Applied GIS

ISSN: 1832-5505
Vol-1 Issue-03 JULY 2013

Analyzing Land-Use Change using GIS, GPS, and High-Resolution Satellite Data

Virendra Kumar[1], Kamlesh Bhalvai[2], Bhawna[3], Dhananjay[4] & V. Rajamani [5]

Abstract

Using multi-date data, satellite remote sensing technology combined with Geographical Information Systems (GIS) is a crucial tool for tracking and analyzing urban sprawl and land use changes on the city's outskirts. Using the Survey of India topographical map from 1972 and satellite images from 2008–2013, this research aims to track and analyze Meerut city's urban growth and land change. According to the SOI topographical map, the city's urban built-up area was 3,523.0 hectare in 1972. The urban built-up area of the city is estimated to be 3752.3 hectares based on analysis of Quickbird images from 2008 and IKONOS data from 2013. In the 36 years between 1972 and 2008, this increased to 3290 hectares, and in the years between 2008 and 2013, an additional 1283 hectares were converted from agricultural land, orchard/plantation, and water bodies to built-up urban land, according to GIS calculations. Urbanization has resulted in the destruction of valuable farmland, plantation, and wetlands. Urban planners and decision makers will benefit greatly from the digital database created for the urban spatial expansion and land transformation of Meerut city, Uttar Pradesh employing temporal data in the GIS domain for the purpose of managing the recommended landuse plans.

Keywords: *Urbanization, Land Transformation, Urban growth, IKONOS Satellite, GIS Data, GISTechniques.*

1. Introduction

Land use map is one of the most important thematic maps, as it provides the planners with present status of land use and pattern of its change in the urban environment is very fast. Up to date land use map is required for monitoring the urban and rural environment. The preparation of land use plan requires the drawing-up and inventory

ISSN: 1832-5505
Vol-1 Issue-03 JULY 2013

of all parcels of land-owned publicly or privately and developed or undeveloped and classifying the parcels of developed land by uses to which they are put. Land use data, like any other data required in urban and regional planning, should be accurate, up-to-date, standardized and comparable. A standardized system of land use classifications has many advantages to offer. This is why satellite remote sensing is widely used for land use/ land cover mapping. Over the years satellites based remote sensing data have been successfully utilized for urban settlement and infrastructure mapping. The knowledge of land use/land cover is important for proper planning and management activities and it is considered an essential element for monitoring and modeling for understanding the earth as a system. For effective landscape planning it is important to understand landform transformation processes and patterns in areas of mixed urban-rural land use on the periphery of cities (Imdad and Janki, 2007). Urban and regional planners require nearly continuous acquisition of data to formulate governmental policies. These policies and programs might range from the social economics and cultural domain to the context of environmental & natural resources planning. The role of planning agencies is becoming increasingly more complex & is extending to a wider range of activities. Consequently there is an increased need for these agencies to have timely accurate & cost effectively data of various forms. Here we will discuss the utility of digital image interpretation in area estimation of detailed urban land use /land cover categories in Meerut city & its surroundings, which is spread over an area of 269 hectare. i.e. residential & commercial, industrial, godowns, cantonment, offices-state/central govt., semi-govt., state/ central govt. institutes- universities technical/colleges and parking spaces, new construction sites and new settlement area etc. Both methods i.e. visual and digital interpretation can be used for identification and mapping of urban settlement and infrastructure using high resolution satellite data. Uttar Pradesh is the most populous state in the country which has 724 cities as per census of India, 2011, i.e Nagar Panchayat/ Nagarpalika Parishad/ municipal corporations. Population growth rate in all such cities are high & a number of colonies have been developed by development authorities and those colonies are being taken up by Nagar Panchayat/ Nagarpalika parishad/ Nagar Nigam, in this connection to assess and monitor actual land use/ area in different land use/ land cover categories and change, transformation, trend of changes for Meerut city & its surroundings, An endeavor has been made to prepare a digital database in GIS domain for Meerut city of Uttar Pradesh, would be useful to Meerut Development Authority for proper land use planning & management.

2. Study Area

Meerut city is located in western part of Uttar Pradesh state. It lies between latitude $28^0 32'$ to $29^0 18'$ N and longitude $77^0 07'$ to $78^0 14'$ E.

Figure 1: Map of study area.

ISSN: 1832-5505
Vol-1 Issue-03 JULY 2013

Meerut city and surroundings is spread over an area of 269 hectare. The town is divided into 70 wards as per Meerut Nagar Nigam.

3. **Objectives**

4. The purpose of this research is to use high-resolution remote sensing data and GIS methods to examine the expansion of urban areas and the alteration of land in the outskirts of Meerut City.

5. **Material and Data Used**

The following dataset has been used to meet out the set objectives

- Survey of India topographical sheet No.53G/4 & 8, 12, 16, 53H/9 & 13 of Meerut city & its environs on 1:25,000/ 1:50,000 scales surveyed between 1966-67 & 1972.
- Guide map of Meerut city on 1:20,000 scale.
- City/Ward boundary map of Meerut city.
- QuickBird Satellite data
- IKONOS Satellite 1m resolution data.
- Ground truth data collected from study area.
- Census of 2011.

6. **Methodology**

To meet the set objectives of the study, The Meerut city settlement and environs is mapped in this project using remote sensing & Geographical information System (GIS) and Global Positioning System (GPS). This project work is carried out to prepare detailed landuse/landcover, it's changes and Land transformation map of the study area. City/Ward boundary map of the area collected from Department of census, Lucknow has been geo-referenced in conjunction with Quick bird satellite data. After geo-referencing of high resolution data using digital image processing software (Erdas Imagine), all available/ collected maps are corrected and referenced to real earth coordinates. Using Arc-GIS software, Quick bird 60 cm. resolution, and IKONOS 1m resolution to know change data and area names and important locations, we interpreted the road /transport-network/ city major /minor roads /streets, railway line, water bodies, drainage /nala etc. as a linear, polygon feature. Land use categories in the research region were defined and mapped using high resolution data after the base map was prepared. The corrected information has also been double-checked and confirmed in the field for use in a survey. The city center and its environs are mapped according to their various land use and land cover types, including residential, commercial, industrial, cantonment, open spaces-parks, fallow land, central and state government offices, semi-government institutions, retail shopping complexes, and places of utilities. In ground surveys, printed maps with satellite imagery overlays have been utilized to compile field data. With the use of a Global Positioning System (GPS) mobile mapper, a thorough ground truth verification/field survey was conducted to determine the precise position of several types of urban land use/land cover categories, together with their real extent and intended usage. In a geographic information system (GIS), properties have been coded for each polygon. The land use map is completed with the inclusion of all required revisions after a GPS field survey of the study region. Final map at 1:16,000 scale was prepared by converting GPS field data into tabular form and then matching and linking it with a digitized map in the GIS domain.Statistical Method Applied

The statistical methods applied in the present study area are mentioned below:

ISSN: 1832-5505
Vol-1 Issue-03 JULY 2013

The comparative study on land use / land cover assist in identifying the trend and percentage of changes between 2008 to 2013 in achieving this the first task was to develop the tables showing the area in sq. km and percentage of change between 2008 to 2013 measured in given each and every land use/ land cover categories. The change of percentage is to determine the trend of change can be calculated by dividing observed changes by the sum of changes.

1. Percentage Area= $\frac{Area\ of\ category\ in\ sqkm}{Total\ Area\ in\ \text{Hectare}}$ ×100
2. Overall change in Category (2008 to 2013) = Change in Category of 2013 Change in Category 2008.
3. Percentage Change (Trend) = $\frac{Observed\ c\ ange}{Sum\ of\ c\ anges} \times 100$
4. Land Consumption Rate=A/P
5. Land Absorption Coefficient= $\frac{A_2 - A_1}{P_2 - P_1}$

Where,

A = Areal extent in hectares and,
P = Population figure
A_1= Areal extent in hectares for early year
A_2= Areal extent in hectares for later year
P_1= Population figure for early year
P_2= Population figure for later year

By applying the above mentioned formulas the various tables for different time periods was prepared to know the percentage and trend of changes which will be discussed in results.

$n = r/100 * P_0$

$P_n = P_0 + (n+1)$

Where,

P_n= estimated population (2023)
P_0= base year population (2013)
r = growth rate (2%)
r = annual population growth
t= number of year projecting

The future expansion for year 2023 was forecasted by correlating the 2013 i.e current population (2011)of Meerut city with help of growth per annum.

7. Results and Discussion

The results and discussions related to urban spatial growth, land use land cover change and land transformation in the present study are explained under the following sub heads.

Urban Spatial Growth, Rate and Direction

Cities in India are getting overcrowded and expanding uncontrollably due to regular migrations. In the process, these urban centers are affected by both natural and human activities in the absence of any planning policy. The physical extension of the cities is engulfing the productive agricultural lands for urban areas. This type of haphazard growth of urban built up land over a period of time could be explained in terms of waves of urban growth (both physical and human). The quantum and direction of waves depends upon various centripetal and centrifugal forces working from city and adjoining area.

It is observed that the outward expansion of urban areas poses a threat to the land use pattern. The rapid pace of urbanization combined with the explosive population growth has made urban and its surrounding areas dynamic. As the limited land of the city gets used, the ever increasing demand creates pressure on surrounding fertile vulnerable lands in and around the city causing faster rate of land conversion from non-urban to urban use. This results in uncontrolled expansion of city as well as problem of providing basic public services and facilities.

Monitoring rate and direction of urban sprawl is necessary for urban planning. Estimation as well as updating the data of any region through conventional methods has severe limitations. Satellite remote

ISSN: 1832-5505
Vol-1 Issue-03 JULY 2013

synoptic coverage makes a reliable source of information. This type of data on a particular area helps in understanding the physical processes and changes in the land use and land cover in space and time. Mapping urban sprawl provides a "picture" of where this type of growth is occurring, and helps to identify the environmental and natural resources threatened by such sprawls, and suggests the likely future directions and patterns of sprawling growth. Analyzing the sprawl over a period of time will help in understanding the nature and growth of this phenomenon. Ultimately the power to manage a sprawl resides with local municipal governments that vary considerably in terms of will and ability to address sprawl issues. The growth of urban area over a period was determined by computing the area of all the settlements from toposheet of 1972 and comparing it with the area obtained from the interpreted satellite imagery for the built up area. Since the sprawl is characterized by an increase in the built-up area along the urban and rural fringe, this attribute gives considerable information for understanding the behaviour of such sprawls. This is also influenced by parameters such as population density and population growth rate etc.

Table 1: Urban Spatial Land Growth Rate per Annum.

YEARS	DATA	AREA	SPRAWL GROWTH	GROWTH %	GROWTH / ANNUM
1972	SOI Top sheet	3752.3	-	-	-
2008	Quick Bird Data	7041.8	3289.5	46.71	93.98
2013	IKONOS Data	8331.1	1289.3	15.47	257

In 1972 the city grew in concentric manner, but after 1972, IKONOS satellite's imageries of 2008, and 2013 has also been used to create vector layer to monitor the growth of city by overlaying of these vector layers of three time period data, the area for 1972, 2008 and 2013 has been calculated in GIS (Table-1 & Fig-2), which is 3752.3 Hectare in 1972, 2928 hectares in 2008, 7041.8 and in 2013, it is 83331.1. Spatial growth , per annum growth and percentage of growth has also been calculated which is 1289 (15.14%) and 1193 Hectare per annum between the years of 1970-71 to 2006 at an interval of 35 years, similarly, Spatial growth , per annum growth and percentage of growth has also been calculated between the period of 2008 to 2013 is 1289.3 Hectare the city has grown mainly towards north direction and marginally towards south-west and south-east, with most of the prime agricultural land and vegetation area getting constructed into built up land.

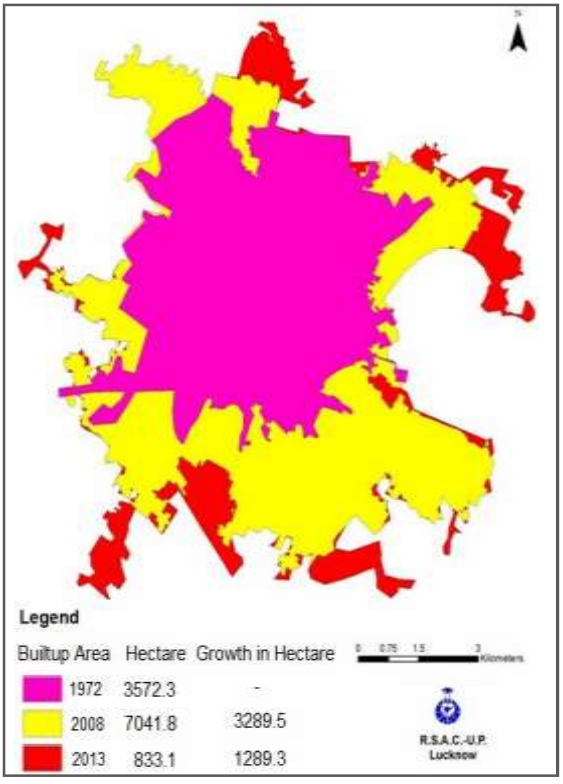

Figure 2: Urban Spatial Growth map from 1972 to 2013.

ISSN: 1832-5505
Vol-1 Issue-03 JULY 2013

A. Landuse/ Land cover (1972)

The urban growth in present study is defined as consisting of all urban land uses i.e. residential, industrial, institutional/ utilities, commercial etc.

Table 2: Landuse/ landcover statistics of study area (1971).

Sl. no	LULC	Area	%Area
1	Bulit-up	3691.1	98.36
2	Agriculture	10.6	0.282
3	Orchard/ Plantation	15.2	0.405
4	Water body	Nil	Nil
5	Park	Nil	Nil
6	Play Ground	Nil	Nil
7	Open Space	35.4	0.943
	Total	3752.3	

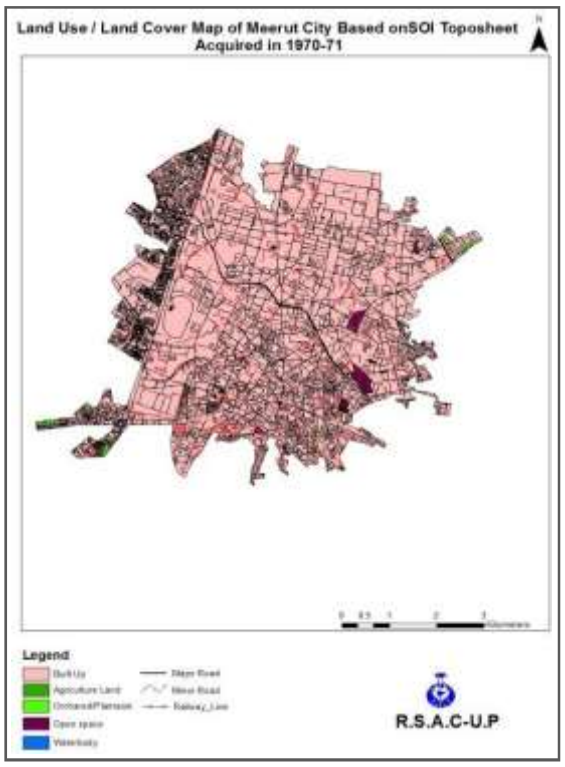

Figure 3: Landuse/Land Cover map (1972).

The present study considers only the physical factor influencing under spatial growth i.e. road/ transport network distance from city core. The demographic/socio-economic factors have not been considered. The urban land use/ Land cover map of Meerut city for year 1972 using SOI topographical map sheet no. 53G/9 has been prepared (Fig 3), and four broad land use/land cover categories identified and mapped using Arc- GIS software. They are built up, orchard plantation, Agriculture and open space and are occupying the area of 3691.1 hectares, 15.2 hectares, 3691.1 hectares and 35.4 hectares respectively.

B. Landuse/ Land cover (2008)

The urban land use/ Land cover map of Meerut city for year 2008 based on QickBird Satellite imagery has been prepared (Fig 4). The seven broad land use/land cover categories identified and mapped using Arc GIS software. They are Agriculture Land (0.815 Hectare), built up (6742.2 Hectare), orchard/plantation (128.3 Hectare), Play ground (11.5 Hectare), Park(15.8 Hectare), Open space(42.2 Hectare) and water body are occupying (20.3 Hectare) area.

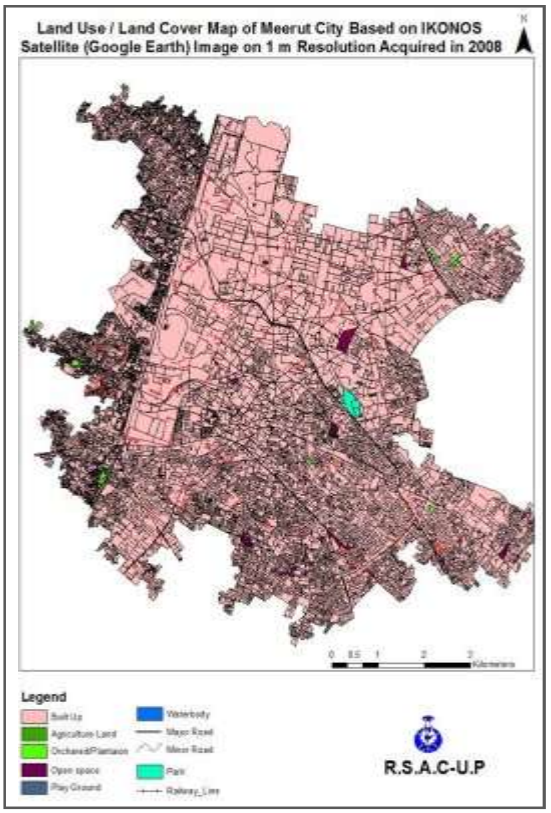

Figure 4: Landuse/Land Cover map (2008).

ISSN: 1832-5505
Vol-1 Issue-03 JULY 2013

Table 3: Land use/ land cover statistics of study area (2008)

Sl. No.	LULC	Area	%Area
1	Bulit-up	6742.2	95.78
2	Agriculture	81.5	1.115
3	Orchard/ Plantation	128.3	1.822
4	Water body	20.3	0.288
5	Park	15.8	0.224
6	Play Ground	11.5	0.163
7	Open Space	42.2	0.599
	Total	7041.8	99.991

A. Landuse/ Land cover (2013)

The urban land use/ Land cover map of Meerut city for year 2013 based on IKONOS Satellite imagery has been prepared . The seven broad land use/land cover categories identified and mapped using Arc GIS software. They are Agriculture Land (78.5 hectare), built up (8089.5 hectare), orchard/plantation (22.7 hectare), Play ground (12.7 hectare), Park (16.7 hectare), Open space(99 hectare) and water body are occupying (12 hectare) area (**Fig 5 & Table IV**).

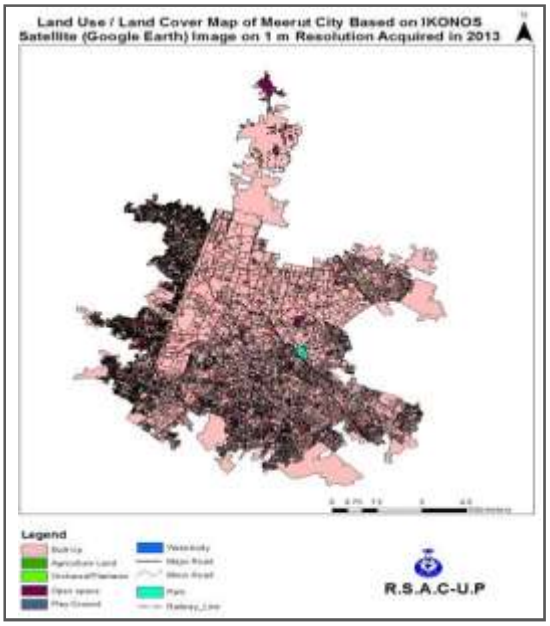

Figure 5: Landuse/Land Cover map (2013).

Table 4: Land use/ land cover statistics of study area (2013).

Sl. No.	LULC	Area	% Area
1	Bulit-up	8089.5	97.1
2	Agriculture	78.5	0.942
3	Orchard/ Plantation	22.7	0.272
4	Water body	12	0.144
5	Park	16.7	0.2
6	Play Ground	12.7	0.153
7	Open Space	99	1.18
	Total	8331.1	99.991

D. Land Transformation between (2008-2013)

The result obtained on land transformation between years 2008 to 2013. It has been observed from Table-5 that the area of agriculture land between years 2008 – 2013 has been decreased to -3 hectare (-0.232%), similarly Built-up (urban area) has increased by 134.7 sq km (104%), Orchard/ Plantation decreased -105.6(-8.19%), play ground 1.2(0.093%) and open space 58.6(4.405%) area has also been increased, water body area decreased to 8.3(-0.64%) respectively.

Table 5: Land transformation statistics of study area between (2008-2013).

Sl. No.	LULC	Area 2008	Area 2013	Change	Trend Change %
1	Bulit-up	6742.2	8089.5	1347.3	104.4
2	Agriculture	81.5	78.5	-3	-0.232
3	Orchard /Plantation	128.3	22.7	-105.6	-8.19
4	Water body	20.3	12	-8.3	-0.643
5	Park	15.8	16.7	-0.09	-0.069
6	Play Ground	11.5	12.7	1.2	0.093
7	Open Space	42.2	99	56.8	4.405
	Total			1289.3	

Note: Area in Hectares

ISSN: 1832-5505
Vol-1 Issue-03 JULY 2013

The comparison between Table-3 and Table-4 shows that the transformation of agricultural land to built up urban land are found to be transformed drastically.

Table6: Land consumption rate, consumption ratio and future perspective.

Year	Land Consumption Rate	Year	Land Absorption Coefficient
1972	0.01	1971-2008	0.004
2008	0.006	2008-2013	0.005
2013	0.006	2013-2023*	0.005
2023*	0.006		

It has been observed from table VIII that the rate of land consumption (LC) and land absorption (LA) per capita/ person between the periods of 1972 to 2008 is 0.01 and 0.006 respectively. Similarly LC and LA between the periods of 2008-2013 is 0.005 which is equal, and during the period of 2013 to 2023 LC and L.A is observed as 0.006 for both year. The LC for 2021 has been estimated as 0.005. Table 7 shows the population of study area from 1971 to 2011 and estimated for 2023.

Table 7: Population of Meerutr city 1971, 2001, 2011 and 2023.

Year	Population	Source
1971	367754	Census of India
2001	1068772	Census of India
2011	1309023	Census of India
2023	1570827	Estimated

8. Conclusion

The study has proved that remote sensing data and GIS technique is a vital tool for urban spatial growth and urban land transformation assessment and monitoring. The measurement of land use/ land cover change is very useful for future realistic planning at local and global level finally although the urban growth cannot be stopped through proper planning and management it can be restricted and directed in a desirable and sustainable manner, in perspective of prime agricultural lands . Government and public investment has increased sub-urbanization and economic growth of the cities. Thus, cities have trapped into themselves an infinite process of qualitative and qualitative development of patterns (Imdad, K. 2014). It should be implemented by the government/urban local bodies that outgrowth of city should be as per the laws and standards decided by housing and urban planning /development authorities to protect the prime agricultural land besides biological and hydrological phenomenon.

References

"Land transformation analysis using remote sensing and GIS techniques(A Case Study)" by A, Arshad et al., 2012. Reference: 2012, 4, 22 Journal of Geographical Information Systems

The 2011 Indian Census. 2011 Population Census Results for Uttar Pradesh. From http://www.census2011.co.in/census/state/uttar+pradesh.html (retrieved January 25, 2015).

High Resolution Imagery for Developmental Planning Using Spatial References in GIS (http://www.GISdevelopmentmet.net/ technology/ rs/ techrsr0014pf.htm) by Gopalan, A.K.S., 2009.

The authors Imdad, Kashif, and Janki Prasad authored a paper titled "Effects of Master Plan 2021 in the Landuse of Metropolitan Lucknow: A

ISSN: 1832-5505
Vol-1 Issue-03 JULY 2013

Study on Landform Transformation." Published in 2010 (January–June and July–December) in National Geographer XLV, pages 89–96. Print.

Imdad, K., and Virendra Kumar. The Intersection of Road Networks and Urban Form (p. Academic Press, LAP LAMBERT, Saarbrucken, Germany.

V. Kumar (2009) Landuse/Landcover Mapping in the Pratapgarh District Using Remote Sensing and Geographic Information Systems. ISPRS Conference in Nagpur.

To create a model of urban spatial growth using cellular automata, Maithani.S. (2010) wrote "Cellular Automata based model of urban spatial Growth."38(4), 604-610, Journal of the Indian Society for Remote Sensing.

Analysis of urban expansion from different time periods using satellite imagery in Istanbul, Turkey, by D. Maktav and F. S. Erber, 2005. Journal of Remote Sensing, Volume 26:797–810.

"Directions for GIS in Urban Planning" (Patkar, V. N., 2003). Map Asia Conference, Urban Planning, GIS@Development, www.gisdevelopment.net/application/urban/overview/urban0042p1/htm.

Status of Urban Growth of Major Cities in Uttar Pradesh: An Assessment using Remote Sensing and Geographic Information System Techniques, Srivastav A.K. et al., 2006. It's the Hyderabad ISPRS Symposium.

Using remote sensing and geographic information system (GIS) methods, Subudhi et al. (1998) modeled urban sprawl and predicted future populations. Pages 125–129 in J.Potonirwachak.