

Original Research Paper

Analysis of Land Use and Land Cover Changing Patterns of Bangladesh Using Remote Sensing Technology

¹Md. Mahmudul Hasan, ²Rashidul Islam, ³Md. Saifur Rahman, ⁴Md. Ibrahim, ⁵Md. Shamsuzzoha, ⁶Ruma Khanam and ⁷A. K. M. Mostafa Zaman

¹Department of Geo-Information Science and Earth Observation, Faculty of Environmental Science and Disaster Management, Patuakhali Science and Technology University, Dumki, Patuakhali-8602, Bangladesh

²Faculty of Environmental Science and Disaster Management, Patuakhali Science and Technology University, Dumki, Patuakhali-8602, Bangladesh

³Geo-Information Science and Earth Observation, Faculty of Environmental Science and Disaster Management, Patuakhali Science and Technology University, Dumki, Patuakhali-8602, Bangladesh

⁴Geo-Information Science and Earth Observation, Faculty of Disaster Management, Patuakhali Science and Technology University, Dumki, Patuakhali-8602, Bangladesh

⁵Department of Emergency Management, Faculty of Environmental Science and Disaster Management, Patuakhali Science and Technology University, Dumki, Patuakhali-8602, Bangladesh

⁶Department of Disaster Resilience and Engineering, Faculty of Disaster Management, Patuakhali Science and Technology University, Dumki, Patuakhali-8602, Bangladesh

⁷Department of Agronomy, Faculty of Agriculture, Patuakhali Science and Technology University, Dumki, Patuakhali-8602, Bangladesh

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Corresponding Author:

Md. Mahmudul Hasan

Department of Geo-Information Science and Earth

Observation, Faculty of Environmental Science and

Disaster Management,

Patuakhali Science and

Technology University, Dumki,

Patuakhali-8602, Bangladesh

Email: mahmudgeo@pstu.ac.bd

Abstract: Bangladesh is a deltaic country situated in the fringe of Bay of Bengal. Land Use and Land Cover (LULC) change is the concerning issue in the present world. Bangladesh is highly vulnerable to LULC changes due to its geographical location and shortage of awareness that's why author conduct this research. The research was focused on analysing the LULC changes pattern of Bangladesh from the years 1990 to 2019 over the last three decades. Total 42 image datasets were used in this study collected from the Landsat Thematic Mapper (TM) 4-5 C 1 level-1 and Landsat 8 (OLI_TIRS) satellite. LULC map for the selected years has been worked out by supervised classification with maximum likelihood algorithm and multi-sectoral supervised classification algorithm to Landsat sensor data. Extract by mask tools was used for cutting the desired location and then exercised tool for image classification with different band combination such as (2, 3, 4) (1, 2, 3) (2, 4, 7) (3, 4, 5) (3, 5, 7). Method used for area calculation is; (Counted pixels)* (pixel size)²/1000000 (m). Research found that major changes happened in urban area, forest, water body and vegetation cover. Here, water body and forest area has decreased; and it was 9.20 and 3.86% of total area. After 29 years 5.18% land had changed to urban area, which is 6.27% of total area and vegetation cover had increased 3.36%. Land cover of Bangladesh is continually changed for overpopulation; damaging water body and forest for unsuited urbanization. Study concludes that 29 years analysis of LULC trend of Bangladesh will help to understand and take necessary action to the line departments to reduce the impact of land use and land cover change as well as provide the changing scenario of LULC all over the country which will be helps to appropriate land use planning and management of Bangladesh.

Keywords: Land Use, Land Cover, LULC Change Analysis, Supervised Classification, GIS and RS, Bangladesh

Introduction

The Land Use and Land Cover (LULC) pattern and change detection assessment are concerned of scientists worldwide for realizing the importance of the land resource to achieve environmental security and sustainable development (Xiubin, 1996). At present, the LULC pattern's changing scenario has become an immense issue for utilizing our natural capital and resources. Here, land use refers to human activity on the earth's surface such as infrastructure building, agricultural cropping and land cover refers to natural or manmade physical properties of the earth surface such as waterbody, vegetation covers etc. LULC has changed expeditiously for urbanization and overpopulation (Sikarwar and Chattopadhyay, 2016; Riggio *et al.*, 2018). This is immense truth for unplanned, changing areas like urban settlements in developing countries (López *et al.*, 2001; Jain *et al.*, 2013). To better understand the impact of LULC change on earth surface area need to analyse the trend of land cover change near about the previous 30 years and predict the chance of future changes of land use (Ojima *et al.*, 1994).

Satellite images are the most common data source for mapping LULC formation (El-Kawy *et al.*, 2011). Satellite image provides the geo-referenced raw pictures (Leprince *et al.*, 2007). Thematic Mapper (TM) imagery is used for land cover mapping (Aplin *et al.*, 1999). The changes in the land cover of the study area are analysed by land cover map using satellite images (Weng, 2002). By using multi-date images, it is possible to changed detection and also monitors and evaluates the use of land cover due to human actions and natural conditions (Yang and Lo, 2002). In this study author used Landsat 5 (TM) and Landsat 8 (OLI_TIRS) satellite images from 1990-2019. For monitoring the changing pattern study create LULC map for the selected years by using the method of supervised classification with maximum likelihood algorithm, multi-sectoral supervised classification algorithm to Landsat sensor data and extract by mask tools. Accuracy measurement work are done to validate the research findings and the result is acceptable level.

Bangladesh is a developing and densely populated country (Cuervo-Cazurra and Genc, 2008), in this country, 834 persons are living per square kilometre (Faisal and Parveen, 2004). Due to high population density, this country's total land area is continually changed including losses of vast agricultural lands (Hossain *et al.*, 2020), waterbodies and forest areas for urban growth and development. Therefore, it is essential to update the present LULC status of the country for proper land use planning, land management and sustainable development at rural, urban and regional level. According to above statements author choose the study area and conduct this research and analyze near

about 30 (thirty) years LULC to find out the LULC changes pattern of Bangladesh.

Materials and Methods

Study Area

Bangladesh, occupying an area of 147,570 km², is located in the eastern Himalayan region of South Asia between 20°34' to 26°38' north latitudes and 88°01' to 92°42' east longitudes (Fig. 1). It is surrounded on three sides predominantly by India, only the South being open to the Bay of Bengal.

Datasets

The data used in this study included 14 Landsat Thematic Mapper (TM) 4-5 C1 level-1 satellite images for each year such as 1990, 2000, 2010 and Landsat 8 OLI/TIRS C1 Level-1 Images for 2019 (Table 1). The image data were freely accessed from the Landsat archive of the United States Geological Survey (USGS) website (<https://glovis.usgs.gov/>) (<https://earthexplorer.usgs.gov/>) (Chavez *et al.*, 1991; Gutman *et al.*, 2008). Here satellite image data were used for the land use and land cover classification (Tucker *et al.*, 1985).

Data Preparation

Four LULC maps were worked out by using of the supervised classification method with maximum likelihood algorithm (Rawat and Kumar, 2015). Land cover map for the selected years are generated by applying a multi-sectoral supervised classification algorithm to Landsat sensor data (Lucas *et al.*, 2007). Landsat 5 (TM) and Landsat 8 (OLI_TIRS) satellite images have seven and eleven bands respectively which were converted to an image by using composite bands (Zha *et al.*, 2003). For supervised classification firstly needed to finish the processing of basic methods like composite band, copy raster, remove clouds and mosaic to new raster, extract by mask and maximum likelihood images classification (Su *et al.*, 2010). The whole processes were finishing by ArcMap 10.8® software Fig. 2.

The copy raster features were removed the background of images with rendering a transparent background. This section was pre-processing for image classification. Haze reduction was performed in this section. For this study image enhancement technique has preferred for histogram equalization. Cloud cover and haze condition were acceptable because it's zero in all images. In the study, the image mosaic to new raster using ArcMap 10.8® software was created from the Landsat images to develop one accurate aerial representation of the study area (Hood and Bayley, 2008). The extract by mask tool was used for cutting the desired location (Magesh and Ch, 2012; Ramírez-Villegas and Bueno Cabrera 2009).

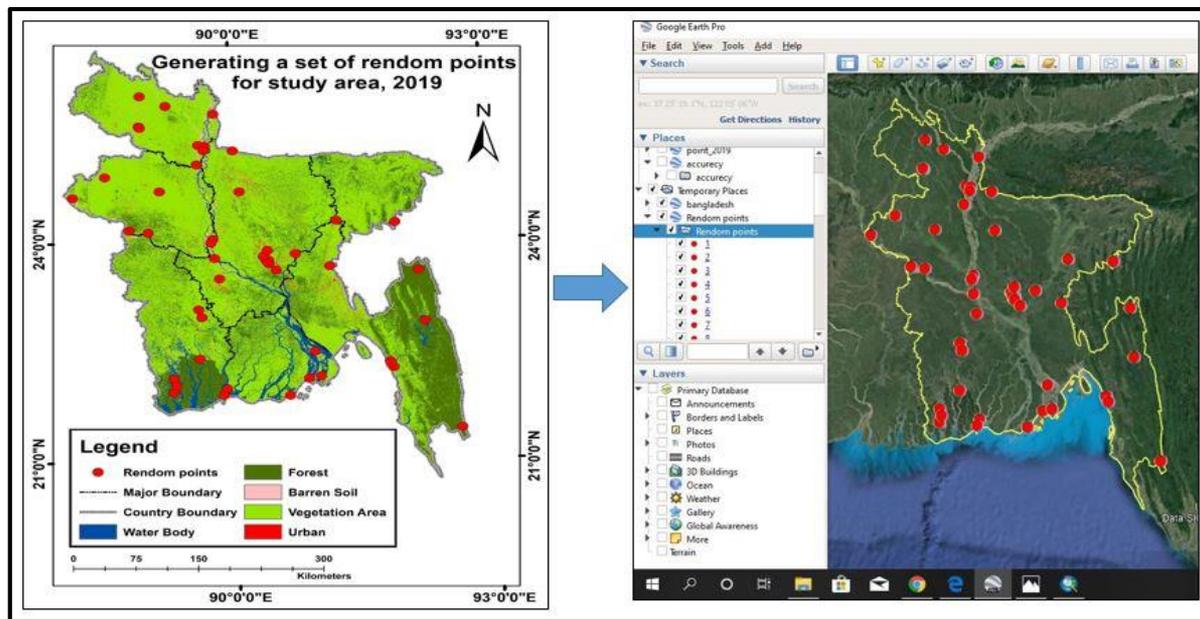


Fig. 1: Study area (Generating random points for accuracy assessment of classified image; Source: Author)

Table 1: Characteristics of the collected Landsat data

Acquisition date	Satellite (Sensor)	Resolution (m)	Cloud cover (%)
07-01-1990	Landsat 5 (TM)	30	0
19-01-2020	Landsat 5 (TM)	30	0
30-01-2010	Landsat 5 (TM)	30	0
24-01-2019	Landsat 8 (OLI_TIRS)	30	0

Classification

In this study, images were classified into five major classes; water body, forest, urban area, barren soil and vegetation cover. The study was used the standard "false color" composite for Landsat 5 TM satellite images which include 7, 4, 2 bands. This combination provides a "natural-like" rendition. Healthy vegetation was bright green, grasslands were appeared green, pink areas represent barren soil, oranges and browns represent sparsely vegetated areas, water was blue and urban areas appear in varying shades of magenta (Crosta and Moore, 1989; Tamouk *et al.*, 2013; Dwivedi and Rao, 1992).

Natural color (4, 3, 2) were used for Landsat 8 TM false-color composite which repeats near what one human eye sees. Where sound vegetation was green, unfortunate greenery was darker. Urban highlights seem white and dim and water was dull blue or dark (Elhag, 2017; Mwaniki *et al.*, 2015; Tamouk *et al.*, 2013; Dwivedi and Rao, 1992). To train for selecting each land use and land cover categories a significant number of pixels were selected in this study. About 350 training data sets for each class have been created and the minimum allowance distance set was 30 m. Finally, the maximum likelihood supervised images classification method was applied by using ArcGIS software. In this research, area calculation was done by following Eq. 1 (Eva *et al.*, 2004):

$$Area = \frac{(counted\ pixels) \times (pixel\ size)^2}{10^6} \quad (1)$$

Post-Classification Change Detection

In this study for processing, analyzing and detecting change of those classified images Arc GIS 10.8®, Google Earth Pro and SPSS software's were used successfully. Finally, area differences with ten years' interval were calculated to find out the LULCC from 1990 to 2019.

Accuracy Assessment

Accuracy assessment was assessed care of matrix using user accuracy, producer accuracy and overall accuracy and Kappa Coefficient. About 150 random points were created and the minimum allowance distance set was 30 m for each class. They were measured using Eq. 2, 3 and 4.

User accuracy was measured using Eq. 2 (Tilahun and Teferie, 2015):

$$User\ Accuracy = \frac{number\ of\ correct\ points\ (value)}{The\ row\ total\ (value)} \times 100 \quad (2)$$

Producer accuracy was measured using Eq. 3 (Tilahun and Teferie, 2015):

$$\text{Producer Accuracy} = \frac{\text{Number of correct points (value)}}{\text{The column total (value)}} \times 100 \quad (3)$$

Overall accuracy was measured using Eq. 4 (Tilahun and Teferie, 2015):

$$\text{Overall Accuracy} = \frac{\text{Number of total correct points (value)}}{\text{The number of points (value)}} \times 100 \quad (4)$$

The Kappa Coefficient equation was used as a measure of agreement between model predictions and reality (Congalton, 1991) or to ascertain if the values comprised in an error matrix represent a result significantly better than random (Jensen and Cowen, 1999). The applied Kappa coefficient values were calculated using by following Eq. 5 (Tilahun and Teferie, 2015; Congalton, 1991):

$$K = \frac{N \sum_{i=1}^n x_{ii} - \sum_{i=1}^r (x_{i+} \times x_{+i})}{N^2 - \sum_{i=1}^r (x_{i+} \times x_{+i})} \times 100 \quad (5)$$

Results

Applying maximum likelihood and multi-sectoral supervised classification algorithm LULC map from the years of 1990 - 2019 is given with ten years' interval Fig. 3 respectively. In 1990, waterbody was 12.51% of the total area. After ten years, this waterbody has decreased almost 1.45% in 2000 and in the next ten years' waterbody has decreased almost 1.85%. Next, nine years' waterbody had also decreased and it was 9.20% from the total area Table 2 and Fig. 3. Forest had decreased by 3.86% from 1990 to 2019. First ten years, it had 0.61% but in the next nineteen years, it had decreased almost 3.25% Table 2 and Fig. 3. On the other side urban area had increased fast; the urban area was only 1.09% of the total area in 1990. After ten years in 2000, it had 2.93% where almost 1.84% had increased. Next ten years it had increased 2.38% and next nine years it had increased 0.96%; that was 6.27% from total area. Almost 5.18% land had changed to urban after 29 years Table 2 and Fig. 3. Barren soil is almost same after 29 years; it has changed 0.26% Table 2 and Fig. 3.

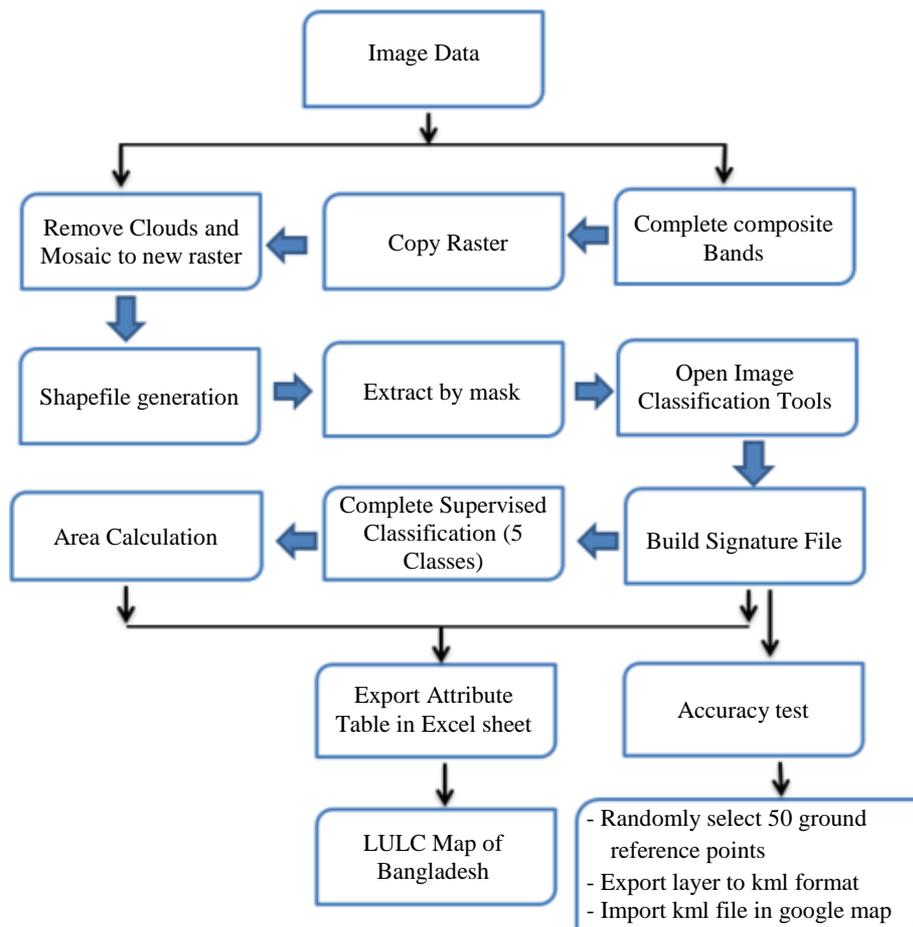


Fig. 2: Methodological framework of the study

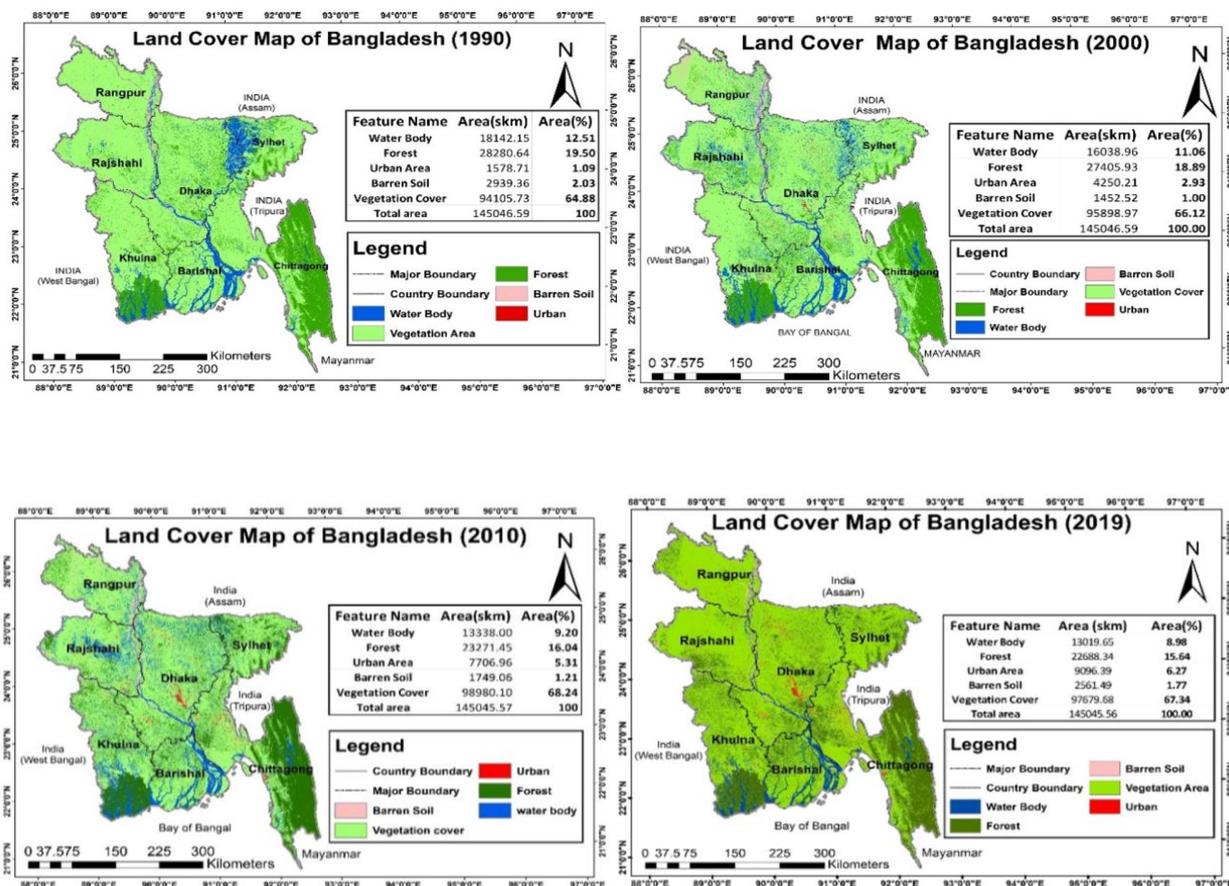


Fig. 3: LULC map of Bangladesh (1990-2019)

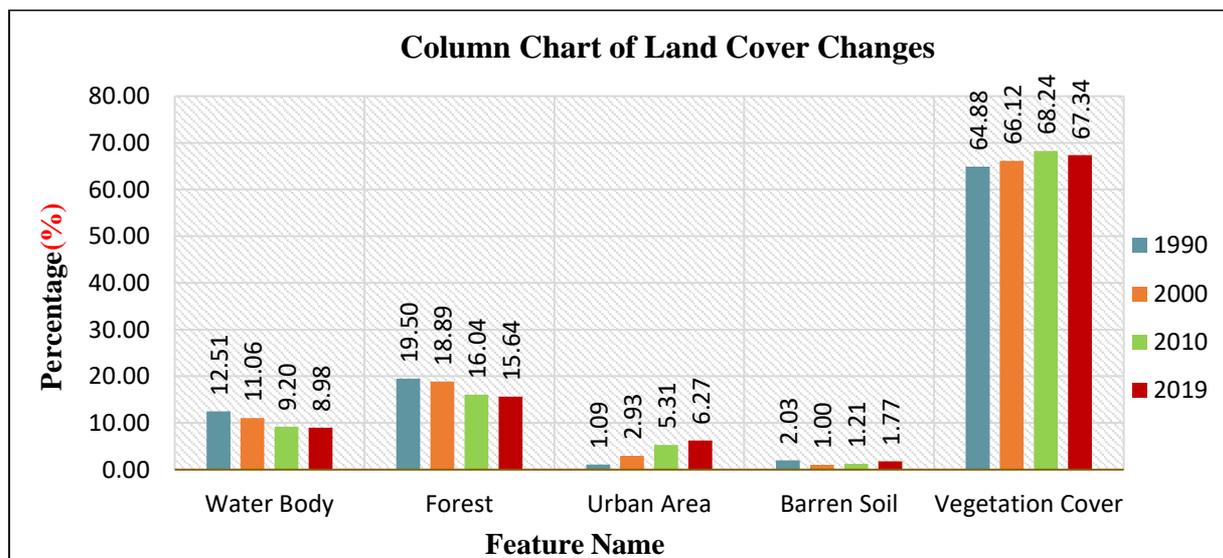


Fig. 4: LULC change status over ten years' intervals in Bangladesh

Table 2: LULC changes data from 1990 to 2019

Name of feature	1990		2000		2010		2019	
	Area (Km ²)	Area (%)						
Waterbody	18142.13	12.51	16038.96	11.06	13338.02	9.20	13019.65	8.98
Forest	28280.64	19.50	27405.91	18.89	23271.45	16.04	22688.34	15.64
Urban Area	1578.71	1.09	4250.21	2.93	7706.95	5.31	9096.39	6.27
Barren Soil	2939.36	2.03	1452.52	1.00	1749.06	1.21	2561.49	1.77
Vegetation Cover	94105.73	64.88	95898.97	66.12	98980.10	68.24	97679.69	67.34
Total area	145046.57	100.00	145046.57	100.00	145046.57	100.00	145046.57	100.00

Table 3: Accuracy measurement of the study period of 1990 to 2019; using user accuracy, producer accuracy, overall accuracy and kappa co-efficient methods

Year	User accuracy (%)					Producer accuracy (%)					Over all accuracy (%)	Kappa co-efficient (%)
	Waterbody	Forest	Barren soil	Vegetation area	Urban	Waterbody	Forest	Barren soil	Vegetation area	Urban		
1990	90%	90%	80%	100%	90%	81.8%	100%	88.9%	90.9%	90%	90%	87.5%
2000	90%	100%	80%	100%	90%	81.8%	100%	88.9%	83.3%	90%	92%	90%
2010	90%	80%	90%	100%	80%	90%	88.9%	90.9%	76.9%	100%	88%	85%
2019	100%	100%	90%	90%	90%	90.9%	90.9%	100%	90%	90%	94%	92.5%

Vegetation cover had increased 3.36% after 29 years. In 1990, it was 64.88% and 2010 it has 68.24% of total area. But the next nine years it has decreased 0.90% which is 67.34% from total area. Table 2 and Fig. 4 has showed for easily understood.

Accuracy Measurement

Accuracy assessment is a valuable step in the processing of remote sensing data. The actuality of the resulting data to a user is established by it (Fung and LeDrew, 1988). The errors of commission that illustrate the possibility of a classified pixel matching the land cover type of its similar real-world geographic location are measured by user accuracy. Producer's accuracy is measured errors of a gap, which is an assessment of how well real-world land cover types can be classified. The overall accuracy of the classified image is compared to how each of the pixels is classified against the demonstrated land cover established from their consisted ground truth data (Riggio and Ndambuki, 2017; Congalton, 1991; Unger Holtz, 2007).

User accuracy's and Producer's accuracy are calculated individually each type such as water body, urban area, vegetation area etc. using Eq. 2 and 3.

Example: In 1990, water body's correct points were 10 and row total and column total were also 10:

$$\text{User Accuracy} = \frac{\text{number of correct points (value)}}{\text{The row total (value)}} \times 100$$

$$= \frac{9}{10} \times 100 \therefore \text{User Accuracy} = 90\%$$

$$\text{Producer Accuracy} = \frac{\text{Number of correct points (value)}}{\text{The column total (value)}} \times 100$$

$$= \frac{9}{10} \times 100 \therefore \text{Producer Accuracy} = 81.8\%$$

In 1990, total number of points was 50 and found total correct points were 49 and errors 1:

$$\text{Overall Accuracy} = \frac{\text{Number of total correct points (value)}}{\text{The number of points (value)}} \times 100$$

$$= \frac{45}{50} \times 100$$

$$= 0.95 \times 100$$

$$\therefore \text{Overall Accuracy} = 95\%$$

Kappa coefficient is calculated using Eq. 5 for 1990:

$$K = \frac{N \sum_{i=1}^n x_{ii} - \sum_{i=1}^r (x_{i+} \times x_{+i})}{N^2 - \sum_{i=1}^r (x_{i+} \times x_{+i})} \times 100$$

$$K = \frac{[(50 \times 45) - \{(10 \times 11) + (10 \times 9) + (10 \times 9) + (10 \times 11) + (10 \times 10)\}]}{[50^2 - (10 \times 11) + (10 \times 9) + (10 \times 9) + (10 \times 11) + (10 \times 10)]} \times 100$$

$$K = \frac{2250 - (1100 + 90 + 90 + 110 + 100)}{2500 - (1100 + 90 + 90 + 110 + 100)} \times 100$$

$$K = \frac{(2250 - 500)}{(2500 - 500)} \times 100$$

$$K = \frac{1750}{2000} \times 100$$

$$\therefore \text{Kappa coefficient, } K = 87.5\%$$

According to this process, here calculated data of 2000, 2010 and 2019 and that's are shown in the Table 3.

Therefore, according to the process of accuracy assessment of the study, the calculated data of the year 1990, 2000, 2010 and 2019 was accurate Table 3.

Discussion

The study area is highly vulnerable to natural causalities due to its geographical location (Paul and Dutt, 2010; Alam and Collins, 2010). Land use and land cover

changing patterns of Bangladesh from 1990 to 2019 were presented here Table 2 and Fig. 3. This study is the first that attempted to combine both techniques and analysis of land cover changes based on supervised classification. This research identifies the land cover changes of Bangladesh in different periods using supervised classification in ArcMap software. Hadeel *et al.* (2009) were showing the application of remote sensing and GIS for LULC change using supervised classification in June 2009. In Northern Australia, mapping of land covers a comparison of objective oriented and pixel-based classification methods are developed using this process (Whiteside and Ahmad, 2005). However, there have been lots of papers that reported the use of supervised classification to detect land cover changes such as Tirupati, India 2013, western Nile delta of Egypt 2011, Southern Appalachian Mountains 2003, South Africa 2007 etc. (Mallupattu *et al.*, 2013; El-Kawy *et al.*, 2011).

In this study, the land cover has been classified into five parts (waterbody, forest, urban area, barren soil and vegetation cover). In this study, the calculated waterbody has decreased 3.53% from 1990 to 2019 Table 2 and Fig. 3. Rai *et al.* (2017) and his colleague were found permanent wetlands decreased from 4.15 to 1.16% between 1967 and 2010 in their research paper in 2017. Sundarbans is located in the southeast area of Bangladesh (Islam and Gnauck, 2009; Chatterjee *et al.*, 2015; Mukhopadhyay *et al.*, 2006). Bangladesh forest area is classified as a hill, Sal and mangrove forest based on topographic setting (Alam *et al.*, 2008; Abdullah *et al.*, 2015; Masum *et al.*, 2008). Over the past time, the forest has been decreasing (Biswas and Choudhury, 2007; Mondal and Debnath, 2017; Iftekhar and Saenger, 2008). Forest cover change has primarily been observed using remotely sensed data for supervised analysis. 3.86% forest area has decreased in the study area from 1990 to 2019 Table 2 and Fig. 3. Raj *et al.* (2017) have found 6.2% of forest area decreased (9054 Km²) over the past 85 years from 1930 to 2015. Hasan *et al.* (2013) also have found that total forest cover was 12.11, 9.02 and 9.84% in 1976, 2000 and 2010 (Hasan *et al.*, 2013). Nevertheless, evaluated that forest area was not changed significantly (8820 to 8840 Km²) between 1990 and 2000. Moreover, diachronic spatial and non-spatial studies of forest area changes have found that LULC was conducted with different factors over time (Biswas and Choudhury, 2007). Various causes of forest cover deterioration have included; poverty, overpopulation growth, taboo felling, enhancement of agricultural land and lack of appropriate policy and implementation of policy (Lambin *et al.*, 2001; Hansen *et al.*, 2013; Hanewinkel *et al.*, 2013). Spatial patterns of land cover exhibited that urban growth followed certain superintendent between the 2000 s and 2010 s depending on the ground elevation (Rai *et al.*, 2017).

Bangladesh has suffered quickly LULC due to speedy population growth and urbanization that resulted from severe contractions in agricultural land (Chakravarty *et al.*, 2012). In this study, the urban area has increased 5.18% from 1990 to 2019 Table 2 and Fig. 3. However, Hasan *et al.* (2013) also found that the urban area increased from 474.95 to 876.16 Km² between 2000 and 2010 (Hanewinkel *et al.*, 2013). Barren soil has not significantly changed from 1990 to 2019 according to this study Table 2 and Fig. 3. The first 20 years 1990 to 2010 vegetation area was increased almost 3.36% but from 2010 to 2019 this area has decreased 0.9% Table 2 and Fig. 3.

Conclusion

Land is an important natural resource for our life. Monitoring LULC changes can help to take planning and implementation step to save land cover. The study takes the advantage of Landsat TM 4-5 and 8 OLI/TIRS satellite images and ArcGIS software techniques to quantify and calculate the land cover change in Bangladesh from 1990 to 2019. Land use change has a significant negative impact on the society and environment of this study area. Highly development of urban area are created the shortage of agricultural land, vegetation and forest. Agricultural, vegetation and forest area were decreased due to increasing residential area and people's livelihood pattern changed with this trend of land use change. Farmers and fishing engage themselves in small business, auto rickshaw driving and such other jobs. Farmers were used hybrid seeds and pesticides to increase their productivity and it creates environmental pollution. Waterbody and forest have changed into urban area cause of overpopulation and development. Waterbody also has filled up for cultivation and urbanization purposes. Trees are cut down for the fulfilment of the infrastructure needs and fuel. GIS and RS was used to process and analysed the data and finally create the map. Research found that changes happened in urban area, forest and vegetation cover and the percentage is shown in Fig. 3 and Table 2 respectively. These changes are shown human impacts on the study area. Results provide vital information on changing scenario of LULC to the line departments. Study provides some recommendation for proper land use and land cover planning and management:

- District and Upazila land use management strategy should be taken up in order to sustainable development, planning and management of LULC
- Government and different NGOs should take steps to provide training about the impact of land use and land cover change
- Community empowered resource management activity should be increased
- Alternative livelihood pattern and its involvement should be increased

Furthermore, the land use management policy of Bangladesh needs to be reconsidered and implement multi-disciplinary research for development of sustainable LULC change management strategy.

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Author's Contributions

Md. Mahmudul Hasan and Rashidul Islam: Research proposal writing; designing for research project implementation; questionnaire development; making guideline for quality data collection; data processing and analyzing; data interpretation; report writing, finalization of the article, reviewing the article.

Md. Saifur Rahman and Md. Ibrahim: Helped in questionnaire development; data processing and analyzing; report writing.

Md. Shamsuzzoha and Ruma Khanam: Helped in report writing and reviewing.

A. K. M. Mostafa Zaman: Helped in proposal writing, making guideline for quality data collection; data interpretation; finalization of the article, reviewing the article.

Ethics

Authors followed standard protocols in the entire research approach from research design to reporting.

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