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A Spatio-temporal change analysis and assessment of the urban growth over Delhi National capital territory (NCT) during the period 1977-2014

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Abstract

Rapid urbanization and urban growth, particularly in the developing worlds, is continuing to be one of the crucial issues of global change in affecting the physical dimensions of cities. This study proposes a technique to extract urban built-up land features from, Multi Spectral Scanner System (MSS-1977), Landsat Thematic Mapper (1998, 2003, and 2014) of part of Delhi NCT in India as examples. The study selected two indices, Normalized Difference Built-up Index (NDBI), Normalized and Normalized Different Vegetation Index (NDVI) to represent three major urban land-use classes, built-up land and vegetation, respectively. The relationship between land use/land cover (LULC) change and population shift and their effects on the spatiotemporal patterns of urban area were quantitatively examined using an integrated approach of remote sensing, geographical information systems (GIS). Consequently, the seven bands of an original Landsat image were reduced into three thematic-oriented bands derived from above indices. The three new bands were then combined to compose a new image. As a result, the spectral signatures of the three urban land-use classes are more distinguishable in the new composite image than in the original seven-band image as the spectral clusters of the classes are well separated. Therefore, the technique is effective and reliable. In addition, the advantages of over NDVI and over NDBI in the urban study are also discussed in this paper. Furthermore, in combination with the detection of LULC change, an analysis of the spatially differential growth rates for developed land area and population size revealed an urban & sub-urban gradient pattern of population shifting, as evidenced by a sharp increase in developed land area within the middle sub-zones at the urban fringe and the exurban sub-zones beyond the outer traffic ring. Consequently, changes in LULC and population shifts resulted in significant variation in the spatiotemporal patterns of the urban area.

Keywords: GIS, Landsat Image, NCT, NDBI, NDVI, Remote sensing.

Introduction

Population growth is a major problem in much urban country like China, India, and Africa etc. Rapid Urbanization causes disorganized and unplanned growth of town and cities. Urbanization has been a universal and important social and economic phenomenon taking place all around the world. Urbanization could be the most powerful and visible anthropogenic force that has brought about fundamental changes in land cover and landscape pattern around the globe. Urbanization and urban growth, especially in the developing world, is continuing to be one of the crucial issues of global change.

Background of the study

Urban sprawl is the scattering of new development on isolated tracts, separated from other areas by vacant land (Ottensmann, 1977). Remote sensing has great potentials in studying urban environments and urban/suburban landscape when high spatial resolution imagery is available (Jensen and Cowen, 1999). Remote sensing data are more widely used for the analysis of pattern and process rather than causes or consequences. In 2009, over 3.4 billion people in the world resided in urban areas as a result of rapid urban growth. This figure is estimated to increase to 6.5 billion by 2050. This urban growth phenomenon has raised challenges for many countries in both the developing and developed worlds. Urban growth is a complicated process involving the spatiotemporal changes of all socio-economic and physical components at different scales.

Problem Identification

Many cities worldwide are growing very rapidly, leaving urban and transport planners with continuous challenges in planning for livable environments. This rapid growth causes complex interrelated urban growth and transportation issues. In most of the developing countries, urban development is occurring in a haphazard manner without concerning the ecological issues. Rapid and unplanned urban growth is also threatening the sustainability of the cities. In this context, it has been a major challenge to the planners and decision makers to identify the spatial-temporal changes occurring over urban areas. Since, urban growth is a continuous process; it can only be identified from analyzing long term spatial-temporal data.

Aim of the Study

The present study aims to identify the spatial-temporal changes occurring over Delhi National Capital Territory region using long term satellite data.

Objective of the study

- To estimate areas under different land use and land cover classes using supervised image classification technique.
- To identify the spatial-temporal changes through change detection technique and detect the pace and direction of urban growth using long term satellite data.
- Identification of urban growth through multi-temporal fractional images and comparing it with fractional images of hyper spectral satellite data.
- Mapping the socio-economic changes of the study area and analyzing the causes of such rapid urban growth in Delhi.

Study Area

Delhi is the capital of India. The state is spread over an area of 1473 square kilometer. According to the Indian geography the state is located at the center of the Indian subcontinent, amidst the ranges of Himalaya and the Ravalli.

Location

The study area is located Centre of the Delhi in India. The study area is bounded by Latitude $28^0 24'16.84''$N to $28^0 52'52.31''$N and Longitude

$77^0$5′12.02″ E to $77^0$10′9.83″E. The total boundary of the study area is 1473.1677sq.km.

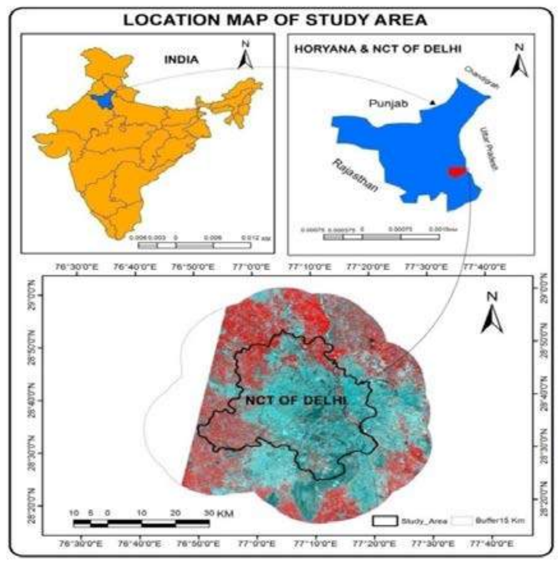

Fig. 1. Location Map of the Study Area.

Topography

The entire topography of Delhi is divided into a ridge, the Yamuna Flood Plain, the Plain. It is interesting to note here that each of these regions is marked by distinct type of vegetation. The ridge area of the city offers the right factors that favor the growth of acacias and other cacti. However, during the monsoon, herbaceous plants grow in abundance in the ridge. As far as the plain region of Delhi is concerned, it is characterized by shish am trees.

Drainage

Drainage pattern of an area is very important in terms of its groundwater potentiality. It is the source of surface water and is affected by structural, lithological and geomorphologic control of an area. This may be due to more or less homogeneous lithology and structural controls. Yamuna River is the main control of drainage system along the NCT of Delhi.

Reverie type of vegetation grows along the plain of Yamuna. National Capital Region in general, is a part of well integrated drainage system of the Ganga basin. Drainage is an important element of physical infrastructure and constitutes removal and disposal of surplus rain/irrigation water from the land.

Vegetation

Vegetation cover in this area has been found to be predominantly. According to report, the total vegetation cover is 367.425 sq. Km., 279.3114sq. Km., 404.3061sq. Km. and 71.5851.Km. in 1977, 1998, 2003 and 2014 respectively. The Vegetation of Delhi varies with its varied topography and comprises small and medium sized plants and shrubs.

Climate

Delhi Weather varies with the different climatic conditions that are faced by this city. Summer weather condition of Delhi is characterized by scorching heat and unbearable temperature. Temperature reaches almost 45^0C in the summer months. On the contrary, winter, which lasts from December to January, is extremely cold. Temperature falls to almost 5^0C during the winter months in Delhi. The rainy season in Delhi begins in June and continues almost till October. Delhi receives most of its rain during this period from the Northwesterly winds. Most of the precipitation occurs in the month of July.

Data Collection

Detection of Urban growth and identification land use change in Delhi using Landsat satellite image. Used temperature mapping algorithm for detection urban growth and Land use & land cover classification have been done using maximum likelihood classification technique.

Table 1. Details of the satellite data used in this study.

SL. No.	Data Use	Year	Source
1	Landsat-7 TM	1998,2003,2014	Glovis
2	Google Earth Image	2014	Google Earth

Table 2. Characteristics of the Landsat 7 TM, MSS and Landsat 8 sensor and the using data was collected from USGS web site.

Sensors	Spectral bands	Spatial resolution	Spectral region	Time of acquisition
Land sat-TM	Band 1: 0.45-0.52µm	30 M	VNIR	1998,2003 February
	Band2: 0.53-0.60µm			
	Band 3: 0.63-0.69µm			
	Band 4: 0.75-0.90µm			
	Band 5: 1.55-1.75µm		SWIR	
	Band 6: 1.04-12.5µm	120 M	TIR	
	Band 7: 2.09-2.35µm	30 M	SWIR	
Land sat-MSS	Band 1:0.50-0.60µm	60m	Green	February 1977
	Band2:0.60-0.70µm		Red	
	Band 3:0.70-0.80µm		Reflected IR	
	Band 4:0.80-1.11µm			
Land sat 8	Band 1:0.45-0.52µm	30m	Visible	2014, February
	Band 2:0.52-0.60µm		Visible	
	Band 3:0.63-0.69µm		Visible	
	Band 4:0.77-0.90µm		Near-Infrared	
	Band 5:1.55-1.75µm		Near-Infrared	
	Band 6:10.40-12.50µm		Thermal	
	Band 7:2.09-2.35µm	60 (30)m	Mid-Infrared	
	Band 8: 0.52-0.90µm	15m	Panchromatic	

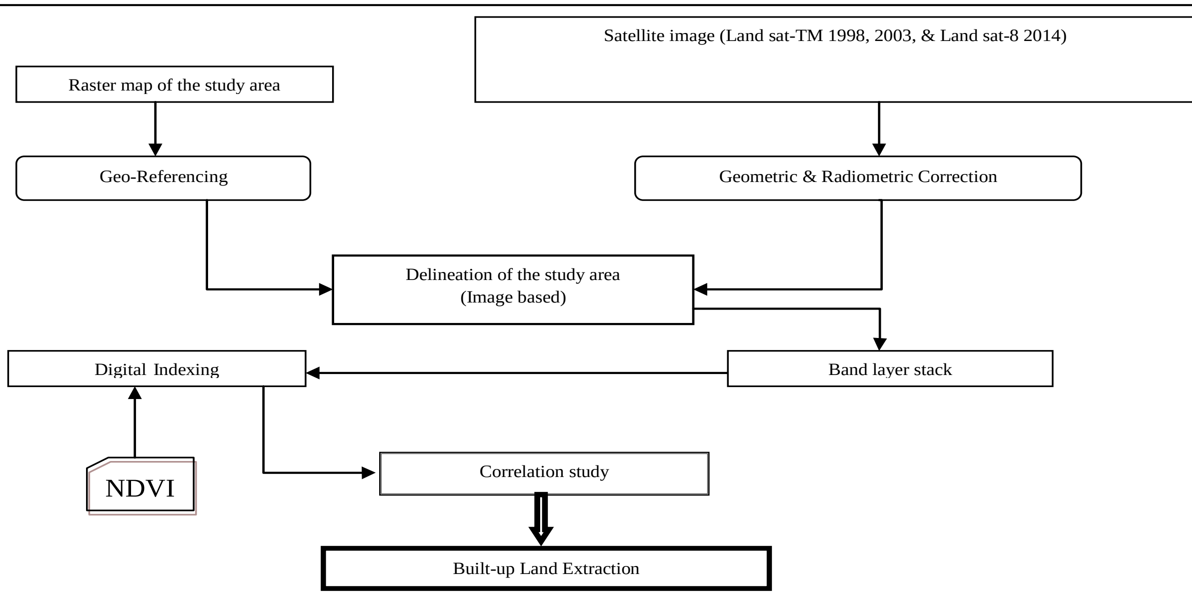

Figure 2. Methodological flow chart.

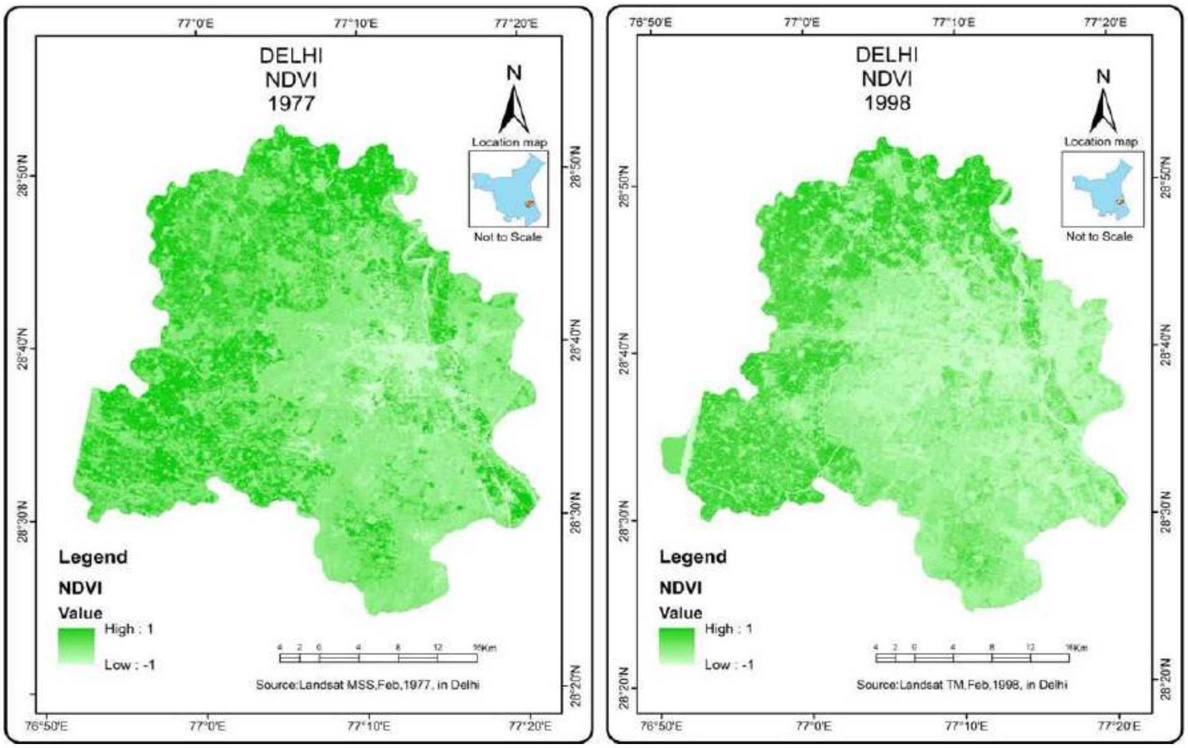

Figure 3. Normalized Difference Vegetation Index in Delhi, 1977 & 1998.

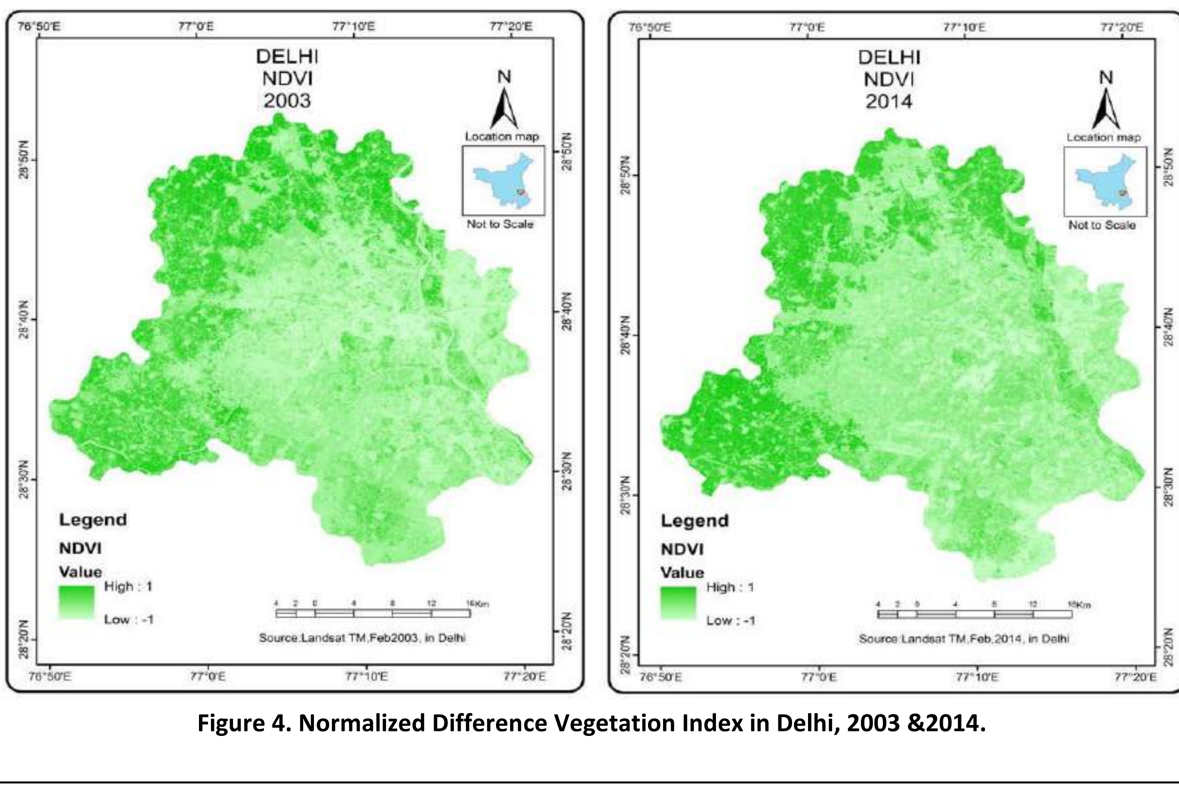

Figure 4. Normalized Difference Vegetation Index in Delhi, 2003 &2014.

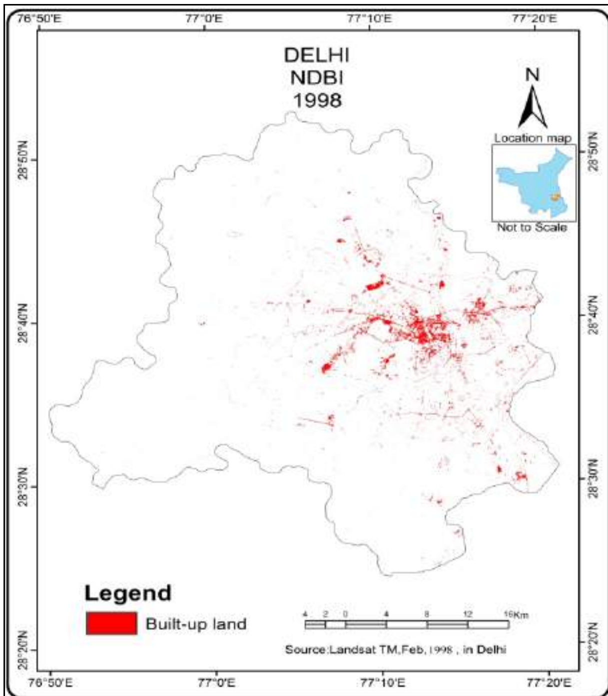

Figure 5. Normalized Difference Built-up Index in Delhi, 1998.

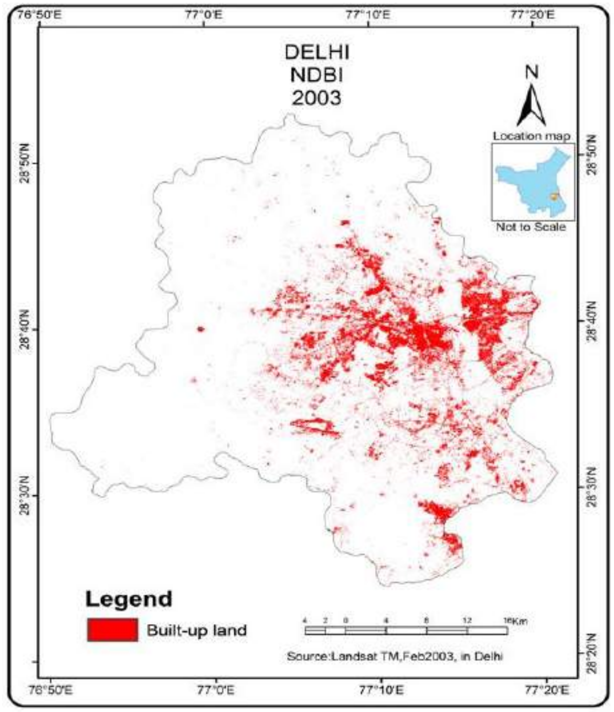

Figure 6. Normalized Difference Built-up Index in Delhi, 2003.

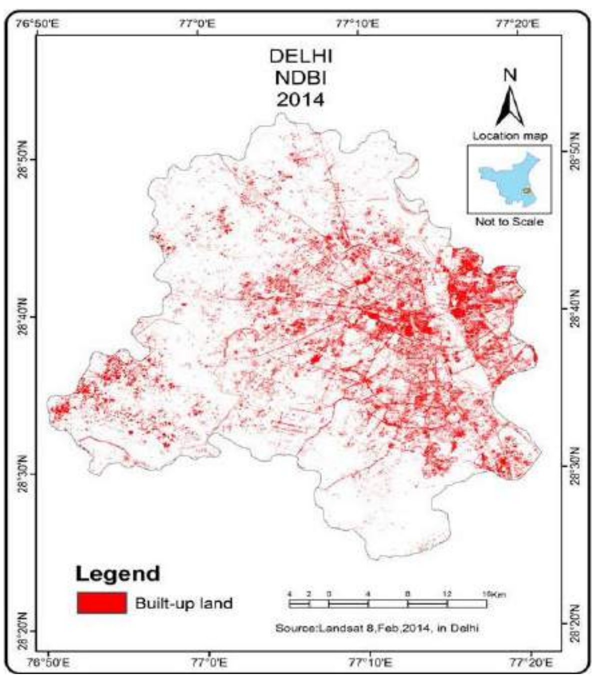

Figure 7. Normalized Difference Built-up Index in Delhi, 2014.

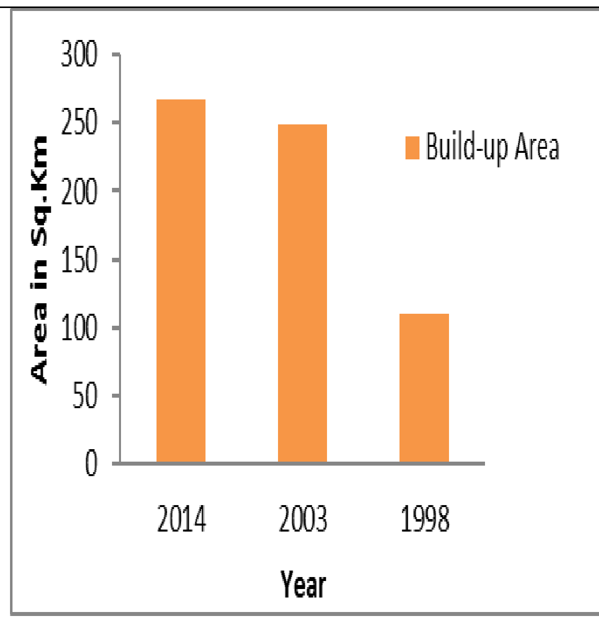

Fig. 8. **Normalized Difference Built-up Index in Delhi, 1998, 2003 & 2014 with Column diagram.**

Different image processing & enhancement technique used for identification the time-sequential changes in land use parents.

Satellite data

The data used for this dissertation consists of-

(1) Landsat7 MMS imagery, from band 1to band 4, on February, 1977.

(2) Landsat7 TM imagery, from band1 to band 7 on February, 1998, 2003.

(3) Landsat 8, 2014 imagery, from band1 to band 8 on February.

Here, Land sat TM, MSS, and Landsat 8 images are used to fulfill this work

Table-2: Characteristics of the Landsat 7 TM, MSS and Landsat 8 sensor and the using data was collected from USGS web site. For the Extraction of Built-up land I used the MidIR, NIR band. Spatial resolution of NIR band of Landsat -TM & Landsat-MSS is 120m and 60m respectively and spectral resolution of visible, infrared & middle infrared region of Land sat-TM & MSS is 30m & 60m. Due its moderate resolution spatial coverage, Land use & land cover classification has been done for change detection analysis.

Instruments Used

Garmin GPS 12: GPS was used to obtain the geographical co-ordinates of the observed filed location during the ground truth study for collecting Well distributed point, & land use/land cover information.

Software's used

Image Processing: ERDAS Imagine 9.0 & ENVI 5.0

Geographical Information System: Arc GIS 10.1

Others: MS-Office-2010(MS-word, MS-Excel) for documentation and calculation.

Data analysis

The primary source of the data used for the built-up land investigation on satellite image. The remotely sensed data used in this test is a Landsat 8, TM/ MSS image. The images are cloud-free and have excellent quality.

Normalized Difference Vegetation Index (NDVI)

Rouse et al., (1974) developed the generic Normalized Different Vegetation Index (NDVI). In the case of this study, NDVI has been used to validate one of the objectives.

$$\mathrm{NDVI} = \frac{\mathrm{NIR} - \mathrm{RED}}{\mathrm{NIR} + \mathrm{RED}}$$

A Normalized Difference Vegetation Index (NDVI) is an equation that takes into account the amount of infrared reflected by plants. Live green plants absorb solar radiation, which they use as a source of energy in the process of photosynthesis. The reason NDVI is related to vegetation is that healthy vegetation reflects very well in the near-infrared part of the electromagnetic spectrum. Green leaves have a reflectance of 20% or less in the 0.5 to 0.7 micron range (green to red) and about 60% in the 0.7 to 1.3 micron range (near-infrared). This spectral reflectance is themselves ratios of the reflected over the incoming radiation in each spectral band individually; hence, they take on values between 0.0 and 1.0. and shows the Normalized Difference Index (NDVI) drives from Land sat satellites image of the year of 2001 and 2011. In Figure: 2 NDVI values 0.0814 to 0.4375 represents the green coverage surface and Figure: 3 NDVI value 0.1559 to 0.4516 represents the green coverage surface.

Normalized Difference Built-up Index (NDBI)

These equation can be used for monitoring the built-up land Zha et al., (2003) calculated a normalized Difference Built-up Index (NDBI).

$$\mathrm{NDBI} = \mathrm{Bui} - \mathrm{NDVI}^{\mathrm{Bui}} = \frac{\mathrm{MidIR} - \mathrm{NIR}}{\mathrm{MidIR} + \mathrm{NIR}}$$

Where, this resulted in an output image that contained only built-up and barren pixels having positive values while all other land cover had a value of 0 or -254. The technique was reported to be 92 percent accurate.

The built-up areas of 2001 and 2011 were extracted from NDBI images. To extract the built-up area from the NDBI images we have to adopt the thresholding technique, where a creating range of DN value is extracted from the index raster which may represent some typical kind of feature of interest. In general, we know that the positive values of NDBI are represent the built-up feature and negative values is represent the other land surface features.

Conclusion

The land-use/land-cover map prepared from Landsat-TM, MSS & Landsat 8 data for identifying the time sequential change of LULC patterns. Built-up area has rapidly increased during 1977 - 2014. It is also noteworthy that the rate of urban growth was highest during 2003 to 2014 and a total increase of high density built-up land was found 47.01%. It was happened mainly at the expense of agricultural land located at the outskirt of the city.

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