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VARIATIONS OF LAND USE AND LAND COVER IN SYLHET SADAR, BANGLADESH, FROM 1990 TO 2020: REMOTE SENSING AND GIS INVESTIGATION

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Abstract

The Earth's surface is undergoing significant land use, and land cover (LULC) changes because of numerous socioeconomic activities and natural events. The study was carried out in Sylhet Sadar to examine land use and land cover changes from 1990 through 2020. To assess land use pattern, multi-temporal satellite imageries (Landsat 7 for the years 1990, 2000 and 2010) (Landsat 8 for the year of 2020) were obtained from USGS GLOVIS. Based on the prior knowledge and a reconnaissance survey, the study area was classified into four major LULC classes: water bodies, urban area, vegetation, and agricultural land. Supervised classification-maximum likelihood algorithm and stratified random sampling were applied to detect the extent as well as the percentage of each LULC class and classification accuracy assessment, respectively. The overall accuracies for the classified images of 1990, 2000, 2010, and 2020 were 88.5 %, 90 %, 90.5 %, and 92.5 %, respectively. Three change detection analyses (1990-2000, 2000-2010 and 2010-2010) were done to detect the shifting process of different land use/land cover classes. The results of this study revealed both an increase and decrease in the different LULC classes over 30 years. The results showed rapid growth of urban area (127.52 km^2) between 1990 and 2020, while the same periods witnessed a reduction of agricultural land (-57.82 km^2) and vegetation (-84.08 km^2).

Keywords: Land use, Land cover, Satellite image, Change detection, Sylhet Sadar.

Introduction

The words “land use” and “land cover” are the two different terminologies with their specific meaning. They should not be used interchangeably (Mare and Mihai, 2016; Mishra et al., 2019). Land cover describes the physical characteristic of the earth surface including forests, bare soil, water, urban structures, vegetation, hills, and so on (Pielke et al., 2011; Rawat and Kumar, 2015; Samal et al., 2016). Land use describes how the land surface and habitat are used by human beings (Liping et al., 2018). Together, a region pattern is the outcome derived from both the land use and land cover, which is influenced by socio-economic factors and utilization by human beings (Rawat and Kumar, 2015). Due to complex interactions between physical environments and human beings, changes occur in land use and land cover (Rawat and Kumar, 2015; Samal et al., 2016; Pielke et al., 2011). Additionally, change in the land cover and land use is primarily driven by anthropogenic activities and natural occurrences (Islam et al., 2018; Turner and Ruscher, 2004). For example, increase in agricultural land, modification of rangeland, deforesting the tropical forest, rapid globalization, and urbanization are the underlying factors of global land use and land cover changes (LULCC) (Islam et al., 2018). The changes in land cover and land use are also driven significantly by socio-economic and biophysical characteristics (Aspinall, 2004; Zeng et al., 2008).

With more than 150 million people, Bangladesh is one of the world’s densest and sixth most populous countries. Experts believe that if the population growth remains constant, then in 2060, the population might reach 230 million, with over 70% living in cities (Gupta et al., 2018). After 1971, the urbanization process was started in Bangladesh, and was limited to Dhaka city only; the pace has accelerated in Dhaka since 1991. After 1991, rapid urbanization began in Sylhet Sadar as well. According to a report published by the United Nations Population Fund (UNFPA) in 2016, urban areas of Sylhet grew substantially between 1991 and 2011. The LULC of Sylhet Sadar and its surroundings has changed because of uncontrolled development and real estate businesses acquiring lowland (Rahman, 2011). As a result, it is vital to determine if uncontrolled development leads to urban sprawl outside of Sylhet.

In recent days, with a shorter time and minimum costs, the remotely sensed data in association with GIS are the best tools to determine the changes in land use and land cover with better accuracy (Boori et al., 2015; Rawat & Kumar, 2015; Lubis and Nakagoshi, 2011).

The arrival of high spatial resolution satellite images and GIS technologies with more innovative image processing results in more consistent observation and modelling of land cover and land use patterns (Lo and Choi, 2004).

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Several extensive research efforts have been made for land use/land cover change detection using remotely sensed images. Yuan et al. (2005) developed a methodology to map and monitor land cover change using multi-temporal Landsat TM data in the seven-county Twin Cities Metropolitan Area of Minnesota. Adepoju et al. (2006) examined the land use/land cover changes that have taken place in Lagos for the last two decades due to rapid urbanization. El Gammal et al. (2010) have used several Landsat images of different time periods (1972, 1982, 1987, 2000, 2003 and 2008) and processed them in ERDAS and ARC-GIS software to analyze the changes in the shores of the lake and its water volume. Bhagawat (2011) presented the change analysis based on the statistics extracted from the four land use/land cover maps of the Kathmandu Metropolitan by using GIS. According to him, land use statistics and transition metrics are important information to analyze land use changes. El-Asmar et al. (2013) have applied remote sensing indices, i.e., normalized difference water index (NDWI) and the modified normalized difference water index (MNDWI) in the Burullus Lagoon, North of the Nile Delta, Egypt, for quantifying the change in the water body area of the lagoon during 1973 to 2011. Bhattacharjee et al (2021) detected land-use and land-cover change in north-eastern wetland ecosystem of Bangladesh using remote sensing and GIS Techniques. Munna et al (2020) used remote sensing and GIS to determine the land use/land cover change in Sylhet city.

Since, very few research works have been conducted on the land use/land cover change of Sylhet Sadar therefore; it is an urgent need for a thorough investigation to estimate the dynamics of land use and land cover change, including the categorization scheme, appropriate classification technique, and landscape measure. In this regard, an attempt was made to visually represent the status of land use and land cover in Sylhet Sadar between 1990 and 2020 by employing maximum likelihood classification and change detection comparison strategy. The objectives included (i) developing a land use/land cover classification scheme (ii) determining trends, spatial patterns, and rates of land-use change in Sylhet Sadar. The results of this study are expected to provide valuable information to detect the land utilization status and the future planning for any land use development in this area.

Materials and Methods

Study area

Sylhet Sadar is located between the latitudes 24°43' and 24°77' north and the longitudes 91°40' and 91°01' east. Sylhet Sadar is the most populated sub-district in Sylhet district, with a 514.26 km^2 area. It is also a metropolitan city and the administrative seat of the Sylhet division, with a population of 554412. The lowest and highest average yearly temperatures are 17.6°C and 33.0°C, respectively (Islam et al., 2019). The map of the research area is shown in Figure 1.

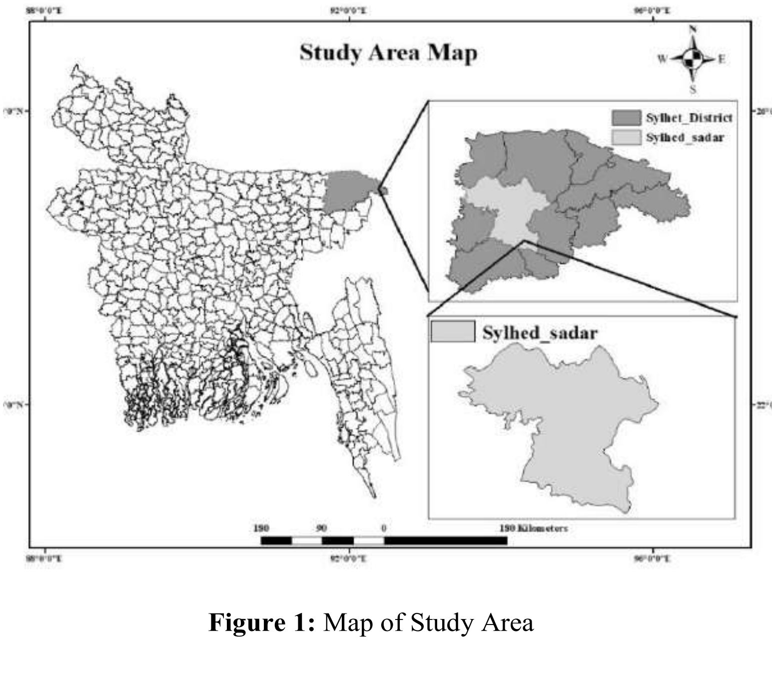

Figure 1: Map of Study Area

Data acquisition and source

Using the USGS GLOVIS website, four satellite images as Landsat 7 (ETM+) of 1990, 2000, and 2010) and Landsat 8 (OLI-TIRS) of 2020 for February at path (136) and row (43) were acquired. The resolution of each Landsat image is 30mx30m. The ground truth data for the land use/land cover classes were collected using Geographical Positioning System (GPS) and Google Earth Pro. This ground truth data was used to assess the overall accuracy of the classification results.

Classification scheme

A classification scheme for the study region was constructed based on a quick reconnaissance assessment with additional information from the thorough literature review. The established classification approach provides a relatively comprehensive classification, with each land use and land cover indicated by a single number. The land use/land cover (LULC) classification scheme is presented in Table 1.

Image pre-processing

Pre-processing satellite images prior to change detection is essential and has the unique goal of establishing a more direct linkage between the data and biophysical phenomena. The images collected from Landsat 7 were pre-processed to remove black scan lines due to the Scan Line Corrector (SLC) failure on May 31, 2003. The raster's stripes were eliminated using ArcMap's "Landsat Toolbox." These satellite images were used in this analysis because they had the same radiometric and geometric corrections as those collected prior to the SLC failure.

Table 1: LULC classification scheme

SL No	Land Use/land cover categories	Description
1	Water Bodies	This land cover class describes the surface of the earth covered with water such as streams, rivers, lakes and so on.
2	Urban Area	Urban regions are high-density settlements with populations exceeding a specified limit.
3	Vegetation	Plant growth varieties that are common in a certain area (for example, forest, hydrophytes).
4	Agricultural Land	The land is primarily used to produce crops.

Image classification

Basically, two image classification techniques are employed for land cover classification. Supervised classification is a land cover type classification method using the sample polygons from the known land cover types. It is the most common method for obtaining land use and cover information. The other type of classification is unsupervised classification, which is a type of land cover classification from the satellite image data when the user does not know how many land cover types are present in the field. For this study, supervised classification was done using ArcGIS 10.5 and ENVI 5.1.

Training sample selection

In this study, training samples were selected for supervised classification and accuracy assessment after data preprocessing. With the assistance of the Maximum Likelihood Algorithm, a supervised classification method comprising four land use/land cover classes has been performed, utilizing all spectral bands except the sixth spectrum, which has thermal properties. Field investigation was conducted, which helped to collect training data. The fieldwork supported the image interpretation of land-cover types defined in the classification scheme. The field observations provided essential information for identifying LULC types within the Landsat scenes as well as for accuracy assessment.

Accuracy assessment

The remote sensing aided land use/land cover maps created in ArcGIS may contain various errors. Therefore, classification accuracy assessment is an important step in evaluating image classification. Stratified random sampling was applied to select the classified pixel. Each 200-test pixel from the classified images 1990, 2000, 2010, and 2020 were selected to assess the image classification results. For images from 1990, 2000, and 2010 the reference data was collected using Google Earth Pro to validate the classified images.

An error matrix is the most common and typical method researchers use to assess the classification accuracy of remotely sensed data (Ismail and Jusoff, 2008). It is also sometimes referred to as a confusion matrix. An error matrix is a square array of numbers set out in rows and columns representing the number of sample units assigned to a particular category relative to the actual category as indicated by reference data (Congalton, 1991). The numbers in the rows represent data from the classified image, while the numbers in the columns indicate the reference data. In this study, standard criteria of accuracy assessment of the classification such as producer's, user's, and overall accuracy, were computed from the error matrix. The producer's accuracy was computed by dividing the total number of correct pixels in a category by the total number of pixels in that category as derived from reference data (column total). The producer's accuracy represents how well a specific area can be classified. The user's accuracy was computed by dividing the total number of correct pixels in a category by the total number of pixels that were actually classified in that category (row total). The results of user's accuracy represent the probability of a pixel classified on the map in a category existing on the ground. The overall accuracy was defined as the total number of correctly classified pixels divided by the total number of pixels in the error matrix (Jensen, 2005). The overall accuracies of the classified images of 1990, 2000, 2010, and 2020 were 88.5 %, 90 %, 90.5 %, and 92.5 %, respectively (Table 2 to 5).

Table 2: Error matrix for 1990 map.

Classes	Reference data				Row total	User's accuracy (%)
	Water bodies	Urban area	Vegetation	Agricultural land		
Water bodies	**42**	1	4	3	50	84
Urban area	1	**43**	2	4	50	86
Vegetation	1	1	**47**	1	50	94
Agricultural land	2	1	2	**45**	50	90
Column total	46	46	55	53	**200**	Overall accuracy 88.5%
Producer's accuracy (%)	91.3	93.5	85.5	85		

Table 3: Error matrix for 2000 map.

Classes	Reference data				Row total	User's accuracy (%)
	Water bodies	Urban area	Vegetation	Agricultural land		
Water bodies	**44**	0	3	3	50	88
Urban area	0	**46**	0	4	50	92
Vegetation	1	1	**47**	1	50	96
Agricultural land	5	1	2	**42**	50	84
Column total	49	48	53	50	**200**	Overall accuracy 90%
Producer's accuracy (%)	89.8	95.8	90.6	84		

Table 4: Error matrix for 2010 map.

Classes	Reference data				Row total	User's accuracy (%)
	Water bodies	Urban area	Vegetation	Agricultural land		
Water bodies	**47**	0	2	1	50	94
Urban area	2	**45**	2	1	50	90
Vegetation	2	2	**46**	0	50	92
Agricultural land	3	2	2	**43**	50	86
Column total	55	49	52	45	**200**	Overall accuracy 90.5%
Producer's accuracy (%)	85.5	91.8	88.5	95.6		

Table 5: Error matrix for 2020 map

Classes	Reference data				Row total	User's accuracy (%)
	Water bodies	Urban area	Vegetation	Agricultural land		
Water bodies	**46**	0	2	2	50	92
Urban area	0	**47**	2	1	50	94
Vegetation	3	2	**44**	1	50	88
Agricultural land	1	0	1	**48**	50	96
Column total	50	49	49	52	**200**	Overall accuracy 92.5%
Producer's accuracy (%)	92	95.9	89.8	92.3		

Change detection

Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times. In this study, the LULC change process in 1990-2000, 2000-2010, and 2010-2020 were detected by applying the post-classification comparison method. This method was adopted due to its simplicity and capability to compare two images from different times. In addition, it is the most common approach widely used to detect changes, with the major advantage of providing "from-to" change information. In this method, two classified images were intersected, and then the area of change was calculated. The results were presented in the form of a change detection matrix.

Results & Discussion

Land use/land cover classification status

The maximum likelihood supervised classification has been adopted successfully to classify land use/land cover (LULC) in Sylhet Sadar. Landsat images used in this study were taken from the USGS GLOVIS website. Four LULC categories were identified in Sylhet Sadar as water bodies, urban area, vegetation, and agricultural land. The extent and percentage of each LULC in Sylhet Sadar over the study period are shown in table 6 and figure 2-5.

In 1990, water bodies occupied 69.46 km^2, 13.51% of the entire area. About 143.67 km^2 area was covered with vegetation. Agricultural land occupied a large portion of the whole area, and that was 164.05 km^2. In the same year, the urban area occupied 137.08 km^2 of the total area (Table 6) (Figure 2). On the other hand, in 2000, the area occupied by water bodies increased to 72.50 km^{2,} which was 69.46 km^2 in 1990. Vegetation coverage dropped by 5.73% to 114.17 km^2 (Table 6). From figure 3, it is very evident that urban area and agricultural land have been increased to 158.96 km^2 and 168.63 km^{2,} respectively. The water bodies reduced from 72.50 km^2 to 57.45 km^2 in 2010 whereas the area covered with vegetation rose by 7.82 % from 114.17 km^2 to 154.43 km^{2,} and the urban area increased from 158.96 km^2 to 172.74 km^2 (Table 6). Compared to the year 2000, it was understood that the area of agricultural land had decreased (Figure 4).

The water bodies occupied 83.84 km^2 of the total area in 2020. Similar to previous years, the urban area occupied a larger portion of the area in 2020, which amounted to 264.60 km^2. Kadir *et al*., (2021) mentioned that the built-up area is quickly expanding. As a result, the quality of the river water in the area is degrading day by day. Due to the enlargement of settlements, vegetation coverage has shrunk significantly, and it fell by 18.43 % from 154.43 km^2 to 59.59 km^2. Degradation of vegetation coverage is caused by over-exploitation of vegetation for food and fodder. Also, there was a declining trend in vegetation because of increased population pressure which accelerated the destruction of vegetative land for accommodation (Bhattacharjee *et al*., 2021). The area occupied by agricultural land reduced to 106.23 km^2 in 2020, compared to 129.64 km^2 in 2010 (Table 6) (Figure 5).

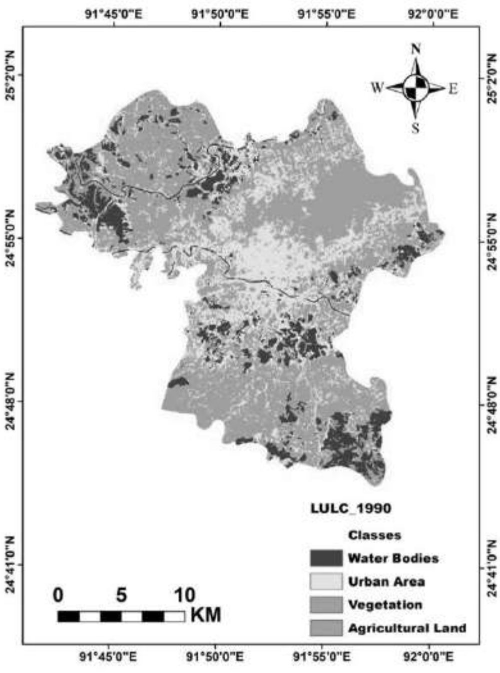

Figure 2: LULC in Sylhet Sadar in 1990.

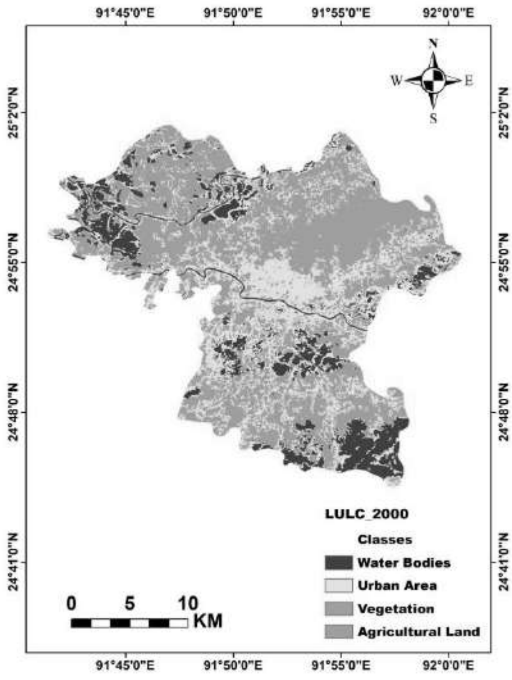

Figure 3: LULC in Sylhet Sadar in 2000.

LULC Type	1990		2000		2010		2020	
	Area (Km^2)	% Area	Area (Km^2)	% Area	Area (Km^2)	% Area	Area (Km^2)	% Area
Water bodies	69.46	13.51	72.50	14.10	57.45	11.17	83.84	16.30
Urban area	137.08	26.66	158.96	30.91	172.74	33.59	264.60	51.45
Vegetation	143.67	27.93	114.17	22.20	154.43	30.02	59.59	11.59
Agricultural land	164.05	31.90	168.63	32.79	129.64	25.22	106.23	20.66
Total	**514.26**	**100**	**514.26**	**100**	**514.26**	**100**	**514.26**	**100**

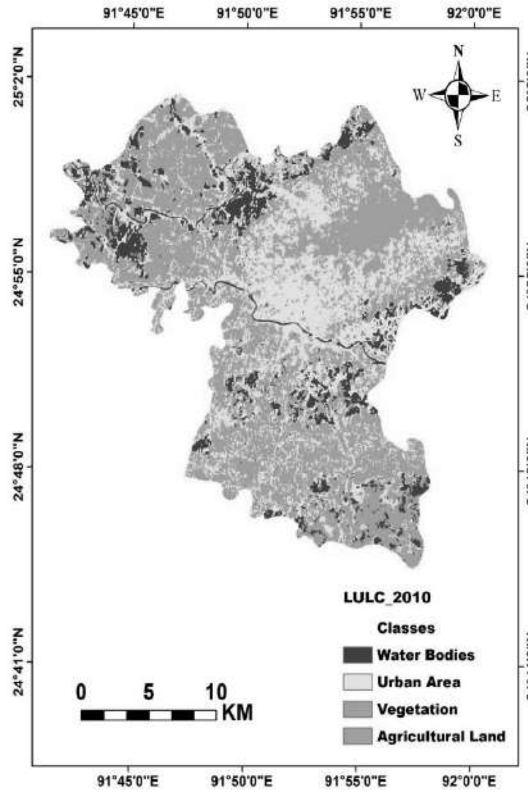

Figure 4: LULC in Sylhet Sadar in 2010.

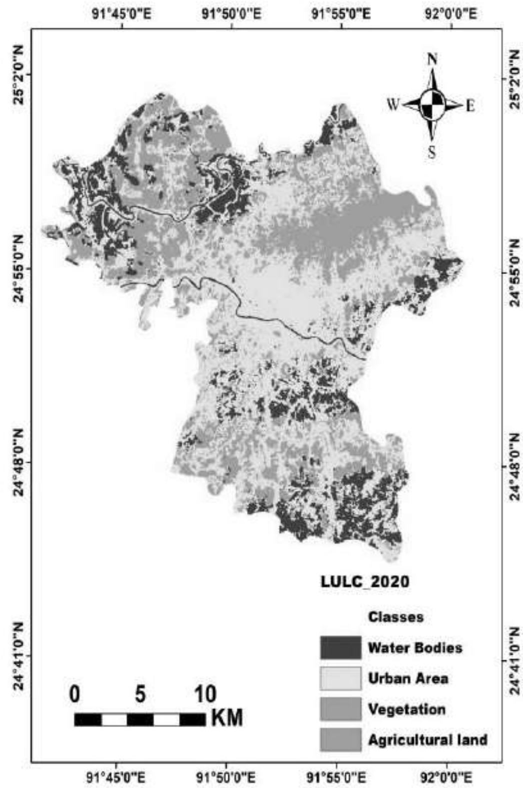

Figure 5: LULC in Sylhet Sadar in 2020.

Table 6: Classification results of the land use/land cover of Sylhet Sadar

Land use/land cover change detection matrix

Land use / land cover change detection matrix was also prepared to understand the changes that occurred in each category over 30 years. From the change detection matrix, it is found that there is a considerable change in the land use / land cover area during the period of 30 years (1990 to 2020). In 1990, there was a significant change from the urban area to vegetation (20.28 km^2) and agricultural land (23.43 km^2). In the same year, 38.56 km^2 of land was covered by vegetation, which was then converted into an urban area in the next ten years. In 2000, 23.51 km^2 agricultural lands were converted into an urban area (Table 7). The conversion of vegetation (38.39 km^2) and agricultural land (38.78 km^2) to the urban area was significant from the year 2000 to 2010 (Table 8). The final change detection matrix was done between 2010 and 2020 in Table 9. From table 9, 81.54 km^2 and 35.86 km^2 of areas under vegetation and agricultural land respectively converted to an urban area, and significant change occurred to an urban area (12.59 km^2) from water bodies.

Table 7: Change detection between 1990 and 2000.

		2000				
1990		Water bodies	Urban area	Vegetation	Agricultural land	Total area (km^2)
	Water bodies	**53.84**	9.10	0.73	5.79	69.46
	Urban area	5.58	**87.79**	20.28	23.43	137.08
	Vegetation	10.80	38.56	**91.69**	2.62	143.67
	Agricultural land	2.28	23.51	1.47	**136.79**	164.05
	Total area (km^2)	72.50	158.96	114.17	168.63	**514.26**

Table 8: Change detection between 2000 and 2010.

		2010				
2000		Water bodies	Urban area	Vegetation	Agricultural land	Total area (km^2)
	Water bodies	**34.57**	7.93	29.01	0.99	72.50
	Urban area	11.00	**87.64**	50.16	10.16	158.96
	Vegetation	2.25	38.39	**70.78**	2.75	114.17
	Agricultural land	9.63	38.78	4.48	**115.74**	168.63
	Total area (km^2)	57.45	172.74	154.43	129.64	**514.26**

Table 9: Change detection between 2010 and 2020.

		2020				
2010		Water bodies	Urban area	Vegetation	Agricultural land	Total area (km^2)
	Water bodies	**40.65**	12.59	0.38	3.83	57.45
	Urban area	13.91	**134.61**	11.21	13.01	172.74
	Vegetation	23.91	81.54	**47.65**	1.33	154.43
	Agricultural and	5.37	35.86	0.35	**88.06**	129.64
	Total area (km^2)	83.84	264.60	59.59	106.23	**514.26**

Change of area analysis between 1990 and 2020

Pearson's Figure 6 summarizes the changes in areas of different LULC categories between 1990 and 2020. Water bodies and urban areas increased by 2.8 % and 24.8 %, respectively, from 69.46 km^2 and 137.08 km^2 to 14.38 km^2 and 127.52 km^2 between 1990 and 2020. According to the findings, vegetation and agricultural land declined by 84.08 km^2 and 57.82 km^2,respectively. The expansion of one LULC type comes at the expense of other LULC classes because LULC alterations are complicated and interconnected.

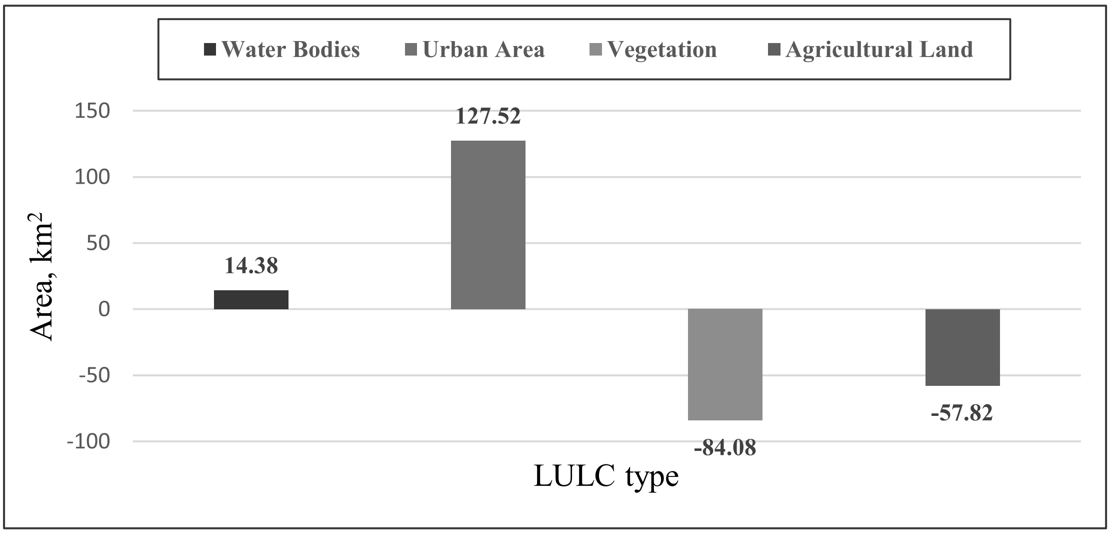

Figure 6: Observed land use/land cover changes between 1990 and 2020.

Over a 30-year period, the general trend of land use and land cover (LULC) changes in Sylhet Sadar was established in this study. The research findings were based on an assessment of land use changes in Sylhet Sadar and a comparison of those changes through time. Geographic Information Systems and Remote Sensing techniques have been used to determine the pattern of change in land use and land cover over time. The observed changes varied from one LULC category to another, with some maintaining a constant change (increase or decrease) over the three analysis periods (1990-2000, 2000-2010 and 2010-2020). From the comprehensive study, it is found that rapid urbanization greatly influences decreasing the vegetative and agricultural land. It was found that water bodies and urban areas rose between 1990 and 2020, while vegetation and agricultural land both reduced, which is concerning for the future. Because LULC changes are intricate and linked, the increase of one LULC type occurs at the price of other LULC types. Changes in land usage have an impact on the area's socioeconomic development and environmental challenges. LULC change detection frequently reveals spatiotemporal patterns of change in land classifications, which can help with sustainable land use and management (Rahimi *et al*., 2020).

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