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Urban pattern extraction within high and medium vegetated terrain through satellite image processing using the index-based built-up index and LANDSAT OLI/TIRS imageries

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***Abstract*—Remote Sensing is the growing division in science, art, social science, and technology that will be the base of every development in our surroundings in the coming days. One of the complex and most challenging remote sensing applications is identifying, monitoring, extracting, and mapping the urban pattern and morphology. But there are several methods and techniques to do so. In this research, one of the feature extraction models is discussed to evaluate the urban pattern of two distinct Indian districts having different vegetation surrounding the urban. Both the study areas have a typical religious value but differ in geography and urban evolution. Spectral index or ratio is the model taken here to extract the urban pattern of these two areas.**

Keywords—Remote Sensing, Spectral Ratio, Built-up Index, Landsat OLI/TIRS

I. INTRODUCTION

Urban is a complex system on the earth with multi-objects and features to fulfill the human livelihood. That's why monitoring and analyzing urban areas from space has always been a big task. It requires very high-resolution satellite images but harder with the medium resolution satellite imageries. Therefore, numerous researches are continuously running remote sensing to recognize and extract urban or built-ups or impervious surfaces. Satellite images are formed by distinct wavelength ranges of the electromagnetic spectrum, mainly from the visible wavelength to infrared. These wavelengths are splits into multiple narrow wavelengths, and each of them is known as spectral bands that are sensitive for particular and distinct features. The number of bands a sensor has can define its category as panchromatic, multispectral, and hyper spectral. A sensor having the specification of a single band is known as panchromatic, more than three bands are called a multispectral satellite, and hundreds of bands means hyper spectral satellite. The spectral bands and the ground area coverage are also vital for the satellite image quality because they are directly related to the image scale. Higher-resolution satellite images have smaller ground area coverage than medium resolution satellite images. Therefore, medium resolution satellite imagery is used to map the large ground area rather than a high resolution. Still, the clear and clean mapping of individual objects requires high-resolution imageries. This research recognizes and pulls out India's two districts' urban patterns or impervious surfaces from two different land types yet religiously related. This research aims to extract the urban pattern of two different terrains, one where urban is surrounded by high vegetation including agricultural land and another urban surrounded by medium greenery through Landsat-8 imageries by applying a built-up index based on three different indices. The research explores the applicability of the built-up index for a different set of data from what data was used for its development. Both areas' extracted urban pattern is also statistically analyzed through an error matrix for assessing their accuracy. And finally, the observations are discussed in the result section and concluded further.

II. BACKGROUND STUDY

The literature of this research involves the built-up indices. Still, it originates from spectral ratios, one of the remote sensing techniques to highlight and extract the pattern of any feature present on the earth's surface, such as vegetation, urban, and water. These features are the significant features of the earth's surface and can be evaluated through spectral ratios. The spectral ratios are formed by the different algebraic combinations of spectral bands of the satellite images' multispectral images. That's why the spectral ratios are also known as band ratios or spectral indices. The spectral ratio is the model that arranges the spectral bands in an expression in such a way that it can help to recognize and evaluate one particular feature in the multispectral image. It is done by analyzing each spectral band's sensitivity to all image features and then arranging them with experiments [1] [2]. In the field of remote sensing, there are numerous spectral ratios for various features [3] [4] [5]. Here we are only emphasizing the spectral ratios used to diagnose the urban pattern, categorized as built-up indices formed by direct bands and formed by indirect bands. The first category has the built-up indices whose expressions are developed using the bands of the multispectral images directly.

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In contrast, the second category of the built-up indices is based on other method's processed images like images acquired by other indices, principal component analysis (PCA), or tasseled cap transformation (TCT) images direct bands. This research is based on one of the built-up indices that belong to the second category, i.e., built indices based on other indices. The built-up index used here is the index-based built-up index (IBI) developed in 2008 by H. Xu 2008 which is based on three different indices: Normalized difference built-up index (NDBI) [6], Soil adjusted vegetation index (SAVI) [7], and Modified normalize difference water index (MNDWI) [8]. According to the [9], IBI enhanced the information which has positive values by suppressing noises having values less than zero so that the built-up or urban pattern can be extracted precisely and the developers of the index have given the expression for IBI as:

$$\mathrm{IBI} = \frac{\left[\mathrm{NDBI} - \frac{\mathrm{SAVI+MNDWI}}{2}\right]}{\left[\mathrm{NDBI} + \frac{\mathrm{SAVI+MNDWI}}{2}\right]}$$

Where,

$$\mathrm{MNDWI} = \frac{\mathrm{Green} - \mathrm{SWIR}}{\mathrm{Green} + \mathrm{SWIR}}, \text{and}$$

$$\mathrm{SAVI} = \frac{\mathrm{NIR} - \mathrm{Red}}{\mathrm{NIR} + \mathrm{Red} + \mathrm{L}} * (1 + \mathrm{L})$$

L is a correction factor for soil brightness, and its value varies from 0 (for high vegetation) to 1 (for low or no green vegetation). Green and Red are the bands that belong to the visible region of the electromagnetic spectrum, NIR is the near-infrared, and SWIR is the short-wave infrared, also called mid-infrared (MIR) from the electromagnetic spectrum. Even there are comparisons between several indices and other methods to recognize the urban pattern in the literature [10].

III. METHODOLOGY FOLLOWED

The methodology that we have followed for this research starts with going thoroughly with the literature of the urban pattern extraction in remote sensing, which includes all the feature extraction techniques, such as various classification methods and spectral ratioing methods. Built-up indices are one of the spectral ratios to recognize the urban pattern, which helps in urban mapping. So, acquiring satellite data is the primary step in satellite image processing and analysis. These satellite imageries undergo pre-processing to get cleaned for any error and clipping the research study area. Further, the built-up index is applied to the image to extract urban patterns. The built-up index used here is based on the other three indices to calculate directly from the satellite image bands. After getting the built-up index image, it is then recoded into just two classes to segment the image into built-up pixels and non-built-up pixels highly. This recoding is done by recognizing the lower and upper threshold values for built-up pixels that finally gives the urban pattern. The urban pattern image is still in need of assessment and analysis not only visually but also statistically. Therefore, an accuracy assessment is done using an error matrix where 100 stratified random sample points were selected and validated through very high-resolution data from Google Earth of the study area. Results from this methodology are shown and discussed in the result section. The entire methods have shown in figure 1, given below.

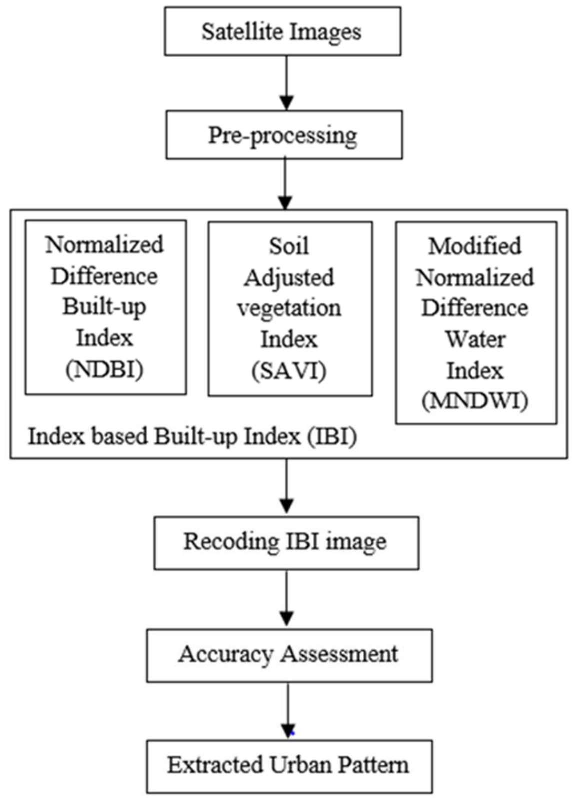

Figure 1: A followed methodology for the research; source: author

IV. STUDY AREA

The area we have picked for this research is one from the state of Uttar Pradesh (U. P.) and one from Haryana India. U. P. is the state in India having many pilgrimage places with their history with time. Haryana is the state which has a lot of agricultural lands, so the urban is evolving differently in both states. Mathura district from U. P. has been taken as the study area for this research whose urban has grown because it is close to Delhi (capital of India) and its religious significance. On the other hand, Haryana belongs to India's Agro-climatic zones as per the 'Planning Commission of India.' We have taken the Kurukshetra district and its connected two districts Karnal and Kaithal, because all these three districts were once known as the Karnal only. The relation between the three districts is that Kaithal was part of

Kurukshetra before 1989, and Kurukshetra was included in Karnal before 1973. Apart from being agricultural land, the Kurukshetra district also has religious significance. The spiritual value for both Mathura and Kurukshetra districts is related to Lord Krishna. According to the Hindu mythology, Mathura is the place known for *lilas* (childhood plays) of Lord Krishna, and Kurukshetra is the place where *Mahabharat* (the epic war) was fought, and Lord Krishna gave the *Geeta Gyan* (knowledge of life as *Karma* and *Dharma)*. Therefore, the reason to select these districts is their same religious significance and diversity as their landforms.

On the one hand, urban areas in Kurukshetra (including Kaithal and Karnal) is evolved within the agricultural land, i.e., surrounded by farming lands and spots in satellite images as several small clusters of built-ups. In contrast, urban in the Mathura district has evolved because of the increasing numbers of pilgrims, which drastically increased the commercial opportunities at the place and the second homes for the pilgrims. That's why these two places were analyzed in this research, knowing the different ratios of the vegetation and built-up present in both areas. This difference can be seen in the figure of the result section.

V. DATA USED

This research is done to pull out the urban pattern through medium resolution satellite; therefore, here, Landsat data is used, which is readily available for most of the areas around the globe and at a low cost or no cost. The images used here are acquired by the sensor Landsat OLI/TIRS, which is the eighth sensor in the Landsat series launched in February 2013 and working till now. Landsat OLI/TIRS or Landsat-8 has a total of eleven spectral bands from visible to the infrared region of the electromagnetic spectrum (Table 1) and as per the U. S. Geological Survey (USGS), the specification for the sensor is given as:

Table 1: Band specifications of Landsat OLI/TIRS, source: [11]

Bands	The range on Electromagnetic Spectrum
Band 1= Coastal Aerosol	0.43-0.45 micro-meter
Band 2= Blue	0.45-0.51 micro-meter
Band 3= Green	0.53-0.59 micro-meter
Band 4= Red	0.64-0.67 micro-meter
Band 5= Near Infrared (NIR)	0.85-0.88 micro-meter
Band 6= Shortwave Infrared (SWIR)-1	1.57-1.65 micro-meter
Band 7= Shortwave Infrared (SWIR)-2	2.11-2.29 micro-meter
Band 8= Panchromatic	0.50-0.68 micro-meter
Band 9= Cirrus	1.36-1.38 micro-meter
Band 10= Thermal Infrared (TIR)-1	10.6-11.19 micro-meter
Band 11= Thermal Infrared (TIR)-2	11.5-12.51 micro-meter

VI. RESULT AND DISCUSSION

The study areas are in figures 2 & 3, and their processed results are discussed separately in this section. In Figures 2 & 3, the first image is the Landsat image showing in false-color composite or band combinations of NIR, Red, and Green to highlight the vegetation and built-up ratio in the area. Kurukshetra district has a higher percentage of the vegetation that is shown in green color than built-up that is in blue color (figure 2a) while in the image of Mathura district (figure 3a) vegetation is in medium-density that is highlighted in green color, built-ups are shown in purple color, and rest of the areas in light color are the representation of the barren lands. The next image in both the figures is the result of IBI, which is interesting because IBI results in different ways as it depends on three other indices as mentioned earlier where the values of the SAVI vary with the value of L. For Haryana, the value of L is taken as zero for high vegetation. For the Mathura district, the SAVI is different because L's value is different, which we have taken as 0.5 as the vegetation is in medium-density, considering the entire area. SAVI is the index which deals with vegetation considering the soil moisture also [12]. Therefore, SAVI plays a vital role in the IBI result but so as the MNDWI because it takes all the water content from the area.

NDBI is the most used built-up index in remote sensing, which gives a moderate result for extraction of the urban pattern. Still, IBI enhances the ability because it eliminates the vegetation and water content from it. The built-ups can be easily seen in index images for both the bright patches' areas within the dark (figure 2b & 3b). The index images are recoded to segregate the built-up from all other features using its upper and lower threshold values and then recolored to enhance the recoded image's visibility where yellow represents the built-ups. In contrast, brown represents the non-built-ups (figure 2c & 3c). The visual assessment of these images can recognize the thinnest pattern of impervious surface from the urban like some roads, specifically in the Kurukshetra district image (figure 2c & 3c).

Further, the IBI recoded result's accuracy is analyzed. An error matrix was used (mentioned in the methodology section), which results in 84% of the overall accuracy for the Kurukshetra area, and 87% for the Mathura district (Table 2). Apart from this, producers and users, accuracy for built-up and non-built-up in both the study areas are calculated as:

Table 2: Accuracy assessment of the IBI recoded images

	Kurukshetra District		Mathura District	
	Producers Accuracy	Users Accuracy	Producers Accuracy	Users Accuracy
Built-ups	81%	87%	74%	100%
Non Built-ups	86%	80%	100%	79%
Overall Accuracy	84%		87%	

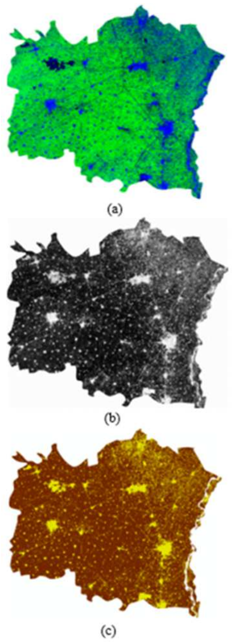

Figure 2: Kurukshetra district (including Kaithal and Karnal) (a) Landsat-8 image, (b) IBI image, (c) Recoded IBI; source: author

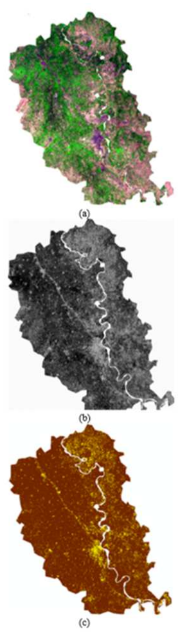

Figure 3: Mathura district (a) Landsat-8 image, (b) IBI image, (c) Recoded IBI; source: author

VII. CONCLUSION

As much as urban is considered a tricky feature to monitor and analyze through the medium resolution, it also opens research challenges and opportunities. Therefore, several built-up indices were developed in the literature, and each of them has its advantages and limitations. This research is an effort to validate one of the built-up indices (IBI) that are differently developed and results differently for distinct areas. With all the processing, observations, and analysis, this research can be concluded about the IBI applicability, which is quite suitable for the flat landforms if we put the correct bands and value for L in the expression. The study areas and the index we have taken here worked perfectly close to the expected outcome, whose visual and statistical assessments are satisfactorily accepted.

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