An assessment of urban environmental issues using remote sensing and GIS techniques an integrated approach: A case study: Delhi, India

Atiqur Rahman[1]* & Maik Netzband[2]

[1]Department of Geography, Faculty of Natural Sciences,
Jamia Millia Islamia University, New Delhi -110 025
E-mail: r_ateeq@lycos.com
* Presenting author

[2]Centre for Environmental Research, Department Urban Ecology,
Environmental Planning and Transport,
Permoserstr, 15, 04157 Leipzig; E-mail: maik.netzband@ufz.de

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1. Introduction

There is an unequal urban growth which is taking place all over the world but the rate of urbanization is very fast in the developing countries especially in Asia. In 1800 A.D, only 3% of the world's population lived in urban centres but this figure reached to 14% in 1900 and in 2000, about 47% (2.8 billion) people were living in urban areas. India no longer lives in villages and 79 million people were living in urban areas in 1961 but it went up to 285 million in 2001. In India and China alone, there are more than 170 urban areas with populations of over 750,000 inhabitants (United Nations Population Division, 2001). Statistics show that India's urban population is second largest in the world after China, and is higher than the total urban population of all countries put together barring China, USA and Russia. In 1991, there were 23 metropolitan cities in India, which increased to 35 in 2001 (Census of India, 1991 & 2001) some of the prominent one are Delhi (13.78 million), Mumbai (13.22 million) and Chennai (6.42 million). There is a mass migration of people from rural to urban and also from smaller to bigger urban areas and then to metropolitan centres like Delhi, Bombay, Bangalore, and Mumbai etc. The major cause anticipated for this is the high in-migration in search of better employment opportunities in these urban centres in comparison to neighbouring states. As urban population increases, the demand of land for various urban activities also increases. The process of urbanization in India gained momentum with the start of industrial revolution way back in 1970s followed by globalization in 1990s. Forests were cleared, grasslands ploughed or grazed, wetlands drained and croplands encroached upon under the influence of expanding cities, yet never as fast as in the last decade (Rahman, 2007).

This explosive increase in the exponential form of ‘Population Growth’ has caused havoc for the human life in the city environment. Doubling and tripling of urban population practically in all major cities and towns and the consequent strain on the existing system manifested in an environmental chaos. Every major city of India faces the same proliferating problems of urban expansion, inadequate housing, poor transportation system, poor sewerage, erratic electric supply, insufficient water supplies etc. An increasing number of trucks, buses, cars, three-wheelers and motorcycles all spewing uncontrolled fumes, surge in sometimes-haphazard patterns over city streets jammed with jaywalking pedestrians, rickshaw and cattle. The phenomena of accelerated urbanization is the main culprit, wherein besides bringing higher standard of living has also brought problems of growth of dense and unplanned residential areas, environmental pollution, non-availability of services and amenities and solid waste generation and growth of slums. Population growth and in-migration of poor people, industrial growth, inefficient and inadequate traffic corridors, poor environmental infrastructure, etc. are the main factors that have deteriorated the overall quality of the city environment. Emerging future of Delhi in the light of its past experiences, current trends, and development initiatives is one of the important issue which shows different social and physical factors affecting the housing and quality of life in Delhi (Misra, et. al. 2001). After independence, when Delhi witnessed a large influx of migrants, within a very short time, the population of Delhi increased more than two folds. To house such a large migrant people city has to expand. The rate of expansion is very fast, unplanned, uncontrolled and most of them are illegal (Rahman, 2006). Mushrooming of illegal construction has become day-to-day phenomena in the fringe areas of all big and medium size cities in India.

The level of pollution i.e. air, water and land has increased because of lack of poor environmental management. This has its direct impact on quality of urban environment, affecting efficiency of the people and their productivity in the overall socio-economic development. India's urban air quality ranks among the worlds worst. Vehicles are the major source of this pollution, today with more than 5 million cars, trucks, buses, taxis, and rickshaws already on the roads in the country's capital New Delhi alone. Each urban centre has a number of environmental problems with varying scale and scopes which are influenced by factors such as size of population and its density, climatic conditions, water resources and the flora and fauna in and around the urban centre (Hardoy et al., 1997). The state of urban environment all over India is deteriorating so fast that the sustainability of the cities is threatened. In metro cities like Delhi, land environment is under stress due to the pressure of rapid urbanization. As the cities expand and population increases, the resources, which are limited, are shared. The lack of services such as water supply, sanitation, drainage of storm water, treatment and disposal of waste water, management of solid and hazardous wastes, supply of safe food, water and housing are all unable to keep pace with urban growth.

So in this context an integrated geo-spatial technology i.e. remote sensing (RS), geographic information system (GIS) and global positioning system (GPS) can contribute substantially in a more supplementary fashion to some of the interactive operations that should become an asset for assessing, understandings, mapping utility and service facility using GPS and solving complex urban environmental issues. By utilizing remote sensing data and implementing GIS mapping techniques, change detection over a period of time of the urban areas can be monitored and mapped for specific developmental projects. Creating linkages between remote sensing data and socio economic data obtained on the ground from household surveys has been recognized as one of the major challenges of land use/land cover change studies (Rindfuss et al. 2003). Satellite Remote Sensing, with its repetitive coverage together with multi-spectral (MSS) capabilities is a powerful tool to map and monitor the emerging changes in the urban core as well as in the peripheral areas of any urban areas. The loss of agricultural land because of rapid urbanization has been detected using remote sensing techniques in some cities of India i.e. Hyderabad, Madras and Nagpur (NRSA, 1994). The situation is severe in India due to unplanned growth of the cities in all directions. The spatial patterns of urban sprawl in all direction over different periods, can be systematically mapped, monitored and accurately assessed from remotely sensed data along with conventional ground data (Lata et. al., 2001).

Keeping these above points in mind in this paper an attempt has been made to assess some of the urban environmental issues which Delhi is currently facing with the help of geo-spatial tools i.e. remote sensing (RS), geographic information system (GIS) and global positioning system (GPS).

1.1 Objectives

The specific research objectives of this paper are as follows:

- ✓ To assess the demographic profile of Delhi
- ✓ To assess the land use/land cover of Delhi during the period1992-2004
- ✓ To assess the thermal environment of Delhi i.e. night time temperature for 2001 and 2005 in order to asses the Urban Heat Island
- ✓ To find out the night time temperature on various land use/land cover
- ✓ To examine the spatial pattern of solid waste generation, collection and its management
- ✓ To assess the industrial pollution i.e. air, waste water and noise

1.2 Study Area

Delhi, the capital city of India is located between the 28º 24' 17" and 28º 53' 00" N latitudes and 76° 45' 30" and 77 º 21' 30" E longitudes (fig. 1) and it spreads over an area of 1,463 km². It is situated on Aravali quartzite rage of Rajasthan. The climate is semi-arid with maximum rainfall is in the month of July (296 mm), October to December are dry. While the hottest months are May and June with mercury levels touching 48°C, whereas, the lowest falls to 4°C at the end of December and early January. The total population of Delhi was nearly 0.4 million in 1901, which kept on increasing slowly and it was 1.74 million in 1951 and 9.42 million in 1991. But sharp rise in population was recorded in the last decade and it reached to 13.78 million in 2001 (Census of India 2001) and as per Registrar General of India (RGI) estimates Delhi's population will be 20.78 million by 2015. East district among all 9 districts of Delhi has been experiencing high growth rate of urban population and it ranks 6th among all districts with 90.19% urban population in 1991, while 98.75% urban population growth recorded in 2001, which is only after Central and New Delhi districts. In Delhi about 79.48% of households have electricity connections and 63.38% of households have toilet facilities (Economic Survey of Delhi, 1991). About 60% of the households have both electricity and toilet facilities, 75.7% have piped water supply (individual plus sharing) while 20% depend on hand-plumps/tube-wells (Economic Survey of Delhi 1999-2000)

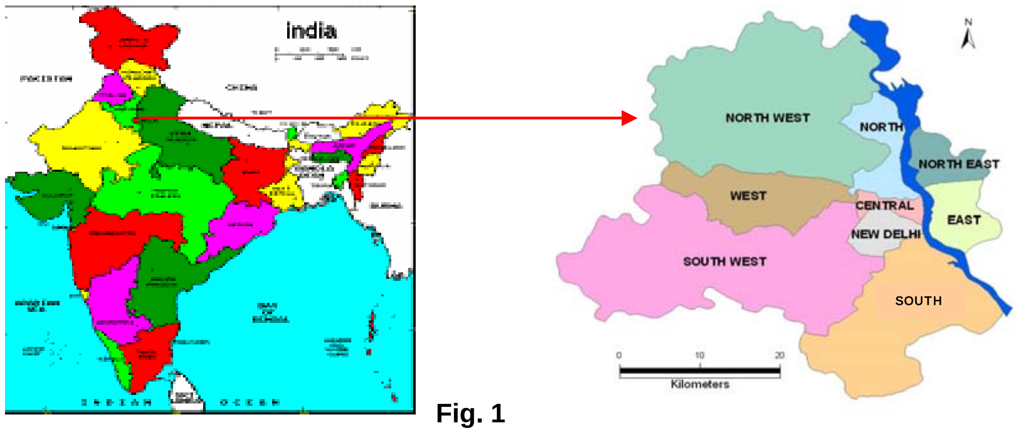


Fig. 1

2. Data source and methodology

2.1 Satellite data

Table 1 Details of satellite imageries used

S. No.	Satellites	Sensors	Date	Resolution	No. Bands	Path	Row
1	Landsat	TM	1992	28.5 m	4	146	40
2	IRS-P6	LISS-III	Feb 2004	23.5 m	3	96	51
3	TERRA	ASTER	Sept. 2003	15.0 m	4	144	48
4	TERRA	ASTER	Oct. 2001	90.0 m	5	13	204
5	TERRA	ASTER	Sept. 2003	90.0 m	5	13	204

2.2 Secondary data

- Demographic data of Delhi, Census of India, Delhi
- Air, noise and waste water pollution data, Central Pollution Control Board, (CPCB), Delhi
- Garbage and solid waste data from CPCB, Delhi Pollution Control Board (DPCB) and Municipal Corporation of Delhi (MCD).

2.3 Methodology for temporal land use/land cover and change detection

Landsat and IRS multi spectral (MSS) satellite image of 1992 and 2004 respectively have been used for generation of land use/ land cover map (fig. 2). The satellite data was enhanced before classification using histogram equalization in ERDAS Imagine 8.7 for the better quality of the image and to achieve better classification accuracy. Further both satellite data were rectified to a common Universal Traverse Mercator (UTM) projection/coordinate system on 1:50,000 scale. The data was resampled to a common spatial resolution of 23.5 m. Then supervised classification was performed using maximum likelihood algorithm of the classified data was recoded and then ground truthing was done and thereafter accuracy assessment matrix was performed**.** Two land use/land cover maps were prepared from i) Landsat TM 1992 and ii) IRS LISS-III satellite data of 2004 thereafter changes in different land use/land cover was observed.

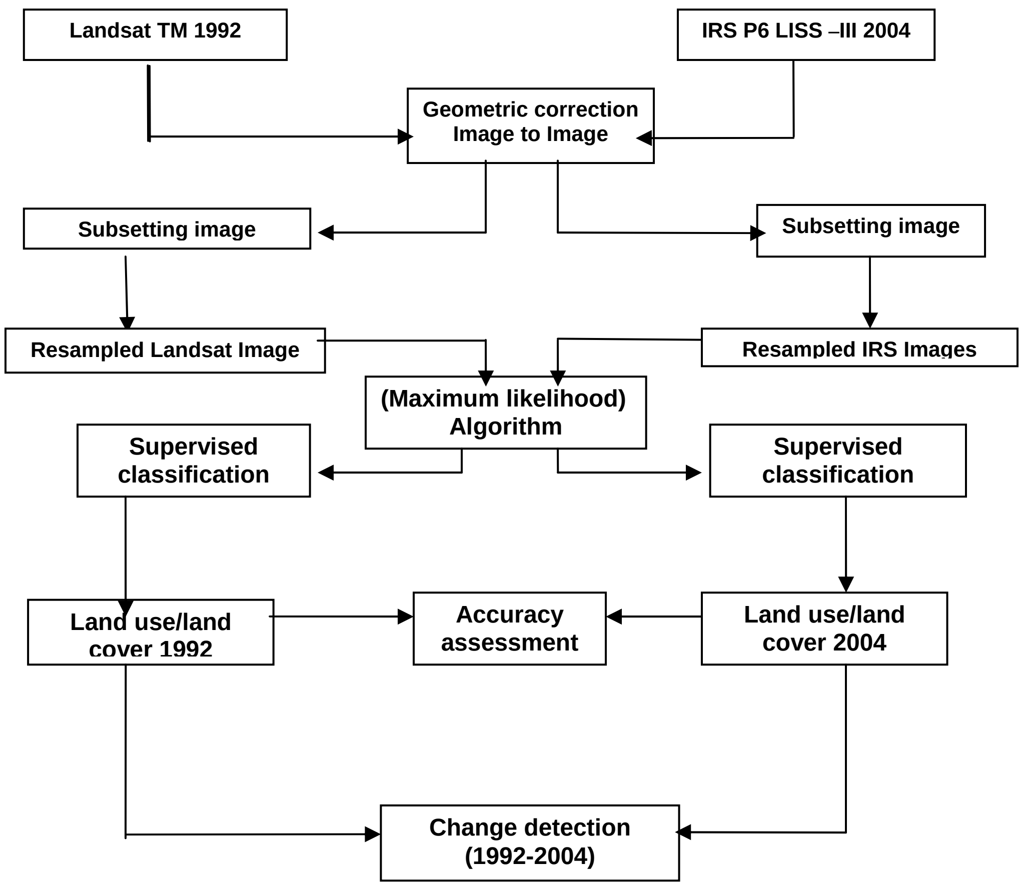


Fig. 2 Flow chart of methodology for land use/land cover & change detection

2.4 Methodology for estimation of surface temperature from satellite data

To asses the surface temperature of Delhi ASTER datasets have been rectified to a common UTM (Universal Transverse Mercator) projection and WGS84 datum using Survey of India (SoI) topographical sheet and then was resampled using the nearest neighbour algorithm. The DN number of LANDSAT-

7 ETM+ and ASTER datasets was converted into spectral radiance. Standard atmosphere parameter along with geometric parameters were estimated using FLAASH 4.1 and were applied to each of satellite data for atmospheric corrections. The flow diagram of multi-spectral data processing and estimation of surface temperature is shown in fig. 3. The procedure involves and successive steps are described below in flow chart.

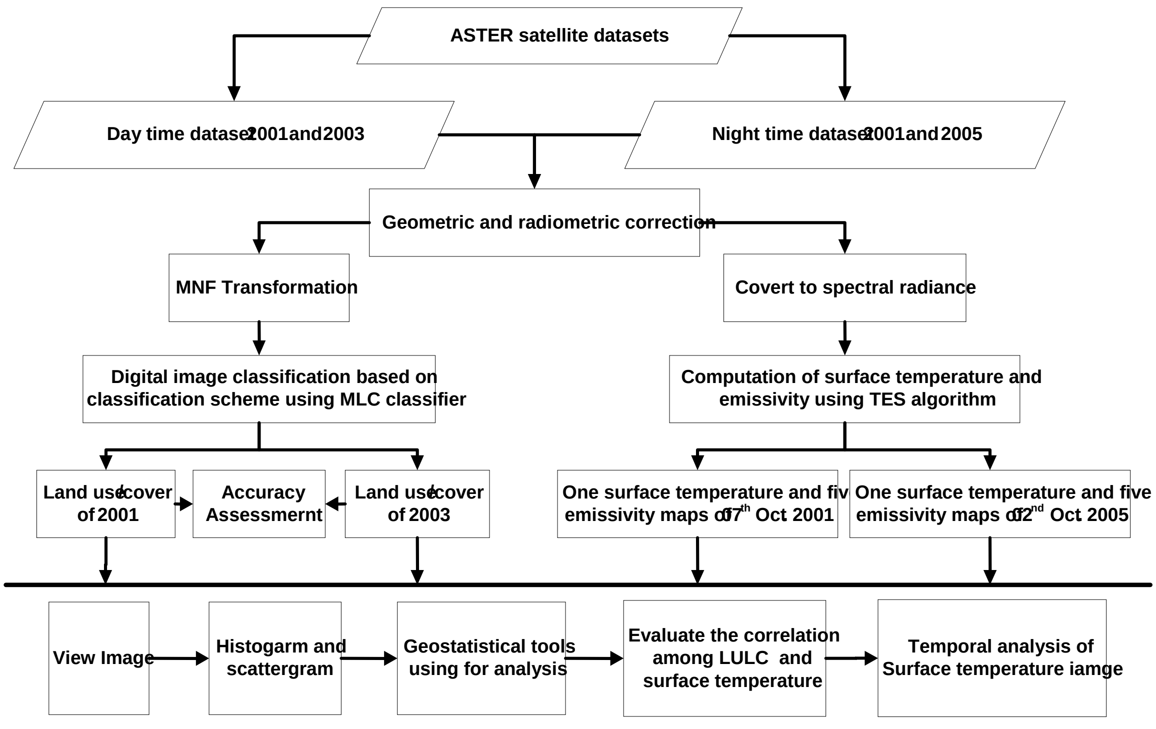


Fig 3 Flow chart and methodology and approach flow chart for surface temperature estimation

2.5 Methodology for solid waste, air, waste water and noise pollution

The map of Delhi collected from Delhi Development Authority (DDA) was scanned, geo-referenced using survey of India (SoI) topographical sheets at scale of 1:50,000 and thereafter it was digitized in ArcGIS software. Various thematic layers were generated in GIS environment using secondary data collected from various Government departments like CPCB and MCD etc.

3. Results and discussion

3.1 Demographic profile of Delhi

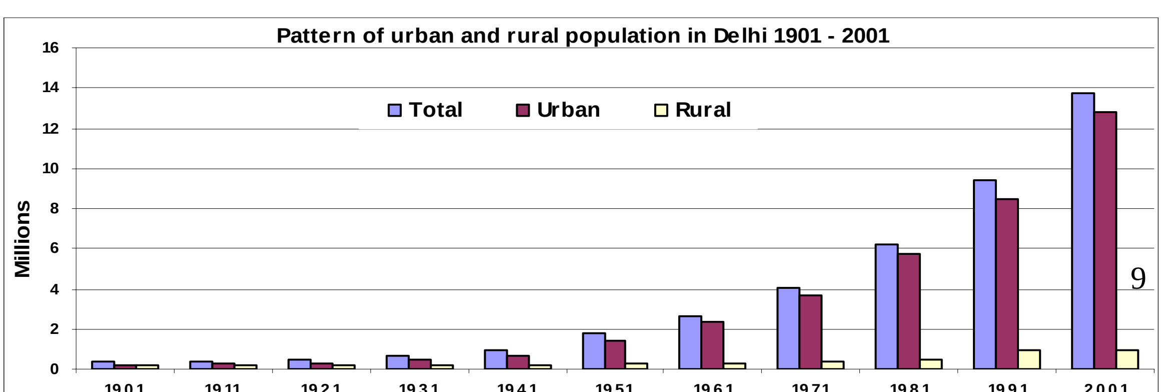
The national capital is attracting people from all parts of India. Delhi is mini India with the largest number of immigrant communities who have made it their home. Every day, 665 persons migrate to Delhi-a number that far exceeds migration to Mumbai (236), Bangalore (165) and Ahemdabad (121) put together (Delhi's First Human Development Report, 2006). Delhi has witnessed a phenomenal population growth during past few decades. From a population of 4,05,819 in 1901, it increased to 13,782,976 in 2001. Since 1951, the population of Delhi has been increasing at an average rate of about 46% every decade (table 2).

Table 2 District-wise area and population of Delhi during 1991 to 2001

District	Area (km^2)	% Area to total area of State	**1991**			**2001**			Decadal growth 1991-2001
			Population (In lakhs)	% to Population of State	Density (pers./ km^2)	Population (In lakhs)	% to Population of State	Density (pers./ km^2)	
North-West	440	29.7	1,778,268	18.88	18,088	2,847,395	20.66	29,395	60.12
South	250	16.9	1,502,878	15.95	26,261	2,258,367	16.38	25,760	50.27
West	129	8.7	1,434,008	15.22	15,986	2,119,641	15.38	22,637	47.81
North-East	60	4.05	1,085,250	11.52	11,116	1,763,712	12.8	16,431	62.52
South-West	420	28.3	1,084,705	11.51	11,471	1,749,492	12.69	12,996	61.29
East	64	4.31	1,023,078	10.86	6,012	1,448,770	10.51	9,033	41.61
North	60	4.05	688,252	7.31	4,042	779,788	5.66	6,471	13.30
Central	25	1.68	656,533	6.97	4,791	644,005	4.67	4,909	-1.91
New Delhi	35	2.36	167,672	1.78	2,583	171,806	1.25	4,165	2.47
Total Delhi	1483	100.00	94,20,644	100.00	6352	137,82,976	100.00	9,294	46.31

Source: Census of India 1991 & 2001

In the 1901 Census, more than 47.34% of Delhi's population lived in rural areas which showed a gradual decline 17.60% in 1951 to 6.99% in 2001. Urban population has increased rapidly since 1911 when the capital of India was sifted from Calcutta (presently Kolkata) to Delhi. The pace of urbanisation was accelerated during 1941-51 when the country was divided into India and Pakistan and a large number of migrant settled in Delhi. With rapid urbanisation, the rural area is shrinking; it has reduced to 591.91 km². (2001) from 1157.52 km². (1961), but urban population kept on increasing and it reached to almost 14 million in 2001 (fig.5). In 2001 the population density was 14,387 and 1,627 persons/km^2 in urban areas and rural areas respectively. Villages of Delhi, which have coexisted with the sprawling urban settlements, still retain a great deal of rural tradition.



The rapid urbanisation has led to the development of new settlements colonies in Delhi. These settlements are categorised by DDA in terms of civic infrastructure, types of houses, authorised, unauthorised settlement, unauthorised-regularised colonies, *Jhuggis* and *Jhoparis* (informal) resettlement colonies etc. More than three people are residing in a single room, is the same condition for 56% of the population of Mumbai followed by 43% population of Kolkata, 30% population of Chennai and 25% population of Delhi. The Master Plan of Delhi 2001 suggested that 1.61 million new dwelling units should be made available during 2001 because housing demand is expected to increase further. The shortage of housing coupled with large influx of migrant population leads to unplanned city's expansion and change in land use/land cover over period of time.

3.2 Land use/land cover change detection

IRS-1C, LISS-III MSS and PAN merged data products has been very useful in urban analysis and urban land use/land cover mapping (NRSA, 2005). Digital mapping technique can be applied for information generation and making an up-to-date urban information (Rathi et. al. 1999). Land use/land cover maps were produced from Landsat TM and IRS 1C LISS-III satellite images of 1992 and 2004 respectively and expansion of Delhi was mapped from 1992 to 2004. The study shows that out of 1,48,312 hect. total geographical area of Delhi aagriculture constitutes 65,114 hect. in 1992 and that declined to (12%) 54,153 hect. by 2004. The major cause of this unprecedented decline in area under agricultural use was due to increase in urban area (table 3 & fig. 6). At the same time high dense residential area get more than doubled in the last twelve years. That is mainly at the cost of high fertile agricultural land (plate 1). Similarly land transformation has taken place all around Delhi in the fringe areas especially in East, South-West and North districts of Delhi. Medium and low dense residential areas have decreased at the cost of high dense residential areas. That means the areas with low built up in 1992 has been converted into densely built up in 2005. The Delhi ridge which once considered being the lungs of Delhi is fast degrading. There is considerable decrease in the ridge area 6.69% in 1992 to 5.52% in 2004 because there is continuous illegal tree cutting, quarrying and construction activity is going on especially in the S-E around Vasant Vihar, Vasant Kunj area and many more areas.

Table 3 Land use/land cover change in Delhi during (1992-2004)

	1992		**2004**	
Land use/land cover	**Area (Hect.)**	**Area (%)**	**Area (Hect.)**	**Area (%)**
Highly dense residential	15,348.87	10.39	34,123.04	22.95
Medium dense residential	12,039.75	8.15	10,706.75	7.20
Low dense residential	10,661.80	7.22	10,324.30	6.94
Rural settlement	1,457.07	0.99	2,773.80	1.87
Commercial	396.87	0.27	527.86	0.36
Airport	2,261.67	1.53	2,160.02	1.45
Institutional	1,718.19	1.16	1,951.32	1.31
Industrial	689.68	0.47	576.03	0.39
Parks and Zoo	1,650.91	1.12	1,429.43	0.96
Stadium and playground	241.07	0.16	383.22	0.26
Historical monument	1,280.43	0.87	1,293.94	0.87
River	1,728.60	1.17	1,075.87	0.72
Drainage	920.31	0.62	1,088.40	0.73
Water body and reservoir	183.97	0.12	189.08	0.13
Canal	142.95	0.10	185.70	0.12
Agricultural land	65,114.21	44.89	54,152.63	36.94
Scrub land	3,521.43	2.52	3,615.58	2.43
Forest	2,331.06	1.58	2,127.34	1.43
Ridge	9,874.87	6.69	8,211.81	5.52
Pasture land	3,286.05	2.23	554.25	0.37
Urban agriculture	8,102.82	5.49	4,755.28	3.20
Riverine green	177.41	0.12	164.48	0.11
Open land	3,507.95	2.38	5,338.12	3.72
Total	**1,48,375.70**	**100.00**	**1,48,375.70**	**100.00**

Plate 1 Encroachment of built up area on productive agricultural lands

Land use/land cover change in Delhi during (1992-2004)

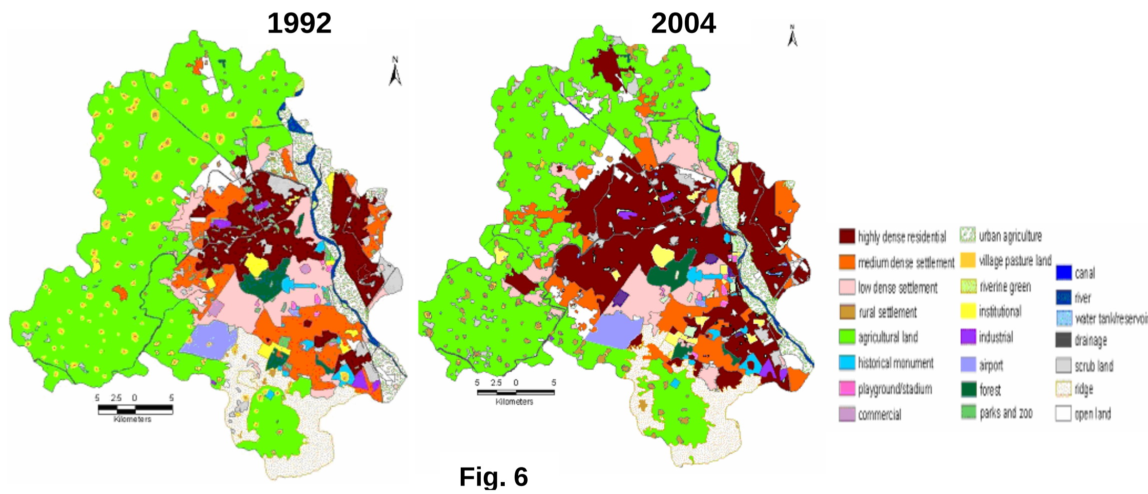


Fig. 6

3.3 Surface temperature assessment

Studies have been done on the relative warmth of cities by measuring the air temperature, using meteorological data since this method is time consuming and it lead to problems in spatial interpolation. Hence satellite borne instruments can provide quantitative physical data at high spatial or temporal resolutions and repetitive coverage is capability of measurements of earth surface conditions (Owen et al., 1998). Temperature data, derived from Landsat ETM$^+$, Vegetation Index (VI) derived from high resolution IKONOS multi-spectral images, digitized data of the city urban infrastructure and 3-D virtual reality models were integrated to assess urban environment quality of Hong Kong (Nichali et. al. 2004). Infrared remote sensing satellite is now being used in estimating the surface physical properties and variables Owen et al. (1998), and Voogt and Oke (2003). For the estimation of surface temperature, derivation of surface emissivity is important. Since the study area is heterogeneous one, hence estimation of surface emissivity at pixel scale was calculated. In the overall determination of surface temperature using LANDSAT-7 ETM+ thermal channel (10.4 - 12.5µm), it would give more accurate values if the emissivity values are obtained for thermal band (b6) from the emissivity determined in 8-14µm wavelength band region.

Figure 7 shows night time surface temperature using ASTER satellite data of 7th Oct. 2001 at 22:35 Hrs. (local time). The estimated surface temperature ranges from 23.90 to 40.01°C (mean temp. 31.40°C). It is observed that in the image, central and eastern part exhibits maximum surface temperature range that corresponds to built-up areas (32 to 36°C). The study shows that some parts of north-west have lower surface temperature corresponding to wasteland, bare soil and fallow land. Water bodies exhibit maximum surface temperature during night due to high thermal capacity. Table 4 shows the surface temperature statistics of night time data over fallow land is (27.44 to 31.27°C), followed by dense vegetation (28.01 to 33.90°C). The highest surface temperature is observed in high dense built-up (31.48 to 36.56°C), followed by water bodies (29.36 to 37.54°C), and low dense built-up (28.15 to 35.86°C). Fallow land and waste land/bare soil due to low thermal capacity cools down faster than other land use/land cover features. Hence fallow land, waste land/bare soil and sparse vegetation is cooler as compared to other land use/land cover features during night time.

Figure 7 further shows that the night time surface temperature using ASTER satellite data of 2nd Oct. 2005 at 22:35 Hrs. (local time). The estimated surface temperature ranges from 26.93 to 38.88°C (mean temp. 32.66°C). It is observed that in the image, central and eastern part exhibits high surface temperatures, corresponding to high dense built-up areas. It is observed that some parts of north-west, north-east and extreme southern part of the image have lower surface temperature corresponding to agricultural cropland, waste land/bare soil and fallow land. Surface temperature over water bodies ranges between 33.01 to 36.00°C during night due to high thermal capacity. Furthermore table 4 shows that during night time over high dense built-up areas, higher surface temperature (34.82 to 36.41°C), was recorded followed by water bodies (33.85 to 36.15°C), commercial/industrial (32.70 to 34.99°C), and low dense built-up (31.89 to 34.65°C), while fallow land, dense vegetation, agricultural cropland and sparse vegetation shows lower temperatures. It is observed that the thermal gradient during night time decreases from high dense built-up to fallow land. Fallow land, wastes land/bare soil and agricultural croplands are cooler as compared to other land use/land cover features during night time due to lower thermal capacity.

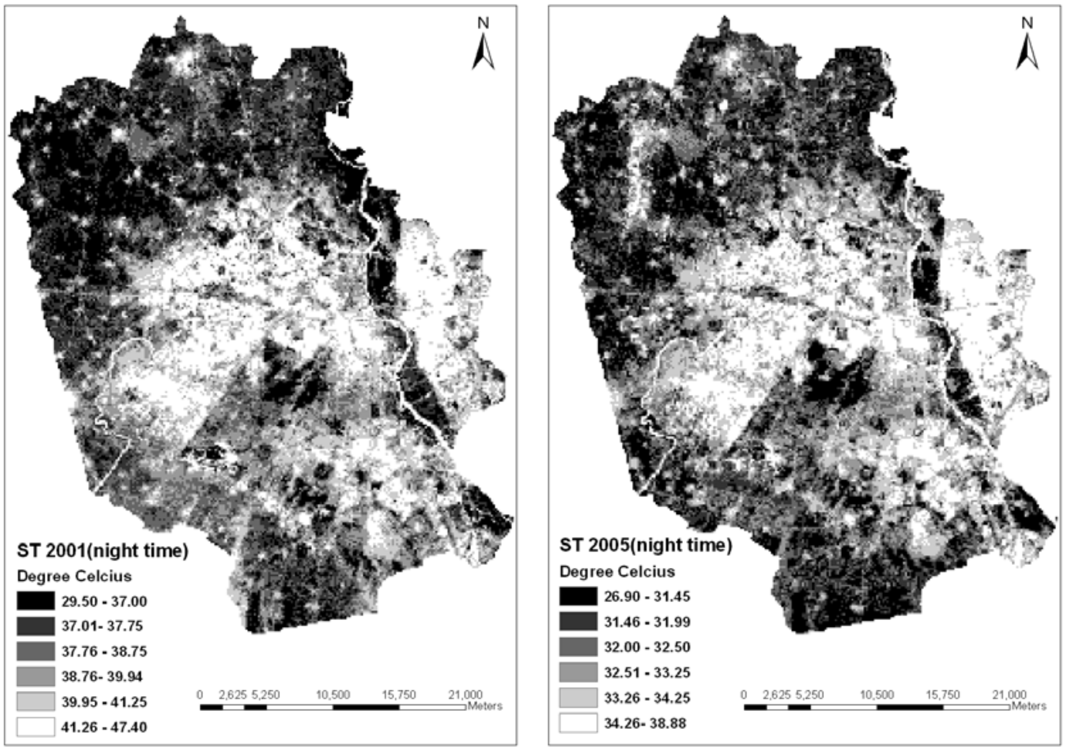


Figure 7 Spatial distribution of night time land surface temperature from ASTER data, 7th Oct. 2001 & 2nd Oct. 2005

Table 4 Comparison of satellite derived night time surface temperature with field measurement

Features	***In the field Observation on 3rd Oct 2005 (21.30 to 23.00 local time) in °C**	**Satellite observation**		**UTM Coordinates (m)**
		ASTER of 07th Oct 2001 (22.35 local time) in °C	**ASTER of 02nd Oct 2005 (22.35 local time) in °C**	
Vegetation	28.50	29.64	31.10	718935/3159479
Vegetation	29.00	30.25	31.30	719570/3169243
Vegetation	29.30	30.67	31.47	718365/3167032
Vegetation	28.00	28.95	30.20	717613/3160398
Average	28.70	29.88	31.02	-
Bare soil	28.50	30.88	31.35	700395/3158756
Concrete (URBAN)	30.10	31.90	32.96	719871/3168740
Concrete (URBAN)	28.30	31.42	32.34	717811/3169012

*This measurement is the mean value 5 to 10 reading

The study clearly reflects that the surface temperature has increased during 2001-2005. On vegetative surface, bare soils and concrete surface the increase of temperature is in tune of nearly 1°C (table 4). This shows that due to pressure of population on one side built-up area is increasing and on the other vegetative area/agricultural land is decreasing that leads to increase in the surface temperature over different land cover classes.

3.4 Solid waste management

In India increasing level of solid waste generation and its management is nowadays a serious problem in the urban areas. High growth rates of population and increasing per-capita income have resulted in the generation of enormous solid waste posing a serious threat to environmental quality and human health. Urban solid waste includes garbage or refuse discharged from residential, market, institutional and industrial activities. India produces about 75 million tones of waste every year, out of which in urban areas 40-50% remains uncollected. The quantity of solid waste generated depends on a number of factors such as food habits, standard of living, and the degree of commercial activities. In 1999 the estimated quantity of garbage generated in Delhi was 8,203 million tons (MT) based on 0.61 kg/capita per day against which only 4885 MT is properly dispose of. However present consumption patterns are indicative of an increase to 11,899 MT and 13,616 MT by 2011 leaving a gap of about 40%. The quantity of solid waste substantially increases during the monsoon because the moisture content increases.

Remote sensing data can be an aid in identification and location of garbage dumping sites and in monitoring the changes in the land use within and near hazardous waste and sanitary landfills (Radhakrishnan, 1996). Land use/land cover analysis of a part of Delhi has been carried out using IRS data to analyze feasibility of a suitable site for hazardous waste disposal site in the Delhi’s national capital region, NCR (Javed and Pandey, 2004). In this paper an attempt has been made to asses the garbage generation and identification of hot spots using GIS and GPS. Table 5 shows Zone-wise solid waste generation and disposal in Delhi during 1996-2005. It is seen that both garbage generation and disposal in the South and East district of Delhi is highest (750 tones/day) and

(528 tones/day) respectively followed by Central Delhi (table 5 & fig. 8) that is mainly because of the high population density in these districts.

Table 5 Zone-wise solid waste generation and disposal in Delhi (1996-2005)

	Zone	Quantity of waste generated/tons/day, (1996)	Quantity of waste generated/tons/day, (2005)	Quantity of waste disposed/tons/day, (1996)	Quantity of waste disposed/tons/day, (2005)
1	City	442.15	522.15	294.84	329.84
2	Civil lines	457.80	537.80	305.76	345.76
3	Shahdara (N)	415.00	485.05	276.64	306.64
4	Shahdara (S)	480.20	566.15	320.32	370.32
5	Sadar Paharganj	403.00	463.00	269.36	299.36
6	Karolbagh	269.37	339.36	269.37	289.36
7	West Delhi	241.62	311.63	241.62	291.63
8	Central Delhi	548.15	620.00	364.00	404.00
9	**South Delhi**	**680.15**	**750.00**	**418.00**	**528.02**
10	Najafgarh	397.15	465.15	265.74	305.72
11	Narela	147.50	207.50	98.28	148.28
12	Rohini	540.10	645.10	426.56	496.56
	Total	5417.61	5922.89	3550.49	4115.49

Source: Central Pollution Control Board, Delhi, 30th Inspection Report (2006)

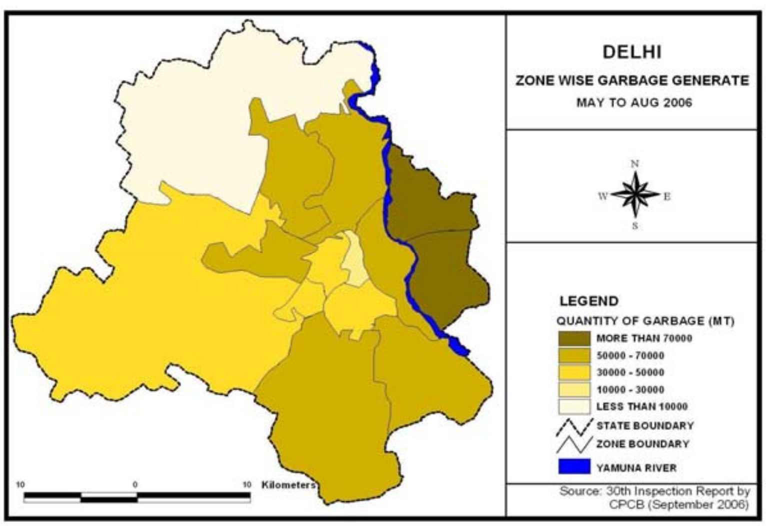


Fig. 8

Figure 9 shows the hot spots which require immediate action with respect to sanitation and maintenance which includes waste receptacles, open dumping of wastes commonly seen along streets, lanes, road divides, footpaths, open ground, open plots, and even in parks. The fig. 9 shows that there are 134 hotspots in MCD zone of Delhi. The hot spots were identified using GIS and GPS field survey in conjunction with survey conducted by central pollution control board (CPCB). Dustbins are very few in number and can't hold enough garbage that is being generated in usually it spills out from bins. So, there is a need to give due care by the municipal authorities.

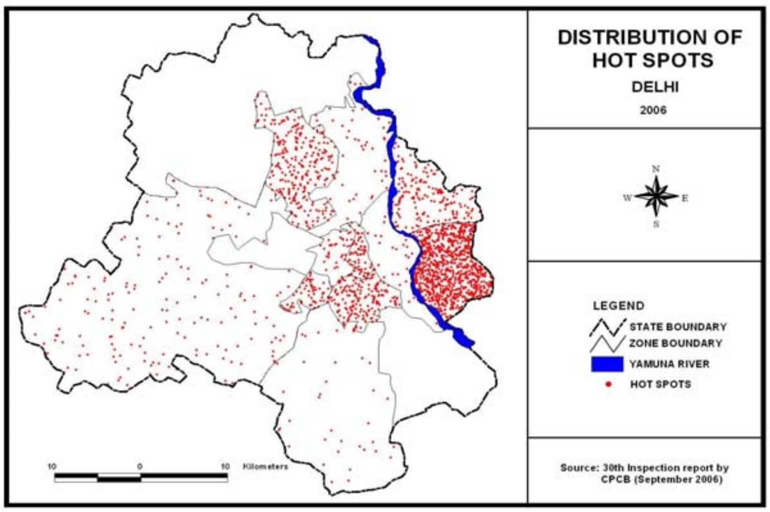


Fig.

3.5 Industrialization and air pollution

In recent times the growth of Delhi is characterized by increase in residential complexes, use of vehicles and rapid industrialization. The deficiencies in both planning and environmental regulations have led to the both health and environmental damages. Apart form being the capital of the country, it has become a centre for the commercial, industrial, social, cultural and educational activities. Figure 10 shows the major industrial areas of Delhi.

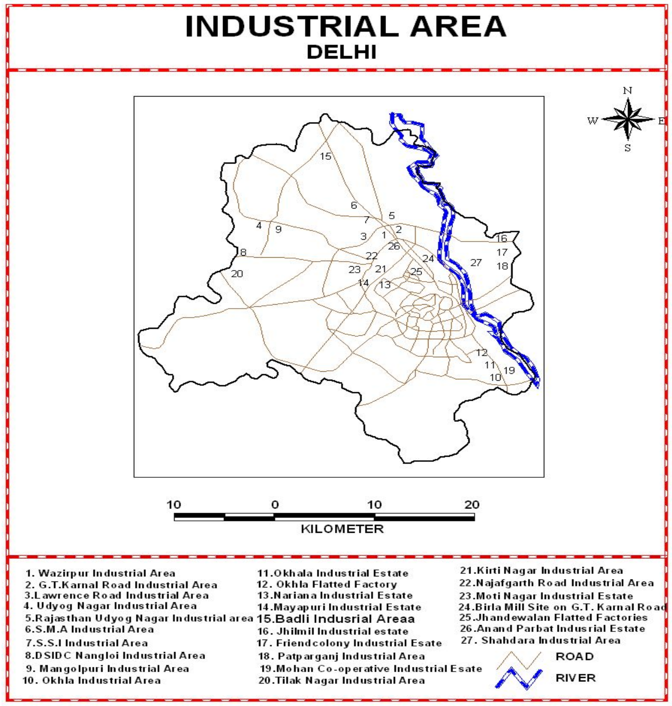


Fig.10

White paper of Government of India on Delhi addresses the state of urban environment of Delhi and worked out for assessing the pollution trends and the prescribed ambient standards (MEF, 1997). Major sources of air pollution in Delhi are vehicles (70%) followed by thermal power plants, industries and domestic coal burring etc. Apart from automobile the two biggest source of air pollution in Delhi are the Babarpur and Indraprastha (IP) thermal power stations (table 6). The 705 MW Badarpur thermal power plant in Delhi alone produces about 4000 tons of fly-ash on daily basis i.e. about one kg. per resident. It can be said today that the city lies under a permanent blanket of smoke, fly ash coats every surface and a good deep breath is likely to wind up a racking cough.

Table 6 Fly-ash generation from the power plants in Delhi

Stations	Capacity	Fly-ash in tonnes/day
Indraprastha (IP)	247.5 MW	1200-1500
Rajghat	135 MW	600-800
Badarpur	705 MW	3500-4000

Source: CPCB, 2006

Normally there is an increase in concentration of all pollutants in ambient air of Delhi except in 2005 where all pollutants has recorded decline (table 7). This is mainly due to the use of cleaner fuels in automobiles i.e. CNG, unleaded petrol, phasing out of more that 8 years old vehicles and various other strict policies of Government as well as the strong action from the judiciary for proper implementation of environmental and transport laws. Figure 11 shows the concentration of CO and SPM which is quite high in most of the districts of Delhi. This is mainly due to again high number of vehicles and as per Economic Survey of Delhi, there were 48,30,136 vehicles in 2005-06 and in one year Delhi adds 3.63 lakh vehicles (The Times of India, 2006).

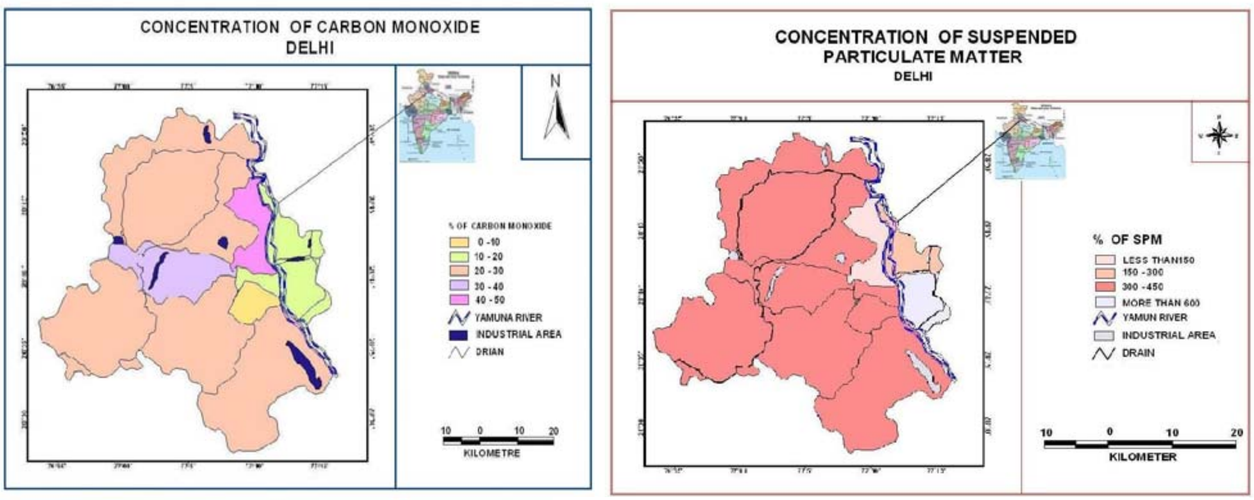


Fig.11

Year	Concentration in ambient air (In ug/m3)				
	SO_2	NO_x	*CO	SPM	RSPM
1999	18.68	44.85	4810	362.58	NA
2000	20.37	42.17	5450	377.92	NA
2001	19.46	40.11	4241	374.92	NA
2002	18.03	71.83	4686	430.83	191.00
2003	14.10	41.75	4183	381.67	150.08
2004	11.33	47.28	3258	455.92	192.25
2005	9.49	45.00	2831	352.30	148.86

Table 7 Year wise annual mean ambient air quality levels in Delhi

Source: Department of Environment, (Govt. of NCT of Delhi) *At ITO intersection

3.6 Water pollution

The river Yamuna covers a 22 km stretch between Wazirabad and Okhla barrage in Delhi which is only 2% of its catchments area, but Delhi contributes about 80% of the river's total pollution load. Nineteen major drains (fig. 12) of Delhi dispose untreated municipal wastewater, approximately 2,871 million litres per day into the Yamuna of which approximately 300 million litres per day are from the industrial sector. Out of this Yamuna River contributes 200 million liters of untreated muck being dumped in it everyday by Delhi's sewerage system that is why it is one of the most polluted rivers in the world (Malik, 2000). The Najafgarh drain alone contributed more than 80% of the waste water entering into the river Yamuna. All this is mainly due to industrialization and increasing population that leads to high discharge of waste water from houses.

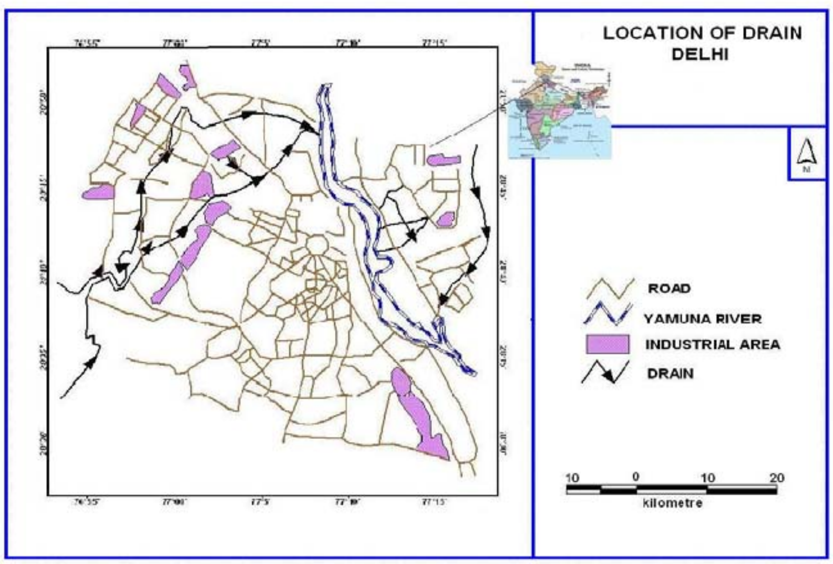


Fig. 12

3.7 Noise pollution

Noise pollution in urban areas is another major cause of concern especially when there is fast increase in number of automobiles. There are many sources of noise pollution In Delhi and most of it is associated with development of roads, air and rail transport and increase in number of industries. Some activities associated with urban living also lead to increased noise levels. Three wheelers, trucks and motorcycles remain the chief source of noise pollution on Delhi roads followed by generators in the residential, commercial and industrial locations that is due to short supply of electricity is summer season. The main industrial areas of Delhi are Wazirpur, Mayapuri, Nariana and some others add lots of noise pollution to the city environment. The effects of urban traffic on environment in terms of population affected by air and noise pollution, using predictive and dispersion models in a GIS environment in Jaipur was studied using IRS-1C LISS-III FCC and PAN data of 1998 (Maithani. et. al., 2002). This paper also addresses the noise pollution variation in Delhi using GIS software with the help of data colleted from CPCB. Figure 13 shows noise pollution level during day and night time. It is seen that most of the district of East and South are recording more than 90 db noise levels but during night time the level of noise goes below 90 db in almost all the districts except in one. The situation is more serious when we examine the noise level during peak hours. Almost all the districts of Delhi recorded more than 93 db noise level which is beyond the permissible limit of 80 db during day time. This high level of noise pollution has many adverse health effects on human e.g. hearing loss and heart stroke etc. So there is an urgent need to put strict regulation to reduce the level of noise in Delhi.

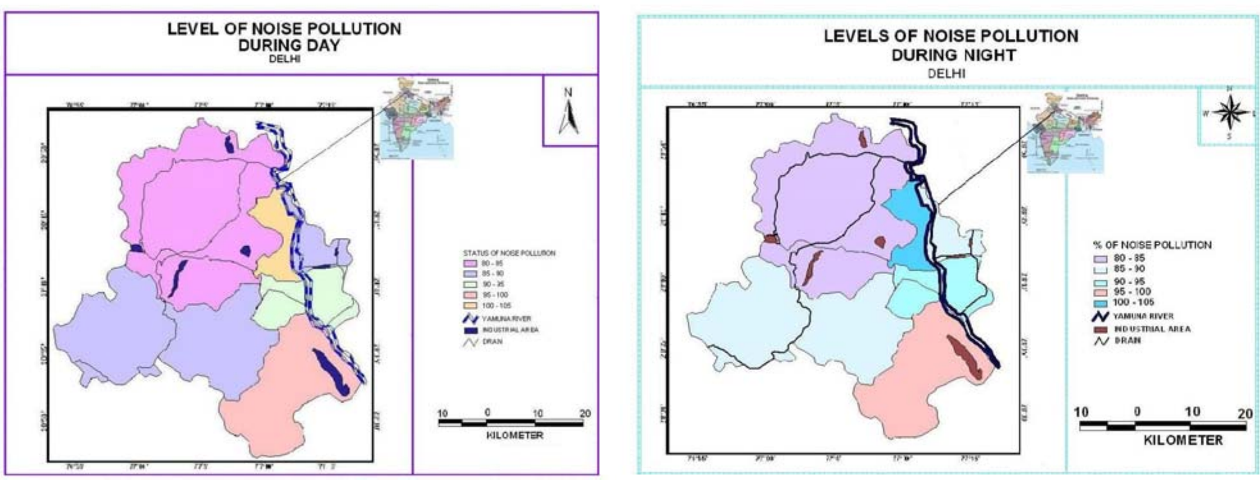


Fig. 13

4. Conclusion and suggestions

The critical issues and challenges of development and management for growing urban centres like Delhi, Mumbai and Kolkata etc. have been the subject of extensive discussions and debates in recent years. The major problems associated with the urban centre in India is that of unplanned expansion, changing land use/land cover, loss of productive agricultural land increase rainfall runoff and depletion of water table etc. It is evident from the foregoing study that major urban environmental problems occur due to high population growth (46.31%) during (1991-2001), uncontrolled and mismanaged urban expansion densely built up area has been more than doubled (122%) during last decade in Delhi. There is obvious reduction (16.8%) in agricultural land because of urban expansion in the fringe areas. Pollution load in terms of air, water, noise, and solid waste generation and disposal etc. has also increased considerably. Management of huge garbage and solid waste including medical waste is very difficult that create unhealthy scene in urban areas. So, remote sensing satellite, with repetitive and synoptic viewing capabilities together with GIS is an important tool to map, assess and monitor the changes in the land use/land cover. High-resolution satellite imagery (IKONOS, Quick Bird) can be used to monitor the urban expansion and illegal housing constructions over a period of time and to find out the potential waste disposal sites for solid waste management. Thermal infrared (TIR) satellite data can be used to assess the so-called ‘urban heat island’, surface temperature and areas with high atmospheric pollution. The thermal satellite data of Delhi clearly shows that there 1-2°C increase in surface temperature in just 4 years that is a subject matter of concern. A database generated from remote sensing imageries in DIP software and thematic maps prepared using socio-economic data in GIS environment could be helpful for sustainable development, planning and good governance of Delhi and some other cities as well.

To fight with the problems of environmental degradation and to meet the challenges of sustainable development, it is suggested that the use of remote sensing and GIS in conjunction with geospatial data is of vital importance.

Therefore, there is need for the use of urban information database that can be generated using remote sensing data and GIS techniques. Top priority should be given to the issues related to the planed development of the city, reduction in atmospheric pollution and traffic congestion etc. The administrative, technical, and managerial people of the urban local bodies (ULBs) need to be strengthened. The official of various government departments should be given thorough exposure and training of remote sensing and GIS for its application and implementation in the urban environmental management plans. The problems and challenges faced by mankind are of national level but it has to be dealt at the local level. So, it can be seen from the foregoing study that the deterioration of urban environmental quality is mainly because of growing population that can be effectively monitored and assessed by using geo-spatial tools.

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