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MONITORING URBAN SPRAWL USING RMOTE SENSING TEHNIQUES: A CASE STUDY OF GURGAON CITY, HARYANA

Manish Kumar
D.K. Tripathi

Abstract

The present study is an attempt to identify and monitor urban sprawl in and around Gurgaon city using remote sensing technique. The multi-spectral high resolution Landsat satellite images of TM (year 1992) and ETM+ sensors (years 2000 and 2006) have been processed in remote sensing software ERDAS Imagine version 9.1 to map and analyze the dominant changes that occurred in land use/land cover features (specially in the built-up area) during the past fifteen years (1992 to 2006). To study the urban sprawl on the fringe of Gurgaon city, development plan of Gurgaon- Manesar Master Plan -2021, encompassing an area of 446.66 km² has been chosen as a case study. It is found that the built-up area is spreading in a ribbon shaped linear pattern mainly along the transport network into the fringe of the Gurgaon city. The study reveals that the built-up area in and around Gurgaon city has increased from 2969.37 ha. to 9129.27 ha. (455.63 per cent) during past fifteen years (1992 to 2006). The analysis was possible by using remote sensing techniques that established its effectiveness in monitoring urban land use/ land cover changes and urban sprawl.

Introduction

The rapid growth and development of urban areas has been an issue of great concern to urban planners, environmental scientists, geographers and decision makers all over the world. In developing countries like India, rapid industrialization and urbanization have resulted huge pressure on environmental resources of the cities. As a consequence, the cities are expanding haphazardly in all directions resulting, large scale urban sprawl and land use changes in fringe areas. Urban sprawl refers to the extent of urbanization, which is a global phenomenon mainly driven by population growth and large scale migration (Sudhira et al., 2004). This dispersed development along highways or surrounding the city in rural countryside is generally referred as sprawl. Sprawl is a term that is often used to describe perceived inefficiencies of development, including disproportionate growth of urban areas and excessive leapfrog development. In India, the percentage of people living in cities and urban areas has almost doubled to 27.8 per cent in 2001 from 14 per cent at the time of independence (Kumar et al., 2007). This is expected to accelerate even further, and by 2021 over 40 per cent of people will be living in urban areas (GGIM, 2005; Census of India, 2001).This indicates the rate of urbanization and the extent of sprawl that could take place in near future. Urban sprawl has

adverse impact on environment and urban sustainability. The sprawling requires more energy and materials and produces more pollution than compact cities. Sprawling results change in land use and land cover pattern, loss of fertile agricultural land and vegetation cover, loss of surface water and depletion in groundwater resources due to increasing built-up area. Thus, there is an urgent need to constantly monitor such changes and take corrective measures by planning of urban utilities and infrastructure, traffic system, water supply and sanitation (Fahim et al., 1999; Awasthi et al., 2002; Raghavswamy et al., 2005; Minakshi et al., 2005; Pathan, 2005). The reliable information related to the growth, pattern and spatial extent of sprawl is prerequisite in urban planning for developing basic infrastructures as well as sustainable urban environment.

Remote sensing and GIS (Geographic Information System) along with collateral data can help in monitoring and analyzing the growth, pattern and extent of urban sprawl. Remote sensing is cost effective technology and is increasingly being used for the impact analysis of urban sprawl (Haack and Rafter, 2006) on the land use land cover changes. During the past about three decades, several studies have been conducted to analyse urban growth and monitoring and mapping urban sprawl using remote sensing and GIS techniques (Green et. al., 1994; Sui, 1998; Wilson, 1998; Yeh and Li, 1998, 2001; Lo, 2001; Lo and Yang, 2002; Yang and Lo, 2003; Cheng and Masser, 2003; Xia and Yeh, 2004; Yang and Liu, 2005; Wu et. al., 2006;Wood, 2007; Jat et al.,2008; Bhatta et al., 2010; Tamilenthi et al.,2011; Tamilenthi and Baskaran 2011-a ; Tamilenthi and Baskaran,2011-b) . Keeping in view the potential of remote sensing and GIS in urban sprawl studies and their importance in city development planning, an attempt has been made to monitor and map out the urban sprawling of Gurgaon city, Haryana . In order to quantify and analyze spatial dynamics of urban built-up areas, digital image processing techniques have been used. This study may contribute in planning and decision making for sustainable development of Gurgaon city.

Objectives

The main objectives of this study are:

i) To map out the urban sprawl of Gurgaon city using satellite data and GIS techniques.
ii) To analyze the spatial distributional pattern of the urban sprawl.
iii) To detect the land use/ land cover changes comparing satellite images of Landsat TM , 1992 ; ETM + , 2000 and ETM + , 2006.
iv) To study the spatial dynamics of urban sprawl.

Study Area

Geographically, Gurgaon city, in Haryana is located at 28° 28' North, 76° 2' East with an altitude of 220 m above mean sea level and situated at the northern edge of Aravali mountain ranges. It is situated 30 km south of national capital New Delhi, about 10 kilometers from Dwarka Sub- City and 268 km south of Chandigarh, the state capital. The climate, except during the monsoon, is characterized by dryness in air, a hot summer and a cold winter. The normal annual rainfall in the Gurgaon is 553.00 mm. and about 77 per cent of the total annual rainfall is received during the south-west monsoon months (from July to mid September). May and June are the hottest months when the mean daily maximum temperature reaches about 41° C. The mean daily maximum and minimum temperature in the coldest month of January vary between 7° C

and 21° C.

It is the sixth largest city and a principal agglomeration in Haryana with a population of around 228,820 persons (Census of India, 2001). The fast growing city, Gurgaon has emerged as an industrial and financial centre. It is one of Delhi's four major satellite cities and is a part of the National Capital Region of India. Over the past 25 years the city has undergone rapid development and construction. The establishment of large number of industries, offices and multinational companies in Gurgaon city and in its environs have made it as a call centre capital of India and an important financial centre (Puri,2007;Taleja, 2009) . The area has a good transport system of road network and is well connected with the adjacent cities. It also has good communication facilities. To study the urban sprawl of the Gurgaon city, the area covered in HUDA (Haryana Urban Development Authority) Gurgaon-Master Plan, also known as Gurgaon-Manesar Master Plan -2021 has been chosen as the area of interest (Fig.1).

Database

Data used in the study are: (i) Landsat 5 ,Thematic Mapper(TM) , Multi-spectral image(acquired in 1992) with bands - red, green and blue , 30m resolution; (ii) Landsat 7 ETM+ acquired in 2000, Multi-spectral with bands - infrared, red, green and blue at a 30 m resolution and Panchromatic -15 m. resolution; (iii) Landsat 7 ETM + acquired on 2006 ,Multi-spectral with bands - infrared, red, green and blue at a 30 m resolution and Panchromatic -15 m. resolution; (iv) Map of Gurgaon Manesar Master Plan- 2021; (v) Arc GIS 9.3 and ERDAS Imagine 9.1 packages and; (vi) Field training data collected through intensive field survey.

Methodology

The overall methodology in this study includes acquisition of satellite data, digital base map creation and their geometric rectification, training data collection, classification of satellite images and comparison and statistical inventories of the land use maps. The Landsat -5 TM multi-spectral data (wavelength range 0.45 - 2.35 μm, 30 m. resolution) of 1992 and Landsat- 7 ETM+ multi-spectral (wavelength range 0.450 - 2.35 μm, 30 m resolution) and Panchromatic (wavelength range 0.52-0.90 μm, 15 m. resolution) satellite data of years 2000 and 2006 for the study area were downloaded through internet from GLCF (Global Land Cover Facility) of NASA. The ERDAS Imagine 9.1 software was used to perform this task. The different bands of the imageries were stacked to produce a False Color Composite (FCC). The Panchromatic data were merged with multi-spectral FCC to enhance spatial resolution of FCCs up to 15 m. The base map (Gurgaon - Manesar Master Plan- 2021) of the study area was imported in computer environment and geo-referenced in GIS environment using map to image registration algorithm. The Ground Control Points (GCPs) common to the map and images were identified to register the map at sub-pixel accuracy using second order polynomial transformation. The sub-setting of satellite images were performed for extracting study area by taking geo-referenced out line boundary of Gurgaon -Manesar Master Plan-2021 map . The subset image was then re-projected. All three images were co-registered to the UTM (WGS84) coordinate system with root mean square errors less than 0.5 pixels per image.

All three images (Landsat TM, MSS,1992; Landsat 7 ETM+,2000 and Landsat 7 ETM+, 2006) were then classified using ISODATA unsupervised classification algorithm (Jensen, 1996). Thirty spectral clusters with 95 per cent convergence value

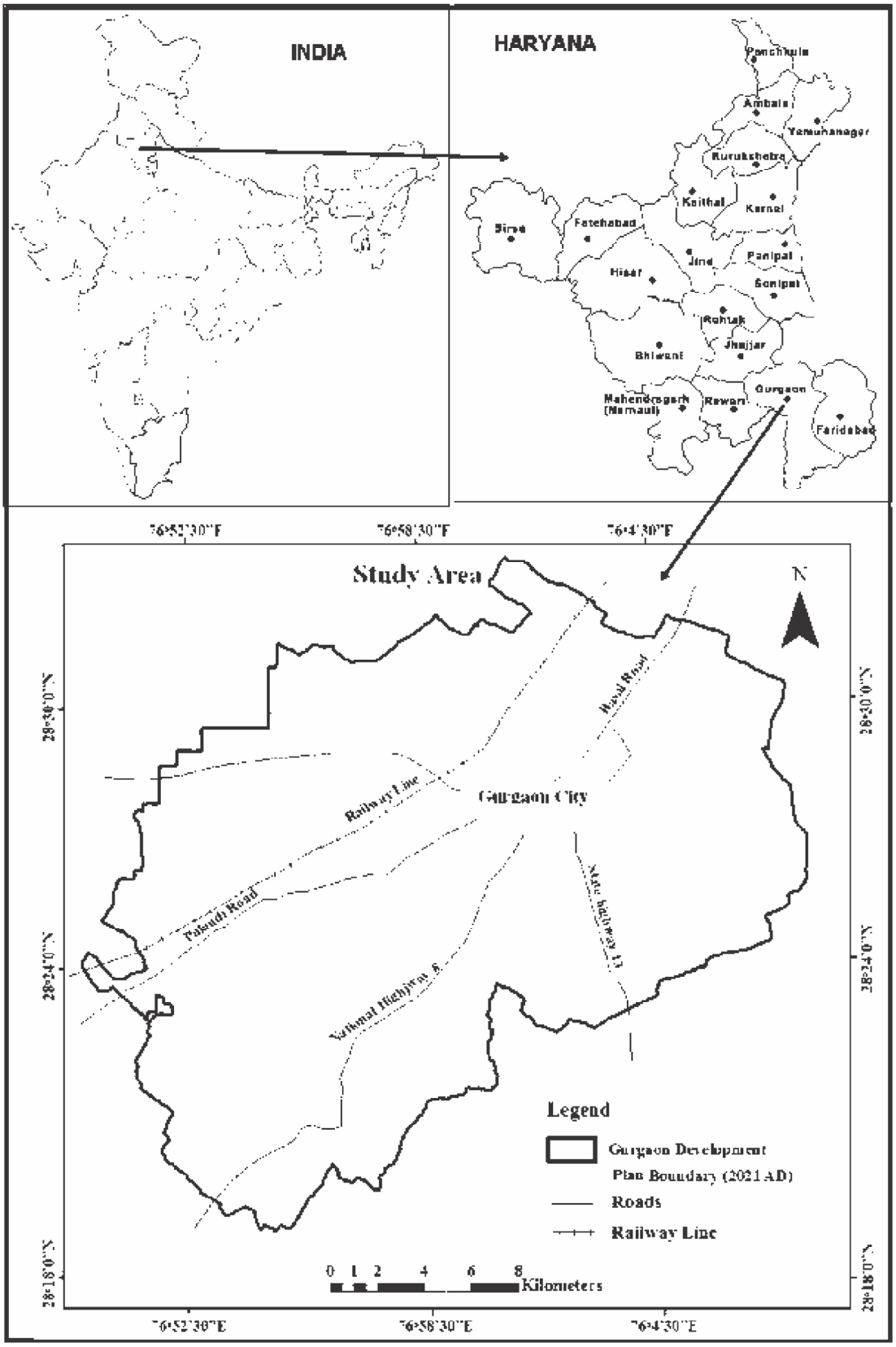
INDIA
HARYANA
Panchkula
Ambala
Yamunanagar
Kurukshetra
Kaithal
Karnal
Sirsa
Fatehabad
Jind
Panipat
Hisar
Sonipat
Rohtak
Jhajjar
Bhiwani
Gurgaon
Mahendragarh (Narnaul)
Rewari
Faridabad
Study Area
N
Gurgaon City
Railway Line
Palwal Road
Delhi-Jaipur Highway
Legend
Gurgaon Development Plan Boundary (2021 AD)
Roads
Railway Line
0 1 2 4 6 8
Kilometers
76°52'30"E
76°58'30"E
76°4'30"E
28°30'0"N
28°24'0"N
28°18'0"N

Fig. 1

were selected to perform unsupervised classification. Through visual examination of Landsat imagery and digitally classified images, we interpreted and reclassified the thirty class output from the unsupervised classification into three classes (i.e. Built-up area, Agricultural land and Other lands) which have taken into consideration. Ground truth information was incorporated in cluster validation. Finally, the resultant classified images were vectorised using raster to vector conversion tool with ERDAS IMAGINE software. The pair -wise comparison of the land use/land cover maps as well as their statistical inventories were made in order to deduce changes in terms of area as well as spatial distribution in GIS environment.

Results and Discussion

The classified images of 1992, 2000 and 2006 based on ISODATA algorithm for land use/land cover-LU/LC (built-up area focused) are presented in figure 2, 3 and 4 respectively. The pixel-based land use/land cover classification computed for both the periods is presented in the Table 1. It reveals that agricultural area in 1992 comprised the largest

Table 1
Gurgaon City: Pixel-Based LU/LC Classification – 1992, 2000 & 2006

Land use/Land Cover Categories	1992		2000		2006	
	Area (ha.)	Area (%)	Area (ha.)	Area (%)	Area (ha.)	Area (%)
Built-Up Area	2003.63	4.54	4973	11.1	11132.9	24.84
Agricultural Area	34786.1	77.39	28228.7	63	29717.9	66.33
Other LU/LC (forest and scrubs)	8011.13	18.17	11599.3	25.89	3950	8.81
Total Area	**44801**	**100**	**44801**	**100**	**44801**	**100**

***Source*:** *Above table is computed and based on the Landsat 5 TM (year 1992) and Landsat ETM+ (years 2000 & 2006) Imageries.*

proportion of 77.39 per cent (34786.1 ha.) of the Total Geographical Area (TGA) and in 2000 it was 63.0 per cent (28228.7 ha) of the TGA. The area under this category in recent data set of 2006 accounted for 66.33 per cent (29717.9 ha.) of the TGA.

During the same period the proportion of built-up area in TGA has increased drastically. It accounted for 4.54 per cent (2003.63 ha.) in 1992, 11.10 per cent (4973 ha.) in 2000 and 24.84 per cent (11132.9 ha.) in 2006. Area under forest and scrub was observed 18.17, 25.89 and 8.81 per cent of the TGA in 1992, 2000 and 2006 respectively. The area under agriculture has slightly increased in 2006 than 2000. It is because of transformation of forest and scrub lands into agricultural area and reclamation of degraded land for agricultural uses.

Spatio-temporal Patterns of Urban Sprawl

Gurgaon city has grown due to large establishment of the national and multi-national companies and the liberal plans and policies of the government for development. The spatial patterns of urban sprawl are clearly in evidence in Figures 2,3 and 4. Large expansion of the built-up area during 1992 to

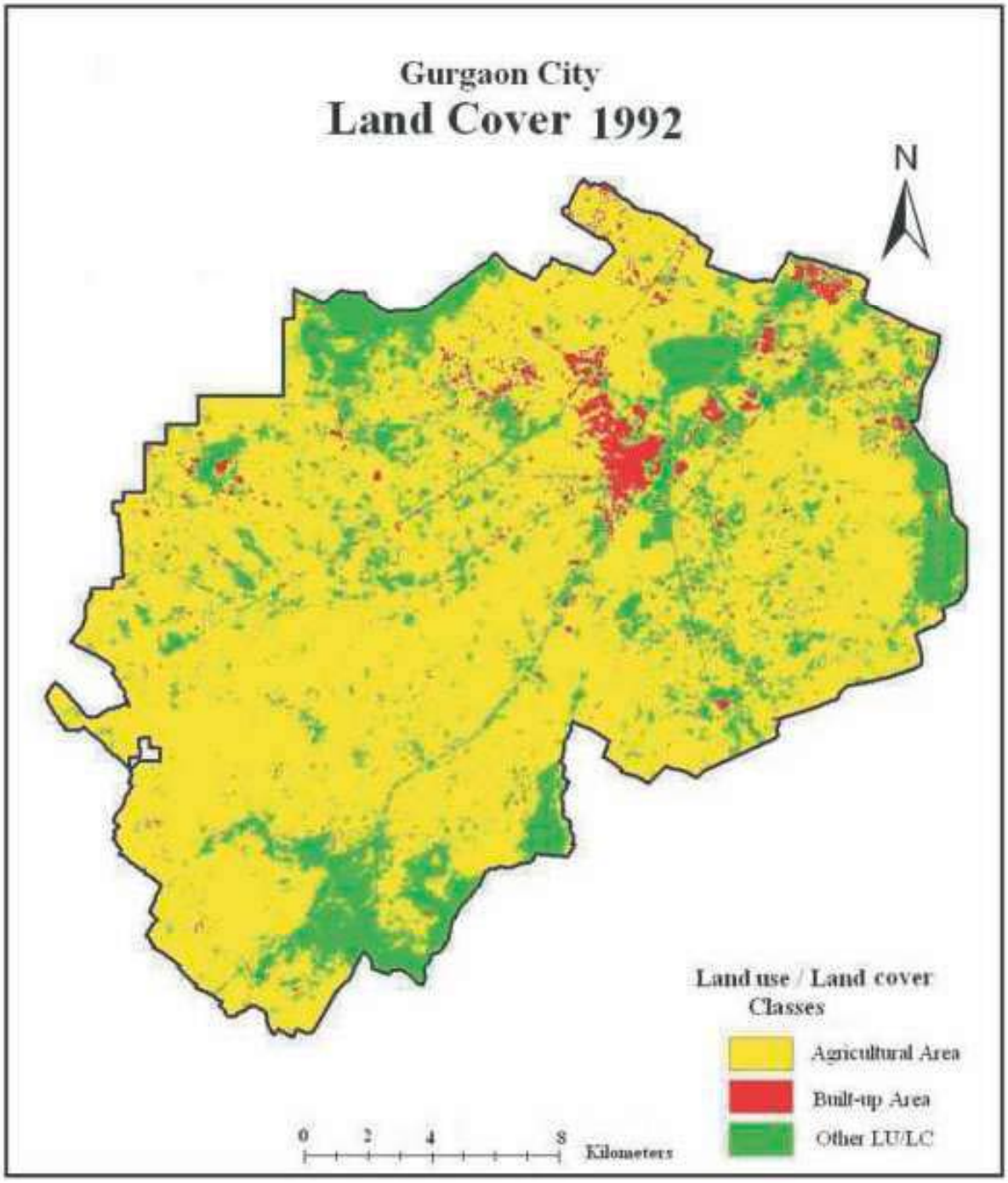

Fig. 2

2006 has been observed. It is clearly revealed that there has been a continuous process of urban sprawl in the fringe area.

On comparing the satellite data sets pertaining to 1992, 2000 and 2006 it is found that the built-up area in and around the Gurgaon city has increased by 2969.37 ha (148 per cent) during the period, 1992 - 2000 (Table 2) . During the next time span, from 2001 to 2006 it has increased 6159.9ha. (123.86 per cent). The total increase in the built-up area during past fifteen years (1992 to 2006) has been observed

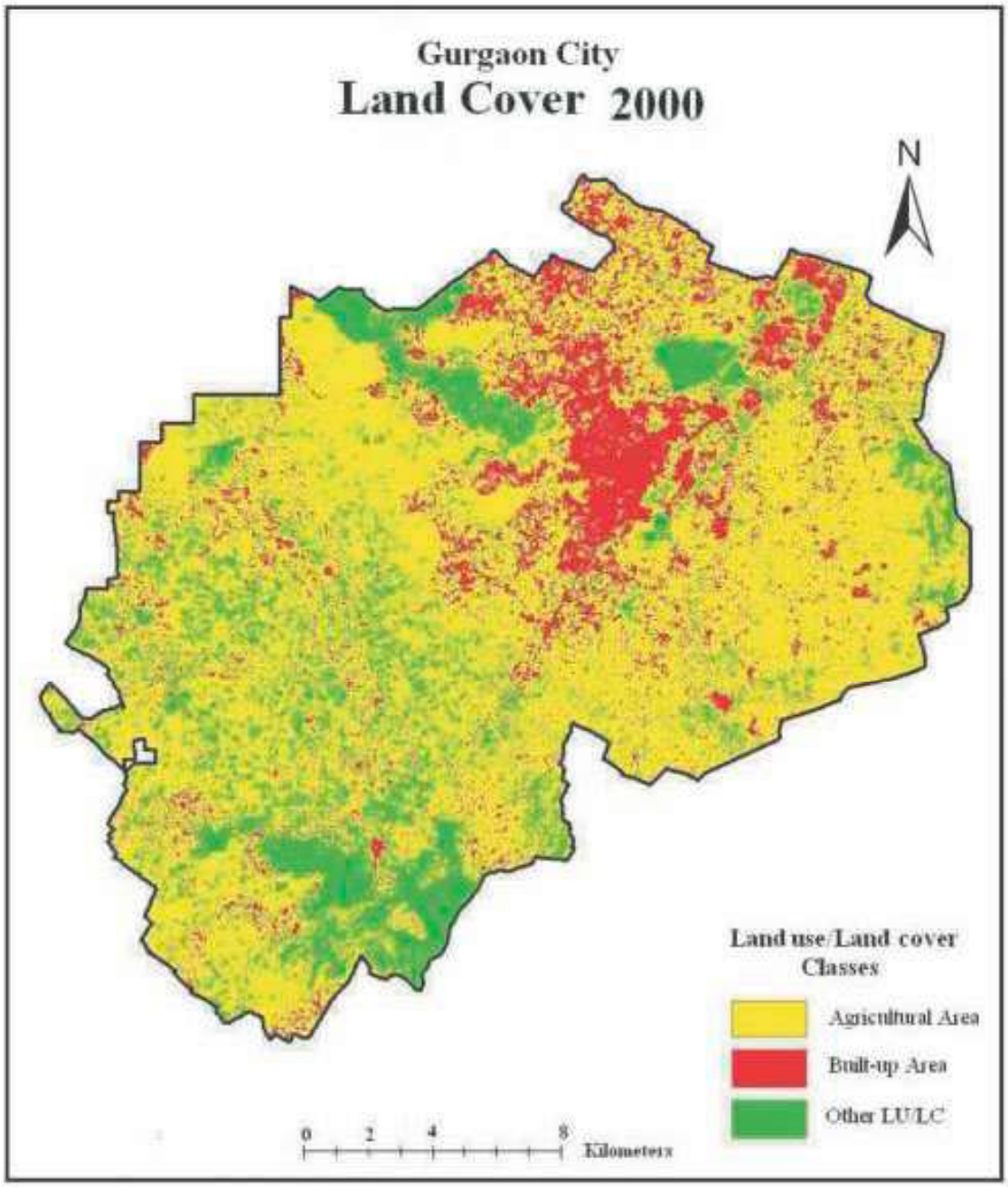

Fig. 3

to be 9129.27 ha. (455.63 per cent, Table 2).

This dramatic increase in built-up area is due to rapid growth of population, continuous establishment of national and multinational companies and development of road network and communication facilities during this phase of expansion of Gurgaon city in the fringe area. The agricultural area had decreased by 14.56 per cent while the others lands by 50.69 per cent during the last fifteen years. The city witnessed 44.78 per cent increase in the area under other uses during 1992 - 2000 due to social forestry and plantation in the open spaces but due to enormous increase of population, the pressure on the woody vegetation increased to such an extent that the area under other uses decreased

Table 2
Gurgaon City: Change in Area Under Land Use/ Land Cover

Land Use/Land Cover Categories	1992 -2000		2001-2006		1992-2006	
	Area (Ha.)	% Change	Area (Ha.)	% Change	Area (Ha.)	% Change
Built-up Area	2969.37	148.20	6159.9	123.86	9129.27	455.63%
Agricultural Area	-6557.4	-18.85	1489.2	5.27	-5068.2	-14.56
Other LU/LC (forest and scrubs)	3588.17	44.78	-7649.3	-65.94	-4061.13	-50.69%

by 65.94 per cent during the period, 2001 - 2006(Table 2).

Table 3 and Fig. 5 describe that during the period of eight years (1992 to 2000) about 6.62 per cent and 8.02 per cent of the TGA has been converted into built-up area and other land uses respectively. The increase in these categories of land use / land cover was at the cost of decline of 14.64 per cent area under agriculture. This depicts that the land under agriculture has been cleared and sold out for development of commercial areas and infrastructural development. This land occupancy phenomenon indicates that the urban expansion and growth is adversely affecting the agriculture of the region.

The analysis of data of post 2000 period reveals a drastic change in the normal course of urbanization. In the period 2001- 2006 it was found that the built-up area increased to 13.74 per cent of the TGA from 6.62 per cent recorded in 1992-2000. The economic reforms through open door policy, relaxation in trade norms, quotas and tariffs and flow of foreign investment during this period has boosted the process of urbanization. With the upcoming of multiplexes, residential townships, call centers, multinational companies , shopping malls and related trade-sector activities in the region chunks of land have been consumed, engulfing more and more of the agricultural and green belts through the process of urbanization. The year 2006 has shown a remarkable growth of built-up areas in large sized settlements away

Table 3
Gurgaon City: Trend, Rate and Magnitude of Change in Land Use /Land Cover

Land use/Land Cover Categories	1992 -2000		2001-2006		1992-2006	
	Area (ha.)	% Change	Area (ha.)	% Change	1992 - 2000	2001-2006
Built-up Area	2969.37	6.62	6159.9	13.74	0.827	2.29
Agricultural Area	-6557.4	-14.64	1489.2	3.33	-1.83	0.555
Other LU/LC	3588.17	8.02	-7649.3	-17.08	1.002	-2.846

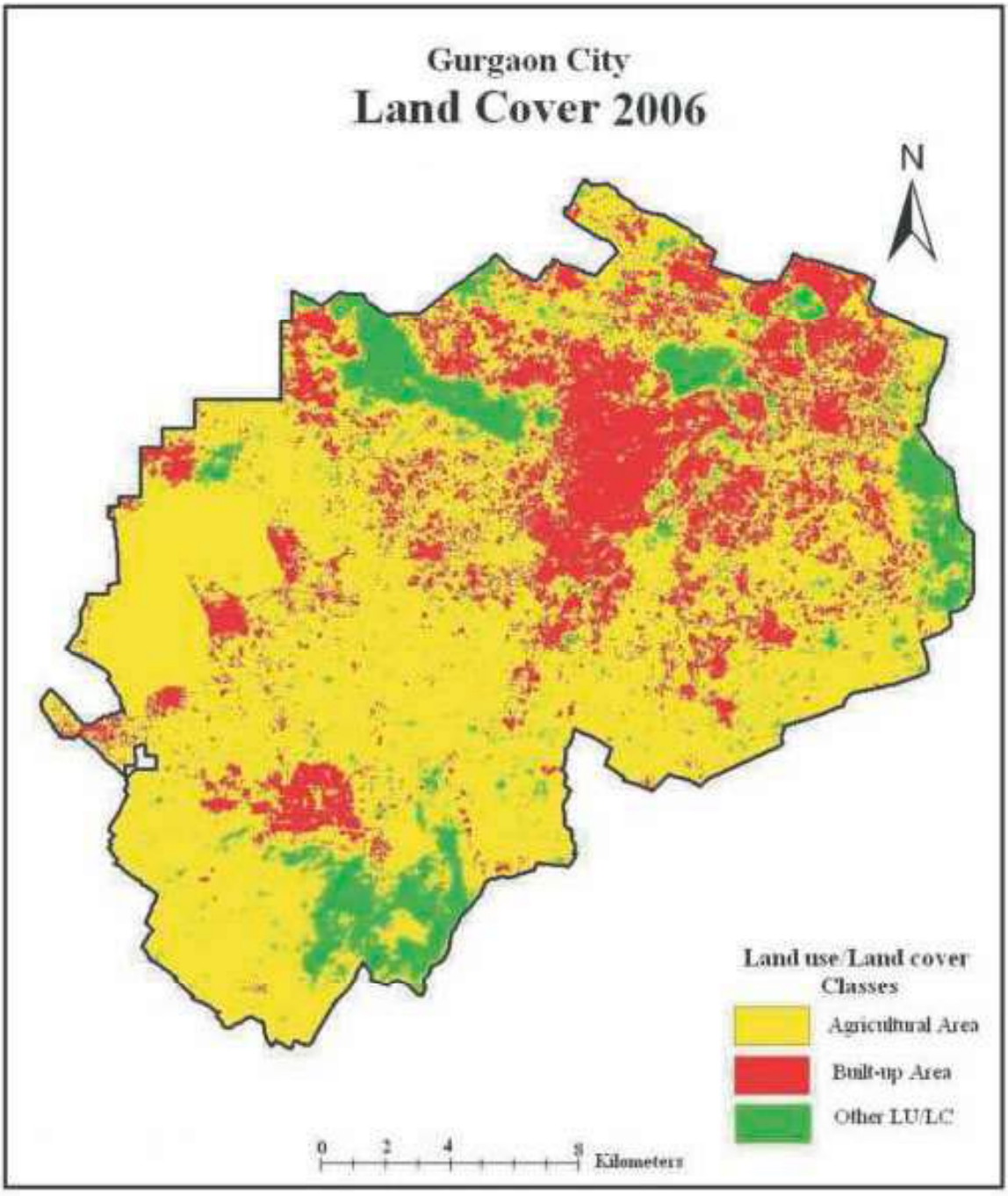

Fig. 4

from the city limits mainly towards the north-south route along the national highway in a linear fashion. The eastern sections have also reported growth in the built-up area. Rest of the region still depicts dispersed built-up land patterns. The plain areas where the accessibility is easy, the expansion of the built-up activities has increased tremendously. Intense expansion of built up area is significant in the eastern flanks due to the industrial activities. The annual rates of transformation of lands of the study area into built-up land were observed

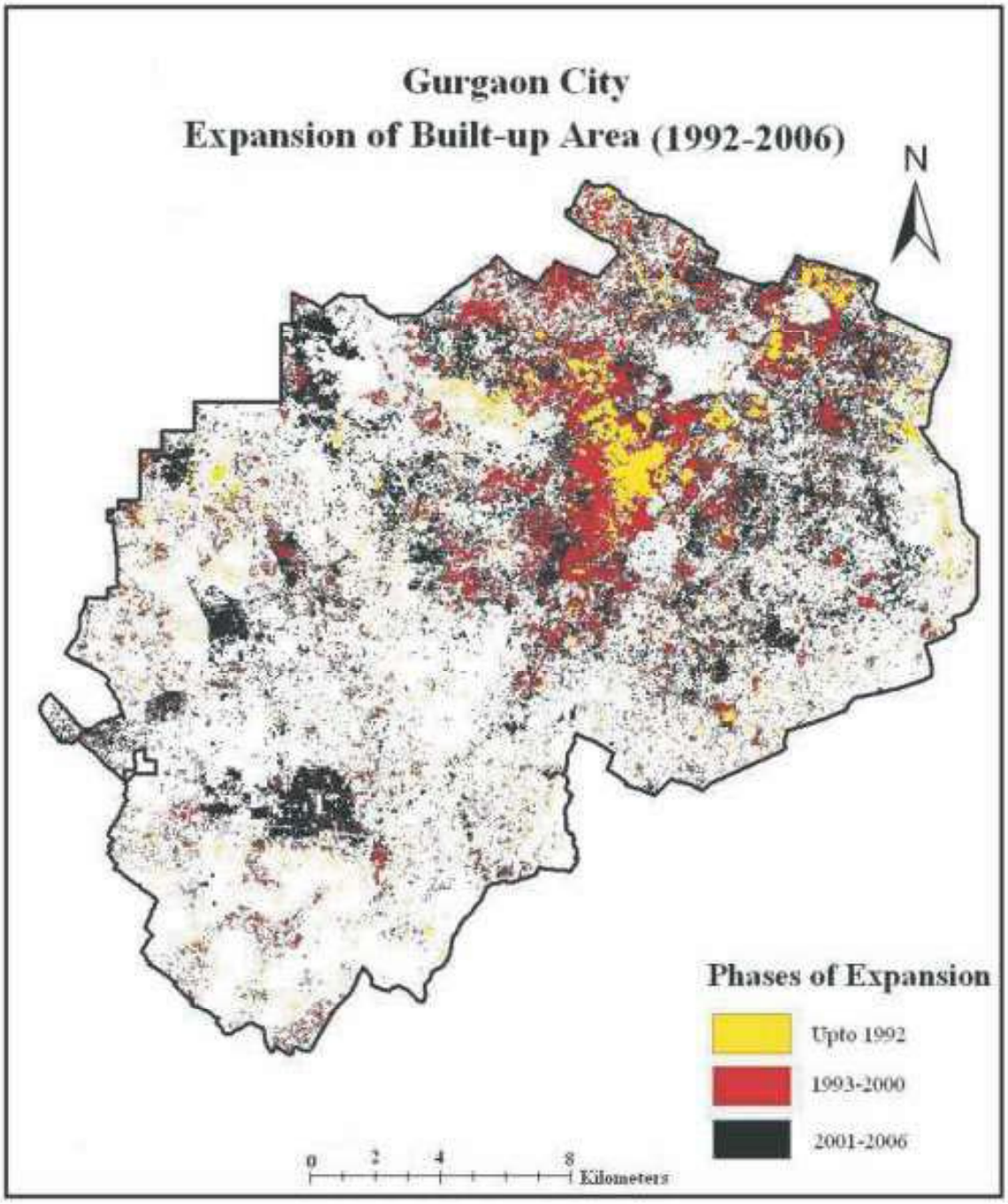

Fig. 5

0.827 and 2.29 per cent during the both the study periods (1992-2000 and 2001-2006) respectively (Table 3).

Conclusion

The study demonstrates the usefulness of remote sensing and GIS techniques , for analyzing spatial extent, nature and magnitude of urban sprawl of any city. A periodical monitoring of urban sprawl using digital image processing of satellite images of different dates may play a vital role in planning for future

expansion and transformation of land for different uses in and around the city. The shrinking fertile agricultural land and forest due to expansion of built-up area (increased 455.63 per cent during1992 to 2006) in fringe of Gurgaon city may cause serious environmental problems like scarcity of fertile agricultural land and drinking water. The study also reveled that the urban sprawling in Gurgaon city is controlled by the transport network and following mainly a ribbon shaped linear spread. The remarkable growth has been observed along the national highways and roads radiating out in all directions. The main arteries along which the sprawl is taking place also include Industrial Model Township (IMT) Manesar.

References

Awasthi,K.D., Sitaula,B.K., Singh,B.R., and Bajacharaya,R.M.(2002): "Land Use Changes in Two Nepales Watersheds: GIS and Geo-morphometric Analysis" , *Land degradation and Development,* Vol.13, pp. 495-513.

Bhatta, B. , Saraswatib, S.and Bandyopadhyay D.(2010): "Urban Sprawl Measurement From Remote Sensing Data," *Applied Geography,* Vol. 30 (4), pp.731-740.

Cheng, J. and Masser, I. (2003): "Urban Growth Pattern Modeling: A Case Study of Wuhan City PR China" . *Landscape and Urban Planning,* Vol. 62, pp. 99-217.

Fahim,M.M. ,Khalil,K.I., Halwela,F., Zaki,H.K., El-Mowelhi,M.N.,and Pax-Lenny,M., (1999): "Identification of Urban Expansion into Agricultural Lands Using Satellite Remote Sensing: Two Case Studies in Egypt". *Geocarto Int,* Vol.1, pp. 45-48.

GGIM. (2005): *Good Governance India Magazine*. Good Governance India Foundation, Kolkata (www.imfochangeindia.org), Retrieved 28-03-2005.

Green, K., Kempka , D. and Lackey, L. (1994): "Using Remote Sensing to Detect and Monitor Land-Cover and Land-Use Change". *Photogrammetric Engineering and Remote Sensing,* Vol.60, pp. 331-337.

Haack, B.N. and Rafter, A. (2006): "Urban Growth Analysis and Modelling in the Kathmandu Valley, Nepal". *Habitat International,* Vol. 30(4), pp.1056 - 1065.

Jat, Mahesh Kumar, Garg, P.K. , Khare, Deepak .(2008): " Monitoring and Modelling of Urban Sprawl Using Remote Sensing and GIS Techniques", *International Journal of Applied Earth Observation and Geoinformation,* Vol. 10 (1), pp.26-43

Jensen, J.R,.(1996): *"Introductory Digital Image Processing"*, Prentice Hall, New Jersey, pp.177-230.

Kumar, J. N. V., Pathan, S. K. and Bhanderi,R.J.(2007): "Spatio-Temporal Analysis for Monitoring Urban Growth-A Case Study of Indore City", *J.Indian Soc.Remote Sensing,* Vol.35 (1), pp.11-20.

Lo, C.P. (2001): "Modeling the Population of China Using DMSP Operational Line scan System Nighttime Data". *Photogrammetric Engineering and Remote Sensing,* Vol. 67, pp. 1037 - 1047.

Lo, C.P. and X. Yang (2002): "Drivers of Land-Use/Land-Cover Changes and Dynamic Modelling for the Atlanta, Georgia Metropolitan Area". *Photogrammetric Engineering of Remote Sensing,* Vol. 68(10),

pp. 1062-1073.

Minakshi, Shrma,P.K. ,Kaur,A. and Vanita.(2005): " Satellite Based Study of Land Transformation in Ludhiana District, Punjab" , *J.Indian Soc. Remote Sensing,* Vol.33, pp.63-68.

Pathan,S.K.(2005): "Miniting Master Plans" *Geospatial Today,* Vol.4, pp.41-46.

Puri, V. K (2007): *"Master Plan 2021 For Gurgaon-Manesar With Complete Map Notified Vide Haryana Govt.: Notification No. CCP (NCR) FDP(G) 2007,"* Jain Book Agency, Cannaught Place, New Delhi.P.6.

Raghavswamy,V.,Pathan,S.K.,Ram Mohan,P.,Bhanderi,R.J.and Padma,P.(2005): "IRS-1C Application for Urban Planning and Development", *Current Science,* Vol.70, pp.1582-588.

Sudhira, H. S. , Ramachandra, T. V. and Jagadish ,K. S.(2004): "Urban Sprawl: Metrics, Dynamics and Modeling Using GIS" , *International Journal of Applied Earth Observation and Geoinformation,* Vol. 5(1), pp. 29-39.

Sui, D. Z. (1998): "GIS-Based Urban Modelling: Practices, Problems, and Prospects" *International Journal of Geographical Information Science,* Vol.12 (7), pp. 651-671.

Taleja, Bhuvesh (2009): *"Business Today - India's leading business magazine".* http://businesstoday.intoday.in, Retrieved 2010-07-16.

Tamilenthi, S., Punithavathi, J., Baskaran, R. and Mohan, R.C.(2011): "Dynamics of Urban Sprawl, Changing Direction and Mapping:A Case Study of Salem City, Tamilnadu ,India", *Archives of Applied Science Research,* Vol. 3 (1), pp.277-286

Tamilenthi ,S. and Baskaran, R. (2011-a): "Geomatic Based Urban Sprawl Detection of Salem City, India", *Recent Research In Science And Technology,* Vol.3(2), pp. 70-76

Tamilenthi, S., and Baskaran, R. (2011-b): "Detecting Urban Change of Salem City of Tamil Nadu, India from 1990 to 2010 Using Geospatial Technology", *International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies.,* Vol. 2 (2), pp.183-195

Wilson, A. G. (1998): "Land-Use/Transport Interaction Models: Past and Future", *Journal of Transport Economics and Policy,* Vol.32, pp. 3-26.

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.

Wu, Shuo-Sheng, Bing Xu and Le Wang (2006): "Urban Land-use Classification using Varigram-based Analysis with an Aerial Photo", *Photogrammetric Enginnering & Remote Sensing,* Vol. 72 (7), pp. 813-822.

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 Lo, C.P. (2003): "Modeling Urban Growth and Landscape Changes In The Atlanta Metropolitan Area", *International Journal of*

Geographic Information Science, Vol.17(5),pp. 463-488.

Yang, X. and Z. Liu (2005): "Use of Satellite Derived Landscape Imperviousness Index to Characterize Urban Spatial Growth", *Computer, Environment and Urban System,* Vol.29, pp.524-540.

Yeh, A.G.O. and X. Li (1998): "Sustainable Land Development Model for Rapid Growth Areas using GIS", *International Journal of Geographical Information Science,* Vol.12 (2), pp. 169-189.

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 (1), pp. 83-98

Manish Kumar, Assistant Professor
NRDMS, Department of Geography
Kumaun University, SSJ Campus
Almora-263601, Uttarakhand

Dr. D.K.Tripathi, Associate Professor
Department of Geography
Kamla Nehru Institute of Physical &
Social Sciences, Sultanpur –228118, U.P.