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Technical Paper

Identifying Most Influential Land Use Parameters Contributing Reduction of Surface Water Bodies in Rajshahi City, Bangladesh: A Remote Sensing Approach



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Abstract

Surface water bodies are one of the irreplaceable natural resources for human survival, and it extensively reduces with increasing the world population. This study modeled the spatiotemporal changes of land use / land cover (LULC) and identified the most influential LULC parameters, which contributes in the reduction of surface water bodies using the Landsat 4 and 5 TM and Landsat 8 OLI images (1992-2017). Rajshahi City Corporation is situated in the Northern piece of Bangladesh. A maximum likelihood supervised images classification algorithm was used for detection of changes in LULC. Matrix union technique was used for identifying the prominent LULC parameters. About 14% of water bodies were filled up in twenty-five year (1992-2017) due to rapid urbanization in Rajshahi City Corporation area. This study can provide an essential move towards necessary actions for preservation of surface water bodies to maintain the ecological balance and environmental sustainability.

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1 INTRODUCTION

Metropolises are engines of development. The dynamic development of urban areas occurs because of the unavoidable changes allocated by many land use /land cover (LULC) parameters (Aboelnour and Engel, 2018; Rahman et al., 2018). LULC change examinations one of the huge apparatuses to survey worldwide change in different spatial-temporal scales (Lambin, 1997; Lambin and Ehrlich, 1997). It reflects the complex interactions of dimensions of human activities and its impact on environment (Xiao et al., 2006). LULC change configurations are depend on natural and socioeconomic expansions accelerated by space and time (Aboelnour and Engel, 2018; Allam et al., 2019).

One of the major parameters for LULC change is rapid urbanization, especially in a developing country. The expansion in population prompts the weights on urban region, farming area, and water assets which consequently subsidizes to LULC changes (Msofe et al., 2019; Sharma, 2019).

Past few decades have witnessed many changes at global scale. The global water resources consumption will be increased by 1.33 times in 2025 when compared to 2070 km³/year in 1995 (Yan et al., 2019). In the past decades, the temperatures have been constantly mounting across the global temperature, and rainfall and precipitation patterns have become unpredictable. The available water resources have become gradually

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limited; with the economic developments and rising population the consumption and usage of the water resources is continuously increasing (Li and Qian, 2018; Liu et al., 2019). The sustainable management of the available water resources is thus of prime importance. Water is an essential natural resource with limited availability. Water bodies play an essential role in the ecological environment and LULC change significantly impact on surface water bodies in rapid urbanized area (Li and Qian, 2018; Liu et al., 2019; Yan et al., 2019). This sort of changes in water bodies extraordinarily influences the neighborhood and local conditions, which would in the long run influence on the worldwide condition. Substantial reduction of surface water bodies mostly because of human-induced LULC changes impacting the worldwide carbon cycle and adding environmental CO₂ (Alves and Skole, 1996; Dannenberg et al., 2018). It is therefore fundamental to recognize most persuasive LULC parameter contribute to reduction of surface water bodies with the goal that its impact on the earthbound biological community can be observed, and main LULC parameters can be defined (Goudie, 2018; Muttitanon and Tripathi, 2005).

The massive demographic development and rapid urbanization causes serious problem to the natural resources especially in developing countries like Bangladesh (Kafy, 2018; Rahman et al., 2018). Rajshahi is one of the largest metropolitan city of Bangladesh currently facing uncontrollable urban growth. The developing cities are also facing urban sprawl which causes an adverse effect on surface water bodies and environmental sustainability (Kafy, 2018). Different land cover change results in declination of surface water bodies by increasing the impervious surface as well as the built-up area (Faridatul and Jahan, 2014). In the last decades, Remote Sensing (RS) and GIS techniques have been used extensively for classifying land cover changes. This classification technique is very helpful to detect the water bodies demolishment resultant from rapid increase in different LULC (Ahmed and Dewan, 2017; Kafy, 2018; Kafy and Ferdous, 2018; Kafy et al., 2018; Mahmud et al., 2011).

Different Geographic Information System (GIS) and Remote Sensing (RS) applications to water resources have achieved throughout the years, and the applications effectively light up the probability of GIS and RS innovation (Rahaman et al., 2018). Ahmed et al. (2013) used Landsat TM and ETM+ to monitor urban growth and temperature changes in the capital city of Dhaka (Ahmed et al., 2013). Mahmud et al. (2011) have identified the spatiotemporal changes of wetland in Dhaka City using GIS and RS (Mahmud et al. 2011). Dewan and Corner (2013) write a book on geospatial perspectives on urbanization, environment and health based on Dhaka megacity (Dewan and Corner, 2013). The information acquired from GIS and RS application provides an updated inventory about the previous and current LULC resources that exist and used by the human (Cyr-Gagnon and Rodriguez, 2019; Rahaman et al., 2018; Singh, 2018; Yan et al., 2019).

This study aims at an integration of RS datasets and GIS techniques to detect the decadal changes in water bodies of Rajshahi City Corporation (RCC) and describes the importance of surface water bodies to establish RCC more sustainable in the near future. The study illustrates the extraction of the persistence of the water bodies over a time using Remote Sensing (RS) images. The application of Geographic Information System (GIS) is helpful to understand the decreasing pattern of water bodies which supports in decision making and achieve sustainable communities in Bangladesh.

2 STUDY AREA

Rajshahi is one of the biggest metropolitan city of Bangladesh which lies between 24°07' to 24°43'N and 88°17' to 88°58'E (BBS, 2011). It was one of the first Municipalities in Bangladesh, established in 1876 and declared as a City Corporation (48.02 km²) in 1987 (BBS, 2013). The region comprises of Barind tract, Diara and Char lands (Figure 1). Rajshahi City situated on the bank of waterway Padma (Clemett et al., 2006; Faridatul and Jahan, 2014). The atmosphere of the region is tropical and it encounters three characterized seasons: (1) sweltering climate from February to June, (2) stormy season from July to October and (3) winter season from November to January. The summer is a lot rainier than the winter in Rajshahi (Ferdous and Baten, 2011). The normal yearly temperature in Rajshahi is 25.8°C with 1419mm of precipitation yearly (Aboelnour and Engel, 2018; Ayub and Miah, 2011; Mahmud et al., 2011). Geological stability encompasses hard rocks having unfavorable hydraulic pressure characterized by poor to moderate groundwater potentials (Haque et al., 2012; Rasel, et al., 2015). The number of water bodies decreased year after years due to urbanization in RCC area (Kafy, 2018; Kafy et al., 2018). 373 ponds were observed in the year 2011 (Kafy et al., 2018; BBS, 2013). Most of the wetland areas were converted into the built-up area which negatively affected the environmental suitability (Kafy et al., 2018).

3 DATA AND METHODOLOGY

This study deals with various multi-temporal Landsat 4 and 5 TM and Landsat 8 OLI satellite images (30m resolution) gained from the USGS website (<https://earthexplorer.usgs.gov>) for the years 1992, 1997, 2002, 2007, 2012 and 2017. The images were captured in cloud free late autumn (September, October and November) (Kafy, 2018; Kafy and Ferdous, 2018) and used to prepare LULC maps. The images were processed in ERDAS Imagine 15 software and final outputs mapped in ArcMap 10.6. The cloud coverage of these images was less than 10% and useful to avoid the atmospheric correction that could affect the accuracy of the classification (Allam et al., 2019; Foody, 2002). All images were geometrically corrected to WGS84 of UTM zone 46N. All these images were captured with maximum one month interval for six different years to avoid the seasonal variation (Kafy et al., 2017).

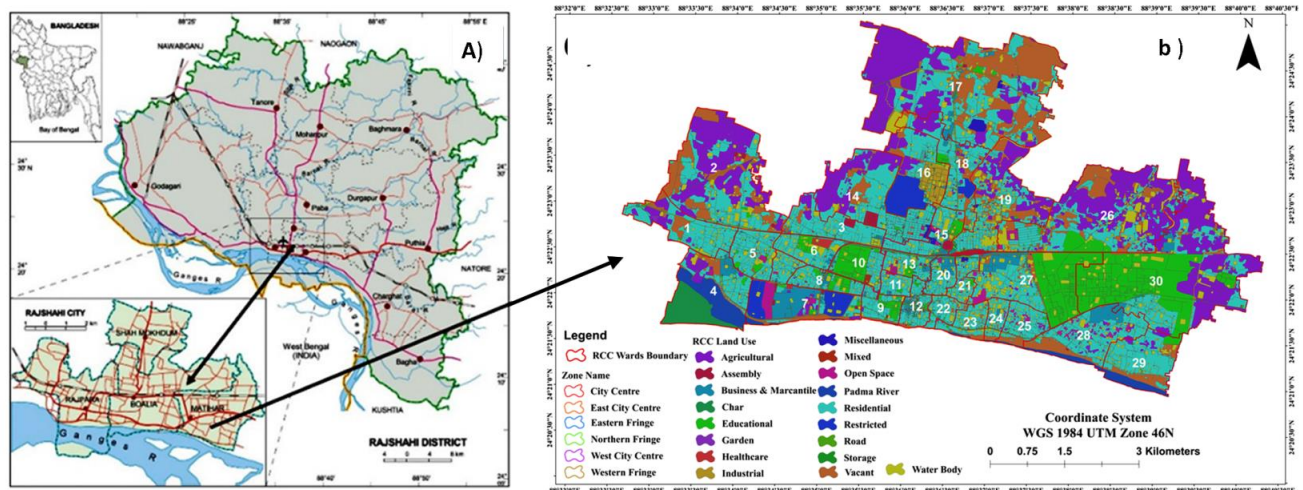


Figure 1. Location of Rajshahi City Corporation (RCC) area: (a) Bangladesh and Rajshahi District and (b) RCC ward boundary and LULC

Band 1 of Landsat 4 and 5 TM satellite and Band 1, 2 and 8 of Landsat 8 OLI images makes noise in the image and create difficulties in taking signature for LULC classification (Estoque and Murayama, 2015; Fisher *et al.*, 2016; Jia *et al.*, 2014; Zhu *et al.*, 2016). Therefore, these bands have not been taken into image processing for change detection of water bodies in the study area (Kafy *et al.*, 2017).

3.1 Image Classification

Four broad categories of LULC (water body, built-up area, vegetation and agricultural land and bare soil) are selected to map the study area. LULC maps of the RCC were prepared for 1992, 1997, 2002, 2007, 2012 and 2017 using Maximum Likelihood Supervised Classification (MLSC) technique in ERDAS Imagine 15 software. Each classified map evaluated for accuracy assessment using available field data and Google Earth images over randomly selected 350 points (Table 1) (Kafy, 2018; Kafy *et al.*, 2017).

3.2 Change Detection using Matrix Union

A change detection technique should be appropriate for the study to identify the water body fill up locations associated with major LULC changes. Application of matrix union tool established in ERDAS Imagine 15 software. This tool is helpful to identify the transformation of number of pixels from one class to another class. Conversion of water body to built-up area, vegetation and agricultural land and bare land classes were estimated after post-classification change in LULC between 1992-1997, 1997-2002, 2002-2007, 2007-2012, 2012-2017 and 1992-2017. These changes were shown in six maps. The locations of water body fill-up in respect of increase of built-up area, vegetation and agricultural land and bare land were detected and mapped in Arc GIS 10.6.

4 RESULTS AND DISCUSSIONS

4.1 LULC Change Analysis

Changes in LULC (1992, 1997, 2002, 2007, 2012 and 2017) can be easily determined using classified images. Water bodies are reducing gradually and replaced by built-up area, vegetation and agricultural land and bare land during the urbanization process of Rajshahi city to fulfill the needs of rapid growth of the city and population (Figure 2). Total water body in Rajshahi was 6.12 km² in 1992 and urban area was 8.8542 km². A little change over the water body was noticed in 2006 which reduced to 4.4991 km². A significant change observed in a last decade. Human settlement encroached upon water body and reduced it to 2.0151 km². Urban area increased to 16.6716 km², which is double than the year of 1996.

The accuracy of classified maps were estimated to verify reliability and acceptance (Allam *et al.*, 2019; Owojori and Xie, 2005). It was estimated based on field check data and Google Earth images. Information about 350 ground truth data points were collected in May 2017 using the stratified random sampling techniques. The reference data and classified images were compared to estimate user's and producer's accuracy (Table 1) (Bakr *et al.*, 2010). Non-parametric Kappa statistics also calculated using ERDAS imagine 15 software. Accuracy was estimated about 85% with no individual class less than 70% for LULC classes mapped using Landsat data, (Foody, 2002; Story and Congalton, 1986). The estimated accuracy of the classified images for six years ranges from 87 to 91 % representing very good results.

4.2 Conversion of Water Bodies into Different Influential LULC

4.2.1 Five years interval

LULC changes from 1992 to 2017 are significantly different in dissimilar areas of water body, built up area,

vegetation and agricultural land and bare lands (Figure 3). The categories: vegetation and agricultural land and water body were reduces from 1992 to 2017 and the

built-up area increased due to upsurge of urbanization. The bare lands are also suppressing show larger amount.

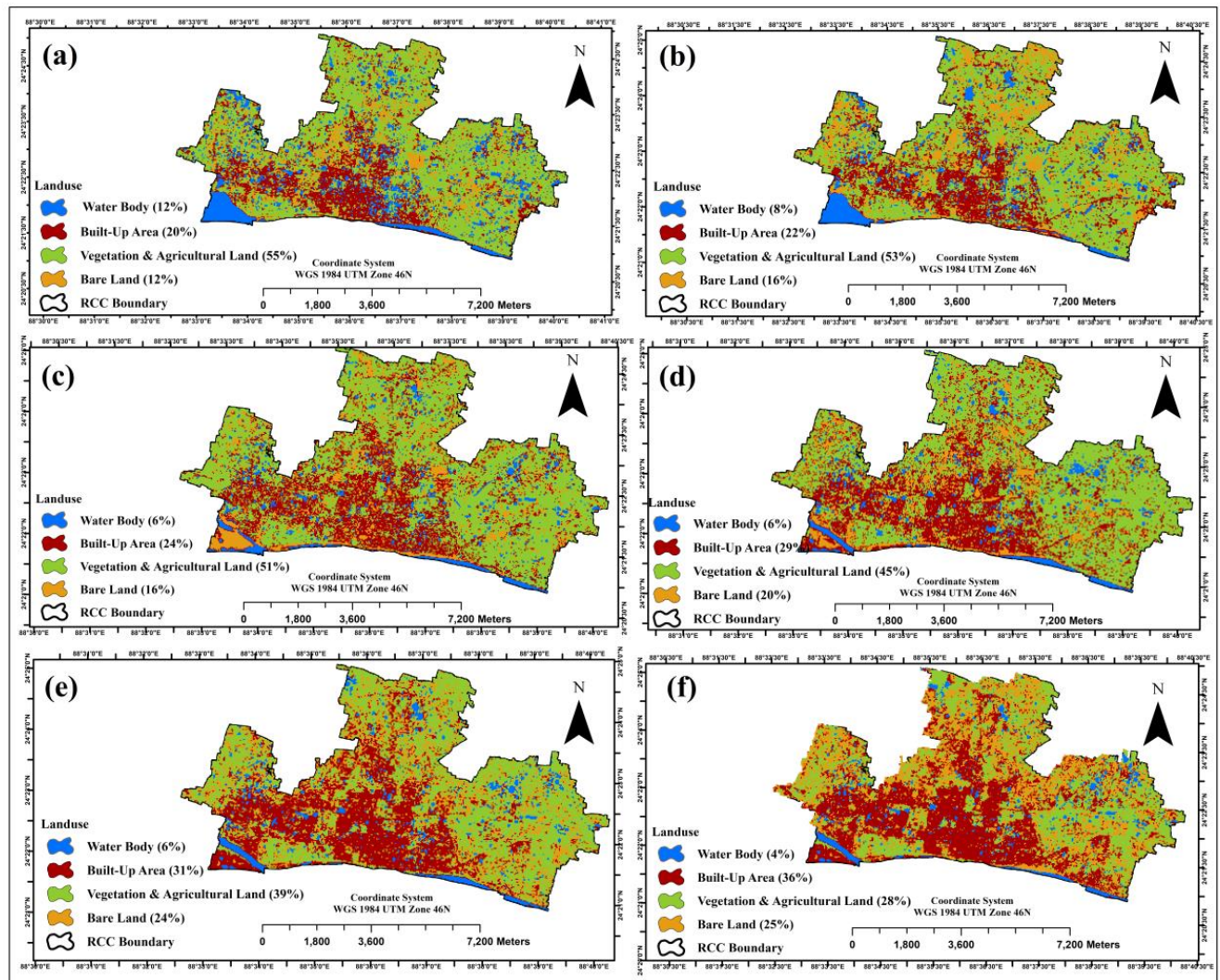


Figure 2. Land use land cover map of Rajshahi City Corporation in 1992 (a), 1997(b), 2002(c), 2007(d), 2012(e) and 2017(f)

Table 1. Classification accuracy

Year	User Accuracy (%)				Producer Accuracy (%)				Overall Accuracy (%)	Overall Kappa Statistics
	Water body	Built-up area	Vegetation	Bare soil	Water body	Built-up area	Vegetation	Bare soil		
1992	100	75	90	95	100	100	100	67	90	0.8887
1997	100	85	85	80	100	100	71	100	90	0.9001
2002	100	80	80	80	100	100	83	100	93	0.9333
2007	100	75	100	85	100	100	100	67	88	0.8767
2012	100	100	90	80	100	100	71	100	88	0.8800
2017	100	85	100	80	100	100	83	100	91	0.9133

The water bodies are filling up due to conversion of land of RCC area for estimated with five years interval (1992-1997, 1997-2002, 2002-2007, 2007-2012 and 2012-2017) (Figure 4). The filled up areas are converted into built-up area, vegetation and agriculture and bare lands.

In 1992-1997, water bodies are converted mostly into built-up areas (3.4%) (Figure 4a), in 1997-2002, converted into built-up area and vegetation and agriculture (1.4%) (Figure 4b). Water bodies are converted probably into built-up areas estimated about 1% in 2002-2007 (Figure 4c), (0.8%) in 2007-2012 (Figure 4d) and 3.5% in 2012-2017 (Figure 4f). Most of the conversions of the water bodies were observed into built-up area in last few years (Figure 5); 1.73 sq. km in 2012-17 and 1.64 sq. km in 1992-1997 (Figure 5).

4.2.2 Ten years interval

The increase in built-up area was observed about 2.32 sq. km in 1992-2002 and 2.10 sq. km in 2007-2017 (Figure 6). The bare lands are also increased. Therefore, both manmade and natural causes are responsible for filling up the ponds.

4.2.3 Twenty years interval

The visible changes are noticed in conversion of built-up area, vegetation and agricultural land and bare land from water body in twenty years interval. Despite of the increase of built-up area and bare land (described as the above 5 years and 10 years interval), the increase level of vegetation and agricultural land is also noticed (0.28 sq. km to 0.99 sq. km) (Table 2). Perhaps it can be estimated that the water bodies are filled up by the farmers to grow crops.

4.2.4 Total loss of water bodies

Water body losses were estimated using RS and GIS techniques for 25 years. Estimated converted area of water bodies to built-up areas is 13.84% (Figure 8) areas due to rapid urbanization without superiority on conservation rules. The conversion of water body into bare land is 10.46% (3.5 km²) of the total area (Table 3) due to natural changes. About 3.82% water bodies are converted to vegetation and agricultural land.

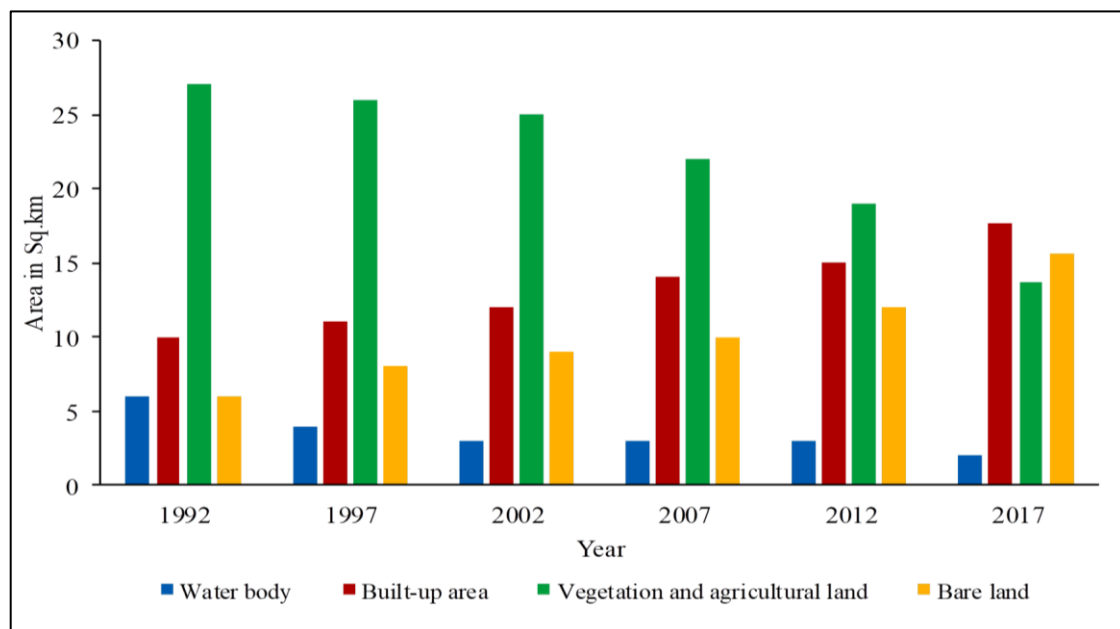


Figure 3. Change of area in different LULC

Table 2. Loss of water bodies

Water bodies converted into	Change (%) in different years interval					
	Ten years			Twenty years		Twenty five years
	1992-2002	2002-2012	2007-2017	1992-2012	1997-2017	1992-2017
Built-up area	4.72	1.82	4.30	4.13	4.89	13.84
Vegetation and Agricultural Land	1.77	0.35	0.81	0.56	2.03	3.82
Bare land	3.30	1.36	3.23	2.76	3.77	10.46
Total	9.79	3.53	8.34	7.45	10.69	28.12

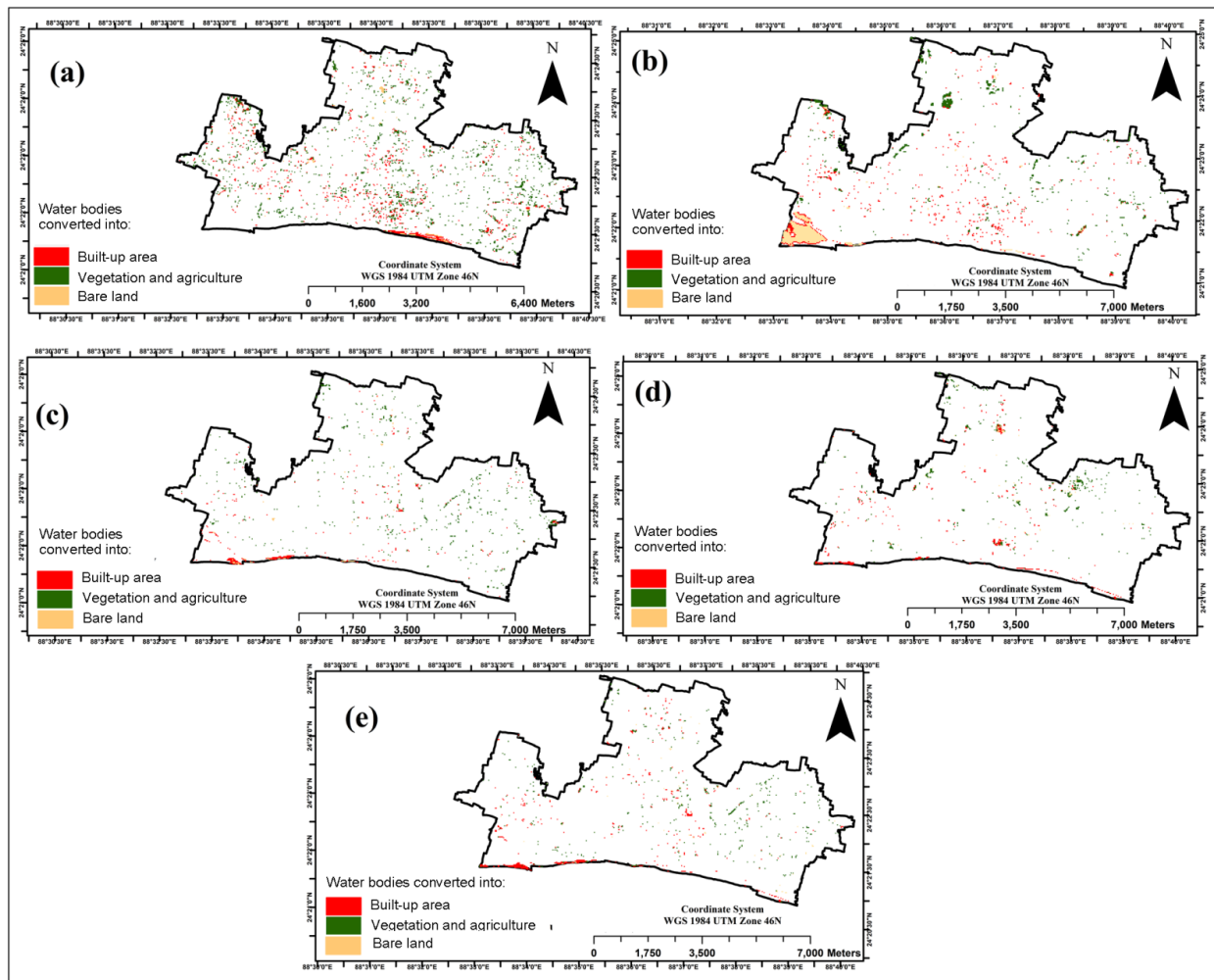


Figure 4. Water body fill up for influential LULC parameters (five years interval): (a) 1992-1997, (b) 1997-2002, (c) 2002-2007, (d) 2007-2012 and (e) 2012-2017

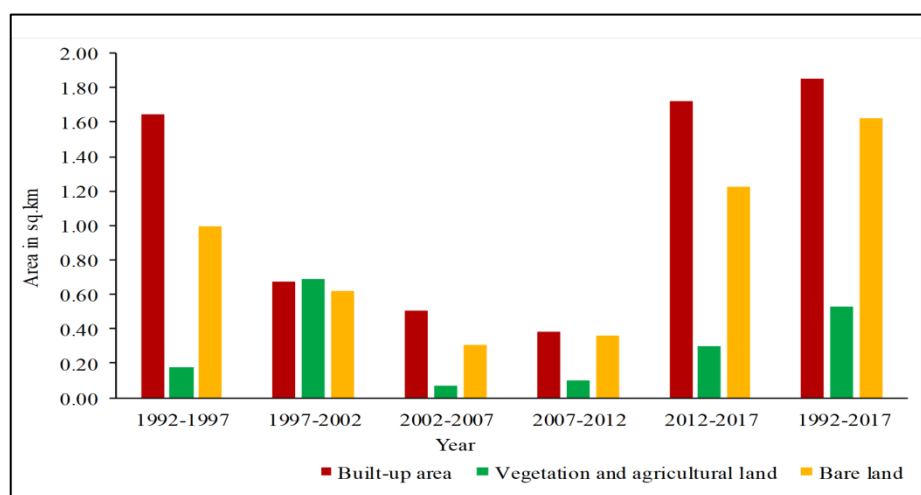


Figure 5. Conversion of water bodies into influential LULC parameters (five years interval)

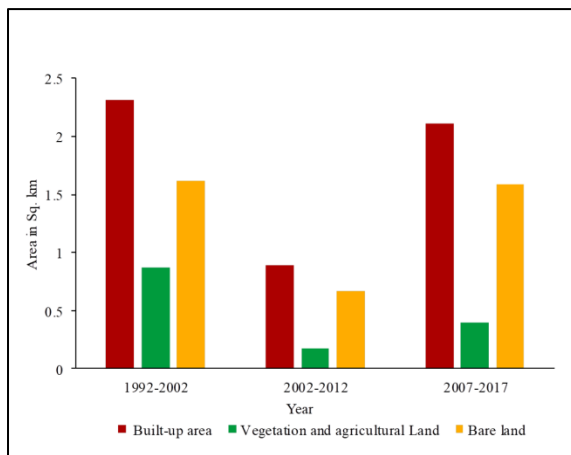


Figure 6. Conversion of water bodies into influential LULC parameters (ten years interval)

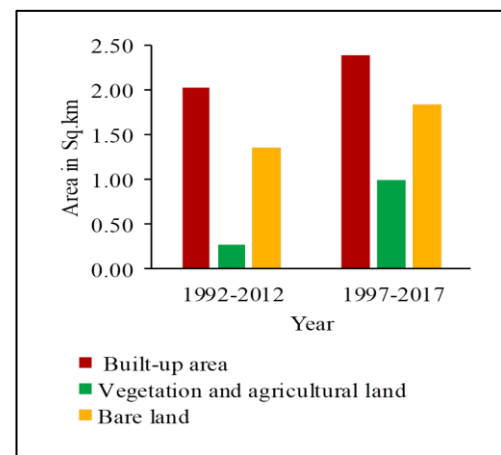


Figure 7. Conversion of water bodies into influential LULC parameters (twenty years interval)

Table 3. Loss of water bodies in 25 years

Water bodies converted into	Area losses	
	km ²	%
Built-up area	6.8	13.8
Vegetation and agricultural land	1.9	3.8
Bare land	5.1	10.5
Total	13.8	28.1

5 CONCLUSION

The study shows that rapid urbanization is the main cause of water body demolition in the study area. Water bodies are critical component to enhance the quality of the physical and social environment of the city. It carries significant aesthetic and environmental value by providing fresh air in its surrounding areas. The water bodies are often seen as a burden and constraint in the process of growth and development of cities and towns in recent years and getting less importance and transforming into other parameters of LULC. This study illustrates the spatiotemporal changes of land cover and identified the most influential LULC parameter which contributes to the reduction of the surface water body. About 13.84% of water bodies were converted into built-up area during the last twenty five years due to urbanization. Biodiversity damage, severe environmental humiliation, water logging, metropolitan flooding and loss of valuable water resources are the serious effects of water body losses. In order to improve the ecological balance of the RCC area, surface water bodies should be conserved and scenic views around the water bodies need to be established to create more attraction for urban dwellers.

This study provides reliable LULC change analysis useful and necessary in the subsequent revision of biodiversity conservation and policy implementation. Government and policymakers need to take essential measures to protect the water bodies from being converted into different LULC parameters. Graduation and post-graduation academic curriculum should also be reinforced by including topics such as water resource management and planning, needs of recent environmental challenges faced by water resources, etc. Finally, enforcement of water related regulations and strengthening environmental awareness will be helpful to reduce the loss of water bodies. This study will also be useful for policy maker to bring effective initiative by providing adequate insight regarding the pattern and reason for water body conversion. Both the local government and people need to join hands to solve the issues pertaining to water bodies.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

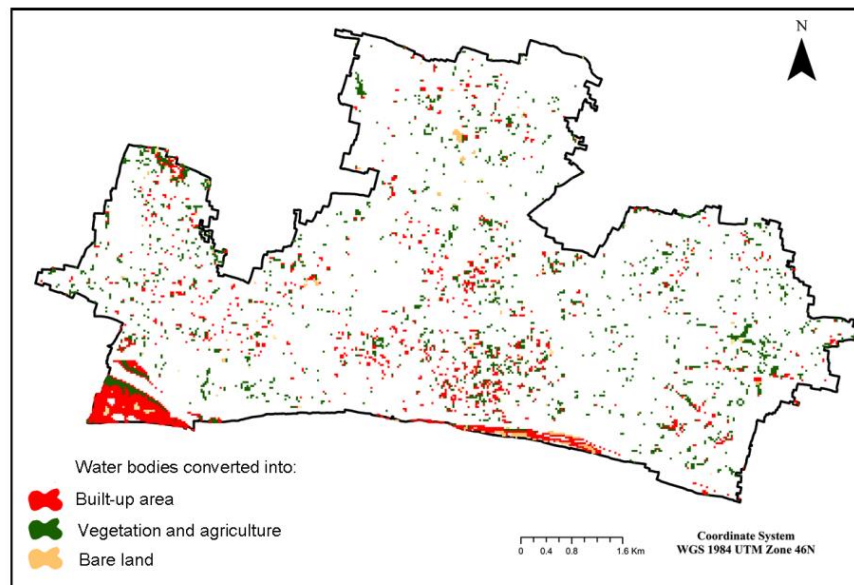


Figure 8. Conversion of water bodies into influential LULC parameter in 25 years

ABBREVIATIONS

GIS: Geographic Information System; **LULC:** Land Use / Land Cover; **MLSC:** Maximum Likelihood Supervised Classification; **RCC:** Rajshahi City Corporation; **RS:** Remote Sensing; **TCC:** True Color Composite.

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