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Evaluating the Long-term Urban Expansion of Ranchi Urban Agglomeration, India Using Geospatial Technology

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Abstract The present study analyzes the built-up expansion of Ranchi urban agglomeration over a period of about 8 decades from 1927–2005. Satellite images and topographical maps were used to evaluate land use dynamics during these periods. Built-up growth of 473.7% during 1927–2005 was primarily at the expense of agricultural land along with reduction of natural water bodies reflects negative impacts of built-up expansion, which increased many folds in recent decades. The built-up growth is also analyzed with reference to population growth, land consumption rate and land transformation. The land loss due to increasing built-up growth of Ranchi were compared with other capital regions and cities along with population increase to provide insight into the possible scenario of built-up expansion in Ranchi urban area.

Keywords Urban expansion · Land consumption · Land transformation · Multi-temporal

Introduction

Urban centers, together with their suburbs, constitute what is now called the built environment. By its very nature, the man made environment that defines the built is often in conflict with the natural environment, and in particular with the goals of sustainability of the land environment and its natural resources. The general perception is that urban centers consume significant resources and pollute the air, land, and water (Yong et al. 2007). The process of urbanization or its growth drives the change in land use/cover pattern, which may also have negative impacts on ecology of the area (Long et al. 2008). Human actions rather than natural forces are the source of most contemporary changes in the state and flows of the biosphere (Fazal 2000). The industrial revolution of nineteenth century and twenty century has permanently altered the pattern of human development and rates of consumption of the world's resources (Blowers 1996). The surface of the Earth is changing rapidly, at local, regional, national, and global scales, with significant repercussions for people, the economy, and the environment. Some changes have natural causes, such as wild land fires or hurricanes, while other changes on the land, such as resource extraction, agricultural practices, and urban growth, are human-induced

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processes (USGS 2007). The next four decades, 95% of the world's urban population growth will be observed by cities in developing countries (UN Habitat 2009) and will make the problem more severe. Due to inappropriate planning and management, accelerated urban growth and tremendous loss in land, especially cropland, have become a great challenge for sustainable urban development (Hasse and Lathrop 2001; Deng et al. 2008).

To understand and predict urban change processes, there is a need to monitor and characterize their spatial landscape patterns by observing them at different states in time. Essentially, it involves the ability to quantify the pattern change using multi-temporal datasets (Singh 1989). Though in monitoring urban growth pattern, high resolution satellite data is being used, yet lower resolution sensors such as LANDSAT TM also have their place as a tool in urban planning (Carlson 2003), which provide the facility to map the urban spatial pattern across space and time from historical urban growth data. Large collections of remote sensing imagery have provided a solid foundation for spatio-temporal analysis of the environment and the impact of human activities (Zhou et al. 2004). Along with GIS, remote sensing methods are very effective in the analysis of urban change (Ridd and Liu 1998; Masek et al. 2000; Hostert and Diermayer 2003; Forsythe 2004). Analyzing such changes assists in better understanding of the history of relationships between human activities and the environment and for the predictions of possible trends for landscape conservations (Doygun 2008). Urban growth identification, quantification, knowledge of the rate at which the various physical parameters are growing shall be helpful in planning for better infrastructure provision in an environmentally sound way (Krishna and Mitra 2007).

Urban Expansion has become one of the most important issues facing Ranchi at the onset of the present decade after reorganizing as a capital of Jharkhand, the 28th state of India in 2000. Housing developments and shopping malls encroach on lands that were formerly open spaces, agricultural land and water bodies. Therefore in the present study multi-temporal satellite images along with topographical sheet (1927) were used to analyse changes in built environment of Ranchi and were also related to population growth during respective periods of observation.

Study Area

In the present study, 321 km² of Ranchi Urban Agglomeration (RUA) was taken up to analyse urban expansion pattern and land consumption trend. The study area is situated in parts of Kanke, Namkum and Ratu blocks of Ranchi district in Jharkhand State, India with a population of 990,000 (United Nations Population Division 2007). Physiographically, RUA is situated on the Chotanagpur plateau, and located between 85°15'–85°25' E longitude and 23°14'–23°25' N latitude. The selection of present study area was done on the basis of apparent continuous built-up development in the peripheral area of the city till 2005. The municipal boundary provided by the municipal authority of the city (i.e., Ranchi Municipal Corporation) (Fig. 1).

Ranchi has been a smaller but important urban centre in the state of Jharkhand. Its importance lies in providing space for the summer and commercial capital of Bihar during the British Raj. The City has a varied ethnicity with 31 sub-castes, which played an important role in political and social movements (Gupta and Sen 2008). Ranchi city has multi-urban functions, like administrative, commerce and trade, cultural besides being an important commercial center. It provides regional services such as higher education and health facilities. Due to its regional importance, it acts as a magnet and does not allow growing any other urban centre in the district (Krishna and Mitra 2007).

Materials and Methodology

Urban expansion and related land consumption studies require spatio-temporal data to evaluate land use/land cover dynamics over the period of time. Therefore, in the present study the satellite images and topographical maps were utilized as reference sources for delineating boundaries of urban/rural built-up lands in the study area. Landsat MSS for the year 1975, Landsat TM for the year 1986 and 1996 and IRS P6-LISS IV of 2005 were used along with USGS topographical sheet of 1927 (Table 1).

The visual interpretation of satellite data was carried out using onscreen interpretation of false color composite (FCC) prepared using spectral bands of IR, R, G through R, G, B combination using Erdas

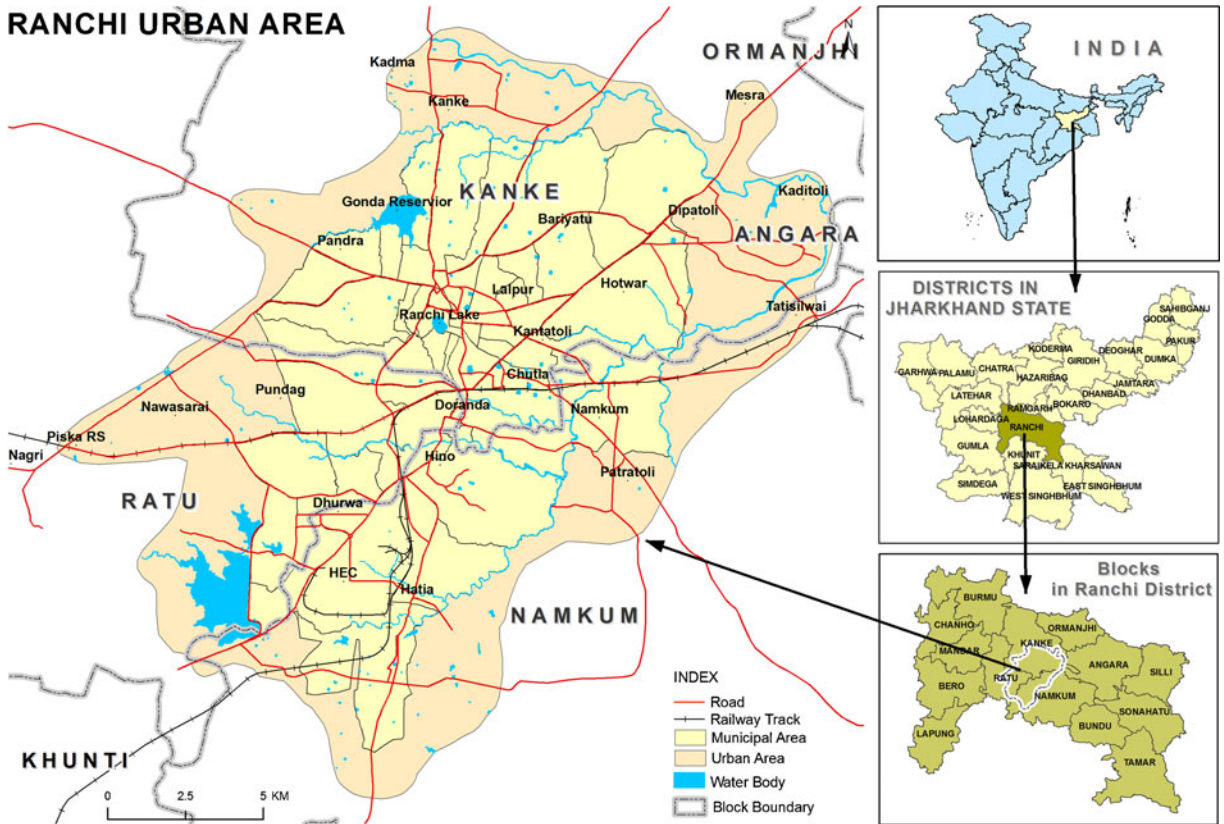


Fig. 1 Location map

Imagine software. The high resolution satellite image i.e. LISS-IV (2005) was geometrically rectified using Survey of India topographical maps and after that satellite image was reprojected to Universal Transverse Mercator (UTM) coordinate system with WGS-84 datum. The geo-rectified LISS-IV images were used as reference image to register the remaining satellite images used in the study. The images were georeferenced by selecting adequate ground control points to achieve RMS errors of less than 0.5. The digital data were displayed on the color monitor as FCC and various land use/land cover (LULC) classes

were delineated. On-screen visual interpretation technique was used to delineate the spatial distribution of various LULC units into five broad categories using image interpretation keys, viz., tone, texture, color, pattern, shape, association etc. The first level land use/land cover (LULC) classification system (Anderson et al. 1976) was modified to five classes i.e., built-up, agricultural land, forest, barren rocky and water bodies. The built-up class includes constructed areas such as residential area, commercial complexes, institutions and slums. The land primarily used for agricultural activities was categorized under agricultural land. The

Table 1 Detailed characteristics of data/satellite images used in the study

Data Source	Path-Row/Map No.	Year of Publication/ acquisition	Spatial Resolution (m)
USGS Topographical Sheet ^a	NF 45-1	1927	Scale-1:250,000
LANDSAT MSS ^b	140-44	1975	80
LANDSAT TM ^b	140-44	1986	30
LANDSAT TM ^b	140-44	1996	30
IRS P6- LISS IV ^c	1791-82 and 6906-61	2005	5.8

^a <http://www.lib.berkeley.edu>

^b <http://gfcapp.umiaccs.umd.edu>

^c www.nrsc.gov.in

area under notified forest boundary/forest land was considered as forest and was demarcated using topographical map. The area under rock outcrop was subjected to barren rocky category. River, ponds, canals etc. were identified under water body category. The other non built-up categories were present in small areas which are not mapable at coarser resolution of MSS sensor.

Initially, LISS-IV satellite images of the year 2005 were interpreted in which the said LULC categories could be identified accurately due to high spatial resolution of about 5.8 m. The remaining satellite image of preceding years were interpreted successively so that details in the satellite images of coarser spatial resolution can be mapped fairly accurately. The minimum mapable unit (MMU) was 1.2 ha for MSS and 0.3 ha for TM and LISS IV. The vectors derived from digitization of various LULC units were checked for accuracy assessment of visual classification. The LULC vectors were converted to raster and the Kappa coefficient was used to make an accuracy assessment for land use classifications (Peng et al. 2008). Based on selective field checks during August 2008, the overall classification accuracy of the LULC map derived from satellite image for the year 1975–2005 was determined, which are ranging from 90% and 95%. The Kappa coefficient for the city was ranging from 0.87 to 0.93. The wrong identities of pixels were corrected and the revised classification maps of LULC were used for area calculation.

Result and Discussion

Land Use Change and Urban Expansion

Ranchi started as a small city occupying an area of around 6 km² in 1869 with a population of approximately 12,000 in 1871 (Gupta and Sen 2008), which rose to 19.90 km² in 1927 and 114.18 km² in 2005 with a population of 46,161 (1927) and 990,000 (2005) respectively (Table 2). The growth of built-up land during the period of 1927–2005 is 473.7% indicating that the built-up land had expanded nearly five times in its size in last 78 years (Figs. 2 and 3).

In 1927, there were only three main urban built-up settlements, i.e. Ranchi, Doranda and Kanke, which comprised of total 19.9 km² (Fig. 4). The surrounding areas of RUA were comprised of small villages or

Table 2 Land use/cover statistics of Ranchi Urban Agglomeration (km²)

Classes	1927 ^a	1975	1986	1996	2005
Built-up	19.90	47.30	55.44	85.10	114.18
Agriculture	288.53	255.32	246.56	218.78	193.92
Barren Rocky	3.09	3.09	3.09	3.09	3.09
Vegetated Land	2.04	1.81	1.41	0.73	0.45
Water body	7.68	13.73	14.74	13.55	9.60
Total	321.24	321.24	321.24	321.24	321.24

^aThe area estimate is based on coarser resolution of Berkeley topographical sheet on 1:250000 scale.

hamlets. Over a period of time the surrounding rural areas merged with the expanding urban areas due to the increasing demand of land which resulted in the formation of 47.30 km² area under Ranchi Urban Agglomeration in 1975. This is mainly due to establishment of many industrial units in and around Ranchi. During the period from 1927–75, the city indicate the annual growth of 2.87% i.e. 0.57 km² per year. In the later period from 1975–86, there was an increase of 8.15 km² area with an annual growth of 1.57% and annual increase of 0.74 km² area (Table 3). In the last 2 decades of the observation periods (i.e. 1986–2005), the built-up growth augmented from 55.44 km² to 114.18 km². The annual built-up growth increased from 2.97 km² per year (1986–1996) to 3.23 km² per year (1996–2005). The annual growth rate was highest i.e., 5.35% in 1986–1996, which reduced to 3.79% with less growth. The trend of yearly growth rate was episodic yet the annual growth rate of built-up expansion was increased by 6.6 times during 1927–2005 (Tables 2 and 3).

During 1927–2005, the agricultural land was reduced by 94.61 km² area with the loss of 32.79%. The annual growth of agricultural land loss was gradually increasing over the observation periods (Table 3). The maximum loss was identified during 1986–96 (–27.78 km²), where annual decrease was 2.78 km². The barren rocky land cover was not changed during the observation periods and hence it remained as non changing land cover feature and occupies 3.09 km² area in all the observation periods. In the south of the Ranchi city, open mixed forest was demarcated. During the study period from 1927–2005, these forest were decreased from 2.04 km² to 0.45 km² with the loss of 77.94%. The maximum loss

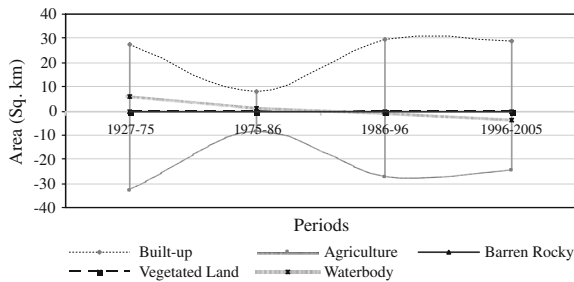


Fig. 2 Net Change in land use/cover in different periods

was observed during 1986–1996 (0.68 km^2), where annual decrease was 4.85%.

The area covered under water body exhibits significant variation during the observation periods. This was due to the non existence of Hatia reservoir, which was constructed in 1962 (Bhatt and Bhargava 2006) (Fig. 4) as well as due to the use of topographical map for the year 1927, having scales of 1:250000. At this scale minor water bodies are not shown which results in lower area coverage by water bodies during the period of 1927. The area under water body was increased from 7.68 km^2 to 9.60 km^2 with the growth of 25% during 1927–2005. The present study shows that during 1927–86, the trend of growth rate was high, afterwards decreasing trend was observed during 1996–2005. This signifies shrinkage of minor water bodies in later periods of observation. In 1975 water body area raised to 13.73 km^2 in 1975 and 14.74 in 1986 with the annual growth of 1.64% (1927–75) and 0.67% (1975–86). In the period of 1986–96 the area under water body was reached to 13.55 km^2 with the annual negative growth -0.81% and to 9.60 km^2 in 1996–2005 with the annual negative growth of 3.24%.

Figure 4: USGS Topographical Sheet 1927, LANDSAT MSS 1975, LANDSAT TM 1986, LANDSAT TM 1996, IRS LISS-IV 2005 (A.1, B.1, C.1, D.1 and E.1)

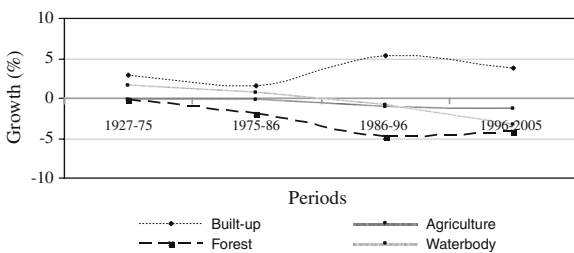


Fig. 3 Annual growth dynamics during 1927–2005

and built-up expansion in Ranchi Urban Agglomeration (A.2, B.2, C.2, D.2 and E.2)

Comparison of Built-up Expansion of Ranchi with Other Indian Cities

Urban development is a major consumer of land. Natural landscape areas around the cities are converted into housing estate, industrial parks, and other kinds of facilities designed to serve the community. Land is typically used for housing, businesses, industry, surface and subsurface infrastructure such as roads, wastewater supply, sewers, and power line, and recreational purpose such as parks and playgrounds. In the U.S., it is estimated that about 100 m^2 of land/sec is lost to urban use; Germany loses about $14 \text{ m}^2/\text{sec}$, and Switzerland loses about $1 \text{ m}^2/\text{sec}$ (RSU 2000). While evaluating the tendency of land loss of Indian cities or major capital regions due to urban growth, it was observed that about 60.57 km^2 of land per year was lost to urban use in New Delhi Region and its surroundings (National Capital Region) (Rahman and Natzband 2007), Whereas Ahmadabad and Lucknow cities were losing 11.12 km^2 per year and 8.25 km^2 area per year respectively (Fig. 5), which are relatively very high when compared to Ranchi, where insignificant 2.24 km^2 area per year was lost to urban land use (Fig. 6 and Table 4). Few growing Indian cities like Aligarh ($0.95 \text{ km}^2/\text{year}$) and Shillong ($0.78 \text{ km}^2/\text{year}$) exhibit less loss of area per year to urban use.

Metropolitan cities like Hyderabad ($1.63 \text{ km}^2/\text{year}$) and Bangalore ($2.63 \text{ km}^2/\text{year}$) exhibits similar growth rate as of Ranchi. These cities are situated in plateau type topography, where potential for built-up growth is limited. On the contrary other capital cities, like Lucknow and Ahmedabad are situated on flat topography, have more potential for urban growth. This is to remark that with such a lower population and equivalent built-up expansion rate in comparison to Bangalore and Hyderabad, Ranchi signifies very high rate of development. Such a high growth rate without following any development/master plan may leads to severe urban problem like surface and sub-surface water scarcity, solid waste disposal problem, air and water pollution, urban hygiene etc. in coming years. According to Cuberes (2006, 2007), there is strong evidence showing that in most countries cities develop sequentially, with the initially largest city being the first to grow. The above scenario resembles

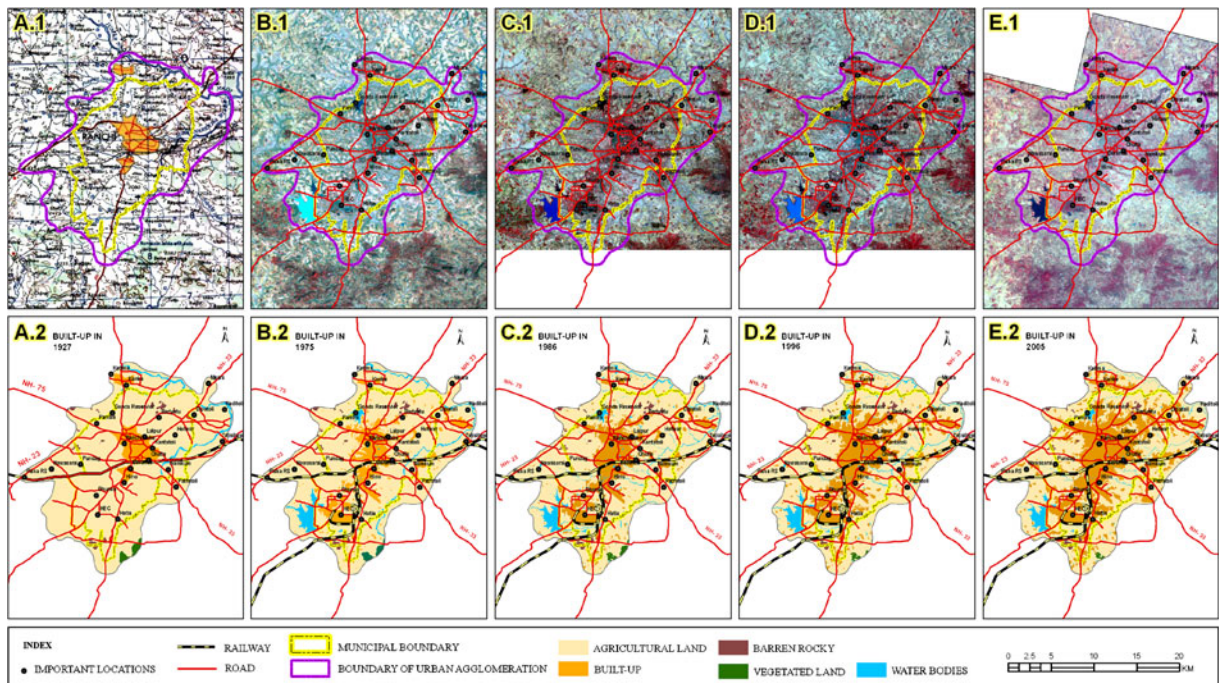


Fig. 4 Built-up expansion in RUA (1927–2005)

that the Ranchi Township is in its initial phase of sequential development and having lesser amount of loss of land to urban land per year.

Land Consumption Rate

Over recent decades extensive urbanization and land consumption processes have become an increasingly prominent but contentious issue in both public and academic discussions on land use change (Antrop 2004). ‘Land Consumption’ refers to the expansion of built-up area which can be directly measured, extent of land that is subject to exploitation by agriculture, forestry or

other economic activities and the over-intensive exploitation of land that is used for agriculture and forestry (EEA). The per person land consumption in each urbanized area (Beck et al. 2003) can be expressed as:

$$a = A/P$$

Where,

- a=area of urbanized land for the average resident or per person land consumption
- A=Area of total urbanized land in a city and its suburbs
- P=Population of that city and its suburbs

Table 3 Periodic and Annual Growth in land use/cover classes in Ranchi Urban Agglomeration

Classes	1927–1975 (48 yrs)		1975–1986 (11 yrs)		1986–1996 (10 yrs)		1996–2005 (9 yrs)	
	Net change in Area (km ²)	Annual Growth (%)	Net change in Area (km ²)	Annual Growth (%)	Net change in Area (km ²)	Annual Growth (%)	Net change in Area (km ²)	Annual Growth (%)
Built-up	27.40	2.87	8.15	1.57	29.65	5.35	29.08	3.80
Agriculture	-33.22	-0.24	-8.76	-0.31	-27.78	-1.13	-24.86	-1.26
Barren Rocky	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Vegetated Land	-0.23	-0.24	-0.40	-2.01	-0.68	-4.85	-0.27	-4.15
Water body	6.05	1.64	1.01	0.67	-1.19	-0.81	-3.95	-3.24

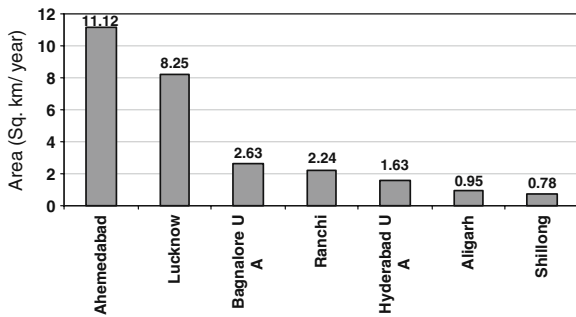


Fig. 5 Loss of land to urban land use

Per capita urban land consumption is not limited to the size of a person’s house lot or to a person’s proportion of the land covered by an apartment complex. It also includes a portion of all the other land that has been converted from rural to urban use to provide for jobs, recreation and entertainment, shopping, parking, transportation, storage, government services, religious and cultural opportunities, waste handling, and education.

The population figure for the year 1927 was calculated using the yearly growth rate of 1921–31 (Table 3). The scatter plot of population versus built-up exhibit good correlation ($R^2=0.95$, Fig. 7) whereas there is no positive correlation between land consumption and population growth rather it was inversely correlated (Fig. 8). In the present study of RUA, the trend of built-up expansion and population growth was approximately similar with some fluctuations during 1927–1975 and 1985–96 (Fig. 9). The population growth trend was almost following the same trend line during all observation periods whereas built-up land increases in episodic manner during the same periods. The minor difference of built-up area and population, when plotted to land consumption per year and population growth rate per year resembles clear picture of local behavior of urban

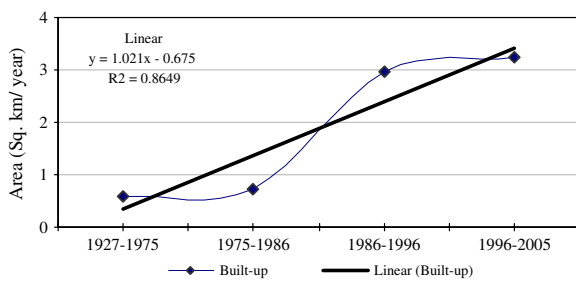


Fig. 6 Loss of land to urban landuse in RUA

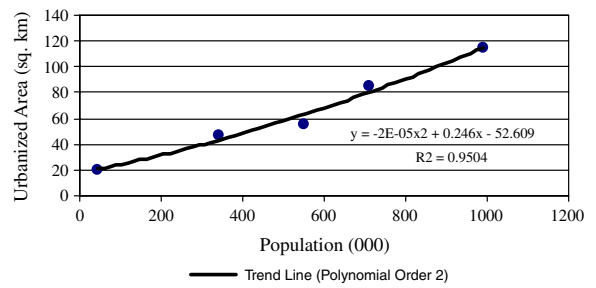


Fig. 7 Population and built-up correlations (1927–2005)

expansion and related activities in Ranchi urban agglomeration during different observation periods. The land consumption per year (Fig. 8) and population increase statistics shows that after reorganization of Ranchi as state capital although population was increased but land was not consumed relatively. The contrasting figure during 1986–96 observed with maximum land consumption rate, when population growth was lowest among the three observation periods (Tables 5 and 6). It revealed that the land consumption was not targeted to accommodate population growth rather the built-up growth was influenced by some other socio-economic reasons. This can be attributed to land acquisition by land developers and industrialist due to its central location in the region and setting up of industries. Therefore, after 1986–96, the trend of land consumption declined whereas after reformation as state capital, population growth increased in Ranchi. It is interesting to note that maximum increase in population was observed during 1996–2005, during which less built-up land was expanded unlike 1986–96.

The land consumption in the RUA was increased at different rates over the years. A steep increase in land consumption from 3.58 sq. m/year during 1975–86 to 18.19 sq. m/year during 1986–96 was observed. Subsequently land consumption rate steadily grew with less increase to 11.62 sq. m/year during 1996–2005 reflecting a proportionate increase in built-up growth with increase in population. This may be attributed to the excess acquisition of land, densification of existing urban area leading to higher population density in the urban core area of Ranchi rather than developing new areas in the periphery. This probably reduced the requirement of new land for further development to accommodate the rising population. The present rate of growth of population and built-up represents that the demand of land in

Table 4 Built-up per year increase in different cities of India

Urban Area	Duration	Built-up Increase (km ² /year)	Source	Formed on as modern city	Population in 2005 (Source: UNPD 2007)
Ahmedabad	1972–1989	11.12	Pathan et al. 1991	1960	5,122,000
Lucknow	1972–1992	8.25	Taragi and Pundir 1997	1947	2,567,000
Bagnalore U A	1971–1991	2.63	Iyer et al. 2007	1947	6,465,000
Ranchi	1975–2005	2.24	Current Study	2001	990,000
Hyderabad U A	1971–1991	1.63	Iyer et al. 2007	1956	6,117,000
Aligarh	1971–2006	0.95	Farooq and Ahmad 2008	N/A	763,000
Shillong	1974–2000	0.78	Jain et al. 2002	1972	260,000 ^a

^aCensus of India, 2001

peri-urban region will become higher in coming years. The construction of Ring road and establishment of a new township as Ranchi new capital area around Kanke would be the important factors for the future development of Ranchi.

Land Transformation

Land transformation is one of the most important fields of human induced environmental transformation, with an extensive history dating back to antiquity (Wolman and Fournier 1987). Land is in a continuous state of transformation as result of various natural and human-made processes and was accelerated and diversified with the onset of the Industrial Revolution, the globalization of the world economy as well as due to the expansion of population and technological capacity (Fazal 2000). The land transformation statistics for RUA has been calculated during the period of 1927–2005, which is based on satellite data observations as well as topographical map of 1927. The Table 7 resembles that during the four observations periods, major changes have been observed in built-up and agricultural classes. The

maximum built-up expansion took place at the cost of agricultural land. In the period 1927–75, 33.12 km² of agricultural land was transformed to built-up land, which increased to 8.16 km² in 1975–86, 29.34 km² in 1986–96 and 28.82 km² in 1996–2005. The annual increase in agricultural land transformation to built-up land was raised from 0.69 km² per year during 1927–75 to 0.74 km² per year during 1975–86, 2.93 km² per year during 1986–96 and 3.20 km² per year during 1996–2005. Insignificant area comprising seasonal water bodies was also converted to built-up land. During 1927–75, the built-up land transformation to agricultural land was high (5.31 km²) which could be attributed to use of topographical sheet of 1927, in which the spatial expansion of built-up was not as accurately marked as evident on satellite images.

Significant amount of area under water body was converted to agricultural land. The 4.83 km² area of water body converted to agricultural land during 1927–75, 4.40 km² areas during 1975–86, 3.63 km² during 1986–96 and 4.66 km² during 1996–2005. The maximum annual land transformation under this

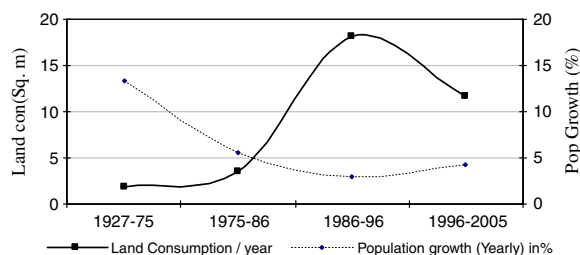
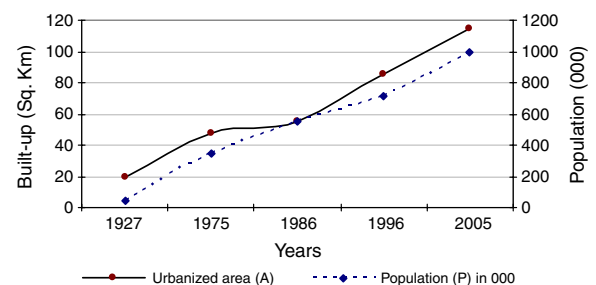
**Fig. 8** Land consumption and population growth per year**Fig. 9** Built-up and population in RUA (1927–2005)

Table 5 Population density and land consumption during different periods in Ranchi Urban Agglomeration

Classes	1927	1975	1986	1996	2005
Urbanized area (km ²) (A)	19.90	47.30	55.44	85.10	114.18
Population (P) (UNPD 2007)	50,517 ^a	342,000	549,000	712,000	990,000
Population density	2,319	7,231	9,901	8,367	8,670
Land Consumption (a) (km ²)	431.10	138.29	100.99	119.52	115.33

^aPopulation figure for the year 1927 was calculated using the yearly growth rate of 1921–31.

District Census Handbook Abstract, 1981(Village & Town Directories)

category was observed during 1996–2005 (0.52 km²). On the other side, significant amount of agricultural land was also transformed to water bodies. In 1927–75, 10.48 km² of agricultural land was converted to water bodies due to construction of some major reservoirs like Hatia Reservoir. During 1975–86, 5.39 km², 1986–96, 2.91 km² and during 1996–2005 it was 0.1 km². This resembles that such inter-conversion of agricultural land and water bodies was influenced by anthropogenic activities. The final loss of agricultural land and water bodies may be credited to expansion of built-up land which has greater significance in the recent decades. The water bodies were also significantly transformed to agricultural land and partially to built-up land in urban core area as evident in satellite images.

The productivity of agricultural area in Ranchi district (Directorate of Agriculture 2006) was correlated with build-up expansion and repercussion agriculture land loss. The rapid growth rate of Ranchi urban agglomeration leads to 308.65 ha of agricultural land loss per year in recent decade (1996–2005), which represents loss of 1051.26 metric tons per year in food grain (mainly rice and maize). If agricultural productivity of 2006 will assumed static, then productivity loss would be 235.7 metric tons per year during 1927–75, which increased approximately 4.5 times till 1996–2005. This indicates towards urgent

requirement of judicious and sustainable planning for future built-up growth keeping in view the sustainable utilization of land and water resources of the region.

Conclusion

Long term evaluation of built-up expansion will provide the insight knowledge of spatial growth of a city. In the present study the chronological pattern of the built-up growth were discussed along with population characteristics of RUA. During its evolution, the city of Ranchi experienced episodic growth in urban land use. The built-up area had expanded more than five times in its size during the last 78 years. In comparison to the other growing cities in India, Ranchi urban growth exhibits early stage of urban development with lower population increase and very high rate built-up expansion. The present study also revealed that there is very good correlation between population and urban expansion in Ranchi Urban Agglomeration during 1927–2005. The population projection (UNPD 2007) indicates that by 2025 the Ranchi urban areas will densified by 577,000 additional populations, which would needs more area to grow for built-up. The transformation matrix clearly revealed that built-up development has primarily altered the agricultural

Table 6 Population and Built-up characteristics during different periods in Ranchi Urban Agglomeration

Characteristics Type	1927–75	1975–86	1986–96	1996–2005
Urban Land increases (km ²)	27.40	8.15	29.65	29.08
Population Increase (Periodic)	295,839	207,000	163,000	278,000
Population growth (Periodic) in%	640.89	60.53	29.69	39.04
Population growth (Yearly) in%	13.35	5.50	2.97	4.34
Land consumption -Periodic (m ²)	92.60	39.36	181.91	104.62
Land consumption -Yearly (m ²)	1.93	3.58	18.19	11.62

Table 7 Land transformation matrix in Ranchi Urban Agglomeration (Area in km²)

a: Land transformation during 1927–75				b: Land transformation during 1975–86				c: Land transformation during 1986–96				d: Land transformation during 1996–2005									
Classes	Built-up	Agricultural Land	Barren Rocky	Vegetated Land	Water bodies	Area in 1975	Classes	Built-up	Agricultural Land	Barren Rocky	Vegetated Land	Water bodies	Area in 1986	Classes	Built-up	Agricultural Land	Barren Rocky	Vegetated Land	Water bodies	Area in 1996	
Built-up	19.90	(0.69 annual) 33.12	0	0.002	0.01	47.30	Built-up	47.30	(0.74 annual) 8.16	0	0.0083	0.0063	55.44	Built-up	55.44	(2.93 annual) 29.34	0	0.02	0.52	85.10	
Agricultural Land	5.31	288.53	0	0.44	(0.1 annual) 4.83	255.32	Agricultural Land	0.00	255.32	0	0.39	(0.4 annual) 4.40	246.56	Agricultural Land	0.18	246.56	0	0.66	(0.36 annual) 3.63	218.78	
Barren Rocky	0	0	3.09	0	0	0	Barren Rocky	0	0	3.09	0	0	0	Barren Rocky	0	0	3.09	0	0	0	3.09
Vegetated Land	0	0.21	0	2.04	0	0	Vegetated Land	0	0.00023	0	1.81	0	1.41	Vegetated Land	0.00	0.00	0	1.41	0	0	0.73
Water bodies	0.42	(0.28 annual) 10.48	0	0	7.68	13.73	Water bodies	0.03	(0.49 annual) 5.395	0	0	13.73	14.74	Water bodies	0.05	(0.29 annual) 2.91	0	0	14.74	13.55	13.55
a: Land transformation during 1927–75				b: Land transformation during 1975–86				c: Land transformation during 1986–96				d: Land transformation during 1996–2005									
Classes	Built-up	Agricultural Land	Barren Rocky	Vegetated Land	Water bodies	Area in 2005	Classes	Built-up	Agricultural Land	Barren Rocky	Vegetated Land	Water bodies	Area in 2005	Classes	Built-up	Agricultural Land	Barren Rocky	Vegetated Land	Water bodies	Area in 2005	
Built-up	85.10	(3.2 annual) 28.82	0	0.05	0.37	114.18	Built-up	85.10	(3.2 annual) 28.82	0	0.05	0.37	114.18	Built-up	85.10	(3.2 annual) 28.82	0	0.05	0.37	114.18	
Agricultural Land	0.03	218.78	0	0.23	(0.52 annual) 4.66	193.92	Agricultural Land	0.03	218.78	0	0.23	(0.52 annual) 4.66	193.92	Agricultural Land	0.03	218.78	0	0.23	(0.52 annual) 4.66	193.92	
Barren Rocky	0	0	3.09	0	0	3.09	Barren Rocky	0	0	3.09	0	0	3.09	Barren Rocky	0	0	3.09	0	0	0	3.09
Vegetated Land	0.00	0.00	0	0.73	0	0.45	Vegetated Land	0.00	0.00	0	0.73	0	0.45	Vegetated Land	0.00	0.00	0	0.73	0	0	0.45
Water bodies	0.12	(0.1 annual) 0.95	0	0	13.55	9.60	Water bodies	0.12	(0.1 annual) 0.95	0	0	13.55	9.60	Water bodies	0.12	(0.1 annual) 0.95	0	0	13.55	9.60	

Figures in bold (diagonally) are under that particular land use in initial year of the relevant period, while the figures in the same column represent the shift in area to other land uses. Similarly, figures in the same row are increase in area, captured from other land uses.

Based on Topographical Map 1927, LANDSAT-MSS 1975, TM 1986, TM 1996 and LISS IV 2005 satellite images

land. In the state like Jharkhand, where arable land is very less and agricultural pattern is mono cropping, it is suggested that the further built-up growth should be planned to impact less stress on the arable land resources.

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