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Application of Remote Sensing and GIS in Assessment and Mapping of Land Cover Change in Jaipur City of Rajasthan, India

Abstract

The land cover of a region describes the type of feature found on the earth's surface and the human activity that is associated with it. Trend, rate and magnitude of land cover change provide necessary tools for development, planning and management of natural resources in any region. In this research land use dynamics of Jaipur urbanizable area were investigated by use of remotely sensed data and geographical information system.The result indicated that there had been a notable change in the land cover pattern of the region in the past seventeen year from 2000 to 2017. The built up area is increased from 9.21% to 19.52% of the total area of the region which indicate the urban-intensification in the region whereas natural vegetation and agriculture cropped land is reduced from 23.40% and 31.06% to 15.82% and 13.16% respectively which further indicate the deteriorating situation of the ecology of the region. Land cover classification map is obtained through maximum likelihood classifier algorithm and the land cover trend is established through cross tabulation change matrix during the study.

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Introduction

The land cover of a region describes the type of feature found on the earth's surface and the human activity that is associated with it. It is dynamic in nature i.e. the different attributes of land cover vary with time and space and this variation could be the result of complicated interactions of socio-economic and naturalfactors. Although the dynamism in trend, rate and magnitude of land cover change creates a great challenge to researchers to monitor its nature precisely, but the study of this dynamism has its own importance as it provides an important input parameter for a number of different agricultural, hydrological and ecological models, which constitute necessary tools for development, planning and management of natural resources in any region. In order to use the land optimally and to provide as input data in modelling studies, it is not only necessary to have information on existing land cover but also the capability to monitor the dynamics of land cover resulting out of changing demands.

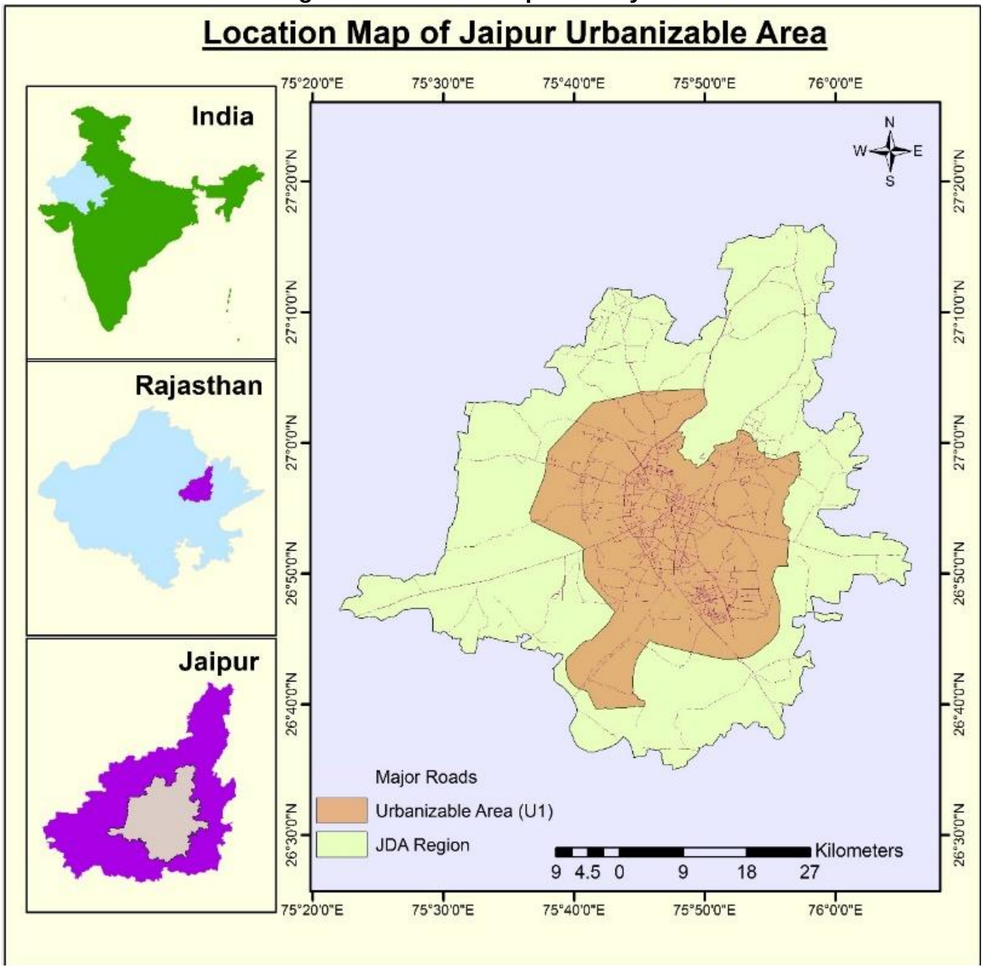
Aim of the Study

With respect to the ongoing debate and global concern about discriminate and unmanaged change in land coverwhich bring 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, the proposed research has been undertaken with the objective to assess the actual state of land cover change in Jaipur city and mapping its dynamic nature over the time.The main aim of the study is to identify, quantify and assess thepresent and multi-temporal scenario of land coverchange with special respect to urbanization in the study areausing remote sensing and GIS as a tool.

Study Area

The study area comprises of 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 north eastern part of Rajasthan. The urbanizable area of JDA region 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). 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. Major part of the study area is relatively flat and characterized by alluvial sandy-plain.In the northern and mid-eastern parts, Aravalli range is situated in the form of Harmara, Niwaru, Nahargarh, Amer, Puranaghat and Jhalana hills and ridges. Some isolated and highly dissected hillocks are also situated in the region.Topographical a level of these varies between 280 meters to around 530 meters above mean sea level.

Figure 1: Location Map of Study Area



Review of Literature

Rapid urbanization has triggered intense changes to Earth's land cover over the last two centuries, and the pace of these changes will accelerate in the future too. Information on land cover is fundamental to many agricultural, hydrological and ecological applications. (Meyer y Turner II, 1994) established a comprehensive analytic framework that leads to a systematic typology, and ideally a scheme of regionalization, of land-use/land-cover change. Satellite remote sensing and GIS have been widely applied in land cover change detection and analysis studies (El Garouani, Mulla, El Garouani, & Knight, 2017; Wu et al., 2006)as it provide multi-temporal data that can be used to quantify thetrend, rate and magnitude of land cover change. The most widely used change detection methods are post-classification comparison and multi- date composite image change detection. (Daniel et al., 2002) in their comparison of land use land cover change detection methods, made use of 5 methods viz; traditional post – classification cross tabulation, cross correlation analysis, neural networks, knowledge – based expert systems, and image segmentation and object – oriented classification.(Opeyemi, 2006) introduced the concept of land consumption rate and land absorption coefficient to aid in the quantitative assessment of the land cover change whereas (Macleod and Congation, 1998) listed four aspects of change detection i.e. Detecting the changes that have occurred, identifying the nature of the change, measuring the area extent of the change and assessing the spatial pattern of the change which is important when monitoring natural resources. Numerous pre-classification change detection approaches have been developed and refined by (Lunetta et al., 2006) to provide optimal performance over the greatest possible range of ecosystem conditions. (Kumar, Kumar, & Shekhar, 2016; Mishra, Mishra, Subudhi, & Ravenshaw, 2006; Rahman, Aggarwal, Netzband, & Fazal, 2011; Verma, Kumari, & Tiwary, 2009) used this technology to evaluate the land cover change scenario in Indian context too.

Material and Methodology

Dataset Used

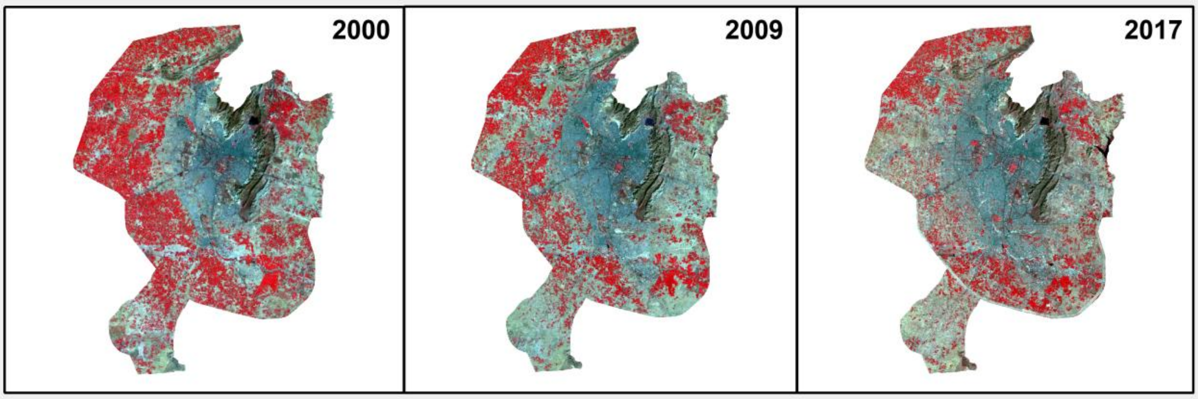
The land cover of a region is not homogenous in space and time. To study such changes there is need to generate a time series of various land cover patterns by using satellite imageries for different time period of the region. The main criteria needed to be fulfilled while selecting the imageries under this land cover change study is that the images should be cloud free (keeping additional criteria as cloud cover below 10%) and acquisition date should be more or less same to eliminate the impact of difference in seasons, sun angle, seasonal vegetation cover, agriculture cropping patterns etc.A set of three Landsat 8 OLI, Landsat 7 ETM+ and Landsat 5 TMland 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 L1TPland 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	Image Quality	Scene Cloud Cover
1	LC08_L1TP_147041_20170224_20170301_01_T1	147/041	OLI_TIRS	24/02/2017	9	0.01
2	LT05_L1TP_147041_20090202_20161029_01_T1	147/041	5_TM	02/02/2009	9	0
3	LE07_L1TP_147041_20000218_20170213_01_T1	147/041	7_ETM	18/02/2000	9	0

Figure 2: Landsat land surface reflectance data product (LaSR imagery) subset of Urbanizable Area (U1) of Jaipur city as False Colour Composite.



Cartosat-1 StreodataDEM

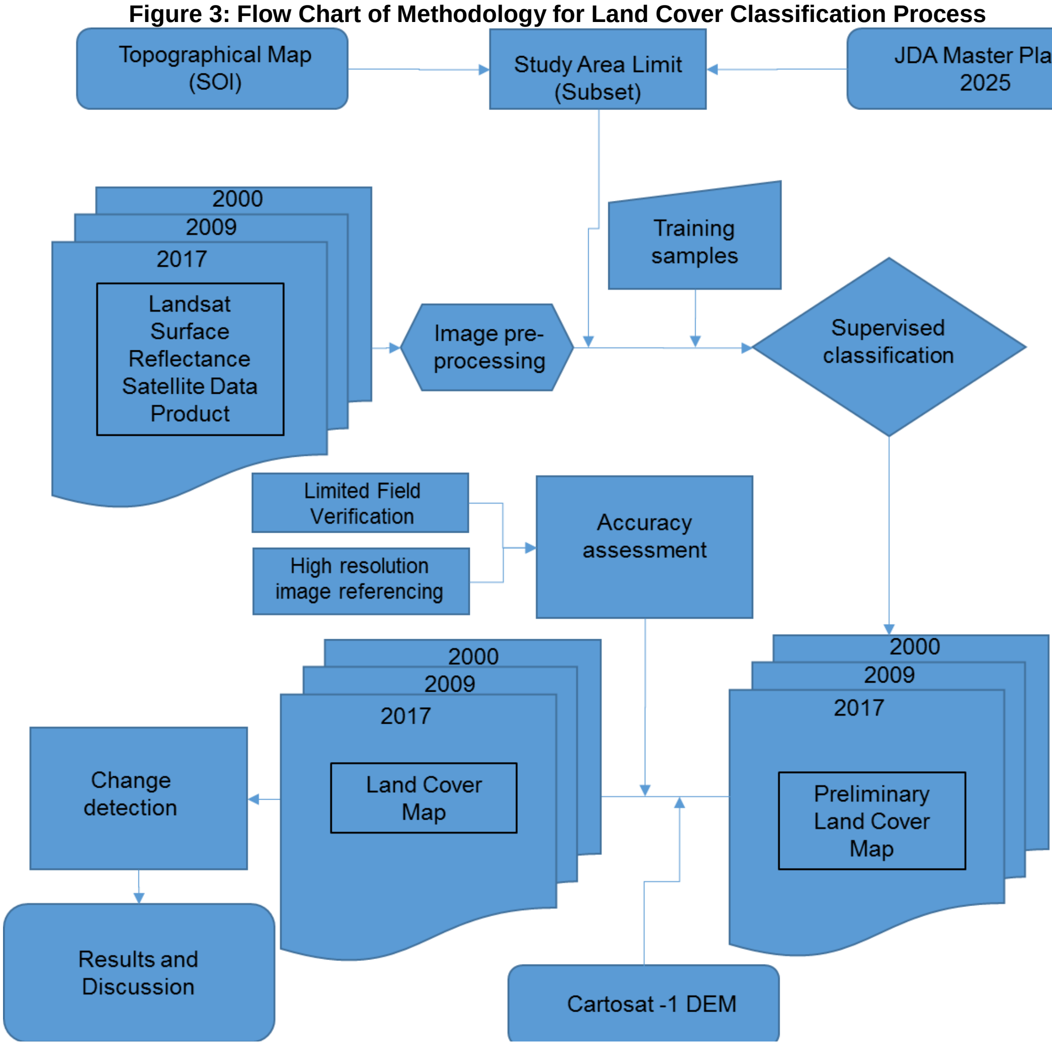
Cartosat-1 Streodata DEMof the region is provided by National Remote Sensing Centre,ISRO and downloaded from their website (http://bhuvan-noeda.nrsc.gov.in)in GEOTIFF format with geographic lat/long coordinates and a 1 arc second (≅30 m) grid of elevation postings. It is referenced to the WGS84 geoid. It was used to providing an elevation reference to the existing topographic conditions.

Methodology

The methodology used in this research work for determining various land cover 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.
3. Computation of various Spectral Indices (NDVI, NDWI etc.) and Masks (masks for cloud, water body, shadows, bare rocks, hills etc.)
4. Mapping of various land cover classes: Semi-automated supervised classification using maximum likelihood classification algorithm(El Garouani et al., 2017);visual image interpretation.
5. Adding surface information to various land cover classes using cartosat -1 DEM. Segregation of agriculture (cropped area) from forest and natural vegetation present on hills.
6. Ground truthing and accuracy assessment. Generation of Error Matrix and computation of overall, user and producer accuracy.
7. Post-classification comparison and land cover change detection(DiGirolamo, 2006) with the help of change matrix.

Figure 3: Flow Chart of Methodology for Land Cover Classification Process



Results and Discussions

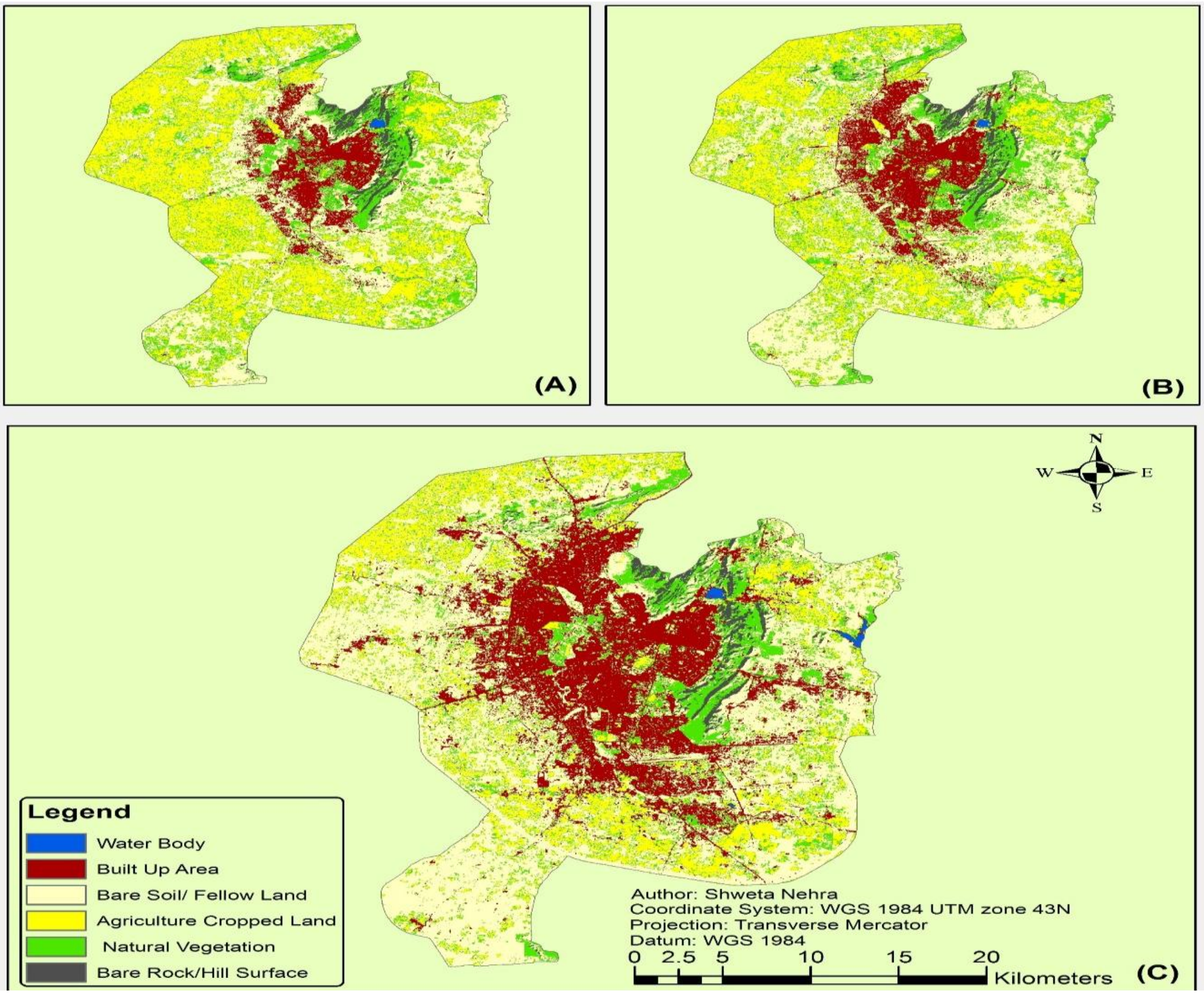
Estimation of land cover change is a challenging task as it requires a lot of field work. But with the advancement in the field of remote sensing and Image processing it becomes feasible to apply semi-automatic techniques and algorithms on satellites data and derive some parameters and spectral Indices through which land cover change can be estimated.

Table 2: Land cover classification scheme with their representative land cover features.

Sr.No.	Class name	Description
1	Water Body	Lakes, ponds, reservoirs, open water
2	Built Up Area	Man-made impervious surface- buildings, transport network, urban infrastructure etc.
3	Bare Soil/ Fellow Land	Land area of exposed soil, barren land, agriculture fellow land
4	Agriculture Cropped Land	Crop fields
5	Natural Vegetation	Mixed forest, shrub land, plantation, dense tree cover
6	Bare Rock/ Hill Surface	Steep and exposed rock/ hill surface

Land cover change analysis for the period 2000 to 2017 has been done using maximum likelihood classifier andthe classified land cover maps for the years 2000, 2009 and 2017 are given in figure 4.The classification results for all the three base years are summarized in Table 3. The investigation has shown that there has been a marked land cover change during the study period of 17 years. The comparison of each class showed that built up area and bare soil/fellow land cover area were increased rapidly whereas area related to agriculture cropped land and natural vegetation was decreased sharply over the period. Other two land cover classes i.e. water body and bare rock/hill surface were showing slight change during the period.

Figure 4: Comparison of classified 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



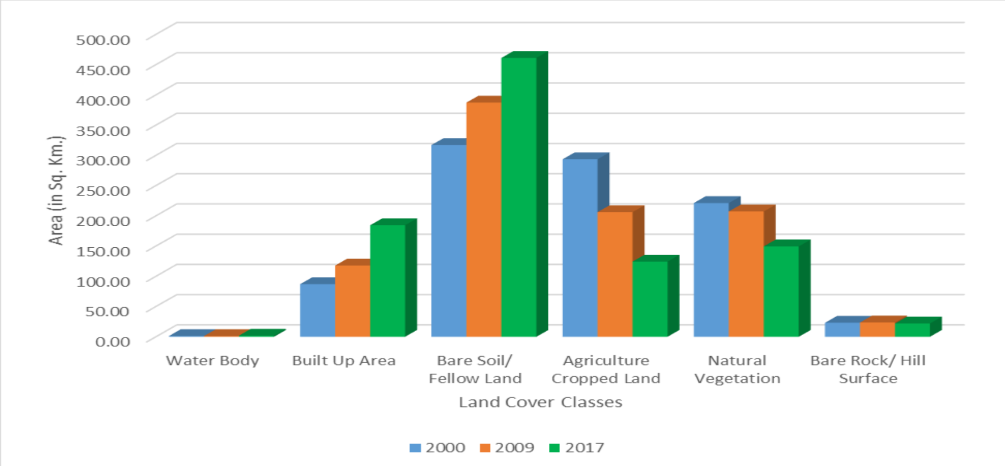
The share of built-up area was 9.2% of the total area in year 2000 which increased up to 19.52% in 2017. The bare soil/fellow land faced an increment in the total share from 33.54% to almost half of the total area i.e. 48.79% during the study period. The agriculture cropped land was decreased from a share of 31.06% to 13.16% whereas natural vegetation land shrank from 23.40% to 15.82% of the total area. The bare rock/hill surface was reduced slightly from 2.46% to 2.32%. Least area covering class of the region i.e. water body was increased marginally from 0.13% to 0.20% over the same period.

Table 3: Land Cover Change between 2000, 2009 and 2017

S. No.	Land Cover	Year								
		2000			2009			2017		
		No. of Pixel	Area (Sq. Km)	Area (%)	No. of Pixel	Area (Sq. Km)	Area (%)	No. of Pixel	Area (Sq. Km)	Area (%)
1	Water Body	1417	1.28	0.13	1276	1.15	0.12	2082	1.87	0.20
2	Built Up Area	96770	87.09	9.21	130983	117.88	12.47	205019	184.52	19.52
3	Bare Soil/ Fellow Land	352235	317.01	33.54	430269	387.24	40.97	512428	461.19	48.79
4	Agriculture Cropped Land	326205	293.58	31.06	229046	206.14	21.81	138158	124.34	13.16
5	Natural Vegetation	245768	221.19	23.40	230281	207.25	21.93	166114	149.50	15.82
6	Bare Rock/ Hill Surface	25808	23.23	2.46	26339	23.71	2.51	24385	21.95	2.32
Total		**1050203**	**945.18**	**100.00**	**1050203**	**945.18**	**100.00**	**1050203**	**945.18**	**100.00**

The land area covered with water has shown a slight decrease from 2000 to 2009 due to the continuous shrinkage of Mansagar Lake, situated in the north-eastern part of the city. Contrary to this, water body area in the region has shown a slight increase from 2009 onwards due to the creation of a new water reservoir near Mukandpura in the eastern part of the study area.

Figure 5: Temporal Variation in area of Various Land Cover Classes in the Study Region



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 cumulative percentage change over the 17 year period is 111.86% for built up area.This increasing trend of 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 built up area is positively correlate 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)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 other class which faced an increment in the total area was bare soil/fellow land with 45.48% increase in the study area during the 2000-2017 period. This increase in the bare soil/fellow land area was due to three main reasons. First, rapid deforestation or removal of natural vegetation cover taken place which rendered land barren and exposed. Second, at urban-rural fringe a large chunk of agriculture land is converted in to sealed surface (vacant plots where agriculture is abandoned but buildings/transport network is not constructed yet) and third, the rapid decrease in groundwater level and deteriorating groundwater quality made lands less productive which were ultimately abandoned by farmers to crop production due to economic inefficiency, resulting in increase of agriculture fellow land area.

Classification results supported that agriculture cropped land cover was decreased over the past17 years by 57.65% from 2000 to 2017. Half of the total area under this class was replaced by bare soil/fellow land during this period. The natural vegetation area of the region which includes mixed forest, shrub land, plantation, dense tree cover etc. was also decreased. During 2000- 2017, 12.41% and 47.24% of the total natural vegetation land cover area was converted into built up and bare soil/fellow land respectively.

To conduct post-classification comparison and to quantify the change in land cover over the past 17 years, classified images of the year 2000 and 2017 were overlaid using a pixel-over-pixel comparison approach(Singh, 1989). The matrix table of "from – to" change class was obtained using change detection statistical tool.The cross-tabulation matrix provides the nature and magnitude ofchange of different land cover classes.

Table 4: Cross-tabulation "from - to" change matrix showing land cover change between 2000 and 2017

Land Cover Class - 2000	Land Cover Class - 2017						
	Water Body	Built Up Area	Bare Soil/ Fellow Land	Agriculture Cropped Land	Natural Vegetation	Bare Rock/ Hill Surface	Grand Total
Water Body	60.83%	20.47%	6.00%	3.81%	7.62%	1.27%	**100.00%**
Built Up Area	0.02%	90.54%	6.01%	0.22%	2.65%	0.57%	**100.00%**
Bare Soil/ Fellow Land	0.22%	22.84%	62.57%	5.18%	9.08%	0.12%	**100.00%**
Agriculture Cropped Land	0.04%	5.75%	52.94%	30.14%	11.11%	0.02%	**100.00%**
Natural Vegetation	0.12%	12.41%	38.97%	9.37%	38.04%	1.09%	**100.00%**
Bare Rock/ Hill Surface	0.13%	2.76%	3.79%	0.81%	12.63%	79.87%	**100.00%**
Grand Total	**0.20%**	**19.52%**	**48.79%**	**13.16%**	**15.82%**	**2.32%**	**100.00%**

Out of the 294 sq km that wasagriculture cropped area in 2000, 124 sq km was still agriculture cropped area in 2017 but the restwas converted to bare soil/fellow land, natural vegetation and built up. At the same time 6% of the total natural vegetation area was also converted in to agriculture cropped area, from 2000 to 2017. Built up area increased from 87 sq km in 2000 to 184 sq km in 2017. The land cover class which built up mainly replaced in 2017 was bare soil/fellow land.

The land use/land cover maps indicatesthat the integration of supervised classification of satelliteimagery with visual interpretation is an effective method forthe documentation of changes in land cover of an area.

Conclusion

These results give insights into the land cover change trend of the region over the last seventeen years. The region experienced overall negative change in agriculture cropped land and natural vegetation cover over the period revealing strong negative impact on ecology and environment of the region. Again, 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. Again this study elucidates the significance of incorporating remote sensing and GIS for change detection study of land cover of an area as it offers crucial information aboutthe spatial distribution as well as nature of land cover changes.The thematic maps of land cover obtained during the study indicatesthat the integration of supervised classificationof Landsat satellite land surface reflectance data product using maximum likelihood classification algorithm with visual interpretation is an effective method forthe documentation of changes in land cover of an area.

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