GEOSPATIAL INFORMATION INTEGRATION, MODELING AND DIGITAL MAPPING OF URBAN SPRAWL: A STUDY OF NOIDA CITY, INDIA

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Abstract

The urban sprawl is mainly occurring over the expenses of productive agricultural land during the recent past. There is an increase in land value due to urban sprawl which has made agriculture less profitable, and the cultivable land is kept fallow prior to merging it with the urban areas. The population is continuously growing and swelling due to in-migration from the countryside's. For instance, the New Okhla Industrial Development Area (NOIDA) is one of the well planned, spacious and greenest cities of the country, India. Due to the expansion of economic activities by the multinational companies and transport network, there has been occurred the fast pace of urban sprawl.

The present study has inquired to answers a number of research questions in detail which are as what are the spatial patterns of land use land cover during 2001 to 2006? How is the growth of spatial urban sprawl impacted to the rural-urban fringe of NOIDA city? Which are the suitable strategies for sustainable urban development for one of the fast growing NOIDA city? However, the present study has considered the urban sprawl as a challenging task therefore, seeks to bring out the noteworthy impacting factors such as the infrastructure and amenities development on the process of urban sprawl in the adjoining areas of NOIDA City.

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. In view of this, 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. The GIS/RS technologies and Entropy Model have been applied to scrutinize the spatio-temporal land use land cover changes and the process of urban sprawl in the adjoining areas of NOIDA city.

There has been a continuous process of urban sprawl in the rural-urban fringe of NOIDA City due to the liberalization of economy, development plans and policies of the state govt. Uttar Pradesh and Central Govt. of India. It has resulted into the establishments of number of national and multinational companies, since the inception of NOIDA as an industrial city. So, it is noteworthy to mention that there has been

occurred a continuous sprawl of urban areas adjacent to the NOIDA City during 1976 to 2006. The Greater NOIDA was created in the recent past as an extension of NOIDA, where the pace of urban sprawl was much faster due to the govt. development plans and policies. 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 adjoining to the NOIDA City at the threshold of the 21st Century.

Introduction

Urbanization is the process of transformation of rural areas into urban areas due to in-migration, industrialization and economic development. The processes of urbanization and economic development are interrelated to each other (Breese, 1978). There are widespread concerns about the understanding and curbing of urban sprawl, which has been cited for its negative impacts on natural resources, economic development and quality of life of the society. There is not, however, a universally accepted definition of urban sprawl. It has been described using quantitative measures, qualitative terms, attitudinal explanations, and landscape patterns. Hence, an attempt has been made to help local, regional and state level land use planners to better understand and address the issues attributed to urban sprawl at large. Currently, debates over urban form have generally focused on the contrast between the "sprawl" often seen as typical of the United States and "compact" urban forms found in parts of Europe. Although these debates are presumed to have implications for developing worlds as well, systematic comparison of urban forms between developed and developing countries has been lacking.

There are studies base on land use land cover derived from remotely sensed satellite imagery, determines the geographic extents, patterns, and classes of urban growth over time (Ward et. al., 2000). Land Use classification in context to the broad categories help to assess the urban settlements, open spaces and unbuilt-up land parcels, recreational and forested areas etc. (Lo and Yang, 2002; Myeong et. al., 2006; Thanapura et. al., 2007; Tucker, 1979 and 1986; Joshi et. al., 2006b; Voorde et. al., 2007; Walker and Briggs, 2007). The rapid urbanization has been described mainly from a socio-economic point of view (McGee, 1991 and 1995). The extent of urbanization and its growth drives the change in land use land cover patterns. Land use and land cover changes may have adverse impacts on environment of the area. So, as a result, increasing research interest is being directed to the mapping and monitoring of urban sprawl using GIS and remote sensing techniques (Epstein et. al., 2002).

Remote sensing is cost effective technology and is increasingly being used for the impact analysis of urban sprawl (Sudhira et. al., 2004; Yang and Liu, 2005; Haack and Rafter, 2006). During the last about three decades, extensive research efforts have been made for urban change detection using remote sensing satellite imagery (Gomarasca et. al., 1993; Green et. al., 1994; Yeh and Li, 2001; Yang and Lo, 2003; Haack and Rafter,

2006). Although the debate over whether a "sprawling" urban form is best for the quality of life has not been fully settled (Dear, 2001). 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 (Harvey and Clark, 1971).

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 urban sprawl. 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. For instance, the NOIDA is losing its share of greens cover.

Study Objectives

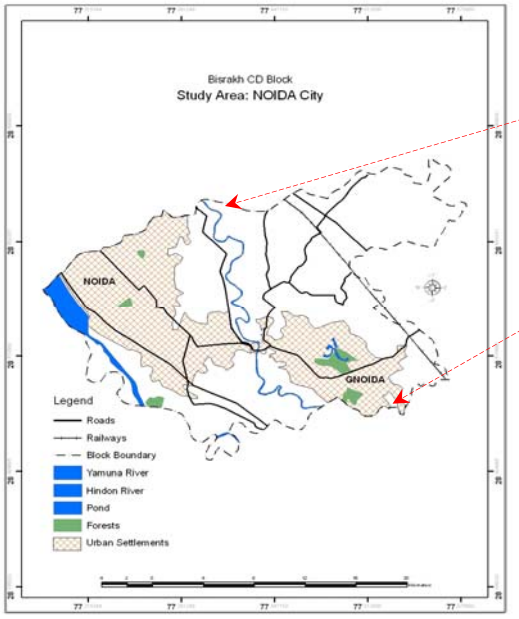
The main objectives of the present study are mentioned as follows:

i. to detect the spatial patterns of land use land cover changes over the periods;
ii. to examine the impacts of population growth patterns and trends on urban sprawl;
iii. to explore suitable strategies for sustainable urban development.

Study Area

The NOIDA City lies between 28^{o}18'12.54" N to 28^{o}22'36.72" N latitudes and 77^{o}10'28.97" E to 77^{o} 15'19.83" E longitudes as is also clearly evidenced by the Figure 1. The city is located in the Bisrakh Census Development Block. The geographical extents of the Bisrakh CD Block lays in between 28^{o}26'1.65" N to 28^{o}40'4.64" N latitudes and 77^{o}16'58.88" E to 77^{o}34'57.51" E longitudes as is revealed by the Figure 1. NOIDA is situated 5 kms. away from Delhi, the capital of India, in the Trans-Yamuna area. On the other hand, the Central Business District (CBD) of NOIDA laid only 15 kms. from Connaught Place, the city centre of Delhi. So, the NOIDA is situated in the north of close to Delhi. It is bounded on the west and south-west by the River Yamuna, on the north and north-west by Delhi and Ghaziabad and on the north-east, east and south-east by the River Hindon. NOIDA falls under the catchments area of the Yamuna River and is formed by deposition of the newer river alluvium known as the khadar. Besides this, recently there was an extension of NOIDA city area in form of the Greater NOIDA (Greater New Okhla Industrial Development Area). The Greater NOIDA comprises by the twin towns of Surajpur and Kasna. The Greater NOIDA is situated between 28o17'30.74" N to 28o20'14.40" N latitudes and 77^{o}15'18.94" E to 77^{o}19'21.77" E longitudes adjacent to the national capital, at a distance of 35 kms. from

Connaught Place (Central Business District), New Delhi. It is bounded by NH-24 by-pass in the North, Grand Trunk (GT) Road in the East, Hindon River in the West as is clearly evidenced by the Figure 1a and 1b.



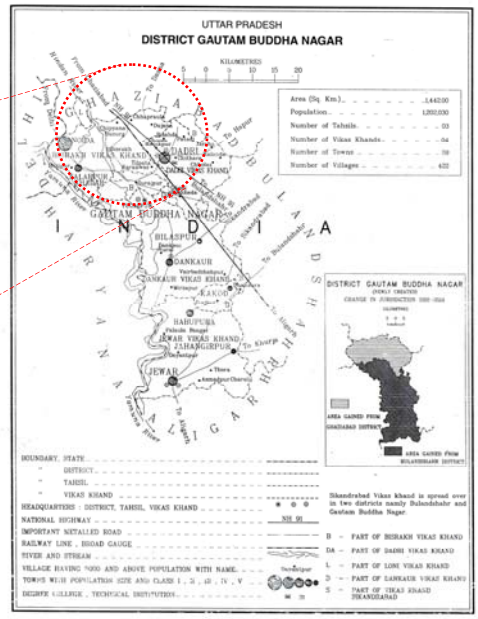


Figure 1a Figure 1b

Figure 1. Geographical Location of Study Area – NOIDA City

Source: Census of India (2007) *Uttar Pradesh – Administrative Atlas*, Vol.-I, Directorate of Census Operations, Uttar Pradesh.

Database Used

The present study has been supported by the primary data generated from the field as well as the ancillary and collateral data collected from the different sources to achieve the above specified objectives of the study. The large scale 1: 25,000 and 1: 50,000 topographic sheets have been collected from the Survey of India (SOI), Dehradun, Uttranchal. Based on the empirical research and personal observations for the NOIDA city, a field survey questionnaire was prepared to generate the primary information concerning to the impacting factors of urban sprawl from the field for the study area. The Primary Field Survey based on the stratified random sampling method of the 25 households from the NOIDA and Greater NOIDA and their rural-urban fringe areas has been conducted during 29th March to 2nd April, 2008. The field checks (ground truth of the training sites) have also been conducted during the primary field survey of the

sample selected sites for the land use land cover classification and the urban sprawl sites. The satellites imagery for the latest two time period 2001 and 2006 have been procured for the present study from the National Data Centre (NDC), National Remote Sensing Agency (NRSA), Hyderabad by the Indian Institute of Remote Sensing (IIRS), Dehradun.

The study area NOIDA is covered by the Indian Remote Sensing (IRS) satellite under the path number 96 and row number 51. The satellite remote sensing data of IRS-1C and IRS-P6 for LISS-III (linear imaging self scanning) sensor which is providing multi-spectral imagery with 23.5-m spatial resolution (NRSA, 1998) have been used in the present study. In addition to this, the data have also been collected from the Census of India, Primary Census Abstract and Village and Town Directory, Gautam Budha Nagar District for 1991 and 2001. The Master Plans of NOIDA for different periods were collected from the Chief Architect, Administrative Office, New Okhla Industrial Development Area authority, Sector – 6A, Uttar Pradesh.

Methodology

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 GIS and remote sensing techniques (Epstein et. al., 2002). Remote sensing is cost effective technology and is increasingly being used for the impact analysis of urban sprawl (Sudhira et. al., 2004; Yang and Liu, 2005; Haack and Rafter, 2006) on the land use land cover changes. During the past about three decades, extensive research efforts have been made for urban change detection using remote sensing satellite imagery (Gomarasca et. al., 1993; Green et. al., 1994; Yeh and Li, 2001; Yang and Lo, 2003; Haack and Rafter, 2006). All these studies have been supported through either an image-to-image comparison or a post-classification comparison for better management and monitoring of urban sprawl.

GIS along with statistical techniques and remote sensing have been used in many urban sprawl studies (Rodriguez-Buchiller, 2004; Lo, 2001; Lo and Yang, 2002; Weng, 2001; Sui, 1998; Wilson, 1998; Wood, 2007, Wu et. al., 2006; Xia and Yeh, 2004; Yeh and Li, 1998; Cheng and Masser, 2003; Sudhira et. al., 2004). The integration of GIS and database management systems has helped in quantifying, monitoring, modelling, and subsequently predicting the urban sprawl. Shannon's entropy has been used in number of studies to quantify urban forms, such as built-up area in terms of spatial phenomenon (Yeh and Li, 2001; Sudhira et. al., 2004; Joshi et. al., 2006a). Shannon's entropy is based on the concept of information theory. It is a measure of uncertainty about the realisation of a random variable, like urban sprawl taking place in the form of built-up land patches in newly developed areas. Shannon's entropy is used to measure the degree of spatial concentration or dispersion of population variable (Xi) among n spatial units or zones. Entropy is also used to indicate the degree of urban sprawl by examining

whether land development is dispersed or compact (Sudhira et. al., 2004 and Joshi et. al., 2006a). Large value of Shannon's entropy indicates dispersion of considered random variable (population density) which indicates occurrence of urban sprawl.

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 and Storeberk, 1978; Joshi et. al., 2006a; Yeh and Li, 2001; Zhang et. al., 2006; Lo and Yeung, 2005). So, finally it is defined and explained as follows:

$$E = -\sum_{i}^{n} pi \log (pi)/ \log (n) \qquad = \sum_{i}^{n} pi \log (1/pi)/ \log (n)$$

So, the research methodology applied in the present research is presented in the Figure 2 schematically through the workflow diagram given below.

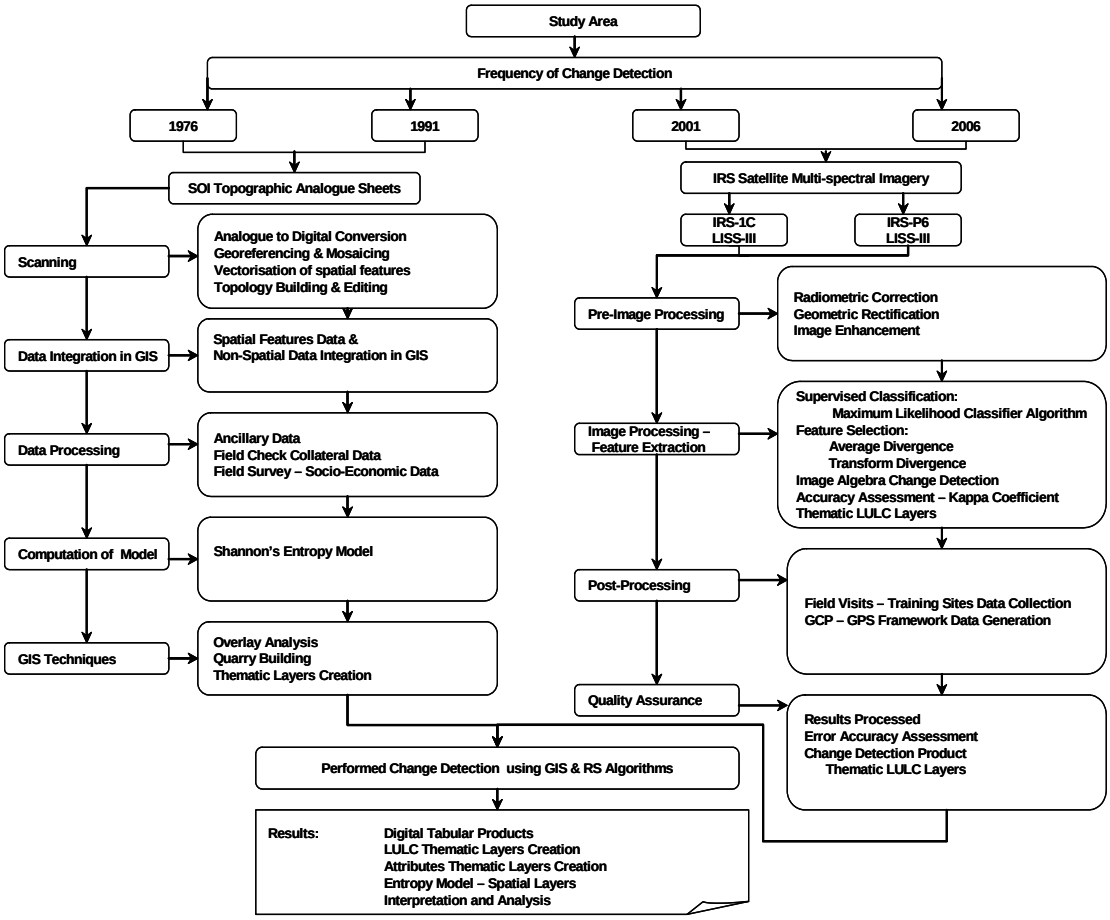


Figure 2. Workflow Diagram of Methodology

Results and Discussions

Spatio-Temporal Patterns of Land Use Land Cover

The land use land cover classification (LULC) has been worked out using multi-spectral satellite imagery with the help of supervised classification algorithm for the period 2001 and 2006. The imagery was classified into six thematic classes as the compact settlement, sparse settlement, open space (settlement), green cover, agricultural land and River Yamuna (water). The pixel-based land use land cover classification computed for both the periods is presented in the Table 1.

Class Name	2001		2006	
	Area (in Sq. Kms.)	% Area to Total	Area (in Sq. Kms.)	% Area to Total
Compact Settlement	423.00	12.00	470.00	13.33
Sparse Settlement	587.50	16.67	712.00	20.20
Open Space (Settlement)	188.00	5.33	202.00	5.73
Green Cover Vegetation	211.50	6.00	220.00	6.24
Scattered Vegetation	47.00	1.33	39.00	1.11
Agricultural Land	1997.50	56.67	1812.00	51.40
Yamuna River	70.50	2.00	70.00	1.99
Total	**3525.00**	**100.00**	**3525.00**	**100.00**

Table 1. Pixel-Based LULC Classification – 2001 & 2006

Source: Above table is computed and based on the IRS Satellite LISS Imagery.

It reveals that the agricultural land comprises the largest proportion of 56.67 per cent of the total geographical area. On the other hand, both the compact and sparse settlements together accounted for 28.67 per cent. In addition to this, the open space (settlement) which has not yet been developed is accounted for 5.33 per cent. Besides this, a small proportion of 6.00 per cent is accounted by the green cover vegetation. The green covered areas are the golf course, botanical gardens, protected and reserved forests areas e.g. the Gulistan reserved forests etc. And a small proportion of 1.33 per cent is the tree vegetation which is scattered all over the area. The water bodies as the River Yamuna and Hindon and the ponds together comprises about 2 per cent of the total geographical area. Besides this, almost the similar kinds of land use land cover patterns were observed with slight changes in during the period 2006 as is evidenced by the Table 1.

Impacts of Population Growth on Land Use

NOIDA was established by acquiring the agricultural land and rural settlements which had only few thousand of inhabitants in 1976. In 1981 there were around 35,541 persons living in the NOIDA City. By 1991 NOIDA had shaped into a new class one town or city with a total population exceeding 1,46,514 persons and it was declared a census town by the Census of India. Later on, the population was increased to 3,05,058 persons in 2001. So, there has been an increasing concentration of population in the NOIDA city since its conception in 1976 onwards as is revealed by the Table 2.

Year	Population	Area (in sq. kms.)	Density (per sq. kms.)	Growth Rate (%)
1981	35541	30.43	1168	-
1991	146514	90.43	1620	75.74
2001	305058	90.43	3373	51.97
2011	700664	90.43	7748	56.46
2021	915249	90.43	10121	23.45

Table 2. Trends of Population Growth in NOIDA City

Source: NCR (1988) National Capital Region, National Capital Region Planning Board, Ministry of Urban Development, Govt. of India, New Delhi; and Census of India 1991 & 2001, Gautam Budha Nagar District, Uttar Pradesh.

On the other hand, following such trends of population increase, the National Capital Region (NCR) Planning Board as well as Census of India has projected that its population is to be more than doubled in 2011 and it would further increased to 9,15,249 persons in 2021. It other words, the NOIDA will be a million plus city in 2021 as is revealed by the projected population figures given in the Table 2.

Spatial Patterns of Urban Sprawl

The NOIDA city region has grown due to the large establishment of the national and multinational companies and the liberal govt. plans and policies for development. The spatial patterns of urban sprawl are clearly evidenced by visual interpretation of the Figures 3a. In other words, by analysis of the Figures 3a there was observed an expansion of the urban area over the period during 1976 to 2006. The urban sprawl consists of three basic forms as the low-density sprawl, ribbon sprawl and leap-frog development sprawl (Harvey and Clark, 1971). As a result, the over all scenario of the process of urban sprawl is presented by the Figure 3a. In other words, the spatio-temporal patterns of urban sprawl in the adjacent areas of NOIDA City are presented by the Figures 3. It is clearly revealed that 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., Uttar Pradesh and Central Govt. of India during 1976 to 2006.

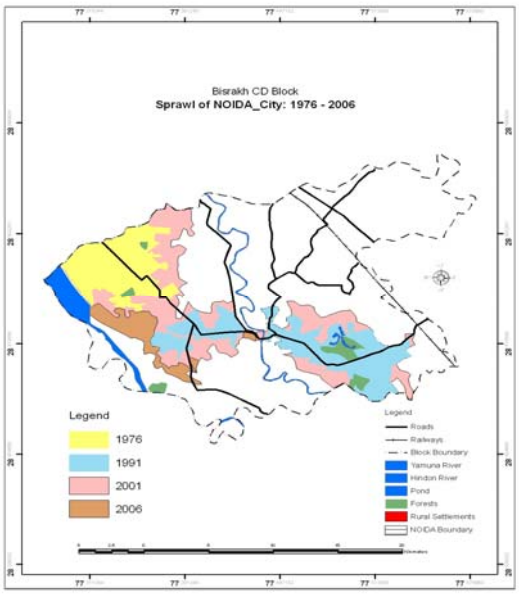


Figure 3a

Figure 3b

Figure 3: Process of Urban Sprawl during 1976 to 2006

A number of national and multinational companies have been continuously grown and prospered over the periods. The present scenario of infrastructure development for example the road network is clearly evidenced by the photos taken during the field survey over the NOIDA Toll Bridge and the Greater NOIDA Expressway connecting to NOIDA and Delhi as presented by the Figure 3b.

Trends of Urban Sprawl

The trends of urban sprawl in terms of built-up area expansion for the NOIDA City in the last 30 years period since 1976 to 2006 are presented in the Table 3. It is clearly revealed that there has been increased in an area of the city. For instance, the NOIDA city was spreading over an area of about 34.10 sq. kms. in 1976. It is increased to 46.80 sq. kms. in 1991 and almost more than doubled to 79.20 sq. kms. in 2001. Furthermore, it was increased to 92.30 sq. kms. in 2006. Besides this, the Greater NOIDA as a part of the city was spreading over an area of 34.20 sq. kms. in 1991. It was increased to 49.60 sq. kms. in 2001 and further increased to 52.45 sq. kms. in 2006. So, the Greater

NOIDA pace of development was much faster than NOIDA due to the govt. development plans and policies.

Year	Sources	Area (in sq. kms.)			% Growth Rate
		NOIDA	GNOIDA	Total	
1976	SOI	34.10	00.00	34.10	-
1991	SOI	46.80	34.20	81.00	57.90
2001	IRS	79.20	49.60	128.80	37.11
2006	IRS	92.30	52.45	144.75	11.02

Table 3. Trends of Urban Growth of NOIDA City: 1976 – 2006

Source: Above table is computed and based on the SOI topographic sheets and IRS satellite imagery.

There was a growth rate of 57.90 per cent of urban area during 1976 to 1991 as is revealed by the Table 3. Later on, it was decreased to 37.11 per cent during 1991 to 2001 and around 11.02 per cent during 2001 to 2006. The main reason for such decline might be due to the more number of industrial cities development such as the Faridabad, Ballabgarh, etc. in the vicinity of NOIDA city. The Multinational companies are attracted towards those states where exist a political stability; so that there will be better economic growth and development of their industries under the stable political umbrella.

Conclusions and Recommendations

It is noteworthy to mention that there has been occurred a continuous sprawl of urban area adjacent to the NOIDA City over the last 30 years during 1976 to 2006. The Greater NOIDA was created as an extension where the pace of urban sprawl was much faster than NOIDA due to the govt. development plans and policies. So, the urban development and expansion are to be planned in the non-fertile agricultural land in order to have sustainable urban and environment development. There is a growing need for the spatial distribution of population which can reduce the population pressure in order to minimize and control the further deterioration of the urban environment and quality of life in the adjoining villages of the NOIDA city. The original inhabitants of the area have been denied to avail the basic socio-economic amenities. This has ultimately resulted into the spurious urban development as is observed in the urban villages of NOIDA. So, the development should take place without compromising to the deterioration of productive agricultural land resources and to the destruction of fragile natural environment and valuable resources. Thus, 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 sustainable urban and environment development

are the most important concerns for the planners and policy makers for the NOIDA City at the threshold of the 21st Century.

It is recommended that the establishment of NOIDA city on the fertile agricultural land is not seems to be economically viable and environmentally sustainable; because the growing urban expansion further swallows the productive agricultural land of the adjoining villages. The process of urban sprawl is engulfing to the rural villages as has been evidenced by the results of the primary field survey. There are widespread spurious developments causing to the number of socio-economic problems. This has ultimately resulted into the deterioration of quality of life in urban areas as is observed in the urban villages of NOIDA. Consequently, the above mentioned recommendations must be taken into consideration in the development planning processes for sustainable urban development. The development should take place without compromising to the deterioration of productive agricultural land resources and to the destruction of fragile natural environment.

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