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Mapping the Built-up Area using Urban Landscape Analysis Tool (ULAT) in Jaipur city of Rajasthan, India

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Abstract: One of the important attributes of land use/land cover in urban areas is built up area. The amount of change in built-up area in a region is an important indicator of urban growth. This study was carried out to assess the dynamic nature of the built-up area in the urbanizable area (U1) of Jaipur city with the help of remotely sensed data and GIS. Landsat surface reflectance data product was used to identify the change in built-up area for the period of 2000 to 2017. The study showed that during the 2000–2009 and 2009-2017 period the percentage area covered by built-up is increased by 35.35% and 56.53% respectively. The magnitude of change over the 17-year period is 96.63 sq. km (percentage change 111%) for built-up area. The results quantify the built-up area change patterns and demonstrate the potential of remote sensing and GIS technique to provide an accurate, economical means to map and analyze changes in the built-up area over time in the urban region.

I. Introduction

Land is the basis for human life on which many of other human activities are based. The increase in population and human activities are increasing the demand on the limited land resources for agriculture, forest, pasture, urban and industrial land uses. Indiscriminate use of this resource may create problems of haphazard development, deteriorating environmental quality, loss of prime agricultural lands etc. It is essential to understand the two basic attributes of this resource i.e., land use and land cover, for proper planning, management and to regularise the use of such resource.

The land use/land cover (LULC) pattern of a region is an outcome of natural and socio-economic factors and their utilization by man in time and space (Opeyemi, 2006). The terms "land use" and "land cover" are often used simultaneously to describe the types of features found on the earth's surface and the human activity that is associated with them.

One of the important attributes of LULC in urban areas is built up area. The amount of change in built-up area in a region is an important indicator of urban growth. The growth of a built-up area in an urban centre is quite obvious with the increasing trend of urbanization but discriminate and unmanaged growth in the built-up area bring lots of serious social and environmental concerns. Big cities and urban agglomerations work as magnets that attract investment, which leads to the development of industrial and service sector, employment generation, immigration and population growth witch intense the process of urbanization. This process of over-urbanization has significant implications in terms of land use/land cover changes in these areas where arable land and vegetative area are consumed rapidly by urban built up. To cope up these implications of over-urbanization and to do planned development of an urban area it is necessary to have a detailed and up to date status of urban growth patterns with trends, rate and magnitude for future prediction.

Although the dynamism in trend, rate and magnitude of urban growth as well as built up area creates a great challenge for researchers to assess its nature precisely, but the study of this dynamism has its own importance as it provides an important input parameter about urbanized area for a number of different hydrological, environmental and ecological models, which constitute necessary tools for development, planning and management of natural resources in any region.

The major breakthrough in the field of these kinds of studies came due to the development of Remote Sensing Technology since 1980's. urban growth studies up to late 60's and early 70's has been based on conventional surveys and ground observations which are at present only suitable if the site is small and easily accessible but in the case of metropolitan areas, it is not preferable as they are very expensive and time-consuming. Land cover changes are dynamic in nature and have to be monitored at specific intervals. The remotely sensed data from space borne sensors provides repetitive coverage and data in digital form which are amenable to computer analysis using Geographic information system (GIS). Development of Remote Sensing technology opened up the opportunity for measuring the dynamic land use changes with greater precision and studies their relationship with population and other related factors (Jalan & Sharma, 2014).

Therefore, an attempt is made in this study to assess the dynamic nature of LULC change with respect of built-up area by manipulating and analyzing different satellite imagery using different G.I.S. Software and to map out the status of spatial urban growth and sprawl of the Jaipur urbanizable area with a view to detecting the land consumption rate and the changes that has been taken place in the study area particularly in its built-up land.

II. Aim of Study

With respect to the global concern about discriminate and unmanaged growth in the built-up area which brings lots of serious social and environmental concerns especially in urban areas, there has been a need to adopt a scenario wise approach in the context of rapid urbanization. In view of the above, this research has been undertaken with the objective to analyze the actual state of the built-up area in Jaipur urbanizable area and mapping its dynamic nature over the time. The main aim of the study is to identify, quantify and analyze the spacio-temporal scenario of built-up area and urban sprawl with special reference to urbanization in the study area using remote sensing and GIS as a tool.

III. Study Area

The study area consists of the urbanizable area (U1) of Jaipur Development Authority (JDA) region, demarcated and defined in Jaipur Master Plan -2025 and form a part of Jaipur district which lies in the north eastern part of Rajasthan. Normally these kinds of studies of an urban centre are limited to its local body governance boundary which is Jaipur Municipal Corporation (JMC) in this case. But in this particular study, the urbanizable area (U1) of JDA region is chosen as the study area because presently the urban agglomeration of Jaipur is expended beyond the city limit so most of the land use/land cover dynamics with respect to the built-up area are happening beyond the JMC limit.

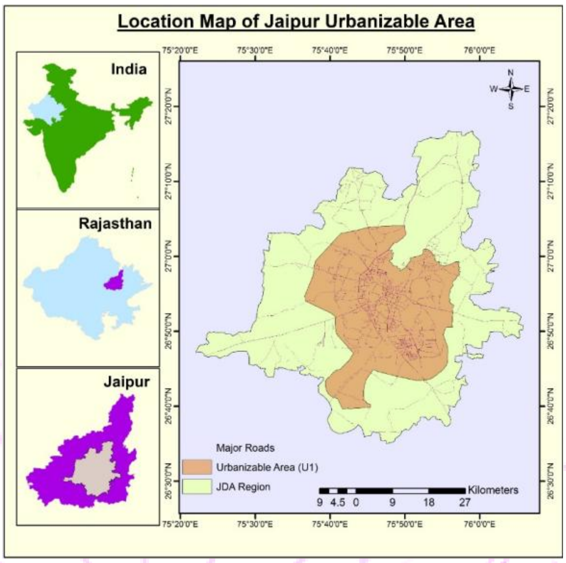

Figure 1. Location map of the study area.

The urbanizable area (U1) envelops municipal corporation region of Jaipur city and 351 revenue villages with an aerial extent of around 945 Km^2 (Master Development Plan-2025 JDA, n.d.). The whole area lies between 26^0 39'38.26''- 27^{0}04'67.66'' N lat. and 75^{0}36'36.59''- 75^{0}57'25.10'' E long. and is characterized by diverse topography. The major part of the study area is relatively flat and characterized by alluvial sandy-plain. In the northern and mid-eastern parts, Aravalli hills and designated reserve forests are situated (District Outline 2015, Jaipur, n.d.).

IV. Material and Methodology

Due to dynamic nature of land use/land cover of a region, a time series of built-up area patterns are generated by using satellite imageries of the different time period. A set of three Landsat 8 OLI, Landsat 7 ETM+ and Landsat 5 TM land surface reflectance product images having high spatial and radiometric resolution were chosen to map and extract the dynamics of land cover change in the region.

In total 3 imageries of Landsat sensor were selected for this study. The required imageries were downloaded in L1TP land surface reflectance data type and GeoTIFF format from USGS's Earth Explorer website (http://earthexplorer. usgs.gov)

Table 1. List of Satellite images used for land cover change study and their specifications.

	Landsat Scene Identifier	WRS Path/ Row	Sensor Identifier	Date Acquired
1	LC08_L1TP_147041_20170224_20170301_01_T1	147/ 041	OLI_TIRS	24/02/2017
2	LT05_L1TP_147041_20090202_20161029_01_T1	147/ 041	5_TM	02/02/2009
3	LE07_L1TP_147041_20000218_20170213_01_T1	147/ 041	7_ETM	18/02/2000

For ground truthing, interpretation and verification of the information extracted from remotely sensed data, the reference data is also used. The reference data was obtained from various sources like Google Earth Pro, the United States Geological Survey website, Bhuwan website, Toposheets of the survey of India etc.

Cartosat-1 Streodata DEM provided by National Remote Sensing Centre, ISRO and downloaded from their website (http://bhuvan-noeda.nrsc.gov.in) is used to providing an elevation reference to the existing topographic conditions in the region.

The methodology used in this research work for work for extracting built-up area and its dynamism in the study area is described in the following steps:

1. Preparation of boundary and base layer map by delineation of urbanizable area (U1) boundary, using ArcMap software with the help of Survey of India (SOI) toposheets and JDA Master Plan – 2025 (Master Development Plan-2025 JDA, n.d.).

2. Image pre-processing (a) Ortho-rectification: Geocoded image in WGS84, UTM Zone no. 43 (b) Radiometric correction and enhancement. (c) Subset and mosaic process.

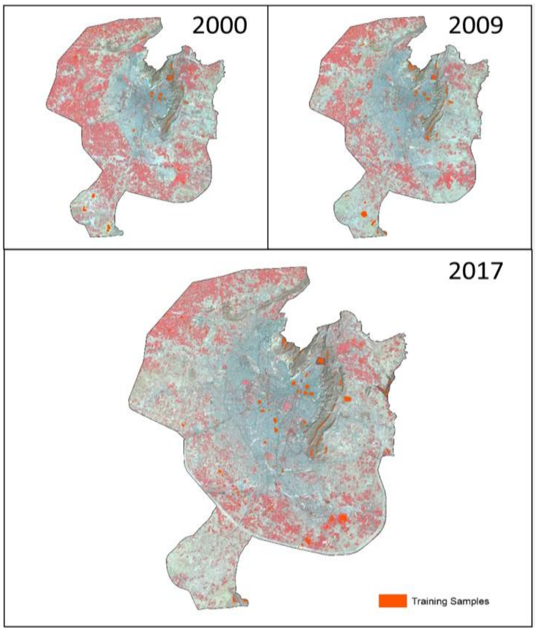

Figure 2. Location of Training Samples for Supervised Classification using Maximum Likelihood Classifier.

3. Adoption of suitable land use/land cover classification system (Anderson et al. 1976). As this study is mainly related to evaluating the change in the built-up area, therefore only three class classification system was adopted for this case study. It includes water body, built-up area and other class. The third one, i.e. other class includes all the classes like bare soil/fallow land, agriculture cropped land, natural vegetation, bare rock/hill surface etc. except water body and built-up.

4. Mapping of various land cover classes by Semi-automated supervised classification using maximum likelihood classifier (Bhandari 2010) and visual image interpretation using various reference data

5. 5. Computation of various spectral indices (NDBI, NDWI etc.) and masks (masks for the cloud, water body, shadows, bare rocks, hills, etc.) (Pauleit, Ennos, and Golding 2005) to refine the classification result.

6. Geo-correction, ground validation and accuracy assessment. Generation of the error/confusion matrix and computation of overall, user's and producer's accuracy with the help of field visit date –captured using GPS.

7. Computation of trend, rate, magnitude of change in the built-up area, land consumption rate (LCR) and land absorption coefficient (LAC).

8. Post-classification, comparison and calculation of various statistics to quantify the built-up area change in the region using Urban Landscape Analysis Tool (ULAT) developed by the Centre for Land Use Education And Research (CLEAR), Natural Resources Management and Engineering, the University of Connecticut in ArcGIS environment.

V. Results and Discussions

The case study of built-up area change analysis for the period 1992 to 2017 has been done using maximum likelihood classifier and the classified land cover maps for the years 1992, 2000, 2009 and 2017 are given in figure 3. The investigation reveals that there has been a marked built-up area change during the study period of 25 years.

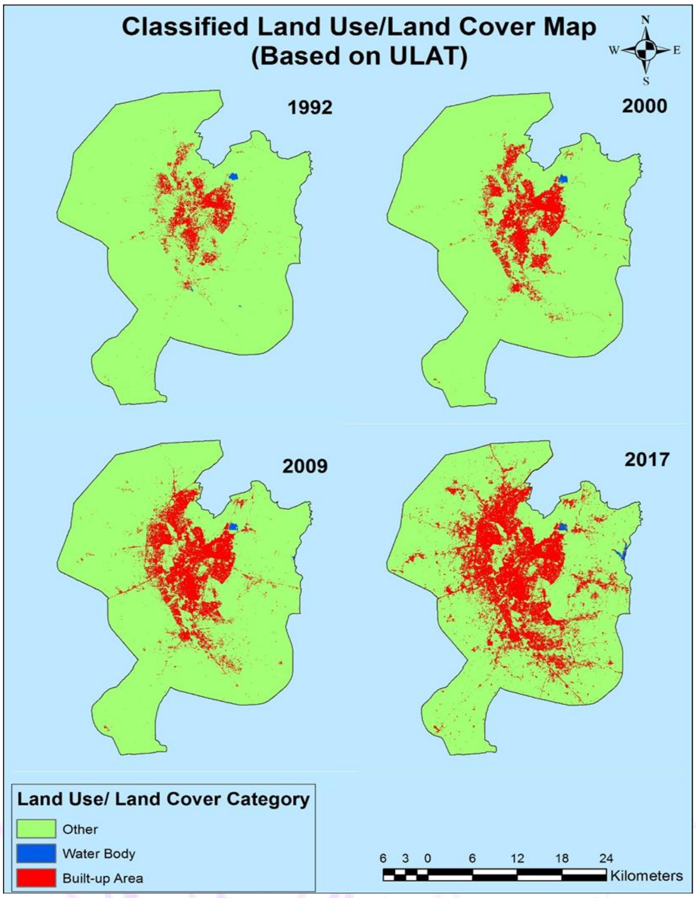

Figure 3: Classified land use/land cover map of Jaipur urbanizable area.

An overlay map (Figure 4) of built-up area to show the location of the change was depicted for the period of 1992 – 2017.

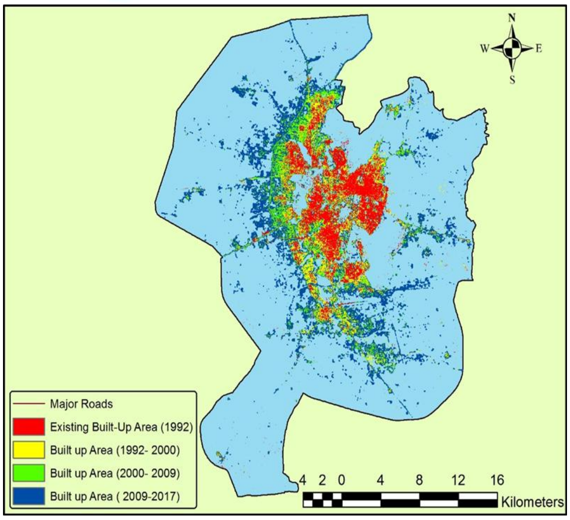

Figure 6.3: Overlay of Built up Area to Show Urbanization Pattern of Jaipur Urbanizable area (U1) During the Period of 1992–2017.

The built-up area change pattern established that the urban growth was mainly limited to the western and north-western part of the already urbanized area up to 2009 as in the northern and eastern part of the city Aravalli hills and ridges were acting as a limiting factor. But after 2009, due to the development of transport facilities and pressure of intense-urbanization, the built-up area has been spreading rapidly beyond this natural barrier but still limited to along the major roads only.

Before 2009, the existence of built-up in the local neighborhood influenced the development of new built-up therefore the growth was relatively compact in nature, but after 2009 the growth of built-up area has more fragmented in nature.

Again, the result establishes that the intensity of built-up area gradually diminishes as the distance from the core city increases and the change is only restricted along the major roads.

VI. Trend, Rate and Magnitude

Following the classification of imageries from the individual years, a multi-date post-classification, comparison change detection algorithm (Adepoju 2007) was used to determine changes in the built-up area in the time interval; 1992 to 2017. The change analysis provides that notable changes occurred in the study area during the period, particularly in the built-up area.

The comparison of the various built-up area changes statistics assisted in identifying the percentage change, trend and rate of change from 1992 to 2017. Following formulas were used to calculate various statistics (Yeates and Garner, 1976, Opeyemi 2006):

LCR is a measure of the compactness which indicates a progressive spatial expansion of an urban centre. Whereas LAC is a measure of change in consumption of new urban built-up land by each unit increase in urban population.

During 1992, 2000, 2009 and 2017, the area covered by the built-up was reported as 60.09 km2, 87.09 km2, 117.88 km2 and 184.52 km2 respectively. The magnitude of change (Kafi, Shafri, and Shariff 2014) was computed as 27 km2, 35.35 km2 and 56.52 km2 for 1992-2000, 2000–2009 and 2009-2017 period respectively whereas the total magnitude of change over the whole 25-year period was 124.5 km2 (percentage change 207%) for the built-up area. This increment in the built-up area correlates with the population growth of the region, which experienced a total increment of 193.15% (Banthia 2001; Directorate of Census Operations-Rajasthan 2001; Master Development Plan-2025 JDA, n.d.) during the same period. It provides an insight that demographic factor plays a vital role in the expansion of the built-up area in the region.

The study reveals that the trend or percentage change in the built-up area was reported as 44.93%, 40.59% and 47.94% during 1992-2000, 2000-2009 and 2009-2017 period. The annual growth rate (rate of change) experienced by the built-up area for 1992-2000, 2000-2009 and 2009-2017 period was estimated as 3.14, 3.65 and 3.83 per annum respectively.

Land Consumption Rate (LCR) and Land Absorption Coefficient (LAC) were also calculated for the present case study. The study reveals that the Land Consumption Rate (LCR) for the built-up area was 0.003754, 0.003884, 0.003523 and 0.003932 hectare per person for the base year 1992, 2000, 2009 and 2017 respectively.

This result gives an insight that from 1992 to 2017, LCR was almost constant without much fluctuation. It seems satisfying, but during the calculation of these results, the vertical development of the city was not considered, if this was done, then the rate of LCR would have increased rapidly, which proves unmanaged urban development in this area. Land Absorption Coefficient (LAC) which is a measure of change in consumption of new urban built-up land by each unit increase in urban population was recorded as 0.0042, 0.0027 and 0.0049 hectares per person for the period of 1992-2000, 2000-2009 and 2009-2017.

VII. Conclusion

This research has been able to establish the rapid built-up growth in Jaipur urbanizable area as well as the location and types of changes that have taken place in the study area. The change analysis showed that notable changes reported in the study area during the studied period, particularly for the built-up area. The temporal analysis of the land cover of the region reveals an increase in urban built-up area by 111.86% from 2000 to 2017 which indicate the urban-intensification in the region.

The study establishes that increases in built up mainly came from conversion of bare soil/fellow land, natural vegetation and agriculture cropped land.

The region experienced the overall negative change in agriculture cropped land and natural vegetation cover over the period which may cause the negative impact on ecology and environment of the region. This study has also demonstrated the significance of incorporating remote sensing and GIS for change detection study of land cover of an area as it offers crucial information about the spatial distribution as well as nature of land cover changes. The thematic maps of land cover obtained during the study indicate that the integration of supervised classification of Landsat satellite land surface reflectance data product using maximum likelihood classification algorithm with visual interpretation is an effective method for the documentation of changes in land cover of an area.

VIII. Reference

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