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Application of Remote Sensing and GIS in Assessment of Spatio-Temporal Change in Built-up Area of Jaipur city, 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.

Keywords: Built-Up area, Land Use/Land Cover, Remote Sensing, GIS, Urban Sprawl, Landsat 8 OLI/TRIS

Introduction

The Land use/land cover (LULC) pattern of a region is an outcome of natural and socio-economic factors and their utilization by the man in time and space. It is dynamic in nature i.e. the different attributes of LULC vary with time and space and this variation could be the result of complicated interactions of socio-economic and bio-physical situations like economic diversification, technological advancement, demographic pressure and many other related conditions.

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 brings 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 plan 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 have 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 of Jaipur Urbanizable Area (U1) for the period of 17 years i.e. from 2000 to 2017 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.

Aim of the 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.

Review of Literature

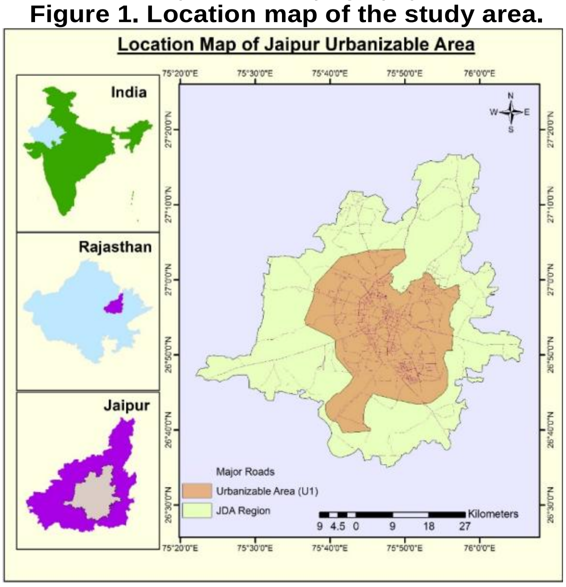
Significant work has been done in evaluating urban expansion and land use change by various researches (Jain, Dimri, & Niyogi, 2016; Tewolde & Cabral, 2011; Xiao et al., 2006) using GIS and remote sensing. The Maximum likelihood supervised classification technique was used by (Dewan & Yamaguchi, 2009) to extract information from satellite data, and post-classification change detection method was employed to detect and monitor land use/cover change. (Bhandari, 2010) used Landsat Images for his research and proved it useful to extract various urban land use dynamics.

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.

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.

Figure 1. Location map of the study area.



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.).

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.

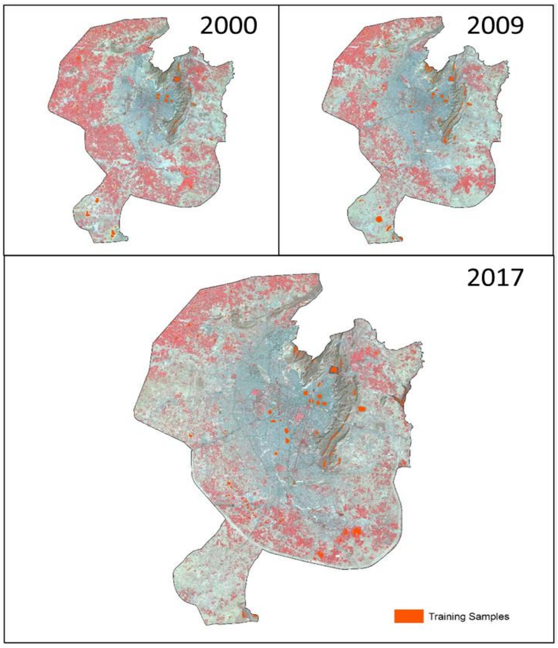
In total 3 imageries of Landsat sensor were selected for this study. The required imageries were downloaded in L1TP land surface reflectance data type and GeoTIFF format from USGS's Earth Explorer website (http://earthexplorer. usgs.gov)

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.

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



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 extracting built-up area and dynamics of land cover change in the study area is described in the following steps:

1. Preparation of Base Map by delineation of Urbanizable Area (U1) boundary by using ArcGIS Software with the help of SOI Toposheets and JDA Master Plan - 2025.
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.
3. Computation of various Spectral Indices (NDVI, NDWI etc.) and Masks (masks for cloud, water body, shadows, bare rocks, hills etc.)(Pauleit, Ennos, & Golding, 2005)
4. Adding surface information to land features using cartosat -1 DEM. Segregation of agriculture (cropped area) from forest and natural vegetation present on hills.
5. Adoption of suitable land use/land cover classification system (Anderson, Hardy, Roach, Witmer, & Peck, 1976). In this study six class classification system is adopted. It includes Water body, Built up area, Bare soil/ fellow land, Agriculture cropped land, Natural vegetation and Bare rock/hill surface as a land use/land cover classes.
6. 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.
7. Ground truthing and accuracy assessment. Generation of Error/Confusion Matrix and computation of overall, user and producer accuracy.
8. Post-classification comparison and built-up area change detection with the help of change matrix (Lu, Mausel, Brondízio, & Moran, 2004; Mas, 1999; Singh, 1989)
9. Computation of trend, rate and magnitude of change in the built-up area.

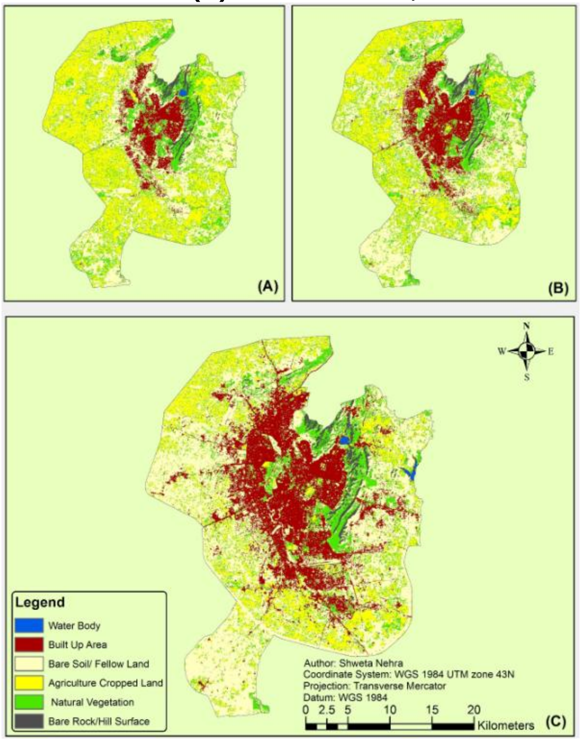
Results and Discussions

Land cover change analysis for the period 2000 to 2017 has been done using maximum likelihood classifier and the classified land cover maps for the years 2000, 2009 and 2017 are given in figure 3. The investigation has shown that there has been a marked built-up area change during the study period of 17 years.

A brief account of these results is discussed in the following paragraphs.

The analysis of error matrix for the year 2017 suggested that the land use/land cover map is classified with an overall accuracy of 84.67% whereas, for the built-up area, the producer's and user's accuracy is estimated as 89% and 82% respectively. The main reason for this omission or commission error (≈ 10-20 %) is, the presence of mixed pixel in the fringe area where built up is sparsely situated with vacant land and natural vegetation.

Figure 3: Comparison of classified Land use/Land Cover map of the Jaipur urbanizable area (U1) obtained from different surface reflectance datasets (A) Landsat 7 ETM+, 18.02.2000 (B) Landsat 5 TM, 02.02.2009 and (C) Landsat 8 OLI, 24.02.2017.



Following the classification of imagery 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 interval; 2000 to 2017. The change analysis showed that notable changes reported in the study area during the studied period, particularly for the built-up area.

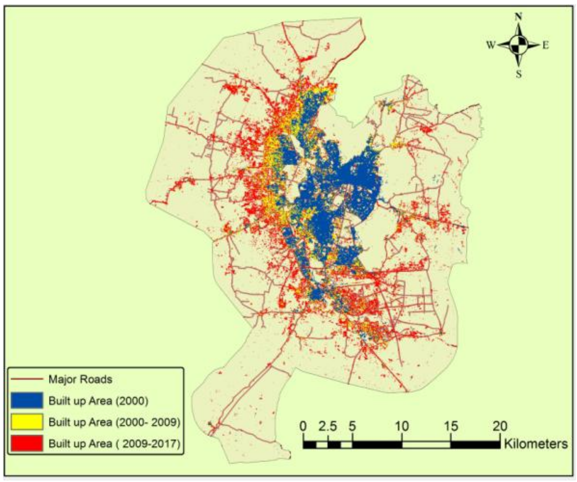
During the 2000–2009 and 2009-2017 period the percentage area covered by the built-up is increased by 35.35% and 56.53% respectively. The magnitude of change (Kafi, Shafri, & Shariff, 2014) over the 17 year period is 96.63 sq. km (percentage change 111%) for the built-up area. This increasing trend of the built-up land cover in the study area reinforces that anthropogenic forces are commonly a major stimulus in the region for land cover change. This increase in the built-up area is positively correlated with the population growth of the region which is recorded as 118% increase (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.

Table 2. Error matrix for supervised maximum likelihood classification for the year 2017.

Classified Data	Refrence Data						
	Water Body	Built Up Area	Bare Soil/ Fellow Land	Agriculture Cropped Land	Natural Vegetation	Bare Rock/ Hill Surface	Row Total
Water Body	49	0	0	0	1	0	50
Built Up Area	0	41	4	0	2	3	50
Bare Soil/ Fellow Land	1	5	41	1	2	0	50
Agriculture Cropped Land	0	0	9	38	3	0	50
Natural Vegetation	0	0	8	4	38	0	50
Bare Rock/ Hill Surface	0	0	3	0	0	47	50
Column Total	50	46	65	43	46	50	**300**
Overall Accuracy =	**84.67%**						

Producer's Accuracy				User's Accuracy			
Water Body	98%	2%	omission error	Water Body	98%	2%	commission error
Built Up Area	89%	11%	omission error	Built Up Area	82%	18%	commission error
Bare Soil/ Fellow Land	63%	37%	omission error	Bare Soil/ Fellow Land	82%	18%	commission error
Agriculture Cropped Land	88%	12%	omission error	Agriculture Cropped Land	76%	24%	commission error
Natural Vegetation	83%	17%	omission error	Natural Vegetation	76%	24%	commission error
Bare Rock/ Hill Surface	94%	6%	omission error	Bare Rock/ Hill Surface	94%	6%	commission error

Figure 4. Overlay of Built up Area to Show the Location of Change during the Period 2000 – 2017.



The annual growth rate for the built-up area was estimated 6.52% per annum. The study revealed that the Land Consumption Rate (LCR) for the built-up area was 38.84, 35.23 and 39.32 sq meter per person for the base year 2000, 2009 and 2017 respectively. These results show that from 2000 to 2017 the LCR increased slightly which seems satisfactory. But during the computation of these results, vertical growth of the city is not considered if this was considered than LCR rate would have shown a rapid increase which gives an insight of unmanaged urban growth in the region.

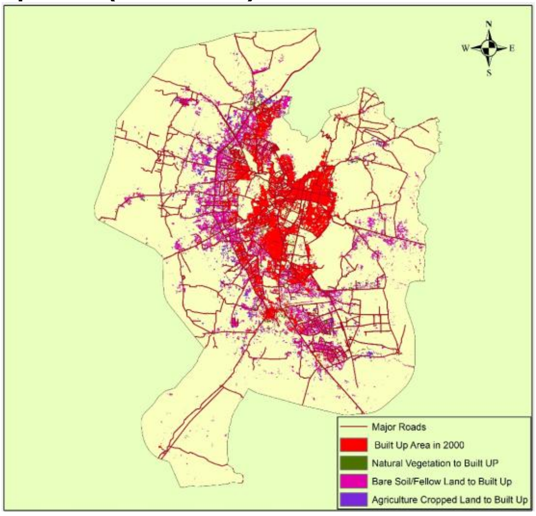
The built-up area change pattern (figure 4) established that the urban growth is mainly restricted to the western and north-western part of the already urbanized area up to 2009 as in the northern and eastern part of the city Aravalli hills and ridges were acted as a limiting factor. But after 2009, due to development of transport facilities and pressure of intense- urbanization, the built-up area spread rapidly beyond this natural barrier but still limited to along the major roads only.

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

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

To further evaluate the results of built-up area conversion, a matrix of land cover changes from 2000 to 2017 was created. The observed unweighted Kappa index (Inca, 2009)for this conversion matrix is 0.3353 with the standard error of 0.0007 meaning significant changes between the classes in studied periods.

Figure 5. Resultant Output Map of Conversion From Various Land Use/Land Cover To Built Up Area (2000–2017)



These results indicate that increases in built up mainly came from conversion of bare soil/fellow land, natural vegetation and agriculture cropped land to built up area. Out of the 96.63 sq km of total growth in urban land use, 60 sq km was converted from bare soil/fellow land, 21 sq km from natural vegetation and 15 sq km from cropped land.

Conclusions

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.

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