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Changing landuse pattern of Siliguri Municipal Corporation using Remote Sensing and GIS techniques, West Bengal

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Abstract

The changes in the land use and land cover are detected and measured by using RS GIS techniques on 30 meter landsat satellite data. To detect and interpret the land use transformation, GIS and remote sensing are combined as a vital tool for the analysis and investigation of spatio temporal data. Siliguri Municipal Corporation (SMC) is undergoing significant demographic growth and economic development and hence experiencing rapid urban expansion and land use changes. The study analyze the spatial variation of land use changes in SMC area over a 27 years period using landsat imageries of three different years. These tools will help the planners and community governments to ensure landscape planning decisions in more sustainable process.

Key words: land use, land cover change, Land use conversion metrics, GIS.

1. Introduction

The physical expansion of built up land influences rapid change of land use/ land cover (LULC) pattern of an area. Land use change analysis has become the key component of global environment change researches (Gutman et al 2004; Rindfuss et al, 2004). Land use pattern of any region is considered as an outcome of the nature of resource utilization by its population (Fuller and Gaston, 2009). With growing population, demands of land for agriculture, newly residential area, land for infrastructure is increasing which leads to encroachment of natural land and related degradation. Siliguri is emerging as a hub of major commercial and administrative activities with growing importance hence reflects in its land use pattern. Monitoring landuse changes over the area throughout temporal periods is accomplished by using Landsat sattelite imageries. Satellite data helps in efficient landscape analysis as such data is regularly updated and easily accessible (Liu & Yeng, 2013). Remote sensing data and GIS technology have been integrated for performing supervised classification and post classification change detection (Aspinall & Hill, 2008; Chen, Zeng, & Xie, 2000). The decreasing area under vegetation cover, water bodies, barren land, agricultural land and built up area expansion is actively tracked through time series remote sensing data. The present paper aims at study the remote sensing and geographic data in the land use patterns, land cover classification using GIS based analysis with following objectives.

Objectives:

i) To study the spatial characteristics and pattern of land use land cover in SMC in last 27 years.

ii) To detect the post classification changes and analyze emerging trend of land use of the study area through GIS based techniques.

Study area

Siliguri is the gateway of whole north east India and nodal agency of development of north of West Bengal. Siliguri is emerging as the 3rd largest town of west Bengal with its immense locational importance. The entire study area falls under the Terai physiographic region. SMC lies at 26° 42' N and 88° 25 ' E coordinates at the southern Himalaya's foot besides the river Mahananda. The elevation of the town is 121 meter above sea level and it covers an area of 41.9

sq. Km. Siliguri Municipality was established in 1949 and Siliguri Municipality gets its status as a corporation in 1994.

The administrative boundary of Siliguri Municipal Corporation (SMC) is divided into two parts : the part lies in Darjeeling district comprises 33 wards out of 47 wards and rest of 14 wards fall in the neighbouring Jalpaiguri district. Siliguri is the fastest growing city in West Bengal after Kolkata and Assansol has registered a total population of 216950 in 1991 which has increased to 513,264 in 2011 as per census of India. Its population density has increased from 5178 persons per sq. km in 1991 to 12250 persons per sq. Km in 2011. Among 47 wards of SMC ward number 46 is the most populous ward with population more than 30 thousand and ward no 11 is the least populous ward with population near 2000 as per 2011 census.

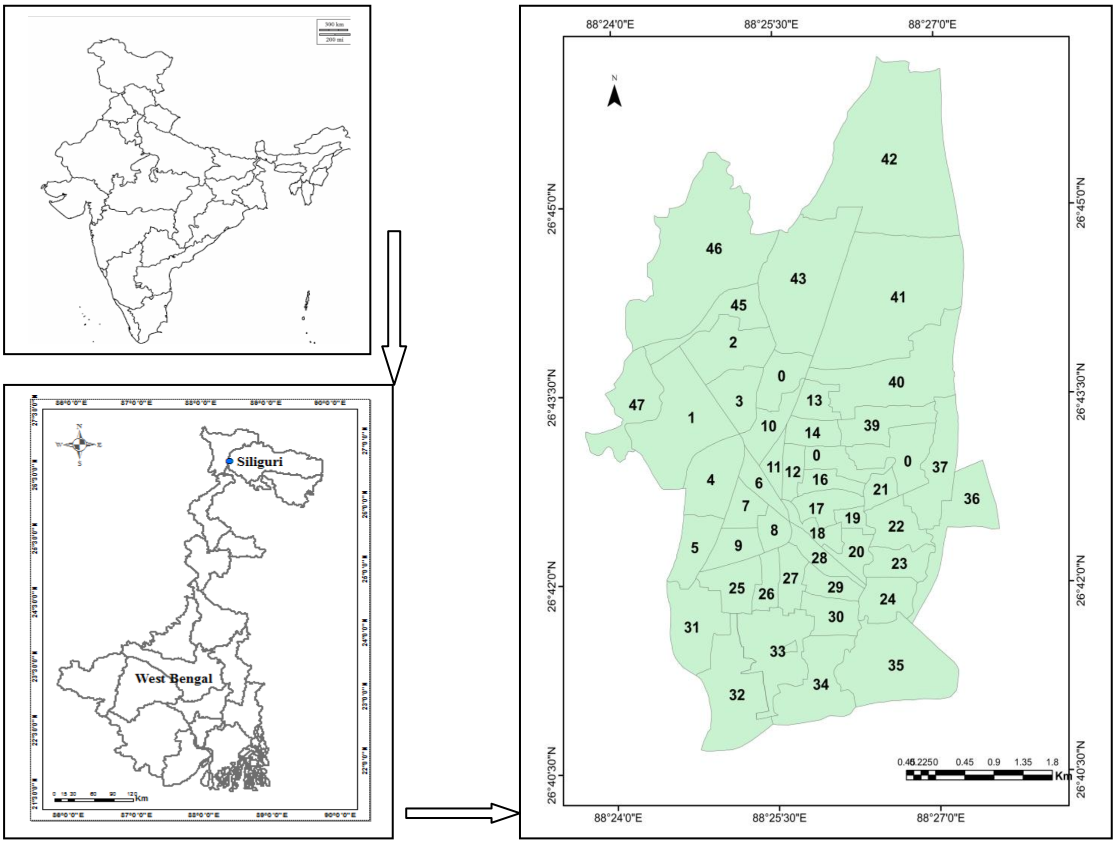


Fig.1 Study area – Siliguri Municipal Corporation (SMC) within India and West Bengal

Data and Methodology

Data Sources

The 30 x 30 m Landsat satellite imagery data derived from the USGS GLOVIS earth explorer were employed in this study. The data utilized are LANDSAT TM (Thematic Mapper) data for the year 1991, 2001and LANDSAT 8 OLI (Operational Land Imager) data for 2017. All images were captured at the same season of the respective years to analysis the changes of land use land cover pattern effectively. Characteristics of the satellite data has provided below:

Table 1. Land sat Satellite Images used in this Study

Satellite	Sensor ID	No of Bands	Acquisition date	Resolution	Path/Row	Projection
LANDSAT 5	TM	7	1991-01-08	30m	139/42	UTM-WGS1984

LANDSAT 5	TM	7	2001-01-19	30m	139/42	UTM-WGS1984
LANDSAT 8	OLI-TIRS	11	2017-12-01	30m	139/42	UTM-WGS1984

Source earth explorer USGS

Methodology

The obtained LANDSAT data of three temporal periods were used to extract the study area with the help of Arc GIS 10.3.1 software. Then the images were georeferenced to UTM 45° N WGS-84 datum for supervised classification using maximum likelihood classification method. The methodology of the present analysis can be divided into three stages: generation of land Use/land covers map, post classification accuracy assessment, and detection of land transformation.

Image Processing and Classification

Landsat TM data for the year 1991 and 2001, band no 1-7 have used except band no 6 as it is a thermal band and from Landsat OLI data band no.1-9 have been used except band no 10 and 11. After band combination, georeferencing, projection setting and geometric correction of the image data, supervised classification technique have been carried out for identifying five land use classes of the study area. A suitable number of signature from each land use classes has collected and merged for preparing land use classification map and necessary output generation in ArcGIS environment.

Accuracy Assessment

The accuracies of classified land use maps were assessed by selecting reference points from each land use layers verified with the help of ground truth data from Google archive images. A total no. of 187 and 191 reference points were superimposed on the classified images of 1991 and 2017 respectively from Google archive data to identify land use classes correctly. User's accuracy (Lunetta et al, 2001), producer's accuracy, overall accuracy and Kappa coefficient have been calculated for post classification accuracy assessment. Kappa co efficient gives more reliable value in accuracy measurement (Ma and Redmond, 1995). The adopted methods for verifying classification accuracies have been calculated by using following formula:

$$\text{Producer's accuracy (\%)} = \frac{\text{Unchanged value of individual class}}{\text{Column total of that class}} \times 100$$

$$\text{User's accuracy (\%)} = \frac{\text{Unchanged value of individual class}}{\text{Row total of that class}} \times 100$$

$$\text{Overall accuracy} = \sum \frac{\text{Diagonal value}}{\text{Total no of points}}$$

Kappa value is computed by calculating obtained value and expected value with following two steps:

$$\text{i) Obtained value} = \sum \frac{\text{Diagonal frequency}}{\text{Total no of frequency}}$$

$$\text{ii) Expected value} = \frac{\text{Sum of diagonal value}}{\text{total no.of points}}$$

$$\text{Accuracy} = \frac{\text{Expected value} - \text{Obtained value}}{1 - \text{Expected value}}$$

Land conversion detection

GIS based reclassification procedure was adopted to address land conversion between different land use classes of three temporal periods. A two way cross tabulation or transition matrix analysis has been adopted to characterise the interchange of landuse between different classes. Information has extracted with the help of land transition matrix to detect the changes in the land use pattern of the study region.

Results and Discussion

Land Use and Land Cover Classification

Using the Landsat images of three temporal periods five major land use types were identified for obtaining the information of land use pattern of SMC. The derived land use categories include sparse vegetation, open space, built up land, water body and waste land. Table 2 provides description of land uses under each category.

Table 2. Description of land use classification

Landuse Classes	S.V	O.S	B.U	W.B	W.L	Row total	User's accuracy
S.V	**32**	2	0	1	0	35	95%
O.S	0	**35**	1	2	1	39	92.70%
B.U	1	1	**37**	0	2	41	93.50%
W.B	1	0	1	**33**	1	36	90.50%
W.L	0	2	1	1	**36**	40	96.10%
Column total	34	40	40	37	40	191	
Producer's accuracy	94.11%	87.5%	92.5%	89.19%	90%		
Over all Accuracy					90.57%		
Kappa co efficient					0.891		

Land use/ cover type	Description
Sparse Vegetation	Scattered trees, bush land, shrubs, patches of grass cover.
Open space	Land under bare soil, cleared land, open ground, park and other exposed area are classified under this category
Built up	Total area of the settlements, infrastructural development, industries, transportation, public utility
Water Body	ncluding river, pond, tanks, water reservoirs and water channels.
Waste Land	Bare, exposed areas, silt and sandy areas.

Table 3.a. Accuracy Assessment of Land Use Land Cover Map of 1991 from Land sat TM data

Source: Computed from image data

Accuracy Assessment

The accuracy assessment of landuse classes map have presented in table no. 3a and 3b. The post land use classification overall accuracy of 1991 and 2017 classified images are 86.09% and 90.57% shows good accuracy result.

Note: Diagonal values represent correctly classified samples for each landuse class. SV-Sparse vegetation, O.S-Open space, B.U- Built up, W.B- Water body, W.L- Waste land.

The reliability of the accuracy result has been made through Kappa coefficient to validate the post classification analysis. Kappa value for 1991 classified image is 0.85 and for 2017's image is 0.89 which indicates the effectiveness of the classification technique adopted in the study.

Table3.b. Accuracy Assessment of Land Use Land Cover Map of 2017 from Landsat OLIdata

Landuse Class	S.P	O.S	B.U	W.B	W.L	Row total	User's accuracy
S.P	**28**	1	1	2	0	32	87.5%
O.S	2	**33**	2	3	2	42	78.57%
B.U	1	0	**36**	1	2	40	90.0%
W.B	1	1	0	**29**	2	33	87.87%
W.L	0	2	1	2	**35**	40	87.5%

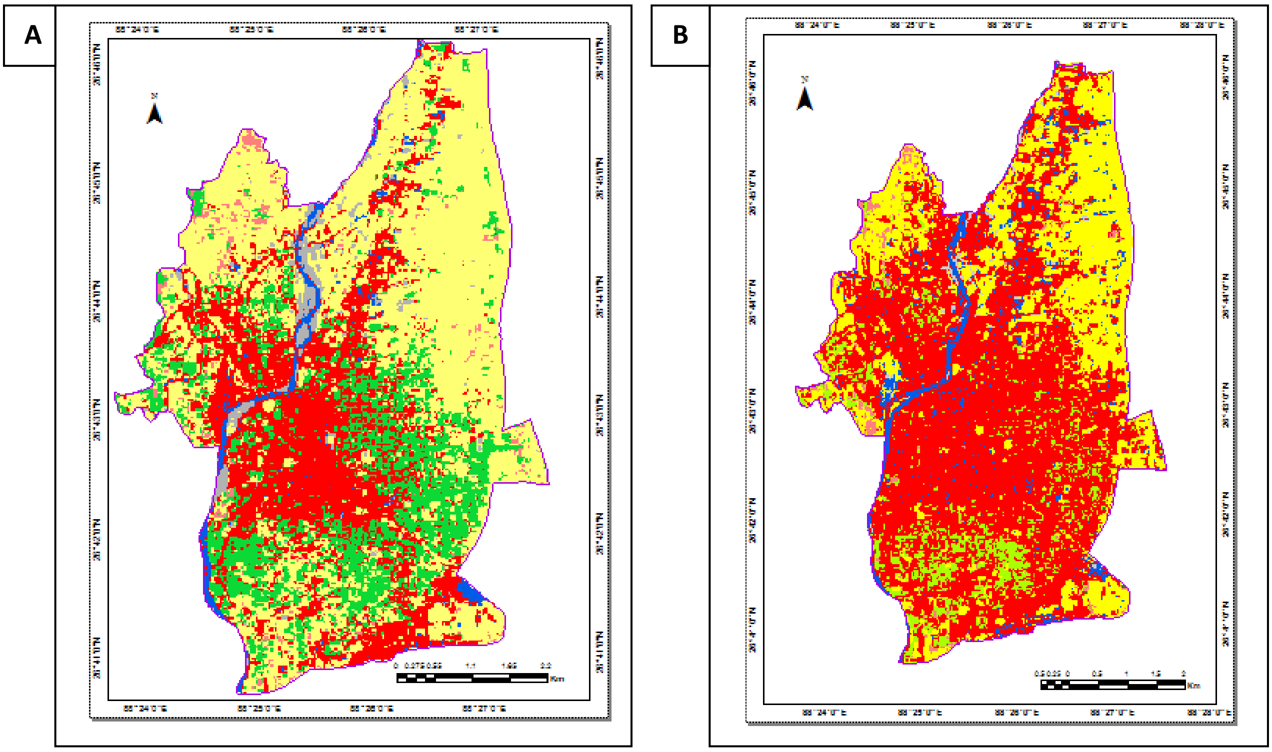
Column total	32	37	40	37	40	187	
Producer's accuracy	93.3%	89.12%	90%	78.37%	87.5%		
Over all Accuracy					86.09%		
Kappa co efficient					0.845		

Source: Computed from image data

Land use change analysis

The state of land use and land cover in three temporal periods has displayed in figure 2 A, B and C. The existing landuse statistics of SMC were presented in table no 4 to insight the area under different land use classes.
In 1991 chief portion of land use is occupied by open space (47.93. %). Bare land, cleared land, open ground and field constituted a major part in the town. The second predominant landuse is built up land which shares 29.41% geographical land of the area in 1991. This indicates that the area have substantial land for accommodating growing population. About 19% area covered by sparse vegetation located in the middle and southern portion. Water body and waste land was found to be the smallest land use type which account for 2.76% and 2.24% respectively of the remaining area.

In 2001 the land use scenario of SMC depicts a quite different picture. Tremendous population growth, shows in figure 4, in last two decades brings changes in the land use pattern of the area. Figure 5 depicts ward wise population density (number of person per sq.km) which implies the intensity of habitation on land. Population density has a significant importance in development planning especially in denser areas.
Rapid growth of constructional land with growing population reflects in drastic reduction of open space to11.73% in 2017. Built up land was the most prevalent land cover occupying 58.38% land cover which results in squeezing of other land uses. Water body area increased to 4.65% in coverage as for improved water management system. Vegetation cover remarkably decreased from 18.46% to 7.83% due to transform of land mainly to residential area. Waste land also remarkably decreased from 2.76% in 1991 to 0.98% in 2001.



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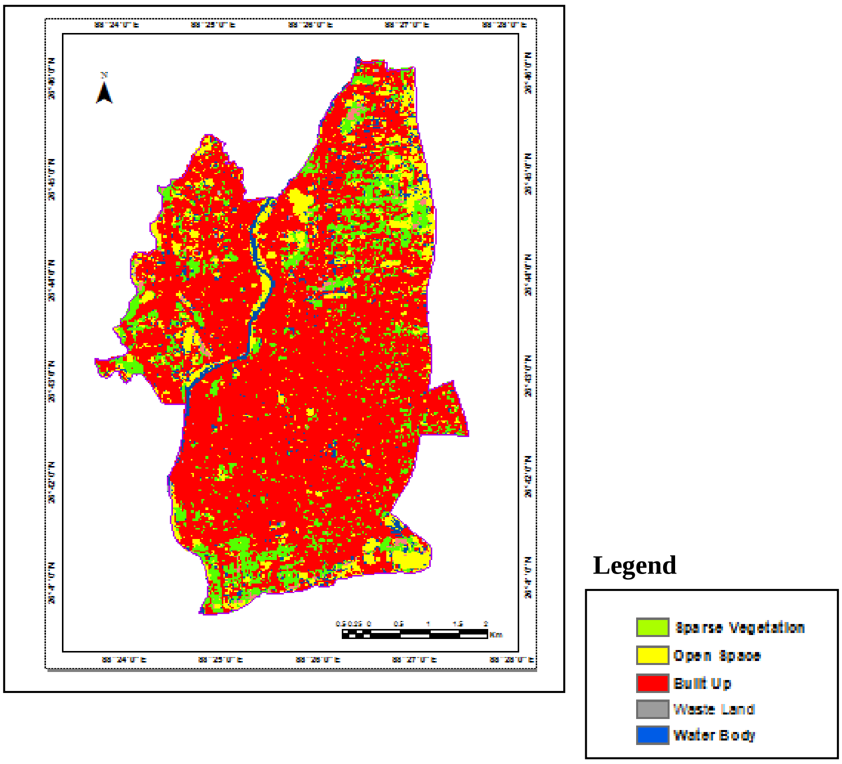

Fig. 2 Land Use/Land Cover maps of SMC (A) 1991, (B) 2001 (C) 2017

Table 4. Area under different land covers of SMC (1991, 2001 and 2017)

Land use/cover	1991(Sq Km.)	Area in %	2001(Sq Km)	Area in %	2017	Area in %	Change in % (1991-2017)
Built up	12.34	29.41	24.46	58.38	26.04	61.72	33.2
Sparse vegetation	7.8	18.46	3.28	7.83	8.62	20.57	2.11
Open space	19.66	46.93	11.73	28.01	3.88	9.26	-37.67
Water body	0.94	2.24	1.95	4.65	2.84	6.78	4.54
Waste land	1.16	2.76	0.4	0.98	0.66	1.56	-1.2

Source: Computed with help of Arc GIS

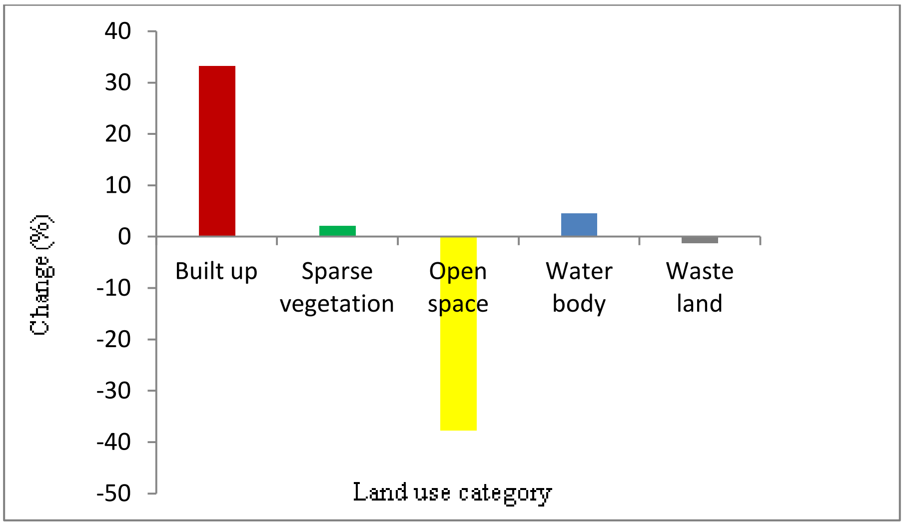

Fig.3 Change detection of different land use from 1991 to 2017

The land use pattern (ref. Fig.2C) in 2017 again dominated by built up land use which cover 26.04 Sq. Km. area sharing 61.72% land cover. Area under residential land, transport and communication, industrial and other constructional activity is substantially accelerated in SMC area from 2001 to 2017. Again open space decreased to 3.88 Sq. Km. sharing 9.26% land cover area, due to the trend associated with filling the open space and intensification of constructional land. Formation of reservoirs, channels improved the water management system of the region which reflected in rise of water coverage area from 2.24% in1991 to 2.4% in 2017. Though there was slight increase in Waste land area and vegetation cover in 2017 which account for 1.56 % and 20.57% land area respectively compare to 2001. This land use change can be clearly visualised from figure no.3.

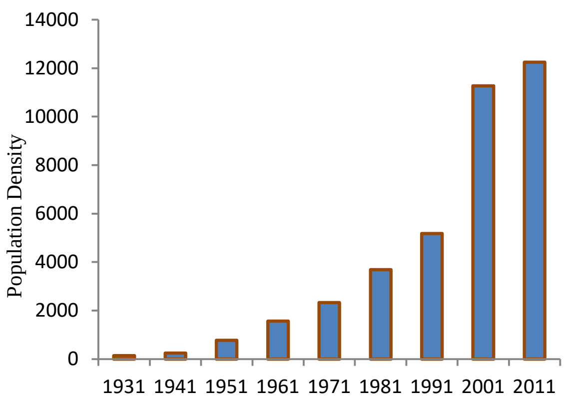

Fig.4 Population growth in Siliguri (1931-2011)

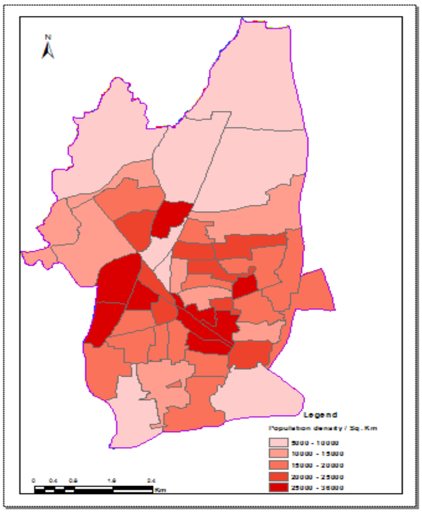

Fig.5 Population density map of Siliguri 2011

Land conversion and land use change magnitude

Land conversion between different land use categories helps in indicating the trend of land use change. Two way land transition matrix (table no.5) have been produced to detect every possible land conversion between classes.
Land conversion map during the study period of 1991-2017 has shown in figure 6, most affected land use area is waste land and open space as 97% and 86.06% of these land use were converted to other LULC types respectively.

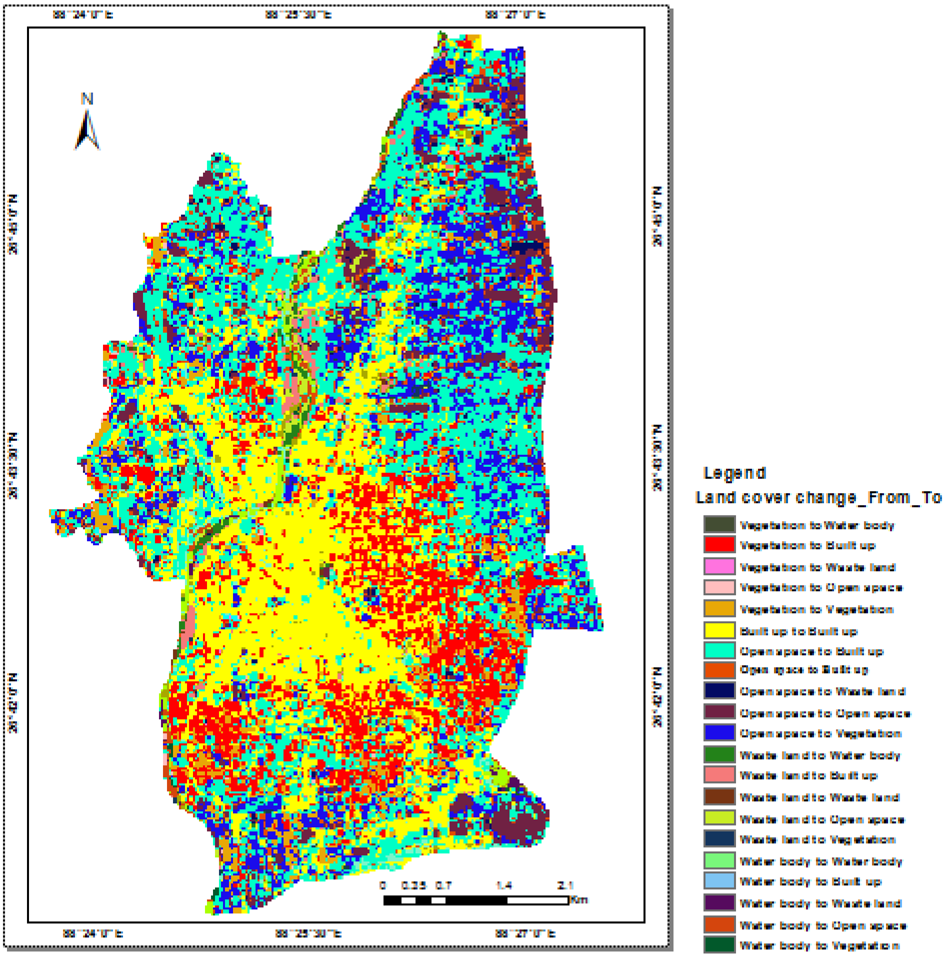

Fig.6 Land cover conversion map of SMC from 1991 to 2017

Built up area and sparse vegetation were found with lowest conversion. In between 1991 to 2017 highest percent change is of built up land (111.02%) where stable built up land (95.257%), water body , waste land, vegetation and open space have chiefly contributed to the increase of built up land. A significant transition of open space (49.75%) to sparse vegetation and water body area is found. 81% converted water body area was share by open space, waste land and built up area. Significant change is marked for vegetation cover which mainly gained its land from open space (24.87%) and waste land (22.52%). This increase of vegetation mainly occurred in the North West and Southern periphery portion of the town as a part of city planning. Below transition matrix shows contribution of different LULC to the increase or decrease of their coverage area.

Table . 5 Transition Matrix of Changed Land Cover from 1991 to 2017, (SMC)

Land cover 1991(Sq. Km)	Land cover 2017(Sq. Km)				
	Sparse vegetation	Open space	Built up land	Waste land	Water body
Sparse vegetation	**2.10 (30.79)**	0.110(1.61)	4.433 (65)	0.019(.66)	0.156 (2.29)
Open space	4.89 (24.87)	**2.744 (13.94)**	09.18 (46.69)	.341 (1.73)	2.51(24.36)
Built up	0.01(0.08)	0.030 (0.24)	**12.11(95.27)**	0.16 (1.26)	.401 (3.15)
Waste land	0.598 (22.52)	0.243 (9.14)	1.491 (56.05)	**0.07 (2.63)**	0.256 (9.62)
Water body	0.07 (9.88)	0.21 (28.49)	1.05 (61.05)	0.07 (9.30)	**0.32 (18.60)**

Source: Computed from image data extraction

Note: Values in the row cells depict the amount of previous land cover contributed to the present land cover shows in columns. The diagonal values in bold represent the stable area of LULC of each class during respective period. Values in parenthesis are the corresponding percentage values

The land use change magnitude is described in table no 6. which illustrates increase and decrease rate of each land use classes. During the period from 2001 to 2017, rate of land loss per year is highest for open space and waste land i.e. size of decreased land is much higher than increased land. Whereas for vegetation cover it gained its area from other land uses almost at the same rate as it loses its area per year. Rate of increased built up land per year is highest among all land uses.

Table 6. Rate of Land Cover Increase/Decrease During the period of 1991 to 2017

Year	**Decreased**		**Increased**		**Overall**	
Land Cover	**Area in Km²**	**Rate(%/Annum)**	**Area in Km²**	**Rate(%/Annum**	**Change (%)**	**Net Change (%)**
parse Vegetation	4.72	2.71	5.57	2.74	5.45	.03
Open space	16.92	8.77	0.56	0.11	8.88	-8.66
Built Up	0.60	0.09	16.15	5.03	5.12	4.94
Water Body	1.89	0.57	3.2	2.69	3.26	2.12
Waste Land	2.59	5.09	.59	1.96	17.05	-3.13

Source: Calculated by author

Conclusion

The analysis carried out both the assessment of spatial and temporal dimension of land use change. Land use data from 1991 to 2017 have been compared to quantify the magnitude of LULC change in SMC for last 26 years. The study provided evidence of rapid urban growth or expansion of built up area in Siliguri Municipal Corporation. The area has experienced very rapid growth rate (396%) of built up coverage from 12.34 Sq. Km. to 61.32 Sq. Km. in between 1991-2017. These built up area have increased significantly at the cost of the decrease of open space, water body, waste land and vegetated area. Natural land covers are mutated into new urban land with growing population.
From the analysis of 1991, 2001 and 2017 land use maps its evident that most of the areas in the town have undergone a transition in status from open and vegetated area to extensively expanding residential and constructional land. Consistent increase of population is the driver of these changes. Population expansion associates a huge amount of loss of natural land. Conversion of natural lands and increase of impervious surface can leads to the degradation of environmental sustainability. Knowledge regarding land cover alteration supports urban land management system. The study has demonstrated satellite remote sensing data can help in monitoring and providing valuable information on land changes. Integrating the knowledge gap and understanding between past and present spatial pattern and nature of changes of the area can provide an effective urban planning and management.

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