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## MONITORING LAND USE / COVER CHANGE OF KANPUR CITY BY USING GEOSPATIAL TECHNIQUES

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### Abstract

*Rapid urbanization leads to dramatic change in urban landscape dynamics. The measurement and monitoring of land use/cover change are crucial to government officials and planners who urgently need updated information. This paper illustrates the use of remote sensing and geographical information system (GIS) techniques to monitor and measure the land use/cover and urban growth of Kanpur city, India. Landsat satellite imageries of two different time periods, i.e., Landsat Thematic Mapper (TM) of 1998 and 2011 were used and quantified the land use/cover changes over a period of 13 years. Supervised Classification methodology has been employed using Maximum Likelihood Technique in ERDAS 9.3. The images of the study area were categorized into four different classes, viz. water body, vegetation, built-up land and open space. The results indicate that the major land use in the Kanpur city is built-up area. During the period 1998 to 2011, the area under built-up land has increased by 15.76 km<sup>2</sup> (16.94%) due to construction of new buildings on agricultural land, areas under vegetation and open space. As a result, the area under vegetation, open space and water body decreased by 14.8% (13.73 km<sup>2</sup>), 2.30% (1.92 km<sup>2</sup>) and 0.02% (0.06 km<sup>2</sup>). The paper also highlights the nature, rate and location of change and the importance of digital change detection techniques for proper land use planning for sustainable and uniform growth of Kanpur city.*

### Introduction

The extent of urbanization or the sprawl is one such phenomenon that drives the change in land use patterns. The sprawl normally takes place around the city centre or in linear direction along the highways. Usually sprawl takes place on the urban fringe, at the edge of an urban area or along the highways. The studies on urban sprawl have been attempted in developed countries (Epstein et al., 2002) and recently in developing countries such as China and India (Jothimani, 1997; Sudhira et al., 2004). The built-up area is generally

considered as the parameter for quantifying urban sprawl. The convergence of GIS, remote sensing and database management systems has helped in quantifying, monitoring, modeling and subsequently predicting this phenomenon. At the landscape level, GIS aids in calculating the fragmentation, patchiness, porosity, patch density, interspersion and juxtaposition, relative richness, diversity, and dominance in order to characterize landscape properties in terms of structure, function, and change (Civco et al., 2002). Modeling the spatial and temporal dimensions has been an intense subject of

discussion in the disciplines like philosophy, mathematics, geography and cognitive science (Claramunt and Jiang, 2001). Modeling of the spatial dynamics rests mostly with the land cover/land use change studies (Lo and Yang, 2002) or urban growth studies.

In order to quantify the urban forms such as built-up in terms of spatial phenomenon, the Shannon's entropy and the landscape metrics (patchiness, map density) are computed for understanding the built-up dynamics (Sudhira et al., 2004). Sprawl has been criticized for eliminating agricultural lands, spoiling water quality, and causing air pollution. As population increases, so does the need for new housing, schools, and transportation networks. In the urban world today, industrial, commercial and residential requirements are markedly different from years past. Decentralization is a trend indicative of urban sprawl and present day industrial, commercial and residential areas are no longer necessarily a part of the urban core.

How to measure urban sprawl has been a hot spot of research. Some research organizations have put forward their indicators for measuring urban sprawl. Besides, many scholars focus on using indicators to measure urban sprawl by establishing multi-dimensional indicators by GIS analysis or descriptive statistical analysis (Ewing and Don, 2002; Song and Knaap, 2004; Tsai, 2005). Remote sensing and GIS, separately or in combination can be used for application in studies of urban sprawl. Several studies have emerged on how to use remote sensing and GIS to monitor and measure urban sprawl (Anthony and Xia, 2001; Sudhira et al. 2004; Huang, et al., 2007; Jat, et al., 2008; Wei, et al. 2006).

An attempt has been made in this study to map out the status of land use/cover of Kanpur city, Uttar Pradesh in view to detect the

land consumption rate and the changes that have taken place during 1998 to 2011 using geographic information system and remote sensing technique.

### Objectives

- To identify land use/cover of Kanpur city using satellite data and GIS techniques.
- To analyze land use/cover change by comparing satellite images of LANDSAT 1998 and 2011.
- To examine the spatial dynamics of urban sprawl during 1998 to 2011.

### Study Area

Kanpur, the biggest city of the state of Uttar Pradesh is main centre of commercial, industrial and educational activities (Fig. 1). It extends between 26° 25' 0" N to 26° 30' 44" N latitudes and 80° 13' 47" E to 80° 24' 21" E longitudes and encompasses an area of 92.67 km<sup>2</sup>. According to the census 2011, total population of Kanpur UA/Metropolitan region is 2,920,067.

It is situated on the southern bank of Ganga River and has an important place in the history of modern India. The city formerly known as textile centre is now called, the commercial capital of the state. It is known for its cotton, woolen textile and leather industries. Apart from leather and textile, the fertilizer, chemicals, two wheelers, soaps, *pan-masala*, hosiery and engineering industries are also operating prominently in the city.

The climate is of a tropical nature and annual temperature varies from 20°C to 48°C. Rainy season extends from June to September, with the period of maximum rainfall normally occurring during the months of July and August. This densely populated city lies in the Ganga basin which is formed of alluvium of the



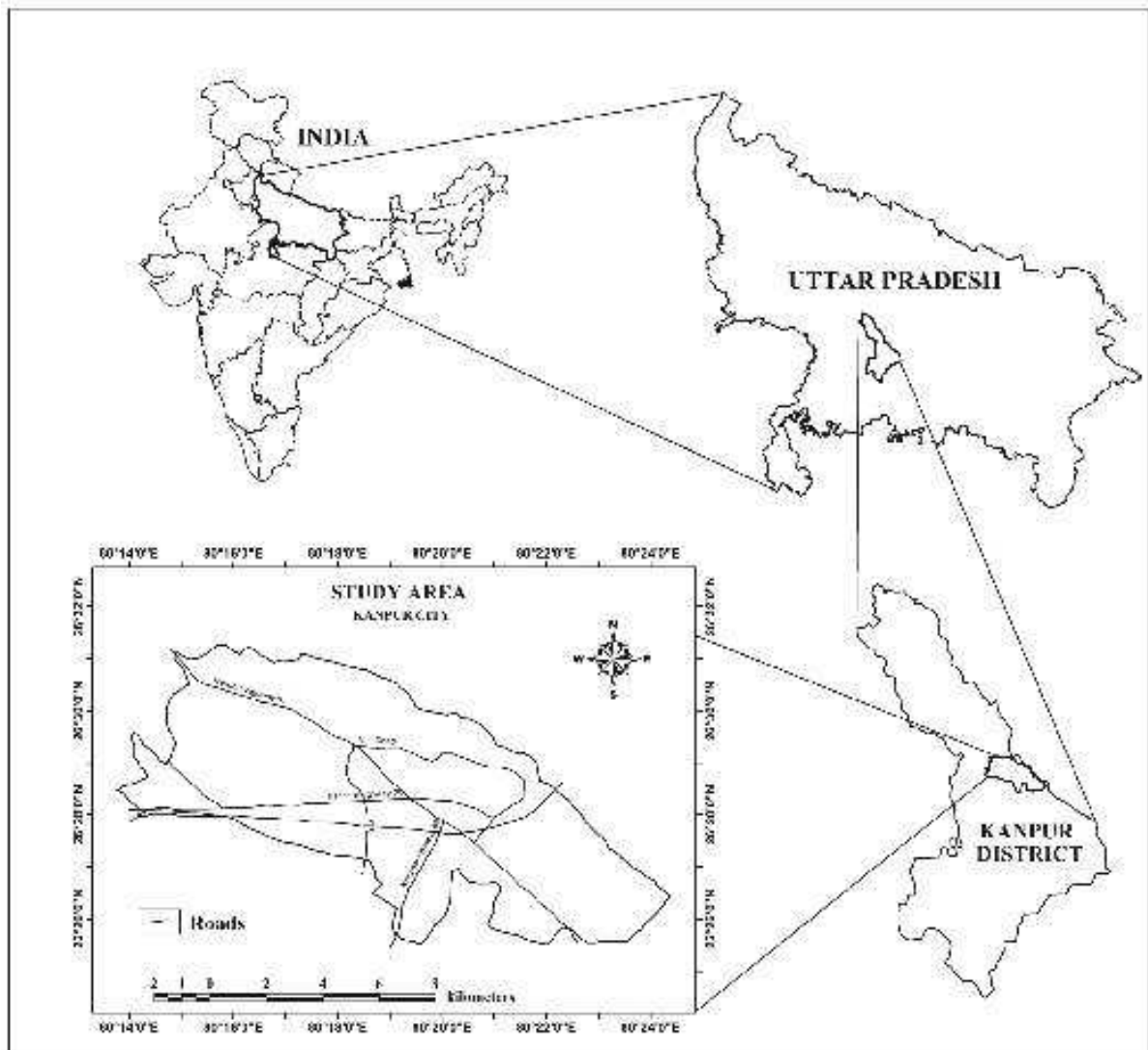


Fig. 1

early quaternary period.

### Methodology

To work out the land use/cover classification, supervised classification method with maximum likelihood algorithm was applied in the ERDAS (Earth Resources Data Analysis Systems) Imagine 9.3 Software. For better classification results some indices such as normalized difference vegetation index (NDVI), normalized difference water index (NDWI) and normalized difference built-up

index (NDBI) were also applied to classify the Landsat images at a resolution of 30 m of 1998 and 2011. With the help of GPS, ground verification was done for doubtful areas. Based on the ground verification the misclassified areas were corrected using recode tool in ERDAS Imagine 9.3. The accuracy assessment was carried out separately for 1998 and 2011. A stratified random sampling method was used to generate the random points. The error matrix and Kappa methods were used to assess the mapping accuracy. Four land use/cover types

have been identified and used in this study, namely (i) water body (ii) vegetation cover (iii) built-up land and (iv) open space. For performing land use/cover change detection, a post-classification detection method was employed. A change matrix (Weng, 2001) was produced with the help of ERDAS Imagine 9.3 software. Quantitative areal data of the overall land use/cover changes as well as gains and losses in each category between 1998 and 2011 were then compiled.

### Results and Discussion

The data obtained through the analysis of multi-temporal satellite imageries are presented in Table 1 to 3 and the results are diagrammatically illustrated in Figs. 2 to 5. Fig. 2 depicts land use/cover status of two study periods i.e., 1998 (Fig. 2A) and 2011 (Fig. 2B); Fig. 3 depicts land use/cover change from 1998 to 2011 in different land use categories i.e., water bodies (Fig.3A) vegetation (Fig.3B), built-up area (Fig. 3C) and open space (Fig. 3D); Fig. 4 diagrammatically illustrates magnitude of change in different land categories while Fig. 5 depicts urban expansion along major roads. A brief account of these results is discussed as under:

#### Land Use/Cover Status

Fig. 2(A) depicts spatial pattern of land use/cover of Kanpur city for the year 1998 while Fig. 2(B) depicts for the year 2011. These data reveal that in 1998, about 0.30% (or 0.28 km<sup>2</sup>) area was under water body, 35.16% (or 32.55 km<sup>2</sup>) under vegetation, 62.24% (or 57.75 km<sup>2</sup>) under built-up use and 2.30% (or 2.14 km<sup>2</sup>) under open space. During 2011 the area under these land cover categories was found to be 0.32% (or 0.22 km<sup>2</sup>) under water body, 20.34% (or 18.9 km<sup>2</sup>) under vegetation, 79.33% (or 73.33 km<sup>2</sup>) under built-up land and 0.20%

(or 0.22 km<sup>2</sup>) under open space respectively (Table 1).

#### Accuracy Assessment

Accuracy assessment results for land use/cover classification exhibited an overall accuracy of 90.0% for 1998 and 87.0% for 2011. The Kappa coefficients for 1998 and 2011 maps were 0.866 and 0.826, respectively.

#### Land Use/Cover Change

The data presented in Table 1, Fig. 3 and Fig. 4, depict that both positive and negative changes occurred in the land use/cover pattern of Kanpur. During this period, the water body decreased from 0.28 km<sup>2</sup> in 1998 to 0.21 km<sup>2</sup> in 2011 which accounts for 0.02% (0.06 km<sup>2</sup>) of total land cover area. The vegetation cover decreased from 32.55 km<sup>2</sup> in 1998 to 18.88 km<sup>2</sup> in 2011 which accounts for 14.8 % (13.65 km<sup>2</sup>) of the total city area. The vegetation land is decreasing due to increasing population of the city which required more land for new settlers.

The built-up area has increased from 57.75 km<sup>2</sup> in 1998 to 73.33 km<sup>2</sup> in 2011 which accounts for 16.94% (15.76 km<sup>2</sup>) of the total sprawl area. This dramatic increase in built-up area is due to rapid growth of population, continuous establishment of national and multinational companies, and development of roads etc. during the study period of Kanpur city in the fringe area. The open space has slightly decreased from 2.13 km<sup>2</sup> in 1998 to 0.22 km<sup>2</sup> in 2011 which accounts for 2.30% (1.92 km<sup>2</sup>) of the total city area. This decrease in open space is due to increase in the built-up area.

#### Land Use/Cover Change Matrix

To understand land conversion in different land categories during the 13 years (i.e., 1998-2011) a change detection matrix

**Table 1**  
**Kanpur City: Area and Amount of Change in Land Use/Cover Categories (1998- 2011).**

Land use/cover categories	Area (1998)		Area (2011)		Change 1998-2011	
	km <sup>2</sup>	Percent	km <sup>2</sup>	Percent	km <sup>2</sup>	Percent
Water body	0.28	0.30	0.22	0.32	-0.06	0.02
Vegetation	32.55	35.16	18.9	20.34	-13.65	-14.8
Built-up area	57.75	62.24	73.33	79.14	15.76	16.94
Open space	2.14	2.30	0.22	0.20	-1.92	-2.30

Source: Landsat Thematic Mapper Satellite Imager.

**Table 2**  
**Kanpur City: Land Use/Cover Change Matrix Showing Land Conversion (Km<sup>2</sup>).**

Land use/cover categories		Year 1998				2011 Total
		Water Body	Vegetation	Built-up Area	Open Space	
<b>Year 2011</b>	Water body	0.14	0.08	0.00	0.00	0.22
	Vegetation	0.03	18.40	0.00	0.47	18.9
	Built-up area	0.11	13.94	57.70	1.58	73.33
	Open space	0.0	0.13	0.00	0.09	0.22
<b>1998 Total</b>		0.28	32.55	57.7	2.14	92.67

Source: Landsat Thematic Mapper Satellite Imagery.

**Table 3**  
**Kanpur City: Urban Expansion along Major Roads**

Proximity to Road (mts)	1998		2011		Change During 1998-2011	
	Urban Area (km <sup>2</sup> )	Urban Density (Urban Area Per km <sup>2</sup> )	Urban Area (km <sup>2</sup> )	Urban Density (Urban Area Per km <sup>2</sup> )	Urban Area (km <sup>2</sup> )	Rate of Expansion of Urban Area (km <sup>2</sup> /Year)
0-100	8.65	0.71	10.51	0.87	1.86	0.14
100-200	7.11	0.68	8.80	0.85	1.69	0.13
200-300	6.05	0.65	7.25	0.84	1.20	0.09
300-400	5.15	0.62	6.21	0.82	1.06	0.08
400-500	4.18	0.61	5.20	0.79	1.02	0.07

Source: Landsat Thematic Mapper Satellite Imagery.

(Table 2) was prepared which reveals that about 13.94 km<sup>2</sup> area of vegetation cover has been converted into built-up area; 0.13 km<sup>2</sup> into open space and 0.08 km<sup>2</sup> into water body. Similarly, about 1.58 km<sup>2</sup> area of open space has been

converted into built-up area and 0.47 km<sup>2</sup> into vegetation cover. Likewise, about 0.11 km<sup>2</sup> area under water body has been converted into built-up area and 0.03 km<sup>2</sup> into vegetation cover.

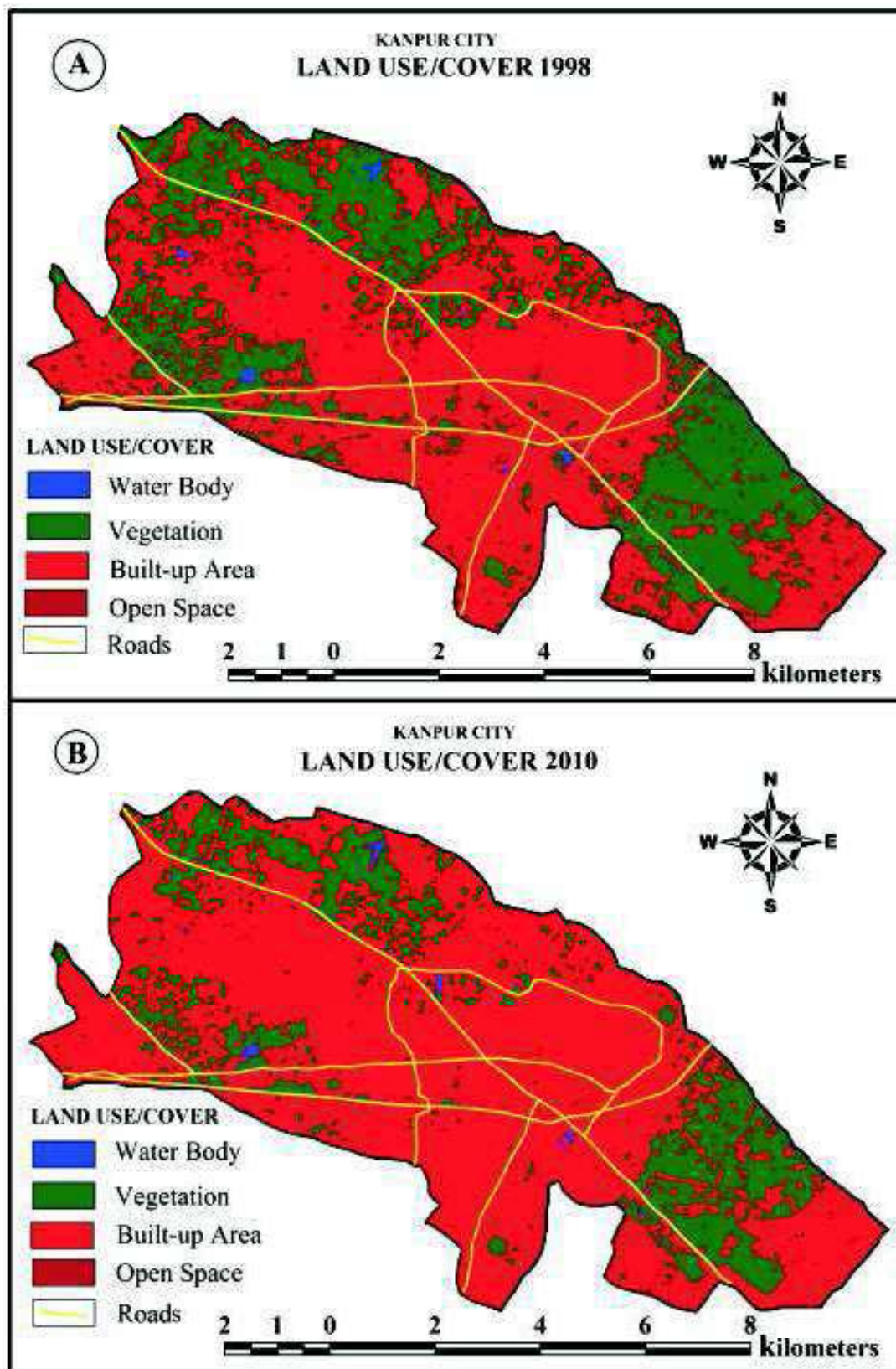


Fig. 2

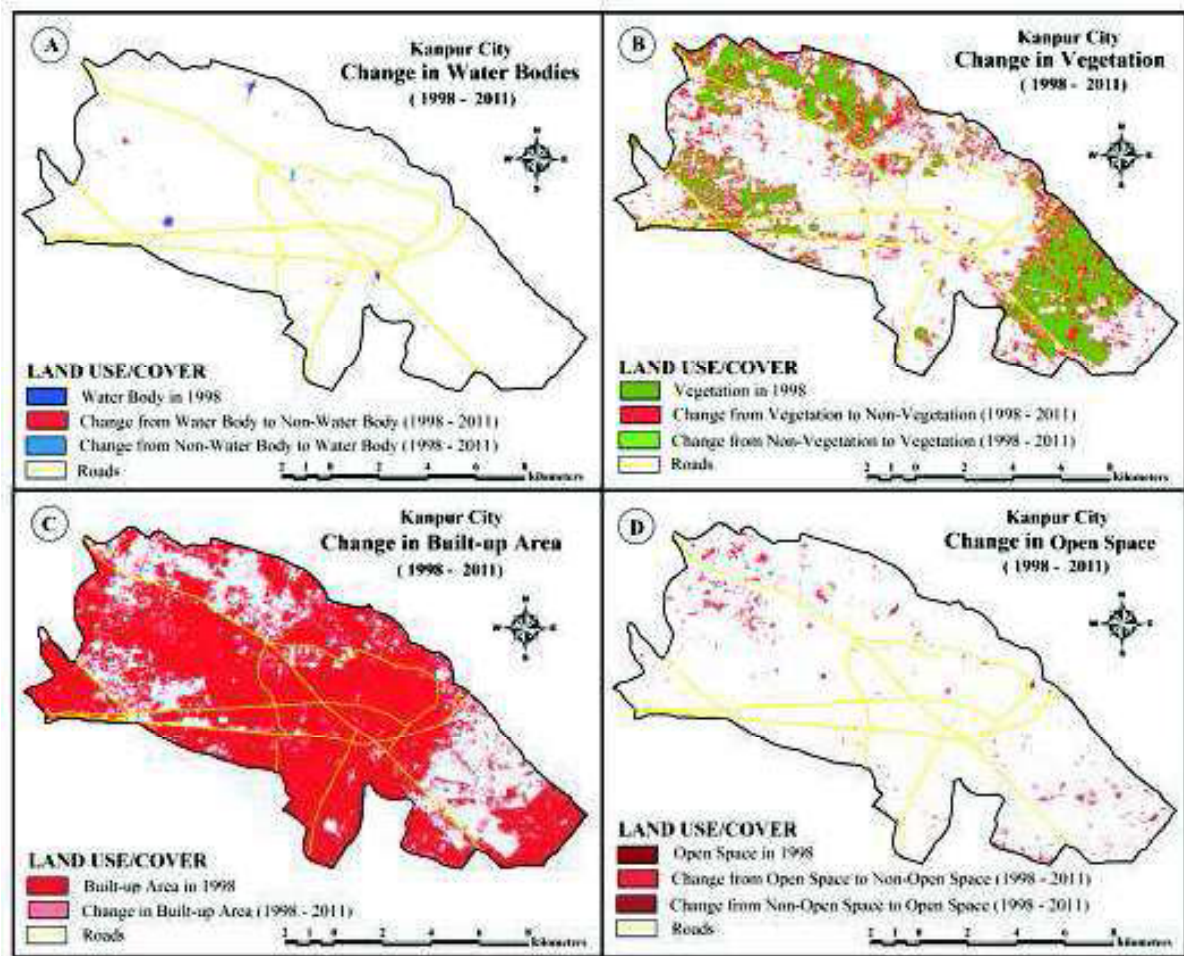


Fig. 3

### Spatial Dynamics of Urban Sprawl

The Kanpur city is known to have undergone extremely fast areal expansion in recent years due to industrialization resulting in an unprecedented population growth over a period of 13 years. Over a period of time, Kanpur has developed linearly from east to west along Ganga River and G.T road. The Central Business District (inner city) is located in the north-central part. It is heavily built up and characterized by mixed commercial and transport related activities. The public, semi-public, residential and other land use activities have been mostly concentrated in the west. Due to physical constraints of river in the north and cantonment in the east, industrial concentration

followed western/ southern expansion. On comparing the satellite data sets pertaining to 1998 and 2011 it is found that the built-up area in and around the Kanpur city has increased by  $15.76 \text{ km}^2$  (16.94%) over the period of 13 years (1998 to 2011).

Urban expansion processes in the Kanpur city during the period of 1998 to 2011 are further examined by analyzing a distance decay concept from major roads (Fig. 5). For this purpose National Highway No. 91, National Highway No. 87, National Highway No. 24, Govind Nagar Road, Mall road etc. have been taken for analysis. For analysing urban expansion, five buffer zones were created along these roads with a width of 100



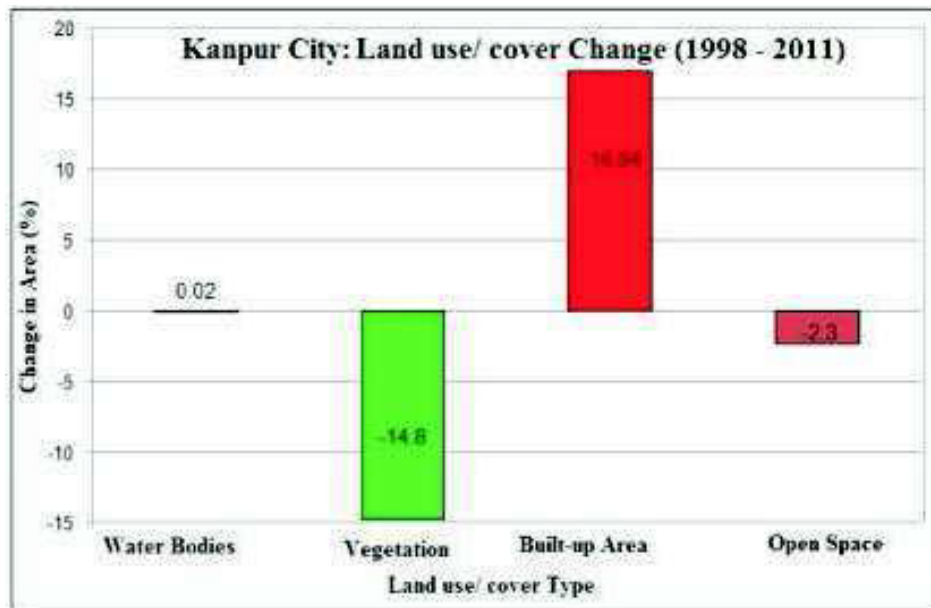


Fig. 4

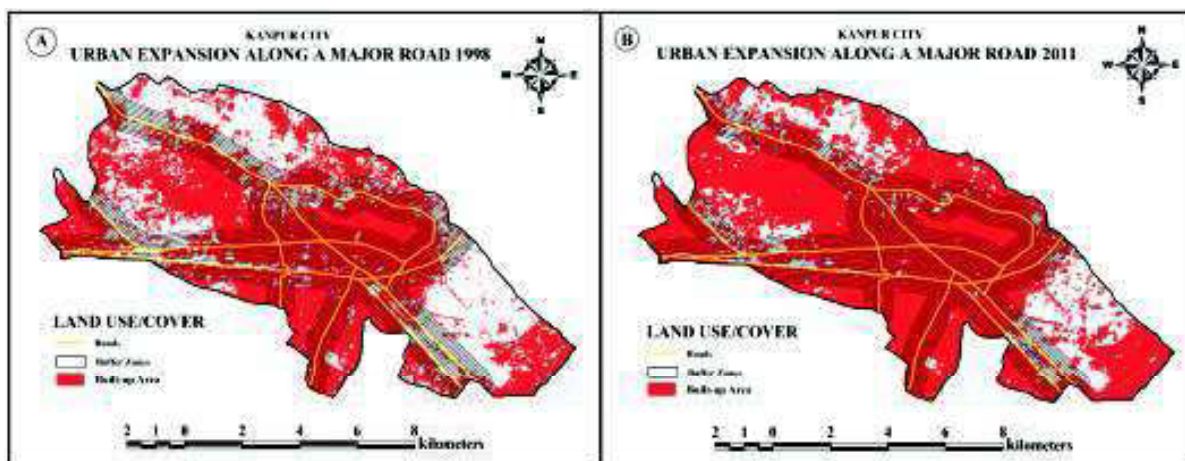


Fig. 5

metres each. The result indicates that the area and density under urban land is decreasing while going the away from major roads. Most urban expansion (51 %) can be observed within a distance of 200 mts from major roads (Table 3).

### Conclusions

The present study reveals that remote sensing and GIS are important technologies for temporal analysis and quantification of spatial

phenomena. Change detection is made possible by these technologies in less time, at low cost and with better accuracy. The study conducted in one of the largest growing cities of the Uttar Pradesh state reveals that multi-temporal satellite data are very useful to detect the changes in land use quickly and accurately. The study reveals that the major land use in the Kanpur city is built-up area. During the period 1998 to 2011, the area under built-up land has

increased by 15.76 km<sup>2</sup> (16.94%). This increase in built-up area is due to construction of new buildings on area under vegetation and open space. As a result, the area under vegetation, open space and water bodies has decreased by 14.8% (13.73 km<sup>2</sup>) 2.30% (1.92 km<sup>2</sup>) and 0.02% (0.06 km<sup>2</sup>) respectively, during the study period. The urban expansion along the major roads (i.e., NH 91, NH 25, NH 86, Govind Nagar Road, Mall road etc.) reveals that occupancy of area and built-up density are decreasing while going away from major roads. Approximately, half of urban expansion can be observed within a distance of 200 mts from major roads while other half can be observed within a distance of 200 to 500 mts. The approach adopted in this study clearly demonstrated the potential of GIS and remote sensing techniques in measuring change pattern of land use/cover in city area. The study not only provides the scientific way to understand the future urban growth but also provides a methodology for assessing urban land use in cost effective and in less time period. The present study is useful for decision making process and helpful for planners and authorities to formulate suitable plan for sustained urban development in the region.

## References

- Anthony, G.Y. and Xia, L. 2001. Measurement and monitoring of urban sprawl in a rapidly growing region using entropy. *Photogrammetric Engineering and Remote Sensing*, 67: 83-90.
- Civco, D. L. and Hurd, J. and Wilson, E. 2002. Quantifying and describing urbanizing landscapes in the Northeast United States. *Photogrammetry Engineering Remote Sensing*, 68: 1083–1090.
- Claramunt, C. and Jiang, B. 2001. An integrated representation of spatial and temporal relationships between evolving regions. *Journal of Geographical Systems*, 3: 411–428.
- Epstein, J., Payne, K. and Kramer, E. 2002. Techniques for mapping suburban sprawl. *Photogrammetry Engineering Remote Sensing*, 63: 913–918.
- Ewing, R. P. and Don, C. 2002. *Measuring sprawl and its impact*. Report of Smart Growth America, 1-42.
- Huang, J., Lu, X.X. and Sellers, J.M. 2007. A global comparative analysis of urban form: Applying spatial metrics and remote sensing. *Landscape and Urban Planning*, 82: 184-197.
- Jat, M.K., Garg, P. K. and Khare, D. 2008. Monitoring and modelling of urban sprawl using remote sensing and GIS techniques. *International Journal of Applied Earth Observation and Geoinformation*, 10(1): 26-43.
- Jothimani, P. 1997. Operational urban sprawl monitoring using satellite remote sensing: excerpts from the studies of Ahmedabad, Vadodara and Surat, India. Paper presented at 18th Asian Conference on Remote Sensing, Malaysia, October 20–24, 1997.
- Lo, C.P. and Yang, X. 2002. Drivers of land-use/land-cover changes and dynamic modelling for the Atlanta, Georgia Metropolitan Area. *Photogrammetry Engineering Remote Sensing*, 68: 1062–1073.
- Song, Y.G. and Knaap, G.J. 2004. Measuring urban form-is Portland winning the war on sprawl. *Journal of the American Planning Association*, 70: 210-225.
- Sudhira, H.S., Ramachandra, T.V. and Jagadish, K.S. 2004. Urban sprawl: metrics, dynamics and modeling using GIS. *International Journal Applied Earth*

*Observation and Geoinformation*, 5: 29-39.

Tsai, Y. H. 2005. Quantifying urban form: compactness versus sprawl. *Urban Studies*, 42: 141–161.

Wei, J., Ma, J., Twibell, R.W. and Underhill, K. 2006. Characterizing urban sprawl using multi-stage remote sensing images and landscape metrics. *Computers, Environment and Urban Systems*, 30: 861-879.

Weng, Q. 2001. A remote sensing-GIS

evaluation of urban expansion and its impact on surface temperature in the Zhujiang Delta, southern China. *International Journal of Remote Sensing*, 22: 1999-2014.

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