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Analysis of Land Change Dynamics and Indices Using Geospatial Technology: A Case of Jaipur City, India

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Abstract- In the past few decades, there was a rapid expansion of urban cities at a global scale which develops the need of monitoring the change in land use and urban settlement area. Remote sensing (RS) is a valuable tool to monitor and understand the causes responsible for Land Use Land Cover (LULC) changes. It can help in the development of city plans and environmental management. In urban areas, there are various factors like increasing population, developmental activities and migration which are further increasing the pressure on city resources and lead to urban expansion. The study is focused on understanding the land use change dynamics of Jaipur city. The LULC maps are prepared for different periods using Landsat-5 and Landsat-8 images for the years 1993, 2000, 2010 and 2015 using maximum likelihood classification method. Major changes are observed in the classes of urban settlement and open land of the study area. In this analysis, different types of indices like Normalized Difference Vegetation Index (NDVI), Normalized Difference Built-up Index (NDBI) and Soil Adjusted Vegetation Index (SAVI) are prepared to identify the vegetation cover, built-up areas of the Jaipur city. The analysis showed that there is an increase in urban settlement and a decrease in natural areas such as open land and vegetation in the city.

Index Terms-Land use/cover, urban expansion, classification, NDBI, NDVI

1. INTRODUCTION

The half of the world's population are urban dwellers and the urban population is expected to reach up to 81% by the year 2030 (Montgomery, 2007). According to the World Bank (2011), the urban population has increased at a proportion of 28.3% in 1950 to 50% in 2010. Urbanization is responsible for declination of natural vegetation cover; alteration in the type of land use; and some significant changes in the prevailing environmental and climatic conditions. RS and GIS techniques are important for comprehensive LULC mapping and detailed understanding of land use changes at various scales (Selçuk et al., 2003). NDVI has a vast application spectrum in the broad range of studies (Brandt et al. 2015, Chen et al. 1998; Santos and Negri, 1997; Zhang et al. 2009). Tian et al. (2014) explained the different types of land use in India during the period 1880-2010 using historical records and satellite data. Karanam and Babu Neela (2017) used the multi-temporal data of Landsat TM data and calculated the BUI, NDVI, and NDBI in the urban area. Guha et al., (2018) used the Landsat-8 images and estimated the relationship between LST, NDVI, and NDBI of the Naples city in Italy. In semi-arid regions, it is of high importance to monitor vegetation to reduce the impacts of drought. SAVI vegetation index is of greater relevance than NDVI in these regions. The NDVI and NDBI are also useful to investigate the influence of vegetation and built-up on Urban Heat Island (UHI). Jayakumar & Arockiasamy (2003) used the remote sensing and GIS technique for LULC mapping and change detection in parts of Eastern Ghats of Tamil Nadu. The objective of the study is to identify different land use pattern and their change detection along with the development of indices to monitor changes in vegetation and built-up areas. Table 1 provides a list of some selected research work carried out in the Jaipur city.

Table 1: List of studies carried out in Jaipur city

Study Title	Data used	Area	References
Change Detection Techniques for Monitoring Spatial Urban Growth	LANDSAT (MSS & TM)	Jaipur	Gupta (2011)
Estimate of Urban Sprawl and LULC Change using Remote Sensing and GIS Techniques	LISS-II, LISS III & LANDSAT-TM	Jaipur	Sankhala & Singh (2014)
Urban Heat Island and Land Use	LANDSAT-7 ETM+ TM	Jaipur	Jalan & Sharma (2014)

2. STUDY AREA

Jaipur city is well known as the Pink City and the capital of Rajasthan state. The city is located in the northeastern part of Rajasthan, located 26.92° N latitude and 75.82° E longitude with an average elevation of 431 m (Figure 1). The city of Jaipur has a mixture of built-up areas, low vegetation area, roads, and industries. In the year 2001, the urban population of Jaipur city was 2.3 million, which increased to 3.07 million in the year 2011 (Census of India 2011).

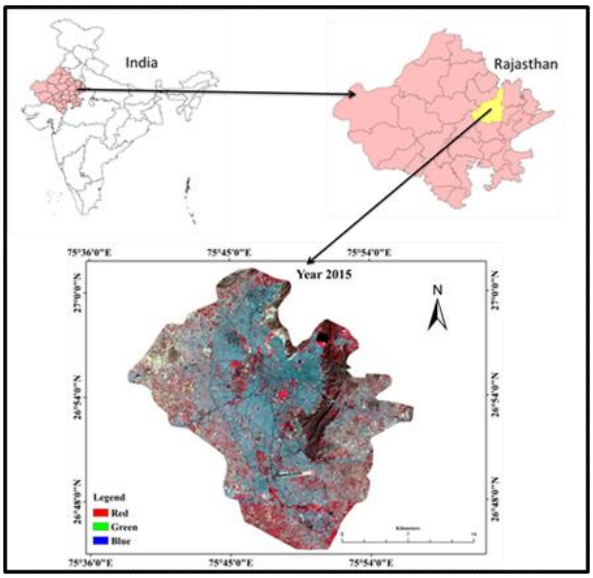

Figure 1. Location Map of Study Area

3. METHODOLOGY AND DATA USED

3.1. *Satellite Data Information*

In this study, Landsat 5 Thematic Mapper (TM) data of 27th April 1993, 14th April 2000 and 29th June 2010; and Landsat 8 OLI data of 23rd April 2015 datasets are used for the preparation of LULC maps and the development of different indices of the Jaipur city. These images are downloaded from the Global Land Cover Facility (http://www.glcf.umd.edu/index.shtml) and (http://www.landcover.org/), United States Geological Survey (USGS) Earth Explorer (http://edcsns17.cr.usgs.gov/NewEarthExplorer/) and Glovis (http://www.glovis.usgs.gov).

3.2. *Image classification and accuracy assessment*

The supervised technique of image classification was used to classify images into five major categories i.e., Waterbody, Vegetation, Urban Settlement, Open Land, Hilly area/rocky area. The Kappa method was used to assess the accuracy of the classification using the samples sites from google earth. Kappa coefficient (k) for the image classification is as follows (Foody 1992):

$$k = \frac{(Total\ sum\ of\ correct) - Sum\ of\ the\ all\ the\ (row\ and\ column\ total)}{Total\ squared - Sum\ of the\ all\ the\ (row\ and\ column\ total)} \quad (1)$$

3.3. *Change dynamics*

A convenient way to assess the post-classification change dynamics is to identify the thematic change based on change statistics. ArcGIS software was used to calculate the thematic change and see the dynamics of land cover change of Jaipur City from 1993 to 2010. The change dynamics are observed in the different years by giving different codes to land use for different period. Example of change dynamics for the period 1993-2000 is explained here. In the year 1993, number code of 1,2,3,4, and 5 are assign to different land uses, whereas code of 8,14,20,26, and 32 are assigned to land use for the year 2000 (Table 2). The study considered the changes in valid classes which convey a significant change in the year wise land use. Table 2 represents the changes of classes into the different classes by the help of a spatial analyst tool in the ArcGIS software. Code 9 shows that there is no changes in the water body class and similar is the case for other classes (code 16, code 23, code 30 and code 37). On the other side, code 11 shows the water class changes in urban settlement class. Only the areas with a change in land use are taken to visualize in the map and see the overall dynamic of change in the Jaipur city.

Table 2: Change dynamics of different land use classes

Class Name	Code	Water	Vegetation	Urban Settlement	Open land	Hilly/rock area
		1	2	3	4	5
Water	**8**	9	10	11	12	13
Vegetation	**14**	15	16	17	18	19
Urban Settlement	**20**	21	22	23	24	25
Open land	**26**	27	28	29	30	31
Hilly/rocky area	**32**	33	34	35	36	37

3.4. *NDVI calculation*

Vegetation cover plays a fundamental role in minimizing environmental issues in urban areas. According to the Batista et al., 1997, the NDVI values ranges from -1 for non-vegetated areas to +1 for vegetation. For the NDVI calculation red band and visible spectrum band and the NIR band are used. The NDVI calculation formula is given in equation 2:

$$NDVI = \frac{(Band\ 4 - Band\ 3)}{(Band\ 4 + Band\ 3)} \quad (2)$$

3.5. *NDBI Calculation*

NDBI is a widely-used index for estimation of built-up area. NDBI values are depending on the spectral signature, range from medium IR band to near IR band. This index is useful for human mapping settlements and surrounding constructions. The values of NDBI vary from -1 to +1 (Zha et al., 2003). The positive value indicates highly built-up areas, whereas the negative values represent other land cover types. Equation 3 shows the formula for calculating the NDBI.

$$NDBI = \frac{MIR\mu m - NIR\mu m}{MIR\mu m + NIR\mu m} \quad (3)$$

3.6. *SAVI Calculation*

SAVI is used in areas where vegetative cover is low (< 40%). The SAVI is calculated by using equation 4 (Huete, 1988):

$$SAVI = (1 + L) * (band4 - band3)/(band4 + band3 + L) \quad (4)$$

where, L is a correction factor of the SAVI calculation. SAVI ranges from 0 to 1. Value 0 shows the very high vegetation cover and 1 shows the very low vegetation cover. If the L values come to 0.5, it shows the intermediate vegetation cover, and when the L value is equal to zero, the SAVI becomes same as NDVI.

4. RESULTS AND DISCUSSION

4.1. *LULC and accuracy assessment of Jaipur city*

In this study, the Landsat-5 and 8 satellite data were used to classify the major land use classes, i.e. Water body, Vegetation, Urban Settlement, Open Land, Hilly area/rocky area. These major LULC classes were calculated for four periods, i.e. 1993, 2000, 2010 and 2015 to understand the changes in LULC classes of different periods which is shown in Figure 2. The classified images were intended for the accuracy based on a random selection of the points for each period. The overall accuracy along with Kappa coefficients for all four years is given in Figure 3.

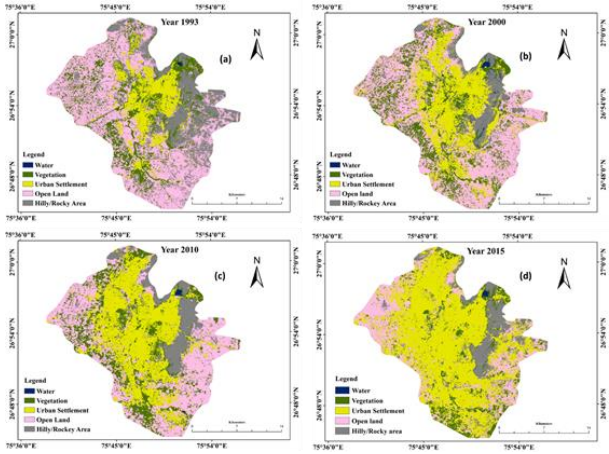

Figure 2. LULC Classification of years (a) 1993 (b) 2000 (c) 2010 (d) 2015 (Chandra et al. 2018)

Table 3 shows the percentage changes in the various classes; the maximum positive change is shown in the class of urban settlement, i.e. 57.39%, that explains the urban area expansion. Open land was converted to different classes, but most of the area was turned into the urban settlement, and the open land shows the decreasing trend in the image classification, i.e. 45.84, 39.48, 33.85 and 19.37% in 1993, 2000, 2010 and 2015 respectively.

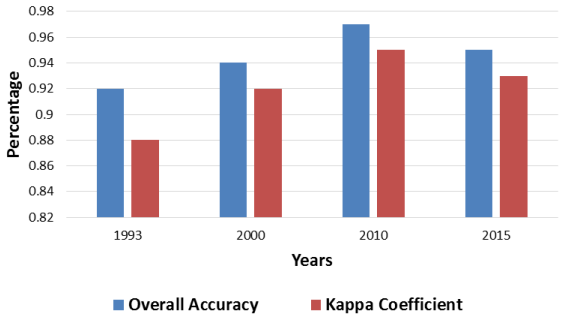

Figure 3. Accuracy assessment of the images in the different years (a) 1993 (b) 2000 (c) 2010 (d) 2015

Table 3: Year-wise percentage changes in the different land use classes

Class Name	1993	2000	2010	2015
Water	0.09	0.98	0.19	0.17
Vegetation	17.90	18.62	18.77	9.66
Urban Settlement	13.54	28.07	35.31	57.39
Open land	45.84	39.84	33.85	19.37
Hilly Area	22.65	12.49	11.88	13.40

Table 4 shows the class wise value changes of different land use when compared in different years. The urban settlement shows the maximum changes due to the growth of urban population and the count value of the urban settlement increases in all four images. Open land area converted into the other land use classes like urban settlement, vegetation, water, and hilly area. The vegetation cover pixel values and hilly area values show the maximum coverage in the area. Analysis of all the years assessed (1993 to 2015) show that the maximum change observed is one of open land to build–up area. Table also presents the change of one landuse to another and change matrix for different periods.

Table 4: Thematic change dynamics of the different land use classes (W-Water, V-Vegetation, US-Urban Settlement, OL-Open Land, HA-Hilly Area)

Year 1993-2000

Reclassify Values	Year	2000				
		8	14	20	26	32
Class Name	1993	W	V	US	OL	HA
W	1	403	0	45	0	0
V	2	2695	48657	15179	16944	10353
US	3	968	2389	65835	359	1420
OL	4	107	35711	45296	149778	9439
HA	5	986	10857	20817	41812	44271

Year 2000-2010

Reclassify Values	Year	2010				
		8	14	20	26	32
Class Name	2000	W	V	US	OL	HA
W	1	749	991	1508	76	1835
V	2	83	50061	15805	27382	4283
US	3	111	11537	116602	11790	7132
OL	4	32	28781	43646	128201	8233
HA	5	1	7029	7467	10150	40836

Year 2010-2015

Reclassify Values	Year	2015				
		8	14	20	26	32
Class Name	2010	W	V	US	OL	HA
W	1	744	101	54	0	77
V	2	108	29862	43815	15799	8741
US	3	6	2225	177684	2861	2240
OL	4	21	12791	69159	78484	16885
HA	5	1	7029	7467	10150	40836

Year 1993-2015

Reclassify Values	Year	2015				
		8	14	20	26	32
Class Name	1993	W	V	US	OL	HA
W	1	357	71	6	0	14
V	2	477	16045	51091	14405	11773
US	3	58	1055	68093	390	1374
OL	4	2	21560	139537	65543	13478
HA	5	4	11892	41950	21166	43563

The urban settlement shows the maximum changes due to the growth of urban population and the count value of the urban settlement increases in all four images. Open land area converted into the other land use classes like urban settlement, vegetation, water, and hilly area. The vegetation cover values and hilly area values show the maximum coverage in the area. Analysis of all four years (1993 to 2015) showed that the maximum change observed is one of open land to build–up area which is represented by the color yellow.

ArcGIS software was used to reclassify the image, in this process the old value of the land used classification remained the same, and new values were changed according to the different classes. Figure 4 shows the thematic change dynamics of different land use classification in the year 1993, 2000, 2010 and 2015 and these land use changes show an increase in the urban area of the Jaipur city.

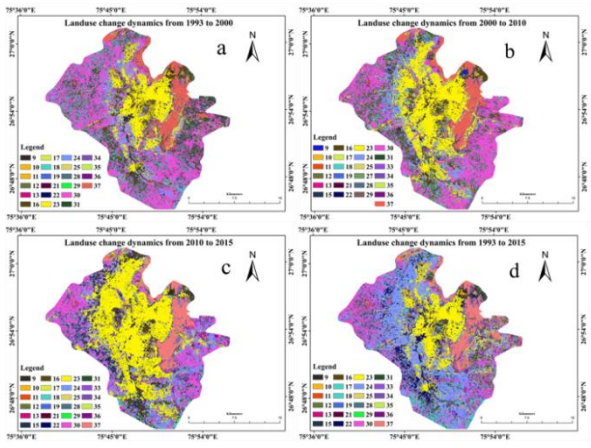

Figure 4. LULC Reclassify value change (a) 1993-2000 (b) 2000-2010 (c) 2010-2015 (d) 1993-2015

Different color coding showing the different land-use classes like yellow color indicates the urban settlement; the blue color shows the water body etc. The study is mainly concerned with evaluating the expansion of urban settlement in the Jaipur city.

4.2. *Changes in Normalized Difference Vegetation Index (NDVI)*

In this study, NDVI was calculated for different periods, i.e., 1993, 2000, 2010 and 2015. NDVI values range from -1 to +1 and different geographical feature shows the different NDVI values. The different layers were classified to extract the different vegetation cover of Jaipur city. The extracted layers of NDVI were spatially compared with the color composite image of Landsat-5 and Landsat-8. The range of NDVI in the year 1993 was -0.01 to 0.71, the year 2000 was 0.63 to -0.01, the year 2010 was 0.04 to 0.56 and year 2015 the range of NDVI was -0.24 to 0.70 (Figure 5). The larger NDVI value shows the good and massive density of vegetation. The negative to zero values range of NDVI indicate minimal vegetation.

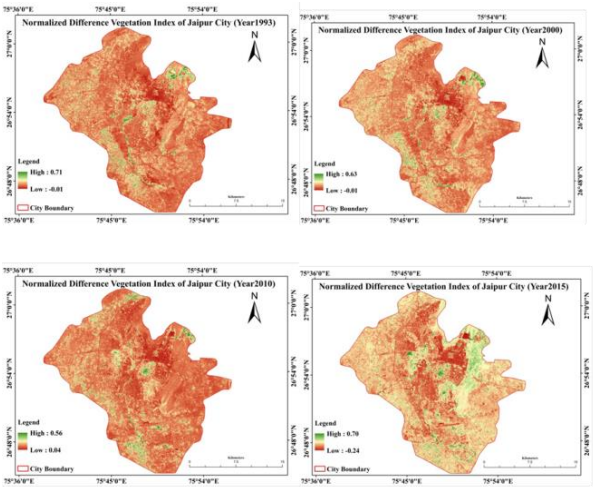

Figure 5. NDVI map of Jaipur city of the year (a) 1993 (b) 2000 (c) 2010 (d) 2015

4.3. *Changes in Soil-Adjusted Vegetation Index*

The spectral indices to be calibrated and the variations of soils are normalized and do not affect the measurements of the vegetation canopy. These improvements to NDVI are convenient because SAVI accounts for variations in soils. For this study, SAVI was used to see the vegetation area in the city like NDVI but it is used in areas where vegetation cover is low (< 40%). In the year 1993, the SAVI was -0.005 to 0.50, the year 2000 was -0.005 to 0.44, the year 2010 was 0.024 to 0.43 and in the year 2015 the SAVI was -0.118 to 0.52 (Figure 6).

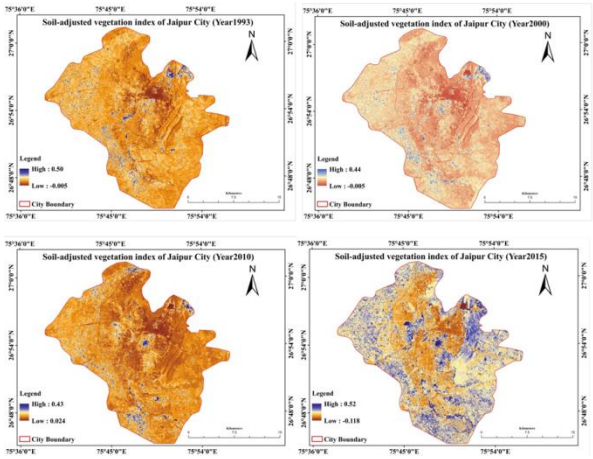

Figure 6. SAVI map of Jaipur city of the year (a) 1993 (b) 2000 (c) 2010 (d) 2015

4.4. *Changes in Normalized Difference Built-up Index*

NDBI has been used for mapping of urban built-up areas by using the Landsat-5 and Landsat-8 data. The main advantage of using NDBI is the unique spectral response of built-up area and other land covers. In the Jaipur city, the NDBI varied from -0.55 to 0.5 for the all the considered years. Figure 8 shows the increases in the built-up area in the city, in the year 1993, the NDBI was -0.55 to 0.22, in 2000 it was -0.50 to 0.50, in 2010 it was -0.32 to 0.26 and 2015 the NDBI was -0.55 to 0.34 (Figure 7).

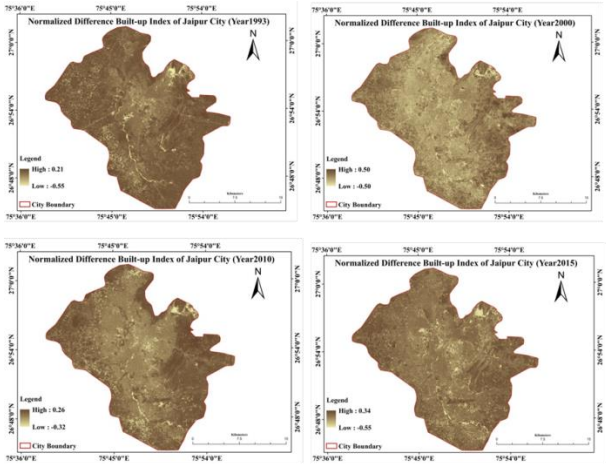

Figure 7. NDBI map of Jaipur city of year (a) 1993 (b) 2000 (c) 2010 (d) 2015

5. CONCLUSION

This study shows that the city of Jaipur is expanding, which in turn may be the result of increasing city population and other economic activities. The open area and vegetatation area are converted into the urban area. In this study using Landsat 5 and Landsat 8 image of the year 1993, 2000, 2010 and 2015 were used to evaluate the relationship between LULC, NDVI, NDBI, and SAVI of the Jaipur city. The conclusion drawn from the study conducted showed that the maximum percentage of the open land class was converted to urban settlement, consequently leading to an extension of urban land. This conversion rate was amplified from 2010 to 2015. The rate of change from vegetation class to urban settlement was constant throughout the study period except the year 2015. The urban settlement has increased and the values of NDVI and SAVI have decreased in the city due to the loss of vegetation area and urbanization. Urbanization is the primary driving process of land cover changes.

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