Remote Sensing of Land
Homepage: www.gathacognition.com/journal/gcj1
http://dx.doi.org/10.21523/gcj1

Technical Paper

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

Abdulla-Al Kafy[1,2]*, Muhaiminul Islam[1], Abdur Rouf Khan[1], Lamia Ferdous[1], Md. Mamun Hossain[1]

1. Department of Urban and Regional Planning, Rajshahi University of Engineering and Technology (RUET), Rajshahi-6204, Bangladesh.
2. Rajshahi Development Authority, Bonolota Commercial Area, Rajshahi-6203, Bangladesh.

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.

Article history

Received: 18 February 2019;
Final form: 26 March 2019;
Accepted: 05 April 2019.

Keywords

Water Bodies;
Remote Sensing;
LULC;
Change Detection;
Urbanization;
Preservation;
Rajshahi.

Editor(s)

Suresh Kumar
Vijay Bhagat

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 km^3/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

* Author address for correspondence
Department of Urban and Regional Planning, Rajshahi University of Engineering and Technology (RUET), Rajshahi-6204, Bangladesh.
Tel.: + 88 1771411138
Emails: abdulla-al.kafy@localpathways.org (*A. Kafy* -Corresponding author); muhaiminul.urp13@gmail.com (*M. Islam*); roufkhanrafi@gmail.com (*A. Khan.*), lamiaferdous127030@gmail.com (*L. Ferdous*); hossainmamun624@gmail.com (*M. Hossain*).

http://dx.doi.org/10.21523/gcj1.18020202

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 CO_2 (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 km^2) 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).

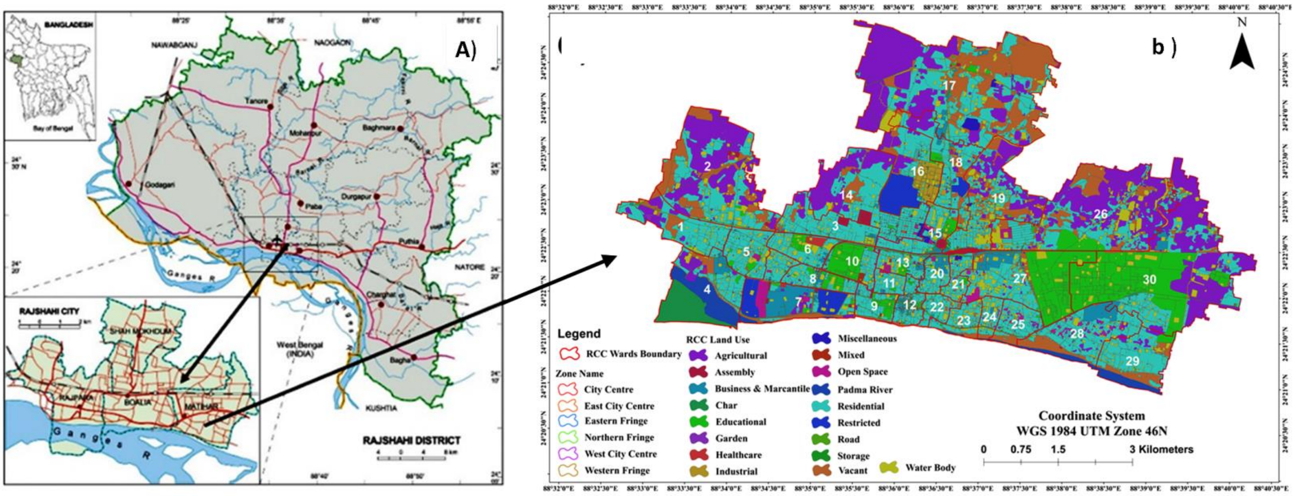

Figure 1. Location of Rajshahi City Corporation (RCC) area: (a) Bangladesh and Rajshahi District and (b) RCC ward boundary and LULC

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 Dection 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 estabilshed 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 km^2 in 1992 and urban area was 8.8542 km^2. A little change over the water body was noticed in 2006 which reduced to 4.4991 km^2. A significant change observed in a last decade. Human settlement encroached upon water body and reduced it to 2.0151 km^2. Urban area increased to 16.6716 km^2, 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.

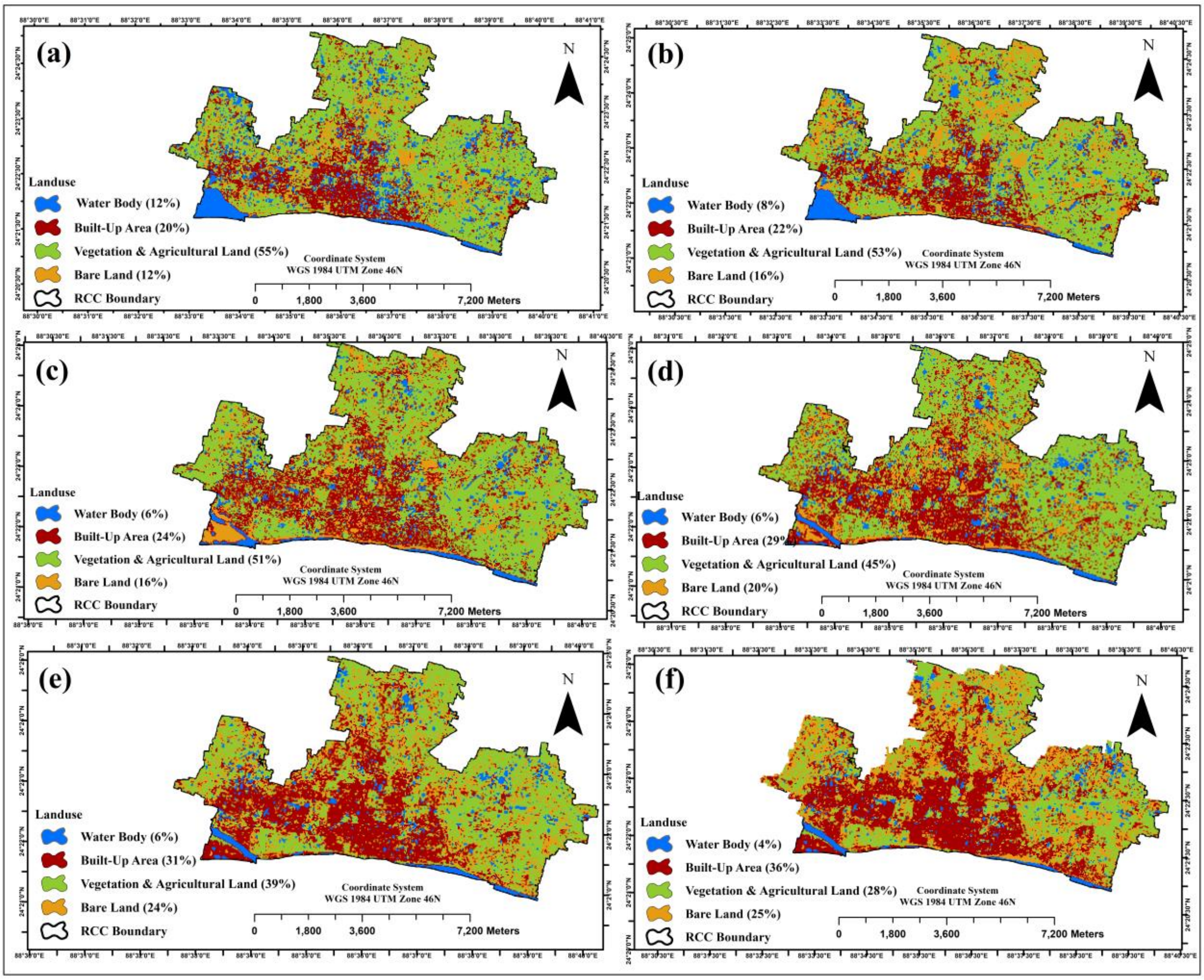

Figure 2. Land use land cover map of Rajshahi City Corporation in 1992 (a), 1997(b), 2002(c), 2007(d), 2012(e) and 2017(f)

Table 1. Classification accuracy

	User Accuracy (%)				Producer Accuracy (%)					
Year	Water body	Built-up area	Vegetation	Bare soil	Water body	Built-up area	Vegetation	Bare soil	Overall Accuracy (%)	Overall Kappa Statistics
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 km^2) of the total area (Table 3) due to natural changes. About 3.82% water bodies are converted to vegetation and agricultural land.

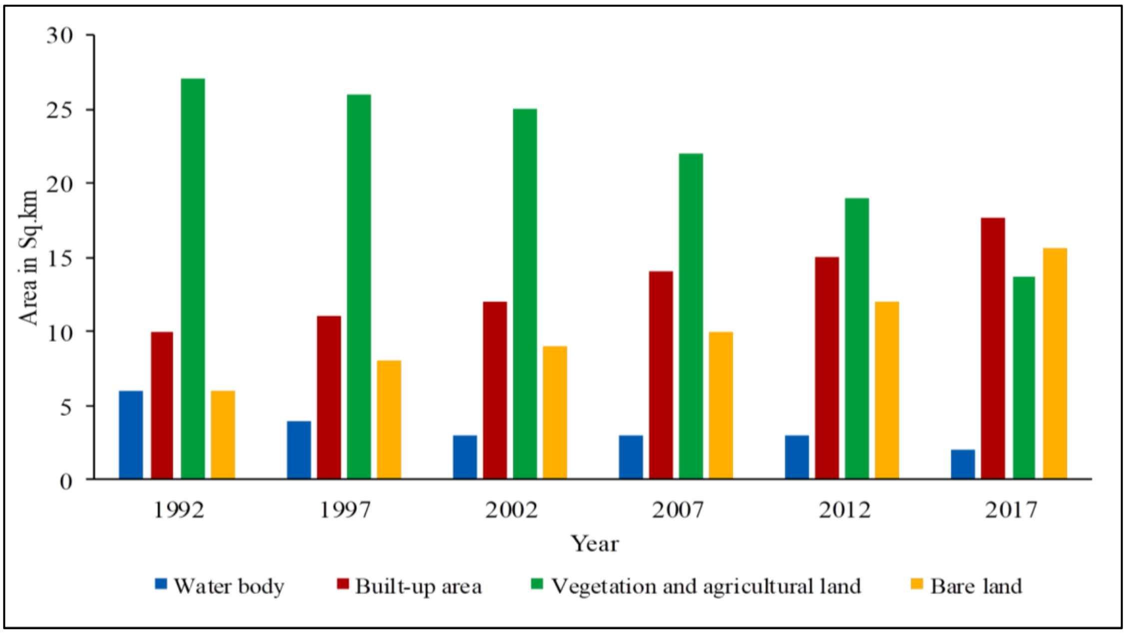

Figure 3. Change of area in different LULC

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

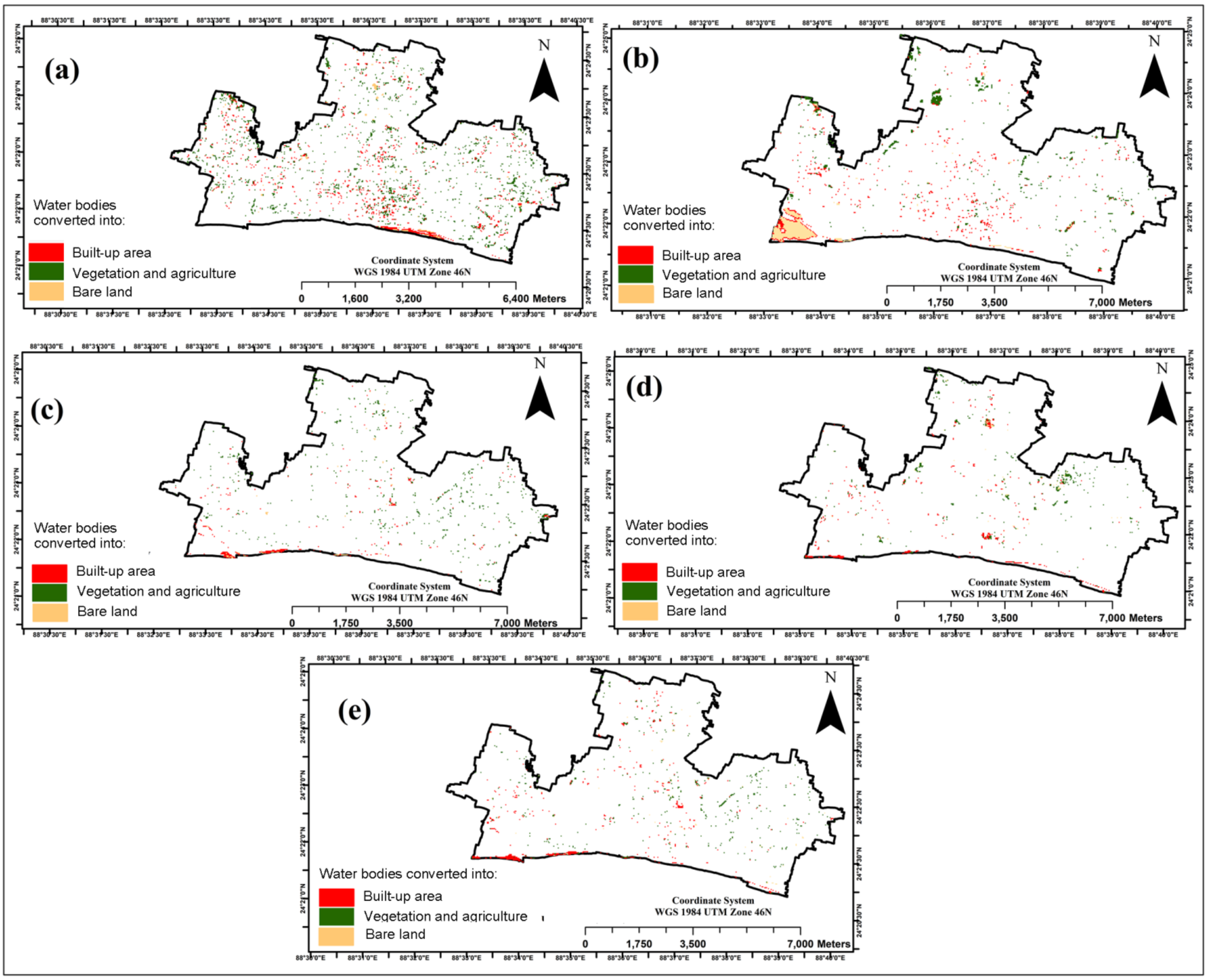

Figure 4. Water body fill up for influential LULC parameters (five years interval): (a) 1992-1997, (b) 1997-2002, (c) 2002-2007, (d) 2007-2012 and (e) 2012-2017

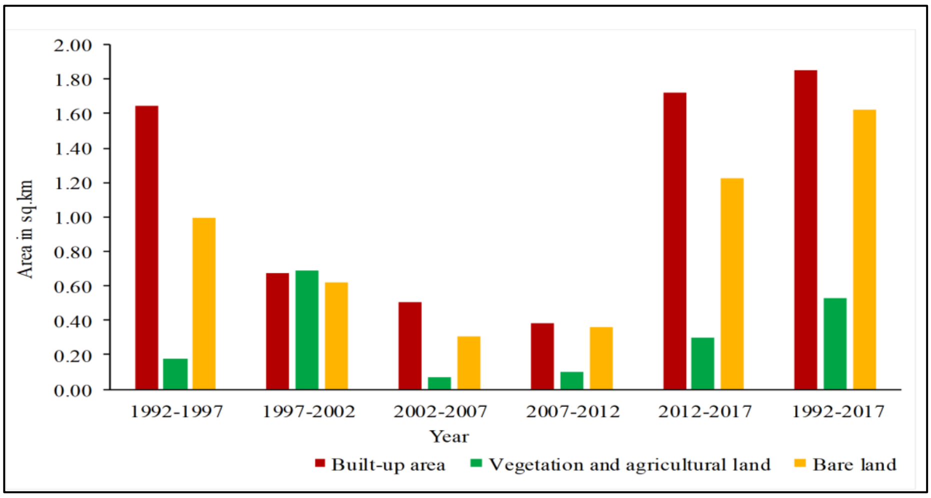

Figure 5. Conversion of water bodies into influential LULC parameters (five years interval)

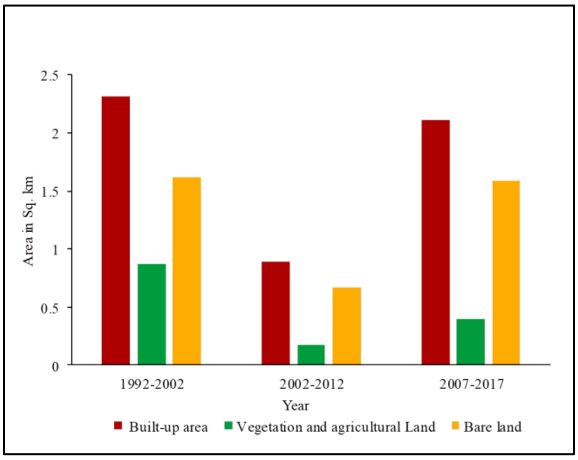

Figure 6. Conversion of water bodies into influential LULC parameters (ten years interval)

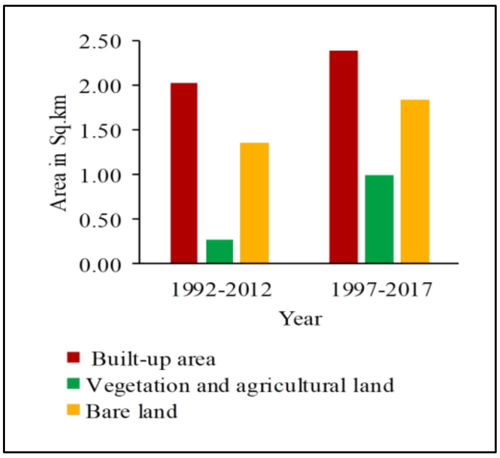

Figure 7. Conversion of water bodies into influential LULC parameters (twenty years interval)

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.

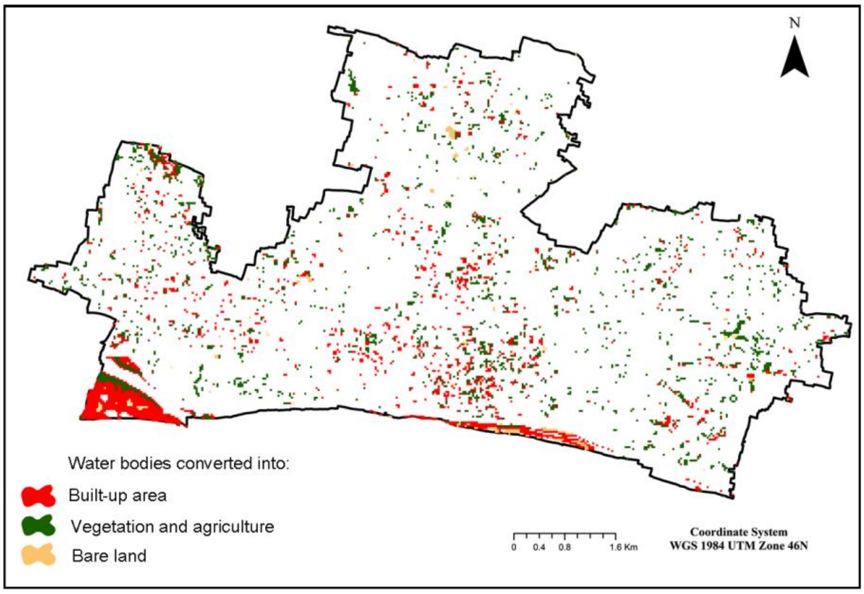

Figure 8. Conversion of water bodies into influential LULC parameter in 25 years

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.

ACKNOWLEDGEMENTS

Authors are thankful to the United States Geological Survey (USGS) for Landsat images.

REFERENCES

Aboelnour, M., and Engel, B. A., 2018. Application of remote sensing techniques and geographic information systems to analyze land surface temperature in response to land use/land cover change in Greater Cairo Region, Egypt. *Journal of Geographic Information System, 10* (01), 57-88. DOI: https://doi.org/10.4236/jgis.2018.101003

Ahmed, B. and Dewan, A., 2017. Application of bivariate and multivariate statistical techniques in landslide susceptibility modeling in chittagong city corporation, bangladesh. *Remote Sensing,* 9(4), 304. DOI: https://doi.org/10.3390/rs9040304

Ahmed, B., Kamruzzaman, M., Zhu, X., Rahman, M. and Choi, K., 2013. Simulating land cover changes and their impacts on land surface temperature in Dhaka, Bangladesh. *Remote Sensing,* 5(11), 5969-5998. DOI: https://doi.org/10.3390/rs5115969

Allam, M., Bakr, N. and Elbably, W., 2019. Multi-temporal assessment of land use/land cover change in arid region based on landsat satellite imagery: Case study in Fayoum Region, Egypt. *Remote Sensing Applications: Society and Environment, 14*, 8-19. DOI: https://doi.org/10.1016/j.rsase.2019.02.002

Alves, D. S. and Skole, D. L., 1996. Characterizing land cover dynamics using multi-temporal imagery. *International Journal of Remote Sensing, 17*(4), 835-839. DOI: https://doi.org/10.1080/01431169608949049

Ayub, R. and Miah, M. M., 2011. *Effects of change in temperature on reference crop evapotranspiration (ETo) in the northwest region of Bangladesh.* Paper presented at the 4th Annual Paper Meet and 1st Civil Engineering Congress, December.

Bakr, N., Weindorf, D., Bahnassy, M., Marei, S. and El-Badawi, M., 2010. Monitoring land cover changes in a newly reclaimed area of Egypt using multi-temporal Landsat data. *Applied Geography, 30*(4), 592-605. DOI: https://doi.org/10.1016/j.apgeog.2009.10.008

BBS [Bangladesh Bureau of Statistics], 2011. Statistical Yearbook of Bangladesh. *Statistics Division, Ministry of Planning, Dhaka, Government of the People's Republic of Bangladesh*.

BBS [Bangladesh Bureau of Statistics], 2013. District Statistics 2013, Rajshahi. Bangladesh Bureau of Statistics.

Clemett, A., Amin, M. M., Ara, S. and Akan, M. M. R., 2006. Background information for Rajshahi City, Bangladesh. *WASPA Asia Project Report, 2*, 1-29.

Cyr-Gagnon, J., and Rodriguez, M. J., 2019. Optimizing data management for municipal source water protection. *Land Use Policy*. DOI: https://doi.org/10.1016/j.landusepol.2018.12.035

Dannenberg, M. P., Song, C. and Hakkenberg, C. R., 2018. A long-term, consistent land cover history of the Southeastern United States. *Photogrammetric Engineering & Remote Sensing, 84*(9), 559-568. DOI: https://doi.org/10.14358/PERS.84.9.559

Dewan, A. and Corner, R., 2013. *Dhaka megacity: Geospatial perspectives on urbanisation, environment and health*: Springer Science and Business Media.

Estoque, R. C. and Murayama, Y., 2015. Classification and change detection of built-up lands from Landsat-7 ETM+ and Landsat-8 OLI/TIRS imageries: A comparative assessment of various spectral indices. *Ecological indicators, 56*, 205-217. DOI: https://doi.org/10.1016/j.ecolind.2015.03.03

Faridatul, I. and Jahan, S., 2014. People's perception regarding the development of community facilities: A case study of Rajshahi City Corporation. *J. Bangladesh Inst. Plan.* 7, 1-16.

Ferdous, M. and Baten, M., 2011. Climatic variables of 50 years and their trends over Rajshahi and Rangpur Division. *Journal of Environmental Science and*

Natural Resources, 4(2), 147-150. DOI: https://doi.org/10.3329/jesnr.v4i2.10165

Fisher, A., Flood, N. and Danaher, T., 2016. Comparing Landsat water index methods for automated water classification in eastern Australia. *Remote sensing of environment*, 175, 167-182. DOI: https://doi.org/10.1016/j.rse.2015.12.055

Foody, G. M., 2002. Status of land cover classification accuracy assessment. *Remote sensing of environment*, 80(1), 185-201. DOI: https://doi.org/10.1016/S0034-4257(01)00295-4

Goudie, A. S., 2018. *Human impact on the natural environment*. John Wiley and Sons.

Haque, M. A. M., Jahan, C., Mazumder, Q., Nawaz, S., Mirdha, G., Mamud, P. and Adham, M., 2012. Hydrogeological condition and assessment of groundwater resource using visual modflow modeling, Rajshahi city aquifer, Bangladesh. *Journal of the Geological Society of India, 79*(1), 77-84. DOI: https://doi.org/10.1007/s12594-012-0001-7

Jia, K., Wei, X., Gu, X., Yao, Y., Xie, X. and Li, B., 2014. Land cover classification using Landsat 8 operational land imager data in Beijing, China. *Geocarto International*, 29(8), 941-951. DOI: https://doi.org/10.1080/10106049.2014.894586

Kafy, A. and Ferdous, L., 2018. *Pond Filling Locations Identification Using Landsat-8 Images In Comilla District, Bangladesh*. Paper presented at the 1st National Conference on Water Resources Engineering (NCWRE 2018) CUET, Chittagong, Bangladesh.

Kafy, A., 2018. *Importance of Surface Water Bodies for Sustainable Cities: A Case Study of Rajshahi City Corporation*. Bangladesh Institute of Planners (BIP).

Kafy, A., Ferdous, L., Faisal, A., Khan, H. and Sheel, P., 2018. *Exploring The Association of Surface Water Body Change and Rapid Urbanization in Rajshahi City Corporation (RCC) Area Using RS and GIS*. Paper presented at the 1st National Conference on Water Resources Engineering (NCWRE 2018).

Kafy, A., Rahman, M. S., and Ferdous, L., 2017. Exploring the association of land cover change and landslides in the Chittagong hill tracts (CHT): A remote sensing perspective.

Lambin, E. F. and Ehrlich, D., 1997. Land-cover changes in Sub-Saharan Africa (1982-1991): Application of a change index based on remotely sensed surface temperature and vegetation indices at a continental scale. *Remote sensing of environment*, 61(2), 181-200. DOI: https://doi.org/10.1016/S0034-4257(97)00001-1

Lambin, E. F., 1997. Modelling and monitoring land-cover change processes in tropical regions. *Progress in physical geography*, 21(3), 375-393. DOI: https://doi.org/10.1177/030913339702100303

Li, P. and Qian, H., 2018. Water resources research to support a sustainable China. *International Journal of Water Resources Development*, 34, 327-336. https://doi.org/10.1080/07900627.2018.1452723

Liu, W., Antonelli, M., Kummu, M., Zhao, X., Wu, P., Liu, J., Zhuo, L. and Yang, H., 2019. Savings and losses of global water resources in food-related virtual water trade. *Wiley Interdisciplinary Reviews: Water*, 6(1), e1320. DOI: https://doi.org/10.1002/wat2.1320

Mahmud, M. S., Masrur, A., Ishtiaque, A., Haider, F. and Habiba, U., 2011. Remote sensing and GIS based spatio-temporal change analysis of Wetland in Dhaka City, Bangladesh. *Journal of Water Resource and Protection*, 3(11), 781-787. DOI: https://doi.org/10.4236/jwarp.2011.311088

Msofe, N. K., Sheng, L. and Lyimo, J., 2019. Land use change trends and their driving forces in the Kilombero Valley floodplain, Southeastern Tanzania. *Sustainability*, 11(2), 505. https://doi.org/10.3390/su11020505

Muttitanon, W., and Tripathi, N., 2005. Land use/land cover changes in the coastal zone of Ban Don Bay, Thailand using Landsat 5 TM data. *International Journal of Remote Sensing*, 26(11), 2311-2323. DOI: https://doi.org/10.1080/0143116051233132666

Owojori, A., and Xie, H., 2005. Landsat image-based LULC changes of San Antonio, Texas using advanced atmospheric correction and object-oriented image analysis approaches. Paper presented at the 5th international symposium on remote sensing of urban areas, Tempe, AZ.

Rahaman, M. F., Jahan, C. S., Arefin, R. and Mazumder, Q. H., 2018. Morphometric analysis of major watersheds in barind tract, bangladesh: a remote sensing and GIS-based approach for water resource management. *Hydrology*, *5*(6), 86-95.

Rahman, M. S., Mohiuddin, H., Kafy, A.-A., Sheel, P. K. and Di, L., 2018. Classification of cities in Bangladesh based on remote sensing derived spatial characteristics. *Journal of Urban Management*. https://doi.org/10.1016/j.jum.2018.12.001

Rasel, H., Hasan, M., Ahmed, B. and Miah, M., 2015. Assessment of Ground Water fluctuation and Recharge due to rainfall in Barind Area under Greater Rajshahi District (North Western Part of Bangladesh). *International Journal of Civil and Environmental Engineering IJCEE-IJENS*, 13(02), 15-25.

Sharma, K., 2019. Urbanization induced land use-land cover changes in the Manipur valley and surrounding hills: A landscape metrics approach. *Environmental Change in the Himalayan Region*, 137-155, Springer.

Singh, A., 2018. Managing the salinization and drainage problems of irrigated areas through remote sensing and GIS techniques. *Ecological indicators*, 89, 584-589. DOI: https://doi.org/10.1016/j.ecolind.2018.02.041

Story, M. and Congalton, R. G., 1986. Accuracy assessment: a user's perspective. *Photogrammetric Engineering and remote sensing*, 52(3), 397-399.

Xiao, J., Shen, Y., Ge, J., Tateishi, R., Tang, C., Liang, Y. and Huang, Z., 2006. Evaluating urban expansion and land use change in Shijiazhuang, China, by using GIS and remote sensing. *Landscape and urban planning*, 75(1-2), 69-80. DOI: https://doi.org/10.1016/j.landurbplan.2004.12.005

Yan, J., Jia, S., Lv, A. and Zhu, W., 2019. Water resources assessment of China's transboundary river basins using a machine learning approach. *Water Resources Research*, 55(1), 632-655. DOI: https://doi.org/10.1029/2018WR023044

Zhu, Z., Fu, Y., Woodcock, C. E., Olofsson, P., Vogelmann, J. E., Holden, C., Wang M. and Yu, Y., 2016. Including land cover change in analysis of greenness trends using all available Landsat 5, 7, and 8 images: A case study from Guangzhou, China (2000–2014). *Remote sensing of environment, 185*, 243-257. DOI: https://doi.org/10.1016/j.rse.2016.03.036

*****