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Land Transformation Analysis of Siliguri City using Remote Sensing and GIS techniques

Sukhendu Jana[1], Dr. (Mrs.) Uma Gole[2]
[1]Research Scholar, S.o.S in Geography, Pt. Ravishankar Shukla University
[2] Prof. & Head S.o.S in Geography, Pt. Ravishankar Shukla University, Raipur

Abstract

During past four decades, Siliguri city has attracted a large number of population due to economic hub of the entire north Bengal, which led to the rapid transformation of its LULC pattern. Therefore, this study is aimed to analyse the LULC changes during 1991 to 2021 by giving special emphasize on built up transformation. The Landsat TM, ETM and LISS IV data has been used for the LULC classification of the Siliguri city. Modified Maximum Likelihood Classifier approach has been adopted to generate the classified image. From the analysis it is found that there is a drastic change in built-up 1254.54 percent in respect to 1991. While teagarden, agriculture land and waterbody declined by -90.06, -97.17 and -88.76 percent, respectively. These changes are harmful for the ecological balance of the city surrounding. It can further impact on the city's sustainable development.

Keywords: Land Use Land Cover (LULC), Built-up, Maximum Likelihood Classifier, Urban expansion.

Introduction

As per the World Bank report 2009, Secondary cities have tremendous potential for upgrading the regional and national Development (World Bank., 2009). In this report significance of medium sized class 1 cities has been given more importance for the betterment of world economy. Historically South and South East Asia has the highest population concentration. In the last few decades, mainly second half of the last century rapid growth of urban population has led to the speculation of urban explosion in this region . On the other hand, the population growth of the developed countries almost stagnant because they already passed the phage. It is worth mentioning that their rate of urban growth also stagnant. Among the Asian countries India and China alone will account for more than 64% of the overall growth of urban populations in Asia and a 42% share of global urban population growth from 2005 to 2025(Sankhe et al., 2011). India with a total urban population of 377 million as per 2011 census, the second largest in the world after China and expected to increase up to 590 million by 2031. According to 2011 census between 2001 and 2011, 92 million people were added to the urban population, the largest decadal increase in the last one hundred years, and for the first time, the net addition to urban population exceeded that of the rural population (Shaw, 2018). Urbanization is a process whereby productive agricultural lands, forests, surface water bodies and groundwater prospects are being irretrievably lost((Pathan et al., 1991). In India, unprecedented population growth coupled with unplanned developmental activities has resulted in urbanization, which lacks infrastructure facilities(Sudhira, Ramachandra, & Jagadish, 2004). Development of new urban areas and expansion of existing cities is inevitable as it is an essential part of sustainable economy but uncontrolled and haphazard urban growth may raise serious problems related to environmental pollution, changes in urban micro climate, loss of biodiversity and ecological balance, human and traffic congestion and moreover quality of urban life (Dutta & Rahman, 2017). Physical expansion of the city, population growth induce land cover change and land transformation are natural process we can't stopped the transformation. It can be regulated trough proper planning and management. The urbanization in India is resulting tremendous changes at ground level which are not given due attention in the discourse of planning, development, administration and policy making. One such area that did not receive much attention is the development, planning and governance is 'urban fringe', (Nallathiga, Taneja, Gupta, & Gangal, 2018) as the city grows to the periphery, many geographical changes at the urban periphery are associated with the transfer of land from rural to urban purpose. The current trend of spatial urban growth in almost all Indian cities has a haphazard pattern, particularly along the urban-rural fringe(Farooq & Ahmad, 2008)

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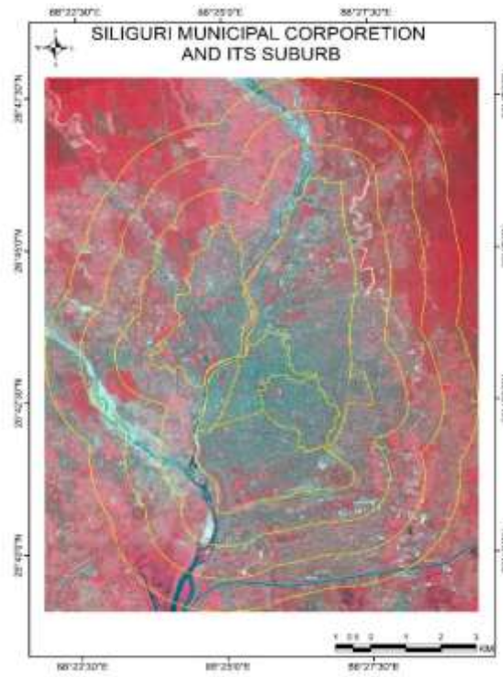


The conventional surveying and mapping techniques are expensive, and time consuming for the estimation of urban growth, by the time information became available to the planner it is outdated because the damage have already been done. Remote Sensing has become well accepted tool for monitoring land dynamics. Statistical techniques along with remote sensing and GIS have been used in many urban growth studies(Mahesh Kumar Jat et al., 2008; Punia & Singh, 2012; Sudhira et al., 2004b) for a proper development of city, it is necessary to monitor and plan the growth of a city. Geographers, planners and people from other discipline also took a keen interest in the study of this type of phenomena. Considering all the facts one attempt has been made for calculating and monitoring the urban growth in reference to Land Use Land Cover of Siliguri city.

Study area:

The Siliguri city, is located in the northern part of west Bengal above the 396 feet from the sea level on the bank of river Mahananda. The latitudinal and longitudinal extent of the city is 26^0 72' N and 88^0 41' E. Siliguri is the fastest growing city in the entire northern part of west Bengal. It is third largest city after Kolkata and Asansol as per 2011 census. Geographically it is located a strategic position in the Siliguri Corridor, a narrow strip of land linking mainland India to its north-eastern states. The city is popularly known as the gateway of North-East India because its corridor establishes a connection between the rest of India and the North-Eastern states. It not only connects the North-Eastern states with the Indian main land it also has the connection with three international boundaries (Bangladesh, Nepal and Bhutan). It also connects hill stations such as Gangtok, Darjeeling, Kalimpong, Kurseong and Mirik and the northeast states to the rest of India. Siliguri famous for four 'T' Tea, Timber, Transport and Tourism. Hundred km radius around the city is the birthplace of the World-famous Darjeeling Tea. Siliguri get recognition and started expanding after getting the municipality tag by the govt. in 1949. Till 1994 the Siliguri municipality has 34 wards under its jurisdiction. After declaration of the Siliguri Municipal Corporation in 1994, 17 new wards are added to its jurisdiction. Siliguri is a unique city as 15 out of 47 wards of the Siliguri Municipal Corporation fall in the neighboring Jalpaiguri district remaining are fall under the Darjeeling district.

Material and method

The following remote sensing imageries were used to compute the land use and land cover of the Siliguri city.

- Landsat Thematic Mapper (TM) image (path 139, Row 41) of 11-05-1991
- Landsat Enhanced Thematic Mapper Plus (ETM+) image (path 139, Row 41) of 26-12-2001.
- Linear Imaging Self-Scanning Sensor-4 (LISS 4) image (Path 107, Row 53) of 17-11-2011 and 16-01-221.

Spectral details of the aforementioned imageries are given in table 1. It is worth mentioning that the thermal bands of Landsat TM and ETM were not considered for the analysis.

Table: 1 Spectral details of the Sensor

Sensor	Spectral Bands (in µm)	Spatial Resolution (in m.)	Spectral Region	Year of acquisition
Landsat TM, ETM	Band 1 0.45–0.52	30	Blue	1991, 2001
	Band 2: 0.52–0.60		Green	
	Band 3: 0.63–0.69		Red	
	Band 4: 0.76–0.90		Near IR	
	Band 5: 1.55–1.75		SWIR	
	Band 7: 2.08–2.35		SWIR	
LISS IV	Band 2: 0.52–0.59	5	Green	2011, 2021
	Band 3: 0.62–0.68		Fed	
	Band 4: 0.77–0.86		Near IR	

The images were acquired as a standard product i.e., radio-metrically and geometrically corrected. As the images are free from cloud no atmospheric correction carried out. Since the urban growth analysis entirely depends on multi-temporal satellite images image to image registration has been done to remove the spatial miss match of the data sets taken from the different agencies and different time period.

Image from different sensor have differences in their spatial resolution. Despite different spatial resolution, images are kept as it is without changing the pixel size or value as not to compromise spatial detail and pixel values (Bhatta, 2009).

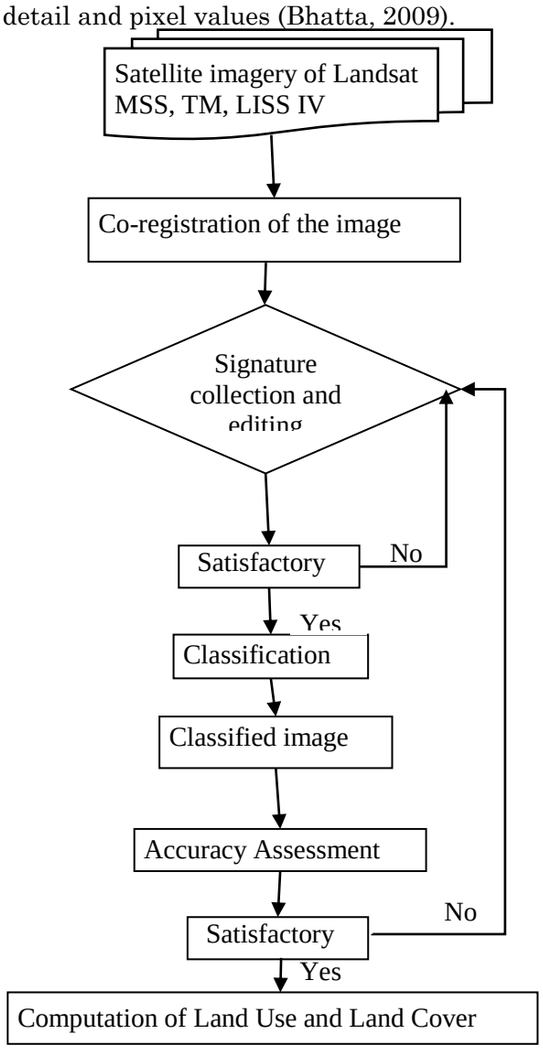


Fig: 1 Flow chart of methodology

The administrative map of Siliguri (SMC area) registered in UTM (Zone 45) and WGS 84 based on the GCP in the first-degree polynomial. The vector map of Siliguri (SMC area) which is generated after vectorization from the above map was used for sub setting the satellite images. In the next stapes co-registered images ware subset with the vector map of the SMC area. The subset raster images were considered as the input for extracting the built up along with other impervious area with the help of well-known Maximum Likelihood Classifier(M. K. Jat et al., 2008b; Mahesh Kumar Jat et al., 2008; Rahman et al., 2011, 2012; Sudhira, Ramachandra, &

Jagadish, 2003; Sudhira, Ramachandra, Raj, et al., 2003). Considering the heterogeneity of the built-up area MLC is used in modified approach. Instead of merging the signatures and then applying the classification, in this research, signatures were kept without merging and they were merged once the classification was over. This could handle the urban heterogeneity well (Mithun et al., 2016). After the classification a total of Six LULC classes i.e., Agricultural Land, Built-up, Vegetation, Tea Garden, Vacant/Fallow Land and Water body were identified based on NRSC level I classification scheme. Identified LULC classes were further authenticated by ground validation, details of authentication have been mentioned in the accuracy assessment. Classified images are converted into vector for further analysis of change detection. Finally, LULC change was estimated by generating multi temporal vector layers for 1991, 2001, 2011 and 2021 and computing their corresponding statistics.

Accuracy assessment

Accuracy assessments determine the correctness of the classified image, it is an important part of the LULC classification and mapping. The classification accuracy quantifies the quality of maps produces and helps to evaluate the applicability of a map for a particular use (Naikoo et al., 2020). Accuracy assessment for remote sensing classification is commonly based on using an error matrix, or confusion table, which needs reference map or high-resolution image, or 'ground truthing' data to support (Bhatta 2008). The techniques like Kappa coefficient, error matrix and indices-based techniques have already been used in several studies for the accuracy assessment of LULC maps produced(Bhatta, 2009; Mondal et al., 2017; Rahman et al., 2011, 2012).

In this study Kappa coefficient technique is used to evaluate the classification accuracy by selecting 380 random points throughout the study area. These points are selected such a way so that it can distribute entire area proportionately. As this is a multi-temporal change detection it is often difficult to verify with traditional method of ground verification. Due to this reason ground verification for the year 1990, 2001, 2011 were taken from the Google Earth pro, for the ground verification of the image 2021 both the field data as well as the Google Earth Pro were also considered for the inaccessible area. The results of accuracy assessment show an overall accuracy level of 84.79 percent, 94.29 percent, 91.46 percent and 88.89 percent for 1990, 2001, 2011, 2021 respectively and the corresponding Kappa statistics was 0.973, 0.9314, 0.8975, and 0.8667 respectively. It is well accepted that for level one classification of land use land cover accuracy should not be less than 80 percent (Anderson et al., 1976).

Dynamics of land use land cover change

Change dynamics of area under each LULC classes during 1981 - 1991

A total of 4190 hectares of land came under Siliguri municipality, this land has been categorized into six broad land use classes namely agricultural land, built-up areas, forest land, Teagarden, vacant land, and water bodies. During the year 1981 Siliguri is not a famous place most of the area was undeveloped.

Siliguri is located in the foothill of the Himalaya, if we check the land transformation between 1981 to 1991 most dominated land cover group was barren land, agricultural land and forest area. In 1991 there is a predominance of vacant and agricultural land throughout the city (table 2) while built up is concentrated mainly at the central part of the city (fig lulc 1991). Forest is mainly concentrated at the north and north east part of the city though we can find forest patches throughout the city. Tea garden is significant part of the land cover there in Siliguri, it is dominated in the north and western part of the city.

Table no. 2

Land Use Land Cover Change Matrix 1981 - 1991

LULC Class/ Year		Land Use and Land Cover at 1991						
		Agriculture	Built-up	Forest	Teagarden	vacant land	waterbody	1981 Total
Land Use and Land Cover at 1981	Agriculture	501.91	152.68	53.65	3.50	103.26	24.18	839.18
	Built up		107.26	1.15		97.33		205.74
	Forest	3.23	0.53	3.48		52.57	1.33	61.13
	Teagarden	3.52	0.34	8.76	8.08	15.04	0.16	35.90
	Vacant land	104.47	121.87	53.11	21.82	2574.63	44.01	2919.90
	Waterbody	3.25	3.39	3.20		67.76	50.55	128.15
1991 total	Grand Total	616.38	386.06	123.36	33.39	2910.59	120.22	4190.00

Source: Computed by author from remote sensing data

In the table 2 a minute details have been given of the interchange of different land use. This way each pair has been calculated and summarised there in table 3.

Change dynamics of land use 1981 to 2021

The eye-catching insight regarding the 1981 to 2021 land transformation was the increase in built-up land and choking agricultural land. At the initial stage of the decade, the total available land under agricultural practices was 839.18 hectares and it continued to reduce 23.74 hectares of land available for agricultural practices. This region is famous for the tea cultivation it is noticed that 35.90 hectares which is 0.86 percent of the total area of the city was under this category in 2021 it reduced to only 3.57 hectares (table 3) and they are located mainly the outskirt of the city fig 3 and fig 4.

Table 3 Trends of land use land cover change (1981 – 2021)

LULC Class/ Year	1981		1991		2001		2011		2021	
	Area in Hec	%	Area in Hec	%	Area in Hec	%	Area in Hec	%	Area in Hec	%
Agriculture	839.18	20.03	616.38	14.71	415.49	9.92	148.49	3.54	23.74	0.57
Built up	205.74	4.91	386.93	9.23	1072.96	25.61	1628.58	38.87	2786.84	66.51
Forest	61.13	1.46	123.36	2.94	242.75	5.79	50.18	1.20	135.77	3.24
Teagarden	35.90	0.86	33.39	0.80	180.72	4.31	1.69	0.04	3.57	0.09
Vacant land	2919.90	69.69	2910.59	69.47	2201.41	52.54	2350.68	56.10	1225.68	29.25
Waterbody	128.15	3.06	120.22	2.87	76.67	1.83	10.38	0.25	14.40	0.34
Grand Total	4190.00	100.00	4190.00	100	4190	100	4190	100	4190.00	100

Source: Computed by author from remote sensing data

Usually in city area due to the infill growth vegetation area synchronized. Siliguri is located in the foothill of Himalaya. It has the legacy of good vegetation cover. That is reflecting the land use land cover. In 1981 61.13 hectare was under forest cover for the next two decades more area has been added in the forest category. But in 2011 it was there in worst condition. In the recent year due to the civic awareness and restoring the park inner city protection over existing forest cover enhances the forest cover and it reached to the 135.77 hectare in 2021 (table 3).

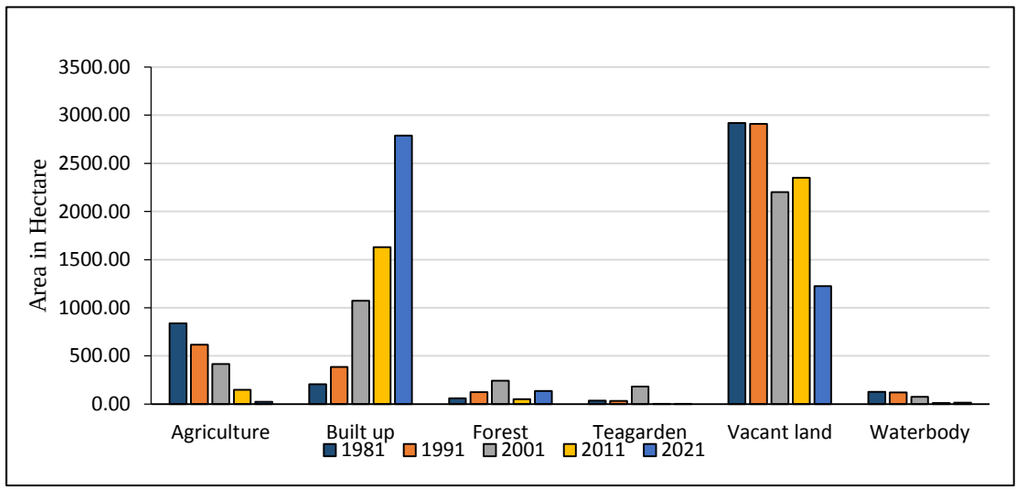
Table no 4 Land Use Land Cover Change Percentage (1981 – 2021)

LULC class	1981	Percentage	2021	Percentage	Change Percentage
Agriculture	839.18	20.03	23.74	0.57	-97.171
Built up	205.74	4.91	2786.84	66.51	1254.544
Forest	61.13	1.46	135.77	3.24	122.0842
Teagarden	35.90	0.86	3.57	0.09	-90.0559
Vacant land	2919.90	69.69	1225.68	29.25	-58.0232
Waterbody	128.15	3.06	14.40	0.34	-88.7629

Source: computed by the author form remote sensing data

The Present study advocates transformation and modification of land (LULC) from one category to another over 40 years (1991-2021). In the 1981s, the total identified built-up area in SMC was 205.74 hectares, it had increased to 386.93 hectares between 1981 and 1991. It further increased to 1072.96 hectares, 1628.58, and 2786.84 hectares in the year 2001, 2011, and 2021 respectively.

Fig. 2: Trends in Land Use Land Cover Change (1981 - 2021)



Percentage change in entire city built-up area in the last four decade (1981 to 2021) is 4.91 percent to 66.51 percent, of the total city area with a massive 1254.54 percent overall change (Table 4). The above study also figures out the continuous concentration of population in SMC which leads to rapid encroachment on physical land and transformed into different kinds of land use practices (Mukherjee and Debnath, 2016).

Discussion

In India, the urbanization has taken place at an unprecedented rate during past few decades, the momentum of growth are noticeable for the small and medium class town rather megacities (Chadchan & Shankar, 2012). Siliguri is one such city which rate of transformation in all classes are quite high (Basu Roy & Saha, 2011; Bhattacharyya & Mitra, 2013; Bose & Chowdhury, 2020; Roy & Kasemi, 2022; Sarkar & Chouhan, 2019). In the initial phase of development during 1991 city is concentrate at the core area of the city (fig 3). Change in land use can found only near the city core. By the year 2011 city mainly expand towards North, North East and southern part of the city (fig 4). The scenario of urban area increasing over the year (fig 4, 5 and 6). Land use maps, built-up area, cropland and open land, forest, and plantations and water bodies are associated with the study area. It has been found that over the period built-up areas have increased consequently at a rapid pace and this rapid increase of built- up areas is associated with the decline of the cropland and open land fig 4, 5 and 6.

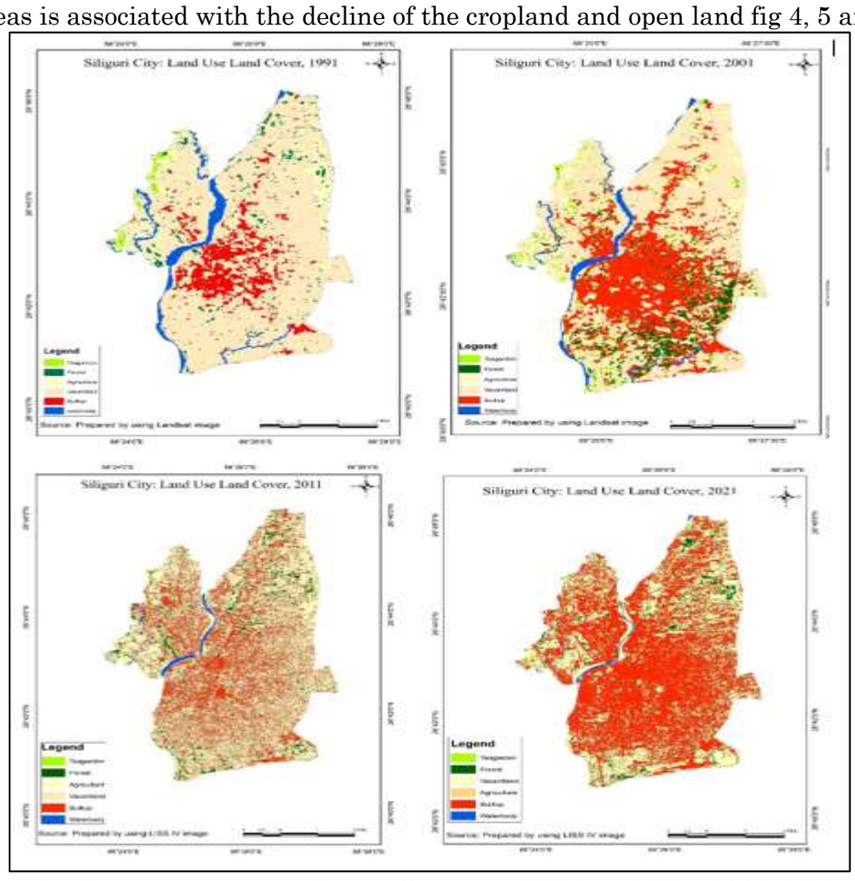


Fig: 3 Land Use Land Cover Change of Siliguri City 1991-2021

Conclusion:

This study is done to examine the spatio-temporal change in land use land cover of Siliguri Municipal Corporation. Rapid change in built up has been noticed, which has increased to about 1254.54 percent from 1991 to 2021. At the same time teagarden, agriculture land and waterbody declined by -90.06, -97.17 and -88.76 percent, respectively (table 4). while the changes in vacant land quite low -58.02 due to lots of addition of vacant land from different land cover class. Most of the cases it is found that vegetation covers of the city affect harshly but in the present study there is an addition of vegetation. The result also shows that the agricultural land and teagarden are the major contributors in the growth of built-up area, it also observed that this urban area mostly expanded over this two land use classes. While the water body also has a significant contribution in built up expansion. The discussion in the previous sections has directed attention to the magnitude and pattern of change in land use land cover of Siliguri city for the last four decades, which should be helpful in terms of guiding future planning and policy making for the city.

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