi, Kolkata and Chennai) to six by the year 2021 (new additions will be Bangaluru and Hyderabad), when India will have the largest concentration of mega cities in the world [2]. Statistics show that India's urban population is the second largest in the world after China, and is higher than the total urban population of all countries, put together barring China, the United States and Russia. In 1991, there were 23 metropolitan cities in India, which increased to 35 in 2001 [1]. It shows that the number of cities is increasing day by day. Research in detecting urban change and development using satellite data has a long tradition in geographic research and planning. Noida and Greater Noida are getting populous mainly due to availability of different means of earning livelihood because Noida has emerged as one of the most preferred industrial area in the

National Capital Region of Delhi. This area proves a good place for living and attracts huge masses due to availability of various necessary facilities for cozy living including means of communication, educational facilities, shopping complexes, malls, utilities and services, parks and other recreational facilities. The reason for urbanization in this area is preference of many individuals to live in or near a city like Noida and/or Greater Noida, which are known as commercial hub of the country. Multitemporal remote sensing data has become very important in the analysis of such changes.

2. MAIN OBJECTIVES

This study delineates urban population growth in the study area in two decades and five years (25 years) using geospatial techniques. The specific research objectives of this study are as follows:

(i). To assess loss of agricultural land due to increase in built up area.

(ii). To assess spatial and temporal patterns of urban change.

(iii). To assess the land use/land cover of Noida during 1986–2011.

(iv). To visualize urban growth by ratio transformation.

(v). To assess the demographic profile of Noida, and increase in households too.

3. STUDY AREA

Coordinates 77°28'23. 677"E 28°30'32. 542"N
Area 53,000 ha (200 sq m)
DistrictGautam Buddha Nagar
State, Country Uttar Pradesh, India
Population 750,057 (Census 2011)
Elevation 200 m (656 ft)

Noida (77°22'46.444"E, 28°35'13. 017"N) acronym for New Okhla Industrial Development Authority came into existence on 19 April 1976. This city is considered as one of the most modern suburbs of Delhi in the National Capital Region. The city is located in Gautam Buddha Nagar district of Uttar Pradesh. Noida is situated in northern part of India and shares boundary with Delhi. River Yamuna binds Noida from the west and southwest and river Hindon from the east and southeast. Delhi shares boundary with Noida from north and northwest side while Ghaziabad from the northeast side. Noida comes under the catchment area of Yamuna river and is based on Yamuna’s old riverbed [3].

Greater Noida (77°30'46.366"E, 28°27'51.508"N) is the proud city to host the first Indian grand prix at Buddha International Circuit. This city is developed as an extension part of Noida due to its proximity to a few industrial towns of Uttar Pradesh on the east. The city is a result of intense pressure on national capital of Delhi and its periphery.

This city shares its boundary with Ghaziabad on the northern side and of course with Noida on the western side. It is broadly bounded by the main national highway, that is called the G. T. Road (NH-24) and river Hindon binds it from the western side. Unlike one of the minus points of Noida it is connected with Indian railway line on the eastern side (Figure 1) [4, 5].

Their corresponding Industrial development authorities govern both Noida and Greater Noida cities.

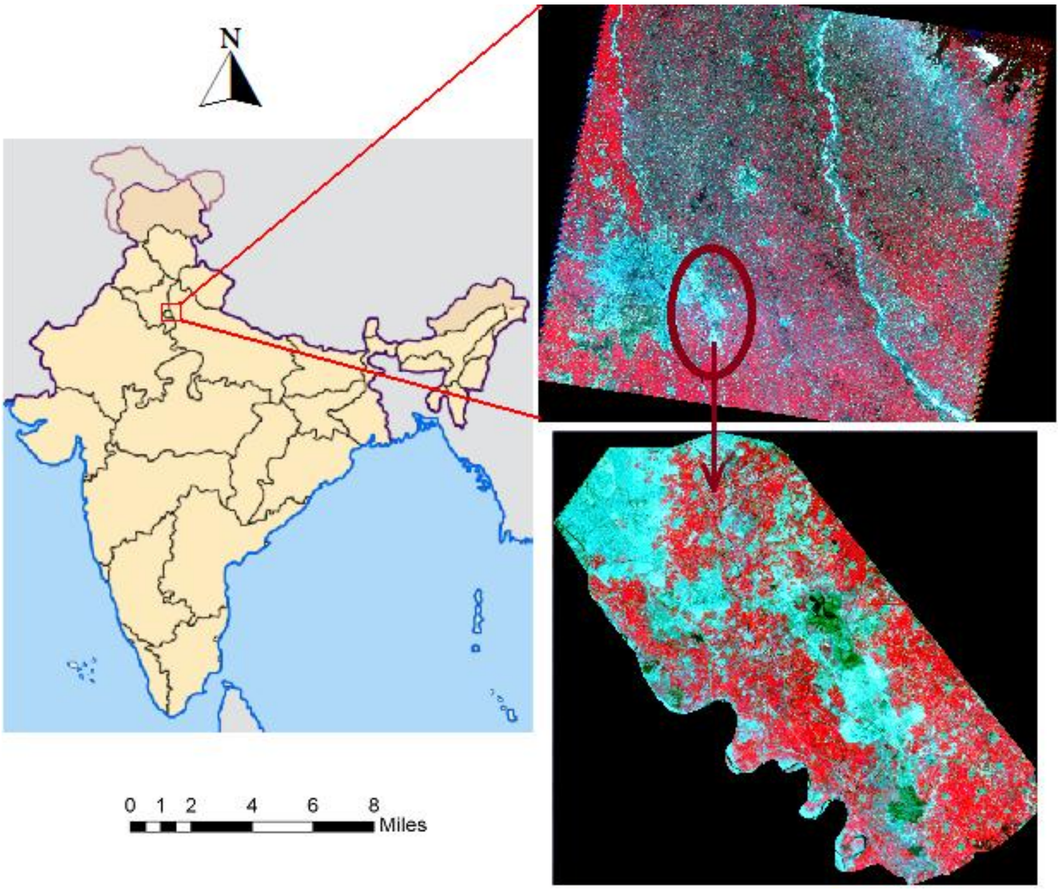


Fig. 1: *The Geographical Location of Study Area in India.*

4. DATA AND METHODOLOGY USED

The main analysis depends on the Landsat scenes of path row 146 040. Out of these three scenes, the study area was subseted using a shape file of area of interest. Then these two scenes were rectified using survey of India toposheet, 40 GCPs using second order polynomial were marked across the scene of study area and resampled to 30 m spatial resolution. After that, radiometric correction and image enhancement techniques were applied (Table I).

Table I: *Datasets Used in Analysis.*

S. No.	Name of Data Used	Scale/Resolution	Year
1.	Landsat	TM 5 30 m	2000 and 2011
2.	Landsat	MSS 57 m	1986
3.	Survey of India Toposheet	1:50000	1999, 2009
4.	Quickbird Scene	0.5 m	2011
5.	City Guide Map	Not scaled	2011
6.	Socio Economic Data	Yearly and Decadal	1991, 2001 to 2011

Without applying radiometric correction, it is not possible to get good results from comparison of temporal imageries, even acquired on the same date (different years) and generated by the same sensor. A few factors responsible for poor or incorrect results are atmospheric conditions (presence of clouds), variation in solar illumination conditions, change in sensors radiometric performance over time, atmospheric scattering and absorption. So, it is necessary to apply radiometric correction on the imagery [6].

If any two datasets are to be used for quantitative analysis based on radiometric information, as in the case of multi-date analysis for detecting surface changes, they ought to be adjusted to compensate for radiometric divergence. Two approaches were used in the study area to quantify the loss of agriculture due to urbanization. The second approach is for visualization purpose only; still, it represents a good picture of change.

First Approach: *Change Detection Analysis*

In this approach, change detection analysis was done using supervised classification (maximum likelihood method). Landsat scenes were classified to generate five classes. These classes are:

- Water bodies: covering all type of water classes, i.e., river, pond, seasonal water, drainage, shallow water and canal
- Vegetation: deciduous forest, mixed forest lands, palms, conifer, scrub and others
- Cultivated land: agricultural area and fallow lands
- Built-up area: residential, commercial, industrial, settlement, village abadi, mixed urban, minor roads and other urban
- Bare soil/Landfill sites: open area, exposed soils, barren land, landfill sites, major roads and areas of active excavation

Using the maximum likelihood classifier, all three images were classified. Then the classified data was converted into the data with sieve classes. Sieve classes method removes isolated pixels occurring in classification images using blob grouping. After applying sieve classes method, every unclassified pixel was assigned to its native class using GIS approaches [7].

Accuracy Assessment: "Accuracy measures the arrangement between a standard (assumed to be correct) and a classified map. This represents the correctness of the classified map. If the final map corresponds closely to the standard, the classified map is thought to be accurate". The classified Landsat scene of the year 2000 has 88.6254% accuracy with kappa coefficient = 0.8771 and the Landsat scene of year 2011 has 82.6984% accuracy with kappa

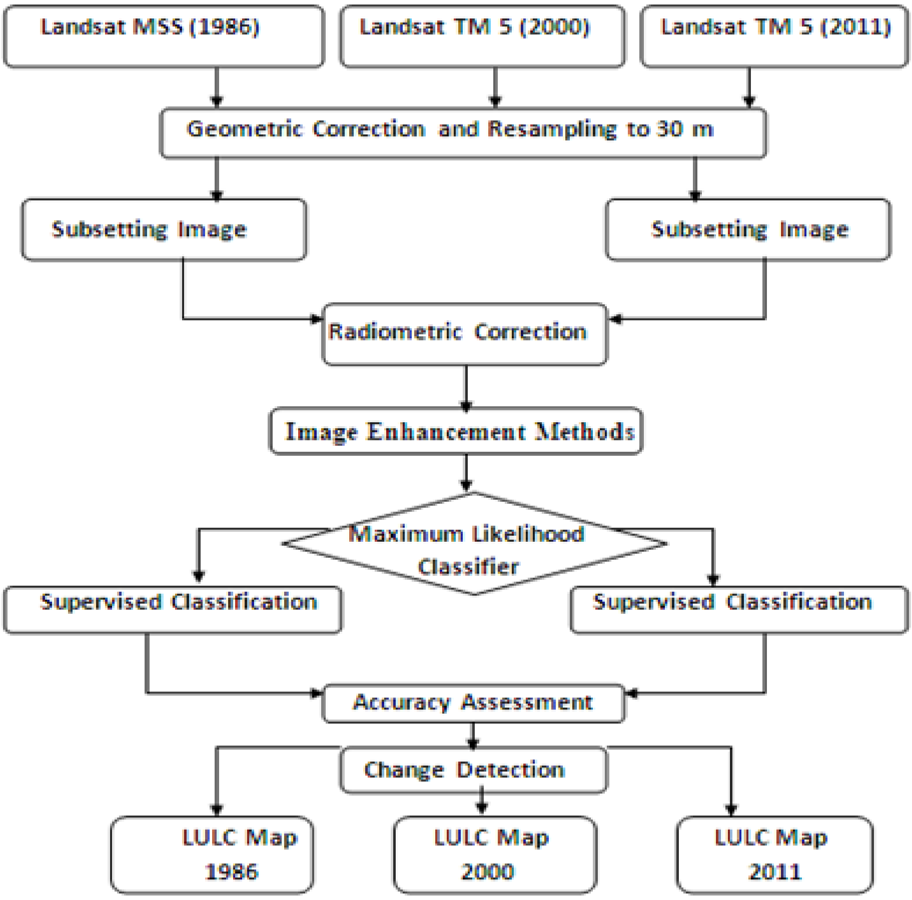


Fig. 2: *Methodology Used in Study.*

coefficient = 0.8161. Accuracy of classified image of 1986 cannot be assessed due to lack of reference data. Various approaches were used to achieve that much accuracy. With these resulting images, change detection analysis was performed to perfectly identify the change (Figure 2).

Second Approach: *Ratio Transformation*

Ratio transformations can be applied on remotely sensed data to reduce the effects of environment and to get information from the desired layers.

According to Landsat science band 3 that lies in between 0.63 to 0.69 µm wavelength region is a strong reflectance region for soils and keeps sensing in strong chlorophyll absorption region. It has the capability to discriminate between soils and vegetation. This band highlights urban areas, barren lands and street patterns. On the other hand, band 4 that lies in between 0.76 to 0.90 µm wavelength region proves its usefulness in crop identification because this band is operational in the best spectral region to distinguish vegetation varieties and conditions. This band also highlights water bodies but barren land, urban areas and major roads have not been highlighted.

So, according to James W. Quinn [8], applying the ratio of band third and fourth of Landsat TM 5 defines barren land and urban area uniquely.

Landsat TM 5 Band3/Landsat TM 5 Band 4 = Bare Soil and Urban Area

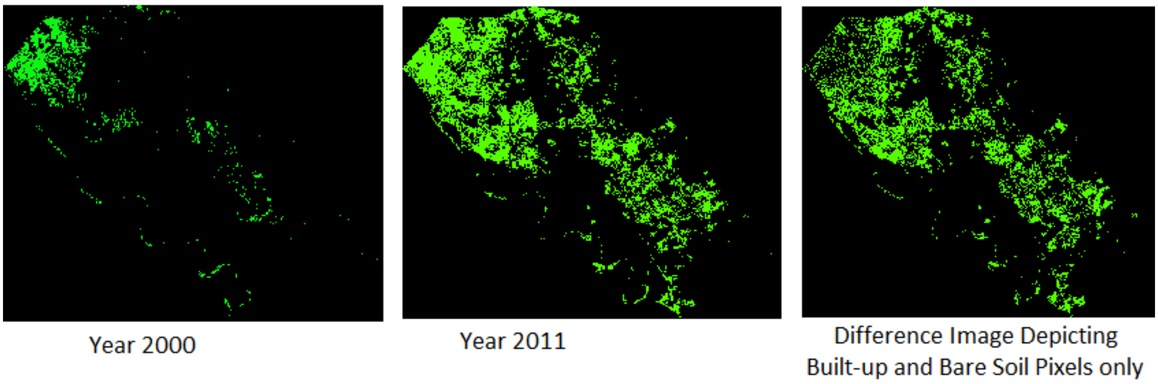


Fig. 3: *Landsat TM 5 "Ratio Transformation," One Layer Image Depicting Built-up Area and Bare Soil Pixels Only.*

This approach was applied using image-processing software to get output as a single-layered image having built-up area and bare soil only. This approach is for visualization purpose only in this study (Figure 3).

5. RESULTS AND DISCUSSION

According to change detection analysis, a very wide change has been observed. The LULC classes those have changed drastically are cultivated land and built-up area. Ultimately, out of these two classes built-up area has increased while cultivated land has decreased. In the year 1986, agriculture (cultivated area) was the dominating land cover class. Agriculture was spread in more than 50% of total area while built-up has occupied 19% of the total area.

In the year 1986, vegetation was all time high (during present study period) having 15% of its share in total area that decreased by 11% in the year 2000 and increased a little (2%) in the year 2011 due to planning of recreational area by town development authorities. In the year 2000, agriculture was the dominating class though it had decreased by 1% and built-up got an increase of 4%. Year 2000's image analysis shows that the class bare soil/landfill sites had grown up from 9% (in 1986) to 21% (in 2000). Water bodies got a decrease of 4% in the year 2000. Analysis shows that class bare soil/landfill sites have their best share in the year 2000 with 21% of total area (Table II).

Table II: *LULC Classes Generated after Classification Showing Area in Hectares during Different Years*.

Change in LULC Categories (Area in Hectares)			
Class/Year	**1986**	**2000**	**2011**
Water Bodies	2605.40	0780.89	1200.06
Vegetation	7833.56	2349.93	3368.97
Cultivated Land	27551.36	26356.19	15840.81
Built-up Area	10090.68	12385.17	24996.63
Bare Soil Landfill Sites	4919.936	11128.59	7594.169

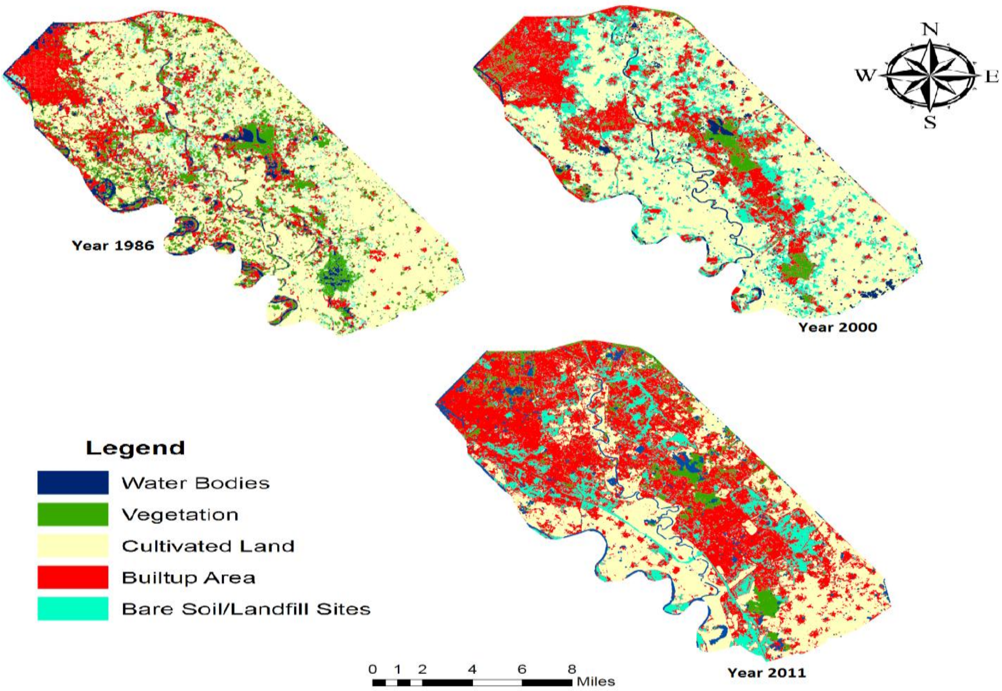


Fig. 4: *Landsat Classified Scenes of Study Area during Year 1986, 2000, 2011, Increase in Built-up, Open Land and Loss of Agricultural Land Can Be Seen Easily.*

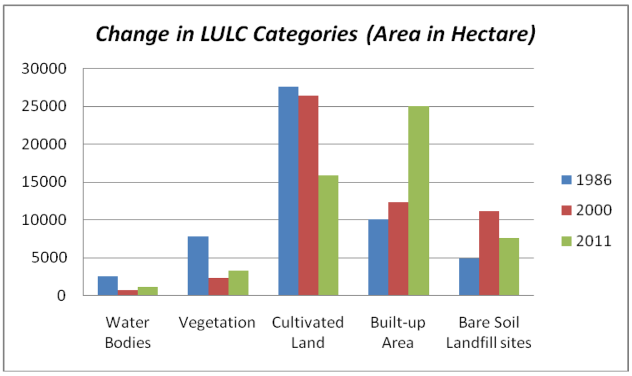


Fig. 5: Change in LULC Categories (Area in Hectares) during 25 Years.

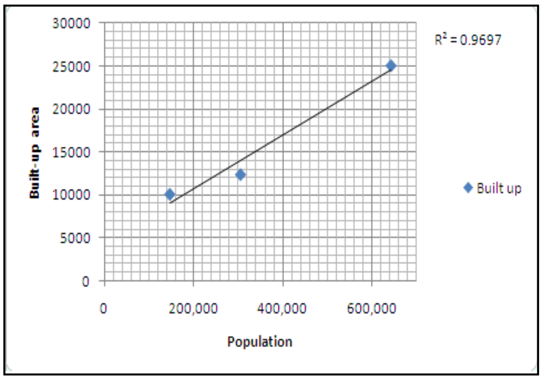


Fig. 6: Regression between Population and Built-up.

In year 2011, the dominating class was built-up area with 48% share of the total area, having 29% of huge change in comparison of built-up in year 1986 and cultivated area shows a huge loss of 22% in comparison of year 1986. In 1986, cultivated land was 27,551.36 ha that has shrunk to 15,840.81 ha in 2011. The above records (Figures 4 and 5) mirror that urbanization is the most widespread cause of the loss of arable land, decline in natural vegetation cover as well as habitat destruction.

Generally, if population increases built-up area will definitely increase. Regression analysis between population and built-up has very strong R^2 (.9697) and provides strength to the above fact. It shows population is proportional to built-up area (Figure 6).

5.1. Demographic Profile

As per 1981 census, the population of Noida was 36,972 and during 1991 census, it was declared a "Census Town" with a population of 146,514. The population of Noida grew by nearly 300% during 1981–1991 and it became one of the fastest growing towns in the country. In the decade of 1991-2001, population grew with a growth of 108.21% (Figure 7). The town contained 68% of the total urban population of Gautam Buddha Nagar district completely overshadowing other towns like Dadri, Dankaur and Jewar. The 1991–2001 decade witnessed slowing down of growth,

which was 108.21%. The decade 1981–1991 was the take off stage of the new township (Noida Development Authority).

According to census of year 2001[1], the population reached 305,058 and recent census of year 2011 shows a drastic change in Noida's population by an increment of 111% with 642,381 people. During 1981–1991, the population increased by a difference of 110,973 inhabitants, in 1991–2001 decade by 158,544 inhabitants and in 2001–2011 decade by 337,323 inhabitants. Greater Noida had 107,671 inhabitants in the year 2011.

Table III: *Landuse Distribution in Noida and Greater Noida (Area in Hectares).*

(Source: Noida and Greater Noida Development Authorities)

	2001	2011	2021 Proposed
Residential	2917.00	6240	10994
Industrial	2688.96	4496	6035
Commercial	0135.74	1380	1724
Institutional	1141.63	2182	3744
Recreational	1569.90	3540	6776
Transportation	1150.32	2582	5244

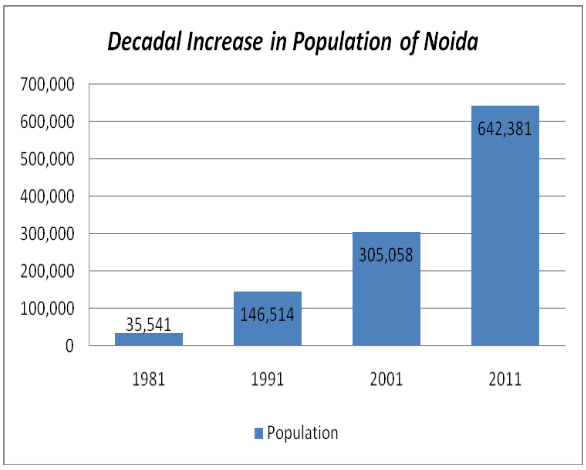
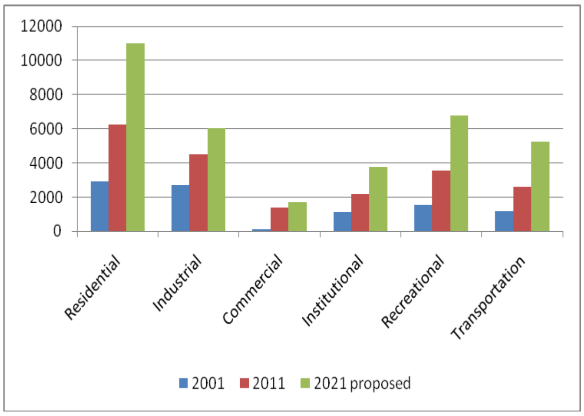


Fig. 7: *Increase in Population of Noida City between Three Decades.*

5.2. Landuse Distribution in Noida and Greater Noida

According to the respective development authorities of the two towns, following records of landuse were provided in the draft of master plan for 2011 and revised draft of master plan for 2021 (Figures 8 and 9) [3, 4]. Table III shows the combined landuse pattern distribution for Noida and Greater Noida. Table facts reveal that main emphasis for development is on residential and industrial categories under built-up class with an increment in recreational and transportation categories also.



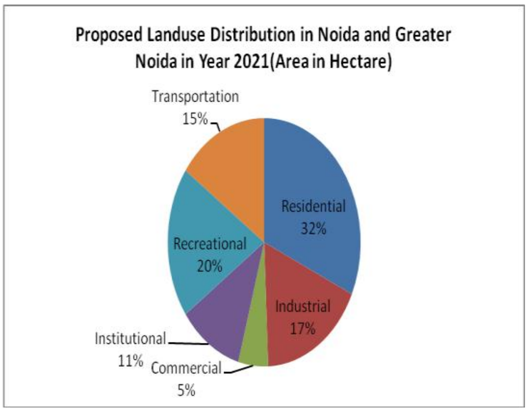


Fig. 8: *Landuse Distributions in Noida and Greater Noida Area in Year 2001, 2011, and 2021 proposed. (Ha)*

Fig. 9: *Proposed Landuse Distributions of year 2021.*

(Source: Noida and Greater Noida Development Authorities)

6. CONCLUSIONS

This study explains LULC changes and the extent of urban expansion in Noida andGreater Noida, India, using remote sensing satellite data in conjunction with socio-economic dataset. Urban expansion and loss of agriculture was quantified for the last 25 years using the post-classification comparison technique. The study area was found to have experienced rapid changes in LULC, particularly in built-up/urban areas and obviously in cultivated land. Change detection analysis reveals that the built-up area has increased by 29% (from 10090.68 ha to 24996.63 ha) and cultivated land has decreased by 22% (from 27,551.36 ha to 15,840.81 ha) during 1986 to 2011.

Results of ratio transformation and post-classification reveal that only two categories, i.e., built-up area and bare soil/landfill sites, have occupied 32,590.80 ha out of 53,000 ha (61% of total area). According to census of India [1], district Gautam Buddha Nagar used to have 204,302 households in year 2001 that increased by 111,976 becoming 316,278 in 2011. This fact also shows a huge rise in urbanization in the last decade. The conversion of agricultural land, vegetation and open area to built-up area/urban land has caused varied environmental degradation with loss of fertile land and its main negative outcomes are directly associated with urban expansion.

Over all, this study reveals decadal change in various LULC classes using RS, GIS and socio-economic data. Being the most influential national capital region towns, Noida and Greater Noida are rapidly running towards urban expansion. Few months ago in Greater Noida, many hectares of agricultural land was acquired from farmers by the state government to develop industrial areas and residential townships. So, in the near future, this area will definitely show a great change in terms of urbanization.

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