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Monitoring Landuse-Landcover Changes in Dhaka City by Integrating Remote Sensing and Ground Based Observations

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Abstract
We have employed remote sensing approach in this study to understand the LULC changes in Dhaka urban area for a period of 26 years. We have used Landsat TM, ETM+ and OLI/TIRS image and employed unsupervised classification to prepare LULC maps from 1989 to 2015. To validate the results fieldwork has also been followed. We have found a decrease of water bodies of 967.14 ha and a decrease of vegetated lands of 2641.59 ha. The rate of decrease is 37.20 ha per year and 101.60 ha per year for water bodies and vegetation respectively. At the same time the urban areas have been increased by an area of 4370.67 ha. The rate of increase of urban structures is 168.10 ha per year. Integrating the spatial changes, we have found a correlation between loss of vegetation and water body with increase of urban structures. Our field observation also provides accuracy of our satellite based observation with an overall accuracy of 82.61%.

Keywords
Dhaka city, Urbanization, Landuse Landcover, Remote Sensing

Introduction

Rapid urbanization is a major problem in mega cities. Unplanned urbanization poses threat to the ecosystem, environment and various other elements. World's urban area accounts for only 3% of the Earth surface but urban sprawling can affect global climate and hydrological cycle (Foley et al., 2005; Grimm et al., 2008). The growth of built up areas are indicative of urbanization (Miller and Small, 2003). So it is necessary to study such growth for the detection of vulnerable zones. Decision of enviroenmental management and planning depends on available LULC changes data (Fan et al., 2007; Prenzel et al.,2004). But studying urban landuse- landcover (LULC) could be complex and spatial heterogeneity could be present (Herold et al., 2004). Besides urban sprawling, various human activities affecting landcover in an area can also be found through LULC studies (Lopez et al., 2001).

Urban growth can pose great threat to the environment (Abdulla and Nakagashi, 2005). Urban planning in megacities can be best achieved through remote sensing approach (Maktav et. al., 2005). Since 1972, the Landsat Multispectral Scanner (MSS), Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) data have been used for different environmental studies (Campbell, 2007). Using single data Landsat imagery LULC studies have been performed from 1960 to 2005 (Dewan and Yamaguchi, 2008). Various change detection methods in last few decades have been developed which are different to each other (Lu et al., 2005). Land cover classification using unsupervised ISODATA classification algorithm has been followed by Mundia and Anyia (2005). In Rize, Turkey, LULC changes have been investigated by Remote Sensing and Goegraphic Information Systems (Reis, 2008). Different techniques are preferred in different regions based on the availability of data, satellite image resolution and level of accuracy required.

In developing countries, the LULC changes can be characterized by rapid urban growth (Jat et al., 2008; Mundia and Aniya, 2006). Like many other cities of developing countries, Dhaka city is growing at a faster rate and could be the third largest megacity in the world at 2020 (World Bank, 2007). Rural to urban migration of people is responsible for rapid urbanization in most cases (Islam, 1996). Because of such unplanned urbanization, Dhaka city has been experiencing climatic variation, intense rainfall, flash flood and other problems. The impervious surfaces created by more urban structures often create water logging problem in monsoon period. But these environmental issues have been studied only in a few numbers using geospatial techniques (Dewan et al., 2007, 2005; Kamal and Midorikawa, 2004; Maathuis et al., 1999). The exisiting landuse in Dhaka city has been disregarded for quantitative studies or mapping (Islam, 1996, 2005). Official landuse statistics have been prepared for Dhaka metropolitan area in 1991 using ground observations techniques (Islam, 1996, FAP 8A, 1991). So it is necessary to prepare proper LULC maps to mitigate the environmental issues in this region. The objective of our research was to prepare LULC maps using unsupervised classification from year 1989 to 2015 and correlate the LULC changes trend with some ground based observations.

Study Area

Our study area (Figure 1) extends from 90° 20′ 0″ E to 90° 29′ 0″ E and from 23° 42′ 0″ N to 23° 54′ 0″ N. It indicates an area of 28572 ha of Dhaka city, Bangladesh. The total Dhaka city area is 30600 ha (Islam, 1996). The major river towards North is Turag river, towards South and Southwast is Buriganga river and towards Eastern side Balu river. The major areas towards North is Tongi, Uttrara and some parts around Dhaka Airport. Towards Southern part, major areas are Matijheel, Old town, some parts of Demra Jatrabari areas. Some of the areas towards west are Mirpur, Dhanmondi, Mohammedpur. Purbachal, Khilgaon and adjoining areas are Eastern peripheral part of the city. The central part is densely populated than the peripheral part. This large population poses threat to the environment of this city. The city area is rapidly expanding through urbanization. As a result it is creating many problems and hazards associated with urban environment.

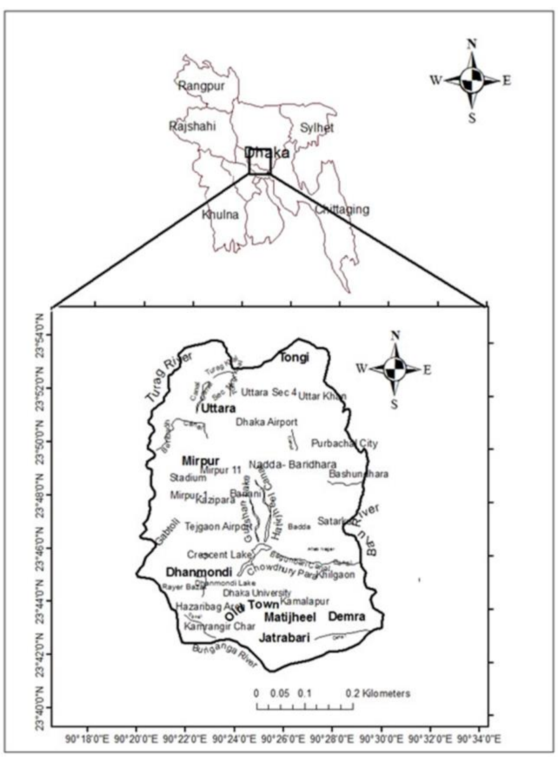

Figure 1: Location and Extent of the Study Area

Materials and Methods

We collected four Landsat satellite images from USGS archive. These images were radiometrically and geometrically corrected. The acquisition year, resolution and sensor types of each image have been given below (Table 1):

Table 1: Satellite images with their acquisition dates and spatial resolution of TIR band

Sensor Platform	Acquisition Date	Resolution
Landsat 4	13 February, 1989	30 m
Landsat 7	28 February, 2000	30 m
Landsat 5	15 February, 2010	30 m
Landsat 8	17 March, 2015	30 m

All of these images individual bands have been layerstacked together except the thermal band. Layerstacking is useful for image classification and identification of individual LULC by color composite process. Finally the region of our study area has been separated from these layerstacked images. An extensive fieldwork has been performed following the LULC classification from satellite data. Handeheld GPS have been used for this purpose to locate and navigate observation points. All of the processing has been done using ERDAS IMAGINE 2014 and Arc GIS 10.2.1 geospatial software. Those software helped to achieve precision with the fast data computation process. We followed a detail study of the LULC both from satellite data and ground observations. The individual Landsat images have been classified and different LULC have been identified. These classes have been observed for a period of 26 years and spatio-temporal changes have been detected. Finally we correlated the results with some ground observations.

The aim of our research was to perform change detection of LULC and hence image classification was useful. We employed unsupervised classification for classifying the individual images. There were several advantages to perform unsupervised classification in this study. But most of all, as there was lack of available ground data for past images used in this study; unsupervised classification would only provide reliable information about the spectral classes. The Iterative Self Organizing Data Analysis Technique or

ISODATA has been followed using ERDAD IMAGINE software. We created 15 spectral classes at first but after merging them with each other by spectral characteristics observation, we got 4 representative information classes (Table 2). Each of these classes has been observed for any changes over the study period.

Table 2: The final LULC classes and their characteristics

Classes (Landuse-Landcover types)	Description of the Landuse-Landcover types
Water Bodies	Includes seasonal and permanent water bodies, marshy lands and other wetlands
Vegetation	Smaller and larger trees, grasses and other vegetations.
Urban Structures	Higher structures, lower buildings of different types have been included in this class.
Bare Lands and Others	Uncultivated lands and Unstructured lands. Also some unidentified pixels have been included in this class.

To evaluate the results of LULC changes and correlate with the image of 2015 to validate our results, an extensive field based observations have been performed. We used handheld GPS to locate different ground observation points and observed the LULC at those positions. We kept similarities of fieldwork with Landsat 8 image of 2015 in terms of image acquisition date and time. We took 23 observations and tried to correlate with the 2015 image to figure out the changes of LULC in our study area. The mixed pixels have been given special consideration for ground based LULC studies.

Results and Discussion

We found interesting results from unsupervised classified maps from 1989 to 2015. We have detected several changes in terms of LULC which could be correlated as the impact of urbanization.

Classified Thematic Map of 1989

The unsupervised classified image of 1989 has been proved successful in identifying different LULC (Figure 2(a)). As our target was to achieve 4 classes, we observed the representative pixels indicating those classes. The dominance of vegetated cover is well observed from the image in and around the study area. Also there were numerous water bodies and wetlands at that time. But urban areas were not very significant at 1989. The major sources of water bodies in this image were Gulshan Lake and Hatirjheel Canal which were widely located at that time. Also along the Southwestern part, near Kamrangir Char and Hazaribag, a well flow of drainage has been observed. Along the Southeastern part, numerous waterbodies and wetlands can be seen near Demra region. Also very other dispersed water bodies were located at that time which constituted total 2414.52 ha of water bodies and wetlands in the study area. This was 8.45% (Table 3) of our total study area.

The vegetation covered areas were mostly on the Eastern part and western part of the city where housing projects have been going on in recent years. About 6634.80 ha area was covered with vegetation which was 23.22% (Table 3) of the study area. On the other hand, most densely structured urban areas were near Matijheel and Old part of Dhaka city. These areas covered 4996.44 ha in this year which was 17.49% (Table 3) of the study area. Also the bared ground and other unidentified pixels in the image covered 14526.18 ha of the study area which was 50.84% (Table 3) of the study area. The bared ground indicating areas have been found as free from urban construction and other developments.

Classified Thematic Map of 2000

During the year of 2000 (Figure 2(b)), the water bodies have been decreased significantly compared to the year of 1989. In 2000, 1998.36 ha have been identified as water bodies and wetlands in the study area which is 6.99% (Table 3) of the study area. The major water bodies of the Gulshan Lake and Hatirjheel Canal was well distinguished in this year's image also. But the Southeastern part has lost some part of water bodies and wetlands. The sporadic water bodies inside the city area were visible in some extent. The Eastern part, near Purbachal has lost some parts of the vegetation in the study area. The total vegetated area was 6488.55 ha in this area, which was 22.71% (Table 3) of the study area. The urban structured area has been progressed towards North in this year. Also some parts of West, near Mirpur, have been identified as rapid urban growth area. The area of urban structures was about 8396.28 ha, which is 29.39% of the study area (Table 3). The bared land and other unused areas have been decreased from 1989 due to urban development. In 2000, these areas covered 11688.75 ha which was 40.91% (Table 3) of the total study area.

Classified Thematic Map of 2010

During the year of 2010, some parts of the study area (Figure 2 (c)) have been changed in terms of changing landuse-landcover (LULC). Most significant is the growth of urban structures which has been reached further North in this year than the year of 2000. The Water bodies have been almost decreased in a significant amount in the Southeastern part near Demra. The water flowing near Kamarangir Char and Hazaribag areas were rarely seen in this year. Total area covering water bodies was about of 1683 ha in this year which was 5.89% (Table 3) of the study area.

The vegetation has also been lost in this year, indicating an area of 4912.65 ha in the study area. The vegetation was 17.19% of the total study area (Table 3). Significant loss of vegetation was towards East near Purbachal region and towards West, Northwest, near Uttara area. The Urban growth has been progressed sporadically and mostly towards Northern region. The urban area covered 8116.29 ha in this year which was 28.41% (Table 3) of the total study area. The bared lands covering study area were 13860 ha, which was 48.51% (Table 3) of the total study area. These bared lands were mostly unused lands and some land filling sites for house construction.

Classified Thematic Map of 2015

The water body during the year of 2015 covered an area (Figure 2 (d)) of 1447.38 ha only, which has been found as 5.07% (Table 3) of the total study area. It means that some of these water bodies have been lost from 2010 to 2015. The urban encroachment is mostly responsible for this problem, which has been found integrating our results. To create more houses the urban water bodies have been degraded by the housing companies. Also significant amount of vegetation has been lost in this year from the previous years. From the image, it has very clearly been seen that the vegetation in the Eastern part, near to Purbachal has been lost in these years. Also, near Demra, towards Southeast, some vegetated cover has been lost. The vegetation covered in this year, an area of 3993.21 ha which has been found as 13.98% (Table 3) of the study area.

The urban structured areas have been increased rapidly in the year 2015. From the image 9367.11 ha areas have been identified as urban structured areas and these were 32.78% (Table 3) of the study area. Urban structured areas have been reached to furthest part of North, near to Turag River in this year. The bared land and other areas covered13764.24 ha in this year, which has been found as 48.17% (Table 3) of the study area. The uncultivated lands, sand filled areas comprised this group and indicative of urban encroachment in some extent.

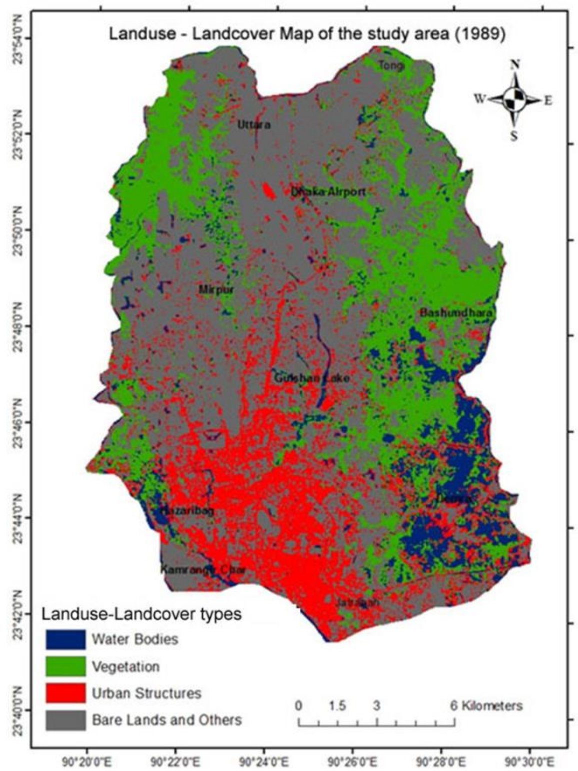

Figure 2 (a): State of LULC Map in the study area (1989-2015)

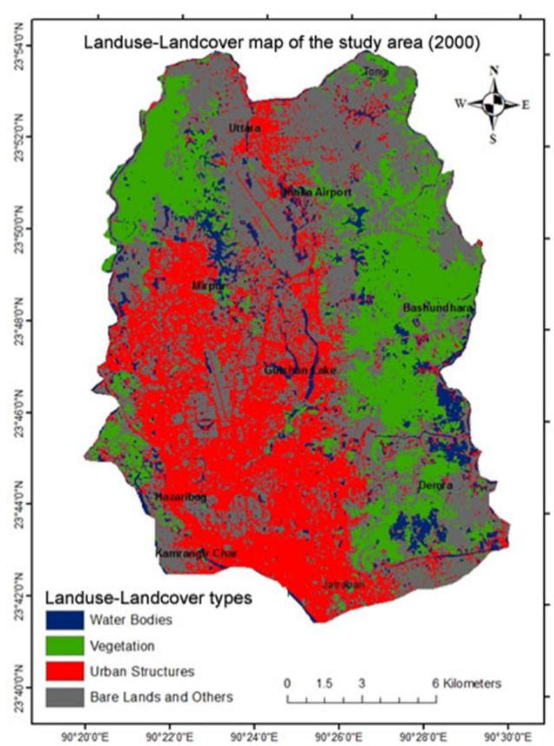

Figure 2 (b): State of LULC Map in the study area (1989-2015)

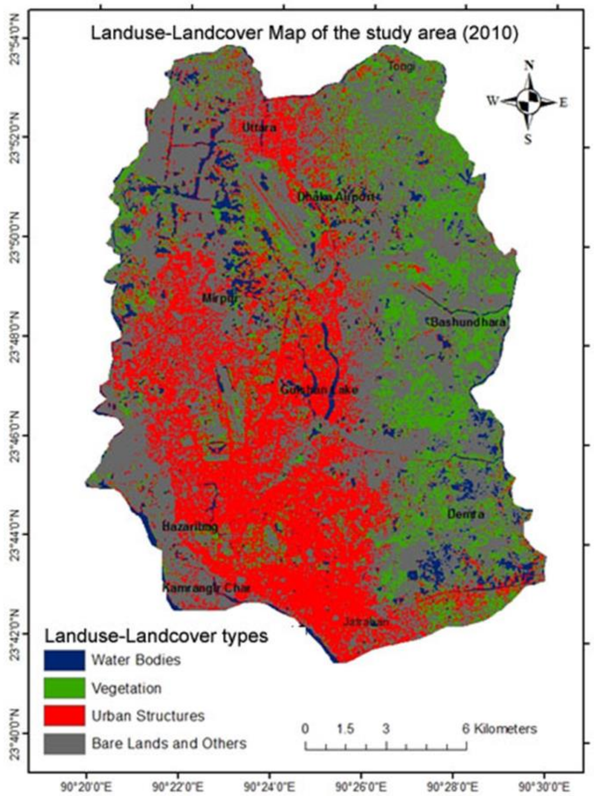

Figure 2 (c): State of LULC Map in the study area (1989-2015)

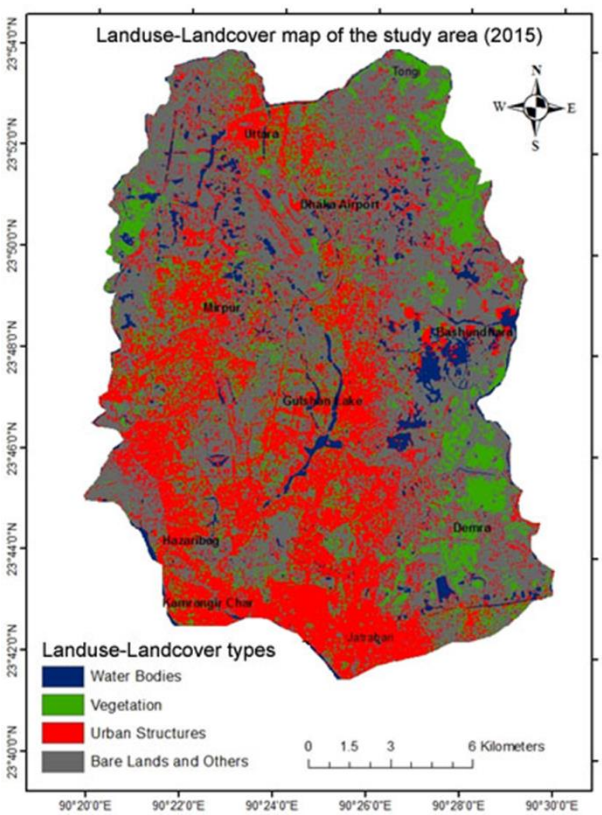

Figure 2 (d): State of LULC Map in the study area (1989-2015)

Table 3: LULC types and their percentages over time

LULC Types	1989	2000	2010	2015
Water Body	8.45%	6.99%	5.89	5.07
Vegetation	23.22%	22.71%	17.19	13.98
Urban Structures	17.49%	29.39%	28.41	32.78
Bare Land and Others	50.84%	40.91%	48.51	48.17

Change Detection of LULC from 1989 to 2015

By integrating the unsupervised classified thematic images and observing the trend of different LULC changes we have found correlation between losses and increases. The losses of water bodies, vegetation has been given rise to the development of urban structures, and in some cases more bare land to build more urban structures. Three changes of LULC types are important for change detection these are water body, Vegetation and urban structures.

For water bodies, we have found 967.14 ha of total decrease which is 40.06% in the study area. The rate of decrease is 37.20 ha per year. Towards Southeast, near Demra and Jatrabari areas and towards Southwest near Buruganga river, Hazaribag and some other areas have lost significant part of their water bodies and wetlands. These areas have been lost by fast urbanization. The R2 value (Figure 4) for water bodies is 0.984 which indicates a good correlation among the changes in different years for this particular LULC.

The losses of vegetated lands are also very significant and we found a total of 2641.59 ha decrease for this LULC. This is 39.81% decrease and the rate of decrease is 101.60 ha per year. The peripheral part at East, Southeast and Northwest suffered mostly by the decrease of vegetation. In Purbachal towards East and near Mirpur embankment towards Northwest have been affected by vegetation losses. The R2 value (Figure 4) for vegetation is 0.924 which indicates good correlation among different year's changes of vegetation covers.

There has been a change of urban structured areas also. In 1989 most of the urban built up areas situated at the Southern part near old town. But from 1989 to 2015, these urban areas have been progressed towards Northern part upto Uttara, Tongi and surrounding areas. The peripheral areas are usually less structured than the central areas but they are also diminishing with time. The increase of urban structured areas is 4370.67 ha. The increase is 168.10 ha per year. The R2 value (Figure 4) for urban structure change is 0.765 which indicates moderate to good correlation among urban structured areas changes.

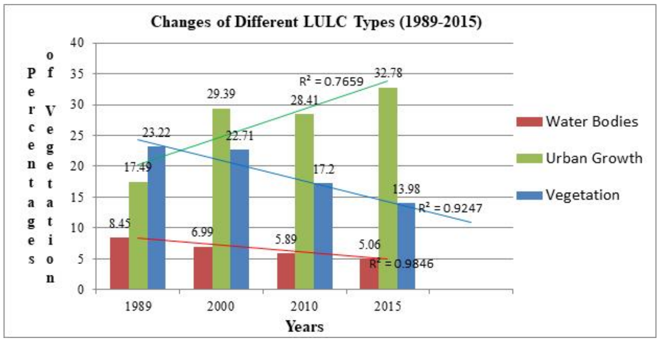

Figure 4: The Changes of different LULC with regression (R) value. The R2 value of 0.765, 0.924 and 0.984 indicates the correlation of different year's LULC changes for urban growth, vegetation and water bodies respectively.

Ground Observations and Accuracy Assessment

Our ground observations correlated well with the remotely sensed LULC types especially for thematic map of 2015. The 23 ground observations have been used as a reference to calculate the accuracy for the observed LULC from LULC maps. Accuracy assessment is vital to validate the remotely sensed data with ground observation or other ground truth data. We found following level of accuracy (Table 4) using ERDAS IMAGINE software:

Table 4: Accuracy Analysis of LULC

	Referenced Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Water Body	2	1	1	50%	100%
Bare Lands and Others	10	11	9	90%	81.82 %
Urban Structures	8	9	7	87.50%	77.78 %
Vegetation	3	2	2	66.67%	100%
Totals	23	23	19		

Overall classification accuracy is about 82.61%. Like classification accuracy, the kappa statistics value gives the assessment of accuracy of remotely sensed data with referenced ground truth data. A value of "1" indicates the best possible accuracy with the ground truth data. Overall Kappa statistics of the observed landuse- landcover has been given below in Table 5.

Table 5: Kappa analysis results for LULC.

Class Name	Kappa Value
Water Body	1.0000
Bare Lands and Others	0.6783
Urban Structures	0.0000
Vegetation	0.6593

Conclusion

The study reveals several changes of LULC in a period of 26 years. Though there was some limitation because of the coarser resolution of Landsat images and mixed pixels, we have found significant results from this research. We have figured out a decrease of water bodies in terms of percentages of 40.06%. We have also observed decrease of vegetation with a percentage of 39.81%. At the same time the urban areas have been increased by percent of 87.48%. The losses of vegetation and water bodies are mostly the impact of rapid and unplanned urbanization. The peripheral part of the city has affected due to losses of vegetation and water bodies whereas urban growth has been expanded in such areas. Field observation of LULC was also consistent with the satellite based observation of LULC and an overall accuracy of 82.61% has been found. The study can be further improved by using satellite images of finer resolution and integrating more ground data.

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