



Land Use/Land Cover Change Matrices Analysis of Sibsagar District, Assam Using Remote Sensing and GIS Techniques

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Abstract

Land use/land cover (LU/LC) undergoes changes over time and space depending upon the physical and socio-economic factors. The analysis of change detection becomes very essential from the point of view of environmental consequences and the demand of sustainable development. In this paper an attempt has been made to examine of LU/LC for the periods 1971, 1991 and 2016 in Sibsagar district of Assam. For the year 1971, the land use/land cover map has been prepared by using Survey of India (SOI) topographic map. For the remaining two years i.e., 1991 and 2016 Landsat ETM data were used. Eight different types of LULC are identified for the district viz., water bodies, agriculture, swamps and marshes, rural settlement, grassland, built up, fallow lands and forests for all the three years. Change and trend analysis were performed for different land use and land covers during the study periods. By observing the change matrices, found that settlements, agriculture, forests and grasslands has been gone under change at very high range. The total area under settlements has increased. Simultaneously 15.28 km² of settlements area are shifted to other land use categories. This kind of dynamics may lead to environmental imbalances and many socio-economic transformations in the district.

Introduction

Land use/ land cover (LU/LC) studies are now conventional and it is become necessary for making judgment of resources. This concept was introduced during mid 1970s. In the early 1980s, terrestrial ecosystems as sources and sinks of carbon were highlighted which underscored the impact of land use and land cover dynamics on global climate via carbon cycle (Houghton *et al.*, 1985). Understanding of LU/LC is significant for nearly all of the planning and management (Lillesand and Kiefer, 1987). Remote sensing imagery has immense contributions in LU/LC studies with the help of GIS (Burrough, 1986; Pathan, 1993; Freiderick, *et al.*, 2001; Yadav *et al.*, 2013). Dynamics of LU/LC was recognized as an agent of changing

environment (Otterman, 1974; Charney and Stone, 1975; Sagan, 1977). Spatiotemporal LU/LC studies have global significance and carried out in different parts of the world (Singh, 1989; Kates *et al.* 1990; Turner II and Meyer, 1994; Moghadam and Helbich, 2013; Verma and Jaiswal, 2013; Briassoulis, 2016; Singh, 2015). Changes these days are more wide-ranging and take place more hurriedly than yet before. The importance of these transformation increases because of the growth of world population, declination of available land mass and our environmental resiliency turns into increasingly strain. As a consequence, any organization needs to observe changing land use and land cover (Green *et al.*, 1994 and Kumari and Srinivas, 2015). Regarding LU/LC change agriculture and fallow lands has been observed remarkable decrease whereas built-up area increased. In contrast to these water bodies have been constant (Rawat and Kumar 2015). But varieties of anthropogenic stress, for instance agricultural growth, deforestation, increasing plantation, mining, industrial development, urban extension, growth of transport system etc. are found to be fundamental driving forces for land cover alterations (Geist and Lambin, 2002). It has been observed that as a result of population growth, urban expansion and infrastructure development fallow land and vegetation have change drastically in the metro cities like Delhi (Mukhopadhyay *et al.*, 2013).

Sibsagar district of Assam has undergone tremendous LU/LC changes since long back. Tea was invented in Sibsaigar district by the British and tea industry grown in large scale followed by oil industries. Tea occupied 7.54% (201.3km²) of total geographical area (TGA) and it has increased to 35.57% (949.21 km²) of TGA in 2016. These two industries attracted people from far flung area to this district. This increase in population and subsequent developmental activities lead to changes the original land cover of the district. In the present study an attempt has been made to assess the spatial distribution of LU/LC for 1971, 1991 and 2016. Based on the data for these periods the change matrices for 1971-1991 and 1971-2016 are examined. The prime objectives of this study are: (i) to produce LU/LC covers maps for the study area during the periods- 1971, 1991 and 2016. (ii) to find outland use and land cover change matrices of the study area.

Method and Materials

Study area

Sibsagar district of Assam, India (Figure 1) lies between 26°45' to 27°15' N latitudes and 94°25' to 95°22' E longitudes. The district covers an area of 2668 km² (rural: 2625.07 km² and urban: 42.93 km².) with an elevation of 86.8 m. Above mean sea level (MSL).

The eastern boundary of the district is bordered by Dibrugarh district of the state and Jhanji river in the west, the southern boundary is surrounded by Tirap district of Arunachal Pradesh and Mon district of Nagaland and the Lakhimpur district of the state lies in the north. The district is comprised of three administrative sub-divisions with 6 revenue circles, 118 gram panchayats and 885 villages.

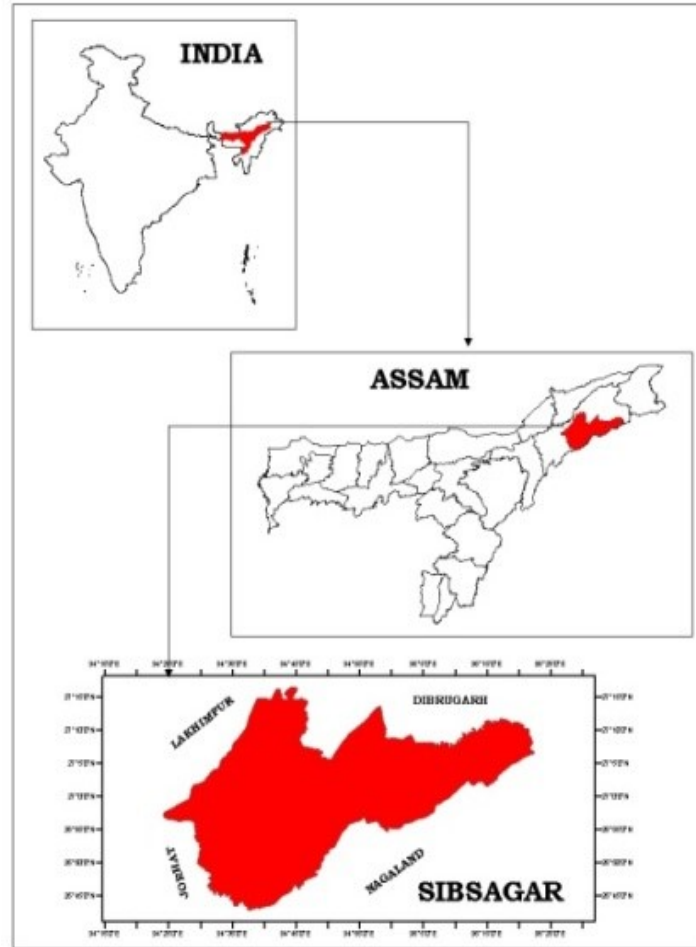


Figure1 Location of the study area

Data sources and methods

For this study multi sources and multi date data have been used. These are Survey of India topographic map of 1971 (covered by topographical sheet numbers 83^I/₁₂, 83^I/₁₅, 83^I/₁₆, 83^M/₄, 83^M/₈, 83^N/₁, 83^N/₅, 83^J/₅, 83^J/₉, 83^J/₁₀, 83^J/₁₃, and 83^J/₁₄) and remotely sensed satellite data for 1991 and 2016 from Landsat ETM image. These sources and distinctiveness of these data sets are presented in Table 1. These data sets were geometrically and radiometrically corrected including applying enhancements for better visualization.

Table 1: Satellite data sources

Year	Satellite	Resolution(m)	Path/Row	Bands	Date of acquisition
1991	Land sat4,5,6 ETM	30	41/135	4,5,6	9/11/1991
2016	Land sat4,5,6 ETM	30	41/135	4,5,6	19/11/2016

Source: Global Land Cover Network maintained by United States Geological Survey (USGS).

The methodology for generating and handling out data for this study is highlighted in Figure 2 and the methodology for image processing and change matrix analysis is presented in Figure 3 which is self-explanatory.

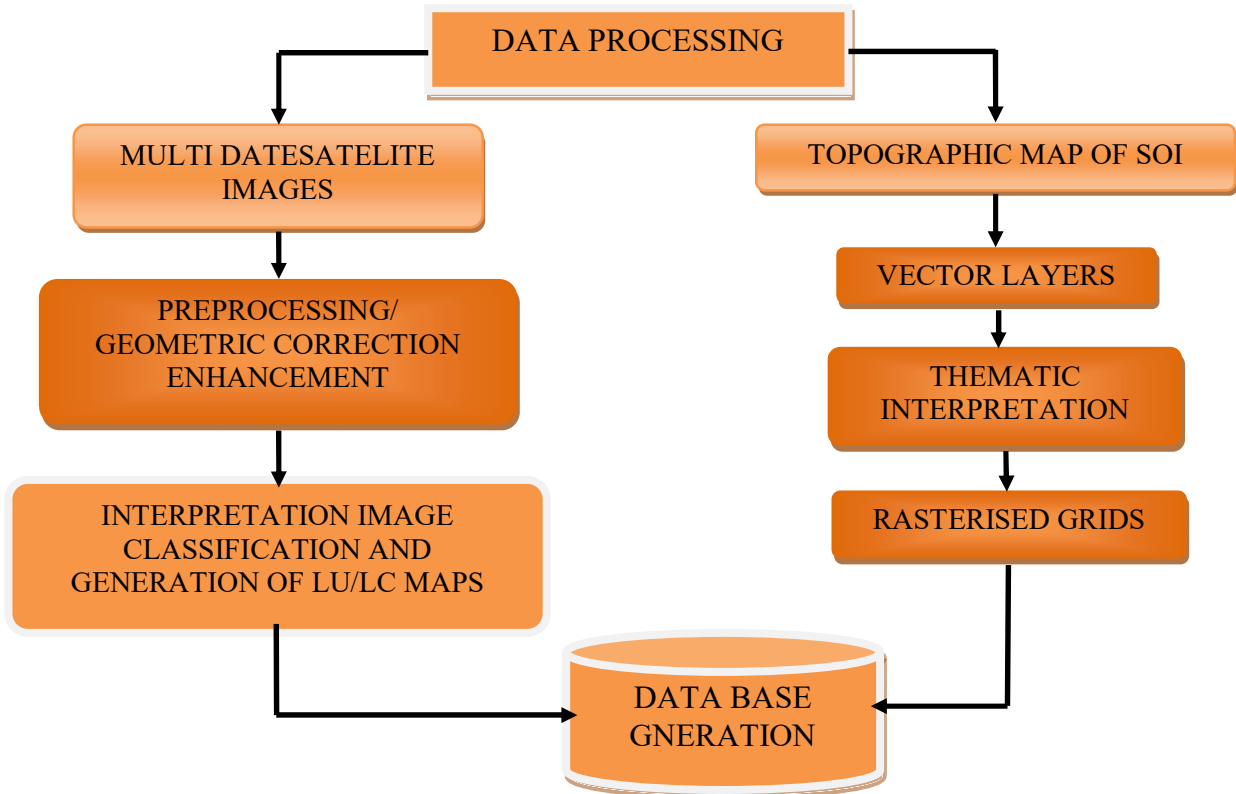


Figure 2Data processing steps for database generation

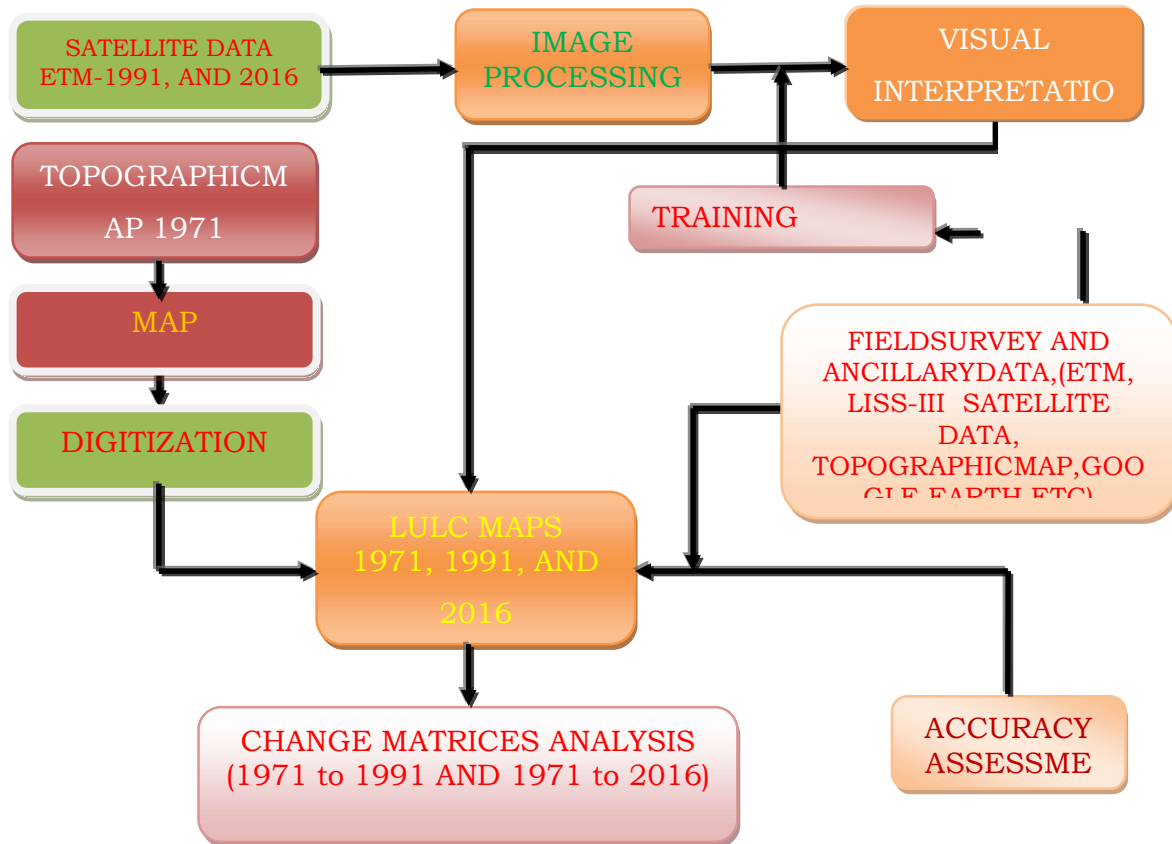


Figure 3Methodology for LU/LC change matrix analysis

Results and Discussion

LU/LC status and temporal dynamics

The status of LU/LC for 1971, 1991 and 2016 is presented in Figures 2 to 9. The Table 2 shows the area wise statistics and percentage of LU/LC categories of the study area for the years 1971, 1991 and 2016. It is observed from the Table 2 that major part of the study area is occupied by settlements (14%-20%) and agriculture (50%-56%) and the area under agriculture and rural settlements is increased significantly. With the exception of water bodies, there lies a substantial change in more or less every class of LU/LC in the district throughout this time.

For the most part of land use found is agricultural land with an area of 56.54% of the overall area after that settlement occupied about 20.22%. The LU/LC categories of water bodies, agriculture, swamps and marshes, settlements, built-up, grass lands, fallow lands and forests were measured for 1971, 1991 and 2016. The temporal changes in it were evaluated. It is initiated that agriculture is the most changeable land use class followed by settlement. As a result of the increase of population in the study area the necessity of agriculture land is extremely high. In consequence of which there is intensification of agricultural and settlements at the cost of marshes and swamps, forests and grasslands which were turned down over the time of almost four decades.

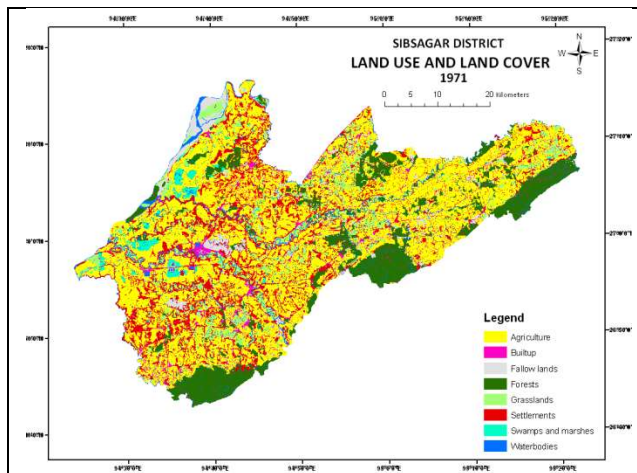


Figure 4. LU/LC of 1971 based on Survey of India Topographic Map, 1971, referred to this map as 1:50,000, Published in 1972.

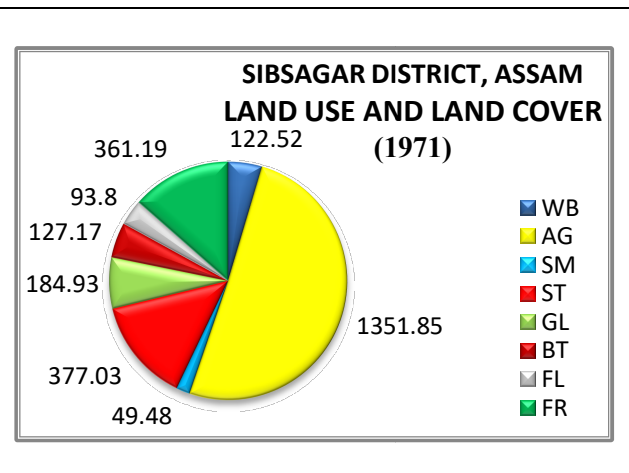


Figure 5. LU/LC of Sibsagar District, Assam 1971
 Note: WB- water bodies, AG-Agriculture, SM-Swamps and marshes, ST-Settlements, GL-Grass lands, BT-Built-up, FL-Fallow land, FR-Forest

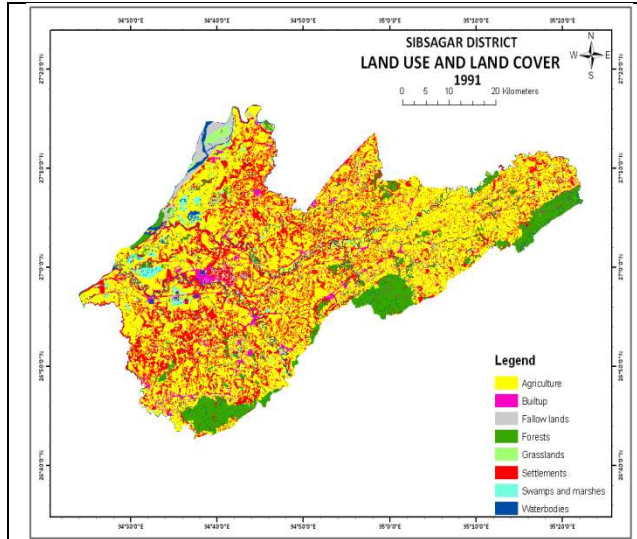


Figure 6 LU/LC of 1991 based on satellite imagery (LAND SAT-ETM, Band 6, 7, 8, Resolution – 30mt. November, 1991.)

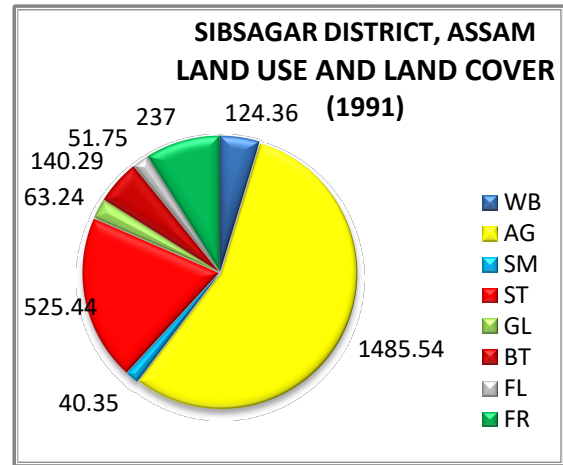


Figure 7 LU/LC of Sibsagar District, Assam, 1991

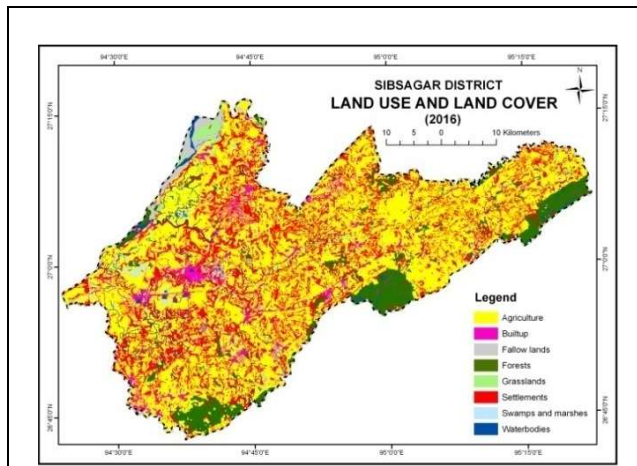


Figure 8 LU/LC status of 2016 based on satellite imagery (LAND SAT-ETM, Band 6, 7, 8)

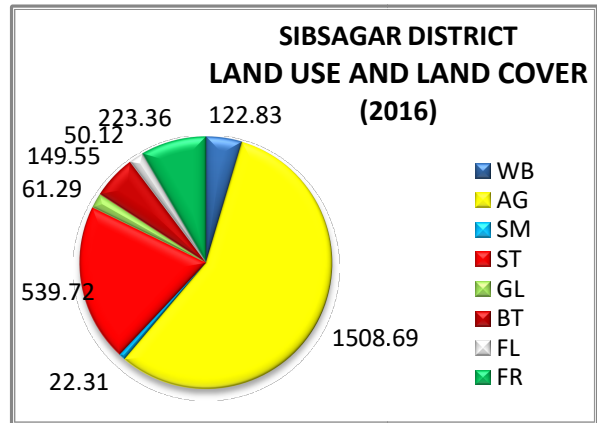


Figure 9 LU/LC of Sibsagar District, Assam, 2016.

Table2: Total geographical area and percentage

LU/LC Class	Area in km ²			Area in %		
	1971	1991	2016	1971	1991	2016
Water bodies	122.52	124.36	122.83	4.59	4.66	4.60
Agriculture	1351.85	1485.54	1508.69	50.66	55.67	56.54
Swamps and Marshes	49.48	40.35	22.14	1.85	1.51	0.83
Settlements	377.03	525.44	538.21	14.13	19.69	20.22
Grass lands	184.93	63.24	61.29	6.93	2.37	1.91
Built-up	127.17	140.29	149.55	4.76	5.25	5.60
Fallow lands	93.8	51.75	50.12	3.51	1.93	1.87
Forests	361.19	237	223.36	13.53	8.88	8.37
Total	2668	2668	2668	100	100	100

LU/LC change matrices status of 1971-1991and 1971 -2016

Both the change matrix tables are summarized in the following tables 5 and 6 for simplification of analysis. The change matrices report the area that each LU/LC class changed to the other class. These matrices are produced by the cross tabulation. It has been produced by the superimposing of two LU/LC maps of different time. In support of the 8 by 8 matrices table presented in the following Table 3 and 4. It has been distinguished from the tables 5 and 6 that all the LU/LC classes the marshes and swamps, grass lands, forests and fallow lands class have shown a considerable negative alteration to the other class in their vicinity for the period of 1971-1991 and continued up to 2016. The area under agriculture has increased by 179.44 km² during 1971-1991 and 215.32 km² during 1971-2016 (Tables 5, 6 and Figures 8, 9). Of the total gained area, forests contributed 73.17 km², while grass land 72.56, fallow land 22.15 km² and swamps and marshes 10.04 km² respectively to agriculture land during 1971-1991. The major factor for such change is population growth and the need of agriculture land for their sustenance and forests contributed 81.96 km², while grass lands 81.67 km², swamps and marshes 25.76 km² and fallow lands 24.15 km² during 1971-2016. This leads to environmental consequences, like flood and erosion. For example, primary field data has been reported that the areas under flood and erosion have been increased from 2.66 km² to 3.49 km² and .142 km² to .658 km² between 1971 and 2016.

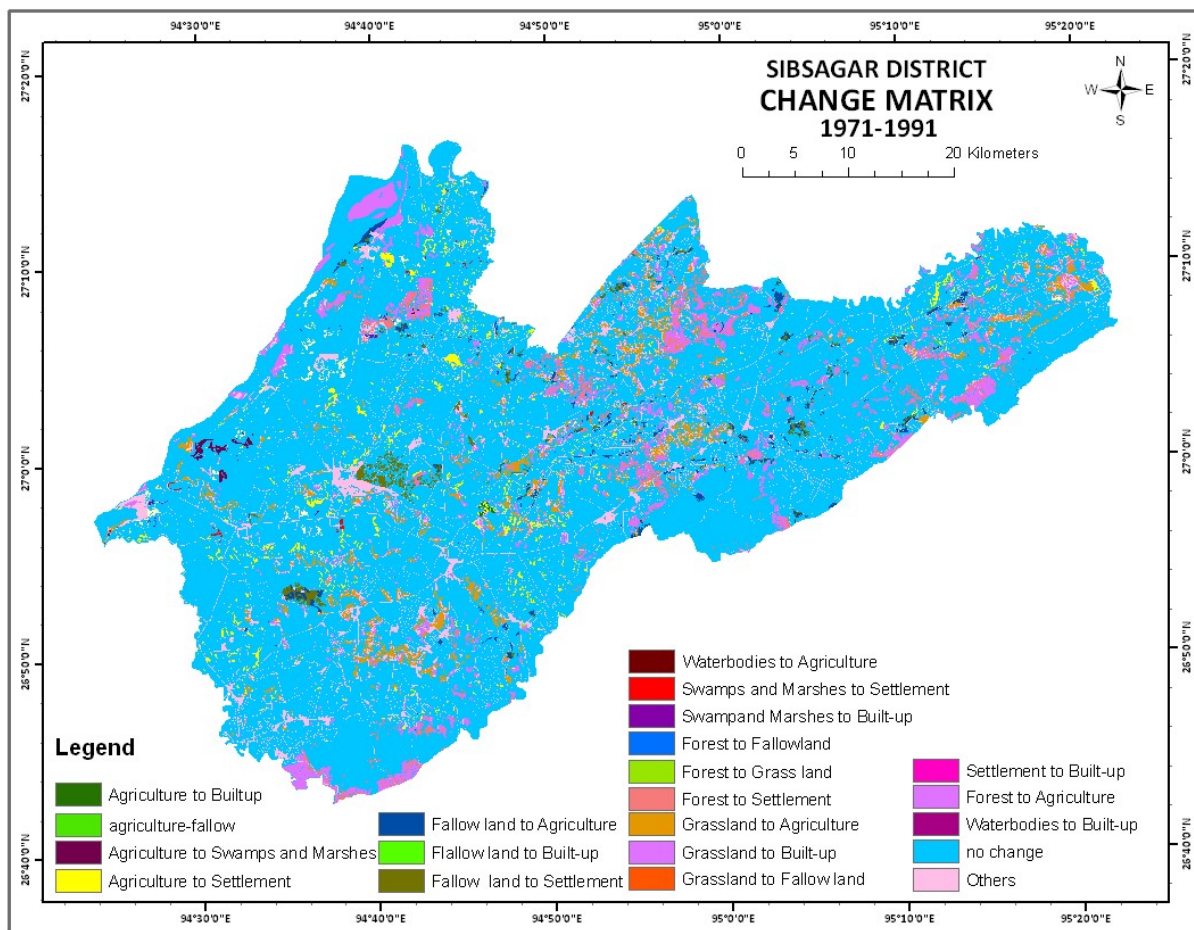


Figure 10 LU/LC Change matrices status, 1971-1991

Table3: LU/LC Change matrix status, 1971-1991

LU/LC Class	Water bodies	Agriculture	Swamps and Marshes	Settlements	Grass lands	Built-up	Fallow lands	Forests	Total 1971
Water bodies	122.32	0.17	0	0.01	0.02	0	0	0	122.52
Agriculture	1.19	1306.1	3.29	37.58	0.82	2.77	0.1	0	1351.85
Swamps and Marshes	0.51	10.04	36.27	1.75	0.87	0.04	0	0	49.48
Settlements	0	1.26	0	366.84	0	8.81	0	0.12	377.03
Grass lands	0.14	72.56	0.78	50.43	59.84	1.18	0	0	184.93
Built-up	0	0.09	0	0.98	0	126.1	0	0	127.17
Fallow lands	0.03	22.15	0	19.55	0	0.57	51.48	0.02	93.8
Forests	0.17	73.17	0.01	48.3	1.69	0.82	0.17	236.86	361.19
Total 1991	124.36	1485.54	40.35	525.44	63.24	140.29	51.75	237	2668

At the same time 45.66 km² of agriculture land are migrated to other land use classes during 1971-1991 and 62.21 km² during 1971-2016. Key proportion of agriculture land migrates to settlement 37.58 km², built-up 2.77 km² during 1971-1991 and 47.51 km² 6.98 km² areas of agriculture land migrates to settlements and built-up during 1971-2016.

Another important LU/LC category is settlements. The total area under settlements has increased by 159.13 km² during 1971-1991 and 178.03 km² from 1971 onwards to 2016 (Tables 5,6 and Figure 8,9). Out of the total increased area, grass lands contributed 50.43 km², while forests 48.83 km², agriculture 37.58 km², fallow land 20.64 km² during 1971-1991 and similarly forests contributed 53.2 km², grass lands 52.74 km², agriculture 47.51 km² and fallow lands 20.64 km² from 1971 onwards to 2016. It is observed from census data of 1971 to 2011 that the number of households increased from 112039 in 1971 to 248367 in 2011. In the same way density of households has been increased from 42 in 1971 to 93 in 2011. Simultaneously 10.19 km² settlements area is migrates to other land use categories during 1971-1991 and 15.26 km² from 1971 onwards to 2016. Major percentage of settlements area shifted to built-up 8.81 km² during 1971-1991 and 13.73 km² during 1971-2016, other migrates of settlement areas are insignificant.

Forest cover is the other dominant land cover category of the study area. During the study period gain area under forests cover are insignificant but the forest cover loss area is most prominent and significant. Right from 1971 up to 2016 total missing of forest cover areas were 137.36 km² which were 124.33 km² between 1971 and 1991. It is seen that of forests cover areas were migrated to agriculture and settlements during 1971-1991 (73.17 km² and 48.3 km²) and 1971-2016 (81.96 km² and 53.2 km²), the reason for which is explained earlier.

Grass land plays an important role to the constitution of LU/LC in the study area. The total decreased area of grass land was migrates to agriculture 72.56 km² during 1971-1991 and 81.67 km² during 1971-2016 and settlements 50.43 km² during 1971-1991 and 50.74 km² during 1971-2016 (Figure 8, Table 5,6). Shifting of grasslands to other LU/LC categories are insignificant.

Further important land use and land cover categories of the study area is fallow land. Mostly fallow lands are shifted to agriculture 22.15 km² during 1971-1991 and 24.15 km² during 1971-2016 and settlements 19.55 km² during 1971-1991 and 20.64 km² during 1971-2016. From the field verification it is decided that primarily fallow lands are produced by agriculture and

built-up activities. From census data it is observed that 37.41 km² fallow lands have been reclaimed for agriculture and settlements during 1991-2011.

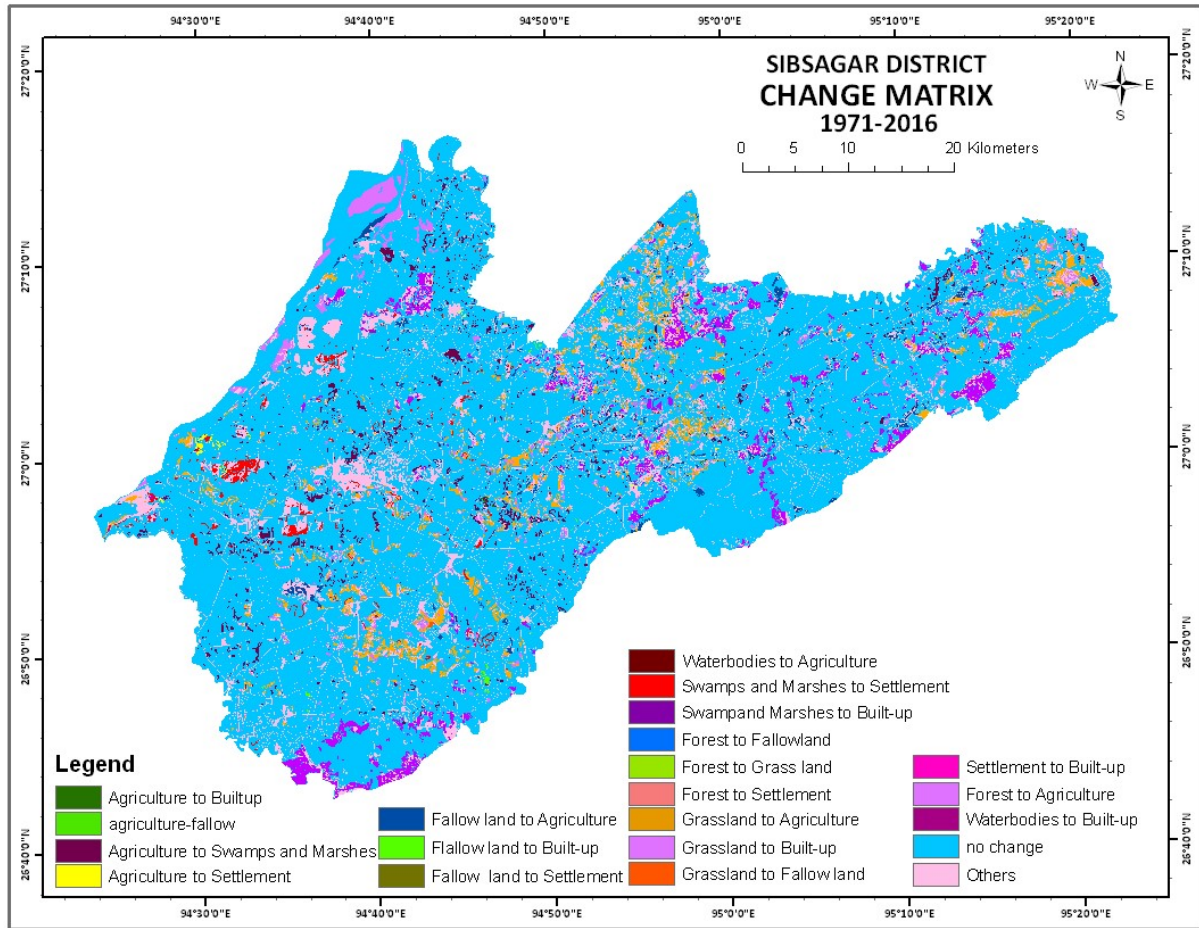


Figure: 11 LU/LC Change matrix status, 1971-2016

Table 4: LU/LC Change matrix status, 1971-2016

LU/LC Class	Water bodies	Agriculture	Swamps and Marshes	Settlements	Grass lands	Built-up	Fallow lands	Forests	Total 1971
Water bodies	121.94	0.53	0.01	0.01	0	0	0	0	122.52
Agriculture	0.00	1293.35	1.8	47.51	4.3	6.98	1.62	0	1351.85
Swamps and Marshes	0.33	25.76	20.02	2.51	0.04	0.83	0	0	49.48
Settlements	0.04	1.25	0	361.64	0.07	13.73	0.1	0.07	377.03
Grass lands	0	81.67	0	52.74	50.48	0	0.08	0	184.93
Built-up	0.14	0	0	1.47	0	125.68	0.	0.25	127.17
Fallow lands	0.03	24.15	0.47	20.64	6.29	0.77	48.15	0.02	93.8
Forests	0.35	81.96	0.01	53.2	0.11	1.56	0.17	223.02	361.19
Total 2016	122.83	1508.69	22.31	539.72	61.29	149.55	50.12	223.36	2668

Regarding loss area swamps and marshes has also faced by similar situation with forests, grass lands and fallow lands. Key percentage of this category is also migrating to agriculture and settlements. During the study period total decreased of swamps and marshes were 13.21km² during 1971-1991 and 29.47km² during 1971-2016. Between 1971 and 1991 agriculture land received 10.04km² and between 1971-2016 agriculture land is increased by 29.47km² which were shifted from swamps and marshes. The tables 5 and 6 reveals that no significant change has

occurred in case of water bodies. This category of LU/LC in the study area remained unchanged between 1971 and 2016. In 1971 water bodies covered 122.52 km² and in 2016 it occupied almost same area 122.83 km² of the study area. Throughout the analysis of the table 5 and 6 it could be summarized that the nature and trends of land use/ land cover change matrices of the study area were remained same. Agriculture, settlements and built-up area were continuously increased in contrast to forests, grasslands, swamps and marshes and fallow lands.

Table 5 LU/LC gain and loss status of 1971-1991 and 1971-2016

LU/LC Class	No Change (area in Km ²)		Area gain in Km ²		Area loss in Km ²	
	1971-91	1971-2016	1971-91	1971-2016	1971-91	1971-2016
Water bodies	122.32	121.94				
Agriculture			1.19	0	0.17	0.53
Swamps and Marshes			0.51	0.33	0	0.01
Settlements			0	0.04	0.01	0.01
Grass lands			0.14	0	0.02	0
Built-up			0	0.14	0	0
Fallow lands			0.03	0.03	0	0
Forests			0.17	0.35	0	0
Total			2.04	0.89	0.2	0.55
LU/LC Class	No Change (area in Km ²)		Area gain in Km ²		Area loss in Km ²	
	1971-91	1971-2016	1971-91	1971-2016	1971-91	1971-2016
Agriculture	1306.1	1293.35				
Water bodies			0.17	0.53	1.19	0
Swamps and Marshes			10.04	25.76	3.29	1.8
Settlements			1.26	1.25	37.58	47.51
Grass lands			72.56	81.67	0.82	4.3
Built-up			00.09	0	2.77	6.98
Fallow lands			22.15	24.15	0.01	1.62
Forests			73.17	81.96	0.00	0
Total			179.44	215.32	45.66	62.21
LU/LC Class	No Change (area in Km ²)		Area gain in Km ²		Area loss in Km ²	
	1971-91	1971-2016	1971-91	1971-2016	1971-91	1971-2016
Swamps and Marshes	36.27	20.02				
Water bodies			0	0.01	0.51	0.33
Agriculture			3.29	1.8	10.04	25.76
Settlements			0	0	1.75	2.51
Grass lands			0.78	0	0.87	0.04
Built-up			0	0	0.04	0.83
Fallow lands			0	0.47	0	0
Forests			0.01	0.01	0	0
Total			4.08	2.29	13.21	29.47
LU/LC Class	No Change (area in Km ²)		Area gain in Km ²		Area loss in Km ²	
	1971-91	1971-2016	1971-91	1971-2016	1971-91	1971-2016
Settlements	366.84	361.64				
Water bodies			0.01	0.01	0	0.04
Agriculture			37.58	47.51	1.26	1.25
Swamps and Marshes			1.75	2.51	0	0
Grass lands			50.43	52.74	0	0.07
Built-up			0.98	1.47	8.81	13.73
Fallow lands			19.55	20.64	0	0.1
Forests			48.83	53.2	0.12	0.07
Total			159.13	178.03	10.19	15.26

Table 6 LU/LC gain and loss status of 1971-1991 and 1971-2016

LU/LC Class	No Change (area in Km ²)		Area gain in Km ²		Area loss in Km ²	
	1971-91	1971-2016	1971-91	1971-2016	1971-91	1971-2016
Grass lands	59.84	50.48				
Water bodies			0.02	0	0.14	0
Agriculture			0.82	4.3	72.56	81.67
Swamps and Marshes			0.87	0.4	0.78	0
Settlements			0	0.07	50.43	52.74
Built-up			0	0	1.18	0
Fallow lands			0	6.29	0	0.08
Forests			1.69	0.11	0	0
Total			3.4	11.17	125.12	134.49
LU/LC Class	No Change (area in Km ²)		Area gain in Km ²		Area loss in Km ²	
	1971-91	1971-2016	1971-91	1971-2016	1971-91	1971-2016
Built-up	126.1	125.68				
Water bodies			0	0	0	0.14
Agriculture			0.72	0.98	0.09	0
Swamps and Marshes			0.04	0.83	0	0
Settlements			8.81	13.73	0.98	1.47
Grass lands			1.18	0	0	0
Fallow lands			0.57	0.77	0	0
Forests			0.82	1.56	0	0.25
Total			12.14	17.87	1.07	1.86
LU/LC Class	No Change (area in Km ²)		Area gain in Km ²		Area loss in Km ²	
	1971-91	1971-2016	1971-91	1971-2016	1971-91	1971-2016
Fallow lands	51.48	48.15				
Water bodies			0	0	0.03	0.03
Agriculture			0.1	1.62	22.15	24.15
Swamps and Marshes			0	0	0	0.47
Settlements			0	0.1	19.55	20.64
Grass lands			0	0.08	0	6.29
Built-up			0	0	0.57	0.77
Forests			0.17	0.17	0.02	0.02
Total			.27	1.97	42.32	52.37
LU/LC Class	No Change (area in Km ²)		Area gain in Km ²		Area loss in Km ²	
	1971-91	1971-2016	1971-91	1971-2016	1971-91	1971-2016
Forests	236.86	223.02				
Water bodies			0	0	0.17	0.35
Agriculture			0	0	73.17	81.96
Swamps and Marshes			0	0	0.01	0.01
Settlements			0.12	0.07	48.3	53.2
Grass lands			0	0	1.69	0.11
Built-up			0	0.25	0.82	1.56
Fallow lands			0.02	0.02	0.17	0.17
Total			.14	.34	124.33	137.36

Accuracy assessment

Calculation the accuracy of the outcome of image classification is of enormous significance since it provides confirmation of how well the classifier is clever to extract the preferred objectives from the image. The overall accuracies for the LU/LC maps of the study area for 1991 and 2016 were 92% and 89%, respectively (Table 7).

Table 7 Accuracy assessment statistics

LU/LC CLASS	Year					
	1991			2016		
	Producer Accuracy(%)	User Accuracy(%)	KAPPA(%)	Producer Accuracy (%)	User Accuracy(%)	KAPPA(%)
Water bodies	100.0	100.0	1.00	100.0	100.0	100
Agriculture	91.38	94.64	0.87	96.08	87.50	0.74
Swamps and marshes	50.00	100.0	1.00	84.21	80.00	0.75
Settlements	100.0	80.00	0.76	33.33	100.0	100
Grass lands	100.0	100.0	1.00	75.00	100.0	100
Built-up	100	100.0	1.00	100.0	100.0	100
Fallow lands	66.67	100.0	1.00	100.0	100.0	100
Forests	88.89	88.89	0.87	80.00	100.0	100
KAPPA	0.87			0.83		
Overall Accuracy	92			89		

The study area has been distressed fast LU/LC due to growth of population that consequences quick decrease in forests, grass lands and marshes and swamps. The study covers the LU/LC change matrices from 1971-1991 and 1971-2016 over the district at different period. The area under agriculture, settlements and built-up area have shown considerable positive conversion and where forests, swamps and marshes, grasslands and fallow lands have shown negative conversion. Of the total decreased area, forests, grass land, fallow land and swamps and marshes contributed to agriculture land. At the same time major percentage of agriculture land are migrated to other land use classes like settlement, built-up, grass lands etc. During primary field study it was observed that most of the forest cover (reserved forests and households' forests), grass lands swamps and marshes and fallow lands were converted to agriculture and settlements area.

Authors Contribution: Narayan Chetry (Assistant Professor) performed the review, data collection and writing of the manuscript; Madine Hazarika (Assistant Professor) has contributed in its analysis and interpretation including the editing of manuscript and also the corresponding author.

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