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A STUDY ON LAND USE/LAND COVER MAPPING AND SPATIO-TEMPORAL CHANGE DETECTION AROUND THE SOUTHERN PART OF DHAKA METROPOLITAN DEVELOPMENT PLAN (DMDP) USING REMOTE SENSING TECHNIQUE

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ABSTRACT

Land use/land cover is an important component in understanding the interactions of the human activities with the environment and thus it is necessary to monitor and detect the changes to maintain a sustainable environment. Many researchers have carried out the similar work in this field adopting different technologies. The purpose of the study is to create a land use/land cover map and investigate the spatio-temporal change in land use around the southern part of DMDP. In this study, satellite remote sensing technologies have been adopted using ArcGIS 10.2.2.

The total study area covers about 211.78 km^2. The two satellite images of Landsat 5 TM (13 December, 2003 and Landsat 8 OLI (28 March, 2019), path-137 and row-44 were downloaded from the earth explorer. Supervised classification technique has been used with Maximum Likelihood Classification algorithm within ArcGIS 10.2.2 environment for image classification. The land use and land cover analysis on the study area has been attempted based on thematic mapping of the area consisting of water bodies, vegetation, urban and non-urban using the satellite image. Another major land use class, Matuail landfill site inside Dhaka South City Corporation was identified separately in the land cover map. The sixteen year time gap between 2003 and 2019 illustrates a major changes in land use. Vegetated area has decreased from 77.57% to 45.5% due to deforestation and non-urban area has increased from 2.3% to 14.93% which indicates an increase in bare lands. Water covered area also decreased from 6.03% to 4.64%, may be due to population growth. There has been a significant change in urbanized area which was due to an increase in population resulting in an increase of urban area by 20.84%. Finally, the accuracy of the result was assessed with the help of Google Earth historical images and an error matrix was created to calculate a variety of accuracy matrices (user and producer accuracy) for the afore-mentioned years. For accuracy assessment, high resolution topographic map would have served better purpose.

Due to expansion of cities in all directions resulting in rapid growth of urbanization, built up and non-urban area has increased and encroached the vegetation and water covered areas. However, as this study applies a 16-years interval for the spatio-temporal change detection from 2003 to 2019, further researches are demanded to investigate the temporal scale problem in all temporal analysis including spatio-temporal modelling and forecasting.

Keywords: *Land use; Land cover; Remote Sensing; Satellite Image; Supervised classification.*

1. INTRODUCTION

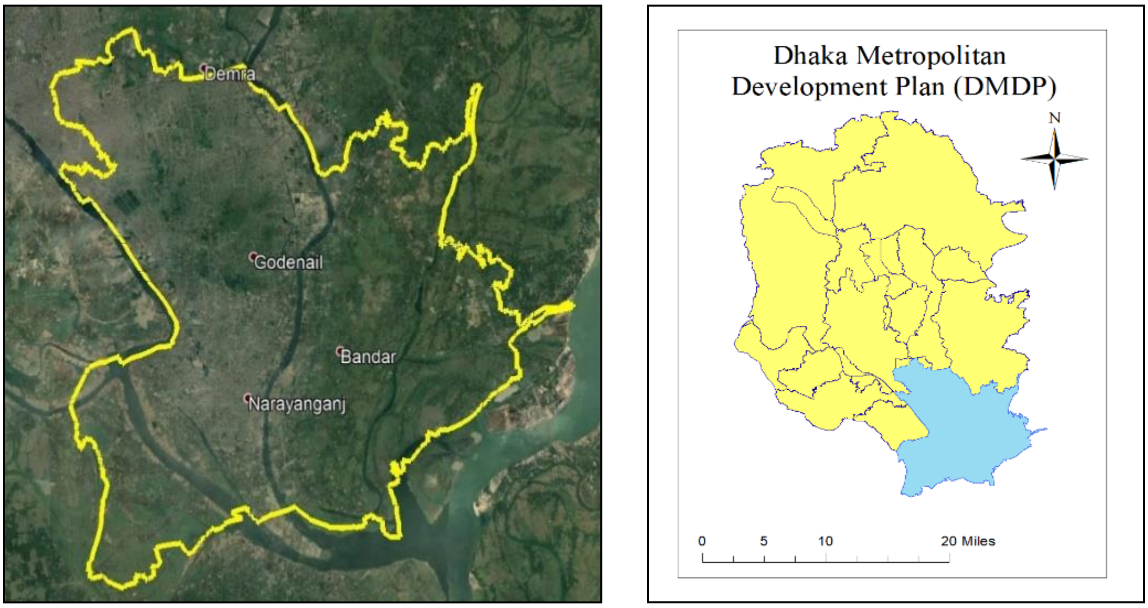
The demand of information on land cover, land use and their changes is increasing at the global, regional and national levels to support policy decisions and regulate management processes. In contrast to survey data, aerial and satellite imagery can be used to monitor the spatial extent of changes in land cover (i.e., conversion) or land conditions. Satellite imagery offers contiguous spatial coverage, facilitates better repetition and replaces costly and slow data collection of different land cover and provides statistical information of the area object [Andualem et al. (2018)]. Remote sensing technologies have made substantial contribution in deriving land cover information and correlating to land-use statistics. Availability of satellite images with different spatial and temporal resolutions have made it possible to map land cover at different scales and carry out analyses of the changes over last three decades. Specifically, remote sensing change detection analyses can be used to identify areas of rapid change to target management efforts. Repeated satellite images and/or aerial photographs are useful for both visual assessment of natural resources dynamics occurring at a particular time and space as well as quantitative evaluation of land cover changes [Gautam et al. (2003)]. A number of deforestation and degradation studies have been conducted in tropical forests using coarse and high-resolution remote sensing data. The temporal evaluation of forest changes based on satellite imagery is becoming a valuable set of technique for assessing the degree of threat to ecosystem GIS on the other hand provides environment to analyze digital data useful for change detection, database development, and modeling of its future change and data dissemination for effective management planning. In the context of Reducing Emissions from Deforestation and Degradation (REDD), Remote-sensing methods are considered to be appropriate for most developing countries to assess historical and future deforestation rates, i.e., forest area change. The latest and accurate information on land use/cover is a prerequisite to the management and planning of urban areas. In the absence of such information, sustainable urban development cannot be achieved and may lead to the mismanagement of scarce resources. Land use and land cover change mapping will help to take up clear strategies for managing natural resources and monitoring environmental changes [Andualem et al. (2018)]. Urban expansion has brought serious losses of agriculture land, vegetation land in the recent years. Unplanned urban land expansion is responsible for a variety of urban environmental issues like decreased air quality, increased runoff and subsequent flooding, increased local temperature, deterioration of water quality, etc. Knowledge of drainage, land use/land cover and hydro-geomorphology and other terrain attributes are important for planning and management activities. Remote Sensing and GIS both from the conventional sources has proved to be an effective tool in planning for Land and Water Resources management. Land and Water Resources Management will imply utilization of land and water resources for optimal and sustained production with the minimum hazard to natural resources and environment. [Land use]

An attempt is made in this study to map out and monitor the status of land use/land cover change and analyze the changes with respect to baseline. The purpose of this study is to create the land use/land cover map and investigate the spatio-temporal change in land use around the southern part of DMDP between the year 2003 and 2019 by adopting Remote Sensing Technique using ArcGIS 10.2.2.The specific objectives of the study are:

- To create a land use map by using Landsat satellite image.
- To monitor the land use changes of the study area.

2. STUDY AREA

Our study area includes Narayangonj Sadar, Bandar, Godenail, Narayanganj Paurashava, Siddhirganj Paurashava and Demra. The rivers in and around this area are the Buriganga to the west, the Meghna river to the east the Ichamati river (local name of the Dhaleshwari in this part) to the south-west, the Sitalakhya and the Old Brahmaputra river crossing through the area north to south. The Dhaleshwari crosses the southwest part and then flows along the southern boundary ultimately draining into the Meghna River. Figure 1 (a) shows the location of our study area in Google Earth.



(a) (b)

Figure 1: (a) Extent of study area; (b) Location of the study area inside DMDP

Our study area also covers Matuail landfill which is located about eight kilometers from Gulistan in the south of Dhaka. It is one of the two landfills serving Dhaka city. Spanning 100 acres, the site is used by the Dhaka South City Corporation (DSCC) to dispose of its municipal solid waste. Now 23 years old, it will reach capacity in a year at most. The Amin Bazar site, used by the Dhaka North City Corporation (DNCC), has already expired last year. Putrid waste swarming with flies and rodents towers in hills tens of meters high. Starting off with an open dump of 50 acres in 1995, a further 50 acres were added to Matuail in 2006. In the initial landfill area, there is a mountain of waste, up to 70 feet (about 21 meters) high, which is closed to further dumping. In the adjacent 50 acres, there is an almost 60 feet (about 18 metres) pile of waste. [DAP,2010]

3. METHODOLOGY

In this study, the observation is limited in detecting the changes in urban land use in a rapidly changing area of the southern part of Dhaka Metropolitan Region by comparing the percentage of land use area calculated from classified images of two different years. The images used in this observation are from Landsat 5 TM and Landsat 8 OLI sensors dated December, 2003 and March, 2019 respectively of path 137 and row 44 which are downloaded from Earth Explorer. In case of Landsat 8 OLI, there are nine spectral band (band 1 to band 9) in which band 8 is a panchromatic band and band 9 is a cirrus band which are not used in classification. In case of Landsat 5 TM, band 1 to 5 and band 7 are spectral band. From Landsat 5 TM band 1 to 5 and band 7 (resolution 30m) and from Landsat 8 OLI band 1 to band 7 (resolution 30m) are used to make composite image for further classification process. There are two image classification techniques used for land cover classification, namely Supervised classification and Unsupervised classification. In this study, the supervised classification technique was used to map the land use cover in desired classes.

A schematic flow diagram showing the methodology adopted for this study is given below, which includes data collection, data processing and preparation, data analysis and final output.

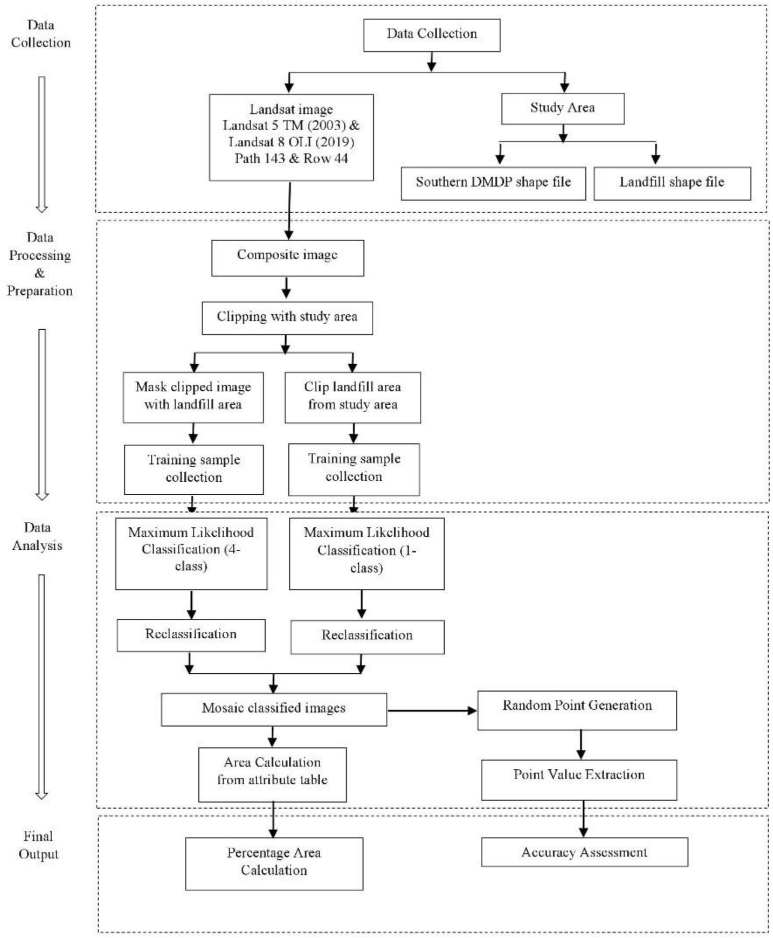


Figure 2: Methodology Flow Chart

3.1 Data Collection

Landsat 5 TM images of December, 2003 and Landsat 8 OLI images of March, 2019 of row 44 and path 137 with the cloud cover less than 10% and spatial resolution 30m X 30m covering southern part of Dhaka Metropolitan Region were downloaded using Earth explorer from the United States Geological Survey website (http://earthexplorer.usgs.gov). All the downloaded images are in *.tif format. The foot print are 170 km North-South by 185 km East-West. Landsat 5 contains six spectral bands with a spatial resolution of 30 meters for Bands 1 to 5 and 7, and one thermal band (Band 6, spatial resolution 120m). For Landsat 8 the satellite carries two different sensors. The Operational Land Imager (OLI) contains nine spectral band (Band 1 to 9) including a pan band and a cirrus band and the Thermal Infrared Sensor (TIRS) contains two thermal band (Band 10 & 11). For this study, the concerned bands are the spectral bands, thermal band is not necessary for image classification. The downloaded folder of the scene also contains metadata file, ground control point and other necessary file.

3.2 Data Proccessing and Preparation

For further analysis of the Landsat images, processing is required which contains merging of the spectral bands to make a composite image and clipping the composite image with the desired study area shape file. In this study, the sanitary landfill situated in Matuail, which is inside the study area, is clipped with a landfill shape file and classified as an individual class. So, the landfill needed to be masked from the clipped area. Before classify the images with maximum likelihood classification, training sample of similar pixels were collected from the processed images. To simplify the training sample selection process, band combination is required for better selection of different classes.

3.3 Data Analysis

After pre-processing of the image has been done, the data is ready for further classification process which includes Maximum Likelihood Classification, mosaicking of classified image, area and percentage of area calculation.

3.3.1 Maximum Likelihood Classification

Maximum Likelihood Classification is a remote sensing classification system in which unknown pixels are assigned to classes using contours of probability around training areas using the maximum likelihood statistics. In this case, from the training sample collected in image processing phase, a signature file (.gsg format) is made before classification. By giving input of the signature file in Maximum Likelihood Classification from Classification toolbar, all cells in the output raster will be classified with each class having equal probability weights attached to their signatures. The masked study area was classified in four classes and the landfill area was classified in one class individually with their own signature file showed. Then the two classified image (masked study area and landfill area) was being reclassified separately in five land classes. When the classification for both four classes and landfill classes were done individually, the two images needed to be mosaicked into one image or more like stitched together by mosaicking technique to get the whole area of five land classes. Description of the following five land use/land cover classes are tabulated below:

Table 1: Description of land use/land cover classes

Code	Land Class	Description
1	Water	This class of land cover describes the areas covered with water either it is river, ponds or man-made dams, water treatment plant etc.
2	Vegetation	It describes the areas with any kind of green vegetation such as ever green trees, cultivated crop lands, cultivable bare lands etc.
3	Urban	This class describes the land covers with buildings, transportation infrastructures which includes commercial, industrial, residential buildings, roads and highways, bridges etc.
4	Non-urban	This class includes the areas that cover bare lands, low lands and under construction lands.
5	Landfill	This is the only land use class which remains constant and covers the area of Matuail sanitary landfill situated in Matuail.

3.3.2 Area and Percentage Area Calculation

After mosaicking the classified images, the five classes are finally combined into one image. Area of each classes are then calculated from the pixel count provided in the attribute table of the image. A new field is created in the attribute table for area calculation. The following formula is used to calculate the area by using field calculator.

$$Area = Count*Cell\ size(X\ \&\ Y)/1000000 \tag{1}$$

Cell size or pixel size for both Landsat 5 and 8 images are 30m*30m. The area is then converted to kilometers. After calculating the area of individual classes the data is then copied to a Microsoft excel work file. And the percentage of the area of each classes are calculated for the two different data of the two mentioned dates with the formula given below:

$$Percentage\ of\ area = (Individual\ land\ use\ area/Total\ area)*100 \tag{2}$$

The result are then compared with graphical representation to show the changes in land use that occur in between the following time period.

3.3.3 Accuracy Assessment

To determine how well the classification process is performed, Accuracy Assessment of the classified image is done by generating a set of random points in the study area. The value for each point is then identified using the Google Earth historical imageries. After that the point values are extracted and compared with the raster values to find the accuracy of the classification method [Andualem et al. (2018)]. The percentage of accuracy of the classified image in comparison with Landsat data was calculated by the following formula.

$$Accuracy(\%) = \frac{Number\ of\ points\ with\ similar\ values}{Total\ random\ point} \times 100 \quad (3)$$

Error matrices for the two different year were developed with the output data which allows us to be able to calculate a variety of accuracy metrices from our data such as User accuracy and Producer accuracy by the following formulas:

$$User\ accuracy = \frac{Total\ number\ of\ correct\ pixel}{Total\ number\ of\ pixel\ actually\ classified\ in\ the\ category} \times 100 \quad (4)$$

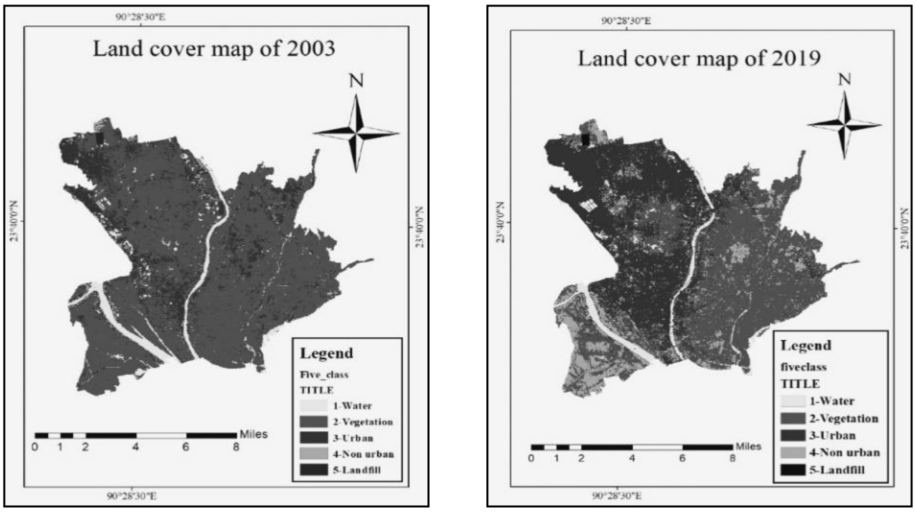
$$Producer\ accuracy = \frac{Total\ number\ of\ correct\ pixel}{Total\ number\ of\ reference\ pixel\ in\ the\ category} \times 100 \quad (5)$$

3.4 Final Output

This study focuses on the analysis of spatio-temporal change detection by land use and land cover mapping through the time series Landsat satellite images. Following the step by step classification and quantification procedures, two land use and land cover maps of 2003 and 2019 were produced by supervised classification process using Maximum Likelihood Classification algorithm. Land cover change detection was obtained within ArcGIS 10.2.2 environment. Five major types of land cover classes were identified within the study area which are water, vegetation, urban, non-urban and landfill site.

3.4.1 Change Detection in Land Use and Land Cover

From the differences between two classified image of 2003 for Landsat 5 TM and 2019 for Landsat 8 OLI, it can be observed that there is a considerable growth in urbanization and decrease in vegetation classes. Areas that cover water also decreased and non-urban areas increased. The land cover map of the two different years are given in figure 3 (a) and (b).



(a) (b)

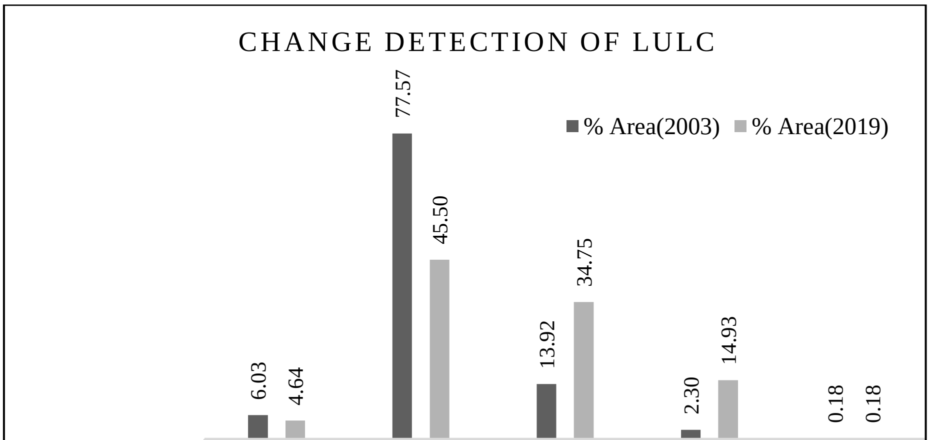
Figure 3: (a) Land cover map of 2003; (b) Land cover map of 2019

Table 2 shows the difference in percentage of area between the different land cover classes in the gap of 16 years.

Table 2: Differences between land class areas of 2003 & 2019

Land cover class	Land cover area of 2003		Land cover area of 2019		Difference (in %)
	Area(km²)	%Area	Area(km²)	%Area	
Water	12.78	6.03	9.82	4.64	-1.40
Vegetation	164.28	77.57	96.35	45.50	-32.07
Urban	29.47	13.92	73.60	34.75	20.84
Non-urban	4.87	2.30	31.63	14.93	12.63
Landfill	0.38	0.18	0.38	0.18	0.00

A graphical representation for the percentage of area changes in between the year 2003 and 2019 is shown in figure 4.



	1-Water	2-Vegetation	3-Urban	4-Non urban	5-Landfill
% Area(2003)	6.03	77.57	13.92	2.30	0.18
% Area(2019)	4.64	45.50	34.75	14.93	0.18

Figure 4: Change detection of LULC

From the above graph, the changes in land cover in the year gap of 16 years (from 2003 to 2019) is clearly visible. Percentage area of vegetation in 2003 is 77.57% (164.28 km²), whereas in 2019 it is 45.50% (96.35 km²). Also the percentage area of urban land in 2003 is 13.92% (29.47 km²) and in 2019 is 34.75% (73.60 km²). This indicates urbanization and also deforestation of the concerned area. Non-urban area of 2003 is 2.30% (4.87 km²) which also increased up to 14.93% (31.63 km²). This indicates the increase in bare land and under construction areas.

3.4.2 Accuracy Assessment

From equation (3), total accuracy of the classified Landsat images for the year 2003 and 2019 were calculated.

For the year 2003, total random point generated was 100 but 99 were inside the study area.

$$Accuracy\ (\%) = \frac{78}{99} \times 100 = 78.8\%$$

And for the year 2019, total random point generated was 100 and all the points were inside the study area.

$$Accuracy\ (\%) = \frac{84}{100} \times 100 = 84\%$$

The error matrix for the two different year including User accuracy and Producer accuracy calculated from equation 4 and 5 were shown in the following table.

Table 3: Error matrix showing classification accuracy of 2003

Land cover class	1-Water	2-Vegetation	3-Urban	4-Non urban	Total	User Accuracy
Water	3	1			4	75
Vegetation	4	66	6	4	80	82.5
Urban	1	3	8	2	14	57.1
Non-urban				1	1	100
Total	8	70	14	7	99	
Producer Accuracy	37.5	94.3	57.1	14.3		78.8

Table 4: Error matrix showing classification accuracy of 2019

Land cover class	1-Water	2-Vegetation	3-Urban	4-Non urban	Total	User Accuracy
Water	4				4	100
Vegetation		39	2	2	43	90.7
Urban	1	3	37	1	42	88.1
Non-urban		4	3	4	11	36.4
Total	5	46	42	7	100	
Producer Accuracy	80	84.8	88.1	57.1		84

5. CONCLUSION

This paper presents the result of the land use change detection of a particular study area for the period of 16 years (2003-2019). The land use land cover mapping and change detection had been done from satellite images using maximum likelihood classification pattern classification algorithm. The result from the study clearly indicates:

1. The decrease in number of vegetation and water area with the increment of urban and non-urban area between the year gaps.
2. It is clear that, urbanization is increasing gradually and therefore vegetation and grasslands are decreasing in the concerned area. The growth of urbanization also affect the decreasing rate of water.
3. Increase in non-urban area indicates the further growth of urbanization as this category includes bare land and under construction lands.

The land use map created in this study can serve as an effective managerial tool for urban planner and environmental scientists. It also gives a thorough idea about the land surface temperature as the land surface temperature is closely related to land use pattern. So the result of this study can contribute useful information for studying Land Surface Temperature (LST).

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