Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 4, Issue, 07, pp.121-126, July, 2012

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

INTEGRATING GEOSPATIAL TECHNOLOGY AND POPULATION CENSUS DATA FOR CITY MANAGEMENT: CASE OF KANPUR CITY, INDIA

***Nina Singh and Jitendra Kumar**

Department of Geography, Faculty of Social Sciences, Maharshi Dayanand University, Rohtak, India

ARTICLE INFO

Article History:
Received 14th April, 2012
Received in revised form
17th May, 2012
Accepted 25th June, 2012
Published online 30th July, 2012

Key words:
Thematic Mapping;
NUIS;
Geospatial Technology;
Geodatabase;
Census Data;
Urban Agglomeration.

ABSTRACT

Urbanization is inevitable and irreversible. In India, more than two-fifths of the total 377 million urban dwellers inhabit 53 metropolitan cities as per 2011 census. This is radically transforming the urban environment of metropolitan areas in the country creating social and environmental problems in the condition of inadequate provision of basic infrastructure for sustenance and proper housing at affordable cost. All this has made the cities mismanaged. A rapid impetus and thrust is required for the development of urban areas on sustainable basis to meet the increasing demand of urban population for housing, infrastructure, civic amenities and green space without comprising the natural resources' assets and quality of life. It is proposed that the urban landscape and human environment be studied by integrating satellite imagery with population census data to support research and planning efforts related to land development and conservation. The idea is reinforced taking Kanpur, the largest urban agglomerations of Uttar Pradesh among cities with at least million population, as a case study. High resolution of Cartosat-1 (PAN image), LISS-IV (MX) satellite, Census Data, Toposheets at scale of 1:50,000, Municipal Corporation map of Kanpur city 2005-06 and Kanpur City Development Plan, 2006 have been used for meaningful analysis. Satellite data have been used for the land-use/land cover classification of Kanpur city, based on NUIS Manual, 2008 which provides the geographic understanding of the city and a key aspect to provide the base for the city management.

INTRODUCTION

The global population is increasingly concentrating in cities. Metropolitan areas in India too are growing at unprecedented rates, creating extensive urban landscapes. 377 million people translating into 31.16 percent live in urban areas in India, as per 2011 Census. As a result, the urban areas face many challenges — economic, social, health and environmental. Many of the farmland, wetland and forest area are transformed into human settlements. It is an accepted fact that a relationship exists between the shape, size, density and uses of a city and its sustainability (Williams *et al*. 2001). The latter has emerged as a major concern as uncontrolled and unplanned development and expansion of the city is a constant threat on environment and quality of life. Kanpur metropolitan area too faces the growing problems of unregulated, unplanned urban development leading to urban congestion, lack of adequate infrastructure and civic amenities, urban sprawl, loss of natural vegetation and environmental degradation. Efficient characterization of the urban environment provides the base for urban planning and decision making and thus facilitates the study of city management. Geo-spatial technologies (GST) provide a flexible environment for entering, analyzing, and displaying digital data from various sources necessary for urban feature identification, change detection and database development. The 21st century has seen a combination of remote sensing and GIS technologies largely used in urban analysis at different scale such as urban growth and its impact on cityscape (Bhatta, 2009), urban growth and city planning (Pham *et al*., 2011), housing growth (Syphard *et al*., 2009), urban vulnerabilities (Bhattarai *et al*., 2010), pockets of urban poverty (Hall *et al*., 2001), detecting slums (Rhinane *et al*., 2011), urban infrastructure planning (Mendes and Lorandi, 2010), urban transport (Zeng, *et al*., 2010), population estimation (Wang and Wu, 2010 and Lu *et al*., 2007) and for sites and characterize landscape (Parrish, *et al*., 2011).

Integration of geospatial technology and census data creates a comprehensive database to assess the urbanisation and quality of life (Weng *et al*., 2007; Rahman *et al*., 2010 and Rao, *et al*., 2012), socioeconomic analysis (Banerjee *et al*., 2002), policy issues (Leipnik *et al*., 2011), land use, land development and urban sprawl (Martinuzzi *et al*., 2007) and exploring the spatial relationship between census and land cover data (Radeloff *et al*., 2000) which provide a wide range of demographic and socio-economic information, and are used in racial and ethnic diversity research (Frey, 2001), urban planning and management. This technology thus constitutes a paradigm shift in the way both consumers and professional

Corresponding author: ninasingh99@gmail.com

decision makers such as engineers, urban planners and researchers address urban problems.

Study Area: Kanpur City

Known to the world as Cawnpore during British rule, it was spelled and re-designated as Kanpur after Independence. The city had become an important centre during the great revolt of 1857 because of its military importance. Formerly known as Manchester of the country and now also called the commercial capital of the state, the city's journey to its current status has been long. It has expanded physically, demographically and economically. The city is located at the intersection of $26^0 27'31"$ N latitude to $80^0 19'14"$ E longitude. Topographically, it is a flat land and located mainly on an alluvial terrace, popularly known as Ganga Plain. Kanpur city is linear in shape having grown along the River Ganga on the right and River Pandu on the left. Many national highways 2, 25 and 34 and 86 cris-cross the city depicting its importance. It is well-connected with other cities by rail and road network.

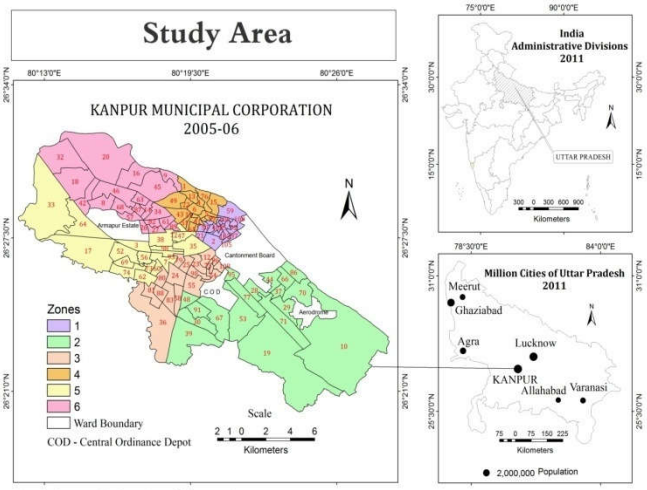

Fig. 1. Geographic location of Kanpur city.

Data source and methodology

High resolution satellite remote sensing image is best suited for mapping urban land-use information on account of high geometric fidelity, clarity of objects, features in their true shape and size, better contextual clarity and interpretability with close proximity to the real world (NUIS, 2008). Therefore, geo-referenced image of Cartosat-1 (2.5 meter), LISS-IV (5.8 meter) and fused image (Cartosat-1+LISS-IV with 2.5 meter resolution) data has been used for the analysis of present study. Other spatial and non-spatial data used for the conduct of present study includes: Topographical sheets No. 63B2, 63B3, 63B7 and 63B8 at scale of 1:50,000, Municipal corporation map of Kanpur city 2005-06, Primary Census Abstract and Town Directory, 2001, Census provisional population total, 2011 and Kanpur city development plan, 2006. ERDAS 9.0 and ArcGIS 9.3 software have been used for the study.

First, the georeferenced Kanpur municipal corporation boundary is extracted from the Kanpur Nagar Nigam map of 2005-06 which is divided into six zone and 110 wards. Second, the geo-referenced municipal corporation boundary overlaid on the satellite data communicates the spatial extent

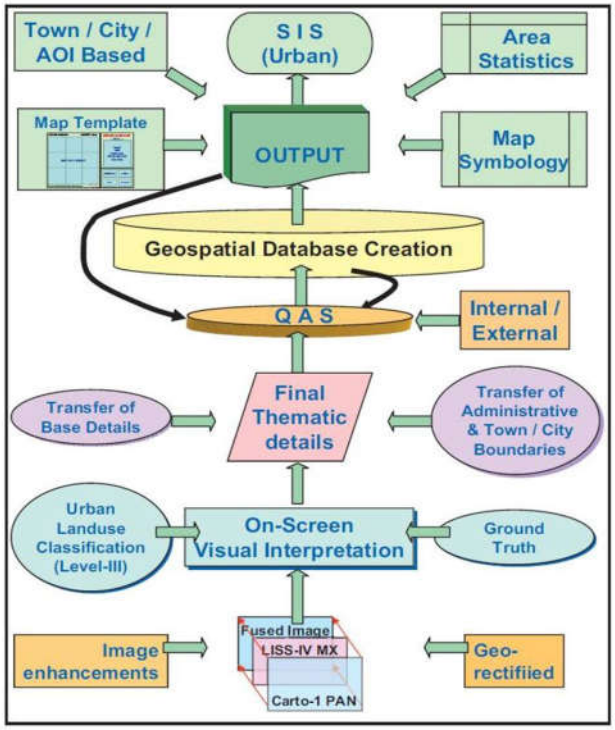

Fig. 2. Methodological Flow chart adopted form NUIS Manual, 2008

Level – I	Level - II	Level – III
Built-up	Built-up (Urban)	Residential Area, Industrial Area, Recreational Area, Vacant Land, Transportation and Communication, Public and Semi-public Area, Public Utilities and Facility, Commercial Area,
	Built-up (Rural)	
Agriculture Land	Crop Land, Fallow Land, Plantation/orchard	
Forest	Dense Forest, Open Forest, Plantation, Mangroves	
Wastelands	Salt-affected, Gullied/ Ravinous, Land with/without scrub, Barren/Rocky, Sandy Area	
Wetlands	Marshy/Swampy, Mudflats, Waterlogged Salt pans	
Water bodies	Canal, Lakes/Ponds, Cooling Pond, Reservoirs, Tanks,	
Others	Quarry / Brick Kilns, Dam / Barrage, Coral reef /Atoll	

Source: Adopted from NUIS Manual, 2008

of the Kanpur city and maps the different land-use/land cover thematic layers (Figure 3) at third level (Table 1) which is based on National Urban Information System (NUIS) Manual, 2008. Third, additionally (from Table 1) slums, planned and unplanned area thematic layers also have been created for the Kanpur city geodatabase. The area which are highly congested, small sized dwelling units with plastic/tin/mud roof usually square or rectangle temporary structure mostly located in marginal areas such as along line, drainage network, inner core areas and near industrial set-up are identified as slums with the help of Google Earth image. Figure 7 shows the integration and process of creating final thematic layers of slums area. Planned areas are identified as those which have regular pattern and those which have irregular pattern are identified as unplanned. Quartile method has been used for the categorisation of data such as population density and slum density. Online Google earth image and Google map were used for better analysis of visual interpretation. GPS survey was conducted for the ground truth which supports the verification of doubtful points and accuracy evaluation. The analysis is based on using the relevant data for Kanpur Municipal Corporation only. The constituent units that otherwise form parts of urban agglomeration have been excluded.

Objectives: The present study aims to make an application of population census data and geospatial technology:

- to study existing land-use pattern resultant upon urban growth and develop a geospatial database for various levels of urban planning like master and zonal plan,
- to integrate geospatial technology and census data using data of residential population density and slum population at micro level and make a case for the upgradation of such areas.

Land-use/ land cover analysis: a special focus on residential land use and slums

Kanpur municipality came into existence on 22nd November 1861 recognized first under the Act XX of 1856. It became a Municipal Corporation in 1959 and urban agglomeration in 1981. It had attained the status of a 'million city' in 1971.The constituent units of the Urban Agglomeration according to the Census, 2011 are: Kanpur Municipal Corporation, Rawatpur Station Yard, Central Railway Colony, Kanpur Cantonment, Armapur Estate, Northern Railway Colony and Chakehri. Together these units account for a population of 2.92 million spread over an area of over 260.21 km^2. 27,67,031 persons are residing in Kanpur Municipal Corporation occupying 230 km^2 area, and the remaining 1,53,036 in other constituent units. In terms of percentage these are 94.76% and 5.24% respectively. Although the city's population growth rate has been on the decline since 1951, it is the largest urban agglomeration of the seven million cities in Uttar Pradesh in 2011and 12th largest urban centre of India. Presently, the city alone contains 6.57 percent of the total urban population of the state. There has been a decline in new industrial investments and no significant change in the employment in defence establishments. The lack of economic drivers of change partially explains the decline.

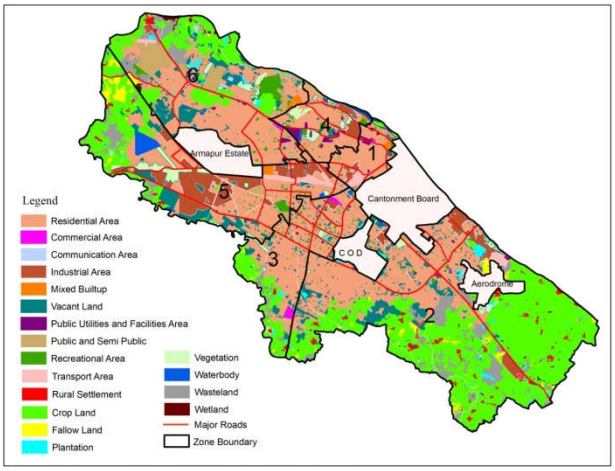

Fig. 3. Land use/land cover of Kanpur municipal corporation, 2006.

The population of Kanpur Municipal Corporation has increased 3 folds with an absolute increase of 1.88 million during 1961-2011 although its areal jurisdiction has remained constant since 1961. As a natural outcome, population density

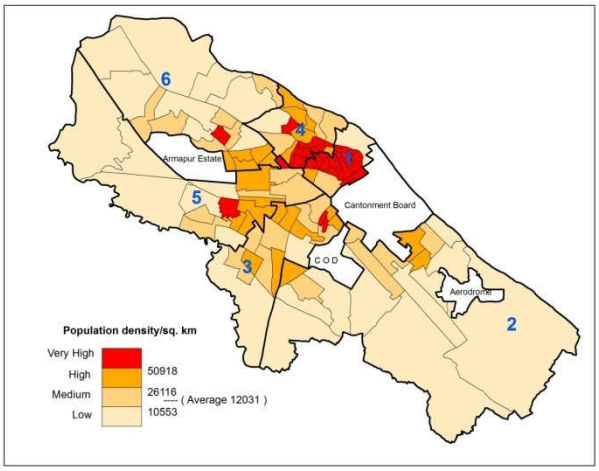

Fig. 4. Ward-wise population density of Kanpur municipal corporation, 2001.

has increased from 3,843 to 12,031 persons per km^2. Despite a slow population growth rate the addition of 2,04,512 persons during 2001-11 is large since the base is substantial. This has implications not only for providing urban infrastructure and civic amenities, but also for reproductive and child health services in urban areas. Administratively, the Kanpur Municipal Corporation (KMC) is divided into 6 zones and 110 wards. All the zones except No. 6 have 18 wards each. The zones vary considerably in area size ranging from 7.67 km^2 in Zone 1 to 93.83 km^2 in Zone 2. 67.01% of the total area of the former is used for residential purpose in comparison to the lowest 28.82% in Zone 2. More than 70% residential areas are unplanned in Zones 1, 2, and 4. Zones 1 and 4 are small in size, largely unplanned, contain very high general residential and slum population density. 35% of the cities' population resides in 7.7% area of these zones. On the other hand, 93.83 km^2 i.e., 40.9% of the total area of the municipal corporation is comprised of Zone 2, which supports a large number of rural settlements along with agricultural area. A number of rural settlements have also increased the area under unplanned category. The unplanned residential area has high density of population and slum pockets located near the industrial area. This is in contrast to other zones like Zone 5 where nearly 2/3rd of the residential area is planned. Also the areas of high density are planned although this zone too is interspersed with slums. In addition, it comprises of area under industrial use, transport, vacant land and vegetation. The other zones fall in between.

The present status of land-use/land cover of Kanpur city is evaluated by visual interpretation of satellite data. It is revealed that the city and particularly the residential areas have not expanded in a planned way. The high proportion of unplanned residential area depicts states' apathy towards planning. Nearly 2/3 area in the outer city and majority percent area in inner core is unplanned. The outer city has more unplanned area in the residential category. It is obvious the state government did not initiate planning of the city land, primarily agricultural, which had been incorporated within the city boundary as far back as 1961 and left it to the market forces. Unplanned development in the city is a severe threat to its ecology and environment. The most dominant land use category is residential closely followed by agricultural land. Both these categories comprise nearly 70% of the total land use. These are followed by vacant land (7.10%), industrial area (6.86%) and transport (2.87%). Residential area spreads

Table 2: Zone-wise Area Configuration and Slum Related Indicators

Zone	Area in km^2	Wards containing slums		Urban population	Slum population	% Slum population	% area for residential use
1	7.67	11	(18)	402625	62820	15.60	67.01
2	93.83	9	(18)	364722	35438	9.72	28.82
3	24.57	14	(18)	395252	70239	17.77	65.32
4	11.04	9	(18)	490989	67307	13.71	55.71
5	45.64	13	(18)	482473	66738	13.83	31.66
6	47.30	15	(20)	415276	65438	15.76	42.85
Total	230	71	(110)	2551337	367980	14.42	38.73

Source: Computed from Kanpur Nagar Nigam Map 2005-06, Census of India, 2001. Slums Data-II, (Ward-wise data of Metropolitan Cities), New Delhi, Cartosat-1 (PAN) and fused image (Cartosat 1+LISS-IV), 2006; Note: Figures in parentheses indicate number of wards

Table 3: Residential Area Organization and Population Density

Zone	Residential area in km^2			Percent area		Urban population	Residential population density persons/ km^2
	Planned	Unplanned	Total	Planned	Unplanned		
1	0.33	4.81	5.14	6.49	93.51	402625	78330
2	6.47	20.57	27.04	23.93	76.07	364722	13490
3	7.39	8.66	16.05	46.03	53.97	395252	24621
4	1.83	4.31	6.15	29.84	70.16	490989	79890
5	9.41	5.04	14.45	65.11	34.89	482473	33388
6	9.06	11.21	20.27	44.69	55.31	415276	20491
Total	34.49	54.6	89.09	38.71	61.29	2551337	28637

Source: Computed from Census of India, 2001. Slums Data-II, (Ward-wise data of Metropolitan Cities), New Delhi and Cartosat-1 (PAN) and fused image (Cartosat 1+LISS-IV), 2006.

Table 4: Land-use/land cover statistics of Kanpur Municipal Corporation

Land-Use Category	Area in km^2	Percent of Area
Residential Area	83.42	36.27
Industrial Area	15.78	6.86
Public and Semi Public	3.89	1.69
Commercial Area	2.70	1.17
Mixed Built-up	3.10	1.35
Recreational Area	3.32	1.44
Communication Area	0.23	0.10
Public Utilities and Facilities Area	1.18	0.51
Vegetation	3.13	1.36
Vacant Land	16.33	7.10
Transport	6.60	2.87
Agricultural Land	74.26	32.29
Waterbody	2.43	1.06
Wasteland	10.38	4.51
Rural Built-up	2.57	1.12
Wetland	0.68	0.30
Total	230	100.00

Source: Computed from Cartosat-1 (PAN) and fused image (Cartosat-1+LISS-IV), 2006.

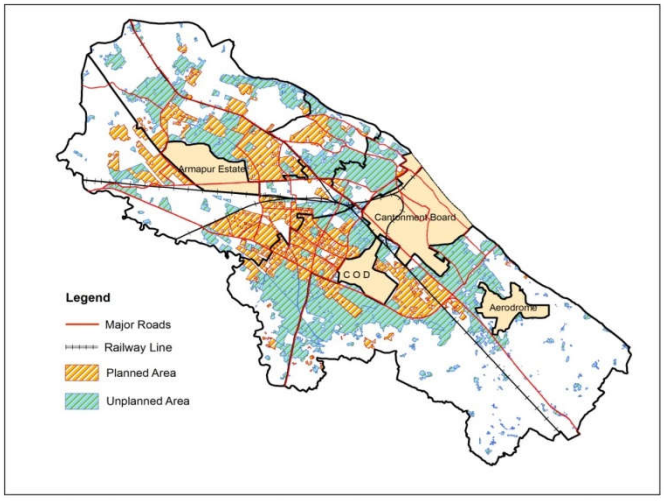

Fig. 5. Planned and unplanned residential areas in Kanpur municipal corporation, 2006.

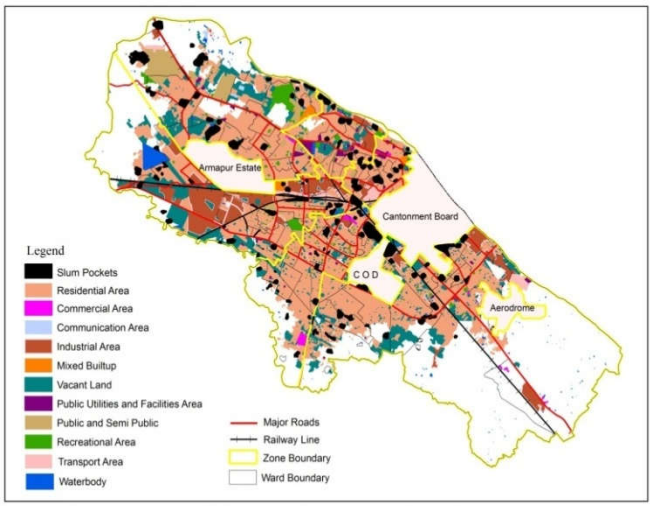

Fig. 6. Location of slum pockets (in black colour overlay on the urban built-up) in Kanpur municipal corporation, 2006.

over 89.09 km^2 (38.73% area) and includes mixed built-up as well as rural built-up area. The old city centre and neighbourhoods are under heavy pressure from increased population density. The housing stock deficit has raised the problem of slums in Kanpur city. Slum colonies reveal the social and economic marginality of a large proportion of the population including migrants. The densely populated wards contain slum areas as the major portion of the ground

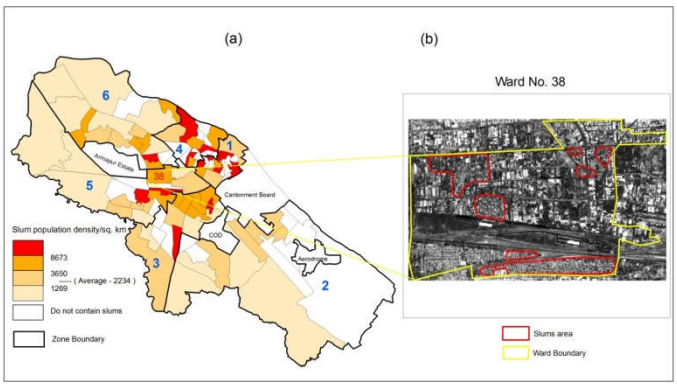

Fig. 7. Integration of geospatial technology and census data to identify the incidence of slums depicting the spatial location of slums in ward and slum population density.

coverage particularly in the inner core of the city. These occur along the industrial area, major transport network, public and semi-public area and on the unattended peripheral parts of the city. 71 of the 110 wards contain slums, both notified and unnotified. Figure 7 shows that prevailing density in some wards is more than 20 times higher than the average of 12,031. The matter of concern is that the high density, congested areas are largely unplanned. As per the survey conducted by DUDA **(***District Urban Development Agency)* and documents from KNN (Kanpur Nagar Nigam), there are 390 total slums in Kanpur. The slum population has grown from 3.68 lacs (14.5 percent of total population) according to census 2001 to about 5.0 lakh in 2006 (Kanpur Nagar Nigam estimate) which is twenty percent of total population. The current slum population is about 6.28 lacs with 1.28 lacs of households i.e. about 21.37% of the total population. A large number of below poverty line (BPL) population (about 60%) also live-in slums. It includes colonies of industrial workers, common slums and population squatting on public land. The slums, commonly known as *Ahatas* and *Abadis* lack civic services resulting in unhygienic living conditions. Immediate attention is required for upgradation of these areas since in combination with manufacturing units juxtaposed; they are far from providing an ambient quality of life. On a serious note, air pollution is emerging as a serious concern in the Kanpur city. According to the national summary report (December, 2010) on air quality monitoring, emission inventory and source apportionment study for Indian cities of the Ministry of Environment and Forest, Kanpur registered increase in air pollution levels due to particulate matter. Among the major causes of air pollution in Kanpur are industrial sector, vehicles, road dust and domestic cooking. Industrial sector is the biggest cause of air pollution in Kanpur due to presence of many small scale industries. Kanpur showed highest concentration of RSPM (Respirable Suspended Particulate Matter), which was three times more than the safety standards.

Concluding remarks

This is not a story of Kanpur alone. It is true for every other Indian city. Haphazard and unplanned urban development is a common phenomenon. There is a widening gap between demand and supply particularly on the issues of affordable housing, provision of infrastructure, civic amenities etc. Undoubtedly, all this has financial implications. The present status of land-use/land cover indicates that majority of the city area is used for urban built-up (53.57 percent) - residential, industrial, transport, public and semi-public followed by agricultural area (32.29 percent). The old city centre/inner core and neighbourhoods with mixed pattern of land use are under heavy pressure from increased population density. The unplanned high density areas are facing the problem of water supply, sewage disposal, transportation, housing, electricity, health and sanitation. About 60 % area in residential category is unplanned. Nearly one-fifth of the population is residing in slums located near the industrial areas, public and semi-public land, and peripheral areas of the city. Population density has increased from 3,848 to 12,031 persons per square km^2 during 1961-2011. Lack of proper planning, land management, funds and habitat policies seem to explain the crisis of city. At a time when the Indian cities are supporting huge populations and are extending their jurisdictions, planning process through conventional methods takes a long time and requires huge man power in preparing maps of varying scales for all the cities for which master plans are prepared. Moreover these are also not cost and time effective. But, Census data used in conjunction with geospatial technologies can serve as an effective tool in urban environment analysis, planning and management. Census provides data pertaining to various attributes of population, remote sensing provides the land-use/land cover data with repetitive coverage and synoptic view, GIS integrates those data with spatial units and GPS verify the pin point location of real data with satellite image to provide a better picture of cityscape. Therefore, it is proposed that the census data and data available from other sources created at disaggregated level should be used in conjunction with geospatial technology for city planning and management. The situation could be most suitably addressed if a complete resource inventory is made by the city planners and decision makers to focus on strategies to bring quick but effective solutions to the problems of the city. With this in view, a case is made for integrating satellite imagery with population census data for studying the city landscape and human environment in the metropolitan cities of India.

Acknowledgement

We sincerely acknowledge the help rendered by Haryana Space Application Centre (HARSAC), Hisar in providing data for the project work on which this paper is based. We are very thankful to Dr. K Venugopala Rao, Head (USD), National Remote Sensing Centre (NRSC) for providing necessary information.

REFERENCES

Banerjee, A., Reddy, K.N. and Paul, P. 2002. Application of Remote Sensing and GIS in Demographic and Socio-Economic Analysis of Dehradun City. Indian Cartographer. 274-285.

Bhatta, B. 2009. Analysis of urban growth pattern using remote sensing and GIS: a case study of Kolkata, India. International Journal of Remote Sensing. 30 (18), 4733-4746.

Bhattarai, K. and Conway, D. 2010. Urban Vulnerabilities in the Kathmandu Valley, Nepal: Visualizations of Human/Hazard Interactions', Journal of Geographic Information System. 2 (2), 63-84.

Census of India, 2001. Primary Census Abstract- Series-1, (UAs/Towns), Registrar General of India, New Delhi.

Census of India, 2001. Primary Census Abstract, Uttar Pradesh, 2nd Edition, Registrar General of India, New Delhi.

Census of India, 2001. Slums Data-II, (UAs/Town), Registrar General of India, New Delhi.

Census of India, 2001. Slums Data-II, (Ward-Wise of Million Cities), Registrar General of India, New Delhi.

Census of India, 2011. Provisional Population Totals, (UAs/Towns), Registrar General of India, New Delhi.

Final Report, 2006. Kanpur City Development Plan under *Jawaharlal Nehru National Urban Renewal Mission* (JNNURM), 330 pp. http://www.jnnurm.nic.in/ nurmudweb/ toolkit/CDP_Kanpur.pdf.

Frey, H.W. 2001. Melting pot suburbs: A census 2000 study of suburban diversity. Census 2000 Series. Center on Urban & Metropolitan Policy. The Brookings Institution Washington, DC, 60 pp.

Hall, G. B., Malcolm, N.W. and Piwowar, M.J., 2001. Integration of Remote Sensing and GIS to Detect Pockets of Urban Poverty: The Case of Rosario, Argentina. Transactions in GIS. 5 (3) 235-253.

Kanpur, 2010. Draft City Sanitation Plan. Administrative Staff College of India, Hyderabad, 290 pp.

Leipnik, M.R., Ye, X. and Gong, G. 2011. Geo-spatial technologies and policy issues in China: status and prospects. Regional Science Policy & Practice. 3 (4), 339-356.

Li, G. and Weng, Q. 2007. Measuring the quality of life in city of Indianapolis by integration of remote sensing and census data. International Journal of Remote Sensing. 28 (2), 249-267.

Lu, D., Weng, Q. and Li, G. 2007. Residential population estimation using a remote sensing derived impervious surface approach. International Journal of Remote Sensing. 27 (16), 3553–3570.

Martinuzzi, S., Gould, W.A. and Gonz´alez, O.M.R. 2007. Land development, land use, and urban sprawl in Puerto Rico integrating remote sensing and population census data. Landscape and Urban Planning. 79, 288–297.

Mendes, R.M. and Lorandi, R., 2010. Geospatial Analysis of Geotechnical Data Applied to Urban Infrastructure Planning. Journal of Geographic Information System. 2 (1), 23-31.

National Summary Report, 2010. Air quality monitoring, emission inventory and source apportionment study for Indian cities. Central Pollution Control Board, New Delhi, 290 pp.

National Urban Information System, 2008. Manual for Thematic Mapping: Using High Resolution Satellite Data and Geospatial Techniques, National Remote Sensing Agency (NRSA), Hyderabad, 110 pp.

Parrish, M.C. and Cymerman, J.H., 2011. Using geospatial data and principles of landscape ecology to identify field sites and characterize landscapes. Annals of GIS. 17 (1), 63-72.

Pham, H.M., Yamaguchi, Y. and Bui, T.Q., 2011. A Case Study on the relation between Urban Growth and City Planning Using Remote Sensing and Spatial Metrics. Landscape and Urban Planning, 100 (3) 223-230.

Radeloff, V.C., Hagen, A.E., Voss, P.R., Field, D.R. and Mladenoff., D.J. 2000. Exploring the Spatial Relationship between Census and Land-Cover Data. Society & Natural Resources. 13, 599-609.

Rahman, A., Kumar, Y., Fazal, S. and Bhaskaran, S. 2011. Urbanization and Quality of Urban Environment Using Remote Sensing and GIS Techniques in East Delhi-India. Journal of Geographic Information System. 3 (1), 62-84.

Rao, K.R.M., Kant, Y., Gahlaut, N. and Roy, P.S. 2012. Assessment of Quality of Life in Uttarakhand, India using geospatial techniques. Geocarto International. 1-15.

Rhinane, H., Hilali, A., Berrada, A. and Hakdaoui., M. 2011. Detecting Slums from SPOT Data in Casablanca Morocco Using an Object Based Approach. Journal of Geographic Information System. 3 (3), 217-224.

Syphard, A.D., Stewart, S.I., Mckeefry, J., Hammer, R.B., Fried, J.S., Holcomb, S. and Radeloff, V.C. 2009. Assessing housing growth when census boundaries change. International Journal of Geographial Information Science. 23 (7), 859-876.

Wang, L. and Wu, C. 2010. Population estimation using remote sensing and GIS technologies. International Journal of Remote Sensing. 31 (21), 5569-5570.

Williams, K. B., Burton, E., Jenks, M. 2001. Defining Sustainable Urban Form: Introduction, in: Williams, K. B., Burton, E., Jenks, M. (Eds.), Achieving Sustainable Urban Form, Spon Press, London, pp. 7-8.

Zeng, W., Chang, X. and Lv, J. 2010. Design of Data Model for Urban Transport GIS. Journal of Geographic Information System. 2 (2), 106-112.

****