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Study of normalized difference built-up (NDBI) index in automatically mapping urban areas from Landsat TM imagery.

Hari Krishna Karanam* and Victor BabuNeela**

*Professor, Civil Engineering, Dadi Institute of Engineering & Technology, Anakapalli.
**Professor, Civil Engineering, Baba Institute of Technology& Sciences, Visakhapatnam.
harigis2007@gmail.com, neelavictorbabu@gmail.com

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Abstract

The Visakhapatnam city lies on the eastern part of India and the urban sprawl in Visakhapatnam town was analyzed using multi-temporal Landsat TM data from 2005 to 2015. Spectral indices namely Normalized Difference Vegetation Index (NDVI), Normalized Difference Built-up Index (NDBI) and Built-up Index (BUI) were generated from the Landsat TM bands covering visible Red (R), Near Infrared (NIR) and Short Wave Infrared (SWIR) wave-length regions. Spectral variations in built-up, open spaces, urban vegetation and water areas were studied by generating two-dimensional spectral plots of NDBI and BUI. Remote sensing images are mainly used for monitoring and detecting the land cover changes that occur frequently in urban and sub-urban areas as a consequence of incessant urbanization. The conversion of satellite imagery into land cover map using the existing methods of manual interpretation and parametric image classification digitally is a lengthy process. Normalized Difference Built-up Index (NDBI) which is used for mapping built-up areas automatically. This method main advantage is the unique spectral response of built-up area and other land covers. Built-up area can be effectively mapped through arithmetic manipulation of re-coded Normalized Difference Vegetation Index (NDVI) and NDBI images derived from TM imagery. This NDBI method is applied to Vishakaptanam Area in this paper and the mapped area results at accuracy of 93.9% indicates that it can be used to fulfill the mapping objective reliably and efficiently. Comparing NDBI with the maximum likelihood classification method, this NDBI method is able to serve as a worthwhile alternative for quickly and objectively mapping built-up areas.

Author correspondence:

Professor, Department of Civil Engineering, Baba Institute of Technology & Sciences, Visakhapatnam

Introduction:

Beginning with the early use of aerial photography, remote sensing has been recognized as a valuable tool for viewing, analyzing, characterizing, and making decisions about our environment. Land covers in urban areas tend to change more drastically over a short period of time than elsewhere because of incessant urbanization. Urbanization has led land covers to change especially frequently in sub-urban areas in Visakhapatnam as a result of rapid economic development. These changes are ideally monitored and detected from remotely sensed images as they are relatively up-to-date and give a panoramic view. The ever increasing population has led to the rise in unplanned urban growth in the suburbs of the city which is usually termed as urban sprawl (Bugliarello, G., 2005). Urban growth on one hand is an indicator of economic, social and political growth whereas, on the other hand it is at the cost of forests, agriculture lands, orchards and greenery of the city (Barnes et al., 2001). The urban land changes, referred to as urban sprawl, have effects for the environmental and socio- economic sustainability of communities (Bhatta et al., 2010); had described the urban sprawl as an unplanned and uneven pattern of growth driven by various processes finally leading to inefficient resource utilization. Urban growth man-agement is critical in the continued growth of a city. The trend specified, using conventional land surveys by department authorities, focuses on land usage, and is often inaccurate in its depictions of how studied lands are actually used. The pace of urbanization is adversely affecting the green cover in the urban areas. With expanding urbanization in the twentieth century, the tree cover in urban areas around the world is declining due to the demand of the area for develop-ment. The identification (location, distribution and size) of the built-up area is of major importance in urban, suburban and agricultural studies. The calcula-tion of its change throughout the time to the detriment of the non-built-up area constitutes a highly important indicator of urban change and environmental de-gradation (Xu, H, 2008 and Weng, Q, 2008). Remote sensing provides reliable scientific tools for the calculation of the built-up area, using intertemporal satellite images and studying the multispectral space.

As Remotely sensed data is mostly available in a digital form, computer-assisted interpretation and processing is made. Irrespective of the specific form of the remote sensing materials, manual interpretation is tedious, time-consuming, and the interpreted results highly depend upon knowledge of analyst. By comparison, supervised classification is much faster and requires far less human intervention. Lo (1990) found that a computer-assisted method of analysis of Landsat data permits more detailed urban land use information to be extracted, but at an accuracy level of 69% (Y. Zha , J. Gao& S. Ni; 2005).

The purpose of this study is to provide a simple application method employing a built- up index (BUI) that can be used in classifying non-urban and urban areas using images from multiple time periods. The study presents a thematic map that shows the progress of urban development by overlapping three images taken at different times. A standardized method that can be commonly applied to different images is required. Based on this method, the direction of urban development and its size can be examined.

1. Location of the study area

The Visakhapatnam municipal corporation area was 120 Sq.km till January 2006 and now expanded to 545 Sq.km and renamed as Greater Visakhapatnam Municipal Corporation (GVMC) and comes under the Visakhapatnam District of Andhra Pradesh. The study area is covered in 65 O/1, O/2, O/3, O/5 and O/6 of Survey of India top sheets on 1:50,000 scales bounded between 17^0 32' and 17^0 52' northern latitudes and 83^0 04' and 83^0 24' eastern longitudes (Fig.1). For the convenience of administration GVMC area is divided into 70 wards, where the area of the ward is based on density of population.

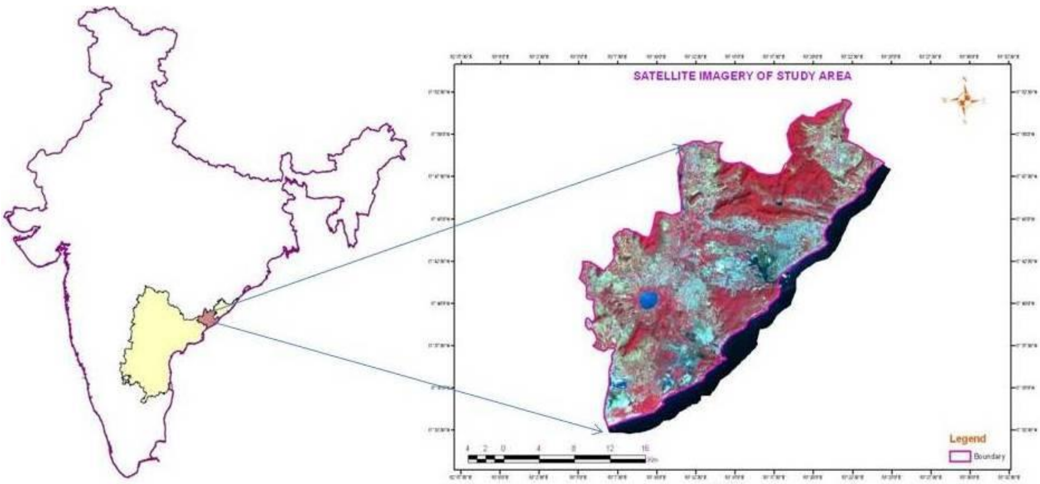

Fig.1: Location map of the study area

2. Normalized Difference Built-up index

Standard false colour composite (4,3,2 RGB) shows various surface covers such as build up , water, vegetation and barren land etc. are distinguishable. An examination of the minimum, maximum and standard deviation of each of the covers in the seven TM bands confirms that these values are most distinctive from one another for each cover in bands 3,4 and 5. There for they are the most useful bands and from which some of the land covers may be potentially differentiated spectrally. For example, river and lakes have a similar shape of profile. It is seen that their digital values (DN) are markedly lower in the fourth and fifth bands. Also, they experience a sharp rise in reflectance in band 6, but a low reflectance in band 7.

NDVI= (NIR-RED)/ (NIR+RED)

Build up areas and barren land experience a drastic increment in the reflectance from band 4 to band 5. But vegetation has slightly larger or smaller DN value (not appreciable) on band 5 than on band 4.And this is the unique increment can be seen between these bands. This enables the build-up area to separate from remaining covers and hence NDBI.Pixel values of representative land covers after differencing and binary recoding (Zha et al…, 2005). The standardized differentiation of band5 and band4 results positive values for build-up pixels. Build up regions are identified by using the images of NDBI and NDVI has shown in Table 1.

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

Build up area= NDBI-NDVI

Table 1: Pixel values of representative land covers after differencing and binary recoding

	Built- Up	Barren	Woodland	Farmland	Rivers	Lakes
NDVI	0	0	264	264	0	0
NDBI	264	264	264 or 0	264 or 0	0	0
NDBI-NDVI	264	264	0 or -264	0 or-264	0	0

Based on the above table, the derived NDBI image was then recorded to create a binary image. The ratio is assigned a new value of 0 if input pixel had a negative index or 264 if its input index was larger than 0. According to the results of above table, subtraction of NDBI and NDVI will lead to only built-up area and barren pixels, while therest of pixels with values of 0 or -264, allowing built-up area to be mapped automatically.

3. Methodology

For the analysis of built up area of the city, Landsat satellite TM (thematic mapper) images are used. Raw image is taken from USGS earth explorer and all the seven bands are stacked to form "false color composite image". Methodology has shown in Figure 2.

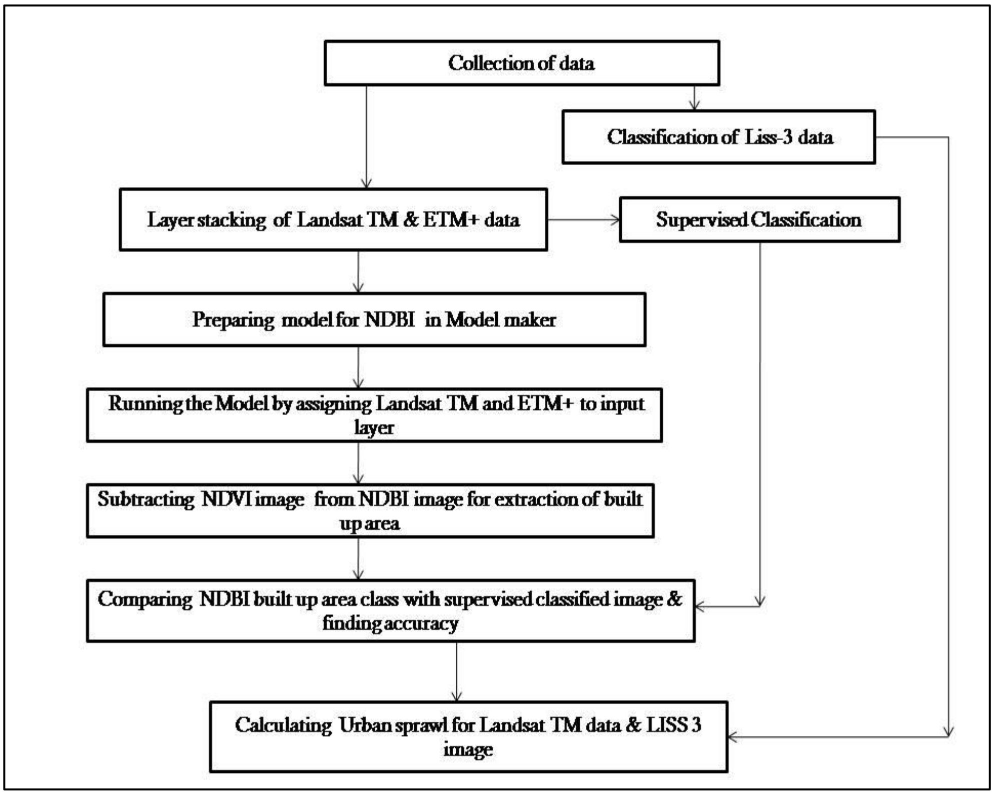

Figure 2: Flow diagram for extraction of Built up Area class

4. Results and Discussions

Using the relationship between band5 and band4 of Landsat Thematic mapper(TM) is used in extracting built up area class. The accuracy of NDBI in extracting built area class is compared with supervised classification. Results showed that NDBI can be used effectively and accurately in classifying built up area. This relationship is used for finding area of built up area class. Urban sprawl for study area is calculated using NDBI relationship for Landsat Thematic mapper(TM) data and LISS-3 image of same study area.

5.1 Measuring the accuracy

For assessing accuracy between NDBI image and Landsat Thematic mapper image, supervised classification is done. Classification is done by defining 5 to 7 classes by varying the training pixels. Initially lesser number of training pixels has been defined for Landsat Thematic Mapper data and overall accuracy assessment, kappa statistics are carried out. Similarly different number of times the image is classified by increasing training pixels for

different classes and over all accuracy assessment, kappa statistics are carried out. Each and every time the accuracy for image
is increased by increasing the number of training pixels. The accuracy of supervised classification for built up area is 88.3%, where as the accuracy for NDBI image is 90.6%.

5.2 Urban sprawl of study area

Area of built up area class for NDBI Thematic Mapper data is measured from unsupervised classified image. Similarly area of Landsat Enhanced thematic Mapper data is measured. Both the areas are compared and tabulated. Urban area for LISS-3 data is calculated using supervised classified image. Difference between the area of urban class for Landsat Thematic mapper data of 2005 and LISS-3 of 2015 data are calculated which is known as urban sprawl.

Urban class area for Landsat Thematic mapper data is 162.56 sq kilometers and that of LISS-3 image urban class area is 214.71 sq kilometers. Urban sprawl for 2005 landsat data and 2015 for LISS-3 data is 52.15 sq kilometers has shown in Figures 3, 4, 5 & 6 and supervised classification has shown in Figure 7 and the values are presented in Table 2. This shows that with in the span of ten years of urban area has increased drastically.

Figure 3: Derived Normalized difference vegetative index (NDVI) for TM data

Figure 4:Derived Normalized difference Build Up index (NDBI) for TM data

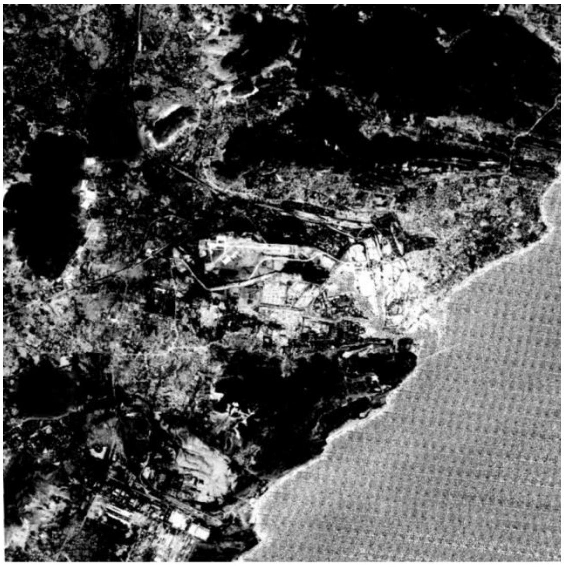

Figure 5: Derived Built up area image TM data

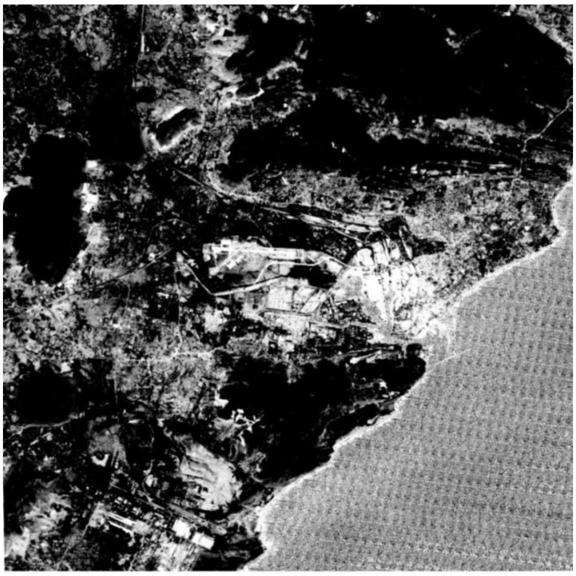

Figure 6: Build Up area (NDBI-NDVI) for image for Landsat ETM+ data

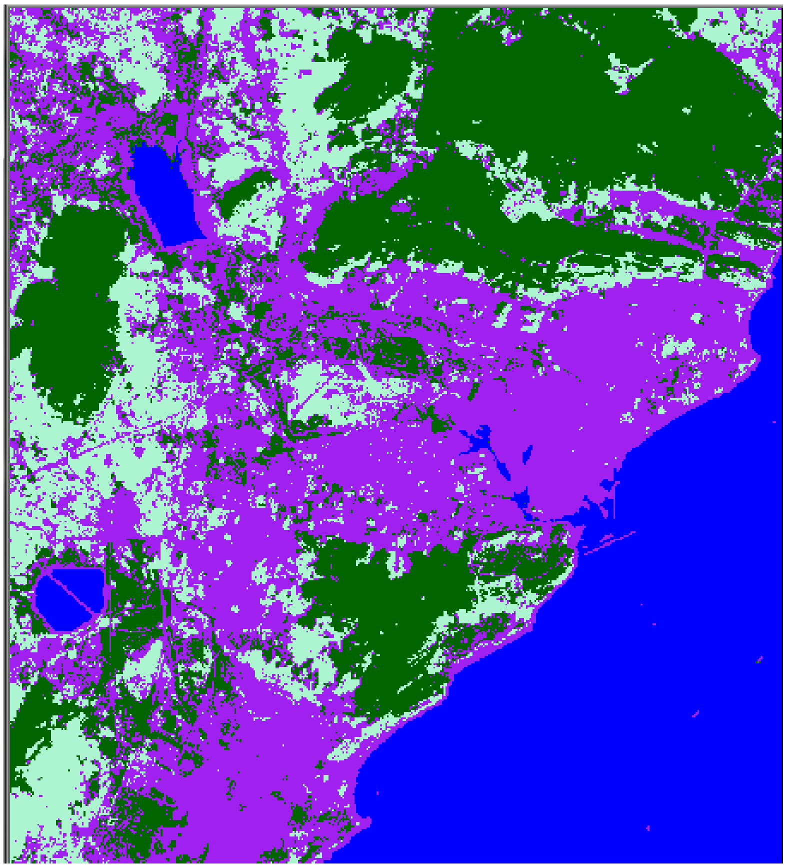

Figure 7: Supervised classification for TM data

Table 2: Calculation of Accuracy for Built up area using Supervised Classification

Trails Count	Total No of built-up area pixels	Built-up area (%)	Overall Classification accuracy for built-up class	Overall Kappa statistics
Trail 1	323654	12.538	83.62	0.7852
Trail 2	348523	13.821	86.81	0.8123
Trail 3	378523	14.728	89.4	0.8345

5.3 Comparison between NDBI and supervised classification

Overall classification accuracy for NDBI image is 92.8% and that supervised classified image for built-up area is 88.7% has shown in table 3. These results of accuracy assessment for NDBI image and supervised classified image for built-up area class shows that NDBI can be used effectively for extracting urban area.

Table 3: Comparison between NDBI and Supervised Classification

Method	Total no of built-up area pixels	Built-up area (%)	Overall classification of accuracy for built-up class	Overall kappa statistics
NDBI	383489	15.83	92.8	0.8951
Supervised Classification	378523	14.57	88.7	0.8527

5.4 Urban sprawl for 2005 Landsat Thematic mapper(TM) data and 2015 LISS-3 data

In order to find out the urban sprawl for study area, we have used (NDBI-NDVI) image of 2005 Landsat Thematic mapper and LISS3 image of 2015. These images are used for calculating urban area in the study area. Urban area for NDBI-NDVI image is done by classifying the image by giving training pixels of urban class, non urban class and finding areas of respective classified urban class. Similarly supervised classification is done for LISS3 image and area for urban class is measured. Difference between areas of 2005 Landsat image and 2015 LISS3 image is determined. This method can be effectively used for finding urban sprawl for temporal data and values has shown in Table 4.

Table 4: Urban Sprawl for Visakhapatnam area

	Landsat TM Data 2005	LISS-3 Data 2015	Urban Sprawl

AREA(Sq. Kms)	178.64	238.68	60.04

The redundancy also considerably enhances the mapping process that can be achieved by direct subtractions of original spectral bands. As NDBI is done through arithmetic manipulation of TM bands and simple recoding of the intermediate images does not require any complex calculations. It is deduced that the proposed NDBI is much more efficacious and advantageous in mapping general built-up areas than the maximum likelihood method. It can serve as an alternative for quickly mapping of urban land.

The assumption that was made in the NDBI method is the spectral reflectance of urban areas in TM5 exceeding that in TM4. This method will generate valid results until the assumption is not violated. Because the reflectance of urban areas exhibits little seasonality, this method is not prone to its impact. However, its performance may be adversely affected indirectly by the presence of other covers whose reflectance is seasonal, such as forest. This problem can be overcome with the selection of images recorded when defoliation is minimal or non-existent. The mixture of built-up areas with barren farmland may be overcome with the use of an image taken when vegetative cover is at its maximum.

Conclusions

The proposed NDBI method is capable of mapping built-up areas at an accuracy levelof 91.6%.The results mapped using NDBI are highly comparable to those frommanual interpretation in quantity. The two sets of results differ from each other by5% and closely match each other spatially, as well. When compared with supervised classification, NDBI facilitates built-up areas to be mapped at a higher degree of accuracy and objectivity. First of all this proposed NDBI model can map only broad urban land covers. For example, urban industrial, commercial and residential areas are impossible to be separated. So in areas like Vishakhapatnam where there is a combination of both industries, commercial and residential areas are difficult to distinguish. Thirdly, this proposed method needs to be tested in all other geographic areas. The success of the proposed method lies in the NDVI value of vegetation being larger than 0. However, the spectral reflectance of vegetation changes from location to location due to different kinds of species and nature of soil and moisture conditions.

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