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Identifying Built-up Area Expansion and Comparing Two Conventional Built-up Area Extraction Method from LANDSAT Imagery: A Case Study on Khulna City

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The expansion of built-up areas in the city is one of the major research subjects in urban planning and development. It indicates how much the built-up area is increasing and the rate of increase over time. Also, the specific regions which are potential for future urban development can be enumerated. This paper uses two methods for built-up area extraction. The first method incorporates the Normalized Difference Vegetation Index (NDVI) and Normalized Difference Built-up Index (NDBI) to extract built-up area from LANDSAT-7-LANDSAT-8 imagery. The second method added Normalized Difference Water Index (NDWI), Short Wave Infrared (SWIR), and Thermal Infrared (TIRS) for built-up area extraction. This study's primary goal is to identify the difference of built-up areas over time. Three years of LANDSAT-7 and LANDSAT-8 imagery (1999, 2013, and 2018) of Khulna city, Bangladesh, has been used in this study. The difference between the two conventional methods has also been reviewed. The satellite image analysis results reveal that the built-up area expansion from 1999 to 2013 is significantly higher than from 2013 to 2018. Results from the two different methods indicate that the use of NDWI, SWIR, and TIRS can increase the accuracy of extracting built-up areas.

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Introduction

The extraction of urban built-up areas from satellite imagery is a difficult task for the cities' heterogenous spatial context, mainly in developing countries [1]. Enhanced Thematic Mapper (ETM+) data of LANDSAT-7, Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) of LANDSAT-8 imagery can provide a simplified method of extracting built-up area [1]–[3]. Though this mapping technique doesn't provide 100% accuracy, the information from this analysis can clearly assume the built-up area expansion of a city [3]. Also, the process is cheap and consume a short amount of time, making it a viable method for quick decision making [3], [4]. SENTINEL and the LANDSAT are the two main satellites that collect Bangladesh's data and provide it without any cost. SENTINEL-2 has better image resolution than LANDSAT-7 and LANDSAT-8, but it is a new satellite, launched in 2016. As the study tries to identify the built-up area from 1999 and 2013, the LANDSAT data is the best choice that is available.

The paper is divided into 4 sections. The second section describes the study area and the two methods used in this study. Section 3 explains the results of the analysis, and the paper concludes with Section 4.

Method

This study is based on Khulna city, an important growing city of Bangladesh located at 22.84564 north latitude and 89.54032 east longitude. The data of the year 1999 has been collected from LANDSAT-7 as LANDSAT-8 launched in 2013. The data of the years 2013 and 2018 has been collected from LANDSAT-8. All these images are of the summer season (April-May) for avoiding cloud coverage.

The first analysis of the study incorporates a conventional built-up area extraction method where the NDBI and NDVI have been calculated using Red band, NIR band, and SWIR band from ETM+ image of LANDSAT-7 and OLI image of LANDSAT-8 satellite imagery. Equations (1) and (2) are showing the calculation of NDBI and NDVI.

$$\text{NDBI} = \frac{\text{SWIR-NIR}}{\text{SWIR+NIR}} \tag{1}$$

$$\text{NDVI} = \frac{\text{NIR-Red}}{\text{NIR+Red}} \tag{2}$$

Later on, the NDVI has been subtracted from NDBI for removing vegetation noise to find

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the built-up area, as shown in Equation (3).

$$\text{Built-up area} = \text{NDBI-NDVI} \tag{3}$$

The *Reclassify tool* has been used to find out the exact urban built-up area. Using different classification methods, it has been found that for LANDSAT-7 imagery, Natural Breaks (Jenks) is the most suitable reclassification method. On the other hand, Geometric Interval is the convenient reclassification method for LANDSAT-8 imagery.

The second analysis further incorporates the NDWI, SWIR, and TIRS with Principal Component Analysis (PCA). Equation (4), (5), and (6) is showing the method in detail.

$$\text{NDBI} = \frac{(\text{PCA SWIR 1,SWIR 2+PCA TIRS1,TIRS2}) - \text{NIR}}{(\text{PCA SWIR1,SWIR2+PCA TIRS1, TIRS2}) + \text{NIR}} \tag{4}$$

$$\text{NDWI} = \frac{\text{Green-SWIR2}}{\text{Green+SWIR2}} \tag{5}$$

$$\text{Built-up Area} = \text{NDBI-NDWI-NDVI} \tag{6}$$

This method has been used only for 2013 and 2018 as LANDSAT-7 doesn't have the necessary band for this method.

Results

Figure 1 is illustrating the results of this study. The maps reveal that the expansion of the built-up area is mainly focused on the city's southern part. Compared to the northern part of the city, the middle part has a noticeable amount of built-up area. But the southern part is dense with the built-up area as these are the main commercial and residential areas of the city. The expansion from 1999 to 2013 is much higher than the expansion from 2013 to 2018, which can clearly be identified. This difference has been explained explicitly in Figure 2, where the built-up area has expanded double in 14 years. But in 2013-2018, the expansion is insignificant, indicating that the city's built up area expansion rate is not constant.

Figure 3 is showing the results of the second method. In this case, the built-up area is less than the first method. The product is more accurate than the first method as even the roads can be detected as built-up lines. The process also reveals that the built-up area decreased from 2013 to 2018, as shown in Figure 4. This statement is actually possible because Khulna was a great industrial area in the early 2000s. But most of the industries are now inactive, and

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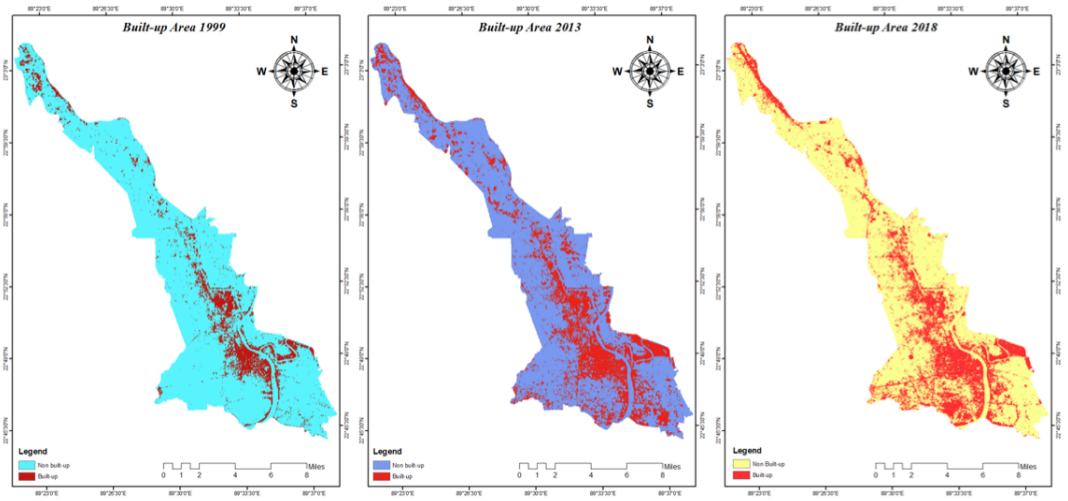

Figure 1. Built-up area of Khulna city according to first method (Year 1999, 2013 and 2018).

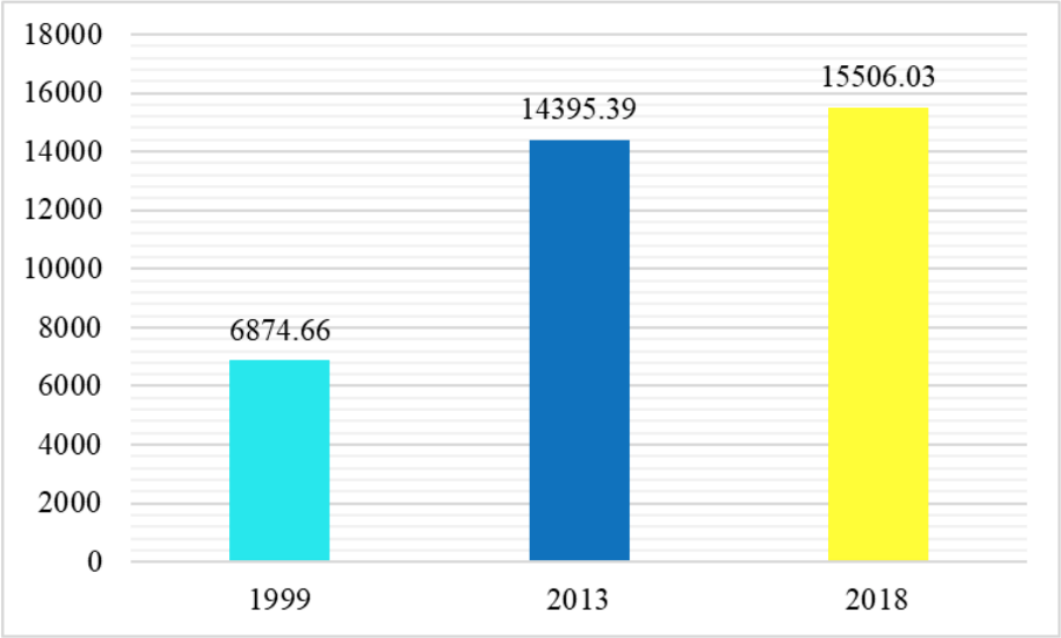

Figure 2. Total built-up area in year 1999, 2013 and 2018 (Acres) according to first method.

some of the buildings have been demolished. Another factor supporting this finding is the decreasing built-up area in the northern part of the city as it was the main industrial area.

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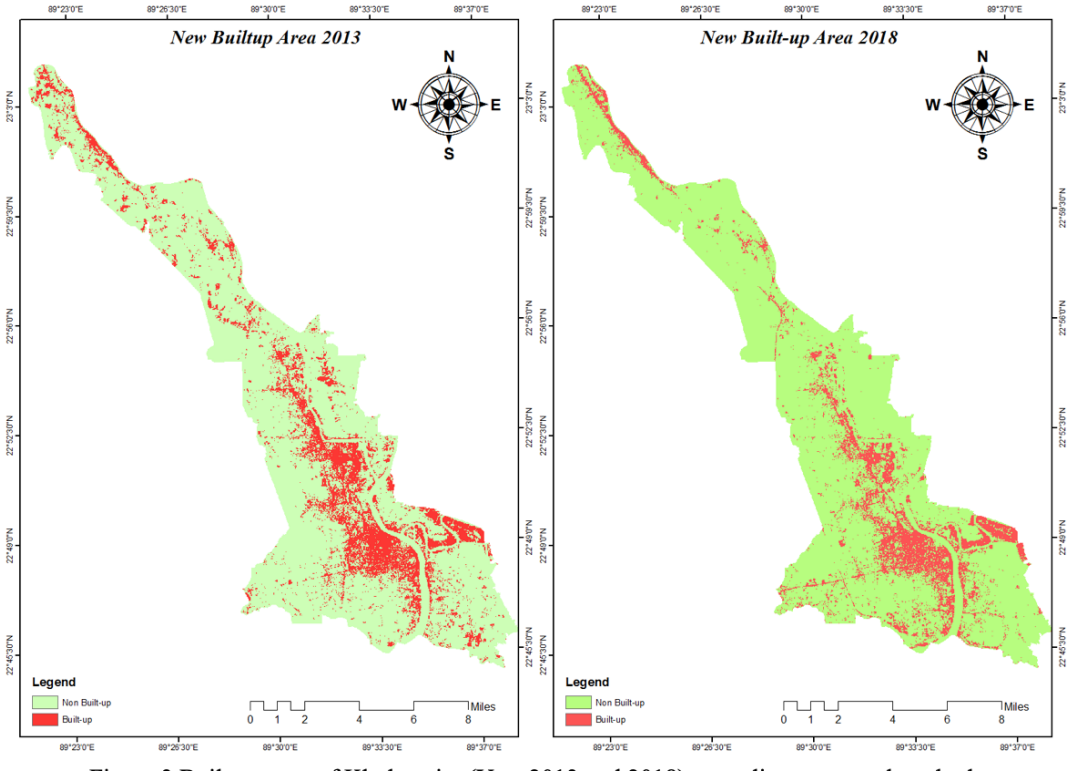

Figure 3. Built-up area of Khulna city (Year 2013 and 2018) according to second method.

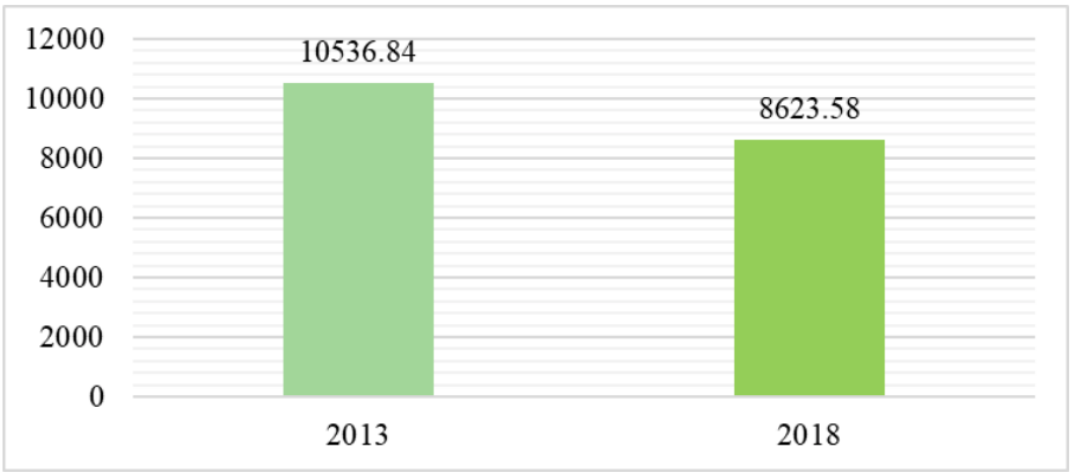

Figure 4. Total built-up area in year 2013 and 2018 (Acres) according to second method.

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Discussion and Conclusion

The methods that have been used in this research are fundamental and conventional. Obviously, the second method is better as it detects the built-up area more rigorously. The traditional built-up area extraction process has shortcomings in terms of refinement [2]. Furthermore, there are more accurate methods have been developed over time, like Automated Built-up Extraction Index (ABEI) and the use of Convolutional Neural Network (CNN) [5], [6]. But still, there are opportunities to use the conventional method and improve the technique with modification, as this study suggests. The methods' simple analytical procedure can also be used to conduct a long time series analysis to quickly understand the city built-up area expansion.

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