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Impact of Rubber Plantation Growth on LULC Changes in Eastern-Himalayan Region of West Tripura District Using Geospatial Approach

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ABSTRACT

Land use and land cover changes depict trends and patterns of an area's land dynamics. The current study revealed the land use characteristics of West Tripura district which is part of the Eastern Himalayan region and shares an international boundary with the neighboring country of Bangladesh. Thus, West Tripura district is a geopolitically highly sensitive area. The capital of Tripura state i.e., Agartala city located in West Tripura district, it gives immense pressure on land use for various developmental activities since Population growth and rapid urbanisation forced. Farmers rely on cash crops rather than subsistence agriculture which impacts the district's land use pattern and modifies the land dynamics. The traditional farmers of West Tripura district very quickly geared to adopt cultivation of rubber plantation from jhum cultivation and tea plantation. All these factors influenced to work out on LULC changes in West Tripura district for the decadal (2000-10 & 2010-20), and for twenty years (2000-20) using Landsat-4 & 5 TM, Landsat-8 OLI and Survey of India topographic maps with help of ArcGIS software for the applications of supervised classification (MLC), Kappa accuracy for Landsat data, conversion matrix, NDVI, NDWI and NDBI. The results revealed that rubber plantations and settlements overlapped on natural vegetation, shrubland, tea plantation, and water bodies in the last 20 years. The water bodies are sinking due to extension of agricultural land. The current study would help to understand the land use characteristics to plan the proper utilization of resources for sustainable development.

Key words: Eastern-Himalayan Region, Geospatial Approach, LULC Changes, Rubber Plantation, West Tripura.

INTRODUCTION

Man can alter the earth's environment through the process known as land utilization which can impact developmental processes that various factors like rapid population growth, urbanization, industrialization, infrastructural development, and the transformation in agricultural practices, etc (Lambin 1997, Aansen et al. 2014, Aldhshan and Shafri 2019, Pande 2020, Foley et al. 2005). The rapidly increasing population is the main reason behind the speedy changes in land use character. It influences the global and local environment and alters the fertile land into urban areas (Wu et al. 2006, Guan et al. 2011, Raj and Vijayan 2012, Toure et al. 2018, Abubakr et al. 2014). In the process of urbanization, the fertile lands are converted into commercial, industrial, and built-up areas. All those factors together influenced to change of the LULC at the terrestrial dynamics and portray the livelihood pattern of a region (Islam et al. 2017, Birhanu et al. 2019, Ewunetu et al. 2021, Sagan et al. 1979, Tan et al. 2010, Pielke et al. 2002, Vitousek et al. 1997). This type of study is more essential to know the strength and weaknesses of a region, it helps researchers and policymakers to build sustainable economic and regional planning (Suresh et al. 2011, Mondal et al. 2016). Currently satellite data are used globally to know LULC changes and it has universally accepted method (Ahmed 2011, Du et al. 2002, Elagouz et al. 2020, Hassan 2017, Debnath et al. 2017, Mishra et al. 2020, Tewabe and Fentahun 2020, Kastha and Khatun 2022). For making detection maps more useful satellite imageries with less cost and GIS software, and even portable GPS handset would use for ground truth verification (Bakr et al. 2010, Barakat et al. 2019, Brondizio et al. 1994, Kachhwala 1985).

Rapid changes in land use patterns have been

observed in India during the last century because of the increasing population, urbanisation and economic growth (Tian et al 2014). In India, the process of urbanisation and development of technology has more impact on forest land, it has decreased from 100 million hectares to 80 million hectares, and agricultural land has increased from 100 million hectares to 120 million hectares from 1880 to 1950 (Richards and Flint, 1994). Hot spots of natural vegetation areas gradually deteriorate in Eastern Himalayas since farmers switch over to cash crops from traditional jhum for the betterment of livelihood (Roy and Roy 2010).

Land use changes in the study area have taken place in different phases. During pre-independent times the agricultural policy of the Raja planned to change unproductive land into productive agricultural fields which has given more dimensions of land utilization in Tripura. After the independence influx of migrated population from Bangladesh settled in Tripura. In 1980, the rubber plantation policy to rehabilitate the jhumia's has given a new direction to the land use pattern of the state (Das and Das 2011, Gautam et al.1985, Sarkar 2011, Bhowmik 2006, Debnath and Debnath 2017). Rapid urbanization has put tremendous pressure on the existing land of Tripura to bring about a radical transformation in the land use pattern (Santra et al. 2018). Therefore, a detailed investigation of LULC is needed for planning for sustainable use and management of natural resources (Packialakshmi et al. 2010). The present study aims to identify the type, trends, and patterns of land use change and to recognize the driving forces.

STUDY AREA

Tripura state was formed in 1972, Agartala city has become the capital of the state, it has located in West Tripura district. West Tripura district more prosperous district compare to other districts since it occurs in all administrative head offices. It lay between latitudes and longitudes of 23°40′N to 24°07′N, and 91°12′E to 91°32′E, the geographical area of West Tripura district is 942.55 km^2. Bangladesh bounds in the northern and western sides

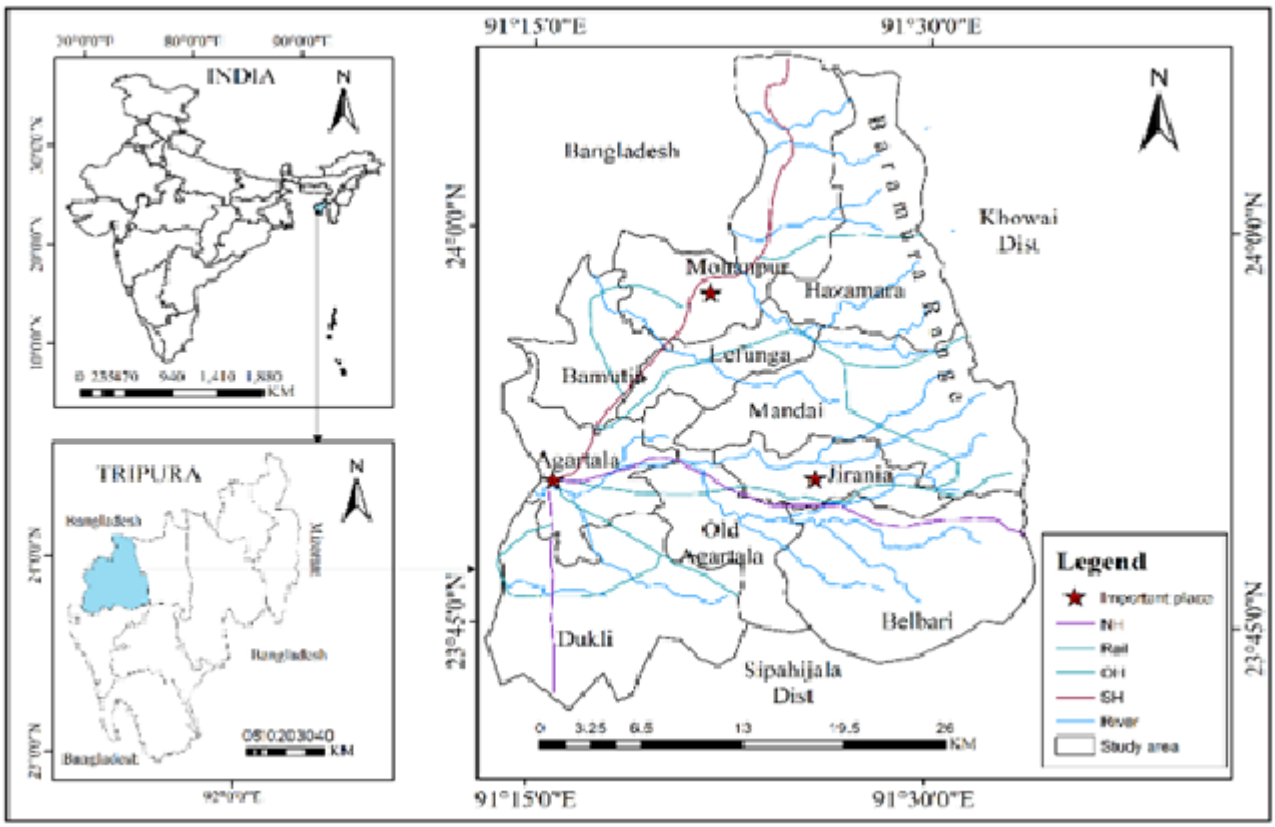

Figure 1. Location map of the study area

of the district where Khowai district is situated in the eastern portion, and Sepahijala district is in the southern portion (Fig. 1). Physiographically, the study area is part of the Eastern Himalayan region (Anees et al. 2022). It has a diversified topography of valleys and ridges which are locally known as the tillas-lungas (Sen et al. 2015). Geologically, the study area falls under the Dupitila, Tipam, and Surma groups of rock formations along with the hill range of Baramura. It has stretched from northeastern to southeastern parts of the study area. As per lithology, the Dupitila groups of rocks are mainly formed with sand and silty clay and the Tipam group of rocks is molded by ferruginous sandstones. The Surma group of rocks is formed by shale, sandstone and mudstones, and recent alluvium deposits found in the course of Haora river basin. The average annual rainfall of the study area is 2038mm, and the average daily temperature is 26.50°C as per the report of IMD, Agartala for the year 2018. The maximum elevation of 258m has been observed in the hilly areas of the Baramura range whereas a minimum elevation is less than 40m, it has located in the western part of the study area. Haora river is the main river that originates in Baramura hills and it flows through important towns like Khumulwng, Khayerpur, and the capital city of Agartala. The district is flooded during the rainy seasons by numerous small rivers, charas, gangs, and nalas. It experiences a warm and humid subtropical climate throughout the year with five distinct seasons, i.e., spring, summer, monsoon, autumn, and winter. All these physiographic and climatic variables impacted the cultural entities of the district. After the formation of West Tripura district in 2012, the total population is 918200, and the population density is 930 persons/ Km^2. According to the 2011 census, the urban population of West Tripura increased from 15 to 42% between 1981 and 2011. Drastic population growth has been observed in the study area.

MATERIALS AND METHODS

The Landsat 4-5 (TM), and Landsat 8 OLI satellite images of 30 m resolution have been downloaded from the USGS Earth Explorer (https://earthexplorer.usgs.gov) for the years 2000, 2010 and 2022 seasonally. All Landsat images have been mosaic for the preparation of a single layer to project on Universal Transverse Mercator (UTM) Zone 46 N to detection of LULC major classes (agricultural land, natural vegetation, rubber plantation, tea plantation, settlement area, shrub land, water bodies, and bare land) changes in the study area with the application of Maximum Likelihood Classification (MLC) for the year 2000, 2010, and 2020 (Table 1, Fig. 2). Before application of MLC the highest number of training samples have been collected for each land use class which is the most essential for assessment of overall accuracy and Kappa accuracy based on user accuracy and producer accuracy values and even checked ground truth verification through google earth images and Survey of India (SOI) topographical maps on scale 1: 50,000 (No. 79M/5, 78P/8, 79M/9, 79M/6, 79M/1) with help of coordinates using portable GPS handset (John et al. 2020, Foody 2002). The selection of more training samples would more accurate for the calculation of MLC. After evaluating the overall accuracy and kappa accuracy would work out the conversion matrix for twenty years and decadal growth rate for the changes of LULC (2000-10, 2010-20) in the study area. The entire process would work out with help of ArcGIS 10.7 software. The following formulas have been applied.

$$\text{Overall accuracy} = \frac{\sum_{i=1}^{r} xii}{N} * 100$$

$$\text{Kappa accuracy} = \frac{N\sum_{i=1}^{r} xii - \sum_{i=1}^{r}(xi+*x+i)}{N^2 - \sum_{i=1}^{r}(xi+*x+i)}$$

according to Congalton 1991

where, r = the matrix's row count, xii = total count of correctly classified pixels in row i and column = are marginal totals of row and column, respectively, N = Total count of pixels in the matrix table.

Area changes in LULC classes = the amount of area in LULC classes for the current year - the amount of area in LULC classes for the base year.

The growth of LULC class has been calculated by dividing the 'Area change into LULC classes with the base year (previous year) and multiplying it by 100

The growth rate of LULC = (Area change in LULC classes / Area of the base year) * 100

Table 1. Spectral characteristics of satellite image data

Satellite & Sensor	Spatial Resolution (m)	No. of bands	Path	Row	Acquisition date
Landsat 4/5 TM	30	7	136	43 & 44	01.05.2000
Landsat 4/5 TM	30	7	136	43 & 44	11.10.2000
Landsat 4/5 TM	30	7	136	43 & 44	13.02.2000
Landsat 4/5 TM	30	7	136	43 & 44	15.05.2010
Landsat 4/5 TM	30	7	136	43 & 44	23.11.2010
Landsat 4/5 TM	30	7	136	43 & 44	08.02.2010
Landsat 8 OLI	30	11	136	44	10.05.2020
Landsat 8 OLI	30	11	136	44	18.10.2020
Landsat 8 OLI	30	11	136	44	04.02.2020

Source: USGS Earth Explorer

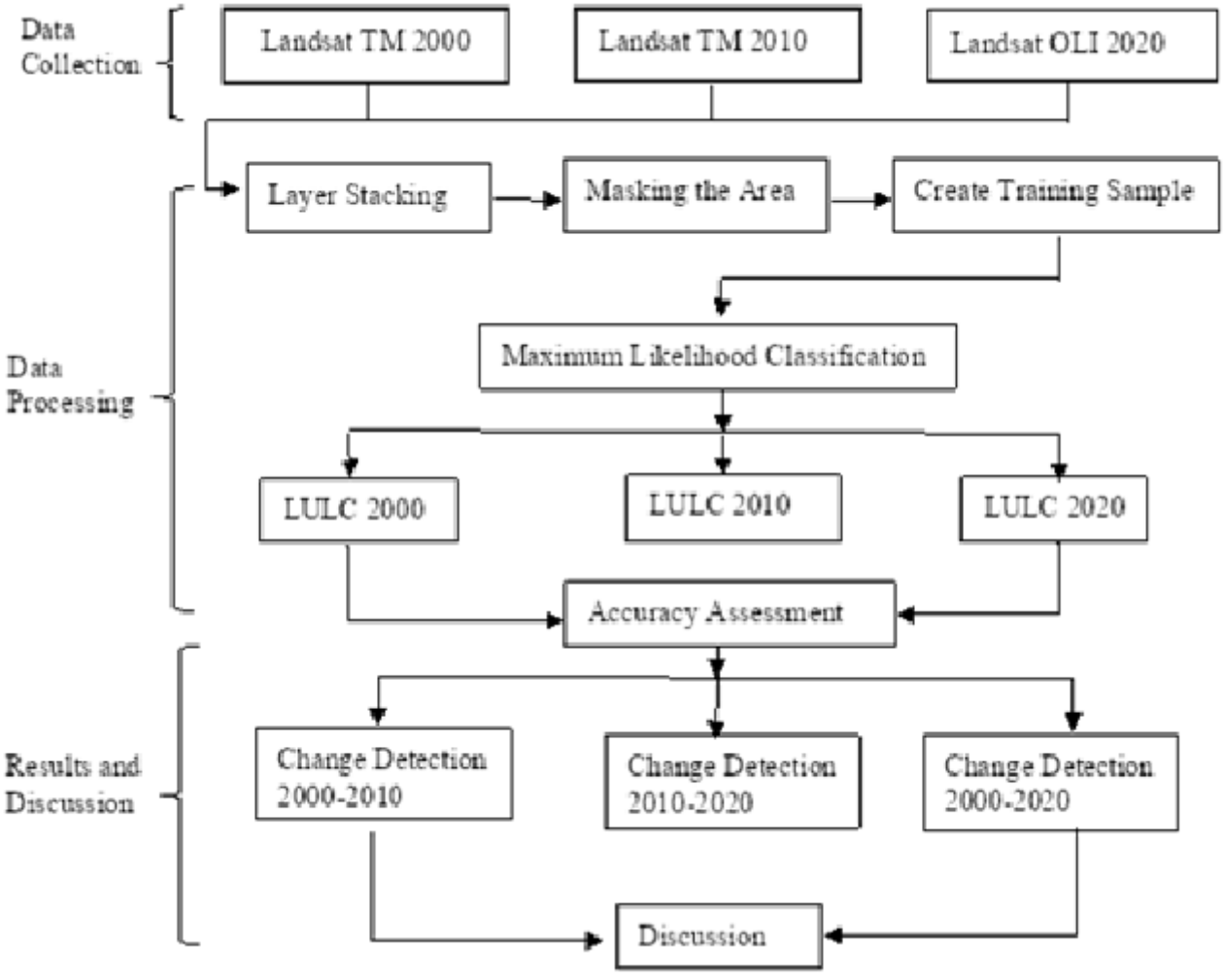

Figure 2. Flow chart of methodology

The Normalized Difference Vegetation Index (NDVI) is the most popular to analyze vegetation health globally (Han et al. 2009). The spectral reflectance of NDVI helps to explore the land use classes to increase the reliability and validity of the research. The classification of NDVI is Landsat 4-5 for the different year 2000 and 2010, and Landsat 8 OLI for the year 2020 data used. The LULC class-wise zonal statistics have been calculated through NDVI data to estimate decadal and seasonal NDVI changes (Singh et al. 2016, Lunetta et al. 2006). The LULC classes were identified as natural vegetation (NV), rubber plantation (RP), tea plantation (TP), agricultural land (AL), settlement area (ST), shrub land (SL), water bodies (WB), and bare land (BL).

NDVI= (NIR - RED / NIR + RED)

(The value of NDVI ranges from -1 to +1. The positive value represents healthy vegetation whereas the negative value of NDVI represents vegetation-free water body area).

The Normalized Difference Water Index (NDWI) was used to observe water bodies for the years 2000, 2010 and 2020.

For Landsat 4-5= (GREEN – NIR) / (GREEN + NIR)

For Landsat 8 OLI= (GREEN – SWIR) / (GREEN + SWIR))

(The value ranges from -1 to +1 whereas the positive value represents the more water bodies are present and the negative value represents settlement and natural vegetation).

Normalized Difference Built-up Index (NDBI) was used to identify the settlement or the built-up area of a region, the value ranges from -1 to +1 where the high value of NDBI represents settlement or built-up area and the low value represents vegetation cover or non-urban areas for the years 2000, 2010 and 2020.

NDBI= (SWIR - NIR) / (SWIR + NIR)

RESULTS AND DISCUSSION

Spatio-temporal analysis of LULC categories for the years 2000, 2010 and 2020

As per Landsat -4/5 TM & Landsat -8 OLI images have identified eight distinct land use classes in West Tripura. They are agricultural land, bare land, natural vegetation, rubber plantation, settlement area, shrub land and tea plantation. In 2000, among all the classes natural vegetation occupied the highest percentage of the area (46.60%), followed by settlement (14.87%), shrubland (9.88%), agricultural land (8.59%), rubber plantation (7.64%), tea plantation (5.96%), water bodies (5.18%) and bare land (1.24%) out of total district geographical area (942.55 km^2). In 2010, natural vegetation is still the highest area among LULC classes that is 39.93%, followed by settlement (17.42%), rubber plantation (16.58%), agricultural land (10.99%), tea plantation (5.88%), remaining occupied less than 6%. In 2020, natural vegetation still recorded a high area that is 26.35%, followed by rubber plantations (22.41%), settlement (21.34%), agricultural land (16.42%), etc. Finally, compared between 2000 to 2020, the percentage of rubber plantations gained from 7.64% to 22.41%, settlements from 14.87% to 21.34%, and agricultural land from 8.59% to 16.42% but drastically decreased categories are natural vegetation from 46.60% to 26.35%, shrubland from 9.88% to 3.25%, waterbodies from 5.18% to 3.38%, and tea plantation from 5.96% to 5.39%. The above LULC classification reveals that radically expands the area of settlements and rubber plantations together occupied near about 43.75% area of the total geographical area (Table 2, Fig. 3).

Assessment of Overall and Kappa Accuracy on LULC categories for the year 2000, 2010 and 2020

The overall accuracy and kappa accuracy were worked out on the basis of User Accuracy (UA) and Producer Accuracy (PA) based on LULC category values extracted from the map of satellite images. Further, the overall accuracy on LULC categories for the year 2000, 2010 and 2020 are 84.36%, 83.96 and 88.81%, respectively, and kappa accuracy is 81.87, 81.32 and 86.88%. Finally, the selected three decades of LULC categories showed kappa and overall accuracy was found more than 80%. Therefore, the candidate selected training samples of LULC categories of agricultural land, natural vegetation, rubber plantation, tea plantation, settlement, shrub land, water bodies, and bare land that were sufficient and more accurate (Tables 3, 4, 5).

Decadal spatiotemporal LULC changes from 2000-10, 2010-20, & 2000-20 (twenty years)

A significant change occurred in land use and land cover categories in the study area for the year 2000, 2010, and 2020. From 2000 to 2010, the LULC

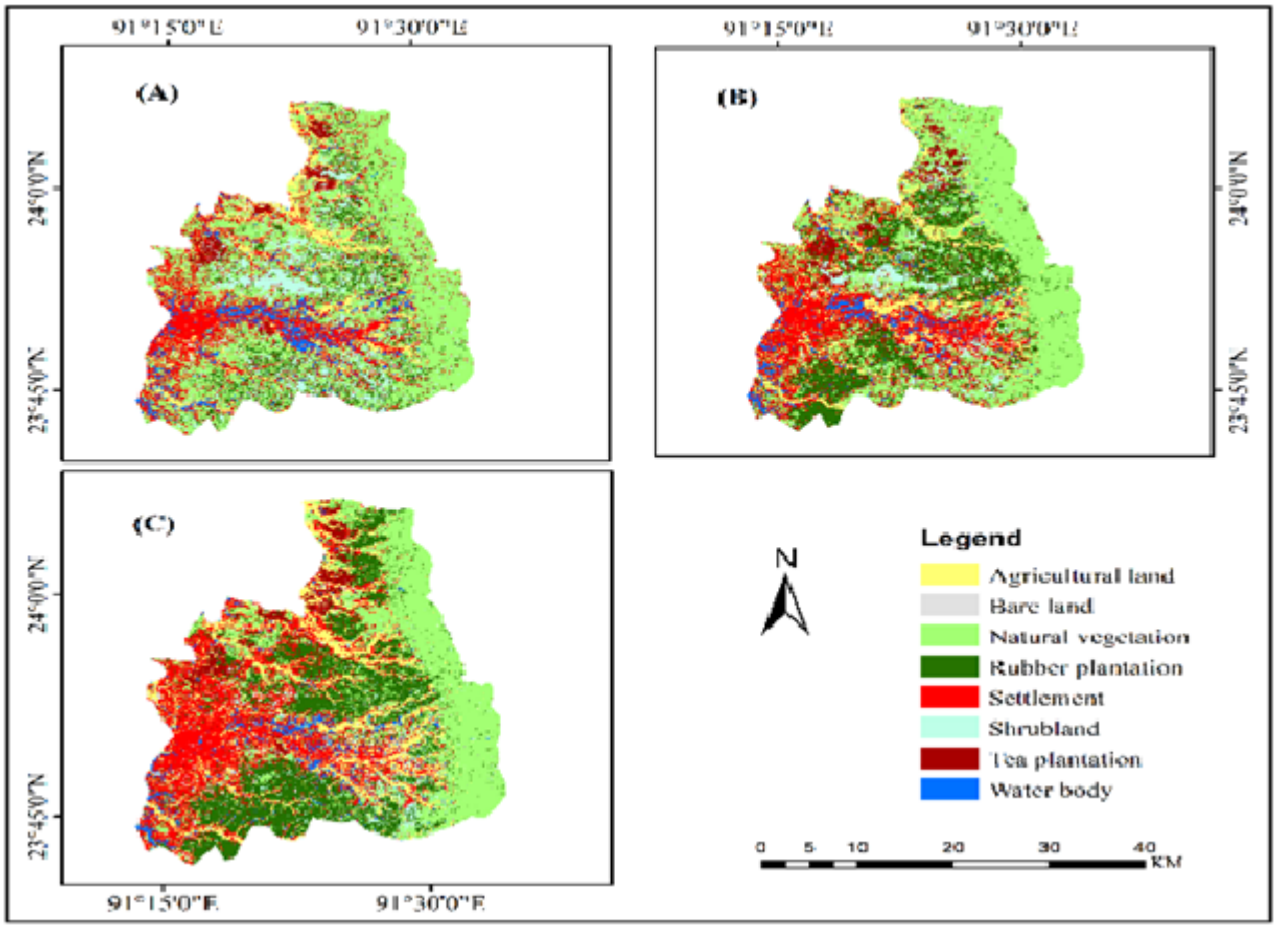

Figure 3. Spatio-temporal changes of LULC of West Tripura district A) 2000, B) 2010, and C) 2020

Table 2. Status of LULC categories of West Tripura district

LULC Categories	2000		2010		2020	
	Area (km²)	Area (%)	Area (km²)	Area (%)	Area (km²)	Area (%)
Agricultural land	80.98	8.59	103.67	10.99	154.81	16.42
Bare land	11.74	1.24	9.71	1.03	13.31	1.41
Natural vegetation	439.28	46.60	376.42	39.93	248.43	26.35
Rubber plantation	72.10	7.64	156.28	16.58	211.29	22.41
Settlement	140.19	14.87	164.20	17.42	201.21	21.34
Shrubland	93.13	9.88	41.20	4.37	30.71	3.25
Tea plantation	56.26	5.96	55.44	5.88	50.89	5.39
Waterbodies	48.87	5.18	35.63	3.78	31.90	3.38

changes showed that the rubber plantation, settlement and agricultural land has been increased by 8.94, 2.55 and 2.4%, respectively, but drastically declined as natural vegetation (6.67%), shrubland (5.51), water bodies (1.4%), remain as negligible. Between 2010 and 2020, rubber plantations, agricultural land, and settlement increased by 5.83, 5.43 and 3.92%, respectively. For twenty years (2000-20) LULC classes show a drastic increase in rubber plantation (14.77%), agricultural land (7.83%), and settlement (6.47%) but remarkable decreases in natural vegetation (20.25%), shrubland (6.63%), water bodies (1.8%), etc (Table 6, Fig. 4).

Table 3. Assessment of Kappa accuracy on LULC satellite data for the year 2000

LULC Categories	AL	NV	RP	TP	SM	SL	WB	BL	TP	UA	PA
Agricultural land (AL)	95	2	0	0	4	2	1	3	107	88.78	82.60
Natural vegetation (NV)	0	94	4	7	0	0	0	0	105	89.52	78.99
Rubber plantation (RP)	0	6	62	4	0	0	0	0	72	86.11	87.32
Tea plantation (TP)	5	15	5	40	0	0	0	0	65	61.53	75.47
Settlement (SM)	0	0	0	0	56	8	0	1	65	86.15	84.84
Shrubland (SL)	5	2	0	0	0	55	0	0	62	88.70	83.33
Waterbodies (WB)	6	0	0	2	0	1	70	0	79	88.60	98.59
Bare land (BL)	4	0	0	0	6	0	0	30	40	75	88.23
Total Producers (TP)	115	119	71	53	66	66	71	34	595		

Overall accuracy=84.36%
Kappa accuracy=81.87%

Table 4. Assessment of Kappa accuracy on LULC satellite data for the year 2010

LULC Categories	AL	NV	RP	TP	SM	SL	WB	BL	TP	UA	PA
Agricultural land (AL)	97	1	0	6	0	1	3	2	110	88.18	88.18
Natural vegetation (NV)	0	89	4	7	0	4	0	1	105	84.76	83.96
Rubber plantation (RP)	0	5	85	8	0	2	0	0	100	85	87.62
Tea plantation (TP)	3	5	4	33	0	2	0	0	47	70.21	58.92
Settlement (SM)	3	2	0	0	62	0	0	3	70	88.57	93.93
Shrubland (SL)	0	4	4	2	0	46	0	2	58	79.31	77.96
Waterbodies (WB)	3	0	0	0	0	2	45	0	50	90	93.75
Bare land (BL)	4	0	0	0	4	2	0	30	40	75	78.94
Total producer (TP)	110	106	97	56	66	59	48	38	580		

Overall accuracy=83.96%
Kappa accuracy=81.32%

Table 5. Assessment of Kappa accuracy on LULC satellite data for the year 2020

LULC Categories	AL	NV	RP	TP	SM	SL	WB	BL	TP	UA	PA
Agricultural land (AL)	101	2	0	0	10	0	2	3	118	85.59	90.17
Natural vegetation (NV)	1	97	2	4	0	2	0	1	107	90.65	89.81
Rubber plantation (RP)	0	3	81	2	0	1	0	2	89	91.01	93.10
Tea plantation (TP)	0	2	3	29	0	0	0	1	35	82.85	80.55
Settlement (SM)	4	2	0	0	85	1	1	1	94	90.42	86.73
Shrubland (SL)	0	2	0	1	0	51	0	0	54	94.44	89.47
Waterbodies (WB)	4	0	0	0	0	0	45	0	49	91.83	93.75
Bare land (BL)	2	0	1	0	3	2	0	27	35	77.14	77.14
Total producer (TP)	112	108	87	36	98	57	48	35	581		

Overall accuracy=88.81%
Kappa accuracy=86.88%

Table 6. Decadal variations of LULC changes in West Tripura district

LULC Categories	2000-2010			2010-2020			2000-2020		
	Area (km^2)	(%)	Average (km^2/Year)	Area (km^2)	(%)	Average (km^2/Year)	Area (km^2)	(%)	Average (km^2/Year)
Agricultural land	22.69	2.4	2.26	51.14	5.43	5.11	73.83	7.83	3.69
Bare land	-2.03	-0.21	-0.20	3.6	0.38	0.36	1.57	0.17	0.07
Natural vegetation	-62.86	-6.67	-6.28	-127.99	-13.58	-12.79	-190.85	-20.25	-9.54
Rubber plantation	84.18	8.94	8.41	55.01	5.83	5.50	139.19	14.77	6.95
Settlement	24.01	2.55	2.40	37.01	3.92	3.70	61.02	6.47	3.05
Shrubland	-51.93	-5.51	5.19	-10.49	-1.12	1.04	-62.42	-6.63	-3.12
Tea plantation	-0.82	-0.08	-0.08	-4.55	-0.49	-0.45	-5.37	-0.57	-0.26
Waterbodies	-13.42	-1.4	-1.34	-3.73	-0.4	-0.37	-16.97	-1.8	-0.84

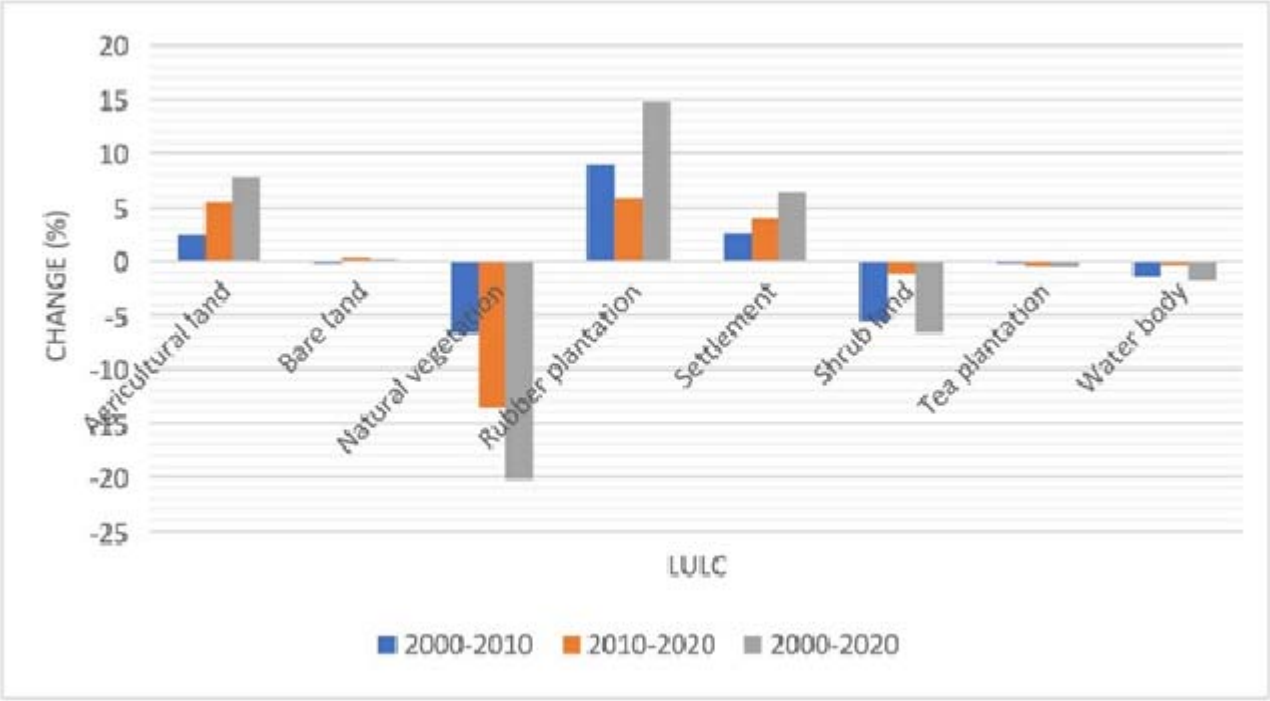

Figure 4. Decadal LULC changes of West Tripura district

The conversion matrix of LULC changes from 2000-20 (twenty years)

The LULC categories of the data were obtained from the selected training samples of the Landsat images. The row would be assigned by LULC data of 2000 (base year), and columns given by the LULC data of 2020 (current year) to work out the matrix with help of MS-Excel but diagonal data shows that unchanged area from the base year to the current year. The overall land use/ land cover conversion from 2000 to 2020 shows that the maximum land conversion occurred into rubber plantations from natural vegetation (100.83 km^2), shrubland (45.34 km^2) and tea plantation (8.90 km^2). Agricultural land was acquired area from natural vegetation (45.47 km^2), waterbodies (18.38 km^2), and tea plantations (12.08 km^2) (De 2000). The settlement expanded on natural vegetation (53.82 km^2), agricultural land (13.78 km^2), and tea plantation (9.95 km^2) areas. The total unchanged LULC area is 441.08 km^2 out of 942.55 km^2 in twenty years from 2000 to 2020 (Table 7, 8, Fig. 5).

Table 7. Matrix conversion of LULC changes in between twenty years (2000 to 2020)

LULC Area in 2000 ($Km^{2)}$	LULC Area in 2020 (Km^2)								
	AL	**BL**	**NV**	**RP**	**SM**	**SL**	**TP**	**WB**	**Total**
AL	**51.15**	2.28	4.77	2.10	13.78	0.40	4.67	1.78	80.98
BL	3.56	**1.42**	2.07	1.05	2.52	0.17	0.85	0.07	11.74
NV	45.47	3.52	**198.58**	100.83	53.82	13.72	21.06	2.24	439.28
RP	1.92	0.45	10.97	**47.79**	4.67	3.26	2.97	0.03	72.10
ST	10.40	2.37	5.46	5.04	**103.67**	2.49	7.48	5.25	140.19
SL	11.23	1.81	14.07	45.34	7.11	**8.51**	4.69	0.52	93.13
TP	12.68	0.76	12.52	8.90	9.95	2.10	**8.28**	0.29	56.26
WB	18.38	0.65	0.35	0.20	6.45	0.23	0.89	**21.68**	48.87
Total	154.81	13.31	248.43	211.29	201.21	30.71	50.89	31.90	942.55

AL=Agricultural land, NV= Natural vegetation, BL=Bare land, RP= Rubber Plantation, SM= Settlement, SL= Shrub land, TP= Tea plantation, WB = Water bodies, *Unchanged land.

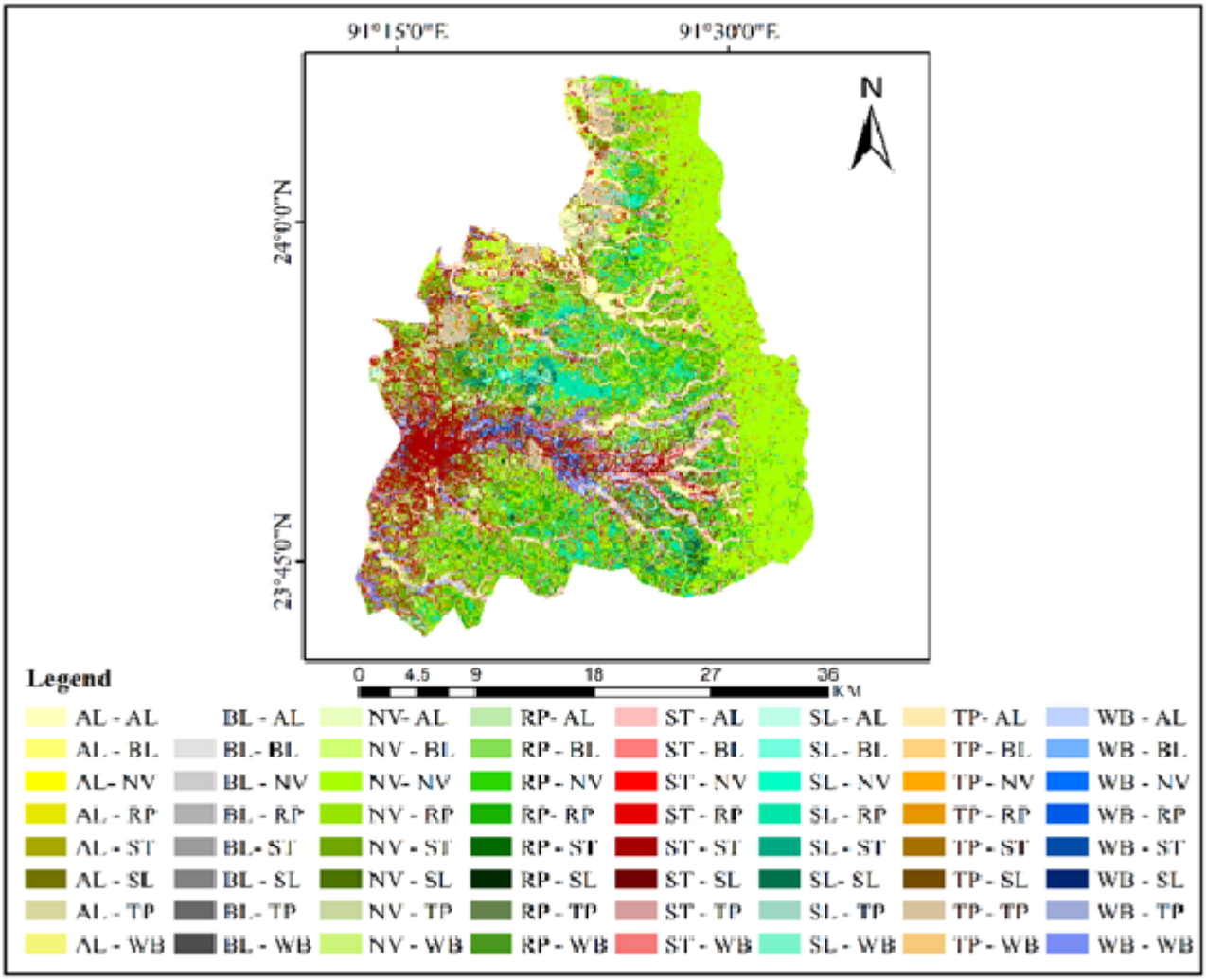

Figure 5. Matrix conversion of spatio-temporal variation of LULC in between twenty years (2000-20) Al=Agricultural land, NV= Natural vegetation, BL=Bare land, RP= Rubber Plantation, ST= Settlement, SL= Shrub land, TP= Tea plantation, WB = Water body

Table 8. Decadal growth rate (%) of LULC categories

LULC categories	2000 to 2010	2010 to 2020	2000 to 2020
Agricultural land	28.01	49.32	91.17
Bare land	-17.29	37.07	13.37
Natural vegetation	-14.30	-34.00	-43.44
Rubber plantation	116.75	35.19	193.05
Settlement	17.12	22.53	43.52
Shrubland	-55.76	-25.46	-67.02
Tea plantation	-1.45	-8.20	-9.54
Waterbodies	-27.09	-10.46	-34.72

Decadal and seasonal variations of NDVI (2000, 2010 and 2020)

The NDVI has a more significant relation to land use and land cover classification since the conversion matrix on LULC showed natural vegetation deterioration in selected decades. Hence NDVI would workout for more validity and reliability of LULC classification. The NDVI high and low values workout seasonally and decadal. The data would detect season-wise i.e., winter, pre-monsoon and post-monsoon. The spatial distribution in winter shows that NDVI value was higher at 0.64 in 2000 but when it has compared to 2020. In 2000, the pre-monsoon of NDVI value was higher at 0.65 which

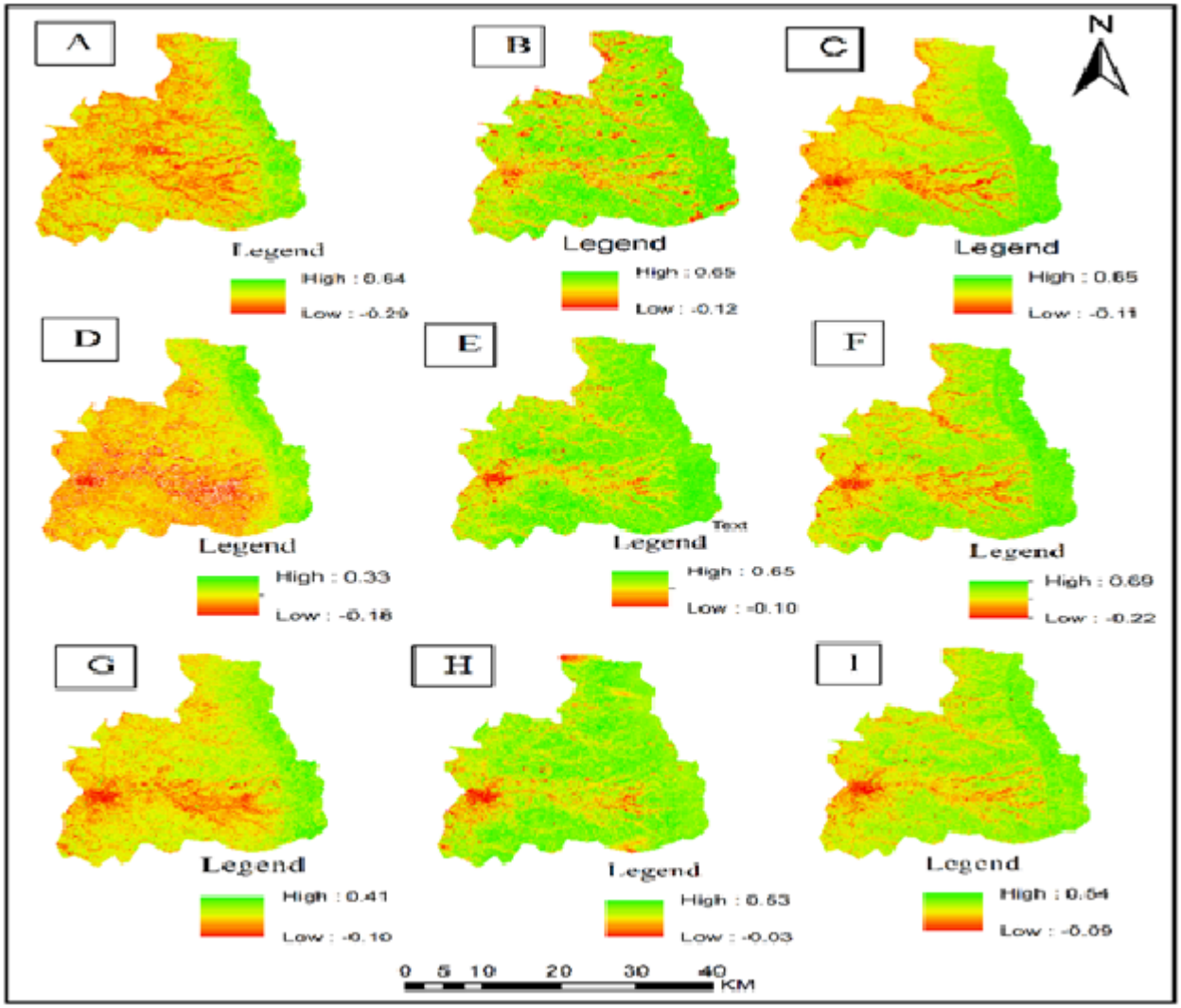

Figure 6. Spatio-temporal seasonal variation of NDVI. A) Winter, 2000, B) Pre-monsoon, 2000, C) Post-monsoon, 2000, D) Winter, 2010, E) Pre-monsoon, 2010, F) Post-monsoon, 2010, and G) Winter, 2020, H) Pre-monsoon, 2020, I) Post-monsoon, 2020

Table 9. LULC seasonal variation of NDVI

Landuse Class	2000			2010			2020		
	Winter	Pre-Mon	Post-Mon	Winter	Pre-Mon	Post-Mon	Winter	Pre-Mon	Post-Mon
NV	0.32	0.38	0.43	0.12	0.51	0.48	0.25	0.38	0.39
RP	0.29	0.24	0.46	0.09	0.49	0.44	0.22	0.39	0.38
TP	0.27	0.23	0.40	0.05	0.48	0.41	0.20	0.36	0.34
AL	0.18	0.17	0.28	0.05	0.36	0.27	0.17	0.32	0.28
SM	0.20	0.22	0.29	0.04	0.33	0.30	0.15	0.28	0.25
SL	0.22	0.24	0.42	0.02	0.37	0.40	0.17	0.32	0.33
WB	0.11	0.27	0.25	0.00	0.32	0.27	0.09	0.28	0.24
BL	0.12	0.15	0.28	0.02	0.24	0.18	0.12	0.24	0.20

NV= Natural vegetation, RP= Rubber plantation, TP= Tea plantation, AL= Agricultural land, SM= Settlement, SL= Shrubland, WB= Waterbodies, BL=Bare land, Pre-Mon = Pre-Monsoon, Post-Mon = Post-Monsoon

Figure 7. NDVI of Land use classes for the year 2000, 2010 and 2020

decrease in 2020 (0.53), and the maximum NDVI value of 0.65 but decrease at 0.54 in post-monsoon (2020). The average mean value of natural vegetation has decreased from 0.37 to 0.34 which has been influenced by rubber plantation and agricultural activity. In 2000, the average value of NDVI for agricultural land was 0.21 which increase at 0.25 (2020) but the healthier vegetation decreases due to the expansion settlement areas (Table 9, Figs. 6, 7).

Decadal variations of NDWI (2000, 2010 & 2020)

The decadal changes of water bodies in the study area workout through NDWI using Landsat 4-5 & Landsat 8 OLI for the above selected years since the conversion of a matrix, the decadal growth rate of LULC and NDVI has shown the water bodies deteriorating in the study area. Further, the NDWI maps show that the values are deteriorating like +0.48, +0.40 and +0.26 for the selected years of 2000, 2010 and 2020 respectively. As per NDWI's explanation, the value ranges from -1 to +1, where the positive value represents the water bodies and the negative value represents settlement and natural vegetation (Fig. 8).

Decadal variations of NDBI (2000, 2010 & 2020)

In this study area, the NDBI value gradually increased from 0.32 in the year 2000, followed by

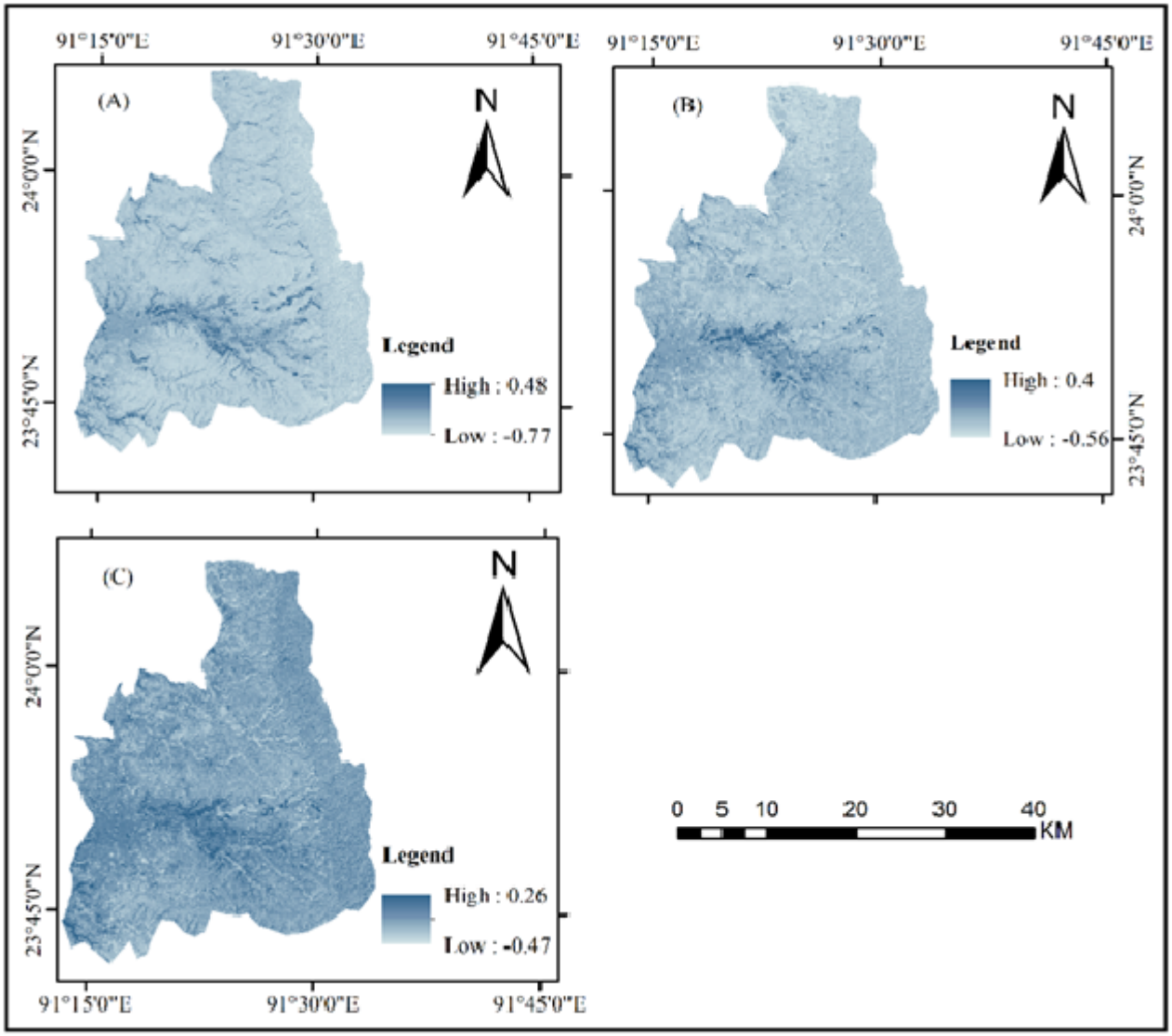

Figure 8. Spatio-temporal variation of NDWI for the year (A). 2000, (B). 2010, and (C) 2020

0.35 in 2010, and 0.37 in 2020. The maximum value recorded during 2020 that is 0.37. It means the built-up area was noticed in the study area in the year 2020 when compared to other decades. In 2000, the figure shows that settlements are dispersed but during 2020 it concentrated on the urban sprawl of Agartala city (Fig. 9).

The decadal growth rate of LULC classes (2000-10, 2010-20 and 2000-20 (twenty years))

During 2000-10, the growth rate of LULC has shown increases in rubber plantation, agricultural land and settlement area at 116.75%, 28.01% and 17.12% respectively remain categories decline drastically, especially shrubland (55.76%), water bodies (27.09%), bare land (17.29%), natural vegetation (14.30%), From 2010-20, the agricultural land (49.32%), bare land (37.07%), rubber plantation (35.19%), and settlement area (22.53%) has shown positive growth remain LULC classes are shown negative growth like natural vegetation (34%), shrubland (25.46%). In the last two decades of LULC growth rate (2000-20), the rubber plantations shows a high positive growth rate that is 193.05%, followed by agricultural land (91.17%), settlement area (43.52%), and bare land (13.37%) (Table 8).

CONCLUSION

The LULC classification reveals that rubber plantation and settlement areas radically expanded. It together occupied near about 43.75% area of the

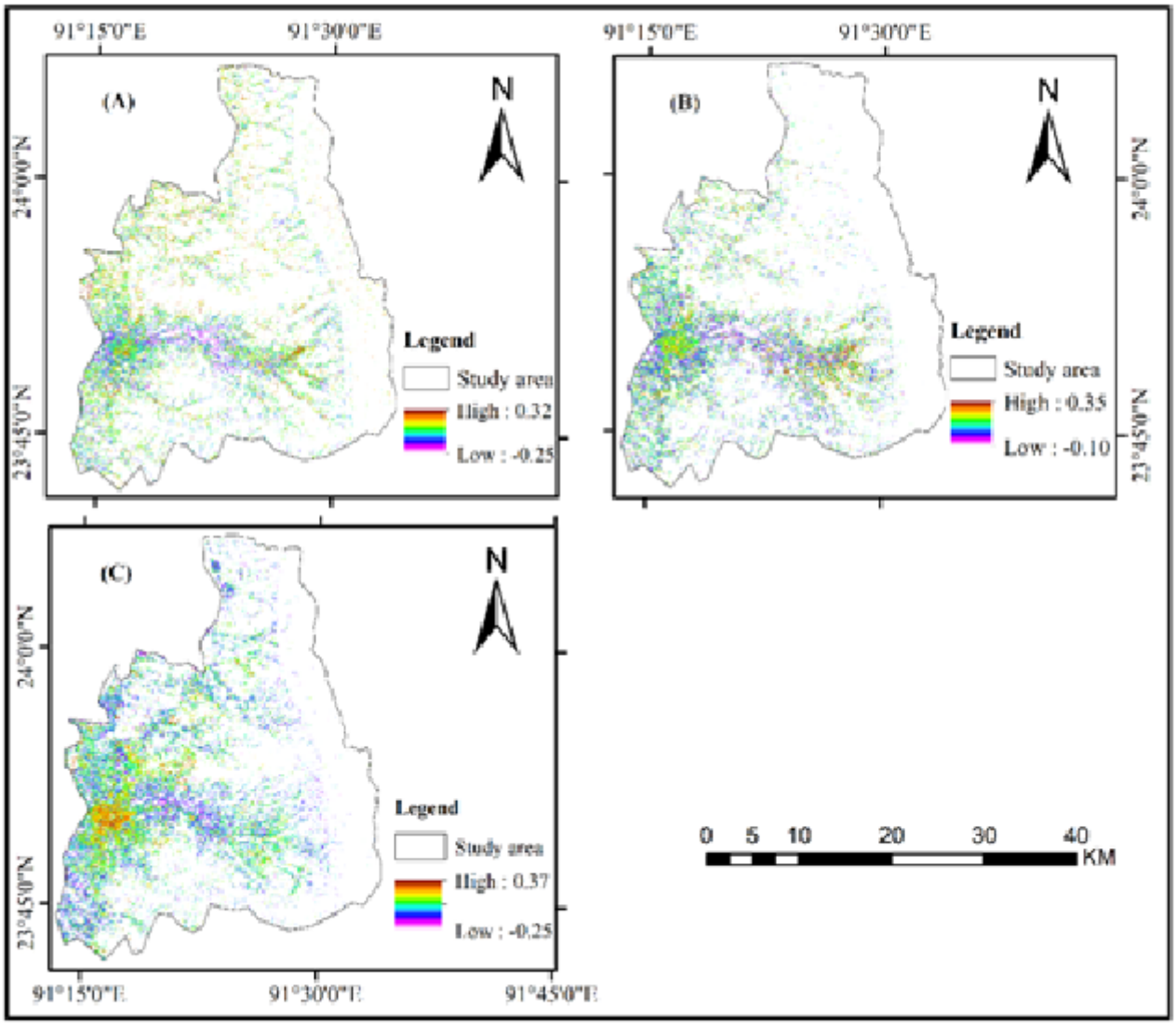

Figure 9. Spatio-temporal variation of NDBI for the year (A). 2000, (B). 2010, and (C) 2020

total geographical study area in the last couple of decades (2000-20). During the last two decades, tilla land has been converted into a rubber plantation area. Since farmers gradually diverted from traditional jhum cultivation to cash crops to enhance their livelihood which is the major cause to increase in rubber plantations. Further, farmers expected stable monetary returns and employment generation from rubber plantations and also state government encouraged the farmers. The second reason is that rapid population growth and urbanisation are forced towards developmental activities since the state capital Agartala city is located in West Tripura district. It has been found that the agricultural land surrounding the Agartala Municipality has been converted into build-up area during the last two decades and even encroaches water bodies for settlement. Agricultural land was also converted into settlements to adjust to faster urbanization. Decadal and seasonal NDVI shows healthy vegetation deteriorated due to the expansion of rubber plantations and settlement. The overall conversion matrix revealed that the rubber plantation and settlement areas overlap on natural vegetation, tea plantation and water body areas. Further, NDWI's result supported that water bodies are deteriorating. Finally, the growth rate of LULC in the last two decades (2000-2020) that rubber plantations show a high positive growth rate, followed by agricultural land, and settlement. All those factors together have changed the land use land cover pattern of the West Tripura district.

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