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Spatio-temporal analysis of land cover changes in the evergreen and semi-evergreen rainforests: A case study in Chittagong Hill Tracts, Bangladesh

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ABSTRACT

The main purpose of this study is to describe the spatio-temporal analysis of land use and land cover status and to identify land cover changes, especially of deforestation and degradation in evergreen, semi-evergreen rainforests of Chittagong Hill Tracts from 1988-2018 by using Landsat 8 OLI-TIRS and Landsat 5 TM satellite imagery. The ArcGIS v10.5 and ERDAS Imagine v15 software were used to process satellite imageries and assess quantitative data for land-use change assessment of this study area. The study revealed that the area of forest land and water body decreased by 17.92% and 5.43% respectively from 1988-2018. On the other hand, the area of agricultural land, barren land and settlement increased by 45.66%, 312.08% and 240.01% respectively. If the present condition remains constant, the projection of future land-use/ land cover changes for the next 15 years will predict that more than 7.37% dense forest (2253.83 ha) land will be decreased and 19.60% agricultural will be converted to other land uses. This study suggests that proper policy should be adopted urgently to conserve residual forest coverage and restore it to regain its past appearance.

Key Words: *Forest conservation, GIS, Land use, Remote sensing and Satellite imagery.*

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I. Introduction

World tropical forests have been going through an extreme level of deforestation and degradation from 1980 to 1990 (Keenan et al., 2015; Langner et al., 2018). Tropical rainforests enumerated one of the most complex ecosystems, which creates an interrupted belt of green around the globe between (23.5^0 north) tropic of Cancer to the (23.5^0 south) tropic of Capricorn (Park et al., 2002). Recently 158000 sq kilometers (39 million acres) tropical forest lost from the world. Bangladesh is a small country of South-Asia having 10.96% of forest coverage in 2016, which are almost evergreen and

semi-evergreen tropical rain forests mainly elongated over Chittagong, Cox's Bazar, Chittagong hill tracts and Sylhet and it occupies 4.54% of total country's landmass,44% national forest land. Primary forests of Bangladesh are degraded due to extreme population growth associated with poverty, intense shortage of fuelwood, fodder and timber (Islam et al., 2001). Tropical wet evergreen/ semi-evergreen and deciduous forests are dominant in Chittagong Hill Tracts, Bangladesh; that coating 43% of total forest land are degraded and destructed immensely because of shifting cultivation, over-extraction of wood, encroachment, settlement, urbanization and wrong management practices (Hossain et al., 2008; Ahammad and Stacey, 2016; Hossen and Hossain, 2018; Hossain et al., 2019).

Change detection, a useful infliction related to land use and land cover changes (LULCC) which is a process that can be applied in the global forest and environmental change research are mainly done on inventory, monitoring and modeling the impact of changes on forests, environment and associated ecosystems at different scales(Chen et al., 2003; El-Kawy et al., 2011). Two terms land use and land cover are closely connected and interchangeable, here land cover define physical characteristics of earth's surface, and land use refers to land used by humans and their habitats (such as agriculture, settlements, industry etc (Kaul and Sopan, 2012; Islam et al., 2018). Growing population pressure and flourishing socio-economic needs converted forest land to settlement, urban and degraded land in an unplanned and uncontrolled way (Hossen et al., 2019). Among all anthropogenic argument of LULCC, urbanization is the most widespread (Iftekhar and Hoque, 2005; Dewan and Yamaguchi, 2009). Natural resources and its distribution like tropical, semi-tropical forests, different land cover change monitoring, land utilization, future planning, and observation can easily be done by this computer-based LULCC mapping (Mengistu and Salami, 2007; Chavare et al., 2015). Dynamic changes in the earth surface can be detected accurately in time to time, without being any contact of the earth surface in remote sensing and GIS application, by using satellite data (Mallupattu et al., 2013; Rawat and Kumar, 2015; Jovanović et al., 2015; Lyu et al., 2016). GIS provides a pliable platform for collecting, storing, displaying and analyzing digital data necessary for identification of every minute by applying sensor capability (Reis et al., 2008; Roy and Roy, 2012). Many studies are going on remotely sensed data and GIS information to address LULCC detection to get accurate and up-to-date land cover change information (Shalaby and Tateishi, 2007; Hosseini et al., 2019).

This paper aims to explore, analyze and illustrate the characteristics of LULCC in Bandarban Sadar Upazila, Bandarban using Landsat time-series imagery from 1988 to 2018. It was deliberately carried the study at Bandarban Sadar Upazila, Bangladesh is a land of beauty and blessed with a lot of natural objects among them Bandarban is one, which now facing huge environmental problems with the fast depletion of its natural resources and creates threats on existing forest cover (Nath et al., 2014; Hossen et al., 2019). During the 19th century, southeastern tropical hill forest lost it's 50% natural coverage due to shifting cultivation associated incendiary fires, population pressure from both indigenous as well as immigration of low land settlers, the encroachment of reserve forests, accelerating deforestation, soil erosion, agroforestry practices, horticultural and commercially teak plantation destroyed almost all climax vegetation in the area and 37% of the total forests of CHTs have been destroyed over time (Rasul et al., 2004; Ahammad and Stacey, 2016). It was selected the almost destroyed tropical forest area of Bandarban Sadar Upazila and tried to find out its LULCC picture from 1988 to 2018 using multi-temporal remote sensing and GIS technique and by doing so to minimize degradation and protect forest cover.

II. Materials and Methods

Study area

The selected study area (Figure 01) was Bandarban Sadar Upazila which considered an important biodiversity hotspot containing a tropical semi-evergreen forest ecosystem but due to continuous deforestation and degradation, this forest is almost destroyed nowadays. Bandarban Sadar Upazila has an area about 501.99 sq km which is located in between 21°55' and 22°22' north latitudes and 92°08' and 92°20' east longitudes. The Upazila is bounded by Rajasthali Upazila on the north, Lama Upazila on the south, Rowangchhari, and Ruma Upazilas on the east, Rangunia, Satkania and Lohagara Upazilas on the west and is bordered by Cox's Bazar, Chittagong, Rangamati and Khagrachari. On the opposite side of the 129-kilometer international border lie Chin and Arakan provinces of Myanmar. It

consists of 5 unions namely Rajbila Union, Kuhalong Union, Bandarban Sadar Union, Swalak, Tankabati.

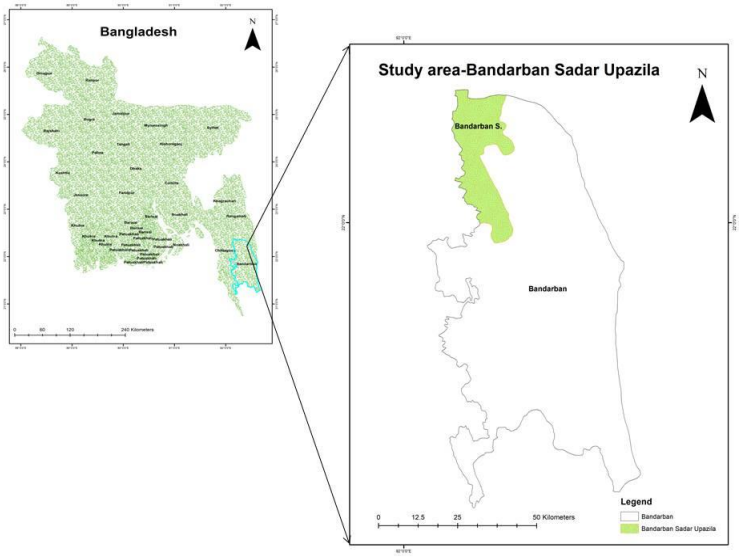

Figure 01. Study area of Bandarban Sadar Upazila

Data acquisition

The recent and latest satellite data that provided by USGS (United States Geological Survey) i.e. Landsat 8 OLI-TIRS (Operational Land Imager/Thermal Infrared Sensor), Landsat 5 TM (Thematic Mapper) for 2018, 1998 and 1988 were used for visual image interpretation, land use change identification and land use classification. The spatial resolution of Landsat 5 and 8 is 30m (Table 01). At the moment of selecting images, it was picked cloud and unwanted shade-free imagery to get accurate data for classification. For this reason, the image was selected within the winter period (November-February). A total of 47287.87 ha of land were estimated for the whole Bandarban Sadar Upazila after supervised image classification by using ERDAS Imagine v15. For this study, it was used those values were considered as accurate.

Data/Image processing

Image processing and performing supervised image classification helps to composite information from imageries. ERDAS Imagine v15 software was applied for image processing. Layer stacking of this software was used to convert three bands (5, 4, 3 for Landsat 8; 4, 3, 2 for both Landsat 5 and 2) into a single layer. From the layer file, Bandarban Sadar Upazila was clipped by using a subset tool and the shape file of Bandarban Sadar Upazila was collected (Figure 02). The atmospheric correction which measured if the satellite image could be affected for the presence of gases, solid, liquid particles from the atmosphere. The term is called the top of the atmosphere which measures radiance near the sensor (Hossen et al., 2019). As it was taken imagery those are free from shade and cloud and in the winter season. So, it did not perform the atmospheric correction process for this study.

Table 01. Detailed information about the satellite data used

Satellite	Sensor	Path/Row	Acquisition Date	Spatial Resolution (m)
Landsat 8	OLI-TIRS	136/44	29-01-2018	30×30
Landsat 5	TM	146/44	20-11-2003	30×30
Landsat 5	TM	146/44	12-12-1988	30×30

Source: GIS Geography (Landsat 8 bands and band combinations) Earth observing system (Landsat 5: TM)

Procedure for Land Use change detection

At first, it has to export a base map for satellite images and shape files of Bangladesh Administrative area were downloaded. The vector layer shape file of Bandarban Sadar Upazila was collected from DIVA-GIS country data. For image interpretation, ERDAS Imagine 15 and ArcGIS 10.5 v software were used to prepare land use category map and by side of this satellite data it was used field survey data (June 2018-December 2018) using and ensuring as to get that data accurate in case of identifying different categories of land uses. A field survey was directed in the study area to find out the latitude and longitude of specific land use categories and recorded. A total of 500 GPS point locations was

taken by using convenient sampling. Google earth images also used to collect GPS locations in remote areas where accessibility is very difficult for inexistent of the road network in hilly areas. As categorized data, study areas land uses were classified into the following 5 groups including Crops land, Barren land, Settlement, Water body and Forest area. The collected land uses data was used to find out the color tone of 2018 Landsat 8 images while training dataset.

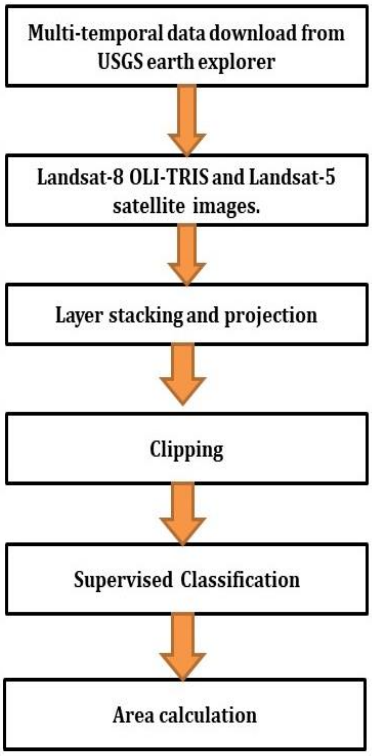

Figure 02. Procedure of satellite image classification

Data analysis

For land cover/land use change assessment Maximum likelihood classification (MLC) approach was used widely. For quantitative analysis of the spatial distribution of land use pattern the following equations were followed:

1. Magnitude of change = Magnitude of the new year – Magnitude of the previous year
2. Percentage Change= $\frac{\text{Magnitude of Change}*100}{\text{Base year}}$
3. Annual rate of Change= $\frac{\text{Final year}-\text{Initial year}}{\text{No of Years}}$

Accuracy was enumerated from the error matrix by dividing the sum of the entries that make major diagonal by the total number of examined pixels. Kappa co-efficient of agreement was also enumerated by using following equations (Hossen et al., 2019).

4. $$K\hat{} = \frac{Po - Pc}{1 - Pc} = 1 - \frac{1 - Po}{1 - Pc}$$
5. $$Pe = \sum_{i=1}^{r} (Pi_1 * Pi_2)$$
6. $$Po = \sum_{i=1}^{r} P\,ii$$

Here,

r = Number of rows in the matrix of error.
Pii = Proportion of pixels in row 'i' and column 'i'.
Pi_1 = Proportion of the marginal total of row 'i'.
Pi_2 = Proportion of the marginal total of column 'i'.

III. Results and Discussion

Land-use pattern of Bandarban Sadar Upazila in 2018, 2003 and 1988

Land use/land cover pattern of Bandarban Sadar Upazila gives us a clear statement about the land use practice in different years. The study revealed that about 5552.1hectare land area (11.74%) under agricultural practices and about 4927.63 hectares area (10.42%) under barren lands in 2018 (Table 02). Forest area coverage was 32822.1 hectare (69.41%) which is a greater portion among all practices. The settlement was 2520.05hectare area which covered 5.33% and the proportion of water body was 1465.98 hectares (3.1%) (Table 02 and Figure 03). The study also revealed that the area of agricultural crops and barren lands were 6461.91 hectares (13.67%) and 2704.95 hectares (5.72%) respectively in 2003. It was found that the area of barren land was lower than in 2018. The area of Forest coverage was 35076hectare which covered the large portion of lands that was 74.18% and the area of settlement and water body was 1760.37 hectares (3.72%) and1284.69 hectare (2.72%) respectively (Figure 04).

The image (1988) analysis describes that an undisturbed natural forest was found in Bandarban Sadar Upazila, the area of forest coverage was 39991 hectares, which was covered almost all over the Upazila (84.57%). In the remaining portion, there were other land-use practices like agricultural crops were practiced in 3815.75-hectare area (8.07%). Barren /fallow land was a very ordinary amount which was 1195.72 hectares (2.53%), Settlement was occupied then only 744.18 hectares which were 1.57% of total amount land area and water body was 1552.17 hectare (3.28%) (Figure 05).

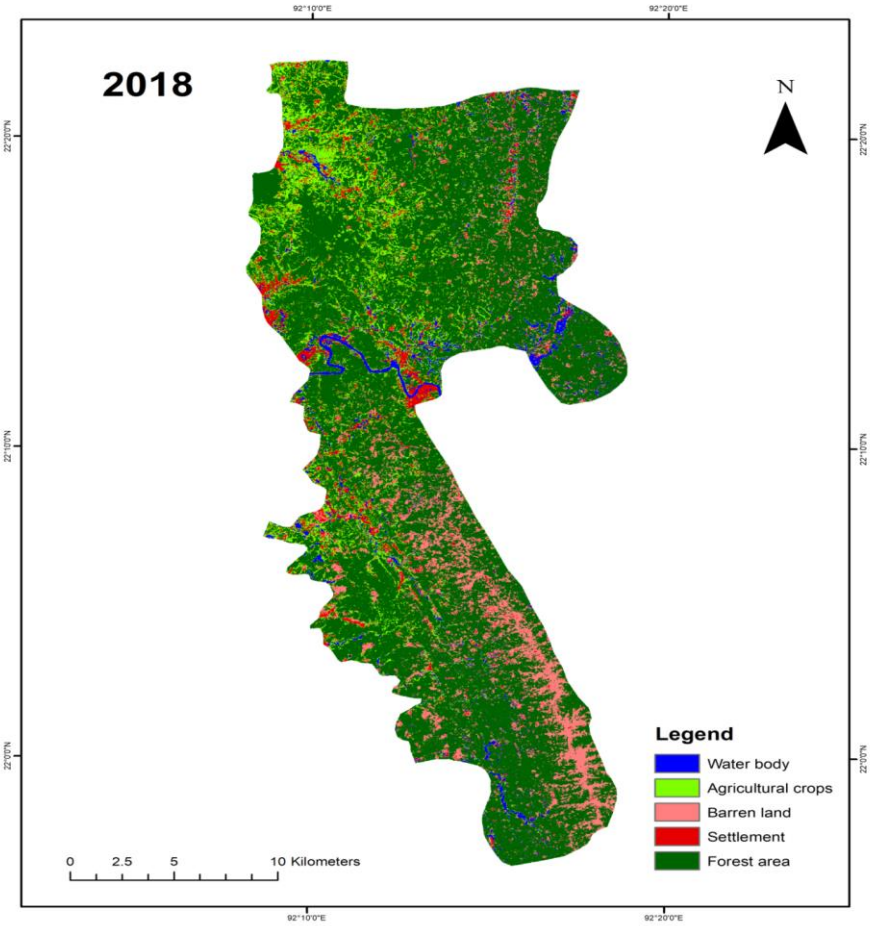

Figure 03. Land use classification of Bandarban Sadar Upazila in 2018

Relative changes in land use in Bandarban Sadar Upazila

Land-use mapping of Bandarban Sadar Upazila provided that spatial distribution of land use categories and land-use changes over the past 30 years. Relative changes in land use of Bandarban Sadar Upazila were assessed based on data presented in (Table 02) and (Table 03). Land use changes from 1988-2018 show a lot of changes occurred and a great portion of forest has been destroyed at this time.

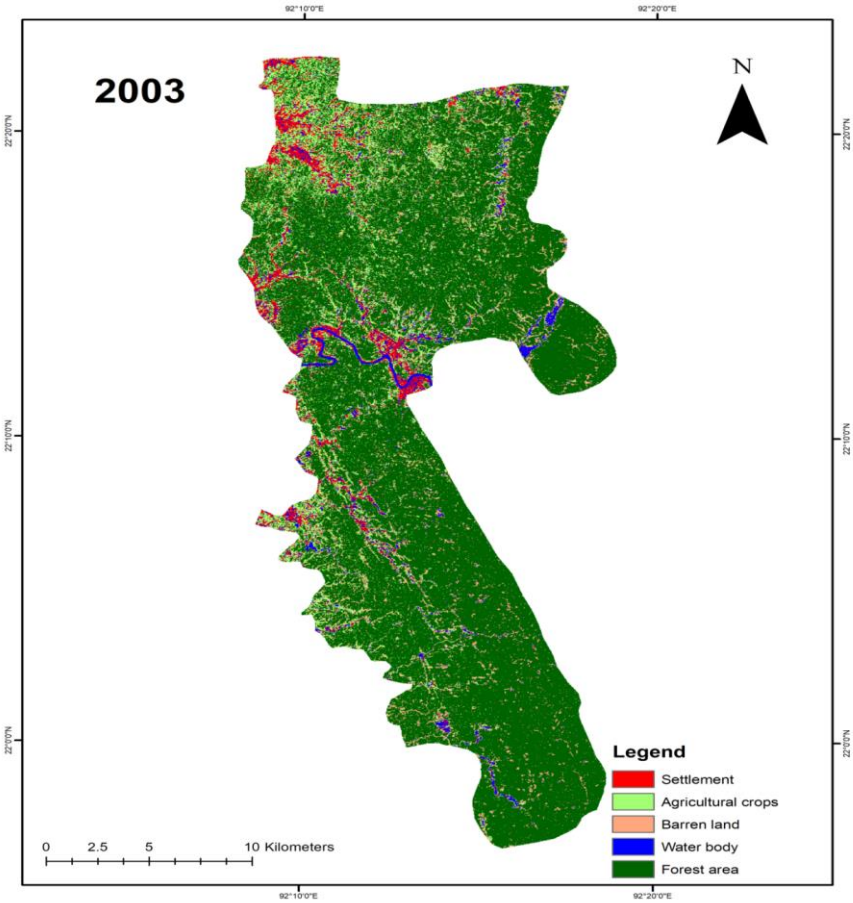

Figure 04. Land use classification of Bandarban Sadar Upazila in 2003

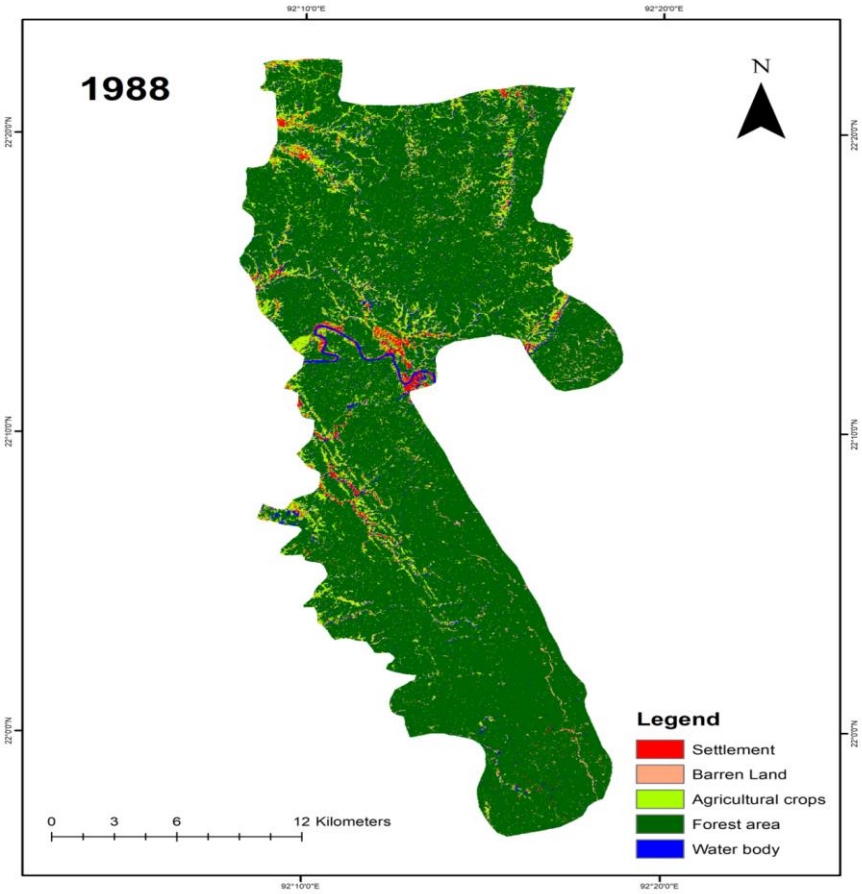

Figure 05. Land use classification of Bandarban Sadar Upazila in 1988

In 1988, the area of agricultural land (3815.75 hectares) was increased (Table 02) and in 2018 it has become about 5552.75 hectares (11.74%). The area of Barren land increased 4927.63 hectares (10.42%) from 1,195.72 hectares (2.53%). Also, the area of Forest land was decreased and it was found about 39990.96 hectares (84.57%) in 1988 and it has become 35,075.95 hectares (74.18%) in 2003 and 32,822.11 hectare (69.41%) in 2018. The area of Settlement increased 744.18 hectares in 1988 to 2,520.05 hectares in 2018 and the water body decreased 1,552.17 hectares land to 1,465.98 hectares land in 2018 (Table 02 ; Table 03 and Figure 06).

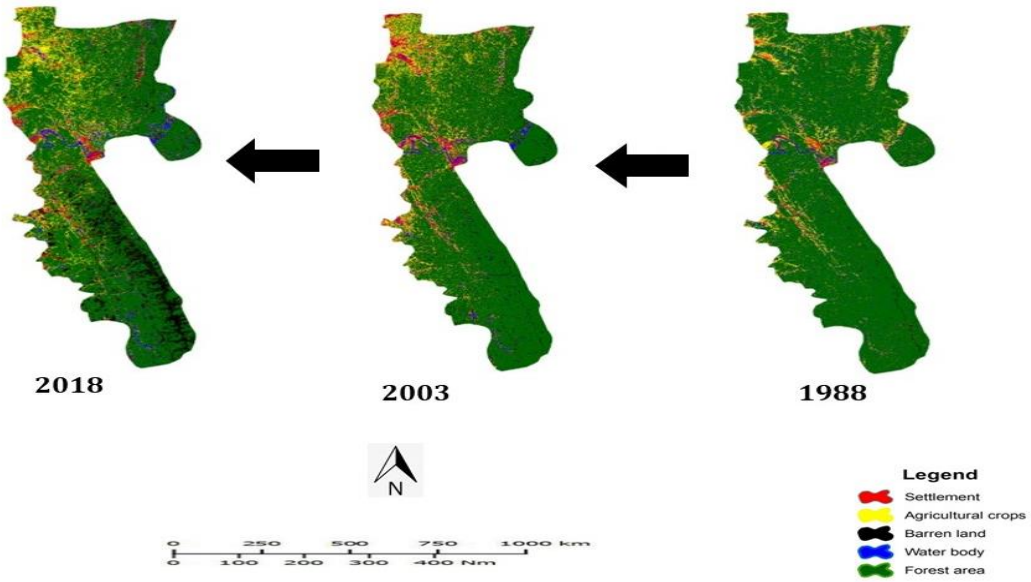

Figure 06. Relative changes of land use from 1988-2018 of Bandarban Sadar Upazila

Table 02. Land use Pattern of Bandarban Sadar Upazila (1988-2018)

Land use category	1988		2003		2018	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Agricultural crops	3815.75	8.07	6461.91	13.67	5552.1	11.74
Barren land	1195.72	2.53	2704.95	5.72	4927.63	10.42
Forest area	39991	84.57	35076	74.18	32822.1	69.41
Settlement	744.18	1.57	1760.37	3.72	2520.05	5.33
Water body	1552.17	3.28	1284.69	2.72	1465.98	3.1

Table 03 shows that land-use change from 1988-2018. In this time, the area of agricultural land was increased 45.66% (116.02 hectares), Barren land 312.08% and settlement 240.01% and the annual rate of change was 118.59 ha. On the other hand, the area of Forest land decreased very rapidly and it was lost about 7166.85ha forest land from 1988-2018 and annual destruction rate was 17.92% (Figure 07). The area of water body decreased by 5.43% (5.61 hectares) land.

Table 03. Land use change assessment of Bandarban Sadar Upazila from 1988 to 2018

Land use category	Land use change: 1988-2003			Land use change: 2003-2018			Land use change: 1988-2018		
	Changed area (ha)	% change	Annual rate of change	Changed area (ha)	% change	Annual rate of change	Changed area (ha)	% change	Annual rate of change
Agricultural crops	2650.13	69.52	176.68	-909.82	-14.08	-60.65	1740.31	45.66	116.02
Barren land	1509.15	126.2	100.61	2222.68	82.17	148.18	3731.84	312.08	248.79
Forest area	-4913.01	-12.29	-327.53	-2253.83	-6.43	-150.26	-7166.85	-17.92	-477.79
Settlement	1019.2	137.51	67.95	759.68	43.15	50.65	1778.88	240.01	118.59
Water body	-265.47	-17.13	-17.7	181.29	14.11	12.09	-84.18	-5.43	-5.61

Note: (-) sign denotes decrease of magnitude of change of land use category in different time frame.

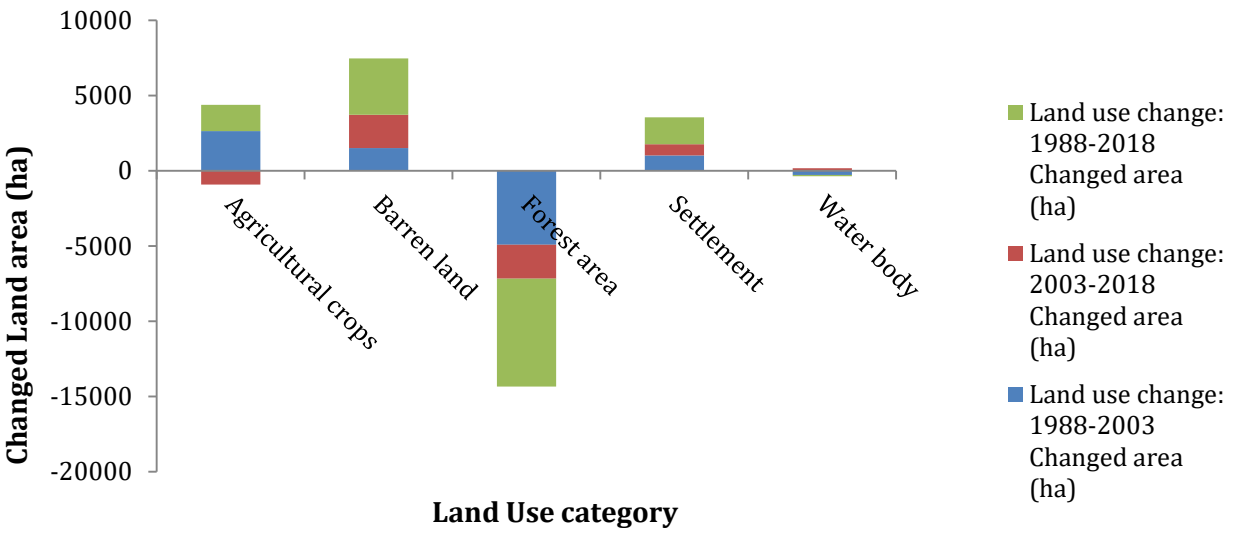

Figure 07. Relative changes of land use in Bandarban Sadar Upazila from1988-2018

Land conversion to different land use practices

The study also revealed that deforestation was occurred for practicing other land uses especially agricultural activities, agroforestry practices, infrastructure or urbanization that all are described in inter-conversion of land-use practices (Table 04 and Table 05). Rapidly changes in land conversion were noticed between 1988-2018 (Figure 08 and Figure 09). The area of forest land was converted into barren land, settlement, agricultural crops and water body. At the same time, other land use practices were also converted to different practices. The rate of conversion was more acute between 2003-2018 (Figure 09) than 1988-2003 (Figure 08) that represents the multiplication of population, settlement, agricultural crops and barren land. It was also found that forest area decreased rapidly due to urban expansion (Figure 09). The study predicts that the area of evergreen and semi-evergreen forests of Chittagong Hill Tracts is going to extinct.

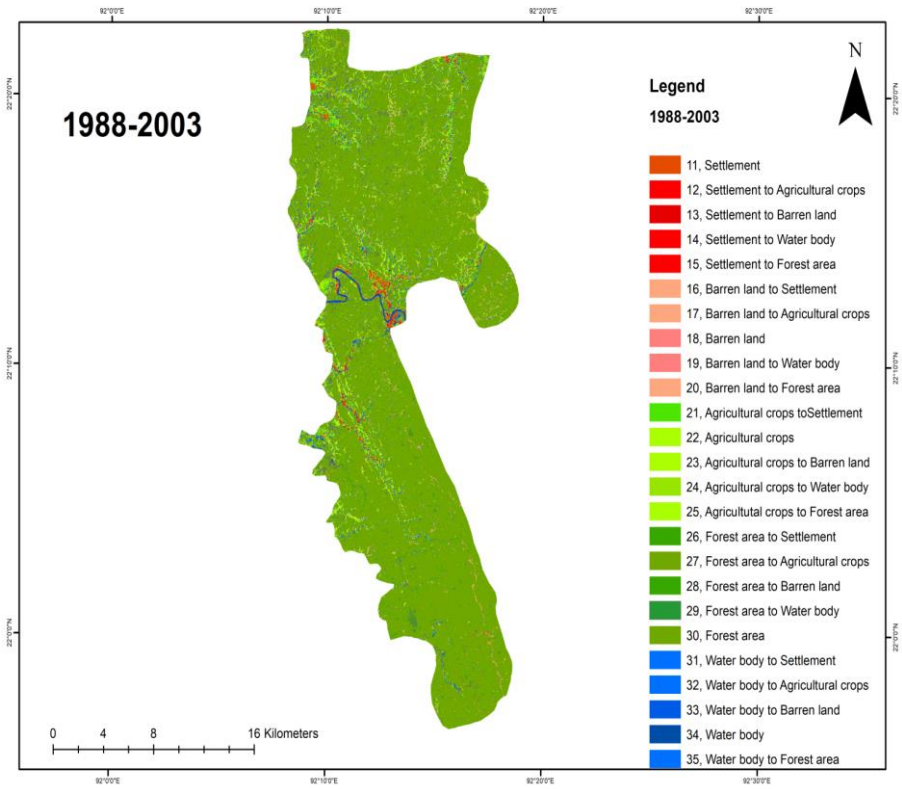

Figure 08. Land use and land cover conversion in Bandarban Sadar Upazila 1988-2003

Table 04. Inter-conversion of land uses from 1988-2003

Land use area(ha)-1988	2003 Land use area(ha)-2003					
Sum of Area(hectare)	**Column Labels**					
Row Labels	Agricultural crops	Barren land	Forest area	Settlement	Water body	Grand Total
Agricultural crops	1511.90	367.12	860.13	765.58	311.03	3815.75
Barren Land	309.14	181.71	576.39	78.44	50.04	1195.72
Forest area	4054.41	2014.44	33122.54	279.81	519.76	39990.96
Settlement	167.86	21.39	47.30	422.84	84.78	744.18
Water body	422.58	121.98	472.45	215.06	320.09	1552.17
Grand Total	**6465.89**	**2706.64**	**35078.81**	**1761.73**	**1285.71**	**47298.78**

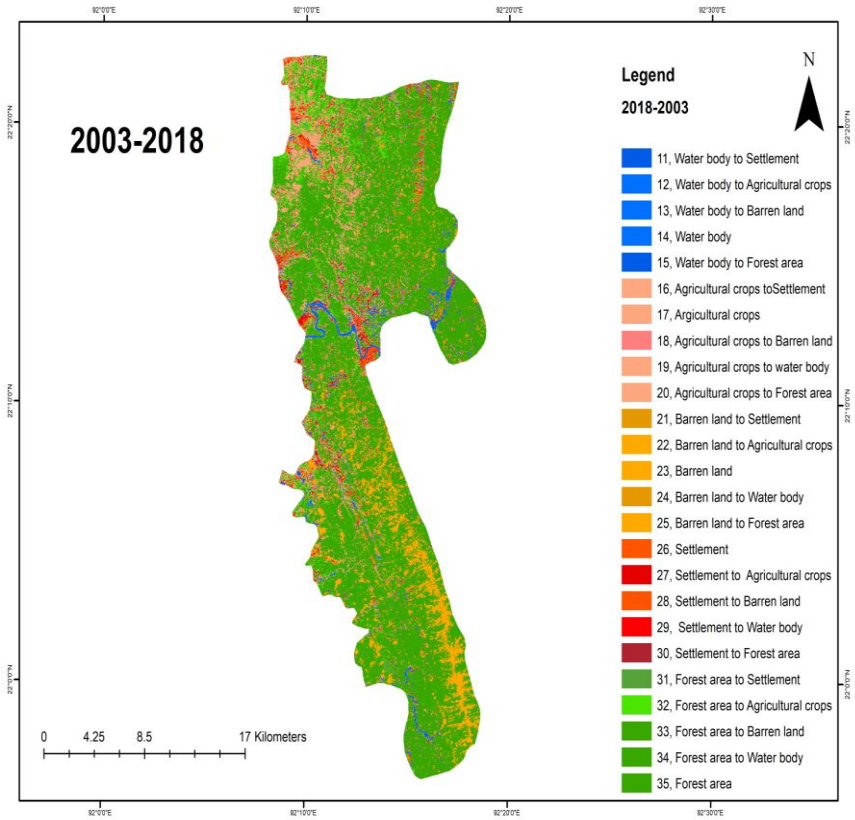

Figure 09. Land use and land cover conversion in Bandarban Sadar Upazila from 2003-2018

Table 05. Inter-conversion of land uses from 2003-2018

Land use area(ha)-2003	Land use area(ha)-2018					
Sum of Area (ha)	**Column Labels**					
Row/Labels	**Agricultural Crops**	**Barren lands**	**Forest area**	**Settlement**	**Water body**	**Grand total**
Agricultural crops	1895.65	299.76	3127.61	816.44	322.45	6461.91
Barren land	413.61	416.13	1521.56	189.30	164.35	2704.95
Forest land	2500.75	4080.91	27539.27	628.21	326.81	35075.95
settlement	422.92	75.33	225.28	662.02	374.83	1760.37
Water body	319.18	55.51	408.39	224.08	277.54	1284.69
Grand Total	**5552.10**	**4927.63**	**32822.11**	**2520.05**	**1465.98**	**47287.87**

Accuracy assessment

Summary of supervised classification accuracy for the 3 different time frames (1988, 2003 and 2018) found from accuracy assessment is shown in (Table 06). The very best accuracy (84%) was found for the 2018 supervised classification and therefore the lowest accuracy (72%) for 1988 (Table 06).

Kappa statistics for 2018 image classification shows a worth of 0.78713 denoting almost perfect/perfect match between the classified and reference data within the arrangement, for the opposite 2 years to discover the value 0.687635 in 2003and 0.65198 in 1988 (Table 06).

Table 06. Overall classification accuracy and kappa statistics of supervised classification of 1988, 2003 and 2018 satellite imageries of Bandarban Sadar Upazila

Year	Classification accuracy (%)	Kappa statistics
1988	72	0.65
2003	75	0.69
2018	84	0.79

Prediction of future land use for Bandarban Sadar Upazila

The prediction process in land use and land cover change has gained attraction nowadays. To estimate the future land-use changes of Bandarban Sadar Upazila it was used prediction method where the trend of growth will remain constant. If the present situation remains constant, the projection of future land-use/ land cover changes for the next 15 years will predict that more than 7.37% dense forest (2253.83 ha) land will be decreased and 19.60% agricultural will be converted to other land uses. On the other hand, 31.09% (2222.69 ha) Barren land, 23.16% (759.68 ha) Settlement and 11.01% (181.29 ha) Water body will be increased in 2033 (Table 07 and Figure 10).

Table 07. Predicted Land use change assessment of Bandarban Sadar Upazila for time frame (2018-2033)

Land-use category	Predicted land use in 2033		Land use in 2018		Predicted land use change in 2018-2033		
	Area (ha)	% Change	Area (ha)	Annual rate of change	Changed area (ha)	% change	Annual rate of change
Agricultural crops	4642.28	9.82	5552.1	-60.6544	-909.82	-19.6	-60.65
Barren land	7150.32	15.12	4927.63	148.179	2222.69	31.09	148.18
Forest area	30568.28	64.64	32822.11	-150.2556	-2253.83	-7.37	-150.26
Settlement	3279.73	6.94	2520.05	50.6451	759.68	23.16	50.65
Water body	1647.27	3.48	1465.98	12.0859	181.29	11.01	12.09

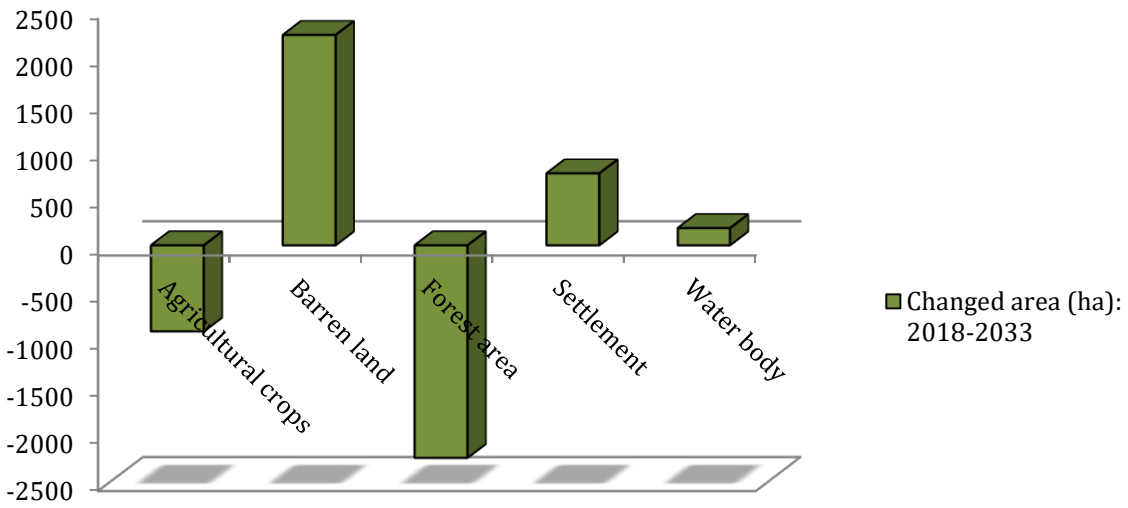

Figure 10. Prediction of future (2033) land use for Bandarban Sadar Upazila

Temporal pattern of land use/land cover change and prediction of trend line

It is possible to find a line diagram from Figure 11, which mainly manifestoes over time and predicts the results which yet not recorded. It also gives a changing trend view of land use and land cover

changes of Bandarban Sadar Upazila in 1988, 2003, 2018 and 2033. Within 45 years it is observed a great change in land-use practices in this Upazila. The graph revealed that no Table changes happened in two land-use classes especially forest area and barren land.

The graph also gives a real picture of the evergreen and semi-evergreen rain forests of Chittagong Hill Tracts, Bangladesh. Forest destruction and human-modified land use changed ruined this precious ecosystem. In 1988 forest area coverage was 84.57% (Table 02) and it decreased gradually with time and it will be 64.6% in 2033 (Table 07). Barren land will be increased for deforestation; it indicates a loss of biodiversity. In 1988, barren land was 2.53% (Table 02), but it will be 15.1% in 2033 (Table 07). It is also noticed that the area of agricultural land was 8.07% in 1998 and it has become 13.67% in 2003 and from 2018, it was started to decrease and finally it will be found 9.82% in 2033 (Table 07 and Figure 11). At the same time, the area of the settlement also increased with the passage of time but the rate is very little. In the case of the water body, it also found very little amount of change from 1988-2033.

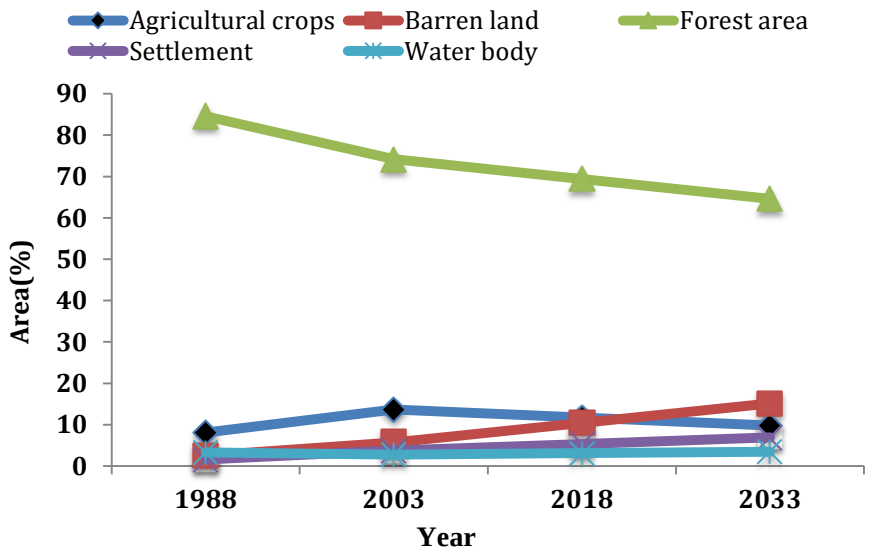

Figure 11. Temporal patterns of LULC area at Bandarban Sadar Upazila

IV. Conclusion

This study provides the LULCC classification of Bandarban Sadar Upazila, Chittagong Hill Tracts and the rate of forest destruction at the same time rapid enhancement of settlement and barren land. The natural forest of the study area is being exhausted due to teak plantation, agroforestry and horticultural practices. This forest conversion is the leading cause of deforestation at present in the Chittagong Hill Tracts. A good quality image has a great impact on final change detection results based on multi-temporal remote sensed data. Although change detection accuracy along with kappa value for 1988, 2003 and 2018 supervised land use classification was good enough to detect the alteration scenarios of site. This result also exhibits that supervised classification was an excellent approach to assess land use and land cover change by using multi-temporal satellite data.

The study represents a lack of management, policy implementation and spatial information in forest conservation and protection process of evergreen and semi-evergreen rainforests of the Chittagong Hill Tracts which can be allayed by remote sensing data and it provides opportunities to estimate LULCC change and their spatial distribution.

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