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Determining Land Use and Land Cover Changes and Predicting the Growth of Dhaka, Bangladesh Using Remote Sensing and GIS Techniques

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Determining Land Use and Land Cover Changes and Predicting the Growth of Dhaka, Bangladesh Using Remote Sensing and GIS Techniques

Abstract. Developing countries are experiencing a rapid growth in the urbanization in recent decades. Urbanization yields many positive effects if happens within the appropriate limits. However, extensive urbanization mostly results in adverse effects. This study aims to evaluate and observe the various changes like vegetation, built-up and water in the urban area of the greater Dhaka area of Bangladesh using Landsat 7 ETM+ and Landsat 8 OLI images between 2011 and 2018 and to predict its future using different GIS and remote sensing techniques. The analysis shows the superabundant growth of the buildup areas as well as degradation in the vegetated and water areas of greater Dhaka, Bangladesh. The classified maps have been assessed through an accuracy assessment. Based on such, the result shows and predict the expected urban growth, vegetation areas and the water index for the year 2020. The experimental result indicates and aims to provide an idea about subsequent understanding on the urban growth of greater Dhaka, Bangladesh.

1. Introduction

Rapid changes in LULC (land use and land cover) in urban areas becoming a major problem for the mega cities like Dhaka, Bangladesh. The conversion for this rapid change are currently occurring at an unprecedented rate. Only monitoring and proper management plans can solve the emerging problems timely and effectively. By using satellite images and their data's we can measure the subsequent changes and take the necessary procedure for the upcoming changes in urban expansion.

Bangladesh has witnessed a rapid change in the urban growth in recent times. Dhaka, the capital of Bangladesh is the prime center for this change. However, with astonishing growth in population of 3 million in 1980's to over 16 million. Dhaka has become one the most densely populated cities in the world where its expansion is disordered and irregular. This growth however has placed without proper planning which is resulting in a city with inadequate urban structure, contraction of river banks, vegetated area and so on. Remote sensing and GIS (Geographic Information Systems) are powerful yet most cost-effective tools for accessing the spatial and the temporal dynamics of LULC [1]. Multi-temporal data are provided through Remote sensing which is useful for the processes and the patterns of LULC change whereas GIS is useful for mapping and analyzing those patterns [2]. Most developed countries have both recent and extensive LULC information, but such scenario is prevalent for developing countries, particularly Bangladesh. For instance. City does not have official land uses patterns or proper statistics, nor the master plans contain maps or quantitative information's on the existing pattern of land uses map in the city [3]. Therefore, this study is an attempt to identify the spatial and temporal dynamics of LULC changes of greater Dhaka to identify a scientific approach to LULC change detection and for the policy makers to access the LULC change pattern in this area of Bangladesh.

The objective for this approach is to collect, record, analyze and to explore multi-temporal data of greater Dhaka using Landsat ETM+ and OLI images ranging from 2011 to 2018 and to predict the future phases of changes in the urban expansion.

2. Study Area

The study area of Dhaka, is located at the center of Bangladesh between 23º55`N and 90º23` E and 23º 39`N and 90º 26`E respectively. The study area surrounded by four river systems: The Bur-iganga, Turag, Tongi and the Balu, which flow to the south, west, north, and east, respectively. As of World Bank data, this city has over 16 million people while the city itself has a population estimated at about 8.5 million with population growth of 4.2% annually and expected to be the third largest city in the world by 2020[4]. It is one of the mostly populated areas and one of the fastest megacities around the world carrying a density of 23,000 people living per square kilometer within a total area of approximate 300 square kilometers [5].

3. System procedure

3.1. Data acquisition

Landsat data (ETM+, OLI) were acquired to evaluate the changes in land cover and uses in the urban expansion of Dhaka city. All the data acquired by Landsat 7 from 2003 has data gaps which are known as SLC-off image. The scenes cover 78 percent of their pixels, but these are the most accurate geometric and radiometric [5] satellite data. This study kept Landsat 7 images as references and collected, recorded, Landsat 8 images to analyze the urbanization patterns in different classification method.

Table 1. Collected Landsat Images

Satellite Data	Spatial Resolution (meters)	Date of Acquired data
Landsat 7 ETM+	30	2013Dec16; 2015Dec22; 2017Dec27
Landsat 8 OLI	15	2013Dec24; 2015Dec30; 2017Dec03

3.2. Methodology

All the images are collected from United States Geological Survey (USGS). There are numerous change detection methods to assess the variations in LULC using satellite data [7]. Among them pre and post-classification comparison are the most used one's. This study followed both among which, pre-classification method includes image differencing [8], change vector analysis and vegetation index differencing [9]. Initially, an unsupervised classification was run by using the ISO data decision rule to determine "naturally" occurring spectral clusters which is subsequently reduced to defined 4 class through the construable of similar/diverse statistics. Next, upon visual assessment and LULC class types were assigned to each index. A supervised classification approach was then followed by using maximum likelihood method to relate the study area pixels. The detailed classification report for all the images are shown in table 2. A detailed workflow of the methodology has shown in the figure 1.

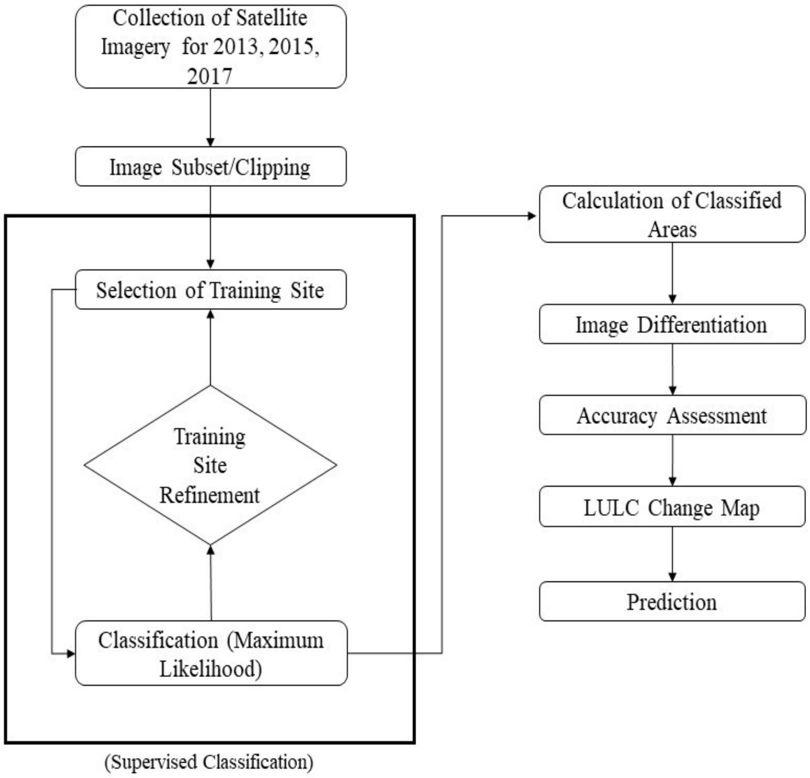

Figure 1. Methodology of the study

Supervised classification has been performed in all the obtained satellite images and the obtained classification report for all the images are shown in table 2. Classification report graph has shown in figure 2.

Table 2. Classification Report

Features	Year 2013 (Sq. km)	Year 2015 (Sq. km)	Year 2017 (Sq. km)
Water	20.18	19.09	14.31
Built-up	122.43	157.13	163.23
Bare soil	87.31	66.25	73.45
Vegetation	69.23	56.78	48.12
Total Area (Sq.km)	299.15	299.25	299.11

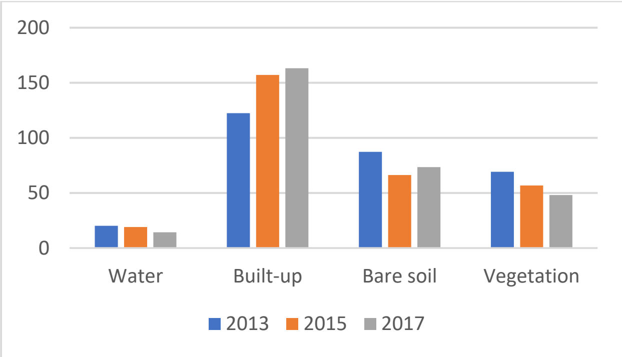

Figure 2. Classification Report for Satellite image

3.3. Data Analysis and Result

The classified output of 2013, 2015, 2017 are showed by figure 3, 4, 5 respectively. The supervised classification has been done based on four separate LULC types: Water index, Bare soil, Built-up and Vegetation index using maximum likelihood classification method which uses Bayes' theorem of decision making. However, several classes were incorrectly classified in classification method of LULC due to their similarities in spectral characteristics. Therefore, a post-classification method was used to improve the accuracy of the classification for its simplicity and effectiveness [6].

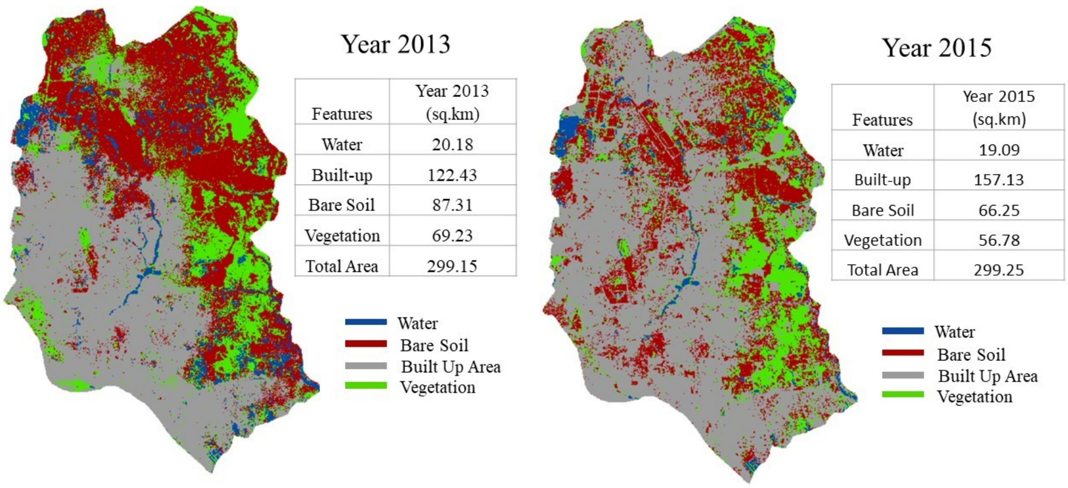

Figure 3, 4. Area index changes for the year 2013, 2015

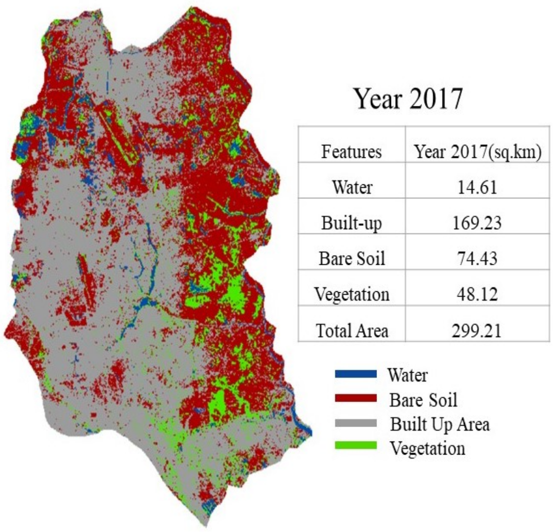

Figure 5. Area index changes for the year 2017

The area has been calculated for the respected index in each time after running post-classification method. The total area calculated is approximately 300 square kilometers. The total accuracy from the Landsat-derived LULC data was 86%, 86.7% and 85% respectively for the year 2013, 2015, 2017 verifying standard accuracy of 85-90% for LULC mapping studies as recommended by Anderson [8] and the result has been shown on table 3. It is comparing the classified image to another data source which in this case, ground truth data exerted from Google earth image. The LULC cover changes are predicted for the year 2019 by using arithmetic progression. The figure3, 4, 5 shows the respected area index changes for the year 2013, 2015, 2017 and predicted result for the expected growth for each index in 2019 are shown in table 4.

Table 3. Overall accuracy assessment

Year	2013	2015	2017
Overall accuracy	86%	86.7%	85%

Table 4. Prediction result of 2019

Features	Year 2013 (Sq. km)	Year 2015 (Sq. km)	Year 2017 (Sq. km)	Year 2019 (Sq. km)
Water	20.18	19.09	14.31	11.85
Built-up	122.43	157.13	163.23	187.33
Bare soil	87.31	66.25	73.45	62.87
Vegetation	69.23	56.78	48.12	37.08
Total Area	299.15	299.25	299.11	299.12

4. Future plan and conclusions

Satellite remote sensing and GIS technology has proven its usability in determining Land use and Land cover changes analysis. That is why this kind of study is a good way organize as well as cost and time effective for urban planners and decision makers. This study shows the changes in terms of built-up, water, bare soil and vegetation indexes of Dhaka city has experienced a massive change in LULC and risen high as it was from 2013 and predicted its growth much higher than the year 2013.As of the data shown for 2017, the total built-up increased 40.8% and the total vegetated area decreased to -21.11%

from what it was in 2013. This follow-up data will be more accurate with the combination of GIS, RS and socio-economic data to understand and predict the spatial and temporal dynamics of LULC changes. Furthermore, this study will continue to improve and analyze the given data and will apply different machine learning techniques and forecast the future growth patterns of Dhaka city using neural network techniques. As reliable and current data are not quite available for Bangladesh, the data's acquired and the calculations will contribute for both the sustainable urban land uses and forecasting the possible future changes in growth patterns.

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