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PREDICTING URBAN GROWTH OF SILIGURI JALPAIGURI PLANNING AREA, WEST BENGAL, INDIA

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Abstract

Geo-spatial modelling has emerged as an important tool to measure urban growth at local, regional and national levels. The present study is primarily focussed on the analysis of urban growth and their future prediction concerning three neighbouring municipal areas of Siliguri, Jalpaiguri and Maynaguri in the state of West Bengal. These municipal areas are parts of a planning region of the state, known as Siliguri-Jalpaiguri Planning Area (SJPA). The study is based on Cellular Automata (CA) and Markov Chain, popularly known as CA_Markov to simulate and predict urban growth in the study area. Simulated results show that Siliguri is going to experience a built-up growth from 32.70 km² in 2001 to an approximately 148.60 km² in 2041. In Jalpaiguri the amount of built-up land is expected to increase from 2.30 km² in 2001 to 18.30 km² in 2041. While, in Maynaguri built-up area is expected to increase from 2.20 km² to 19.60 km² during the same time period. The study has also found that such an expansion in urban built-up area is taking place, principally at the expense of land under agricultural use and forested categories. The study reveals that in Siliguri urban area, agricultural land is predicted to decline from 328.60 km² to 214.90 km² between 2001 and 2041. Whereas, during the same span of time a declination in agricultural land from 35.50 km² to 26.60 km² in Jalpaiguri urban area and 55.60 km² to 46.90 km² in Maynaguri urban area, has been predicted. Therefore, this study highlights the need for a balanced regional planning intervention that may address the problems of unplanned built-up expansion and associated haphazard land conversions.

Keywords: Cellular Automata, Markov Chain, Urban growth modelling, Siliguri, Jalpaiguri, Maynaguri.

Introduction

Urbanisation has been perceived as a process encompassing physical, demographic and functional growth of settlements classified as 'Urban' (Pacione, 2009; Randolph and Storper, 2023). Globally, urbanisation has been acclaimed as a phenomenon, associated with infrastructural development, higher income levels and consequent socio-economic prosperity of mankind. At the same time, urbanisation has also been debated to be a process causing a host of issues like environmental pollution, inequalities, congestion, land use conversion, imbalanced settlement hierarchy and others. These issues are much more acute in developing countries, as compared to their developed counterparts (Pucher et al., 2005; Banerjee and Dutta, 2024).

With approximately 377 million urban population in 2011, India has emerged as one of the fastest urbanising countries of the world. With this large size of urban population, accompanied with an ever-increasing rate of urbanisation, India has been placed along the frontier of a host of urban issues. One such major issue is associated with over concentration of urban infrastructure in a small number of metropolitan agglomerations and resulted polarisation of infrastructural development (Ramachandran, 1989; Banerjee, 2023). Thus, despite extensive planning for balanced urban and regional development in India during post-independence period, significant regional disparities in terms of urban development remained a major concern for national policies (Sharma, 2020). Moreover, among Indian states, the state of West Bengal has traditionally been criticised for its extraordinary regional imbalance and associated polarised concentration of urban and industrial infrastructure in and around the state capital (Ghosh and Chakma, 2014; Banerjee and Saha, 2024). This polarised development trajectory has been translated into an imbalanced settlement hierarchy where small and medium-sized cities, especially those which are spatially distant from the state capital, have perpetually suffered from infrastructure deficiencies. Such circumstances are principally caused by an underperformance of spatial planning mechanisms at local and regional scales (Banerjee and Dutta, 2024). This makes it obligatory to study the urban growth trajectories of those cities which in one hand are neglected by policymaking institutions since long, and on the other hand are not being focussed upon by academic literature on urban growth analysis. Against this backdrop, the present study seeks to simulate and predict urban growth in three selected municipal bodies of Siliguri, Jalpaiguri and Maynaguri located in the Siliguri-Jalpaiguri Planning Area (SJPA) of West Bengal.

Objectives of the Study

Major objectives of the study are:

- to analyse the prevailing pattern of urban growth and predict its future pattern in three selected municipal areas of SJPA, and
- to suggest for the development of a balanced urban hierarchy in the SJPA region of West Bengal.

Study Area

The study area comprises of three neighbouring municipal bodies of Siliguri, Jalpaiguri and Maynaguri, situated in the planning region of SJPA, West Bengal (Fig. 1). Located at the cross-section of 26°73' N latitude and 88°40' E longitude, the city of Siliguri is the largest municipal area in the region. Siliguri has been recorded as the fastest-growing urban agglomeration of West Bengal with a decadal population growth rate of 46.40 per cent between 2001 and 2011 (MoUD, 2015). Within a span of last six decades, a small town has been metamorphosed into a thriving 'metropolis-in-the-making', and the pace of this evolution has been accelerated in the last two decades (Ghosh, 2018; Banerjee and Saha, 2024).

Considering the demographic size, Siliguri is distantly followed by the city of Jalpaiguri in the SJPA region. Jalpaiguri is situated along the western bank of river Teesta at the cross-section of 26°52' N latitude and 88°72' E longitude (Fig. 1). The Census of India, 2011 has recorded the population of Jalpaiguri urban agglomeration as 1.69 lakh,

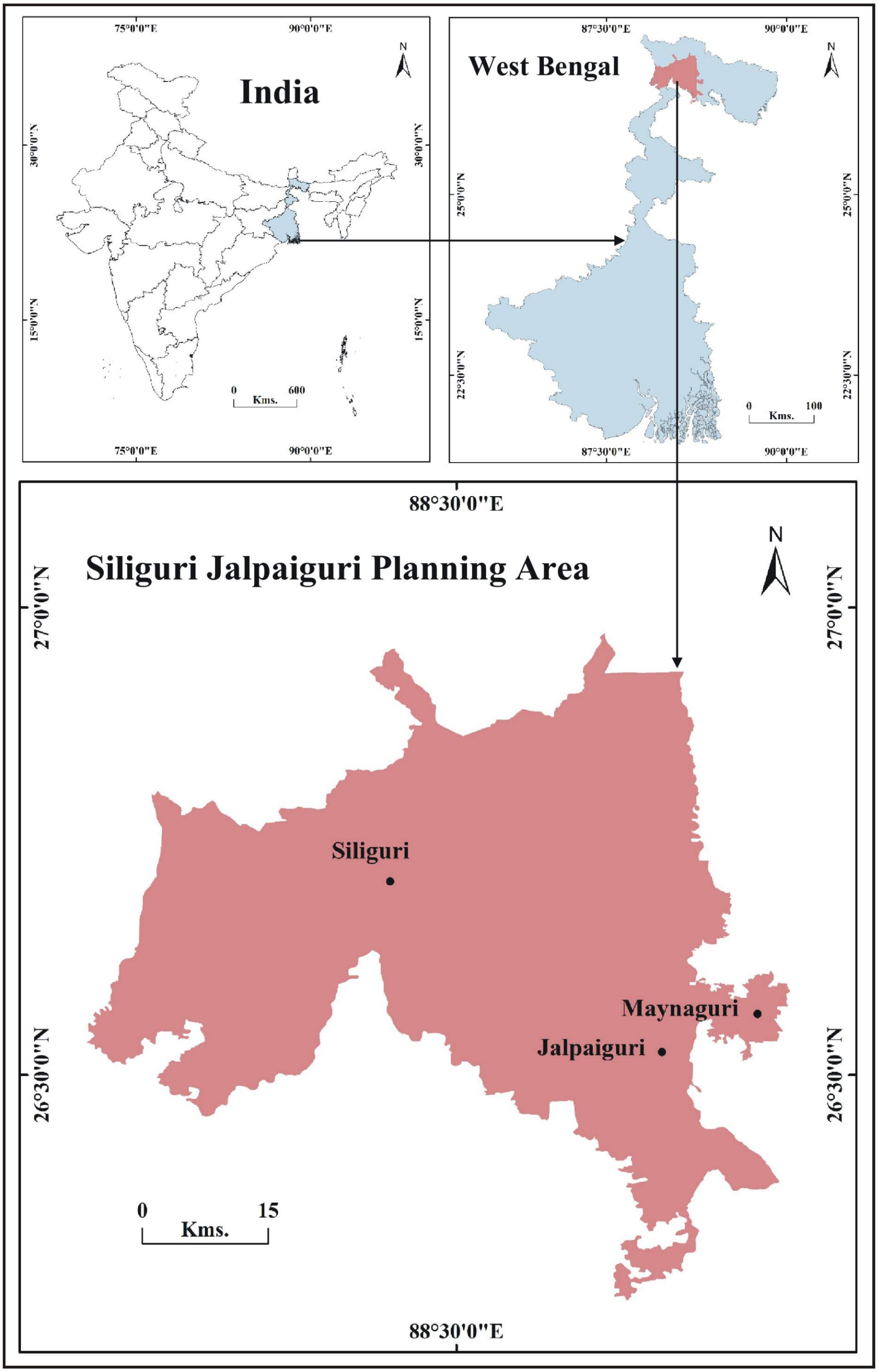
India
West Bengal
Siliguri Jalpaiguri Planning Area
88°30'0"E
27°0'0"N
26°30'0"N
Siliguri
Maynaguri
Jalpaiguri
0 15
Kms.

Fig. 1

Table 1
Siliguri Jalpaiguri Planning Area: Data Used for the Preparation of Land Use/LandCover Maps

Satellite Imageries							
Year(s)	Satellite	Sensor	Spatial Resolution (Metres)	Date of Capture	Path	Row	Number of Bands
2001	Landsat 7	ETM	30 × 30	29/12/2001	139	041, 042	7
2011	Landsat 5	TM	30 × 30	01/31/2011	139	041, 042	7
2021	Landsat 8	OLI-TIRS	30 × 30	10/11/2021	139	041	7
2021	Landsat 9	OLI-TIRS	30 × 30	12/11/2021	138	042	7

Topographical Sheets			
Publication Year(s)	OSM (Open Series Map) Number	Sheet Number	Scale
2010	G45L15	78F/15	1:50,000
2011	G45K5	78B/5	1:50,000

DEM Dataset			
Study Area	Dataset	Imaging Date	Spatial Resolution
Siliguri, Jalpaiguri, Maynaguri	Shuttle Radar Topography Mission (SRTM) Arc-Second Global	11/02/2000	1-ARC (30 Metres × 30 Metres)

Source: Compiled by Authors.

which has been nearly 1 lakh in 2001. Furthermore, the town of Maynaguri is the third largest municipal body of SJPA with a registered population of around 30 thousand within its urban area in 2011. Maynaguri is spaced at the junction of 26°57' N latitude and 88°82' E longitude (Fig. 1). These urban areas have been deliberately chosen in order to facilitate a comprehensive comparative analysis, enabling to understand their urban growth trajectories and spatial patterns of development.

Database and Methodology

In order to prepare land use maps, temporal remote sensing data of Landsat 7 (Enhanced Thematic Mapper), Landsat 5 (Thematic Mapper), Landsat 8 (Operational Land Imager-Thermal Infrared Sensor) and Landsat 9 (Operational Land Imager-Thermal Infrared Sensor) have been collected for the reference years of 2001, 2011 and 2021 respectively from United States Geological Survey (USGS, 2023) Earth Explorer platform (https://earthexplorer.usgs.gov/) (Table 1). The data for digital elevation model (DEM) has also been extracted from the same platform, whereas the road data has been obtained from the website of Open Street Maps (OSM) (https://www.openstreetmap.org/#map=13/26.5647/88.8286). The OSM data have been collected for the reference year of 2021. Furthermore, the remote sensing data have been supplemented with the information gathered from Survey of India topographical maps (of 1:50,000 scale) and imageries from Google Earth platform.

There are a sound number of methods, devoted to modelling and simulating the spatio-temporal scale of urban expansion and subsequently predicting its future course. Cellular Automata (CA), for instance, is a specific kind of 'discrete dynamic model' that has a number of special advantages for analysing complicated non-linear phenomena like urban growth (Lu et al., 2004; Yeh et al., 2021; Zhang et al., 2023). The popularity of CA in modelling urban growth can be attributed to a number of factors including its flexibility, simplicity and capabilities to combine the spatial and temporal aspects of urban growth phenomena. Moreover, since the last decade, CA model has been integrated with a number of mathematical models like Markov Chain for better accuracy (Al-Shalabi et al. 2013; Sarkar and Chouhan, 2019). The Markov Chain is a system with mathematical properties, which assumes that the transformation probability of any cell is dependent on the present state of the cell, its neighbouring cells and the time elapsed (Maithani, 2010; Sarkar and Chouhan, 2019; Theres et al., 2023). Thus, integration of CA with Markov has compensated for the growth constraints and consequently acquired substantial scholarly attentions since the last decade (Olusina et al., 2014; Yeh et al., 2021).

Creation of Input Data

In order to prepare land use maps for the reference years of 2001, 2011 and 2021, the Maximum Likelihood Classification algorithm has been used, with nearly 50 training samples for each class in each specific year. A total 9 land use/land cover (LULC) maps have been prepared, representing the LULC conditions of three buffers, depicting the urban areas of Siliguri, Jalpaiguri and Maynaguri, in three reference years, respectively. The LULC maps have been validated with K statistics with nearly 100 control points for each map. For Siliguri, the overall accuracy of classified LULC maps has been 83.70 per cent, 84.01 per cent and 79.10 per cent for the years of 2001, 2011 and 2021, respectively. In the buffer of Jalpaiguri, for the same time points, the classification accuracy has been 77.40 per cent, 85.10 per cent and 81.50 per cent, respectively, which has been recorded as 79.60 per cent, 80.01 per cent and 81.10 per cent, respectively for the buffer of Maynaguri.

Other than LULC maps, a number of input data have also been prepared within GIS environment. For instance, the OSM data have been processed and rectified to prepare the basic road layer for the study area. The same data have been used to prepare the 'distance to roads' database, which is an essential input data for CA_Markov modelling to simulate urban growth in the given region. Similarly, the DEM data have been used as an input file to prepare the slope map for the study area. At the final stage of data preparation, all of the input images have been converted into 8-bit radiometric resolution data in order to make them suitable and synchronised for the model.

Data Preparation and Model Calibration

Being a bottom-up model, urban CA is usually data-hungry and to a great extent, depends on a large set of input data for the simulation of real-world urban phenomena (Yeh et al., 2021; Theres et al., 2023). Furthermore, CA_Markov is an amalgamation of two distinct models, where CA, which is a spatially constraint deterministic model, is combined with a stochastic model i.e. Markov Chain (Parker et al., 2003; Zhang et al., 2023). In CA_Markov, the future condition of a cell is predicted on the basis of its previous state, current state and transition rules. The mechanism of CA_Markov can be depicted in terms of a simple mathematical expression as (Ahmed and Ahmed, 2012):

$$S^{t+1} = f(S^t + N)$$

where t and $t+1$ represent specific time periods (years) under consideration, S^t is the condition of a cell at t time (year) that can change into S^{t+1}

by the time (year) *t+1*. Finally, N and *f* represent the state of neighbourhood cells and transition rules, respectively.

The condition of a cell in a given point of time can be derived through the land use map. Therefore, the land use maps of the specific area of interest for the reference years are the most fundamental input data in a CA_Markov model. Furthermore, it is asserted that the growth of urban clusters in the real-world is directed by a large number of factors having complicated associations with each other at national, regional and local scales. Therefore, to a certain degree, it is important to make use of spatial constraints, in order to improve the performance of simulation modelling. Without these spatial constraints, CA_Markov modelling will produce urban growth patterns simply based on previous trends. A diverse range of input data is used in the CA_Markov modelling as spatial constraints, some of which are associated with the physical landscape characteristics like slope, digital elevation etc., whereas a number of input data represent anthropogenic factors like roads, distance to roads and built-up land etc. that influence urban growth (Fig. 2).

Delimitation of Buffers

A 15 km. buffer has been drawn from the central business district of Siliguri city to understand the pattern of urbanisation beyond the statutory boundary of the municipal corporation. However, the boundary of the buffer has been slightly modified from the southern part in order to exclude the portion, falling under the territory of Bangladesh. The size of the buffer has been reduced to 5 km. for both Jalpaiguri and Maynaguri, in order to create conformity with the small size of these urban areas as compared to Siliguri.

CA_Markov Modelling

Once all the input data for the study area have been prepared, the CA_Markov modelling has been ready to run. The TerrSet software has been used to run the model and to monitor the spatial pattern of urban growth in three urban clusters of Siliguri, Jalpaiguri and Maynaguri. The LULC maps of 2001 and 2011 have been used as the main reference maps in the model to simulate the LULC map for the year 2021. Then, the actual LULC map of 2021 and the simulated map of the same year have been compared to validate the model. A two-step validation has been performed. In the first step, the accuracy level of the simulated LULC map of 2021 has been calibrated with K statistics by taking the actual LULC map of 2021 as the reference. The value of the K statistics ranges between 0 and 1, where 0 stands for the absolute dissimilarity between the compared pair of maps and 1 represents the exact opposite condition i.e. absolute similarity between the maps under consideration. Subsequently, a Chi-square Goodness-of-fit test has been performed with the help of the following mathematical expression:

$$X^2 = \sum \frac{(O-E)^2}{E}$$

where X^2 is the calibrated value of the Chi-square statistics, O is the observed frequency (area under each land use category in the simulated LULC map) and E is the expected frequency (area under each land use category in the actual LULC map). Further, the Chi-square test has been performed under the following hypothesises: (i) H_0 is the simulated map and the actual map are significantly similar and (ii) H_1 has no statistically significant similarity between simulated and actual maps. Finally, the model has been tested at 95 per cent level of significance. Once the model

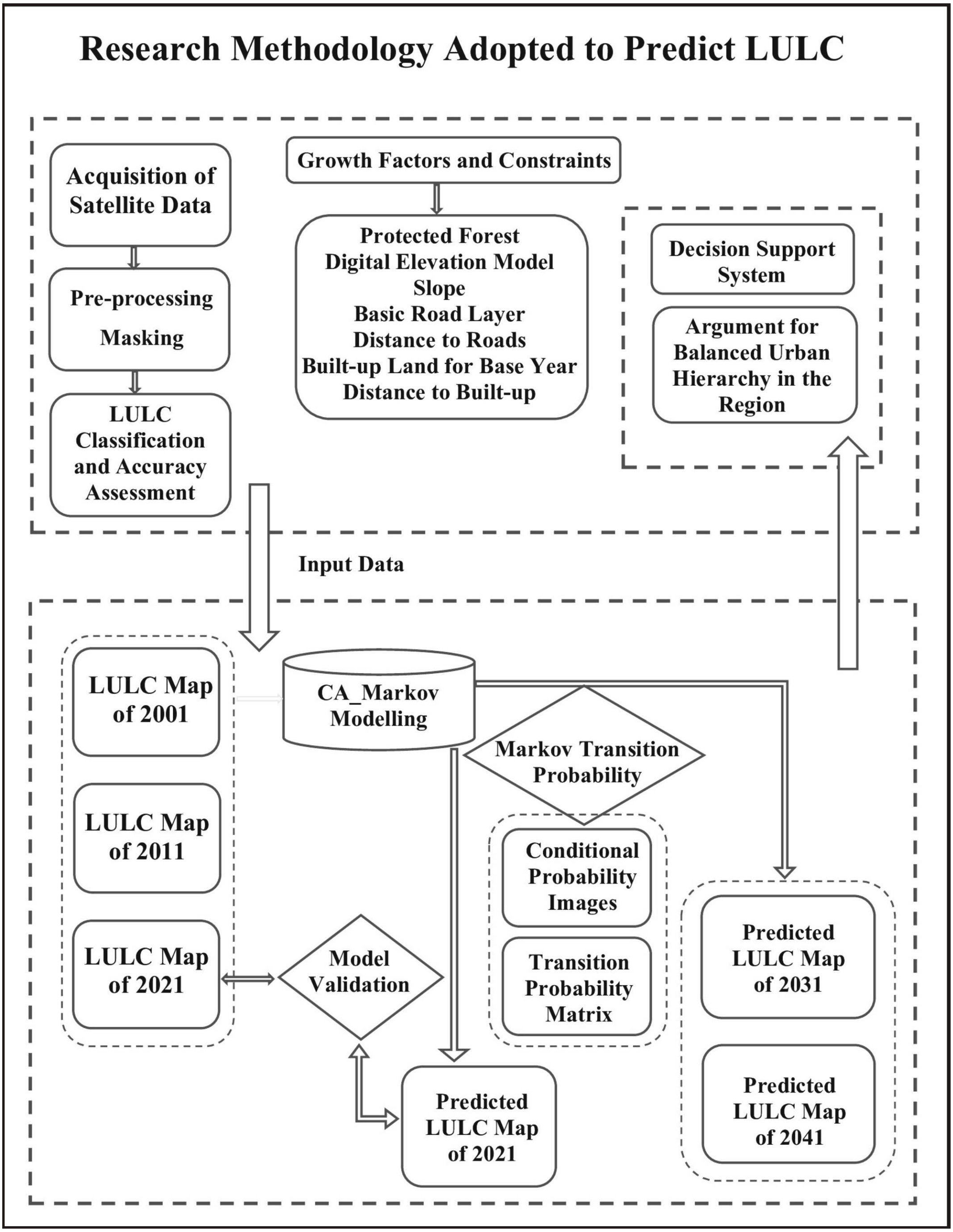
Research Methodology Adopted to Predict LULC
Acquisition of Satellite Data
Pre-processing
Masking
LULC Classification and Accuracy Assessment
Growth Factors and Constraints
Protected Forest
Digital Elevation Model
Slope
Basic Road Layer
Distance to Roads
Built-up Land for Base Year
Distance to Built-up
Decision Support System
Argument for Balanced Urban Hierarchy in the Region
Input Data
LULC Map of 2001
LULC Map of 2011
LULC Map of 2021
CA_Markov Modelling
Markov Transition Probability
Conditional Probability Images
Transition Probability Matrix
Model Validation
Predicted LULC Map of 2021
Predicted LULC Map of 2031
Predicted LULC Map of 2041

Fig. 2

has been successfully validated, the future urban growth prediction has been performed for the years 2031 and 2041, respectively.

Results and Discussion

Model Validation

Validation of the urban growth model is a very essential part of the overall growth prediction endeavour as it indicates the prediction ability and accuracy of the model. As stated earlier, the validation has been performed for the reference year 2021, related to Siliguri, Jalpaiguri and Maynaguri urban areas under consideration. The values of the Kappa coefficient for Siliguri, Jalpaiguri and Maynaguri have been 0.80, 0.87 and 0.85 respectively, which indicate a satisfying ability of the model to predict future urban growth. Furthermore, results of the Chi-square Goodness-of-fit test show that in case of Siliguri, Jalpaiguri and Maynaguri, the computed values of Chi-square statistics are much lesser than the critical value at 95 per cent level of significance (Table 2). Thus, the null hypothesis (H_0) has been accepted and it has been asserted that the actual land use maps for the year 2021 and the simulated maps for the same year are significantly similar.

Urban Growth

In Siliguri urban cluster, a significant and steady surge in built-up land from a mere 32.70 km² in 2001 to a commanding 97.40 km² in 2021 has been recorded, thus registering a growth of nearly 300 per cent within a span of 20 years (Table 3). The simulated maps for 2031 and 2041 also depict similar trends, where nearly 28 per cent and 19 per cent built-up growth in and around the urban cluster of Siliguri have been predicted. Furthermore, it has been found that the major part of urban growth around Siliguri has taken place at the cost of the conversion of agricultural land into built-up area. This thing has also become evident from a sharp declination of area under agricultural land from 328.60 km² in 2001 to 275.60 km² in 2021, which is likely to further decline by 234.00 km² in 2031 and 214.80 km² in 2041.

Thus, the intricate trajectory of urban growth within Siliguri urban agglomeration unveils a compelling narrative of urban expansion and transformation (Fig. 3, 4 and 5). Over this temporal span, the landscape around Siliguri urban cluster has undergone a remarkable metamorphosis, characterised by an apparent transformation of agricultural landscape into a burgeoning urbanised territory (Fig. 6).

As evident from the LULC maps (both the actual and the predicted) the city of Siliguri is growing at an enormous rate towards the western direction. It is attributed to a number of possible factors, like the existence of large market clusters in Matigara and Bagdogra towards the west; the burgeoning real-estate market along the National Highway (NH) 27, non-availability of reserved forest, unlike the northern and eastern peripheries; the location of Bagdogra Airport in Bagdogra and the University of North Bengal. All these factors together, amalgamated with the socio-economic imperatives and demographic dynamics of the city, have contributed to a westward surge in built-up land.

The city of Jalpaiguri, a distant follower of Siliguri in terms of demographic size in SJPA region, is also characterised by a rapid built-up expansion from 2.30 km² in 2001 to a remarkable 9.10 km² in 2021, which is expected to grow by 14.60 km² and 18.30 km² in 2031 and 2041, respectively (Table 3). The

Table 2

Siliguri Jalpaiguri Planning Area: Model Validation by Chi-square Goodness-of-fit Test, 2021

LULC Categories	Area (km²) in the Simulated Map *(O)*	Area (km²) in the Actual Map *(E)*	$(O-E)^2$	$\frac{(O-E)^2}{E}$	Remarks
Siliguri					
Agricultural Land	269.10	275.70	43.56	0.16	$X^2 = \sum \frac{(O-E)^2}{E}$ = 4.56 Degree of Freedom (6-1) = 5. $X^2_{0.05}$ (5) = 11.07 The computed value of Chi-square statistics is lesser than the critical value. Therefore, the null hypothesis is accepted.
Built-up Area	85.20	97.40	148.84	1.53	
Rivers/ Water Bodies	15.80	12.30	12.25	0.99	
Sand Bar	19.90	19.50	0.16	0.01	
Tea Plantation	95.30	98.40	9.61	0.10	
Vegetation Cover	200.60	182.60	324.00	1.77	
Total	**685.90**	**685.90**	-	**4.56**	
Jalpaiguri					
Agricultural Land	32.50	34.90	5.76	0.17	$X^2 = \sum \frac{(O-E)^2}{E}$ = 0.49 Degree of Freedom (6-1) = 5. $X^2_{0.05}$ (5) = 11.07 The computed value of Chi-square statistics is lesser than the critical value. Therefore, the null hypothesis is accepted.
Built-up Area	10.60	9.10	2.25	0.25	
Rivers/ Water Bodies	5.30	4.90	0.16	0.03	
Sand Bar	11.20	11.40	0.04	0.01	
Tea Plantation	5.40	5.10	0.09	0.02	
Vegetation Cover	13.40	13.00	0.16	0.01	
Total	**78.40**	**78.40**	-	**0.49**	
Mayaguri					
Agricultural Land	53.20	54.00	0.64	0.01	$X^2 = \sum \frac{(O-E)^2}{E}$ = 0.85 Degree of Freedom (6-1) = 5. $X^2_{0.05}$ (5) = 11.07 The computed value of Chi-square statistics is lesser than the critical value. Therefore, the null hypothesis is accepted.
Built-up Area	12.30	9.90	5.76	0.58	
Rivers/ Water Bodies	1.30	1.50	0.04	0.03	
Sand Bar	0.40	0.30	0.01	0.03	
Tea Plantation	1.20	1.20	0.00	0.00	
Vegetation Cover	10.00	11.50	2.25	0.20	
Total	**78.40**	**78.40**	-	**0.85**	

Source: Compiled by Authors.

magnitude of built-up growth in and around Jalpaiguri urban cluster is also remarkable despite the small size of the city. This growth, emblematic of an urbanising phenomenon, underscores the proliferation of residential and commercial domains in the city.

However, unlike Siliguri, where the major part of urban growth took place over the

Table 3
Siliguri Jalpaiguri Planning Area: Area under Land Use/ Land Cover Categories, 2001-2041

LULC Categories	Area (km²)				
	2001	2011	2021	2031	2041
Siliguri					
Agricultural Land	328.60	292.50	275.60	234.00	214.90
Built-up Area	32.70	58.50	97.40	124.60	148.60
Rivers/ Water Bodies	18.60	15.90	12.40	15.90	15.80
Sand Bar	21.90	19.90	19.50	19.90	19.90
Tea Plantation	79.30	97.20	98.40	92.80	90.10
Vegetation Cover	204.80	201.90	182.60	198.70	196.60
Total	685.90	685.90	685.90	685.90	685.90
Jalpaiguri					
Agricultural Land	35.50	42.90	34.90	28.20	26.60
Built-up Area	2.30	3.60	9.10	14.60	18.30
Rivers/ Water Bodies	5.80	5.50	4.90	4.90	4.90
Sand Bar	13.80	10.60	11.40	11.40	11.40
Tea Plantation	3.60	4.20	5.10	7.00	6.60
Vegetation Cover	17.40	11.60	13.00	12.30	10.60
Total	78.40	78.40	78.40	78.40	78.40
Maynaguri					
Agricultural Land	55.60	57.60	54.00	50.20	46.90
Built-up Area	2.20	6.40	9.90	15.30	19.60
Rivers/ Water Bodies	3.20	1.50	1.50	1.30	1.20
Sand Bar	5.30	2.60	0.30	0.20	0.20
Tea Plantation	0.30	0.20	1.20	1.30	1.20
Vegetation Cover	11.80	10.10	11.50	10.10	9.30
Total	78.40	78.40	78.40	78.40	78.40

Source: Compiled by Authors.

agricultural land, in Jalpaiguri, urban growth primarily took place over the vegetated tracts, during the initial decade from 2001 to 2011 (Fig. 7, 8 and 9). In the subsequent decade, between 2011 and 2021, the growth of built-up land extended much beyond the vegetated tracts and encompassed agricultural land as well (Fig. 10). Furthermore, the city of Jalpaiguri is expanding at a visible rate towards the northern direction, following the course of NH 27, connecting Jalpaiguri with Siliguri in the west and Maynaguri in the east. From the urban growth trend of the city, it has been evidently clear that the NH 27 is likely to be a decisive factor for the growth of the city in coming years. Additionally, the existence of Jalpaiguri Government Engineering College, Super Speciality Hospital, extended building of Kolkata High Court and the location of several industrial plants along the highway are important factors, governing the growth of the city towards the northern direction.

Maynaguri, the smallest one among all the three selected cities of SJPA region, both in

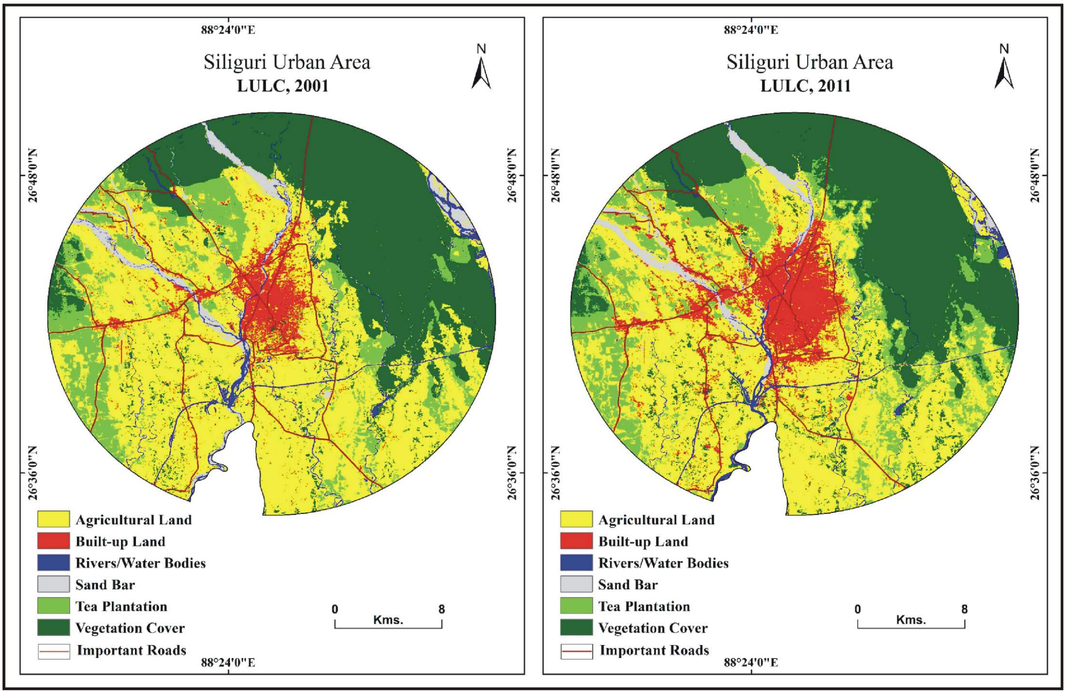
Siliguri Urban Area
LULC, 2001
Siliguri Urban Area
LULC, 2011
N
88°24'0"E
26°48'0"N
26°36'0"N
Agricultural Land
Built-up Land
Rivers/Water Bodies
Sand Bar
Tea Plantation
Vegetation Cover
Important Roads
0 Kms. 8

Fig. 3

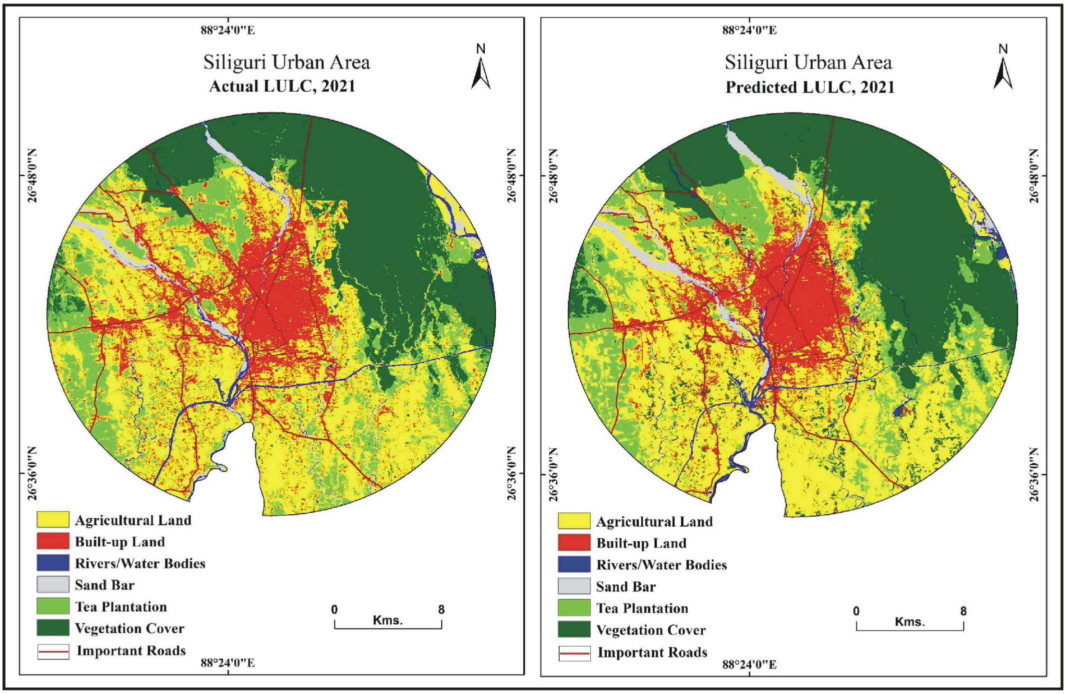
Siliguri Urban Area
Actual LULC, 2021
Siliguri Urban Area
Predicted LULC, 2021
N
88°24'0"E
26°48'0"N
26°36'0"N
Agricultural Land
Built-up Land
Rivers/Water Bodies
Sand Bar
Tea Plantation
Vegetation Cover
Important Roads
0 Kms. 8

Fig. 4

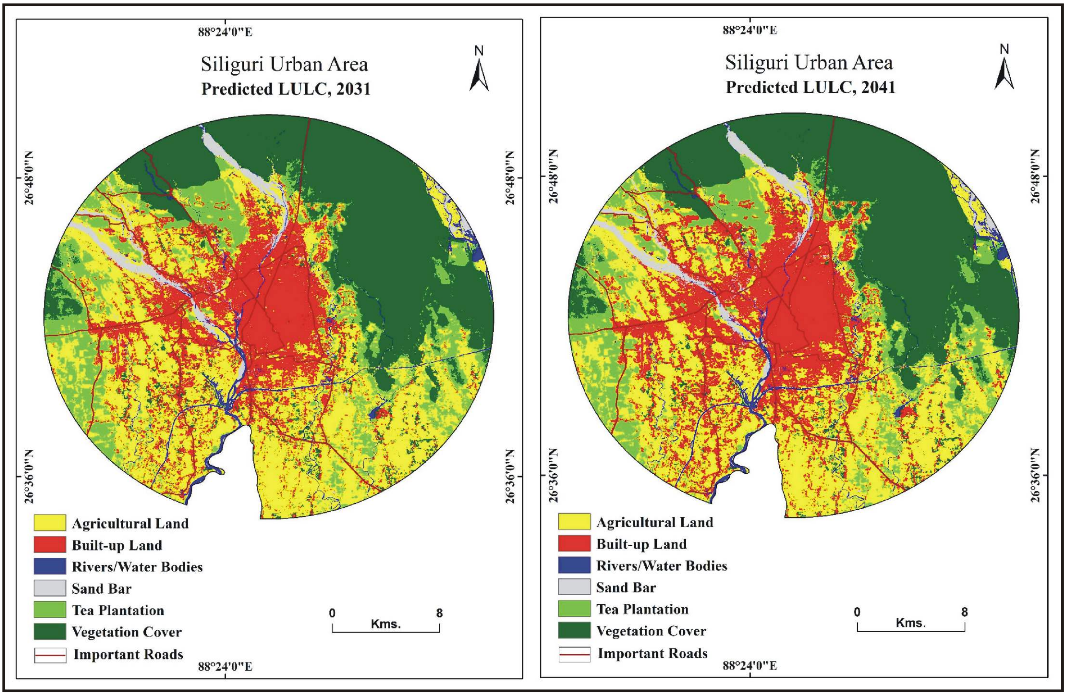
Siliguri Urban Area
Predicted LULC, 2031
Siliguri Urban Area
Predicted LULC, 2041
N
88°24'0"E
26°48'0"N
26°36'0"N
Agricultural Land
Built-up Land
Rivers/Water Bodies
Sand Bar
Tea Plantation
Vegetation Cover
Important Roads
0 Kms. 8

Fig. 5

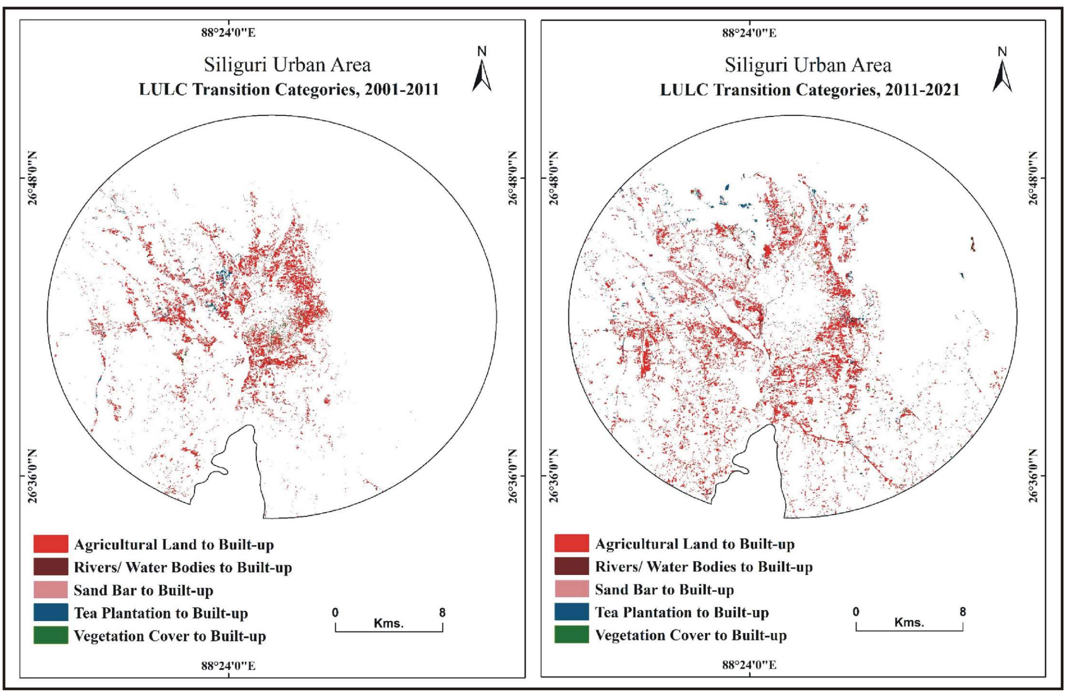
Siliguri Urban Area
LULC Transition Categories, 2001-2011
Siliguri Urban Area
LULC Transition Categories, 2011-2021
N
88°24'0"E
26°48'0"N
26°36'0"N
Agricultural Land to Built-up
Rivers/ Water Bodies to Built-up
Sand Bar to Built-up
Tea Plantation to Built-up
Vegetation Cover to Built-up
0 Kms. 8

Fig. 6

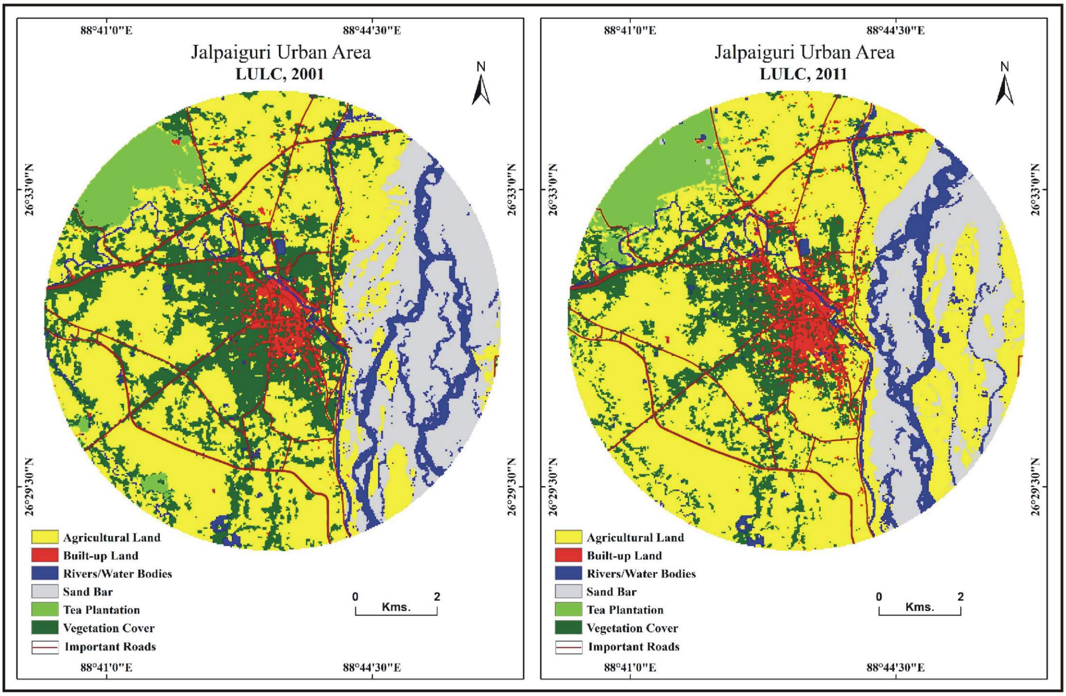
Jalpaiguri Urban Area
LULC, 2001
Jalpaiguri Urban Area
LULC, 2011
N
88°41'0"E
88°44'30"E
26°33'0"N
26°29'30"N
Agricultural Land
Built-up Land
Rivers/Water Bodies
Sand Bar
Tea Plantation
Vegetation Cover
Important Roads
0 Kms. 2

Fig. 7

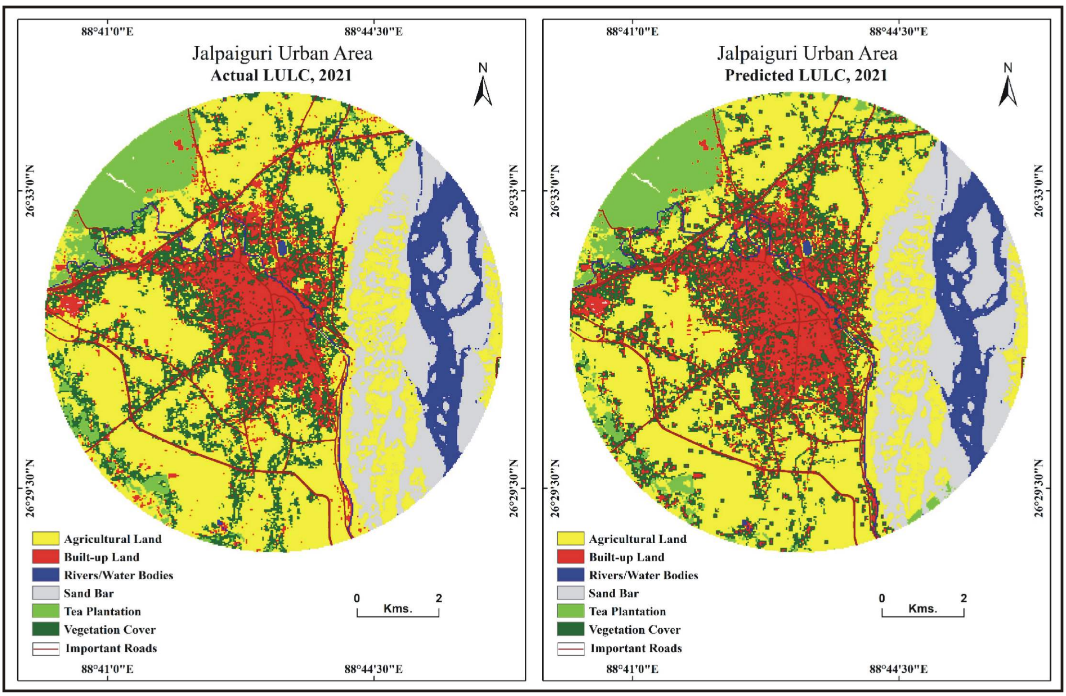
Jalpaiguri Urban Area
Actual LULC, 2021
Jalpaiguri Urban Area
Predicted LULC, 2021
N
88°41'0"E
88°44'30"E
26°33'0"N
26°29'30"N
Agricultural Land
Built-up Land
Rivers/Water Bodies
Sand Bar
Tea Plantation
Vegetation Cover
Important Roads
0 Kms. 2

Fig. 8

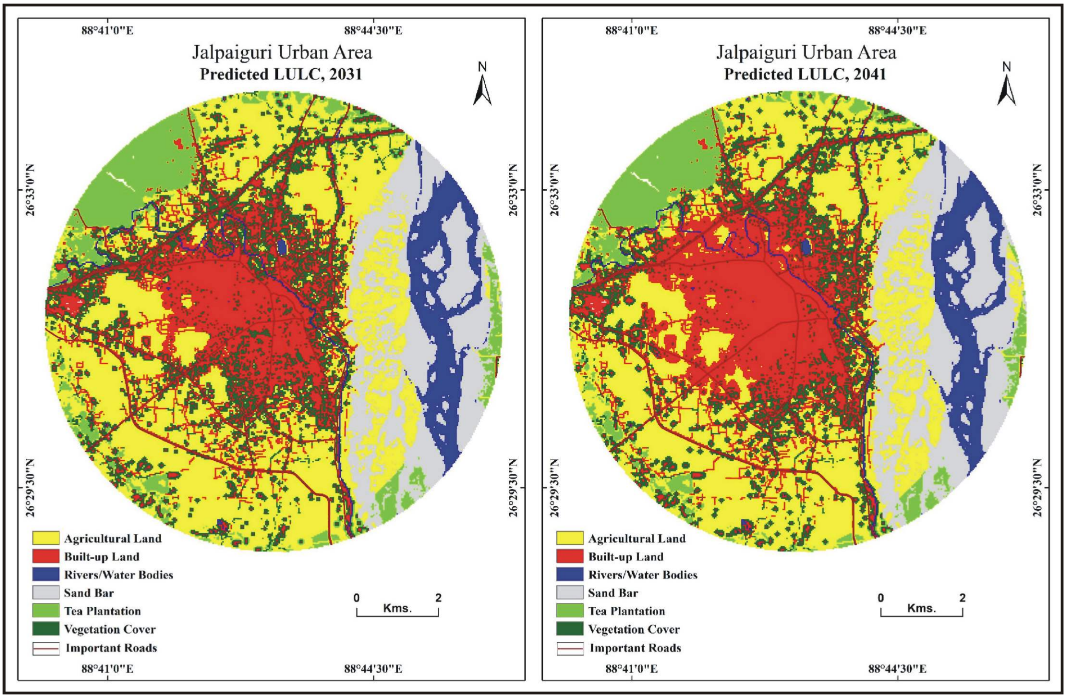
Jalpaiguri Urban Area
Predicted LULC, 2031
Jalpaiguri Urban Area
Predicted LULC, 2041
88°41'0"E
88°44'30"E
26°33'0"N
26°29'30"N
N
Agricultural Land
Built-up Land
Rivers/Water Bodies
Sand Bar
Tea Plantation
Vegetation Cover
Important Roads
0 Kms. 2

Fig. 9

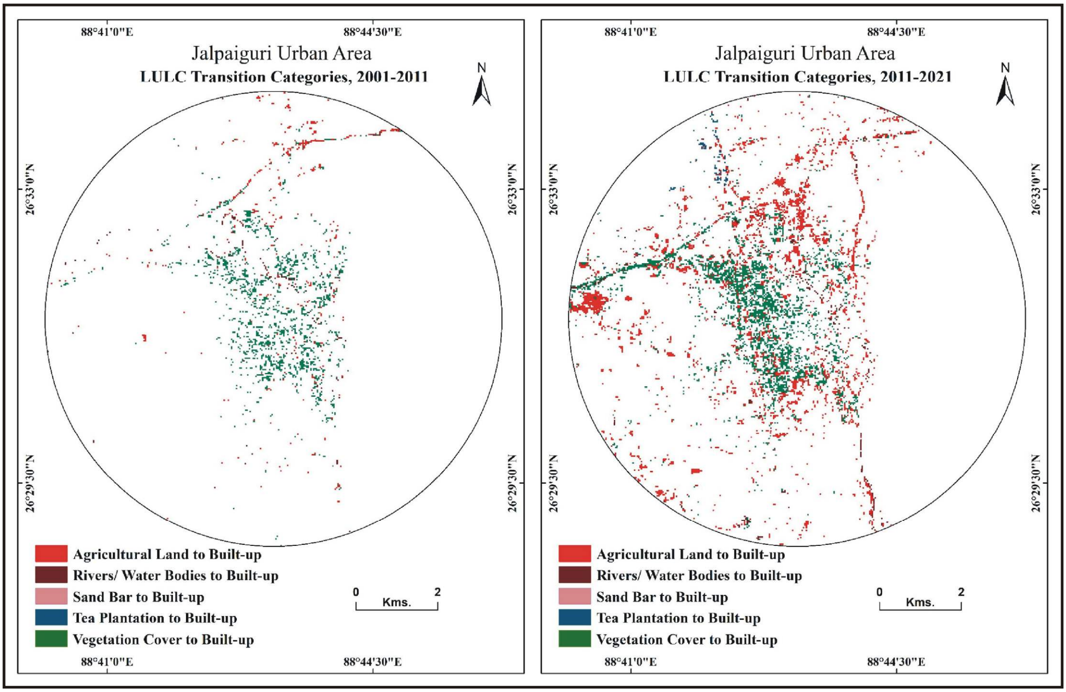
Jalpaiguri Urban Area
LULC Transition Categories, 2001-2011
Jalpaiguri Urban Area
LULC Transition Categories, 2011-2021
88°41'0"E
88°44'30"E
26°33'0"N
26°29'30"N
N
Agricultural Land to Built-up
Rivers/ Water Bodies to Built-up
Sand Bar to Built-up
Tea Plantation to Built-up
Vegetation Cover to Built-up
0 Kms. 2

Fig. 10

terms of area and population size, has a very typical pattern of urbanisation that is highly dissimilar from that in Jalpaiguri. In Maynaguri, major built-up growth took place outside the municipal limits, mostly along the NH 27 towards the west and south-east, NH 17 towards the south, as well as along the New Jalpaiguri-New Alipurduar-Guwahati railway route towards the north. The new Maynaguri railway station, located on that line, has been an important growth nucleus, guiding the expansion of the city towards the northern direction. The villages around Maynaguri, mostly situated along the NH 27 and NH 17 are also expected to grow at a faster rate. In 2001, the urban area of Maynaguri encompassed around 2.20 km^2 of land, which has increased by 9.90 km^2 in 2021 (Table 3).

Looking ahead towards the year 2041, simulated results indicate a significant expansion in built-up area in and around Maynaguri (Fig. 11, 12, and 13), with an anticipated increase of 15.30 km^2 in 2031 and 19.60 km^2 in 2041. With regard to the land conversion scenario, the urban area of Maynaguri shows marked similarities with Jalpaiguri. Between 2001-2011 vegetation cover contributed more to the expansion of built-up land, whereas in the decade that followed, built-up growth has principally taken place over the agricultural tracts (Fig. 14). This transition in land utilisation underscores the intricate dynamics of urban growth and the ever-increasing demands posed on both natural ecosystems and agricultural resources in the locality during the timeframe under consideration.

Urban Growth and Balanced Regional Development in SJPA

It has become evident from the preceding discussion that the urban clusters of Siliguri, Jalpaiguri and Maynaguri hold the position of prominence in the planning region of SJPA. However, among all these urban centres, Siliguri undoubtedly assumes the role of the most important city, followed in stature and spatio-demographic scale, by Jalpaiguri and Maynaguri, respectively. Nonetheless, the trajectory of Siliguri's unparalleled urbanisation raises apposite concerns with regard to the possible emergence of imbalanced polarisation at regional scale and the accompanying biases in infrastructural development. Siliguri, being a demographic and commercial magnet in the region has experienced burgeoning growth in service sector over the last three decades, attracting a visible influx of migrant population not only from different parts of India and West Bengal, but also from the neighbouring countries of Bangladesh and Nepal. However, such a growth of Siliguri carries with it the potential risks of over-concentration of economic opportunities and a skewed agglomeration of infrastructural facilities, likely to cause intra-urban as well as rural-urban disparities by aggravating socio-economic inequalities. This has been a perpetual problem at the state level in West Bengal, where the extraordinarily imbalanced regional development pattern has emerged due to the Kolkata-centricism of the state. Appearance of the same problem at regional scale in SJPA will defy the very objective of formulating a planning region, where one can expect a planned development and judicious allocation of infrastructural facilities. Siliguri's association with some eco-sensitive zones, like Baikunthapur forest, Mahananda Wildlife Sanctuary and others, further makes the concern more acute.

In order to confront these challenges

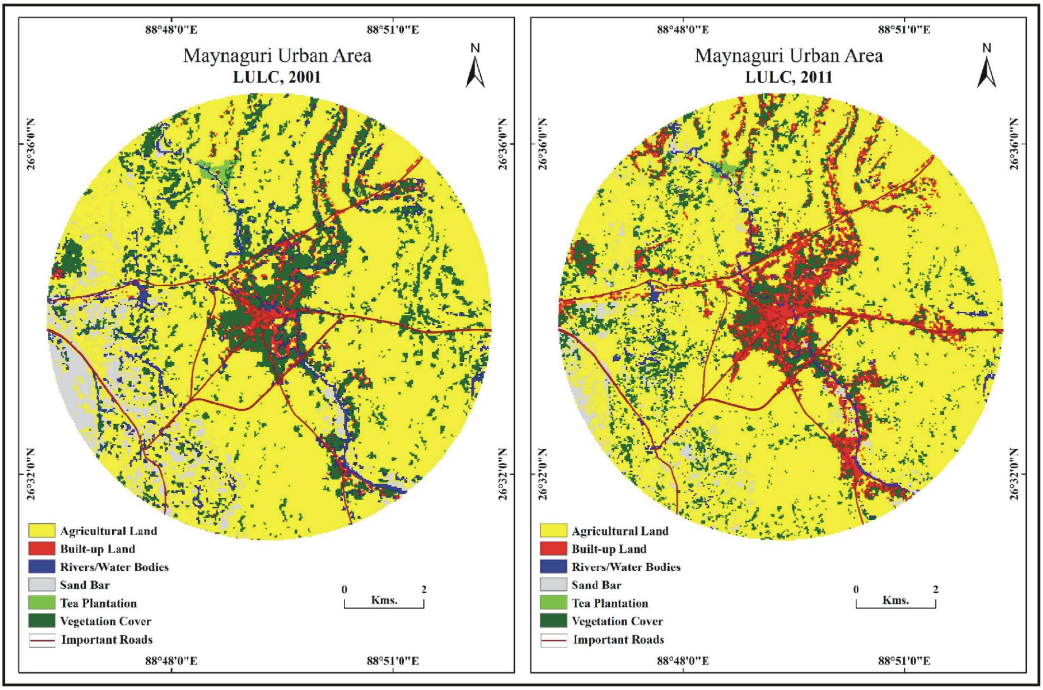
88°48'0"E
88°51'0"E
Maynaguri Urban Area
LULC, 2001
N
26°36'0"N
26°32'0"N
Agricultural Land
Built-up Land
Rivers/Water Bodies
Sand Bar
Tea Plantation
Vegetation Cover
Important Roads
0 Kms. 2
88°48'0"E
88°51'0"E
Maynaguri Urban Area
LULC, 2011
N
26°36'0"N
26°32'0"N
Agricultural Land
Built-up Land
Rivers/Water Bodies
Sand Bar
Tea Plantation
Vegetation Cover
Important Roads
0 Kms. 2

Fig. 11

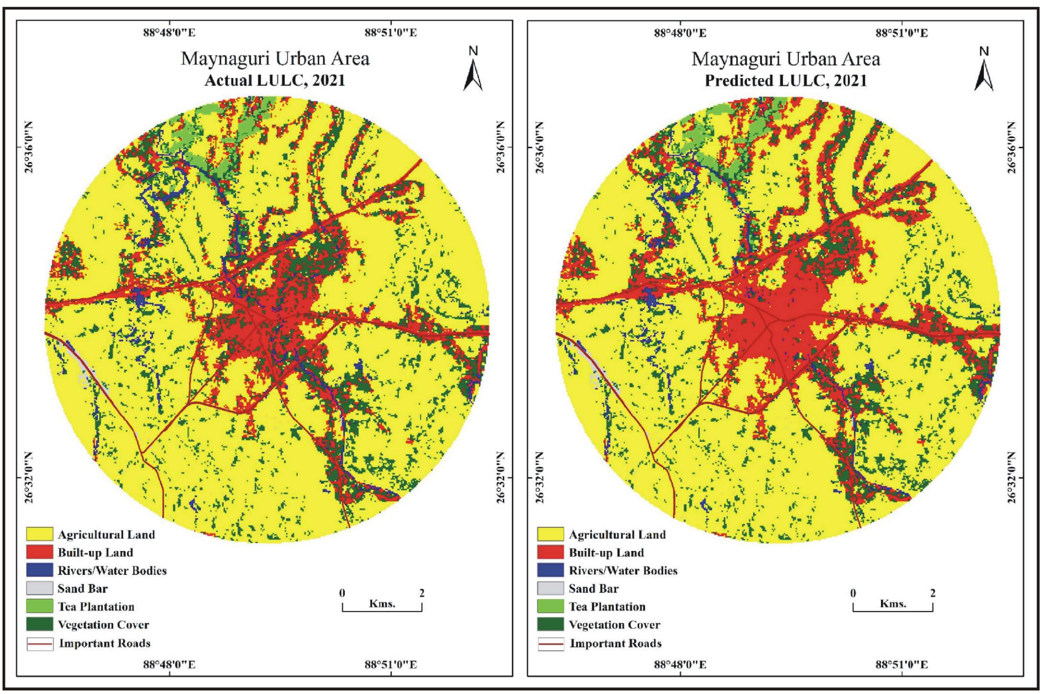
88°48'0"E
88°51'0"E
Maynaguri Urban Area
Actual LULC, 2021
N
26°36'0"N
26°32'0"N
Agricultural Land
Built-up Land
Rivers/Water Bodies
Sand Bar
Tea Plantation
Vegetation Cover
Important Roads
0 Kms. 2
88°48'0"E
88°51'0"E
Maynaguri Urban Area
Predicted LULC, 2021
N
26°36'0"N
26°32'0"N
Agricultural Land
Built-up Land
Rivers/Water Bodies
Sand Bar
Tea Plantation
Vegetation Cover
Important Roads
0 Kms. 2

Fig. 12

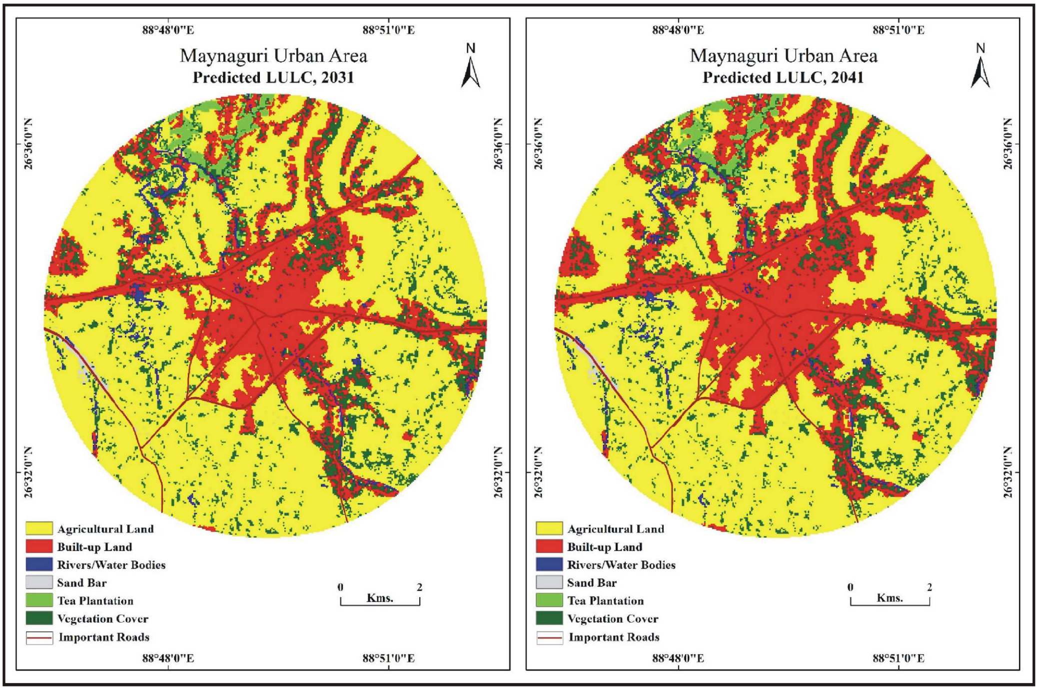
88°48'0"E
88°51'0"E
Maynaguri Urban Area
Predicted LULC, 2031
N
26°36'0"N
26°32'0"N
Agricultural Land
Built-up Land
Rivers/Water Bodies
Sand Bar
Tea Plantation
Vegetation Cover
Important Roads
0 Kms. 2
Maynaguri Urban Area
Predicted LULC, 2041

Fig. 13

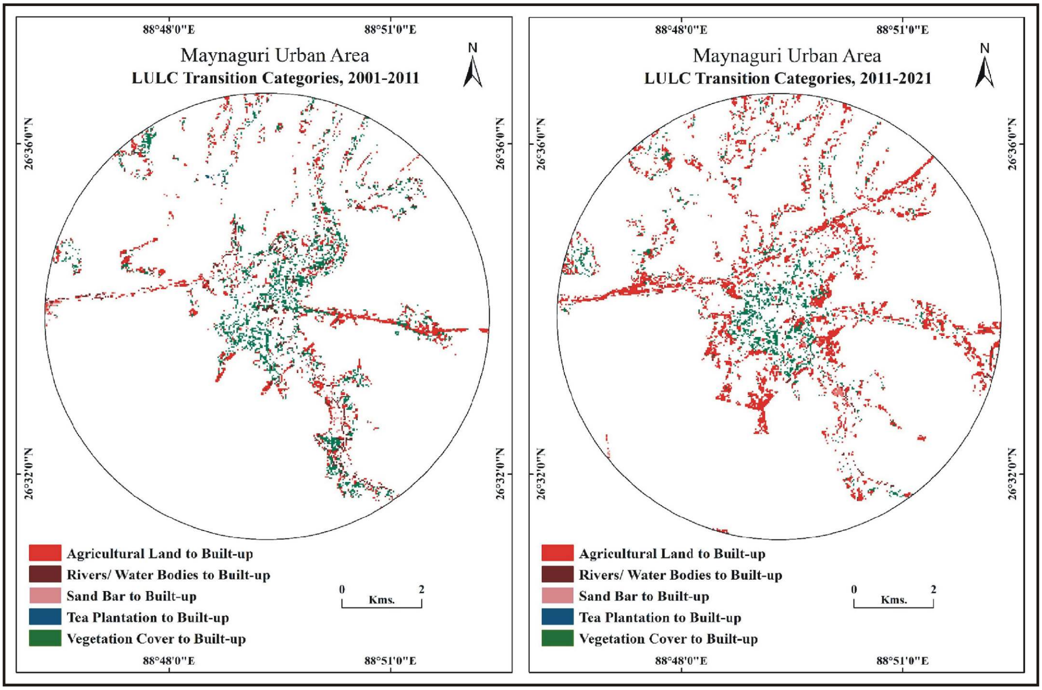
88°48'0"E
88°51'0"E
Maynaguri Urban Area
LULC Transition Categories, 2001-2011
N
26°36'0"N
26°32'0"N
Agricultural Land to Built-up
Rivers/ Water Bodies to Built-up
Sand Bar to Built-up
Tea Plantation to Built-up
Vegetation Cover to Built-up
0 Kms. 2
Maynaguri Urban Area
LULC Transition Categories, 2011-2021

Fig. 14

through proper planning mechanisms, and ensure an equitable and resilient urban growth trajectory for the region, it is utterly essential to address strategic urban planning that can bring up a balanced hierarchy among urban places in the region. Furthermore, the already existing robust transport connectivity among Siliguri, Jalpaiguri, Maynaguri and other urban clusters of the region, is an essential ground over which the notion of balanced regional development can be established. This is evident that all of the three cities under study are showing an enormous tendency to grow towards and along the existing regional transportation networks. The role of rail and road transportation systems in advancing a balanced network of settlements in the region needs to be acknowledged by the statutory policies. The potentials of both rail and road-based transit-orientated development (TOD) as a regional planning tool is worth emphasising in this regard (Banerjee and Saha, 2023). The TOD is potent enough to not only drive the future growth of existing urban bodies from default to design, but also can lead for a polycentric development in the region. Additionally, the study also suggests for planned decentralisation of infrastructural facilities in smaller urban clusters, instead of over-concentrating them in and around Siliguri urban agglomeration. Besides, it is necessary to look at the existing built-up growth trajectory of urban places in order to foster a balanced urban hierarchy in the planning region (SJPA). It is also important of focus upon the axial growth pattern of urban bodies along transportation networks and their intersection with the system of other land uses, especially forested and agricultural tracts. This will help to address the problem of unplanned land use conversion and hence, drive the future built-up growth towards sustainability and resilience.

Conclusions

The study has initiated a comprehensive investigation into the dynamic phenomenon of urban growth in and around three urban bodies of Siliguri, Jalpaiguri and Maynaguri, by employing a CA_Markov modelling technique. These urban bodies are parts of Siliguri Jalpaiguri Planning Area (SJPA) of West Bengal. It is discerned by the study that the urban areas under consideration have experienced conspicuous expansion in built-up land since the last two decades and this trend of profound urban expansion is going to perpetuate over the next two decades. The results also indicate that increase in built-up land surrounding three municipal bodies has been accompanied with a fast declination in agricultural and forested land. The findings further suggest that Siliguri will experience the highest absolute built-up expansion from 97.40 km² in 2021 to a potential 124.60 km² in 2031 and 148.60 km² in 2041. Such a growth in built-up area is driven by its prominent urban dynamics. The built-up area in and around Jalpaiguri is expected to increase from 9.10 km² in 2021 to a potential 14.60 km² in 2031 and 18.30 km² in 2041. In Maynaguri during the same span of time the built-up area is expected to increase from 9.90 km² to 15.30 km² and 19.60 km², respectively. This trend points towards haphazard growth of built-up area around these urban bodies at the cost of land under agriculture or other uses. Addressing these issues by planning institutions will be crucial for having a sustainable urban development in SJPA region and avoiding future complications on land use dynamics. Strategic interventions are needed to guide this growth in a more organised and sustainable direction. Therefore, the outcomes of this study are expected to facilitate the formulation, and judicious implementation of urban and regional planning endeavours resulting sustainable urban development in SJPA planning region of West Bengal.

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