Urban Growth Analysis of Nagpur Citythrough Index Based Model

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Abstract

Urban growth is a spatial and demographic process and refers to the increased importance of urban centre as a concentration of population. The objectives of is to find out the built-up area and to analyse the urban growth of the city through the index-based model. The present study examines the use of the model for delineation of growth of Nagpur city. The Built-up Index (IBI) is proposed for rapid extraction of built-up land feature in the satellite imagery. Three different thematic indices have been used in constructing the IBI, viz. Soil Adjusted Vegetation Index (SAVI), Modified Normalized Difference Water Index (MNDWI) and Normalized Difference Built-up Index (NDBI) which together represent three major components of vegetation, water and built-up land, respectively. The satellite images of Landsat 7 (ETM+) and 8 (OLI) have been used in the present study. By using IBI, the built-up area is extracted from the satellite images of 2000 and 2015. The study has utilised IBI algorithms to identify built-up regions and their growth in the study area. From the IBI study, it has been observed that the built-up area of Nagpur City in 2000 was 41.69 km2 while in 2015, it has increased 145.19 km2. This kind of study is helpful to identify of urban growth and change in the land use patterns.

Keywords: IBI, SAVI, MNDWI, NDBI, Urban Growth

1. Introduction

The Land use and Land cover (LU/LC) changes are among the most important factors for analysing environmental changes such as deforestation, urbanisation and forest degradation. Urban development is the process of emergence of the world dominated by cities and by urban values(Clark, 1982). It is important to draw a clear distinction between the two main process of urban development – urban growth and urbanization. According to Clark (1982), urban growth is a spatial and demographic process and refers to the increased importance of town and cities as a concentration of population within a particular economy and society. Urbanization on the other hand is non-spatial and social process, which refers to the changes of behaviors and social relationships that occur in social dimensions as a result of people living in town and cities.

Urban growth is a spatial and demographic process and refers to the increased importance of urban centre as a concentration of population within a particular economy and society. The main objectives of this study is to find out the built-up area in Nagpur city and to analyse the urban growth of the city through the index-based model. The present study examines the use of the model for delineation of growth of Nagpur city. The Built-up Index (IBI) is proposed for rapid extraction of built-up land feature in the satellite imagery. Three different thematic indices have been used in constructing the IBI, viz. Soil Adjusted Vegetation Index (SAVI), Modified Normalized Difference Water Index (MNDWI) and Normalized Difference Built-up Index (NDBI) which together represent three major components of vegetation, water and built-up land, respectively. The satellite images of Landsat 7 (ETM+) and 8 (OLI) have been used in the present study. By using IBI, the built-up area is extracted from the satellite images of 2000 and 2015. The study has utilised IBI algorithms to identify built-up regions and their growth in the study area. From the IBI study, it has been observed that the built-up area of Nagpur City in 2000 was 41.69 km2 while in 2015, it has increased 145.19 km2. This kind of study is helpful to identify of urban growth and change in the land use patterns. The ability to monitor the built-up landdynamics and changes in the urban extent in a timely and cost-effective manner is highly desirable for local communities and decision makers alike. Fortunately, satellite remote sensing technology offers considerable promise to meet this requirement and satellite imagery has been used to discriminate built-up area from non-built-up area for the last decades. A popular method for the definition of built-up land areas began conventional multispectral classification. However, this may not produce satisfactory accuracy, normally less than 80%, due to spectral confusion of the heterogeneous built-up land class.

Therefore, the Built-up Index (IBI) is proposed for the rapid extraction of built-up land feature in the satellite imagery. The Three different thematic indices has been used in constructing the IBI, Soil Adjusted Vegetation Index (SAVI), Modified Normalized Difference Water Index (MNDWI) and Normal Difference Built-up Index (NDBI), which together represents three major components of vegetation, water and built-up land, respectively (Xu et. al., 2008).

A new index for transforming remote sensing data was proposed and evaluated for mapping built-up and bare land areas. The index was able to map built-up and bare land areas with a single calculation and was referred to as the Enhanced Built-up and Bareness Index (EBBI). The EBBI is the first built-up and bare land index that uses the NIR, SWIR, and TIR channels simultaneously. The EBBI was applied in Denpasar, Indonesia, to distinguish between built-up and bare land in an urban area, and the results obtained by the EBBI were compared with those determined by other available remote sensing indices (Abdul Rahman As-syakur, 2012)

Aim and Objectives

The aim of the study area is the urban growth analysis of Nagpur city (2000 - 2015) through index based model. Following are the objectives of the study -

- To find out the urban built-up area in Nagpur City.
- To analysis the urban growth of the Nagpur City through the index-based model

2. Study Area

The study area is conducted in Nagpur City, which is the winter capital and the third largest city of the Indian state of Maharashtra and largest city of central India. It is a major commercial and politicalcentre of the Vidarbha region. The study area is enclosed by Latitude 21˚ 3’ 30’’ N to 21˚ 15’ 47’’ N and Longitude 78˚ 57’ 20’’ E to 79˚ 11’ 20’’ E. The total margin of the study area is 306.08 km2. Nagpur falls under tropical savannah climate.

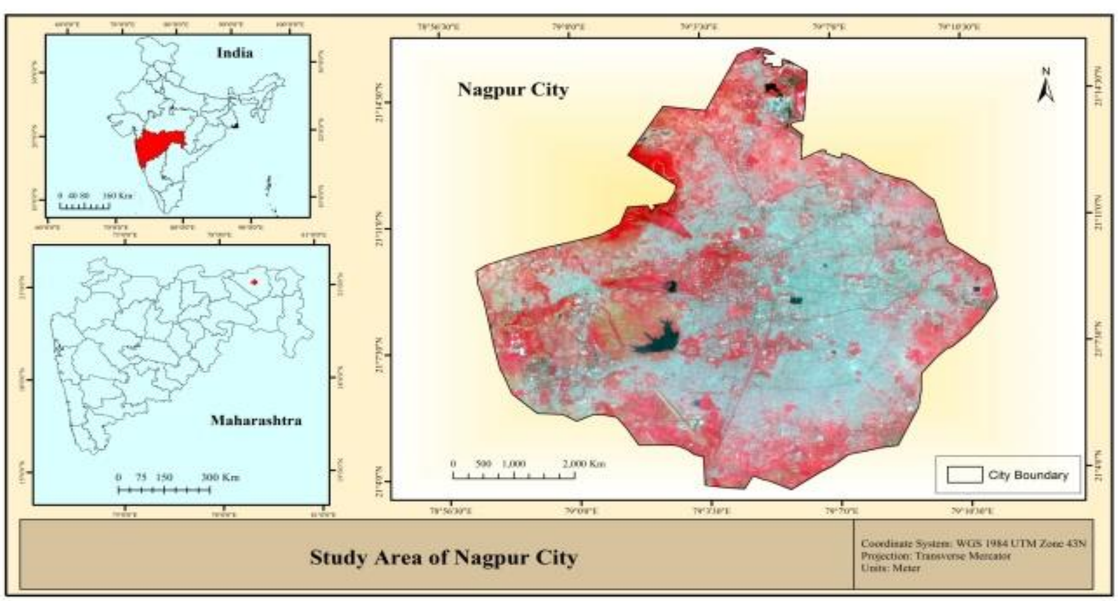

Fig. 1 Location of the Study Area

3. Materials and Methods

The main source of data used for the built-up land exploration is satellite images. The details of remotely sensed data used in the study area are given in Table. The images were cloud-free with excellent quality. Previous studies has been conducted in urban growth by Gupta et al., 2014. In the present study, a methodology has been planned to conduct the spatial-temporal analysis to study the urban growth in 2000 and 2015. The above process is based on the model which requires three indices, namely Soil Adjusted Vegetation Index (SAVI) (Eq. 1) and Modified Normalized Difference Water Index (MNDWI) (Eq. 2) and Normalized Difference Built-up Index (NDBI) (Eq. 3).

These are the indices, which are widely used to extract different features from remote sensing data. Therefore, the intention is to reject the information for vegetation and water to ascertain the built-up land. Feature extraction has been done by using the following formulas of the particular indices,

SAVI={(NIR - Red) (1 + l)}/(NIR + Red + l) (1)

MNDWI=(Green - MIR)/(Green + MIR) (2)

NDBI=(MIR - NIR)/(MIR + NIR) (3)

where,

NIR = B4 (ETM+) & B5 (OLI),

Red = B3 (ETM+) & B4 (OLI),

MIR = B5 (ETM+) & B6 (OLI),

Green = B2 (ETM+) & B3 (OLI),

l = Correction factor, whose value ranges from 0-1 and totally depends upon the plant densities of the area. If there is very high plant density, then value of l will be zero.

The SAVI is used for evaluation of vegetation fabrication instead of NDVI, because SAVI is more sensitive than NDVI in detecting vegetation in the low plant covered the areas such as urban area. The SAVI can work in the area with plant cover as low as 15%, while NDVI can only work effectively in the area with plant cover above 30% (Ray, 2006).

The MNDWI modified from the Normalized Difference Water Index (NDWI) of McFeeters (1996) by the substitution of a middle-infrared band such as ETM+5 for the NIR band used in the NDWI (Xu et al., 2006). As a result, the MNDWI has an advantage over the NDWI by removing built-up land noise when applied to open water enhancement.

The NDBI has been developed to classify urban and built-up areas (Zha, et.al. 2003). A unique feature is that the mean value of built-up land is greater than those of vegetation and water in the NDBI band. After extracting the required features in raster form, from all above the indices, Index-based Built-up Index (IBI) (Eq. 4) can be used by applying a formula, mentioned below:

$IBI = NDBI - (SAVI + MNWDI)$ (4)

After the final calculation, the raster obtained will be IBI, which shows the enhanced built-up features in it. After successful reclassification, it is able to extract the built-up class only from the output index for different threshold values for different outputs.

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

Sr. No.	**Data Use**	**Year**	**Sources**
1	Landsat 7 ETM+	October 2000	Earth Explorer
2	Landsat 8 OLI	October 2015	

4. Results and Discussion

4.1 Soil Adjusted Vegetation Index (SAVI)

To evaluate the rate of urban growth, there have been used differences in SAVI between subsequent images. The motivation of SAVI is related to vegetation is that the healthy vegetation reflects very well in the near-infrared part of the electromagnetic spectrum.

Green leaves have reflectance of 20% or less in 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 reflectance is the ratio of the reflected energy over the incoming radiation in each spectral band individually; hence, the values lies between -0.703297 and 1.31225 in Figure 2 and -0.14073 to 0.991666 values in Figure 3 of the year of 2000 and 2015 respectively.

The SAVI images from subsequent dates are then subtracted; producing a map of SAVI in which a positive value represents high vegetation and negative values represent low vegetation. However, the application of the SAVI is to extract the vegetation in sequence of these regions which is consistently mixed up with built-up land noise.

4.2 Modified Normalized Difference Water Index

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The MNDWI is more suitable for enhancing and extracting water information for water within a background dominated by built-up land areas because of its advantage in reducing and removing built-up land, vegetation and soil noises. This index maximizes the reflectance of water by using green light wavelengths and minimizes low reflectance of MIR by water features.

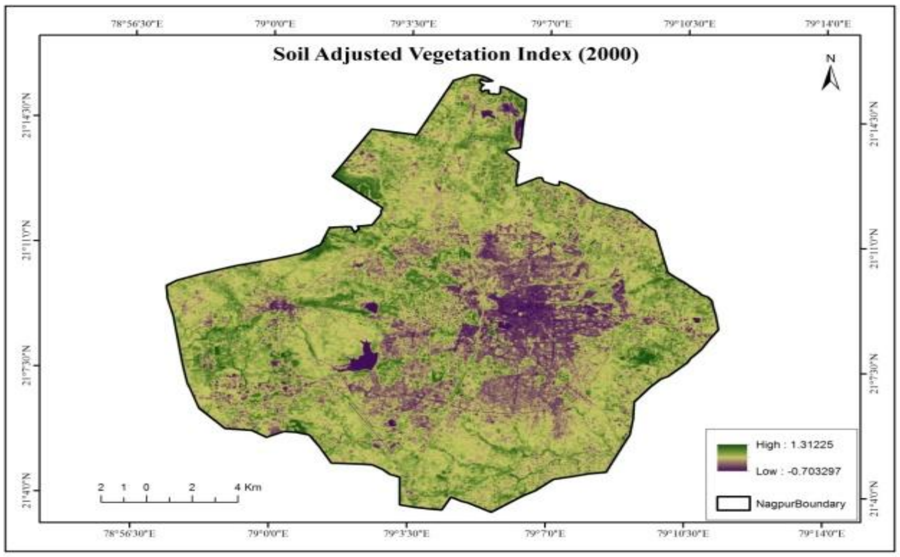

Fig. 2 Soil Adjusted Vegetation Index (2000)

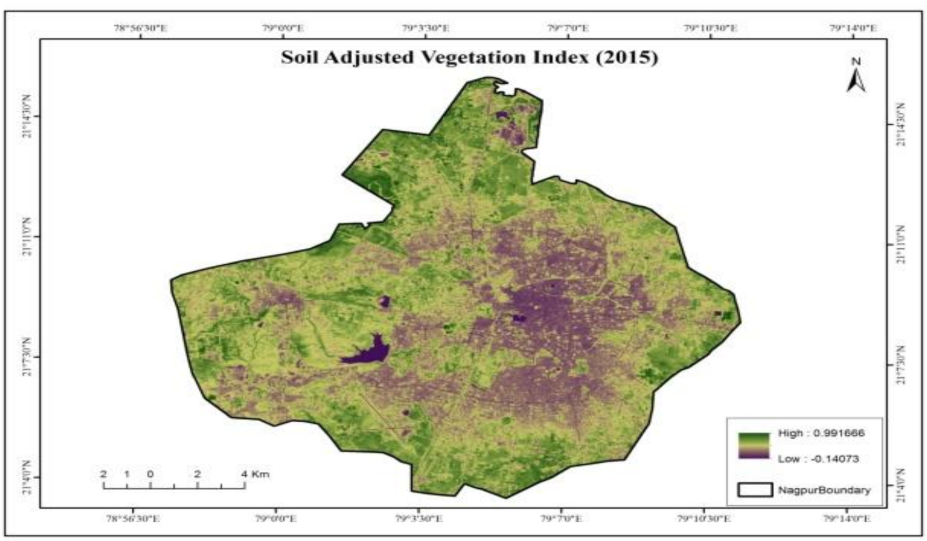

Fig. 3 Soil Adjusted Vegetation Index (2015)

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Kamila (2015) used a different technique to estimate and monitor the urban built-up land features from Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) imagery. In the study, three indices were selected, viz., Normalized Difference Built-up Index (NDBI), NormalizedDifference Water Index (NDWI) and Normalised Differences Vegetation Index (NDVI) to represent three major urban land-use classes, built-up land, open water body and vegetation respectively. 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.

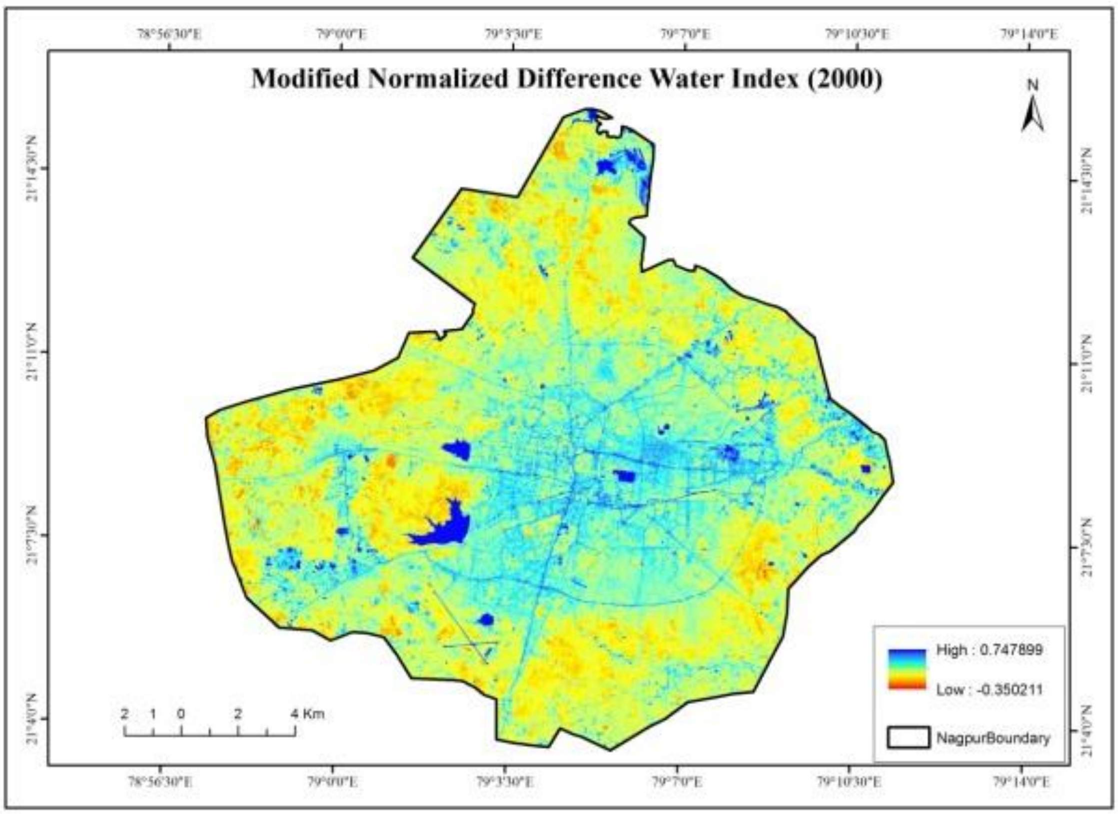

Fig. 4 Modified Normalized Difference Vegetation Index (2000)

As result, water features are enhanced in some areas of vegetation to having positive values, because little amount of water available in healthy vegetation and soil are suppressed due to negative values as represented in Figure 4 and Figure 5 of the years 2000 and 2015, respectively. However, the application of MNDWI in water regions with built-up land background like in the cases of study area was not as successful as expected. The extracted water in sequence in these regions was consistently mixed up with built-up land noise because many built-up lands also show positive values in the MNDWI derivative image (Figure 4 & 5) of the year of 2000 and 2015. In the year of 2000, the MNDWI image shows high and low values, which are 0.747899 and – 0.350211 respectively (Figure 4) andin the year of 2015, the values range between 0.259524 and – 0.445112, and these are the highest and lowest values of the MNDWI respectively in Figure 5

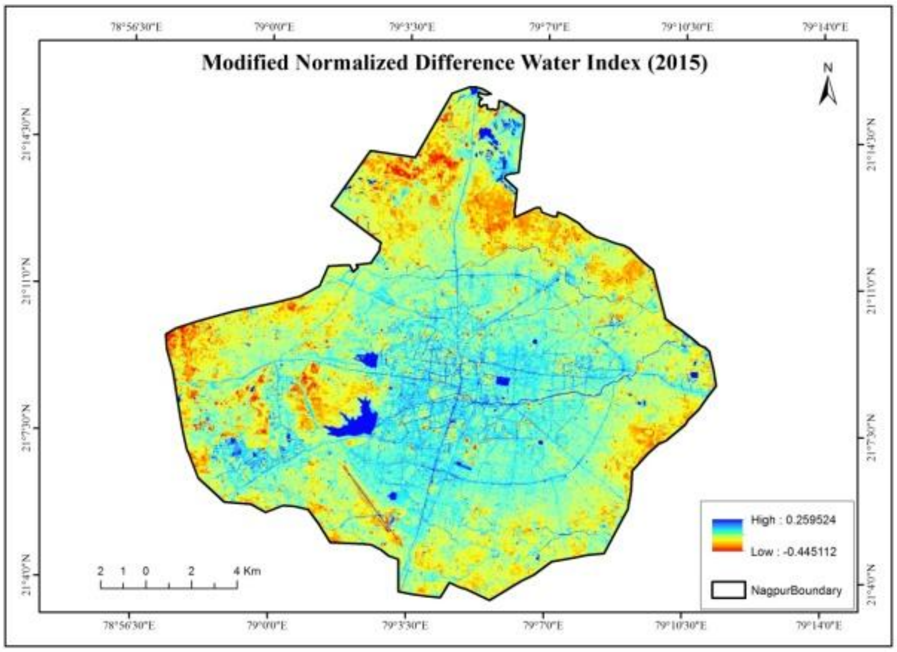

Fig. 5 Modified Normalized Difference Vegetation Index (2015)

4.3 Normalized Difference Built-up Index

The NDBI based on the rule that the built-up area has higher reflectance in mid-infrared band is higher than in near-infrared band. The built-up areas of 2000 and 2015 were extracted from NDBI images in Figure 6 & 7. In general, the positive value of NDBI represents the built-up features and the negative value represents the other land surface features.

The NDBI images show the built-up land of the years 2000 and 2015 respectively. NDBI has positive and negative values, which segregate the built-up and non-built-up lands. The range of value is 0.379845 – 0.642857 which represents built-up and non-built-up lands respectively in

Figure 6 and in 2015, and the highest and lowest range of value is 0.207496 – 0.373757, which represents same land surface features in Figure 7. But, disadvantage of NDBI is that the positive values do not show the built-up land but also shows the barren land features, because the range of spectral reflectance is same for both land features. The NDBI is one of the best methods for the extract of built-up areas, but not suitable for this study area, because this study area is not high densely built-up areas.

4.4 Index-based Built-up Index

The IBI can enhance the built-up land features easily because the subtraction of the SAVI band and the MNDWI band from the NDBI will result in positive values for built-up land pixels only. The index takes advantage of the condition where the features with higher NDBI values but lower SAVI and MNDWI values are enhanced. Obviously, the IBI is a normalized difference index and thus has such features as: 1) a ratio-based index, 2) values ranging from – 1 to +1 and 3) enhanced information has positive values, while the suppressed background noise generally has zero to negative values.

After applying the expression of the IBI, the negative values represent non-built-up areas and positive values represent the built-up land features in the years of 2000 and 2015 respectively (Figure 8 & 9). The built-up areas are extracted by the IBI.

The IBI has been constructed by three indices viz., SAVI, MNDWI and NDBI, to extract the vegetation, water and built-up lands from the study area, somewhat limited in built-up feature extraction as NDBI allow to extracts little soil and barren land in it due to same reflectance as of built-up. This limitation is overcome by IBI in Figure 9 which shows built-up areas mixed with barren lands. IBI extracted not only built-up areas but also little soil and barren land in the year of 2015 in Figure 9. The IBI map shows the built-up land has been increased between the years from 2000 to 2015 (Figure 8 & 9). The IBI has enhanced the built-up land features with dark red tone, while vegetation and water are considerably suppressed as background noise with a yellow-green tone (Figure 8 and 9).

Table 2 explains to the statistics of the indices such as, SAVI, MNDWI, NDBI and IBI that shows the segregation between the vegetation, water and built-up land features. Table 2 not only shows the maximum and minimum values but also shows mean and standard deviation

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values of the output for the years. In the present work, this value has been manually determined for all outputs.

Table 2: Statistics of the thematic indices (SD = Standard Deviation)

Year	Built-up Area (Km^2)	Non-Built-up Area (Km^2)	Total Area (Sq km)	Total % of the Area	
				Built-up	Non-Built-up
2000	41.69	264.39	306.08	13.62	86.38
2015	145.19	160.59	306.08	47.44	52.56

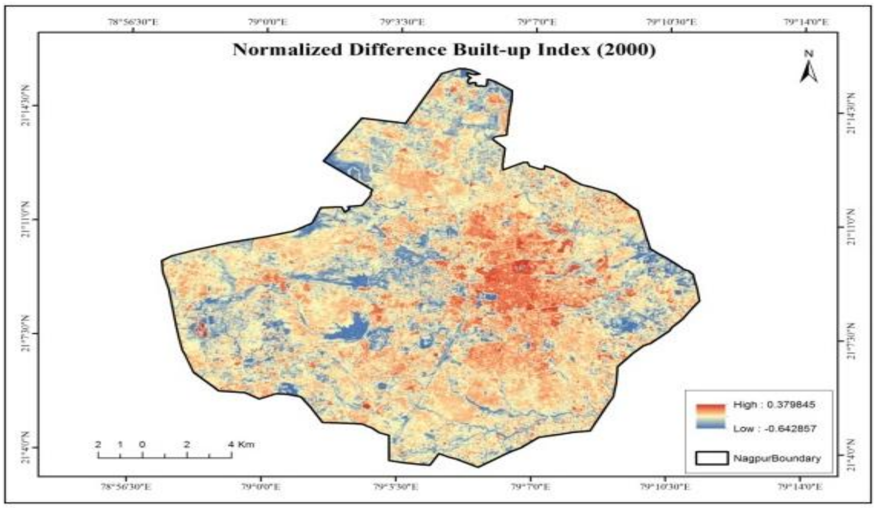

Fig. 6 Normalized Difference Built-up Index (2000)

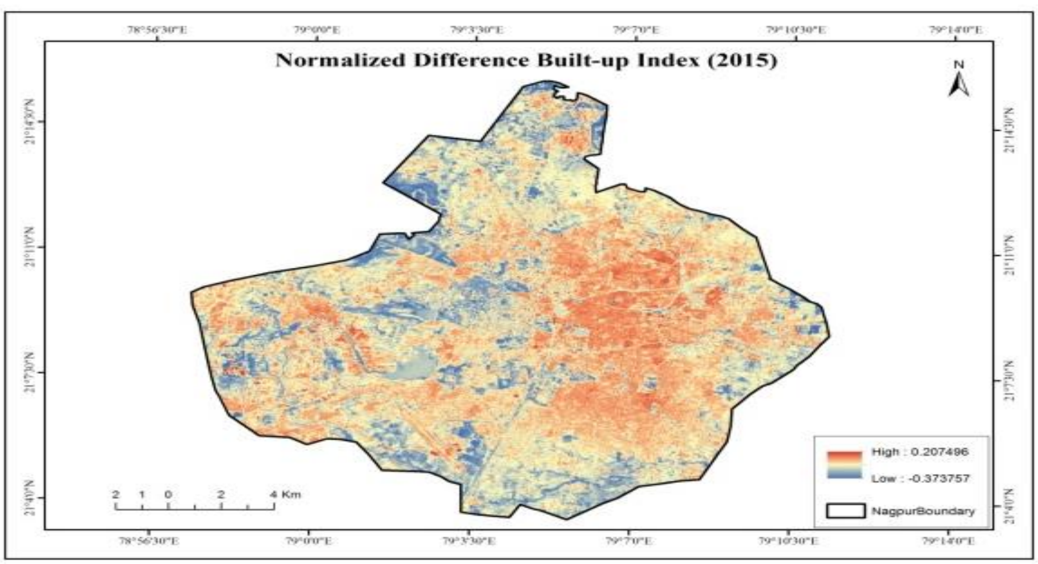

Fig. 7 Normalized Difference Built-up Index (2015)

Table 3. Area of built-up mask in 2000 & 2015

Indices	2000			
	Max	Min	Mean	SD
SAVI	1.31	- 0.70	0.43	0.27
MNDWI	0.75	- 0.35	- 0.13	0.08
NDBI	0.38	- 0.64	- 0.06	0.09
IBI	0.92	- 1.82	- 0.36	0.34
	2015			
Indices	Max	Min	Mean	SD
SAVI	0.99	- 0.14	0.41	0.16
MNDWI	0.26	- 0.45	- 0.10	0.05
NDBI	0.21	- 0.37	- 0.08	0.06
IBI	0.30	- 1.30	- 0.40	0.21

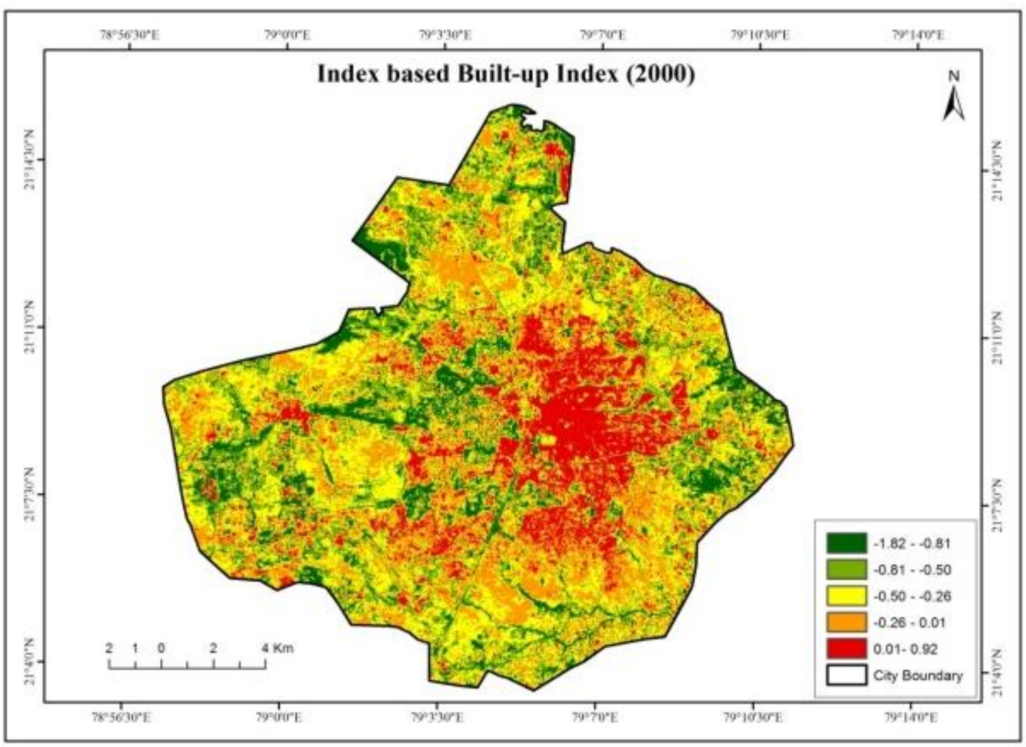

Fig. 8 Index-based Built-up Index (2000)

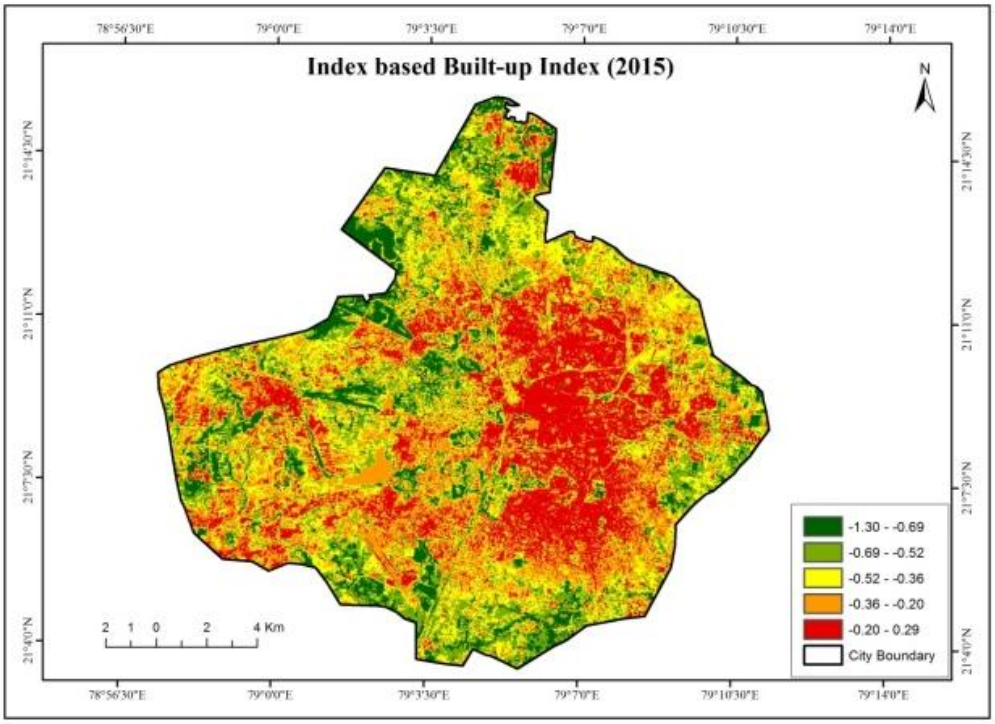

Fig. 9 Index-based Built-up Index (2015)

4.5 Urban Growth Analysis

The main objective of this study is the urban growth analysis of Nagpur City through index-based models. In the present study, for urban growth analysis, the rapid extraction method for built-up areas, which is also known as IBI method, is used. The IBI constructed on the three thematic indices viz., SAVI, MNDWI and NDBI, which represents three land surface features such as the vegetation, water and built-up areas. In this study, two time period data for the urban growth analysis of Nagpur city has taken for the year 2000 and 2015 respectively. By using IBI, the built-up area is extracted from the satellite imagery of the year 2000 and 2015. The IBI shows the real position of the built-up areas for Nagpur City, which is the main purpose of urban growth analysis. In this present study, the results show the significance of the bands and reflectance in the thematic setup as in all outputs the vegetation cover near to built-up portions is also eliminate easily. It is clearly observed from the built-up mask that is urban land use which has increased in aforementioned years. Total area of the study boundary is 306.08 km2 and the area covered by each built-up mask is shown in the Table 3.

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The use of Indices Combination with Supervision Classification methods to extract urban built-up areas, vegetation and water features from Landsat Thematic Mapper (TM7) imagery covering Dar es Salaam and Kisaraweperi-urban areas. The study uses three indices; Normalized Difference Built-up Index (NDBI), Modified Normalized Difference Water Index (MNDWI), and Soil Adjusted Vegetation Index (SAVI) to reduce the seven bands Landsat TM7 image into three thematic-oriented bands. Data correlation, spectral confusion and redundancy between original multispectral bands were significantly reduced upon application of the techniques. 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 since the spectral clusters of the classes are well separated. (Muakapuja, 2013)

In this study, urban growth is rapidly expanded between 2000 to 2015, a two years span, which shown in Figure 10 as well as Table 3 also provide the statistical information about the built-up area of Nagpur city. In Figure 10, dark red tone indicates the actual built-up area in 2000, and the area spread in 41.69 km2 and represented by electron gold tone, whereas the 145.19 km2 areas is observed in year 2015. In Nagpur city built-up area is rapidly increased and others lands features are decreased between 2000 and 2015 years span (Table 3).

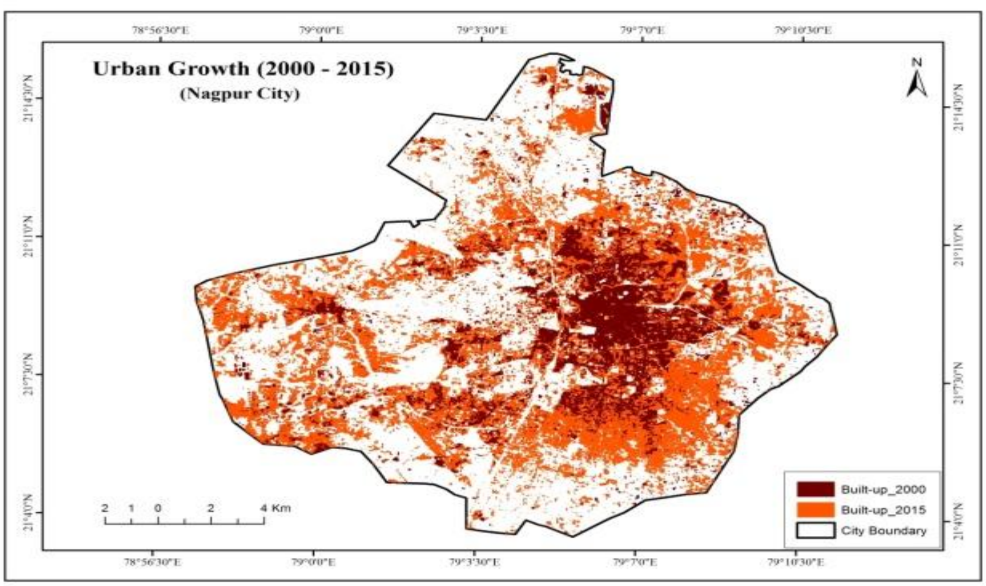

Fig. 10 Urban growth (2000 - 2015)

In Figure 10, there has been a drastic change in the land use pattern of Nagpur City with increasing population and experiences haphazard urban development which indicates urban growth and linear development along the roads. Many factors are responsible for this pattern such as the availability of educational, agricultural, social, cultural, economic and political importance. The validation of the IBI is carried out by the quantitative assessment of the accuracy the extracting of urban built-up land features. To extract urban built-up areas from the IBI images (Figure 8 and 9), a threshold value was manually determined. Here, accuracy assessment was done for the classified maps after verifying the ground truth verification. Through the logic calculation on the new image, the urban built-up lands were finally extracted with overall classification accuracy is 93.33% with a kappa coefficient of 0.9000. Above all the result of indices shows that the IBI has a positive correlation exist with built-up land features, but negative correlations with the vegetation and other non-built-up land features. Here, within slight limitation as IBI is extract little soil and barren land in it due to the same reflectance as of built-up.

5. Conclusions

Analysing the growth of urban built-up areas at regional level has been attempted by various authors using Landsat data. Researchers have worked out IBI approaches to delineate built-up regions from diverse remotely sensed data. This study has surveyed the available IBI algorithms to identify built-up regions and growth in the entire study area. From the IBI study it has been observed that the built-up area of the Nagpur City in 2000 was 41.69 km2. While in 2015 has increased to 145.19 km2. IBI is a very useful model for evaluating urban areas and productivity of other land features, but this method has a limitation. The regions with highly heterogeneous landscapes are still problematic withrespect to subdividing urban areas. An improved model is realistic, but due to the non-uniqueness of spectral reflectance of features over a different period of time, there will never be one best outcome. For better results, model should be improved through space and time.

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