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Urban Growth Monitoring and Analysis of Environmental Impacts on Bankura-I and II Block using Landsat Data

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Abstract This study put forward a technique to estimate and monitor the urban built-up land features from Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) imagery taking into account of two blocks in Bankura District, West Bengal as examples. In this study three indices have been selected, viz., Normalized Difference Built-up Index (NDBI), Normalized Difference Water Index (NDWI), and Normalized 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. This considerably reduced data correlation and redundancy between original multispectral bands, and thus significantly avoided the spectral confusion of the above three land-use classes. 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. Through logic calculation on the new image, the urban built-up lands were finally extracted with overall accuracy ranging from 91.5 to 98.5 percent. Therefore, the technique is effective and reliable. In addition, the advantages of over NDVI and over NDWI in the urban study are also discussed in this paper.
Keywords *Landsat; Bankura; NDVI; NDWI; NDBI; Remote Sensing and GIS*

1. Introduction

Urban sprawl is refers to diffusion 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). An important part of urban monitoring is to obtain information about the geometric elements of urban setting. Studies have exposed that entropy is a good statistic for measuring the spatial distribution of various geographic phenomena (Batty, 1972). Rapid urban development and impressive change of landscape have been recently witnessed in some developing countries as a result of rapid economic development. Mukherji, S. (2005) quarrel that slump as a pattern or a process is to be distinguished from the causes that bring such a pattern about or from the consequences of such patterns. This statement clearly utters that analysis of pattern and process should be differentiated from the analysis of causes and consequences. Remote sensing data are more widely used for the analysis of pattern and process rather than causes or consequences.

2. Literature Review

A broad literature review revealed the most significant attributes of urban form that are associated with infrastructure service costs. Since they are only valid for a specific extent, they are standardized as per-capita or per-unit costs (Burchell, et al., 2005). At the sub-regional level, the spatial pattern of urbanized areas, especially the quantity of centralization and contiguousness of built-up areas is of particular importance. In compact, contiguous patterns, infrastructure costs are significantly lower than in spread-out patterns (Carruthers, Ulfarsson, 2003; Speir and Stephenson, 2002). The urban sprawl phenomenon has been studied intensively by North American researchers (Ewing, et al., 2002, Hasse and Lathrop, 2003). According to Jaeger, Bertiller, Schwick, and Kienast urban sprawl denotes the extent to which an area is built-up and the extent of its dispersion in the landscape. The more the area is occupied by buildings and the more the buildings are dispersed, the higher the degree of urban sprawl is (Sabet Sarvestani, et al., 2011). While urban sprawl may be a progression equally shared by developed and developing countries, specific causes and characteristics conflict considerably. In the developed world, for instance, causes for urban sprawl vary from punter preferences to new Strategies of capital accumulation in cities through real estate development (Muñiz, Calatayud and García, 2007). However, the study of the causes behind urban sprawl remains less explored in the developing world. More examples of how this process unfolds in specific areas are needed to explore trends, causes and consequences that enrich our understanding of the urbanization process in areas where this process is more intense. An unfettered land market, open spaces left between existing built-up areas and new development are soon filled with further development. Therefore, sprawled areas could be transformed into a more compact urban form associated with more efficient infrastructures (Peiser, 1989). In this sense, urban sprawl is regarded as a temporary transformation phase in a long-term process which would finally result in an efficient spatial arrangement of urban land uses regarding the costs of infrastructures.

3. Study Area

The study area is located in Bankura district of West Bengal state. The study area is enclosed by Latitude 23^0 22’ 57.41” N to 23^0 09’ 25.21” N and Longitude 86^0 53’ 45.64” E to 87^0 14’ 16.01” E. The total margin of the study area is 416.79501 sq.km.

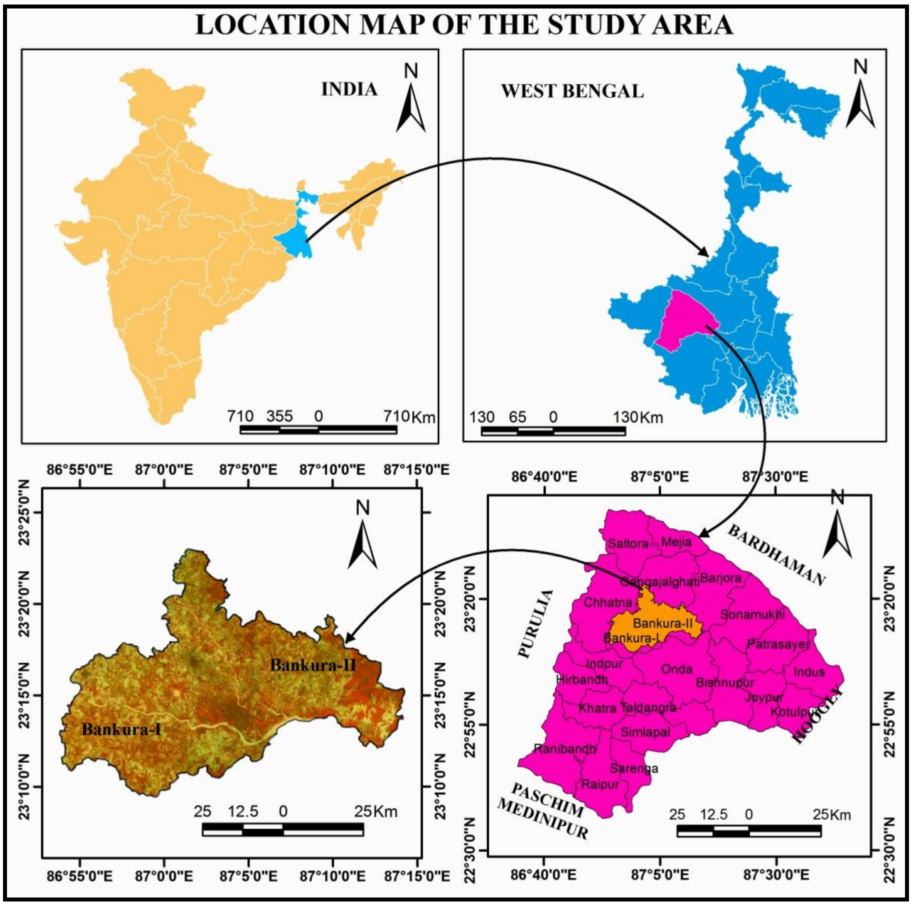

Figure 1: *Location Map of the Study Area*

3.1. Objectives

The main objective of the present paper is to find out urban growth and its impact on environment for the entire study area.

3.2. Data Used

The primary source of the data used for the built-up land exploration on satellite image. The details of remotely sensed data used in this study are given in Table 1 and Table 2. The path & row of the image is 139 & 44. The images are cloud-free and have excellent quality. Sub-scenes covering the study area were supplementary extracted from two images.

Table 1: *Details of the Satellite Data Used in this study*

Sl. No.	Data Use	Year	Source
1	Landsat-5 TM	24 October, 2001	USGS
2	Landsat-7 ETM+	26 October, 2011	Glovis
3	Google Earth Image	2010	Google Earth

Table 2: *Characteristics of the Landsat 5 TM & 7 ETM+ Sensor*

Launched	March,1984
Decommissioned	--------------
Altitude	705 km

Sensor	TM/ETM+
Spatial Resolution	Band 1 to 5,7 (30 m) and Band 6 (120 m)
Spectral Resolution	Band 1 – 0.45-0.50 Band 2 – 0.52-0.60 Band 3 – 0.63-0.69 Band 4 – 0.78-0.90 Band 5 – 1.55-1.75 Band 6 – 10.4-12.5 Band 7 – 2.08-2.57 Band 6^1 & 6^2 (60 m for ETM+) instead of Band 6 in TM
Temporal Resolution	16 days
Swath	185 km
Period	99 minutes
Inclination	98.2^0

3.3. Methodology

This study is an applied one and the methods of investigation are both descriptive and analytical. To identify and monitor the urban growth, the urban land-use was grouped into three other oversimplifying categories: vegetation, open water and built-up-land.

Based on these three mechanism, three thematic indices, the normalized differences vegetation index (NDVI), normalized differences water index (NDWI) and normalized differences built-up index (NDBI) were preferred to symbolize the three major land-use classes. So the intention is to reject the information for vegetation and water to ascertain the built-up land.

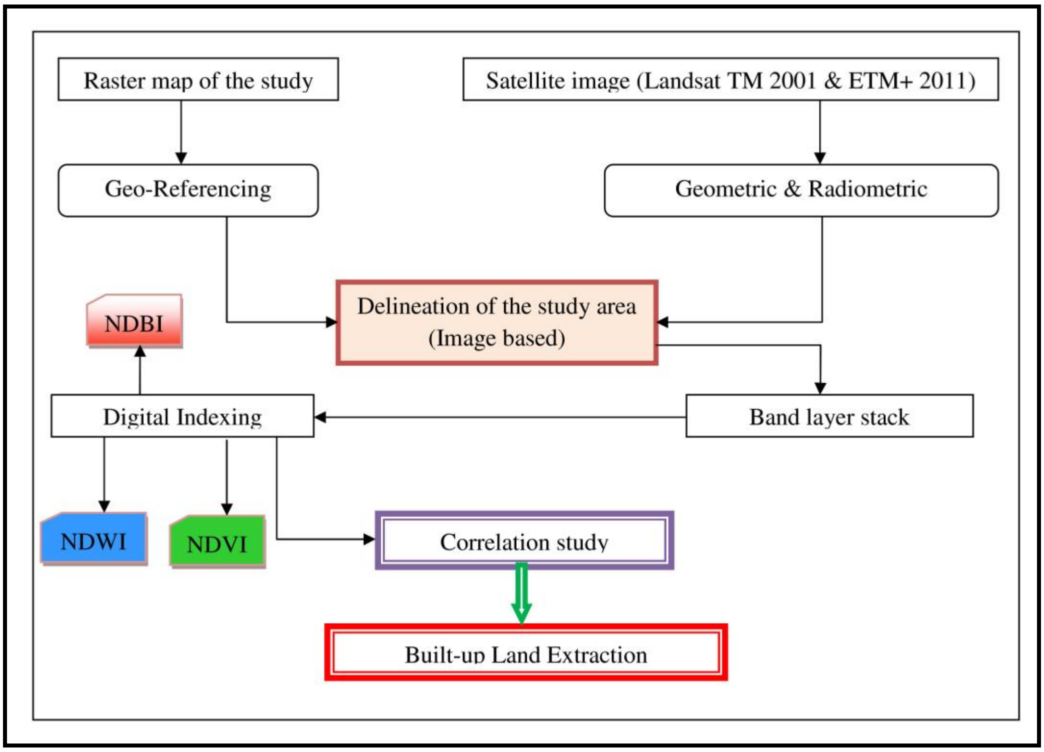

Figure 2: *Flow Diagram of the Methodology*

The NDVI is used for evaluation of vegetation fabrication in the study areas (Streutker, 2002; Chen, et al., 2004), while the Normalized Difference Water Index (NDWI) can be used for the fortitude of Vegetation Water Content (VWC) under the physical principles (Gao, 1996). Although NDVI has limited capability for estimating VWC (Ceccato, et al., 2002), it is ideal to incorporate NDVI and NDWI to represent the state of vegetation. (Zha, et al., 2003) has developed the Normalized Difference Built-up Index (NDBI) to classify urban and built-up areas. The utilization of NDVI, NDWI and NDBI could represent Land Cover types of the urban area quantitatively.

4. Results and Discussion

4.1. Normalized Difference Vegetation Index (NDVI)

To evaluate rates of urban growth, we use differences in NDVI between subsequent images.

NDVI= NIR (band 4) – RED (band 3) / NIR (band 4) + RED (band 3)

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 (Rouse, et al., 1974). The motivation 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).

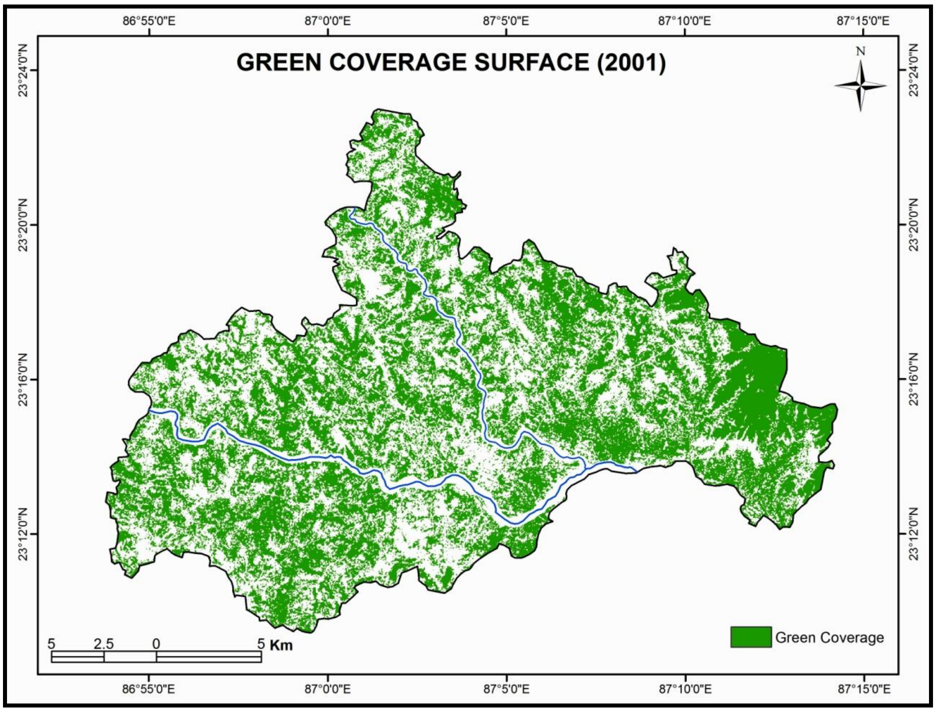

Figure 3: *Normalized Difference Vegetation Index*

This spectral reflectance is ratios of the reflected over the incoming radiation in each spectral band individually; hence, they take on values between 0.0 and 1.0 in Figure 3 and Figure 4. Shows the Normalized Difference Index (NDVI) derived from Landsat image of the year of 2001 and 2011 respectively.

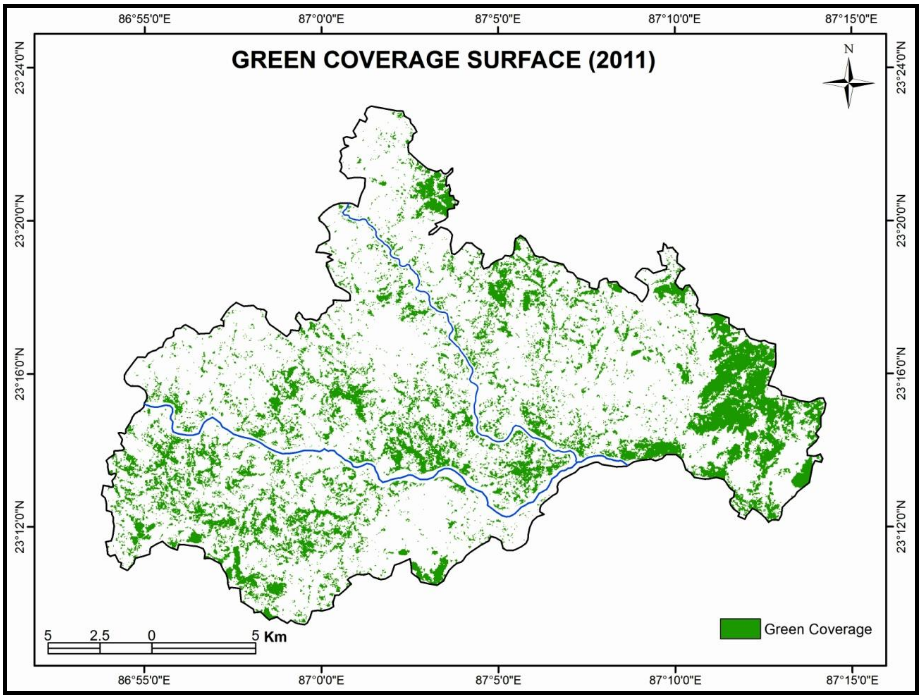

Figure 4: *Normalized Difference Vegetation Index*

We first calculate NDVI for each image (Figure 3 and Figure 4). For Landsat TM & ETM+, NDVI is defined as (band4 - band3) / (band4 + band3). NDVI images from subsequent dates are then subtracted, producing a map of NDVI in which positive values represent 'greening' (increased vegetation) and negative values represent 'browning'(de creased vegetation). We then pick a threshold NDVI value by visual assessment to differentiate true urban growth (large negative NDVI) from noise (small negative NDVI). Typically, threshold values are found within recently-developed residential areas where the spatial pattern of roads evidently indicates intensification but the introduction of landscaping typically modulates NDVI values (Jensen, J.R., 1999).

4.2. Normalized Difference Water Index (NDWI)

Gao (1996) proposed the Normalized Difference Water Index (NDWI) to delineate open water features. NDWI is expressed as follows:

NDWI = NIR (BAND 4) – MidIR (band 5) / NIR (BAND 4) + MidIR (band 5)

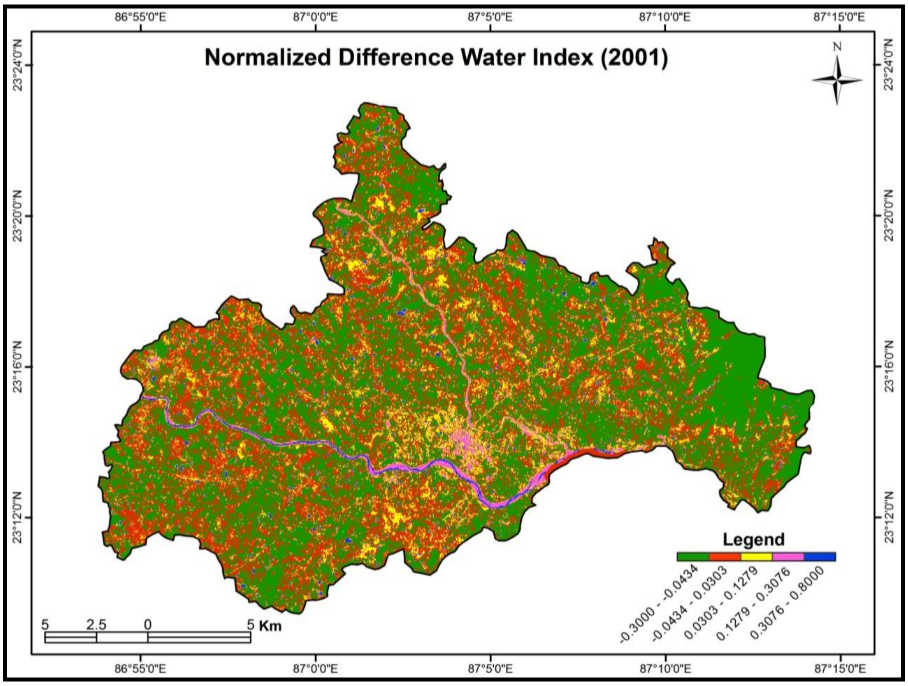

Figure 5: *Normalized Differences Water Index*

This index maximizes reflectance of water by using green light wavelengths and minimizes low reflectance of NIR by water features while taking advantage of the high reflectance of NIR by vegetation and soil features. As a result, water features are enhanced unsettled to having positive values and vegetation and soil are suppressed due to having zero or negative values.

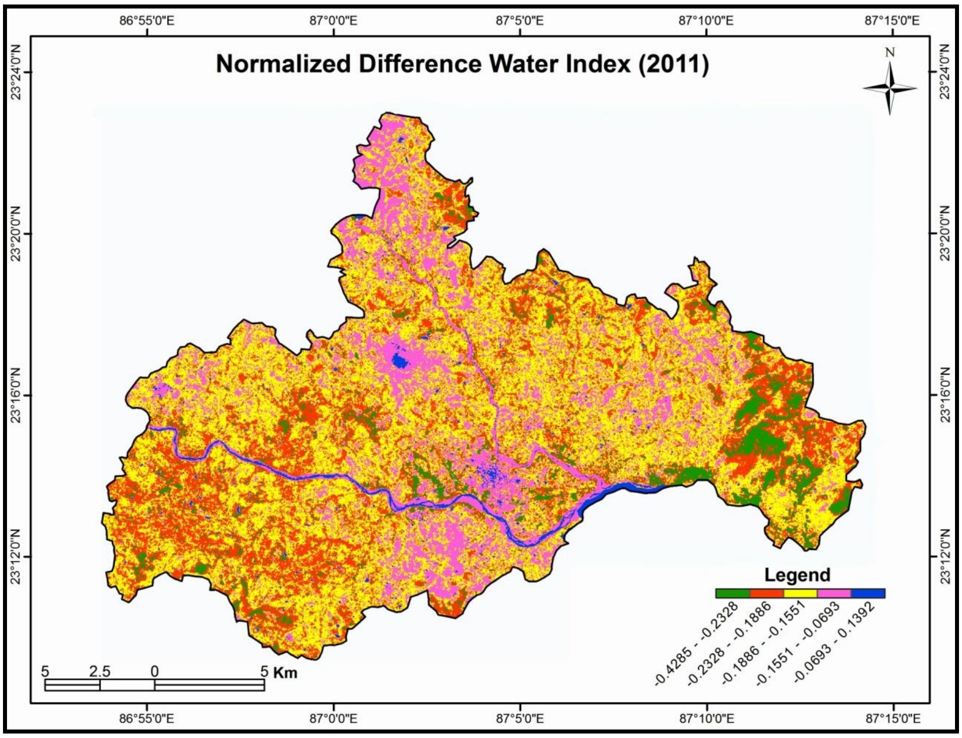

Figure 6: *Normalized Difference Water Index*

However, the applications of the NDWI in the water regions with built-up land background like the cases of study area were not as successful as expectation. The extracted water in sequence in these regions was consistently mixed up with built-up land noise because many built-up lands also have positive values in the NDWI derivative image. The signature facial appearance of built-up land in NIR band and MidIR band shown in Figure 5 and Figure 6 are analogous with those of water, i.e., they both reflect. Consequently, the computation of the NDWI also produces a positive value for built-up land just as for water.

4.3. Normalized Difference Built-up Index (NDBI)

The study proves that the method is less effective in TM images. Low-resolution images frequently have more spectral information rationally. For the reason, we tried to find a solution from the view of spectrum. (Zha, et al., 2003) proposed a Normalized Difference Building-up Index (NDBI) based on the rule that the building-up area has higher reflection in mid-infrared band is higher than in near-infrared band.

$$\text{NDBI} = \text{Bui} - \text{NDVI}$$

BUI = MidIR (band 5) – NIR (band 4) / MidIR (band 5) + NIR (band 4)

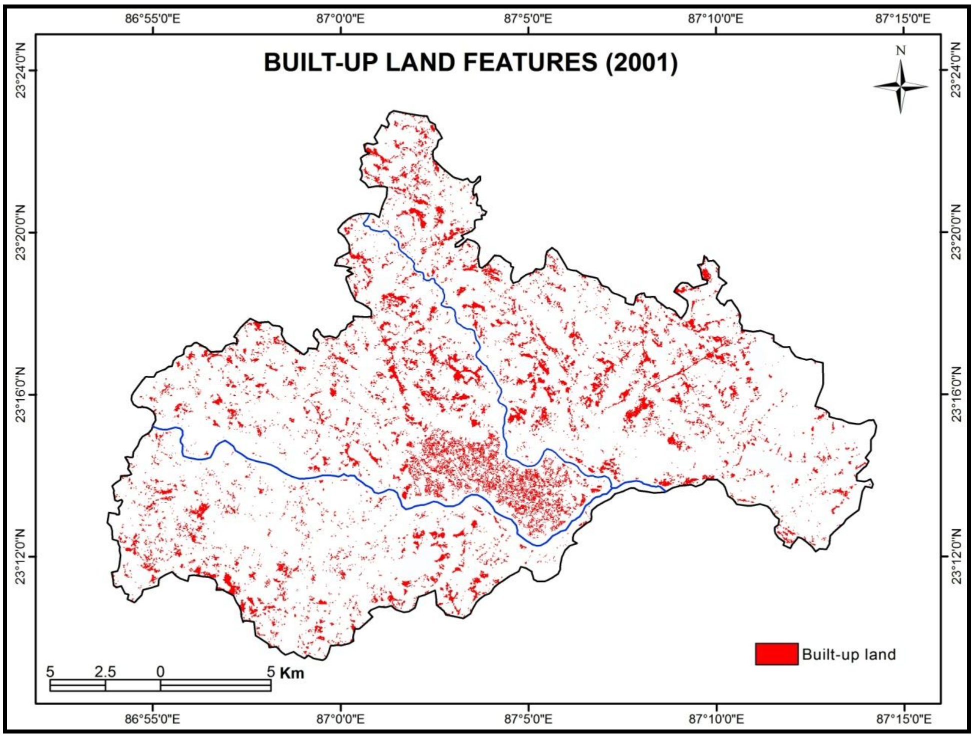

Figure 7: *Normalized Difference Built-up Index*

The built-up areas of 2001 and 2011 were extracted from NDBI images. To extort the built-up area from the NDBI images we have to implement the thresholding method, where a creatain range of DN value is extracted from the index raster which may symbolize some typical kind of feature of interest. In general, we know that the positive values of NDBI represents the built-up features and negetive value represents the other land surface features.

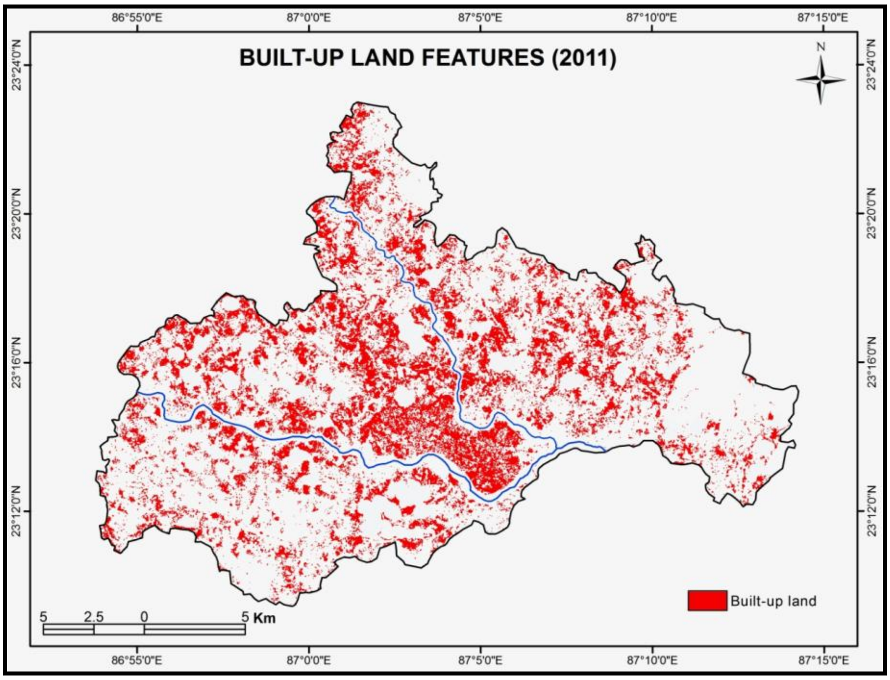

Figure 8: *Normalized Difference Built-up Index*

The figure depicts the relative values of extracted BUI (2001) and BUI (2011) in the sample, and also shows the relative relationship of BUI in 2001. BUI takes the form of high values in the urban areas and low values in the non-urban areas. Accuracy assessment was done for the classified maps after verifying the ground truth verification. Through logic calculation on the new image, the urban built-up lands were finally extracted with overall accuracy ranging from 91.5 to 98.5 percent.

5. Conclusions

Monitoring the growth of built-up areas at regional level has been attempted by various authors using the Landsat data. Researchers have worked out NDBI approaches to delineate built-up regions from diverse remotely sensed data. This paper has surveyed the available NDBI algorithms to identify built-up regions and there growth in the entire study area. From NDVI study it has been observed that in 2001 the area of NDVI was 211.983 sq.km, where in 2011 the area of NDVI value has been decreased into 83.2782 sq.km. Similarly from the NDBI study it has been observed that the value of NDBI in 2001 was 42.8627 sq.km, where the value of NDBI in 2011 has been increased into 106.635 sq.km therefore, it has huge impact on environment which are summarized below.

- **Ecological Effects of Urban Sprawl**

Development plans that promote sprawl have a number of consequences for local ecosystems (Luther, 2005). Many hold true for any development in the wild land-urban interface.

- Destruction of wildlife habitat.
- Introduction of non-native invasive plants and animals into natural areas.
- Increased human and pet exposure to diseases such as rabies and Lyme disease.
- Increased risks of water pollution from oil and gasoline washing off paved surface sand from pesticides, lawn fertilizers, and other chemicals.
- Increased potential for flooding and soil erosion due to impervious surfaces such as concrete or pavement.

- Decrease in groundwater for wells and irrigation caused by abundance of impervious surfaces.
- Increased risk to life and property from wildfires.

- **Social and Economic Effects of Urban Sprawl**

Urban sprawl can also negatively affect social and economic conditions in communities in several ways (Luther, 2005).

- Increased community costs for maintaining roads, school bus routes, sewers, and other services needed when and residences are spread out.
- Ongoing increases in property taxes to meet growing need for services, which may pressure rural landowners to sell to developers.
- Increased need for automobiles; increased noise, traffic, pollution; reduced potential for bicycling and walking.
- Isolation of the young, poor, and elderly who cannot drive or lack access to cars.
- Increased cost and difficulty of providing public transportation.
- Increased time needed for transportation reduces time available to spend with family and friends or contributing to the com-munity.
- Loss of agricultural and forestry jobs, and traditional land practices.
- Reduction of rural character or community sense of place.
- Increased ordinances that regulate logging, noise, or odors.

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