Geovisualisation and Spatio-Temporal Modelling from Satellite Imagery: A Study of Million+ City, Ghaziabad, NCR Region, India.

Madan Mohan

Department of Geography, Faculty of Natural Sciences, Jamia Millia Islamia (Central University), New Delhi, INDIA.
E-mail: drmdnmohan@gmail.com

Abstract. The geographic information in form of spatial and non-spatial data have largely been used in the present information technology time by the society. The spatial data have a complex structure involving space, time and presentation. The integration of spatial and non-spatial data and its visualisation is known as geographic visualisation or geovisualisation. The urban sprawl is the process of transformation of rural areas into urban areas due to in-migration, industrial growth and transport network infrastructure development. Urban sprawl has been quantified by considering the built-up area as the key feature of sprawl, which can be obtained either from physical field survey or through remote sensing satellite imagery. A large number of studies are dealing with quantification of the spatial patterns of urban sprawl with the help of Remote Sensing and GIS. In all these studies, however, concluded with different methodologies in quantifying the urban sprawl. But it is found that there is common approach to consider the behaviour of built-up area and population density over the spatial and temporal changes which has taken place in most of the cases of spatial pattern of urban sprawl. So, the urban sprawl is the process of transformation of rural areas into urban areas due to in-migration, industrial growth and transport network infrastructure development. In the recent past, a lot of attention has been paid to understand and analyze the process of spatial patterns of urban sprawl. It is noteworthy to mention that over the periods, there has been continuous process of urban sprawl in the rural-urban fringe of Ghaziabad City due to the liberalization of economy, development plans and policies of the State Govt. of Uttar Pradesh and Central Govt. of India.

Keywords: Geovisualisation, Remote Sensing, Urban Sprawl, Economic Development, Development Plans and Policies.

1. Introduction

The geographic information in form of spatial and non-spatial data have largely been used in the present information technology time by the society. The spatial data have a complex structure involving space, time and presentation. The integration of spatial and non-spatial data and its visualisation is known as geographic visualisation or geovisualisation. The visualisation involved the use of maps or 3D displays to represent physical space. So, the multiple interactively linked view providing different perspectives into the data has become a kind of standard in geovisualisation. Urban Sprawl is the process of transformation of rural areas into urban areas due to in-migration, industrial growth and transport network infrastructure development. In the recent past, a lot of attention has been paid to understand and analyze the process of spatial patterns of urban sprawl. A large number of studies are dealing with quantification of the spatial patterns of urban sprawl (Couch et. al. 2005, Sultana & Weber 2007, Bruegmann 2006, Siedentop 2010). In all these studies, however, concluded with different methodologies in quantifying the urban sprawl. But it is found that there is common approach to consider the behaviour of built-up area and population density over the spatial and temporal changes which has taken place in most of the cases of spatial patterns of urban sprawl. Due to the continuous in-migration of peoples from the countryside's, the urban areas continue to expand over the periods. This process of urbanization emphasizes that once a direction of urban growth picks up momentum, it becomes very difficult to reduce sprawl in spite of the fact that sites may not be entirely suitable for expanding a new town.

In view of this, the conventional surveying and mapping techniques are expensive and time consuming for the estimation of urban sprawl. Such information is not easily available for most of the urban centers and cities. So, as a result, increasing research interest is being directed to the mapping and monitoring of urban sprawl using geospatial technologies which is best suited for geovisualiation of spatio-temporal land development as well as for modelling of the process of urban sprawl. Remote sensing is cost effective technology and is increasingly being used for the impact analysis of urban sprawl (Jat et. al. 2008, Xia & Anthony 2007). During the past, for more than three decades, extensive research efforts have been made for urban change detection using Remote Sensing Satellite Imagery and Geographic Information Systems for impact analysis assessment of urban sprawl (Rodriguez-Buchiller 2004, Xia Li & Anthony 2004, Yang and Lo 2003).

In lieu of this, the present study has considered the urban sprawl as a challenging task therefore, seeks to bring out the noteworthy impacting factors

of the process of urban sprawl. Besides this, Urban sprawl has been quantified by considering the built-up area as the key feature of sprawl, which can be obtained either from physical field survey or through remote sensing satellite imagery. Over the periods, there has been a continuous process of urban sprawl in the rural-urban fringe of Ghaziabad City due to the extension of transport network corridors, liberalization of economy, development plans and policies of the state govt. of Uttar Pradesh and Central Govt. of India. It has resulted into the establishments of number of national and multinational companies, since the inception of Ghaziabad as an industrial city. So, it is noteworthy to mention that there has been occurred a continuous urban sprawl in the rural-urban fringe of the Ghaziabad City over the periods. It has largely been responsible in the transformation of physical landscape which is creating socio-economic and environmental concerns at large. Hence, the present research would make an attempt to help local, regional and state level land use planners and policy makers to better understand and address the issues attributed to urban sprawl.

2. Conceptual Framework on Urban Sprawl

In the recent past, a lot of attention has been paid to understand and analyse the process of spatial patterns of urban sprawl. Studies are dealing in-depth with considerable progress in quantifying the spatial patterns of urban sprawl (Yeh and Li 2001, Epstein & Kramer 2002). The urban sprawl consists of three basic spatial forms as the low-density sprawl, ribbon sprawl and leapfrog development sprawl (Yeh and Li 2001, Yang & Lo 2003, Shannon 1948). An increasing pace of urbanisation is usually associated with and driven by the population concentration in an area over the periods. The extent of urbanization drives the change in land use patterns. Exact information on the extent of urban growth is of great interest for the development authorities for growing urban and suburban areas for diverse purposes such as urban planning, water and land resource management, and infrastructure and amenities development (Wolman et. al. 2005).

Urban development authorities and municipal corporations are required to devote more time, attention and effort to manage land use and other resources for accommodating the expanding population. Urban sprawl monitoring is the basic information for the development authorities for formulation of long term planning and policies (Cho 2005, Wood 2007). Although the debate over whether a “sprawling” urban form is best for the quality of city life has not been fully settled. There are number of dimensions of sprawl such as the density, continuity, concentration, clustering, centrality, mixed uses, and proximity which were considered for urban

sprawl. Urban green spaces have important amenity values that include provision of leisure opportunities and aesthetic enjoyment. So, they are usually ignored or underestimated by urban planning policy-makers, with the result that remnant urban green spaces are being gradually encroached upon by the urban sprawl process.

3. Objectives and Research Questions

The main objectives of the present study are mentioned as follows:

i. to analyse growth trends of urban population;
ii. to geovisualise spatio-temporal patterns of urban land use;
iii. to analyse process of land use transformation and urban sprawl;
iv. to suggest suitable strategies for urban development.

The present study has enquired the process of urban sprawl which is a challenging task for the urban development authorities, therefore, seeks to answers a number of research questions in detail which are mentioned as follows:

i. How has the urban population growth took place in the past century?
ii. What are the geospatial patterns of land use from 1972 to 2009?
iii. Which are the impacting factors responsible for the urban sprawl?
iv. What are the most suitable strategies for urban development?

So, the present research has made an attempt to help urban planners and policy makers.

4. Database of the Study

The spatial information from the open series topographic sheets on the scale of 1:25,000 have been extracted in form of the boundary maps and other relevant spatial features information. These digital topographic sheets have been obtained from the Survey of India, Dehradun. On the other hand, the multispectral digital imagery of the IRS series of satellites was procurred from the National Remote Sensing Centre (NRSC), Indian Space Research Organisation (ISRO), Department of Space (DOS), Govt. of India, Hyderabad, India. The high resolution multispectral digital imagery of the Landsat satellites have also been obtained from the United States Geological Survey (USGS) website. The details of the satellite imagery used in the present study is given in the *Table-1* below:

Date of Acquisition	Satellite	Sensor	Spatial Resolution (in meters)	No of Spectral Bands	No. of Spectral Bands Used	Wavelength (in micrometers)
1972	Landsat-2	MSS	80	4	4, 5, 6	0.5-0.6|0.6-0.7|0.7-0.8
1975	Landsat-3	MSS	80	4	4, 5, 6	0.5-0.6|0.6-0.7|0.7-0.8
1989	Landsat-5	TM	28.5	7	2, 3, 4	0.52-0.60|0.63-0.69|0.76-0.90
1997	IRS-1C	LISS-3	23.5	4	2, 3, 4	0.52-0.59|0.62-0.68|0.77-0.86
2001	IRS-1D	LISS-3	23.5	4	2, 3, 4	0.52-0.59|0.62-0.68|0.77-0.86
2006	IRS-P6	LISS-3	23.5	4	2, 3, 4	0.52-0.59|0.62-0.68|0.77-0.86
2009	Landsat-5	TM	28.5	7	2, 3, 4	0.52-0.60|0.63-0.69|0.76-0.90

Notes:
Image courtesy of the U.S. Geological Survey (USGS), United States of America.
Image courtesy of the National Remote Sensing Centre (NRSC), Hyderabad, India.

Table 1. Details of the multispectral satellite imagery of Landsat and IRS Satellites.

The present study is also based on the latest data available from the different sources to achieve the specified objectives of the research. There are different sources of ancillary data available from the records of the Census of India 2001 and 2011. So, the Primary Census Abstract, Final Population Total, and the Village and Town Directory and the the Census Atlas – Ghaziabad District and Uttar Pradesh State have been used in the research. In addition to this, a number of development plans and policies, records, reports and documents published by the different States and Central Government departments and ministries have also been collected from the Department of Land and Development and the Department of Urban Development, Ministry of Urban Development, Govt. of India, New Delhi.

5. Research Methodology

Urban Land Use mapping for the study area have been carried out by standard methods of analysis of remotely sensed data followed by ground truth collection, and visual interpretation of satellite imagey. The Landsat and IRS visible and infrared spectral bands have been used of which details is given in the above *Table-1*. The Digital Image Processing was carried out with the help of ERDAS Imagine software based on broadband satellite imagery. Besides this, the present study is based on the spatial and non-

spatial data analyses in the ArcGIS application software for geographic analysis and geospatial processing. So, the software's specific in-built Algorithms, mathematical / statistical methods and models have been applied in the present research. However, the land use classification scheme has been worked out and applied in the the present research is given in the *Table 2* as follows:

	Level-I		**Level-II**		**Level-III**
1	Built-up Land	**1.1**	Compact Settlements	**1.1.1**	Unplanned Residences
		1.2	Sparse Settlements	**1.2.1**	Planned Residences
				1.2.2	Industrial Units
		1.3	Unbuilt-up Space		
2	Forests Cover Land	**2.1**	Protected Forests	**2.1.1**	Natural Vegetation
		2.2	Reserved Forests	**2.2.1**	Tree Plantation
3	Water Body	**3.1**	River Channels	**3.1.1**	Hindan River
		3.2	Canals	**3.2.1**	Hindan Canal
		3.3	Ponds		
4	Cultivated Land	**4.1**	Agricultural land	**4.1.1**	Cropped land
				4.1.2	Fallow land
5	Transpotation Network	**5.1**	Roadways	**5.1.1**	Metalled Roads
				5.1.2	Unmetalled Roads
		5.2	Railways	**5.2.1**	Railways Tracks
				5.2.2	Railways Stations
6	Others	**6.2**	Wastelands	**6.2.1**	Barren lands
				6.2.2	Brick Kilins

Table 2. The land use classification scheme.

The Shannon's Entropy Model which is empirically validated has been applied for measuring the degree of spatial concentration or dispersion of geospatial variable (Xi) among n zones (Shannon 1948, Haynes et. al. 1980, Haynes & Storeberk 1978, Joshi et. at. 2006, Yeh & Li 2001, Zhang et. al. 2006, Lo & Yeung 2005). So, finally it is defined and explained as follows:

$$S = \sum_{i=1}^{n} pi \log(1/ pi)/\log(n) \quad (1)$$

Where:

$pi = xi / \sum_{i=1}^{n} xi$ and xi is the observed value in the i th zone in total of n zones.

The entropy value ranges from 0 to 1. If the distribution is maximally concentrated in one region, the lowest value zero will be obtained. Conversely, an evenly disperse distribution across space will give a maximum value of 1. The major difference between entropy and traditional indices of spatial dispersion is that its value is invariant with the value of zones, the number of observation (n).

Since the entropy can be used to measure the distribution of a geographical phenomenon, thus the measurement of the difference on entropy between time t+1 and t can be used to indicate the magnitude of change in the degree of dispersal of land development or urban sprawl. It is defined as follows:

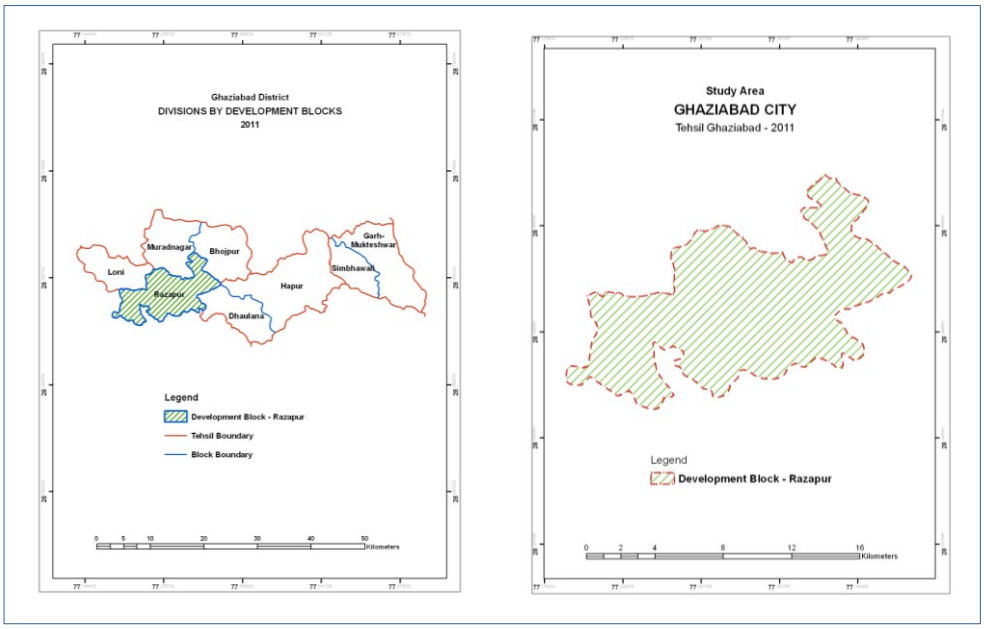
$$\Delta Sn = Sn\ (t+1) - Sn\ (t) \quad (2)$$

The dispersal of urban areas from a city centre will lead to an increase in the entropy value. The change of entropy can be used to identify whether land development is toward a more dispersal (sprawl) or compact pattern. So, the typical patterns of urban sprawl are categories into three classes as the concentrated (Low Development); the dispersed (Medium Development); and the scattered (High Development). These three types of urban sprawl patterns are reflected from the entropy. The multi-spectral signatures of remote sensing and entropy model have been applied to scrutinize the geospatial and temporal land transformation caused by to the process of urban sprawl.

6. Study Area

Ghaziabad City is one of the important million+ city of the Uttar Pradesh State in the Sub-Region of NCR. It is located at about 22 kms. from the National Capital Territory (NCT) Delhi and is an important industrial and trading center in Delhi Metropolitian Area (DMA). The city is located on the Grand Trunk road and about a one and half kms east of the Hindon River at 28^{0} 40‘ N latitude and 70^{0} 25‘ E longitude on National Highway (NH-24)

connecting the city with Delhi-Mordabad-Lucknow as is evidence by the *Map 1 and 2*. Two other National Highways i.e. NH-58, Lucknow-Varanasi passing through Niti Pass and NH-91 to Bulandshrahr also passes through the city. The State Highway (SH-57) connects the city to Baghpat and Sahaaranpur. The city is bounded by the NCT Delhi in the west and NOIDA City in the south. The geogaphical location of the million+ Ghaziabad City is presented in the *Map-1 & 2* below:



Map 1 & 2. Map 1 shows the location of the study area – Ghaziabad City in the boundary map of development blocks; Map 2 shows boundary map of the study area – Ghaziabad.

Ghaziabad as a district was declared on 14th November 1976. Ghaziabad is situated in an agricultural area in the western part of the Uttar Pradesh. From the historical, cultural, mythological and archaeological point of view, Ghaziabad has been a prosperous city. This has been proved from the research work and excavations undertaken in the district. The historical excavation work carried out at the mound of Kaseri situated on the bank of Hindon River, 2 km north from Mohan Nagar, shows that there was existed ancient civilization dated back to 2500 B.C. In terms of topography, there has been existed almost flat terrain. The average elevation is 200 m above mean sea level. The climate is dry and healthy, intensely hot during summer (May-June) temperature rises to 45° C and quite cold in winter (December-January) drops to 20° C. Geologically, it is the part of Indo-Gangetic alluvium, which consist of sand, clay, kankar and reh. The strata consists

mainly of sandy soil which is quite fertile and loamy. The depth of sub-soil water table is about 10-15 metres below ground level and the seasonal variation is about 5 metres. It is drained by the Hindon River which finally merges in the Yamuna River.

7. Growth Trends of Population

Ghaziabad city has witnessed unprecedented growth of population especially during the last three decades. It began as a small settlement near Delhi with a population of 11275, which grew to 23.58 lakh in 2011 as is evidenced by the *Table-3*. During 1971-2011 period, the city population recorded an increase of 16.21 times and during 2001-2011 it increased by 1.43 times. Whereas there was population growth of 143.52 per cent during 2001-2011 decade which signifies that the city's population has been growing at a very rapid pace compared to other cities of Uttar Pradesh (UP) State's of the Sub-Region of NCR. As per 1981 Census, the density of Ghaziabad was 2393 persons per sq. km. which increased to 3541 persons per sq. km. in 1991. Later on, the density was increased to 6701 persons per sq. km. in 2001. This was mainly due to increase in the jurisdiction of Municipal Corporation. The area of Municipal Corporation also increased from 120.00 sq. km in 1981 to 144.50 sq. km in 2001. However, in actual terms, it is observed that as per the land use pattern, the population density is about 10144 persons per sq. km in 2011.

The rapid growth of Ghaziabad city is mainly due to vivid and multifarious reasons, which include proximity to Delhi, establishment of planned industrial estates, discouragement to the establishment of large-scale industries in NCT Delhi and political stability in the UP Sub-Region of NCR. Although of late, especially during the last decade, a number of small and big industrial units in the city were closed down and retail trade could not take off as expected. However, the tertiary sector (services) became the biggest source of employment and thereby city experienced rapid population growth. In addition to this, there are two more reasons for the rapid growth of population as first, due to the availability of fertile land the nearby villages wherein the population desired to improve their living conditions settled down in Ghaziabad; and secondly, due to close proximity to NCT Delhi, the middle class families, which were unable to purchase houses in NCT Delhi, preferred to purchase house/land in the Ghaziabad City. All these reasons clearly reveal the prevalence of pull factors in Ghaziabad City and push factor from NCT Delhi. The majority of people settled down in Trans-Hindon area of the city and they used to work in NCT Delhi, which is an indication of growing urbanization in the DMA area and to be part of Ghaziabad Urban Agglomeration.

Year	Urban Population	Growth Rate (in per cent)	Area (in sq km)	Density (per sq km)
1901	11275	-	-	-
1911	11304	00.26	-	-
1921	12343	09.19	-	-
1931	18831	52.56	-	-
1941	23834	26.57	-	-
1951	43745	83.54	-	-
1961	70438	61.02	57.37	1228
1971	137033	94.54	89.0	1,539
1981	287170	109.56	120.0	2,393
1991	511759	89.25	144.5	3,541
2001	968521	89.25	144.5	6,701
2011	2358525	143.52	232.5	10,144

Source: Census of India 2011, Village & Town Directory; and District Census Handbook, Ghaziabad District.

Table 3. Growth rate and density of population in Ghaziabad City.

Furthermore, the post-independence period witnessed establishment of industries and thereafter with the discouragement of large-scale industrial establishments in NCT Delhi, the city developed in all the spheres. It may be stated that till 1971 the development of city was self-induced, however, consequently due to spill over of population of NCT, Ghaziabad witnessed rapid population growth. It may be observed from the above table that during 1921-31 and 1941-51 there was sharp increase in the growth rate of population mainly due to establishment of grain markets and oil mills, breweries and administrative offices during 1930's and influx of refugees. The planned development begun in 1961, which further attracted population contributing the growth of 94.54 per cent during 1961-71 and 109.56 per cent during 1971-81 and 89.25 per cent during 1981-91. Thereafter, the growth population again showed increasing trend and recorded a phenomenal growth rate of 143.52 per cent during 2001-2011 as is evidenced by the above *Table-3*.

However, there are many factors responsible for rapid population growth as well as development of Ghaziabad which are as firstly, the Uttar Pradesh State Industrial Development Corporation (UPSIDC) developed industrial estates like Sahibabad, Kavinagar, Bulandshahr Road, Loni Road, Meerut

Road and G.T. Road whereas Ghaziabad Development Authority (GDA) developed residential and physical infrastructure; secondly, the fertile land coupled with widespread agriculture attracted labour due to the relative prosperity and displacement of labour in surrounding rural areas which became a "push factors" for the population migrating towards an employment generating area during 1950's and 1960's; thirdly, the high land values in the real estate market of NCT Delhi and availability of relatively cheaper land in Ghaziabad next to NCT Delhi; fourthly, the transport corridors connecting NCT Delhi to the resource base of the Western Uttar Pradesh via Ghaziabad gave impetus to the trade and industrial activities.

8. Urban Land Use Trends and Patterns

The urban land use classification (ULUC) has been worked out using multi-spectral satellite imagery with the help of supervised classification algorithm for the period of 37 years from 1972 to 2009. The satellite imagery were classified into six thematic classes as the built-up settlement, forests cover land, water bodies, cultivated land, transportation network and others. The pixel-based land use classification computed for the seven periods 1972, 1975, 1989, 2001, 2006 and 2009 is presented in the Table 3.

Class	1972	1975	1989	1997	2001	2006	2009
Built-up Land	37.74	43.61	34.83	49.47	48.87	57.43	63.17
Cultivated Land	52.53	51.26	51.32	34.42	33.11	24.99	21.13
Forests	3.81	3.59	2.60	8.97	12.97	11.73	6.80
Water Bodies	1.16	1.34	1.58	3.54	0.85	0.79	2.09
Transport Network	4.66	0.15	9.46	3.29	3.94	4.86	6.59
Others	0.10	0.05	0.20	0.32	0.26	0.20	0.22
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

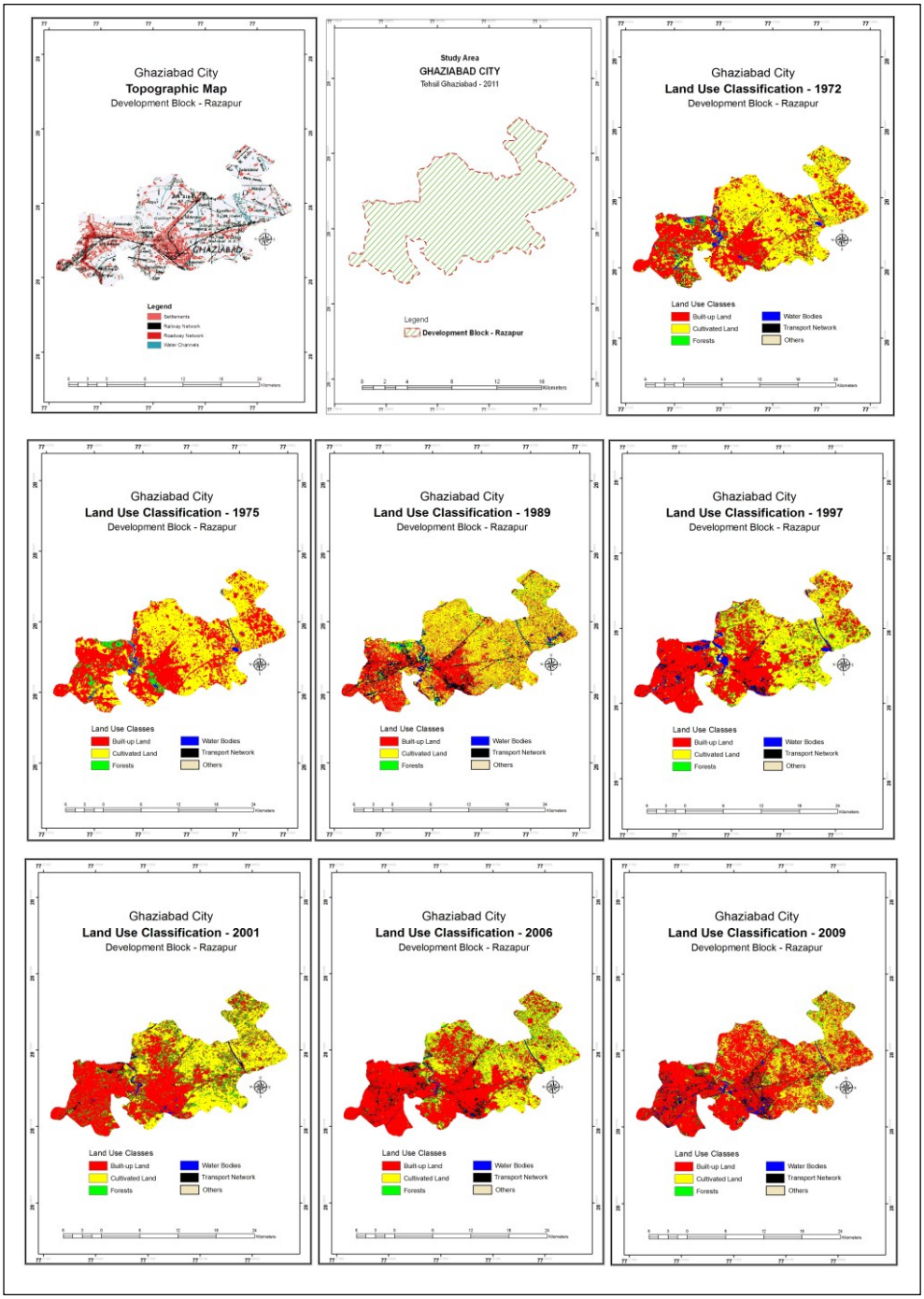
Source: Computed & Tabulated from the IRS and Landsat Satellites Imagery.

Table 4. Land Use classification for Development Block, Ghaziabad.

It is evidenced from the above *Table 4* that the cultivated land comprises the largest proportion of 52.63 per cent of the total geographical area in 1972. Over the periods its proportion has been declined steadily, particularly from 1997 period onwards from 34.42 per cent to 21.13 per cent in 2009. In other words, the cultivated land has shrinked almost to half from 1972 to 2009, due to the expansion of the built-up area, as is evidenced by the *Table 4*. On the

other hand, the built-up land comprises by both the compact and sparse settlements together accounted for 37.74 per cent in 1972. The built-up land proportion has been increased over the periods continuously and nearly double to 63.17 per cent in 2009. In addition to this, the area under forest cover has shown an increase over the periods which has almost doubled to 6.80 per cent in 2009, due to the green cover regeneration and plantation of trees for development of recreation facilities in and around the built-up areas of the Ghaziabad City over the periods. The water bodies comprises by the Hindon River and the ponds together accounted for 2.09 per cent in 2009 of the total geographical area. The transport network area proportion has been increased from 4.66 per cent in 1972 to 6.59 per cent in 2009. The significant proportion of 9.46 per cent increase is recorded during 1989 period. Besides this, a negligible proportion of area is accounted by the other land use class which comprises by the wastelands like barren lands and brick kilns wide spread over the areas in the development block particularly in the surrounding vicinity of the Ghaziabad City as is evidenced by the *Table 4*.

With the increase in population, the residential areas have seen tremendous increase, however, the pace of development could not match the provisions for both physical and social infrastructure and services as per the requirement of the growing population. It has been observed in the context of urban landuse pattern that there is exorbitant increase in land prices (for plotted houses), which has led to the development of multi-storied apartments (Group Housing) residential units. The Trans-Hindon areas especially Shalimar Garden, Ramprastha, Kaushambi, Vaishali, Rajender Nagar have witnessed large scale construction of group housing flats on the plots with size of 500 sq. mt. to 1000 sq. mt. This development has by and large been in an unauthorized manner thereby resulting in extreme strain on infrastructure / facilities and services. The areas meant for plotted development where 2 to 3 dwelling units are supposed to be developed has been converted into multiple dwelling units (15-20) on a plot of 500 sq. mt. to 1000 sq. mt. So, the high rise building with high density not only alters planning principles drastically; but have serious adverse repercussions on the overall city infrastructure and any up-gradation or augmentation of the same is offset by multifold increase in the dwelling units. Consequently, there are problems of low level of access to basic infrastructure like absence of drainage and sewerage, shortage of drinking water, absence of proper solid waste management etc. resulting in deteriorating quality of life.



Map 3 to 11. Map 3 to 11 shows changing urban land use patterns in the Ghaziabad City.

The development of Trans-Hindon areas without any consideration of planning for basic amenities and infrastructure facilities have in fact led to mushrooming of large number of residential colonies at the periphery of NCT Delhi. The decade of 1970's has also witnessed the decline of developed industrial areas due to economic liberalization and impingement of other uses on industrial areas have increased alarmingly with invasion of development of commercial activities like Shopping Malls and Multiplexes. Hence, with the increase of privatization of education, the educational and technical institutions have also sprung up all over in Ghaziabad. Such educational institutions have largely came up on land acquired from agricultural use and some industrial areas have been converted into the usage of educational and institutional area development.

8.1. Process of Planned Development

The First Master Plan for Ghaziabad was prepared in 1961 with a perspective of 1981. In 1961, the area of the city was 57.37 sq. kms. In Master Plan-1981, about 58.53 sq. kms. was proposed for development, however against this only 43.65 sq. kms (74.60 per cent) was developed as shown in the *Table 5*.

Sl. No.	Land use Category	Area (in sq. km.)	Area (in percentage)
1.	Residential	46.70	55.05
2.	Commercial and Trade	02.74	03.22
3.	Industrial	17.10	20.16
4.	Office	02.80	03.30
5.	Community Facilities	02.53	02.98
6.	Green Belt-Park, Open Space, Recreational Areas	03.99	04.70
7.	Undefined Areas	00.16	00.19
8.	Railways	02.32	02.73
9.	Roads/Bus Stands/ Depots	05.20	06.13
10.	Others	01.29	01.52
	Total	***84.55***	***100.00***

Source: Master Plan of Ghaziabad 2021, Ghaziabad Development Authority, Uttar Pradesh, Ghaziabad.

Table 5. Existing urban land use classification for Ghaziabad City 2003.

The next Master Plan notified in 1986 in which the total developed area was 59.33 sq. kms while the Master Plan-2001 proposed 100.39 sq. kms. as developed land. In actual terms only 84.55 sq. kms. (84.21 per cent) was developed area. In this context, the category-wise breakup of the developed land is evidenced by the above Table-5.

According to the Master Plan of Ghaziabad (MPG-2021), the total development area of Ghaziabad is 84.55 sq. kms. of which 46.70 sq. kms is under residential use which is constituting 55.03 per cent of the developed land. This is followed by industrial use of 20.16 per cent and 6.13 per cent use under the roads, bus stands. All these three uses together constituted more than three-fourth of the total land use of the city. Among the entire land uses category both residential and industrial uses have witnessed intensive development. The land under residential use was 16.48 sq. kms. in 1961, which increased to 31.60 sq. kms. in 1984 and 46.70 sq. kms. in 2003. This has resulted into an increase in area under residential use in about 40 years has been 2.8 times. As far as industrial development is concerned, the 1961-81 period witnessed expansion, as the city was perceived as industrial town with 0.91 sq. kms of land developed per year. However, the 1991-2001 period has not witnessed industrial development as many industrial units got closed down due to number of prevailing reasons like shortage of water and power and other infrastructure facilities unavailability. Furthermore, the focus of industrial development in Uttar Pradesh sub region shifted to NOIDA and Greater Noida with the establishment of separate industrial development authorities for both these towns. There is further possibility of setting up of new industries as there has been shifting of polluting units from NCT Delhi towards satellite towns in the UP sub-region of the NCR.

8.2. Urban Development and Planning

The planned development of Ghaziabad City began way back in 1958, when the Uttar Pradesh State Government issued notification to declare development (regulated) area and subsequently in another notification in 1977. The Ghaziabad and 137 villages in its surroundings were declared as Ghaziabad Development Area (GDA). The development area of Ghaziabad today is 452 sq. km. The development of Ghaziabad could be seen as the influence of nearby city/town. During 1950-60 decade, the Ghaziabad was perceived as satellite town in Master Plan of Delhi, MPD-1962 and it was envisaged to be developed as satellite town. Whereas during 1960-80, the industrial development gave it as an image of Industrial Township. So, with the close proximity with Delhi, it has been deeply influenced by the developments of NCT Delhi. The development in Ghaziabad especially the Trans-Hindon area can

also be seen as metropolitanisation of fringe areas of a large city. With the UP sub region, in addition to Ghaziabad, NOIDA and Greater NOIDA have also developed since 1980's and late 1990's. The development of these towns to some extent had distributed the population on one hand; there has been distribution of economic activities on the other.

Ghaziabad is one of the important industrial center of UP sub region which has iron and steel manufacturing units, ceramics, pipe, vegetable oils, picture tube, medicine, beverages. The heavy and large-scale industries are developed in Trans-Hindon areas adjoining to the G.T. Karnal Road, center of Link Road / Bulandshahr Marg. The small and medium industries have been developed in the Industrial Estates at Meerut Road, Kavi Nagar Industrial Estate and Loni Road Industrial estate. The number of industrial workers in Ghaziabad was 5876 in 1961, which increased to 30338 in 1981 and 54558 in 1991. The number of industrial units was 124 in 2000 which declined further to 109 in 2003. Similarly, number of small and medium industrial units was 13720 in 2000 wherein 71245 workers were engaged and increased to 15848 in 2002 with 87832 workers. The main reasons behind increase in small and medium industrial units due to recent shifting of polluting industries from NCT Delhi towards Ghaziabad.

9. Conclusions

Consequently, the increasing pace of urban sprawl has resulted into the large scale agriculturally productive land conversion into the concrete jungle or built-up area. The agricultural land resource is under stress due to the increasing pressure of population. This has resulted into widespread destruction of the fertile agricultural land and natural vegetation as well as the shrinkage of 'green cover' in the study area. However, for sustainable development the authorities need tools to monitor how the land is currently being used, assess future demand, and take steps to assure adequacy of land for future development. In other words, the development authorities need to know urban sprawl phenomenon and in which way it is likely to develop in the near future. So, there is a need for better planning of infrastructure and amenities for urban development. Over the periods, there has been a continuous process of urban sprawl in the rural-urban fringe due to the liberalization of economy, development plans and policies of the State Govt. and Central Govt. of India. There have been establishments of number of national and multi-national companies which have resulted into the continuous urban sprawl in the Ghaziabad City Region. On the other hand, it has resulted into the rise of land values not only in Delhi but also in the Ghaziabad City region.

10. Recommendations

It is noteworthy to mention that in the UP sub-region, the pace of urban sprawl was much faster due to the govt. development plans and policies than in the other participating states of the NCR Region. Moreover, the present research has made an attempt to help local, regional and state level land use planners and policy makers to better understand and address the issues attributed to urban sprawl. Therefore, the urban expansions are to be planned over the non-fertile agricultural land for sustainable urban and environment development which are the most important concerns for the new urban sprawling areas in the UP sub-region of the NCR at the threshold of the 21st Century.

The city has its own problems and often comes under the shadow of Delhi metropolis and unable to realize its own potential. Some of the major planning and developmental problems of Ghaziabad City are as firstly, the separate identity of Ghaziabad is somewhat diluted under the shadow of NCT Delhi thereby the city has not been able to come up as self-induced bustling urban center in NCR; secondly, the economic base with declining industries and new economic activities coming-up in unplanned manner has disturbed the physical development of the city; thirdly, the unauthorized colonization on agricultural land has resulted in unauthorized and uncontrolled development wherein there is an absence of basic infrastructure facilities on the one hand and it gives rise to numerous problems for planned development like regularization of colonies and augmentation of infrastructure services / facilities on the other. Furthermore, the lack of strict enforcement of Building Bye Laws and Master Plan provisions has also been responsible for haphazard development; fourthly, the prevalence of non-conforming land use mainly in terms of offices, schools, hospitals, shops located in residential premises;

Fifthly, the excessive congestion on major arterial road for example Ambedkar Road and GT Road. In addition to this, due to absence of planned parking spaces, on-road parking of trucks, buses and other vehicles has created serious traffic and transportation problems. Like-wise, the encroachment by rehris, kiosks and thelas have further worsened the intra-traffic movement in the city; sixthly, the absence of proper solid waste management has caused dumping of wastes into pits thereby resulting in pollution of land, air and water resources; seventhly, the uneven distribution of water supply, absence of sewage system and drainage system has added to the woes of city infrastructure; eighthly, the absence of common Effluent Treatment Plan in the industrial areas of the city has led to mixing of chemical effluents, which

has ultimately polluted the Hindon River and ground water resources; finally, the indiscriminate exploitation of ground water has led to drastic fall in the level of ground water.

References

Bruegmann R (2006) Sprawl: A Compact History. *Annals of the Association of American Geographers*, Vol. 96, No. 3, pp. 666-667.

Cho J (2005) Urban Planning and Urban Sprawl in Korea. *Urban Policy and Research*, Vol. 23, No. 2, pp. 203-218.

Couch C, Jay K, Henning N, Dieter R (2005) Decline and sprawl: an evolving type of urban development - observed in Liverpool and Leipzig, *European Planning Studies*, Vol. 13, No. 1, pp. 117-136.

Epstein J, Payne K, Kramer E (2002) Techniques for mapping sub-urban sprawl, *Photogrammetric Engineering & Remote Sensing*, Vol. 63, No. 9, pp. 913-918.

Haynes K E, Phillips F Y, Mohrfield JW (1980) The Entropy: Some Roots of Ambiguity, *Socio-Economic Planning Structure*, Vol. 14, pp. 137-145.

Haynes K E, Storeberk V (1978) The Entropy Paradox and the Distribution of Urban Population, *Socio-Economic Planning Structure*, Vol. 13, pp. 1-16.

Jat, M K, Garg P K and Khare D (2008) Modelling of urban growth using spatial analysis techniques: a case study of Ajmer city (India), *International Journal of Remote Sensing*, Vol. 29, No. 2, pp. 543-567.

Joshi P.K. et. al. (2006) Entropy as an indicator of fragmented landscape, *Current Science*, Vol. 91, No. 3, pp. 87-99.

Lo C.P. and Albert K.W. Yeung (2005) *Concepts and Techniques of Geographic Information System*, New Delhi, Prentice-Hall of India, Pvt. Ltd.

Rodriguez-Buchiller A (2004) *Expert Systems and Geographic Information System for Impact Assessment*, London & New York, Talyor & Francis.

Shannon Calude (1948) *A Mathematical Theory of Communication*, Bell System Technical Journal, Vol. 27, pp. 379-423 and 623-625.

Siedentop S and S Fina (2010) Monitoring urban sprawl in Germany: Towards a GIS-based measurement and assessment approach, *Journal of Land Use Science*, Vol. 5, No. 2, pp. 73-104.

Sultana Selima and Joe Weber (2007) Journey-to-Work Patterns in the Age of Sprawl: Evidence from Two Midsize Southern Metropolitan Areas, *The Professional Geographer*, Vol. 59, No. 2, pp. 193-208.

Wolman, Harold, George Galster, Royce Hanson, Michael Ratcliffe, Kimberly Furdell and Andrea Sarzynski (2005) The Fundamental Challenge in Measuring Sprawl: Which Land Should Be Considered?, *The Professional Geographer*, Vol. 57, No. 1, pp. 94-105.

Wood, John (2007) Synergy city; planning for a high density, super-symbiotic society, *Landscape and Urban Planning Cities and Sustainability*, Vol. 83, pp. 77-83.

Xia Li and Anthony Gar-On Yeh (2004) Analyzing spatial restructuring of land use patterns in a fast growing region using remote sensing and GIS, *Landscape and Urban Planning*, Vol. 69, pp. 335–354.

Yang, X. and C P Lo (2003) Modelling urban growth and landscape changes in the Atlanta metropolitan area, *International Journal of Geographic Information Science*, Vol. 17, No. 5, pp. 463-488.

Yeh, A.G.O. and X. Li (2001) Measurement and monitoring of urban sprawl in a rapidly growing region using entropy, *Photogrammetric Engineering and Remote Sensing*, Vol. 67, No. 1, pp. 83-98.

Zhang, Yan, Zhifeng Yang and Wei Li (2006) Analyses of urban ecosystem based on information entropy, *Ecological Modelling*, Vol. 197, No. 1, pp. 320-342.