



Change Detection Techniques for Monitoring Spatial Urban Growth of Jaipur City

Rupesh Kumar Gupta

Abstract

This paper has focused on the monitoring of land use land cover over 34 years. The study is based on secondary and satellite data along with statistical techniques as well as limited field verification. The result shows that the growth of population from 0.63 million in 1971 to 2.9 million in 2001 and the decadal growth rates of 58.82, 55.37 and 53.09 percent along with annual average growth rate has been in the range of 4.1 to 4.7. Population growth has major driving forces of land use change. For example, the crop area has shrunk by 1.60 sq km per year, fallow land 2.94 sq km per year, and wasteland 0.59 sq km per year in last 34 years, whereas built-up area has increased with the rate of 4.46 sq km per year or 1.02 percent per year. Based on the use of multi resolution and multi temporal satellite data of 1975 to 2009, spatial and temporal changes in the various types of land uses and land cover of the city are detected and discussed.

1. INTRODUCTION

Urbanization is now a common feature of all developing countries. Primate cities and mega cities are emerging in developing countries. Growth in the population of cities in developing countries has been attributed to various factors including natural population increase and rural-urban migration. The cities of the developing world have especially experienced population growth. Urban growth has been criticized for its inefficient use of land resources and energy and large scale encroachments on agricultural land. These impacts threaten the principle of sustainable development. However, sustainable urban growth management and development planning need to take account of the dynamic processes of temporal urban change. The measurement of urban form can provide a more systematic analysis of the relationships between urban form and process (Yeh and Li, 2001). Batty and Longley (1994) classified urban growth as generally organic (or natural) or planned (or artificial). The distinction between the two is multi fold and often blurred. Basically, planned growth appears to be more man made in that the patterns produced are more regular, reflecting more control over the building processes. Most cities and towns provide a blend of both, usually containing elements of the planned against a backcloth of organic growth. Urban growth is a broad and vague concept that can be subdivided into various types - sprawling or compact, dispersed (scattered) or clustered, continuous or leapfrog, spontaneous or self-organizing, planned or organic. It may comprise physical growth, population growth, economic growth and environmental change (decline), although there is often a focus on the physical aspects in the domains

Rupesh Kumar Gupta, M.Tech., Ph.D. Delhi School of Economics, Department of Geography, University of Delhi. Email: gisrs@oneindia.in



of remote sensing and GIS. The appearance of a circular configuration is actually a phenomenon of self-organization (Benati, 1997). This classification is based on the land use pattern, particularly the spatial land use change detection.

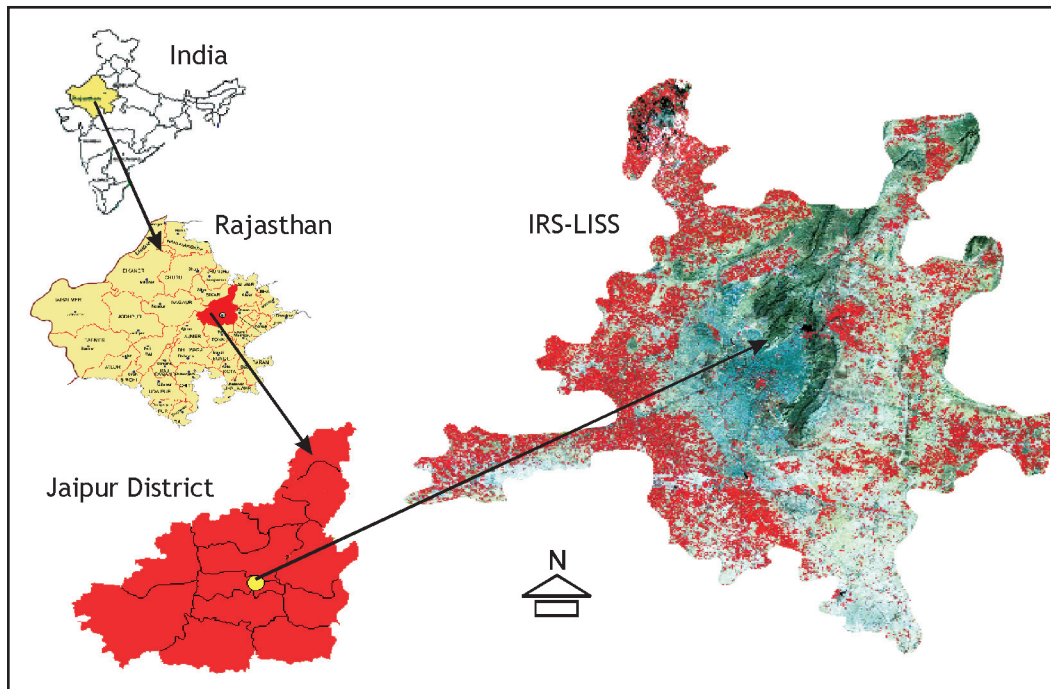
During the last five decades, a series of events has occurred in India (such as the Green Revolution in 1960s, and economic reforms of the 1990s). These have brought about unparalleled changes in the urban development of Indian cities. The exploration of an urban development process that spans so long a period is crucial to decision-making for sustainable land management and future urban development and planning. Previous studies of Indian urbanization have paid less attention to spatial and temporal dimensions due to the lack of available data. Presently, however, new opportunities are emerging with the development of new technologies. As a result of the rapid development of remote sensing (RS) and geographical information sciences and techniques, increasingly large-scale studies of urban development have been facilitated (Masser, 2001). By using GIS, it is technically possible to integrate large quantities of data for further spatial analysis related to urban development. However, it has become common knowledge that urban development is a complex dynamic process, which involves various physical, social and economic factors. With these considerations in mind, this work puts forward a spatial and temporal analysis perspective for monitoring urban growth patterns.

2. STUDY AREA AND RESEARCH METHODOLOGY

Jaipur Region is considered for the purposes of land use and potential urban heat island studies. This is bounded by 26°54' north latitude and 75° 45' east longitude (Fig. 1). This work is focused on the city of Jaipur. The study covers the area of Old Jaipur boundary with 444.72 sq km area or 44,472.27 hectares. The whole city has experienced an environmental crisis in terms of depletion of ground water, forests, soil erosion, flora and fauna and climate change.

The entire area towards the east has experienced substantial deforestation. This has further deteriorated due to mining operations for building stones. Devastation of trees and soil cover has turned hilly areas into rocky exposures. Wasteland areas are continuously increasing and degrading the environment. Salinization is prominent in west and the southwest of the region. All these phenomena adversely put heavy pressure on the environment, which in turn has caused environmental changes in the ecosystem and their subsystems.

One of the prerequisites for understanding urban growth is successful land use change detection. This is made possible by accurate registration of the satellite imageries so that the overhead pixels represent the same location. There is a wide range of techniques used for land use change detection to study urban growth. Some of the major techniques include composite image, image comparison, comparison of classified images, combination of classified images,

Fig. 1: Location Map of Study Area

radar classification, and so on. The technique employed in this study is based on the comparison of the classified images. In order to carry out analysis, the primary construct is to acquire the data source. Therefore visual interpretation is still a reliable solution and is applied in this study for the creation of land use and cover maps, especially when toposheets, existing maps and images are used together for temporal change detection.

Each image set has been classified into different categories viz. built-up area; high-medium-low density, forest-plantation, waste land, water, crop land; fallow-open spaces and degraded land. The polygons were identified by independent labels attached to the centroid of each polygon. These polygons were labeled as training sites. Confirmed training sites as per land use category were selected using signature editor and the values were merged to give an average pattern for the land use category. The signatures were then assigned conventional colors based on standard theme. Different color signs the different categories. The visual interpretation method applied to see the land use categories and its changes during different time periods. The technique employed for ground truth aimed at localizing and characterizing field observations. Finally, this full database was attached to the coverage in which each polygon was characterized by many attributes like the category number, area and perimeter of the polygons. Urbanizing region was identified and assessed in order to produce the evaluation made between different periods. By keeping in all the land use categories the impact of urbanization on other land uses and vice versa was investigated.



3. RESULTS AND DISCUSSION

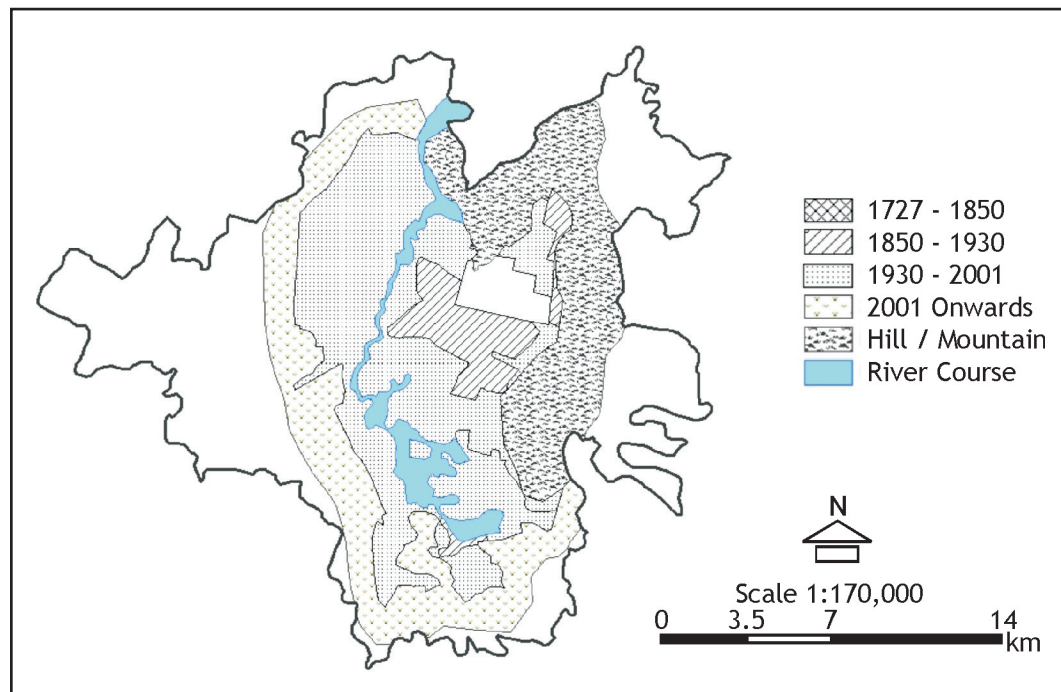
The spatial and temporal growth pattern of Jaipur can be divided into four distinct phases. Each phase has made a special contribution to the development of Jaipur. Understanding of these phases would enable us to understand the growth trends better and appreciate the efforts that have gone into making Jaipur the city it is today. The spatio-temporal growth of Jaipur has been shown in Fig. 2.

Phase I: 1727-1850 AD: Jaipur, founded by Maharaja Sawai Jai Singh II in 1727 A.D. is one of the few planned cities of its times based on the principles of ancient town planning doctrine of Shilpa Shastra. By 1734, the main markets of the town including Johari Bazaar, Sireh Deorhi Bazaar, Kishanpole Bazaar and Gangauri Bazaar had been built.

Phase II: 1850-1930: During this phase, the city grew out of the confines of the walled city. The establishment of a railway line in 1868 A.D. fueled the growth of the city.

Phase III: 1930-1970: In 1930s, five development schemes, Fateh Tiba, area south of Ramniwas Bagh, Ashok Nagar, New Colony in Jalu Pura and Bani Park commonly known as A, B, C, D, E respectively were conceived to provide residential plots, land for public institutions and other amenities for the increasing population. Rajasthan University was inaugurated in 1947 thereby opening opportunities for the southward growth of the city.

Fig. 2: Urban Growth Pattern, Jaipur





Phase IV: Post 1970s: During the last 3 decades, major growth direction has taken place towards the southwest and northwest of the city due to the presence of hills in the northern and eastern sides acting as natural barriers.

4.1 Satellite Data Base Studies

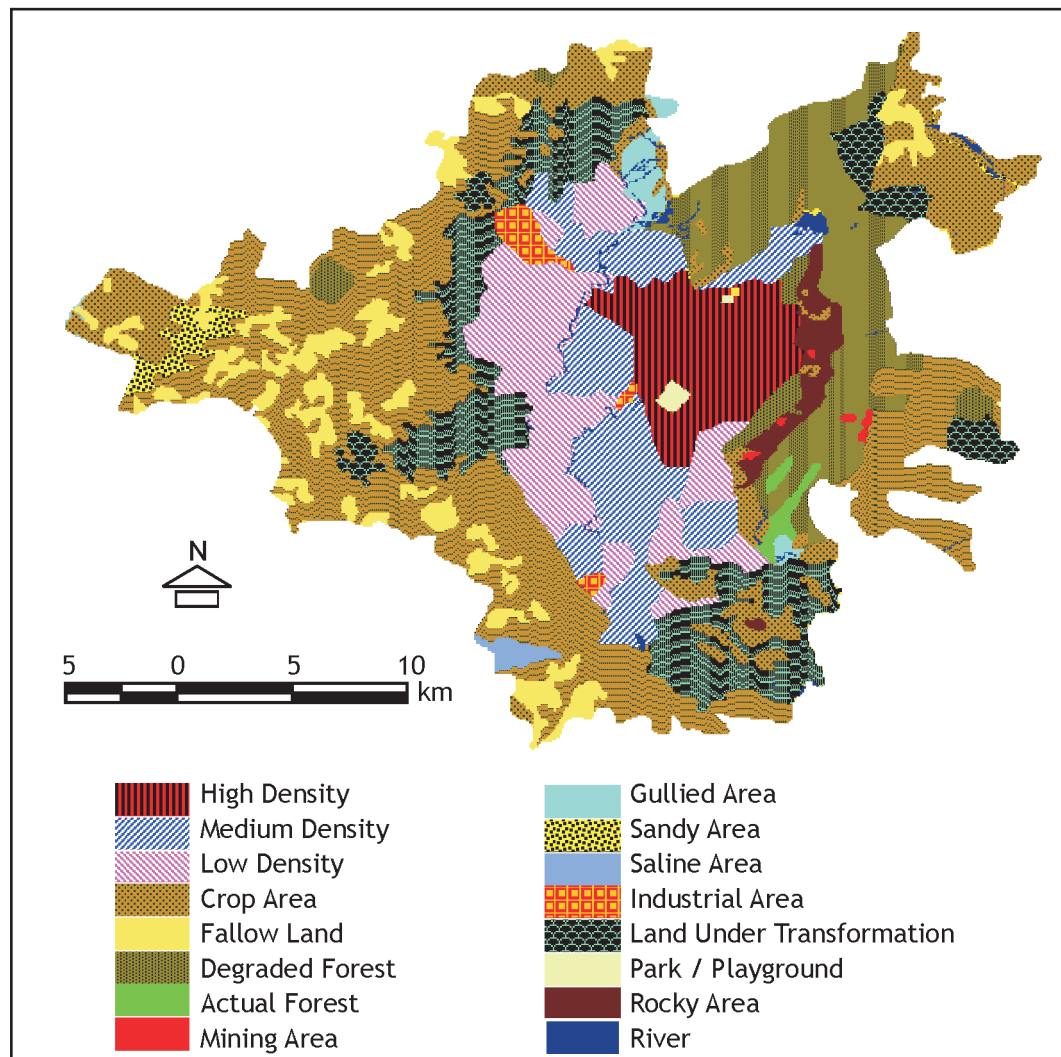
Multi-temporal and multi-resolution satellite data now provide the potential for mapping and monitoring urban land use change. We have developed an approach using satellite imagery, trained with the high resolution data sets that identify impervious surface areas (built up land, road network, vegetation, water bodies, etc.) at high resolution.

Change detection study shows change from 1975 to 1986. Change detection analysis shows that Jaipur city is expanding into nearby agriculture and open areas and density of built up land has also increased from low and medium density to high density. Total built up land in 1975 was 10.4 percent of total study area, which has become almost double and covered 19 percent land of the study area. Category wise changes are as under:

- **Built-up Area:** High density built up land covered 1,002.41 hectares of land in 1975, which is about 2.25 percent of the study area. Medium density area covered 1,377.04 hectares (3.1 percent) and low density area covered 1,038.64 hectares (2.34 percent) of area. 146.53 hectares area was converted from medium to high density, 926.21 hectares area from low to medium density, and 149.24 hectares from low to high density. Major changes are observed in southern and western parts where density of houses has increased to high density and open areas have been converted into built up area (see Table 1 and Fig. 3).
- **Cropped Area:** A total of 16,385.65 hectares was cropland in 1975, about 26.55 hectares of land is converted to high density, 815.5 hectares to medium density and 1,059.49 hectares to low density, which is reclassified as a new class crop to settlement. This shows that 1,901.55 hectares of area has been converted from crop to settlement. Apart from this, 35.71 hectares of area has been changed to mining and 94.96 hectares of area has been used for industrial purposes (Fig. 3).
- **Fallow Land:** Out of the total area of 12,308.26 hectares was fallow land, 3,942.14 hectares of land remains unchanged, 8,366.12 hectares land has been changed to degraded forests, low density and industrial area respectively. These categories are further reclassified as new built up areas for the change from crop to low density and new industrial area for the change from fallow to industrial class.
- **Degraded Forests:** Out of the total area of 2,275.03 hectares remains degraded forests. Noticeable change has been found in the crop category where about 248.74 hectares land has been changed from degraded forests to new crop area, whereas a positive change has also occurred:



Fig. 3: Land Transformation During 1975 - 1986



317.43 hectares of land got converted into new plantation category. It shows the increasing trend in the greenery of the city.

- **Plantations:** During this period of change, this category remained unidentified as the satellite data LANDSAT (MSS & TM) which was used for getting the change during this period has coarse resolution (79m x 79m) and below minimum delineation unit. Moreover in Jaipur city there were no areas, which were particularly defined for the plantation purposes. So limited and less quantity of plantation activity occurred in different land use categories like degraded forest area, gullied area, and scrubland, etc. in scattered form and hence reclassified in New Plantation class.
- **Actual Forest:** No change was found in this class during 1975-1986 period. This area is within the notified forest boundary and it is spread over very



small area i.e. 53.68 hectares which is only 0.12 percent of the total study area (44,472.27 hectares).

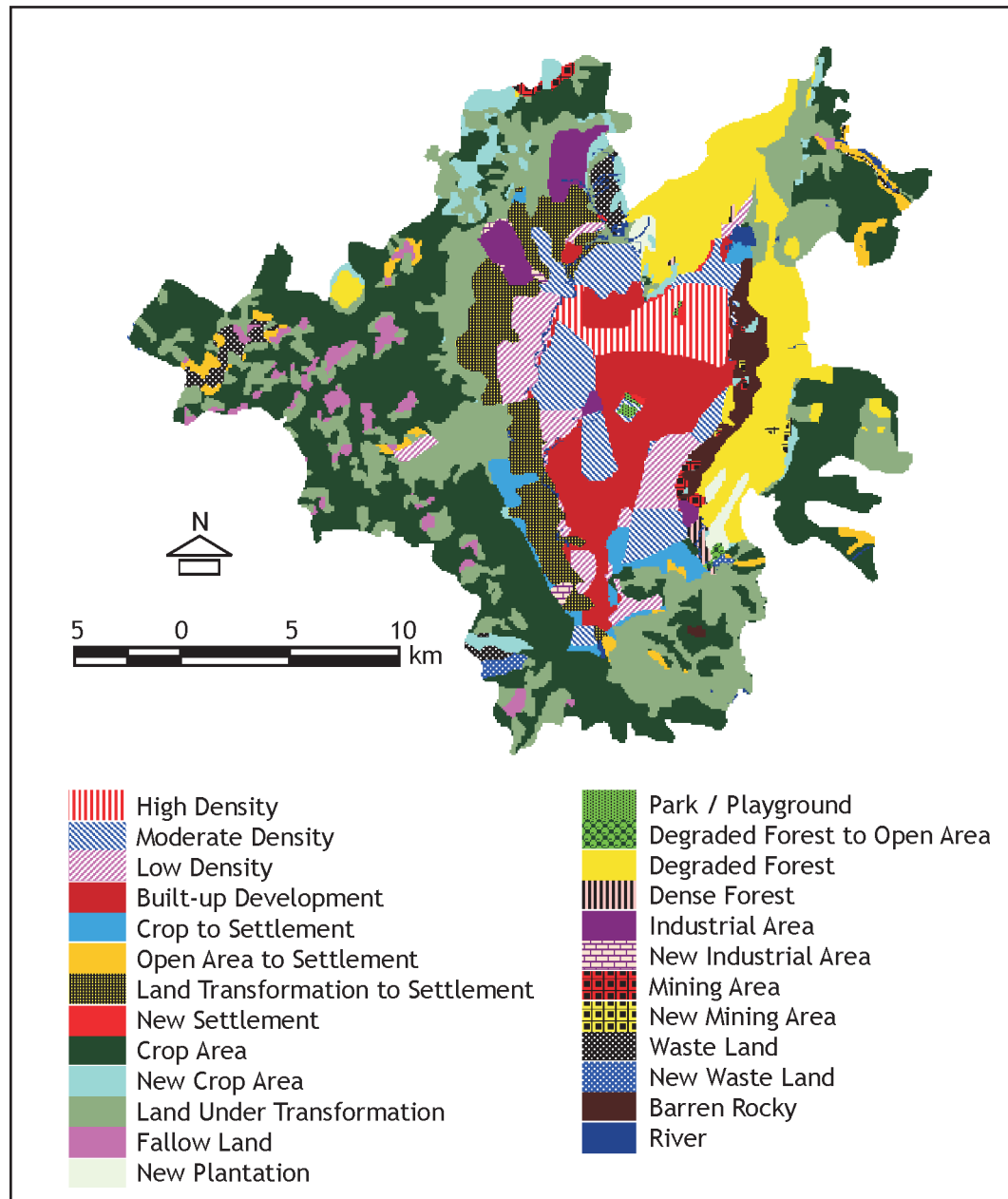
- **Mining Area:** Mining area exists in the study area in the form of mainly stone quarrying found near foothills of Jhalana and Nahargarh hill ranges. As Jaipur is developing with a fast rate, so to cater for the needs for the building activities, these areas are being used for the quarrying of building stones. During 1975-1986, the area under mining increased from 48.61 hectares to 167.56 hectares, showing more than threefold increase.
- **Gullied Area:** 249.4 hectares of land under mining has changed to gullied area, which is classified as new wasteland. This area is basically mined out area and dumping ground where gullies have developed.
- **Sandy Area:** During this period sandy area has changed to many new categories, and maximum land has been changed to crop area (2,092.7 hectares). This is the positive change as wasteland is utilized for agricultural purposes due to the pressure for production of vegetables and crops. This is classified as new crop area. Other major portions have changed to settlement (667.18 hectares) and grouped as New Settlement Class. 117.79 hectares sandy area has changed to plantation and classified as New Plantations. 654.51 hectares has changed to fallow land. Area which remains as sandy during this phase was 681.2 hectares.
- **Saline Area:** Out of the total 334 hectares saline land 230.8 hectares remains unchanged, whereas 103.28 hectares of land has been changed to crop area and classified into new crop area.
- **Land Under Transformations:** This category mainly shows the transition phase. 6,979.9 hectares land in this category has remained as open land. About 913.88 hectares of land has been transformed to built-up category and grouped as Land under Transformation to settlement class in aggregate class table. This shows that the city is developing outwards, and is encroaching upon agricultural lands. 38.02 hectare land has changed to crop area regrouped as new crop Area. 11.4 hectares land has been used for plantation, aggregated as New Plantation class in aggregate table.
- **Industrial Area:** This category remained as such during this study period. Only 302.8 hectares of land was used for industrial activities.
- **Rocky Area:** About 1.78 percent of land has been found under this category. This is the hilly area devoid of any green cover.
- **River:** 249.6 hectares of land is occupied by the riverbeds. These areas are generally sandy riverbeds found in Dhund river catchments.

4.2 Change During 1986-1991

During 1986-1991 major changes have been observed in two land use classes i.e. agriculture and built up land. Crop area has decreased considerably, whereas



Fig. 4: Land Transformation During 1986 - 1991



built up land has increased to accommodate the increasing population of the city. New colonies are being developed on the agricultural lands, and open lands. Changes in different land use and cover categories observed in this time period is described below (also see Table 1 and Fig. 4).

- **Built-up Development:** This category comprises of three classes, high density, medium density and low density. High-density area of 1,986



remains unchanged covering 1,268.12 hectares (2.85 percent) of land. Medium density built up area of 1,841.64 hectares has changed to high density, and 2,372.26 hectares (5.33 percent) of land remains unchanged. Low-density class has also contributed to built-up land. Here 48.38 hectares and 1,271.69 hectares of land have been transformed to high density and medium density area respectively.

- **Cropped Area:** Out of the total crop area, 13,733.87 hectares of land remains as crop area, and 703.53 hectares (1.58 percent) of land has been transformed to built up land, which is further classified as crop to settlement. 2.48 hectares land of crop area is converted into mining area and 12.96 hectares of crop land has been converted to industrial use (Fig. 4).
- **Fallow Land:** Out of a total area 583.14 hectares of land has remained as fallow during this period. 25.86 hectares of fallow land has been used for built-up development, which is grouped as new settlement in aggregate table. Apart from these 96.83 hectares of fallow land has been converted into saline area and regrouped as new wastelands.
- **Degraded Forests:** Total area under this category was 3132.12 hectares. 189.16 hectares of degraded forest area has been changed to plantation category. Apart from this, 48.33 hectares of land has been converted into mining activity. 23.22 hectares land has been transformed into built-up area.
- **Plantation:** New Plantation areas have been developed in various land use areas, like degraded forest, gullied area and sandy area in 1991(see Table 1).
- **Actual Forest:** Most of the dense forest areas have changed to degraded forests due to droughts or decline in vegetative cover and only 112.32 hectares of land has remained unchanged.
- **Mining Area:** New areas have been added to mining category and hence no changes have been found during this period, 167.27 hectares of land comes under this category.
- **Gullied Area:** 227.92 hectares of gullied area in 1986 remained unchanged in 1991, 106.33 hectares land has been converted into plantations and grouped as new plantation class, 77.18 hectares converted to cropped area, which is classified in new crop area class in aggregate class table and only 4.67 hectares changed to built-up land.
- **Sandy Area:** Major part of this sandy wasteland has been changed to cropped area (580.32 hectares). This positive change is further classified as new cropped area. 280.40 hectares of land remained unchanged. 24.35 hectares land switched over to built- up land of low density and 7.03 hectares land to plantation. 22.52 hectares land converted into gullied area and grouped as wasteland class.



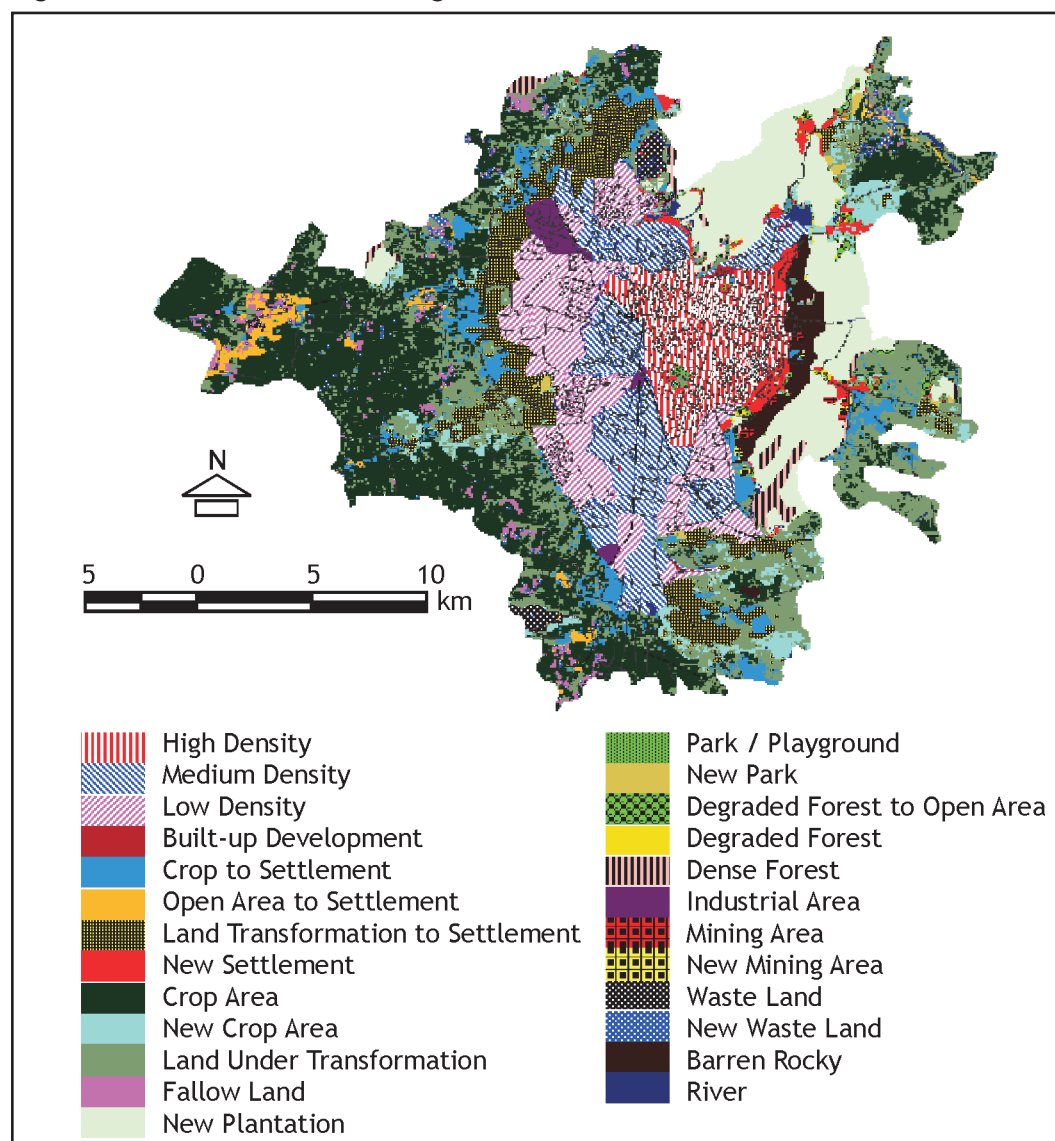
- **Saline Area:** 74.17 hectares of area in 1986 remained saline and remaining 120.10 hectares of area was converted into cropped area. This positive change is probably due to reclamation of saline lands or due to utilization of saline marginal land on account of over pressure for producing more crops. These areas are classified as new crop areas.
- **Land Under Transformation:** A considerably large part of land under transformation has been utilized for residential purposes (2,500.76 hectares) and industrial purpose (74.30 hectares). This shows that Jaipur city has expanded at a faster rate especially in southern and western directions. Some parts have been used for agriculture and for growing vegetables. Remaining 8,896.6 hectares land remained as land under transformation for future utilization.
- **Park and Playground:** 51.84 hectares land has been used for parks and playgrounds during this period and 28.8 hectares land of this category has been change into built-up land.
- **Rocky:** Total area of barren rocky category was 786.36 hectares in 1986, which remained same in 1991 also as barren rocky areas as it could not be utilized for any urban land use.
- **River:** Area under this class was 249.35 hectares of study area.

4.3 Change During 1991-2003

During 1991-2003 time major change have been found within and between two land use classes i.e. agriculture and built up land. Crop area has decreased considerably, whereas built up land is increasing very fast, as population of the city is increasing at a fast rate. To meet the housing need of the people new colonies are being developed on agricultural land. Some positive changes have been found from the ecological point of view like, afforestation carried on degraded forest area. Different land use and land cover wise changes were observed during 1991-2003 as described below (see Table 1 and Fig. 5).

- **Built-up Development:** High density built up area of 1991 remains unchanged to 2,367.42 hectares and 51.49 hectare area of, medium density built up and 10.48 hectares low density areas have been converted into high density areas (Fig. 5).
- **Crop Area:** 10,340.01 hectares of land was under this class. 1,750.87 hectares of agriculture land has been transformed into built-up land, 25.98 hectares into mining, 10.43 hectares into parks and playgrounds.
- **Fallow Land:** Fallow land of 1991 around the city has been converted into many other land uses. Mainly it is converted into saline area (129.72 hectares), scrubland (173.72 hectares) and built up land (169.98 hectares).

Fig. 5: Land Transformation During 1991 - 2003



- Degraded Forests:** A major positive transformation has occurred in this time period viz. 4,222.77 hectares of land of this class has changed into plantation because of emphasis on afforestation. This is further reclassified as new plantation category. About 534.13 hectares land changed to built up land. 219.11 hectares land changed to crop area, 154.71 hectares to fallow land, whereas only 3 hectares of land been occupied by mining activities (Table 1 and Fig. 5).
- Plantation:** Few areas of land use classes like gullied (81.45 hectares), sandy (0.35 hectares), parks and playgrounds (6.51 hectares) and degraded forests (4222.77 hectares) has been changed to plantation category, and


Table 1: Change During 1991 to 2003

Class Name	1975-1986		1986-1991		1991-2003	
	Area (Hectares.)	Area (Per Cent)	Area (Hectares.)	Area (Per Cent)	Area (Hectares.)	Area (Per Cent)
High Density	1002.41	2.25	1268.12	2.85	2367.42	5.32
Moderate Density	1377.04	3.10	2372.26	5.33	3639.92	8.18
Low Density	1038.64	2.34	1766.42	3.97	3808.92	8.56
Built Up Development	1221.98	2.75	3161.72	7.11	61.98	0.14
Crop to Settlement	1901.55	4.28	703.53	1.58	1750.87	3.94
Open Area to Settlement	3330.89	7.49	630.89	1.42	490.69	1.10
Land Trans to Settlement	913.88	2.05	2500.76	5.62	2978.84	6.70
New Settlement	42.57	0.10	56.68	0.13	599.67	1.35
Crop Area	16435.70	36.96	13727.63	30.87	10340.01	23.25
New Crop Area	390.01	0.88	1068.88	2.40	1185.29	2.67
Land Under Transformation	6979.85	15.69	8846.67	19.89	7003.12	15.75
Fallow Land	2212.07	4.97	700.19	1.57	435.05	0.98
New Plantation	317.43	0.71	295.49	0.66	4304.22	9.68
New Park	11.40	0.03	51.84	0.12	26.78	0.06
Degraded Forest to Open Area	126.60	0.28	32.20	0.07	99.53	0.22
Degraded Forest	3645.56	8.20	4318.68	9.71	354.99	0.80
Dense Forest	53.68	0.12	112.32	0.25	38.13	0.09
Industrial Area	302.80	0.68	808.24	1.82	523.64	1.18
New Industrial Area	608.95	1.37	87.26	0.20	65.43	0.15
Mining Area	48.50	0.11	167.27	0.38	28.97	0.07
New Mining Area	150.62	0.34	50.80	0.11	355.28	0.80
Wasteland	1161.45	2.61	583.03	1.31	305.45	0.69
New Wasteland	152.76	0.34	119.35	0.27	767.92	1.73
Barren Rocky	790.96	1.78	786.36	1.77	255.86	0.58
River	249.64	0.56	249.35	0.56	65.43	0.15
Road Network					2153.32	4.84
Rail Network					143.08	0.32
Others	5.30	0.01	6.34	0.01	65.09	0.15
Total	44472.27	100.00	44472.27	100.00	44472.27	100.00

Sources: Personal Analysis based on Satellite Data

are mentioned in new classified category new plantation. Actual forest cover 523.64 hectares land under dense forest remained as such. Where mining area covered 65.43 hectares of land. Gullied area remained same i.e. 195.72 hectares of land. 81.45 hectares land changed to plantation, 44.18 hectares to built-up land, 20.74 hectares to crop area. Sandy area



spread on 23.39 hectares remained unchanged, 250.16 hectares changed to crop area, 95.5 hectares changed to fallow land, 67.91 hectares changed to built-up land. Saline area also remained unchanged and it covered 136.17 hectares of land.

- **Land Under Transformation:** 7,003.12 hectares land was under this category. 911.81 hectares has changed to crop area, and built up land (301.85 hectares), 89.11 hectares land to parks and playgrounds. Under this category 20.28 hectares has come, where industrial area covers 322.79 hectares land. Other land like, rocky which cover 767.92 hectares of land and degraded forest and fallow land categories that changed to scrub land category. River covered 255.86 hectares of land during this period.

4.4 Change During 2003-2009

During 2003-2009 major changes were found within and between two lands use classes i.e. agriculture and built up land. Crop area has decreased considerably. Different land use and land cover wise changes were observed during 2003-2009. These are as follows: crop land decreased by 15 sq km whereas the fallow land by 5.87 sq km, on the other side built up land increased by 46.87 sq km, and major changes also seen in high density that is from 21 to 41 sq km during this time period (Table 1 and Fig. 6).

High density built up area of 2003 remained unchanged to 24.44 sq km and low density built up area of 126.65 sq km increased 16.44 sq km and 2.41 sq km low density areas has been converted into high density area. 147.47 sq km of land was under this class in 2003. 20.91 sq km of agriculture land has been transformed into built-up land, and it reduced to 126.56 sq km (see Fig. 6).

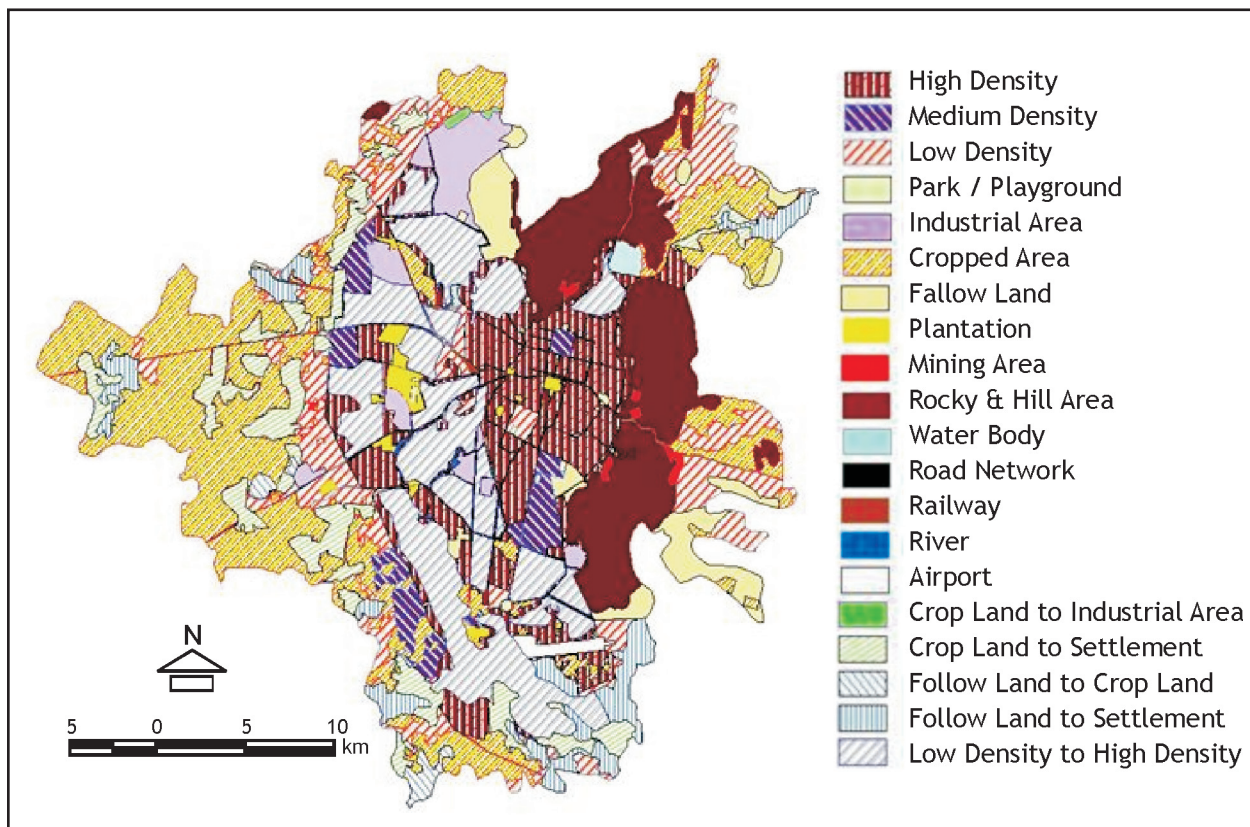
4.5 Urban Growth: 1975-2009

Population size of the walled city is 0.4 million on an area of 6.7 sq km, and Jaipur Municipal Corporation (JMC) has 2.3 million people on an areas of 288.4 sq km, and the total population of JDA is 2.7 million on an area of 1,464 sq km as per Census 2001. The Municipal body was recognized in 1926 and a Municipal Act was in passed in 1929. Recently, it achieved the status of a Municipal Corporation and its jurisdiction is now spread over 64.75 sq km. The old city occupies 9.8 sq km. Average density of population works out to be 38,610 persons per sq km. The city is growing at a fast rate. The growth rate of population was 5.9 percent per annum in 1991-2001 as against 4.9 during 1981-1991. Poverty level in Jaipur is estimated at 36 percent (Census of India). Management of tourism is not a direct responsibility of Jaipur Municipal Corporation.

The statistics reveal that the area continued to increase from 1975 to 2009. Due to barrier of hill and mountains in the north, north east and east part, the



Fig. 6: Land Transformation During 2003 - 2009



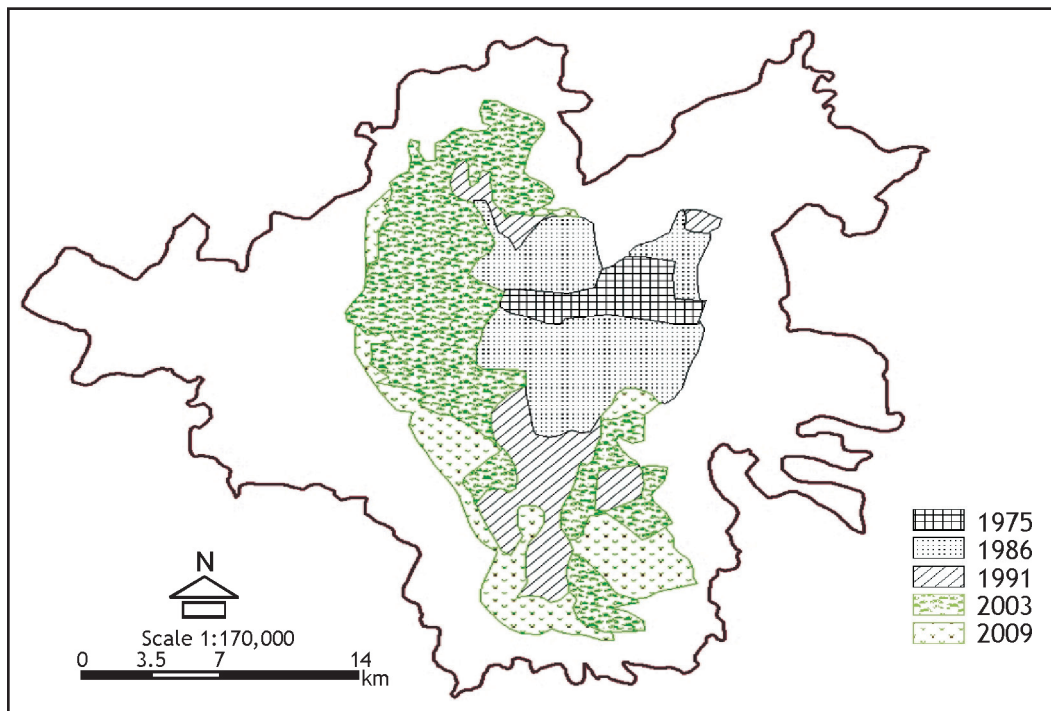
city has grown towards south, south west and west direction along major roads and plain areas. Most of the settlement on the base of fallow land and crop land. During 1975 to 1986 the high density built up land increased by 73 percent whereas, the medium density showed the increase of 144 percent. But the low density areas showed less growth of only 38 percent (Table 1 and Fig. 7).

The high density urban built up land grew much more during 2003 and 2009 where it was 88 percent. During 1991 to 2003 more than 200 per cent growth has been recorded in low density areas. During 1975 to 2009, the total built up land was 46.39 sq km, in 1975, 83.92 sq km in 1986, 113.3 sq km in 1991, 172.62 sq km in 2003 and 197 sq km in 2009 (see Fig. 7). Here the area has grown by 1.02 percent per year, much rapidly than the last decade due to development of infrastructure and industries.

4. MAJOR FINDINGS

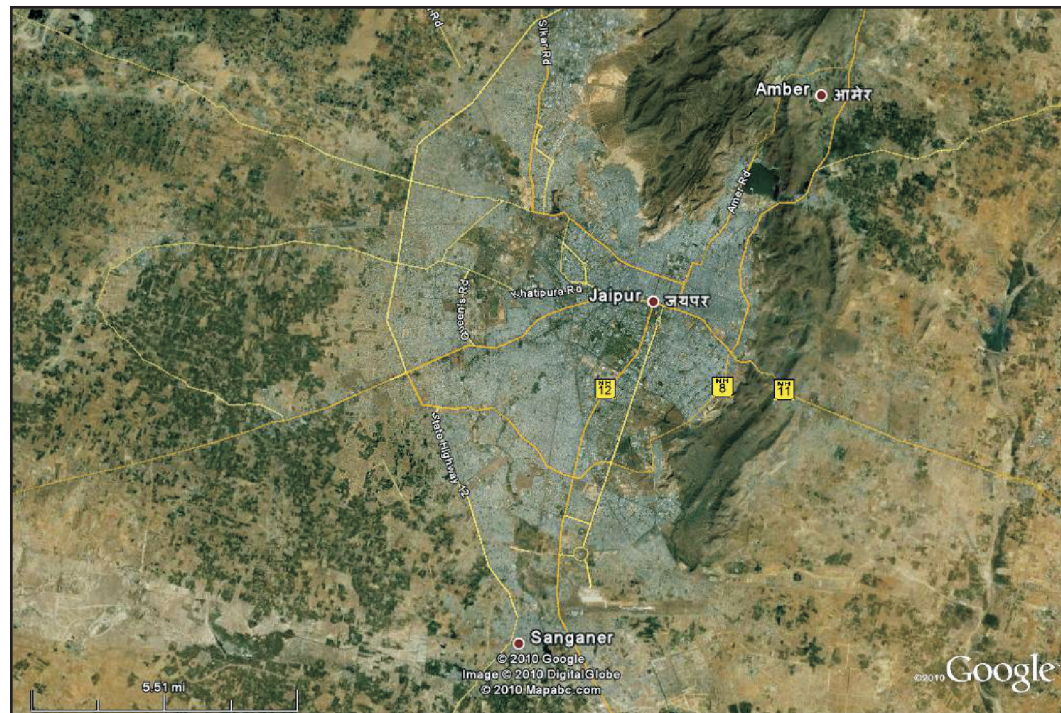
- Major conversions of fallow and agriculture land into commercial, residential and the other urban land uses.
- Population has grown from 0.3 million in 1951 to 2.3 million in 2001 and 2.9 million in 2009. The annual average growth rate from 1971 to 2001

Fig . 7: Urban Growth 1975 - 2009



has been in the range of 4.1 to 4.7. Infrastructure did not grow according to growth of population.

- Population growth has forced the change in land use. For example, during 1975-2009, the crop area has shrunk to 1.60 sq km per year and cropped area has reduced from 35 to 23 percent, fallow land has reduced from 28 to 5 percent that is 2.94 sq km per year, wasteland from 14 to 9 percent.
- The forestland continues to be stable due to awareness of NGOs and the people. The area under forest is protected by government and did not show any reduction. In 1975, it was 6.55 percent covered which in 2009 was 12.70 percent.
- Waste land is also being converted into crop land and used for agricultural activities; it was 14 percent in 1975 while it stood at only 9 percent in 2009.
- Major expansion is observed in the western, southern and south-eastern parts along the national highways, engulfing the productive cropped areas, fallow land, and degraded forest land.
- The impact of mega city Delhi and development of physical infrastructure, especially the transport system, have triggered many land use changes.
- Open areas, greenery of surrounding areas as well as its vicinity to Delhi are some factors, which attract the people towards this pink city.

Fig. 8: Satellite Map of Study Area

5. CONCLUSIONS

Residential area has higher rate of expansion after 1975, the major expansion is observed in the western, southern and south-eastern parts and along the national highways 8, 11 and 12. Towards the south it has expanded about 20 km from Ajmeri Gate covering Sanganer town and even along the Tonk road. Towards western direction it has almost reached to Bagru town, which is about 35 km away from the city. The city has expanded towards southern and western directions engulfing productive cropped area, fallow land, and degraded forest land. The urban area has covered the surrounding towns, which are developing as the satellite towns like Sanganer, Bagru, Chomu, Achrol, Kanota, etc. Jaipur city is putting heavy pressure on the ecologically sensitive areas by way of deforestation and mining in Nahargarh and Jhalana reserve forest areas.

Major problems associated with this urban centre is that of unplanned expansion, changing land use and land cover, loss of productive agricultural land that is from 280.85 sq km to 126.56 sq km during 34 years and wasteland declined from 62.47 sq km to 42.24 sq km. Built up land increased from 46.39 sq km in to 197.96 sq km whereas the maximum expansion is observed in low density built up land. The correlation analysis depicts that positive and high level of correlation is found between population and built-up land. As far as correlation of population and agriculture land with other variables is concerned, it has high and negative correlation and it does not show any significant relationship with other variables.



REFERENCES

- Batty, M. and Longley, P. (1994) *Fractal Cities: A Geometry of Form and Function*, Academic Press, San Diego.
- Benati, S. (1997) A Cellular Automata for the Simulation of Competitive Location, *Environment and Planning: Planning and Design*, Vol.24, pp.205-218.
- Clarke, K.C. and Gaydos, L.J. (1998) Loose-Coupling a CA Model and GIS: Long-Term Urban Growth Prediction for San Francisco and Washington/Baltimore, *International Journal of Geographical Information Science*, Vol. 12, No.7, pp.699-714.
- Ewing, R.H. (1997) Is Los Angeles Style Sprawl Desirable? *Journal of the American Planning Association*, Vol. 63, No.1, pp.107-126.
- Gaubatz, P. (1999) China's Urban Transformation: Patterns and Process of Morphological Change in Beijing, Shanghai and Guangzhou, *Urban Studies*, Vol. 36, No.9, pp.1495-1521.
- Gupta, R. and Sen, A. (2008) Monitoring Physical Growth of Ranchi City by Using Geo-Informatics Techniques, *ITPI Journal*, Vol.5, No.4, Oct-Dec, pp 38-48.
- Gupta, R. (2008) Urban Growth Monitoring through Geo-Informatics: A case of Ranchi City, *Uttar Pradesh Geographical Journal*, Kanpur, Vol.3,pp. 1-10.
- Gupta, R. (2006) Study of Population Change and Urban Land use relationship Using an Integrated Remote Sensing and GIS Approach, *The Deccan Geographer*, Vol.44,pp.1-12.
- Gupta, R. and Raghavswamy, V. (2005) 'Population growth and land transformation in Gurgaon Haryana: spatio-temporal analysis using remote sensing and GIS techniques', in *Space Science and Technology for Geographical Research and Applications*, B.S.Publication, Hyderabad, India.
- Gupta, R. and Nangia, S. (2005) *Population explosion and land use changes in Gurgaon city region-a satellite of Delhi metropolis*. In International Conference proceeding of International Union for the Scientific Study of Population. In: <http://iussp2005.princeton.edu/download.aspx?submissionId=50502>
- Masser, I. (2001) Managing our Urban Future: The Role of Remote Sensing and Geographic Information Systems, *Habitat International*, Vol.25, pp.503-512.
- Ottens, H. (2002) *GIS-Based Decision Support for Urban Planning Strategies*, The 29th International Geographical Congress, Seoul, Korea.
- Wu, F.(1998) The New Structure of Building Provision and the Transformation of the Urban Landscape in Metropolitan Guangzhou, China, *Urban Studies*, Vol.35, no.2, pp.259-283.
- Yeh, A. G.O. and Li, X. (2001) Measurement and Monitoring of Urban Sprawl in a Rapidly Growing Region Using Entropy, *Photogrammetric Engineering and Remote Sensing*, Vol. 67, No. 1, pp.83-90.