JOURNAL OF ENVIRONMENTAL GEOGRAPHY
Journal of Environmental Geography 9 (1–2), 7–13.
DOI: 10.1515/jengeo-2016-0002
ISSN: 2060-467X

ANALYSIS OF URBAN SPRAWL DYNAMICS USING GEOSPATIAL TECHNOLOGY IN RANCHI CITY, JHARKHAND, INDIA

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Research article, received 1 March 2016, accepted 11 May 2016

Abstract

The availability of remote sensing satellite data at various spatial, temporal and spectral resolutions provides enormous opportunity to map the urban sprawl. When coupled with Geographic Information System (GIS) it is possible to evaluate, analyse and integrate large data. We need to understand and quantify the urban sprawl on spatial and temporal scales which forms a basis for better planning and sustainable management of cities and towns. The city of Ranchi has witnessed unprecedented urban growth after assuming the status of a capital of Jharkhand state, India in 2000. The increasing population has put pressure on the natural resources of the city. The urban growth has been in a haphazard manner at the cost of agricultural lands, forest land and open green spaces such as park, garden and recreational forestry.

The present study analysed the urban sprawl in Ranchi city, using Landsat data from 1976, 2002 and 2015. The study revealed that the annual urban growth rate was 1.76 ha/yr over the period from 1976 to 2002 whereas the annual growth rate was 2 ha/yr over the period from 2002 to 2015. The northern side of the city has witnessed more expansion in 2002 when compared with the growth in 1976. Increase in urban density was seen at the distances of 3, 4,5,6,7 and 8km between 1976 and 2015 and the rate was higher than 25%.The driving factors of the development were infrastructure, educational and business expansion. Thus, spatial analyses of urban sprawl are a prerequisite for curbing the unplanned urban growth and ensure sustainable living.

Keywords: urban sprawl, geospatial, Landsat, Ranchi, urbanization

INTRODUCTION

The ever increasing population has led to the rise in unplanned urban growth in the suburbs of the city which is usually termed as urban sprawl (Theobald, 2001; Bugliarello, 2003). Urban growth on one hand is an indicator of economic, social and political growth whereas, on the other hand it is at the cost of forests, agriculture lands, orchards and greenery of the city (Torrens and Alberti, 2000; Barnes et al., 2001). There are several definitions which define urban sprawl; Bhatt et al. (2010) had described it as an unplanned and uneven pattern of growth driven by various processes finally leading to inefficient resource utilization. There are several negative impacts associated with urban sprawl, some of them are having an impact on ecosystem and forests leading to fragmentation of habitats (Macie and Moll, 1989) increase in air/water pollution and greenhouse gases due to increase in fossil fuel consumption (Stoel, 1999) and increase in traffic congestion (Silambarasan, 2014).

Accelerated urbanization is the current scenario in India, one of the most populated nations of the world. The urban population in 1901 was 26 million, which rose to 62 million in 1951. The period between 198 and 1991 witnessed a rise to a figure of 285 million, accounting 27.8% of the total population (Jaysawal and Saha, 2014). The degree of urbanization varies in different states of India, with Goa being the most urbanized state constituting 49.77% of the urban population. Other states like Gujarat, Karnataka, Rajasthan, Madhya Pradesh, Bihar and Jharkhand are reported to have medium urbanization (Census, 2001).

It is necessary that urban sprawl is quantified and studied at local and regional scales such that proper measures are taken to ensure sustainability in urban planning. The parameter which can be used to quantify it is the built up area (Epstein, 2002). The conventional methods of mapping are time consuming and require heavy manpower, thus becoming a Herculean task. An advanced technological approach which is able to provide us accurate information over different time scales is required. In light of this, satellite remote sensing data in conjunction with Geographic Information Systems (GIS), provides an opportunity to study urban sprawl (Pande et al., 2012; Longeley, 1999). In the past four decades in India, satellite remote sensing data have been used extensively to monitor Earth's natural resources and study the changes taking place on the surface over different time periods.

Several studies have analysed urban sprawl at regional, local and temporal scales (Boori et al., 2015; Griffiths et al., 2010). The urbanization pattern of the greater Asmara area in Eritrea was studied using satellite remote sensing data of Landsat. They analysed land use/ land cover change using a data object based image analysis and urban sprawl using Shannon entropy (Tewolde and Cabral, 2011). Urban sprawl of the Ajmer city (Rajasthan was studied at mid-scale level for 25 years (1977-2002) where they used Landsat TM,MSS,ETM+, and IRS LISS III data (Jat et al., 2008). Landsat imagery of Kansas City of United States of America (USA) was used to generate a time series of land cover data over the past three decades (Wei et al., 2006). Long term trends and patterns of urban sprawl were studied. in south India and its surrounding area, by Rahman et al. (2010) using IRS P6 data and topographic sheets in the GIS domain along with Shannon's entropy model to assess the urban sprawl. In the Udupi district of Karnataka state in India, Urban sprawl patterns were analysed using (LISS and PAN images of 2003 and LISS IV and Cartosat images of 2013), which showed that barren /waste land was also converted to settlement /built up area (Silambarasan, 2014).

Singh et al. 2014 have studied the urban expansion in Ranchi city during the period from 1996 -2007 using an IRS LISS III sensor. Similarly, Pandey et al. (2012) using Cartosat –I stereo pairs satellite images studied the urban built up area of Ranchi township for over a period of eight decades (1927-2010). The present study is an attempt to quantify urban sprawl in the Ranchi city for a period of 39 years using Landsat data of 1976, 2002 and 2015.

The city which is the 46 th largest urban cities in India and the third largest in the state after Jamshedpur and Dhanbad (Census, 2011). It is known for coal belts and forests (Jha, 2016). The population is mainly dominated by tribes whose primary source of income is derived from agriculture, cattle farming and collection of forest produce. Deforestation, which is a consequence of urbanization has left these forest dependent communities in a pitiable situation. Low agriculture produce and poor economic condition of farmers has led them to migrate to better places in the vicinity of major towns. Establishment of Industries, infrastructure development, education and health facility etc. have attracted rural population to capital city (Kumar et al., 2011).

The objectives of the present study are 1) evaluating the urban growth in Ranchi city for the years 1976, 2002 and 2015 using Landsat data and GIS. 2) Analysing and quantifying the urban sprawl of Ranchi city during the three time periods mentioned above. It is believed that the urban growth or expansion has taken place more rapidly after the creation of the capital city of Ranchi. Thus, the study aims to analyse the urban growth patterns before and after the formation of the capital city.

STUDY AREA

The study area is the city of Ranchi. It is the capital of Jharkhand state of India, which was, carved out of the Bihar state on 15th November 2000. The southernmost part of the earlier state of Bihar constitutes Jharkhand. Since then it has progressed as a capital city opening opportunities for new employment, trade and infrastructure development. The city is located between 85^0 13' to 85^0 25'E and 23^0 13' to 23^0 26' N. The latitude and longitude of city center are 23°22′N; 85°20′E. The average elevation

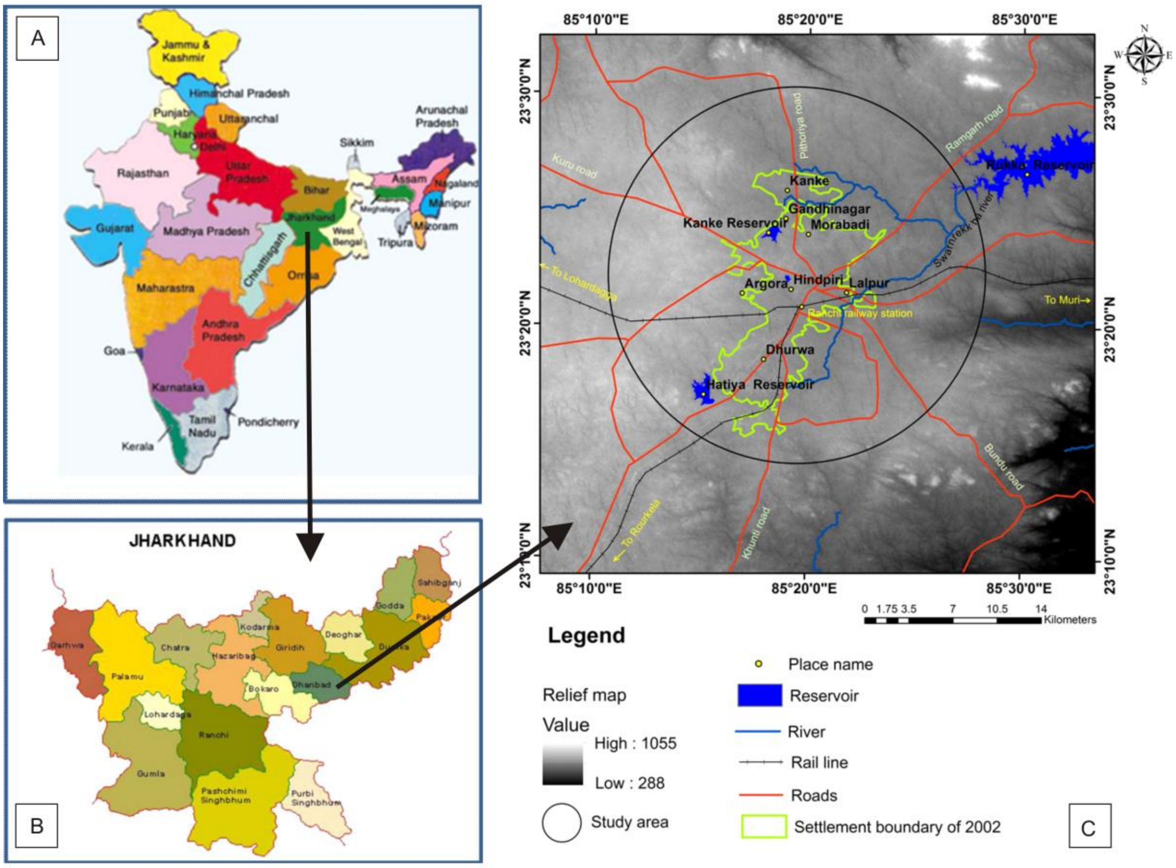

Fig. 1 The location of the study area A) map of India B) map of Jharkhand and C) relief map of the study area

of Ranchi city is 652 m from sea level. Its municipal area is 175.12 km^2. The city is adorned with numerous waterfalls and is also known as "City of waterfalls". The local river system constitutes Subarnarekha and its tributaries. The city's water supply is fulfilled by Kanke, Rukka and Hatia dams (Pandey et al., 2012).

The pleasant climate of Ranchi prevalent throughout the year is because of its location and the surrounding forests. It was once the summer capital and was given the status of the hill station. Summer temperatures range from 20 °C to 42 ^{0} C, winter temperatures from 0 °C to 25 ^{0} C degrees. The coolest months are December and January. The annual rainfall is about 1430 mm (56.34 inches). Figure 1 shows the location of the study area.

The census in India is conducted at an interval of ten years. The population of Ranchi city as per census data for the past four decades is as follows: In 1971, 255 thousands of human population; in 1981, 489 thousands; in 1991, 599 thousands; in 2001, 846 thousands and in 2011, 1073 thousands (Ranchi Master Plan 2037, 2015).

MATERIAL AND METHODS

Image acquisition and preprocessing

The satellite image used for the analysis was of Landsat 2 MSS (1976); Landsat 7 ETM + (2002) and Landsat 8 (TIRS) for the year 2015. The details of the data are given in Table 1.The satellite data selected was cloud free. All the datasets were downloaded from United States Geological Survey (USGS) website as a georeferenced data set. The images were corrected for radiometric and atmospheric distortions during the pre- processing stage. The data obtained was in a Geo TIFF format for each individual band. The various bands were layer stacked to produce a composite image which was converted into IMG format for further study and analysis. Image processing software used was ERDAS Imaging (version 9.0) and ARC GIS Spatial Analyst (version 10.1).

Table 1 Details of satellite data

Image Dates	20-12-1976	23-12-2002	9-5-2015
Spacecraft	Landsat 2	Landsat 7	Landsat 8
Sensor	MSS	ETM+	OLI_TIRS
Spatial resolution (m)	60	30 15 (PAN)	30 15 (PAN)
Radiometric resolution (bit)	8	8	16
Number of bands	4	8	11
Path / Row	151/44	140/44	140/44
Projection	UTM	UTM	UTM
Zone	45	45	45
Datum	WGS84	WGS84	WGS84
Ellipsoid	WGS84	WGS84	WGS84

Image classification

The bands utilized for analysis are Landsat MSS (4, 3, 2); Landsat 7 ETM+ (5, 4, 3) and Landsat 8 (5, 4, 3). The study area was extracted from the false colour composite (Fig. 2). The images retained their original pixel size despite the chances that there might be a difference in classification accuracies. To maximize correspondence between classified maps, a uniform methodology was applied on each dataset.

The urban area boundary was visually interpreted on false colour composite and extracted from each of the datasets of three time periods. On FCC it appears as cyan/white and of various geometric shapes such as rectangle, square, etc. In each of the extracted urban area data, Normalized Difference Vegetation Index (NDVI) was executed to delineate the vegetation classes in the urban landscape by using the density slicing method (Singh, 1989; Pilon et al., 1988). The NDVI is the best suited index to delineate vegetation from the FCC.

An unsupervised classification approach is a classification procedure based on ISODATA algorithm, in which the similar pixels are assigned into a group (Lillisand and Keifer, 2004). Thus, it was used for extracting water and urban (settlement). Finally vegetation, urban and water were integrated in one layer using the ERDAS Imagine model maker. Flowchart (Fig. 3) shows the methodology adopted for the following study.

Thus, according to Anderson (1976) we successfully delineated first level of LULC classes, namely vegetation, water and urban for each time period. The description of various classes is mentioned in the given Table 2. Accuracy assessment is a significant step in image classification for evaluating quality of classified image (Forkuoand and Frimpong, 2012). Accuracy assessment was computed for each classified dataset using a stratified random sampling method wherein 100 points were generated for each category and each point was assigned to the respective class based on ground knowledge.

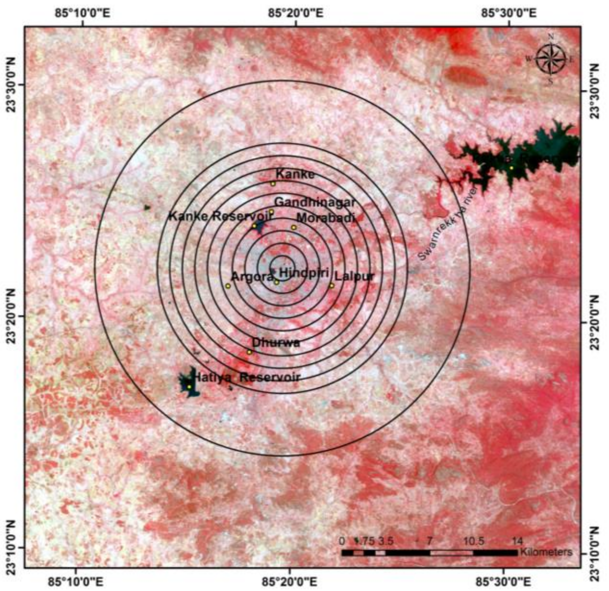

Fig. 2 The study area –false colour composite (FCC) of Landsat data (2015). The bands used are NIR-Band 5, R-Band 4, and Green-Band 3 along with multi buffer ring around the city

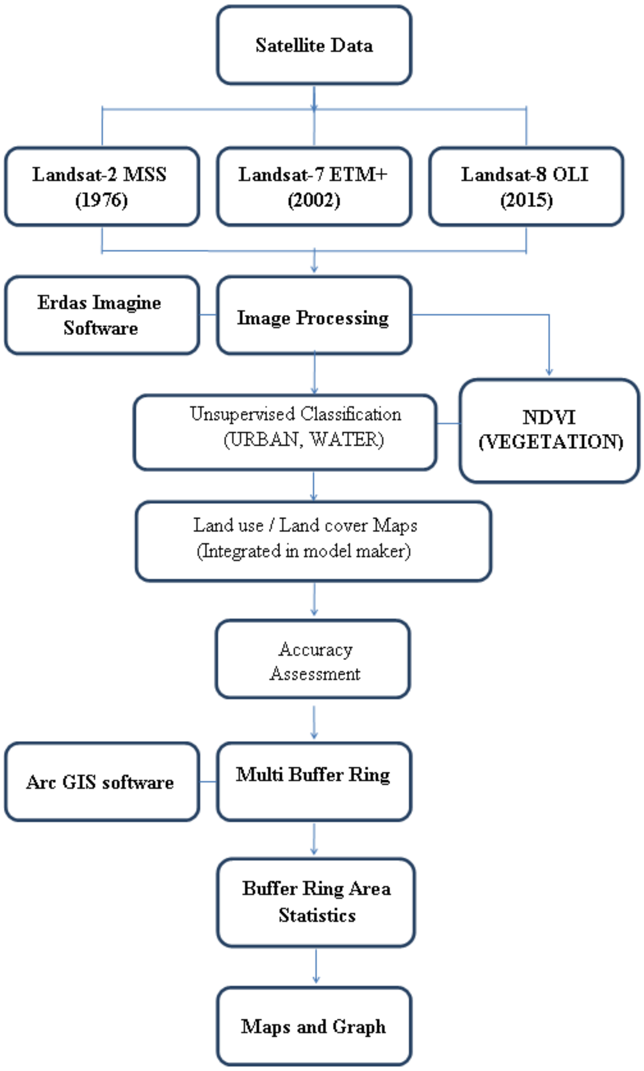

Fig. 3 Flow chart explaining the methodology

Table 2 Description of land use/land cover classes

Urban/built up	Residential, Commercial, Industrial , Transportation, Roads, Mixed urban and Open in urban
Vegetation	Agriculture, Plantation, Parks, Orchards and Forest
Water bodies	Dams or Reservoirs, Ponds, River, Lakes, Stream, Seasonal waterlog area

After classification of the images, multi buffer rings were created in Arc GIS (using the multiple ring buffer option), specifying the distance of 1 km from the city centre. Ten such rings were generated each ring of 1 km buffer. Beyond the tenth ring, one ring of 5 km buffer was generated. In ERDAS Imagine the matrix option of GIS utility was utilized to extract the area of each class in different ring. The city center point of our study is taken Firayalal Chowk (latitude and longitude 23°22′12" N; 85°19′30" E).

The matrix generated for all the time periods were analysed in MS EXCEL for urban density and urban growth rate using the following formulae (1) respectively:

$$UD = \frac{SA}{TA} \quad (1)$$

where UD means urban density of the specified ring, SA implies settlement area of the specified ring and TA means total area of the specified ring.

Urban growth rate

In order to monitor the spatial distribution of urban expansion intensity, we adapted the annual urban growth rate index (AGR). Annual urban growth rate (AGR) is used for evaluating the speed of urbanization (Maquboli et al., 2015; Boori et al., 2015). AGR (2) is defined as follows (Xiao et al. 2006):

$$AGR = \frac{UA_{n+i} - UA_i}{nTA_{n+i}} \times 100\ \% \quad (2)$$

where AGR means annual growth rate, A_{n+i} refers to the total land area of a ring, and nT is the interval of time (No. of years) between initial and final year; UA_{n+i} denotes the urban area at the final year whereas UA_i denotes the urban area at the initial year.

RESULTS AND DISCUSION

Land use/land cover maps

The final output map of land use/land cover shows three major categories that are vegetation, settlement (urban/built-up) and water (Fig. 4). The overall accuracy of the land use/ land cover of the year 1976, 2002 and 2015 were 90%, 92% and 92% respectively. The kappa accuracy, noted was 0.83, 0.87 and 0.87 respectively. The complete area statistics of land use/land cover of the year 1976, 2002 and 2015 is given in Table 3.

For all the three time periods analysed, it is seen in table 3 that there is an increasing trend in the urban area from 1976 (5034.16 ha), 2002 (10,335.24 ha) and in 2015 (14,561.39 ha) whereas the area of vegetation first decreased from 10.69% in 1976 to 9.23% in 2002 and later slightly increased to 9.71% in 2015. The area of water has first increased from 0.53% to 1.38 % from 1976 to 2002 and later on reduced to 0.81% in 2015 (Table 3). The increase in water is attributed to the fact that in 1976, the Kanke dam site was not included in urban built up area, in 2002; the Kanke dam reservoir has been included. Whereas in 2015 the decrease in water body is because of seasonal variation as the data belongs to the summer season.

Later using the Equation 2 and details from Table 3, urban growth was calculated. It was seen that 58.53% growth in built up area (settlement) over the period of 39 years from 1976 to 2015. In the first 26 years (from 1976-2002), urban growth was 45.84% at an average annual growth rate of 1.76 ha/yr. In between time period (2002 – 2015) over the period of 13 years urban growth was

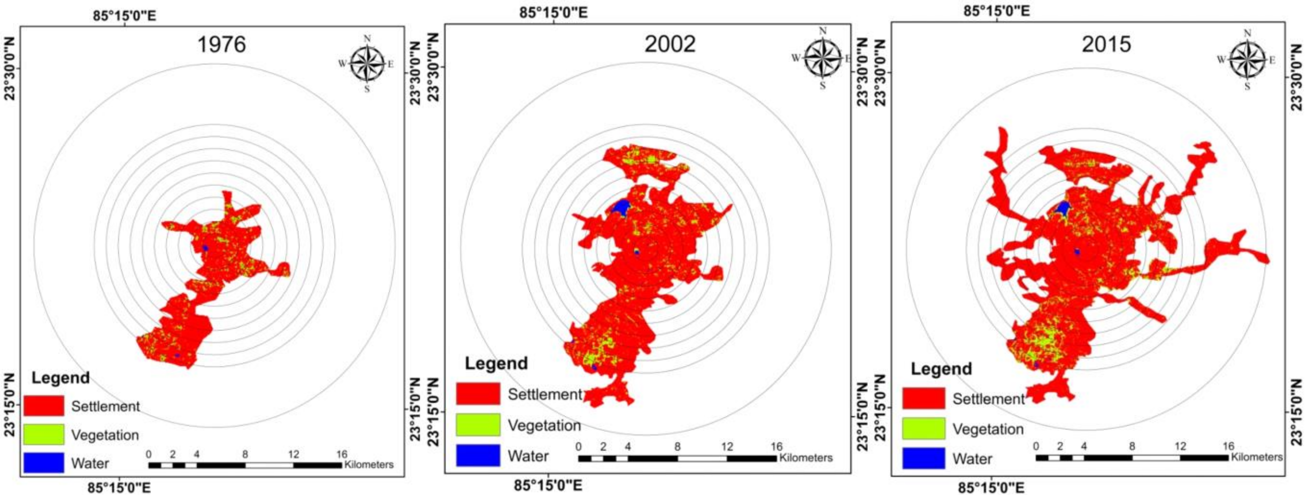

Fig.4 Multi buffer ring around the city overlaid on Land use/Land cover map in 1976, 2002 and 2015

25.96% with the average annual growth rate 2 ha/yr. Thus, the city expanse rate has increased furthermore 13.6% (0.24 ha/year.) over the period of 2002 to 2015 when compared with the period 1976 to 2002 (Fig. 5).

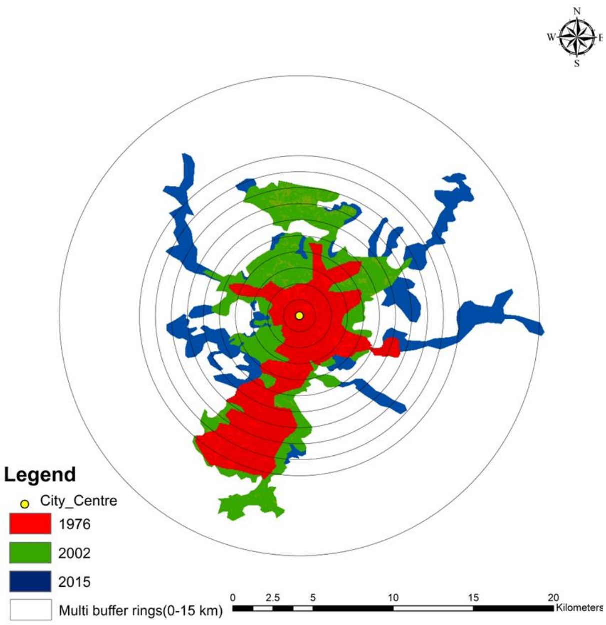

Fig.5 Urban growth of Ranchi city

Urban density patterns and urban growth rate

The city (Land use/Land cover class) density patterns around the city center were also examined to ascertain whether different zones have represented different densities. Figure 6 shows 11 (10+1) buffer ring zones from 1 to 10 km at a distance of 1km each and one 5 km buffer ring from 10 to 15 km distance. The observations show that it has been reasonably true that the first three zones represent the areas that are within the walking distance from the city center.

It is observed that in the city center, the urban density was more than 85% for the last 39 years. In 1976, urban density was reduced dramatically around 50.8% on the distance of 3 km from the city center and 15.6% on 5 km, and less than 1 % at 15 km (11^{th} ring).

When comparing the time periods of 1976 and 2015 on the distances of 3, 4, 5, 6, 7 and 8 km, the urban density has increased very high (more than 25%).If we compare only the time periods of 1976 and 2002 at the distances at 3, 4 and5 km, the urban density has highly increased (more than 25%). From 2002 to 2015, at the distances of 7 and 8 km, urban density was increased (more than 15%) (Fig. 6).

In 1976, at the city center urban density was 86%, the share of vegetation was 8.6%, and water was 5.3% (Fig. 6). From 1 to 2 km distance from the center, the urban/built-up area reduces to (76.13%) and

Table 3 Zonal statistics of land use/land cover (1976, 2002 and 2015)

Land use/ land cover	Area in 1976 (ha)	%	Area in 2002 (ha)	%	Area in 2015 (ha)	%
Urban (settlement)	5034.16	88.77	10335.24	89.38	14561.39	89.46
Vegetation	606.24	10.69	1067.49	9.23	1581.74	9.71
Water	30.61	0.53	160.11	1.38	133.01	0.81
Total	5671.01	100	11562.84	100	16276.14	100

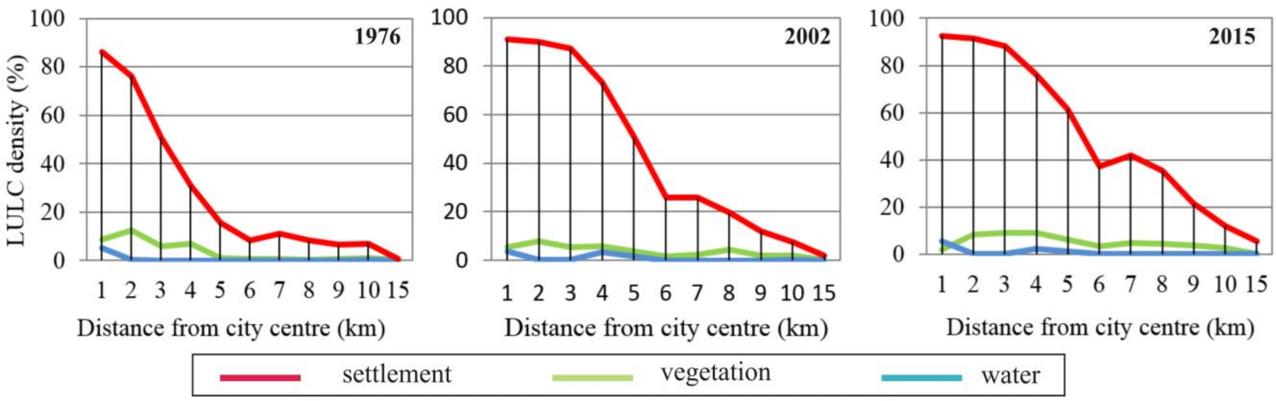

Fig.6 Land use/Land cover class density percentage from 1-15 km distance for 1976, 2002 and 2015

vegetation increases to 12.3%. From 2 to 3 km distance from the center, the urban/built-up area reduces to (50.8%) and vegetation also reduced to 5.82%. From 4-to 6 km distance, both urban and vegetation classes were showing a decreasing trend.

In 2002, the city center urban density was 91%, the share of vegetation was 5.3%, and water was 3.7% (Fig. 6). At a distance of 1-2 km from the center, the urban/built up area is more or less the same (90%) whereas vegetation has increased up to 7.7%. At a distance of 2 to 3 km from the center, the urban/built-up area very slightly reduces to (87.3%) and vegetation has reduced to 5.35 %. At a distance of 4 to 5 km from the center, the urban/built-up area sharply reduces to 50.78% and vegetation has also shown a decrease of 3.6 %. From 5 to 6 km distance from the center, the urban/built-up area sharply reduces to 25.74% and vegetation has reduced to 1.58 %. At 15 km (11^{th} ring) the urban/built-up area was 2% and vegetation has decreased to less than1 %.

In 2015 (Fig. 6) at the city center, urban density was noted was 92.6% and vegetation was 2%, and water was 5.3%. From 1 to 3 km distance, urban/built-up areas reduce at a slow pace to 88.2 %, but the vegetation area increased to 9.1 %. From 6 to 7 km distance from the center, the urban/built-up area increased to 42 % and vegetation has increased to 4.85 %. From 7 to 8 km distance from the center, the urban/built-up area reduces to 35.37% and vegetation has reduced to 4.54 %. From 1 to 8 km distance from the center, the urban/built-up area has always been found to be greater than 35 % in 2015 whereas urban/built-up area was always found to be greater than 35%, in 2002 is up to 1 to 5km distance. Urban/built-up density and vegetation is continuously showing decreasing trend from 7 km onwards to 15^{th} km(11^{th} ring) reached up to 5.3 %, 0.27% respectively at 11^{th} ring.

Description of spatial expansion

It is observed that in 2002 the northern side of the city has more urban growth as compared to the growth in 1976 as seen in Figure 4. The city has witnessed growth and development in north east, north west, west and south from the core of the city. It has been noticed that major growth is concentrated along national highways (NH-23, NH-33 and NH-75) which serve as major transportation corridors. Even though it is observed that built up development took place in Ranchi in a haphazard manner (Kumar et al., 2011). Since past 83 years as records say the township has increased more than six times (Pandey et al., 2012). Earlier the built up area was concentrated around the city center like Ranchi lake and northern parts like Kanke, later, after 1976, a sudden increase built up area in north, east and west of the city centre was seen. A whole sale vegetable market Pandra Mandi is situated at a distance of 8 Km from the city centre (along NH-75), which is a hub for villagers to sell their produce. It is equipped with modern facilities to store the farm produce. Various institutes like Indian Institute of coal management (established in 1994) in Kanke, Reliance Mega mart, Birsa Agricultural University (Faculty of Forestry established in 1980) are some of the major institutes and shopping complex in this area.

In the north of the city, along Kanke dam are new establishments in localities like Morabadi, Jawahar Nagar and Gandhinagar. New colonies such as Pundag, Nijam Nagar and Bhitha Basti have sprouted which once bore a deserted look few years ago. National Highway (NH-23) in northeast leads to Mesra which has become an educational hub with various new technical and educational Institutions. In the south of the city after Ranchi became a capital, massive expansion of Ranchi airport is seen. It is an extension of Doranda locality and with the development people have started residing there too. In the west is the Harmu Nadi, where once open fields were there, now taken over by residential and commercial establishments. Engineering and Medical colleges have come up in areas like Baryatu, Tatisilwai and Namkum, which are on the outer fringes of the Ranchi city. In 2007, Khelgaon a sports complex has also been established at Hotwar (along NH-23) during the national games.

Future growth is likely to be noticed in and around areas like Kanke, Bariayatu, Ratu, Buti, Namkum, Tatisilwai and Hatia. Thus, the increase in built up area has been at the cost of agriculture and open fields. Higher development is observed in low elevation zones due to availability of ground water (Pandey et al., 2012). As over a period of time, demand for water has increased, putting at stake the water bodies in the Ranchi urban area.

CONCLUSIONS

The above study shows that coarse resolution satellite data like Landsat can be successfully used to monitor the urban sprawl of Ranchi city. The study quantifies the urban sprawl at various distances from the city centre. Simultaneously, changes in vegetation and water were also noted. Initially the urban/built up area was concentrated in the city centre, which gradually spread both north and south directions. Mostly land used for urbanization was open spaces in the city and left over lands between adjoining buildings. Later, vegetated areas were also converted to built up area. As a result, the city has witnessed increase in traffic congestion, pollution, and loss of the green cover, erratic rainfall and unpleasant weather.

In order to achieve sustainability in urban planning, we should develop the open spaces as parks, playgrounds and nurseries. Along roadsides spaces should be spared for planting trees which provide shade and purify the polluted air. Water bodies should not be encroached for residential purposes. A buffer around them must be left before any construction work is undertaken. Water conservation practices should be encouraged by the government as well as the public to combat the water crisis in the future.

Such data are vital information for city planners and managers to curb unplanned urban growth provide proper drainage facility and ensure that the natural resources are not exploited badly. Incorporating such data in town planning and management would benefit the citizens and further ensure a sustainable livelihood.

Acknowledgements

The authors are grateful to USGS portal for the free download of Landsat data which was used in the analysis. We are also grateful to the reviewers for providing valuable suggestions.

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