Paper ID: CE 0325

A Study on Diminishing Trend of Surface Water Sources in Northern Bangladesh using Remote Sensing

M. Kamruzzaman[1], M. Humaira[2]

[1] Department of Civil Engineering, RUET, Bangladesh (kzaman@ce.ruet.ac.bd)
[2] Department of Civil Engineering, RUET, Bangladesh (humairarojoni30@gamil.com)

Abstract:

Surface water bodies are compulsory feature for the ecosystem which can directly or indirectly control hydrological phenomena including drought, climate change, precipitation, etc. The matter of concern is the amount of surface water resources is diminishing in some drought-prone areas including the Northern region of Bangladesh due to anthropogenic activities, which can lead to a greater risk of drought. To predict the drought risk, we have assessed the past and present surface water sources using Remote Sensing of Rajshahi district as a representative of Northern Bangladesh. The analysis of land cover change from 1995 to 2020 has been done using Landsat images (Landsat 8-9 OLI/TIRS C2L2, Landsat 7 ETM+C2L2, Landsat 4-5 TM C2L2, Landsat 1-5 C2L1) from USGS Earth Explorer as data source & ArcGIS as an analysis tool. The image analysis has been done using Iso-cluster unsupervised classification. The land has been classified into 4 different classes, namely built-up area; vegetation and agriculture; surface water; and bare land. For area calculation, 30m x 30m pixels have been used. Accuracy assessment has been done by user's accuracy, producer's accuracy, overall accuracy, and kappa coefficient. Google Earth pro and public map datasets have been used for ground truth data. Finally, the land cover changes have been visualized by creating maps and graphs. The result showed that the surface water bodies in the study area are decreasing at an alarming rate. The built-up areas are increasing and will be increased more in the future due to development purposes and population growth, which indicates a future threat of water scarcity and severe drought in Northern Bangladesh. So, data from the study can bring maximum output for future risk management in agriculture-based planning, food resources, and water availability. Additionally, the result of the study can be used as an informative source for future research.

Keywords: *Drought, Geographic Information System, Land cover change; Remote Sensing, Surface water.*

1 Introduction:

Surface water bodies play an important role in sustaining agricultural, industrial, and domestic water needs. So, understanding the dynamics of wetland availability and its diminishing tendencies is getting attention of researchers for successful water management and sustainable development. In recent years, population growth and economic development continue to place growing demands on water resources worldwide, including Bangladesh(Hasan et al., 2021). The water body of Bangladesh has been decreased 3.31% from year 1990 to year 2019, whereas urban area has been increased 5.18% (Hasan et al., 2021). As Rajshahi District, located in the northwestern portion of Bangladesh, it has faced more substantial challenges in recent years as a result of the falling trend of water bodies(Kamruzzaman & Ray, 2022). This tendency is ascribed to a number of issues, including overextraction, changing meteorological conditions, and insufficient recharge methods. Reliable and accurate monitoring techniques are essential to address this issue and establish educated groundwater and surface water management strategies. Remote sensing and ArcGIS software provide a potential tool for tracking and analyzing wetland changes over huge geographic areas (Ahmed & Erum, 2012). An effective analysis of land use change over time is possible using of satellite imagery and GIS-based hydrological data. Remote sensing and GIS approaches have proven to offer more accurate and cost-effective data assessments than other traditional methods and surveys(Baig et al., 2022). Remote sensing uses space-based satellites to categorize the earth's distinctive features, which can help track changes to the land surface because they continuously monitor the earth's properties(Baig et al., 2022). Landsat 8-9 OLI/TIRS C2L2, Landsat 7 ETM+C2L2,

Landsat 4-5 TM C2L2, Landsat 1-5 C2L1 images downloaded from USGS Earth Explorer has been used as source data in this study. For ground truth data to assess accuracy Google Earth pro and public map datasets have been used. Rajshahi district is a representative of Barind tract of Bangladesh(Kamruzzaman & Ray, 2022). This portion of Bangladesh has been at great risk of drought due to groundwater scarcity and surface water declination trend due to urbanization, high temperature and low rainfall intensity (Al Kafy et al., 2021; Kamruzzaman & Ray, 2022). Therefore, this study aimed to assess the past and present surface water sources in Rajshahi district, Bangladesh and to analyze the land cover change from 1995 to 2020 comparing the magnitude of transformation of wetlands, built up area, vegetation and barren lands of past 25 years.

2 Methodology

2.1 Study Area Profile

In this research, Rajshahi district, the divisional center of Rajshahi division has been selected as the study area (Figure 1). It is located in the Northwestern part of Bangladesh at the bank of Padma. The Northwestern part of Bangladesh is severely drought prone area(Rahman & Mahbub, 2012), which needs to be studied to determine the risk of water vulnerability in near future. This area is geographically situated between 24˚20'N and 25˚35'N latitudes and 88˚20'E and 89˚30'E longitudes. This area is one of Bangladesh's most important commercial and educational centers(Al Kafy et al., 2021). According to the Population Census 2011, total number of households of Rajshahi district was 6,33,758 and total enumerated population was 25,95,197. Among which the major portion 59.78% is located in the rural areas and the rest 40.22% in the urban(Bangladesh Bureau of Statistics, 2013). Though it is an agricultural zone, this area has seen a significant level of industrialization since the completion of the Jamuna Bridge in 1998. Due to rapid urban migration to achieve better life possibilities and an abundance of work options, there was an urban influx in this region(Al Kafy et al., 2021).

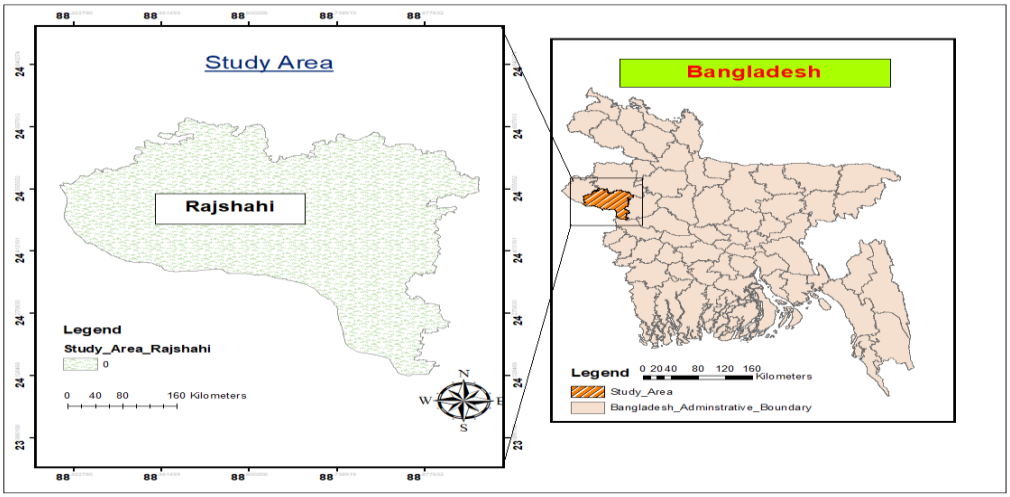

Figure 1. Study Area for Land Use Land Cover (LULC), Rajshahi, Bangladesh

2.2 Data Collection and Data Properties

The study period was selected from 1995 to 2020. The set of study period was at 5 years of interval: 1995, 2000, 2005, 2010, 2015, and 2020. One set of multispectral Landsat satellite data were acquired from USGS Earth explorer to examine the land use land cover change in the selected study area. Though all the images had nearly 0% cloud cover over the study region, cloud cover was set to 10%. Since Landsat satellite data is free from radiometric and geometric distortion, we avoided preprocessing stage of the images. In Table 1 a detailed properties of data have been shown.

Table 1. Data properties collected from USGS Earth Explorer

Year	Acquired date	Sensor	Spatial resolution	Cloud cover
1995	28 January 1995	Landsat 5 TM	30m	0% to 10%
2000	26 January 2000	(Bands 3 to 7)		
2005	13 April 2005			
2010	06 February 2010			
2015	24 March 2015	Landsat 8 OLI		
2020	06 April 2020	(Bands 3 to 7)		

2.3 Flow chart of LULC Prediction

To determine the land cover change of selected study period ArcGIS 10.6.1 software has been used. The accuracy assessment of acquired data from ArcGIS has been done using ground truth data from Google Earth pro. The total methodology is shown by a flow chart in Figure 2. The Landsat images were classified into four categories which are mentioned in Table 2.

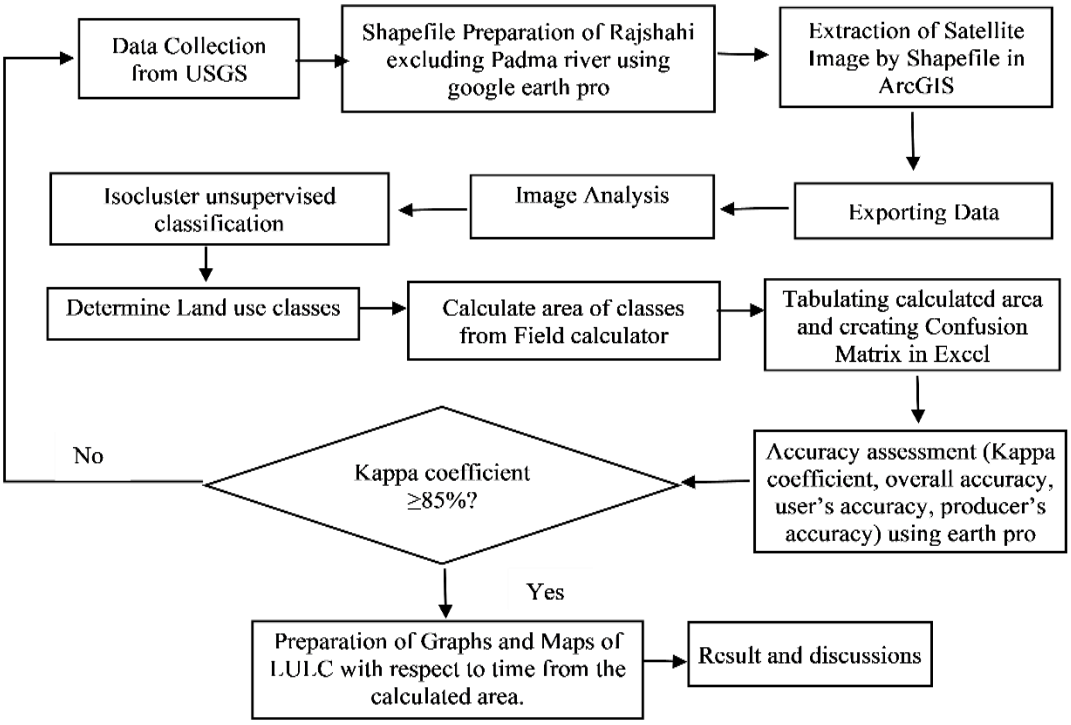

Figure 2. Flow chart of methodology of LULC prediction.

Table 2. LULC types

Land Cover type	Detailed Description
Built-up Area	Residential, industrial, functional areas, impervious layers, and transportation network
Surface Water Body	Small Rivers, wetlands, ponds, water reservoirs, canals, and streams
Vegetation	All types of vegetation, herb, shrubs, cultivation, and agricultural lands
Bare Land	Fallow land, sand, large playground, open ground, empty agricultural lands and land fill sites

3 Results and Discussion

Iso-cluster unsupervised classification algorithm was applied to Landsat images from years 1995 to 2020 with 5 years interval, 2 maps shown in Figure 3. The LULC data shows a diminishing trend with time. From Table 3 we can see, in year 1995 the water body was 10% of total area, while the built-up, vegetation and barrens were 3.45%, 68.91% and 17.62% respectively. The water bodies have been decreased in respective years 2000, 2005, 2010, 2015 and 2020 from 5.6% to 2.8%. The result is vulnerable according to water demand and rainfall intensity of Rajshahi district (Kamruzzaman & Ray, 2022).

Table 3. Land Use Land Cover (LULC) area percentage from year 1995 to 2020

LULC	**Time**					
	1995	**2000**	**2005**	**2010**	**2015**	**2020**
Water Body	10.00%	5.60%	5.40%	4.60%	3.80%	2.80%
Built Up area	3.45%	4.70%	5.50%	6.26%	6.70%	12.83%
Vegetation	68.91%	65.60%	62.59%	58.42%	57.85%	55.51%
Barren Land	17.62%	18.97%	26.51%	30.72%	34.10%	28.86%

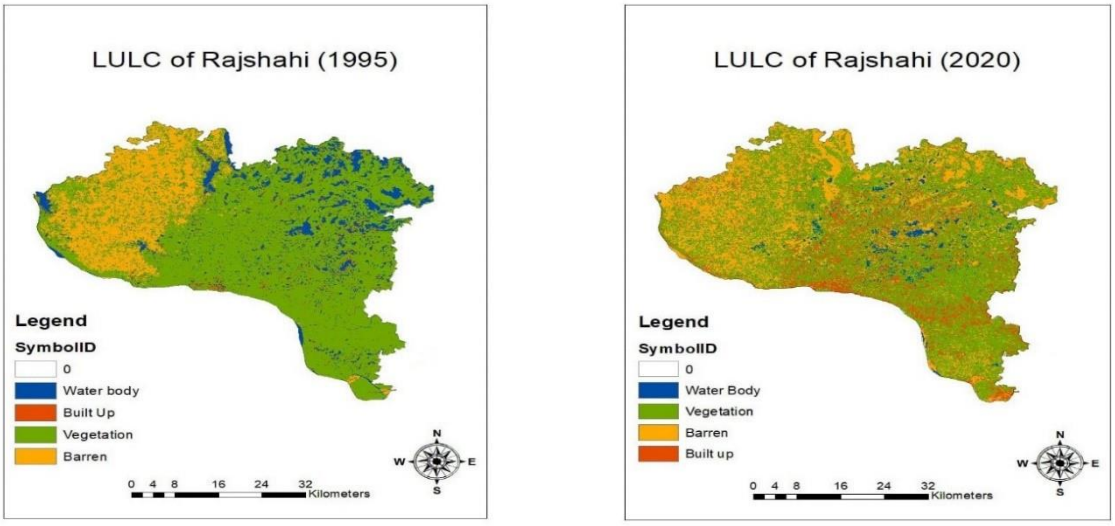

Figure 3. LULC maps from year 1995 to 2020

The vegetation through these years has reduced tremendously from 68.91% to 55.51%. The mostly concerned matter is the rapid increment of built-up area through these years. In 1995 the built-up area of Rajshahi district was 3.45%, while it has increased to 12.83% in 2020. This indicates that the surface water bodies are decreasing while the water demand is increasing with rapid growth of urban areas, which may lead to severe water scarcity in near future. Another matter of concern is the barren lands are increasing since the east part of Rajshahi has been detected to transform into agricultural land from high vegetation land. From year 1995 to year 2020 the bare land has increased from 17.62% to 28.86% which includes the empty agricultural lands. It is clear that decreasing tendency of surface water body is threatening vegetations, which has already started to affect the seasonal regularity of this area. The trends of LULC are shown in Figure 4.

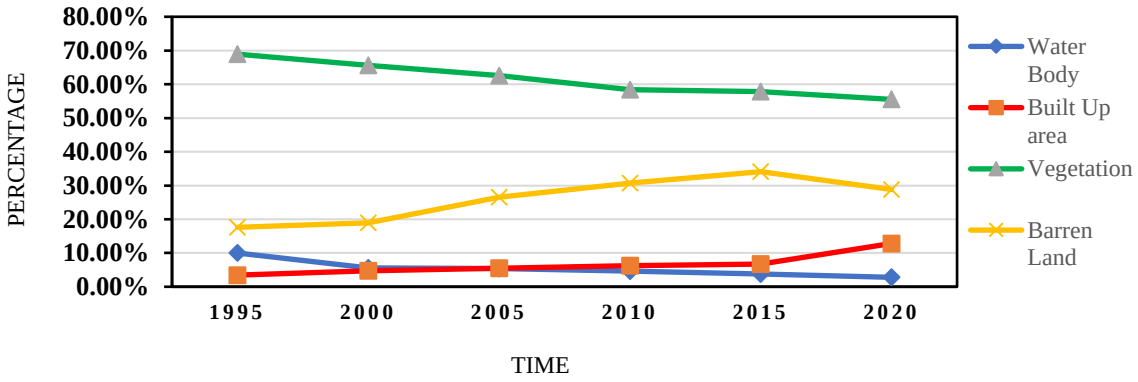

Figure 4. LULC tendencies from year 1995 to 2020

4 Accuracy Assessment

Accuracy assessment has been done using google earth pro. Randomly 40 points were selected in all the classified images of 1995 to 2020 (10 points for each class). Those points have been examined by Google Earth Pro of every study year. The points have been tabulated in excel and assessment has been done using following equations (Hasan et al., 2021):

1. User accuracy= $\frac{\text{Total number of correctly classified pixels}}{\text{Total number of row pixels}} \times 100\%$
2. Producer's accuracy= $\frac{\text{Total number of correctly classified pixels}}{\text{Total number of column pixels}} \times 100\%$
3. Overall accuracy= $\frac{\text{Total number of correctly classified pixels(diagonal)}}{\text{Total number of reference pixels}} \times 100\%$
4. Kappa coefficient = $\frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_{+i}.x_{i+})}{N^2 - \sum_{i=1}^{r}(x_{+i}.x_{i+})}$

Table 4. Accuracy assessment of LULC from 1995 to 2020

Study years	Producer's Accuracy				User's Accuracy				Overall Accuracy	Kappa coefficient
	Water Body	Vegetation	Built Up	Barren land	Water Body	Vegetation	Built Up	Barren land		
1995	100%	50%	100%	100%	100%	100%	100%	66%	90%	86%
2000	100%	83.3%	83.3%	100%	100%	100%	100%	75%	92%	88.9%
2010	100%	100%	83.3%	100%	100%	100%	100%	87.5%	95.8%	94.4%
2015	100%	100%	86%	100%	100%	100%	100%	83.3%	96%	94.4%
2020	100%	100%	83.3%	83.3%	100%	86%	100%	83.3%	92%	88.9%

From, Table 4 the accuracy assessment can be identified. The kappa coefficient has found more than 85% which means acquired data are excellently correct(Hasan et al., 2021)

5 Conclusion and Recommendations:

Land Use Land Cover (LULC) change can affect the total industrial and economical situation of any region. Rajshahi district has low rainfall intensity as per requirement. Additionally maximum portion of population this area depends on agriculture which ca be directly affected by surface water diminishing trend. As from the result, it is clear that decreasing water surface body and increasing urbanization has already been responsible for increasing bare land. Moreover, the remaining water surface bodies are not satisfactory. Even the ground water recharge of this study area

is not enough to handle the land cover change situation(Kamruzzaman & Ray, 2022). Our study recommends following issues to handle to future water scarcity risk:

- Ensuring sustainable water supply management at Upazila level and implementing LULC policies.
- Adopting certain reuse process of water and reliable water treatment process.
- Legal action against unnecessary waste of water at local level.
- Community awareness through campaigns and social media.

References:

Al Kafy, A., Abdullah-Al-Faisal, Al Rakib, A., Akter, K. S., Rahaman, Z. A., Jahir, D. M. A., Subramanyam, G., Michel, O. O., & Bhatt, A. (2021). The operational role of remote sensing in assessing and predicting land use/land cover and seasonal land surface temperature using machine learning algorithms in Rajshahi, Bangladesh. *Applied Geomatics*, *13*(4), 793–816. https://doi.org/10.1007/s12518-021-00390-3

Baig, M. F., Mustafa, M. R. U., Baig, I., Takaijudin, H. B., & Zeshan, M. T. (2022). Assessment of Land Use Land Cover Changes and Future Predictions Using CA-ANN Simulation for Selangor, Malaysia. *Water (Switzerland)*, *14*(3). https://doi.org/10.3390/w14030402

Bangladesh Bureau of Statistics and Informatics Division Ministry of Planning Government of the People's Republic of Bangladesh. (2013). www.bbs.gov.bd

Hasan, Md. M., Islam, R., Rahman, Md. S., Ibrahim, Md., Shamsuzzoha, Md., Khanam, R., & Zaman, A. K. M. M. (2021). Analysis of Land Use and Land Cover Changing Patterns of Bangladesh Using Remote Sensing Technology. *American Journal of Environmental Sciences*, *17*(3), 64–74. https://doi.org/10.3844/ajessp.2021.64.74

Kamruzzaman, M., & Ray, B. (2022). Climate-induced groundwater drought monitoring in Northwestern Bangladesh using remote sensing. In *CUET*. www.cuet.ac.bd/icace

Rahman, Md. M., & Mahbub, A. Q. M. (2012). Groundwater Depletion with Expansion of Irrigation in Barind Tract: A Case Study of Tanore Upazila. *Journal of Water Resource and Protection*, *04*(08), 567–575. https://doi.org/10.4236/jwarp.2012.48066

Ahmed, & Summra Erum. (2012). *Remote Sensing and GIS Application in Wetland Change Analysis: Case study of Kallar Kahar*. https://www.researchgate.net/publication/267575387