



Predicting the land use and land cover change using Markov model: A catchment level analysis of the Bhagirathi-Hugli River

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Abstract Land use and land cover are important biophysical factors which have a major role in different terrestrial processes on the earth. Land use and land cover change are a vital element of global environmental change. It is very essential for regional development and land use management towards sustainable development. The different time's period satellite images in the study area have been studied to understand temporal as well as the spatial variability of land use and land cover (LULC) change. In this, an attempt was made to adopt the Markov model for obtaining and investigating the dynamics of land use change. Markov model was used as a stochastic model to make quantitative comparisons of the land-use changes between time periods extending from 2001 to 2010. Model performance was evaluated between the empirical LULC map obtained extracted from Landsat 8 (2017) image and the simulated LULC map obtained from the Markov model. The future land use distribution in the year 2019 and 2028 was acquired using a Markov model. This result shows that the Markov model and geospatial technology together are able to effectively capture the spatiotemporal trend in the landscape pattern in this study area.

Keywords LULC · Maximum likelihood · Kappa statistics · Markov model · Transition matrix · Validation

1 Introduction

Land cover and land use are distinct but closely linked characteristics of the earth's surface. Crops, natural vegetation, grasslands, roads, and buildings are categories of cover, as are soil, ice, and water; agriculture, logging, grazing, and urban development are land uses. Changes in land cover wielded by land use that can be divided into two types: *modification* and *conversion*. The *modification* is a change of condition within a cover type. The *conversion* is a change from one cover type to another [1]. Man is a great modifier of landforms and among them, the fluvial system is the most vulnerable one. Man uses land according to his own choice or necessity within some given chances. Since the beginning of the human civilization, man wants to live along the river because of the easy access of the livelihood and they are using land, depending on its natural factors which include geological structure, nature of landform, drainage system (river, rake etc.) climate, soil types, natural vegetation, groundwater etc. Even the evolution of human culture also depends on prevailing land cover-land use systems. With the passage of time, human started modifying the land cover and land use on the basis of social factors (food habit, demand, religious purpose etc.), economic condition (advantages of irrigation, electricity, transport, the supply of labours, capital etc.) and are ignoring the natural phenomena. The surface of the earth is undergoing rapid land-use/land-cover changes due to various socioeconomic activities and natural phenomena [2]. These integrated changes are hampering the river health [3] and leading flood, bank erosion etc. Even the expanding urbanizations are reducing natural vegetation and have severe impacts on riverine ecosystem and in the quality of water [4]. Changes in land cover and land-use can alter the runoff regime, the pattern of sediment supply of many

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rivers [5] and can also increase the sensitivity of catchment to climatic events [6]. However, many shifting land use patterns driven by a variety of social causes, result in land cover changes that affect biodiversity, water and radiation budgets, trace gas emissions and other processes that come together to affect climate and biosphere [1].

Models of landscape change are important tools for understanding the forces that form landscapes. One inspiration for modeling is to examine the implications of extrapolating short-term landscape dynamics over the longer term. Now a days, with the enhancement of more advanced remote sensing and GIS technology, geo-analysis models, monitoring the status and dynamic change of LU/LC have become one of the most rapid, credible and effectual methods [7–9]. The research methods of land use dynamic change in previous papers included a land use the dynamic index, transfer matrix, and driving force analysis [10, 11] and integrated dynamic degree of land use [12] Markov model has been widely used in the analysis of LU/LC and dynamic changes and future predictions of land use change [9, 13–16].

Throughout the world, all the major rivers are under great threat due to rapid land cover and land use changes and the Bhagirathi-Hugli River is not an exception. Three rivers of moribund deltaic Bengal, Bhagirathi, Mathabanga, and Jalangi came to be known as Nadia Rivers [17–19]. The Bhagirathi-Hugli River is the prime river of Nadia district which forms the boundary between Nadia and Purba Bardhaman districts and is considered as the lifeline [20] of Nadia and Purba Bardhaman districts as well as West Bengal. The Bhagirathi-Hugli River is one of the major distributaries of the Ganga River. After originating from the Ganga River near Mithipur in Murshidabad, it is flowing through the districts of Murshidabad, Nadia, Purba Bardhaman, Hugli, Howrah, Medinipur and finally falls in the Bay of Bengal. The Bhagirathi is commonly known as Hugli from the confluence of the river Jalangi at Swarupganj in Nabadwip towards downstream.

For the present research part of the Bhagirathi-Hugli River catchment, located within the Nadia and Purba Bardhaman districts of West Bengal is taken into consideration. Along the selected study area both rural and urban types of land cover and land use have been found. This particular area is experiencing the characteristics of both rural and urban and possessing a great diversity of land-use and land cover including agriculture, vegetation, industry, residential and transportation and fisheries etc. Here most of the changes occurred randomly. But with the increasing population pressure, men are creating several nuisances which degrading the natural system of the river and unplanned and unscientific uses of land create erosion, sedimentation, and thereby decreasing the depth of the river. In every monsoon season, this particular study area is

being inundated by flood water and experience bank erosion, channel shifting of the river.

This study has taken to analyse the dynamic changes in land use and land cover from 2001 to 2010 along the Bhagirathi-Hugli river catchment within the study area and predict the future LULC change in the area in 2019 and 2028 along the Bhagirathi-Hugli river catchment within the study area using the Markov model. An attempt was also made to obtain simulated LULC for the year 2017 and validated of it.

2 Materials and methodology

2.1 Study area

The selected course of the Bhagirathi-Hugli River is forming the district boundary between Nadia and Purba Bardhaman Districts. This particular watershed area is located in the heart of the Bengal Delta [21]. The latitudinal and longitudinal extension of the study area lies between 23°12'08.20" N to 23°46'11.88" N and 88°05'05.44" E to 88°29'43.50" E. Its area is 955.45 Sq. km (Fig. 1). This area is an alluvial formation of the rivers belonging to the Ganga- Hugli river system. From the SRTM DEM, it is found that the maximum elevation of the study area of Bhagirathi-Hugli river basin about 33 m, located in the north and north-western part where a minimum elevation of 3 m is noticed along the river course as well as in the south and south-eastern part of the study area (Fig. 2). The Nadia District is located on the eastern bank and the Purba Bardhaman District is on the western bank of the river. The Bhagirathi is commonly known as Hugli from the confluence of the river Jalangi towards downstream. Within the study area, the Bhagirathi-Hugli River is having a length of about 122.4 km.

2.2 Materials

Landsat TM, ETM + satellite data are used in this study those have been download from USGS Erath Explorer website (Table 1). 1972–1973 SOI topographical maps of 1:50,000 scale and Google maps are also used for study area boundary map.

2.3 Methodology

2.3.1 Pre-processing of satellite image

Pre-processing of satellite image is an important procedure before going to be the best analysis image classification. Atmospheric correction is performed over all the images using dark object subtraction (DOS) method using the

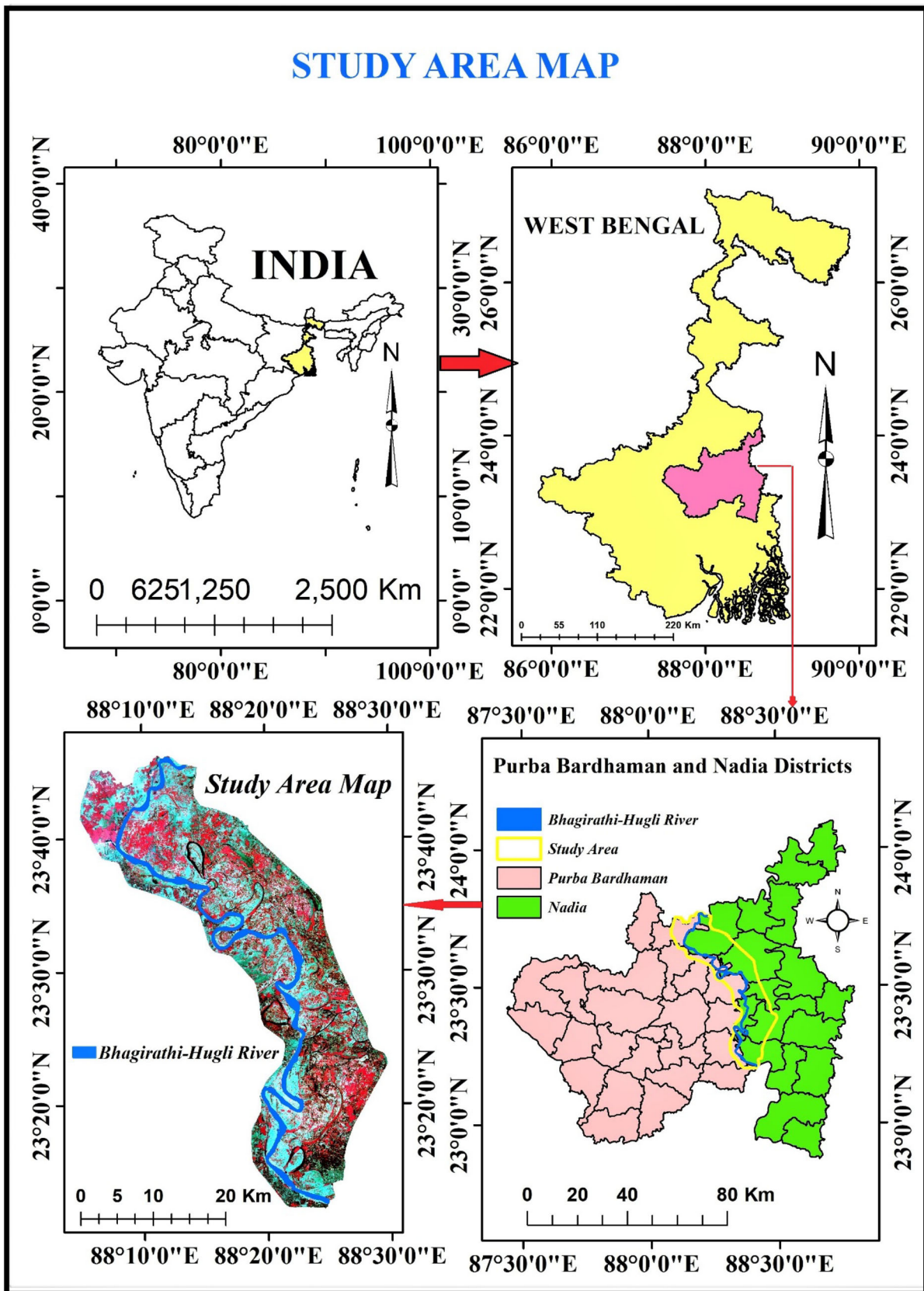


Fig. 1 Location map of the study area

Fig. 2 DEM of the study area

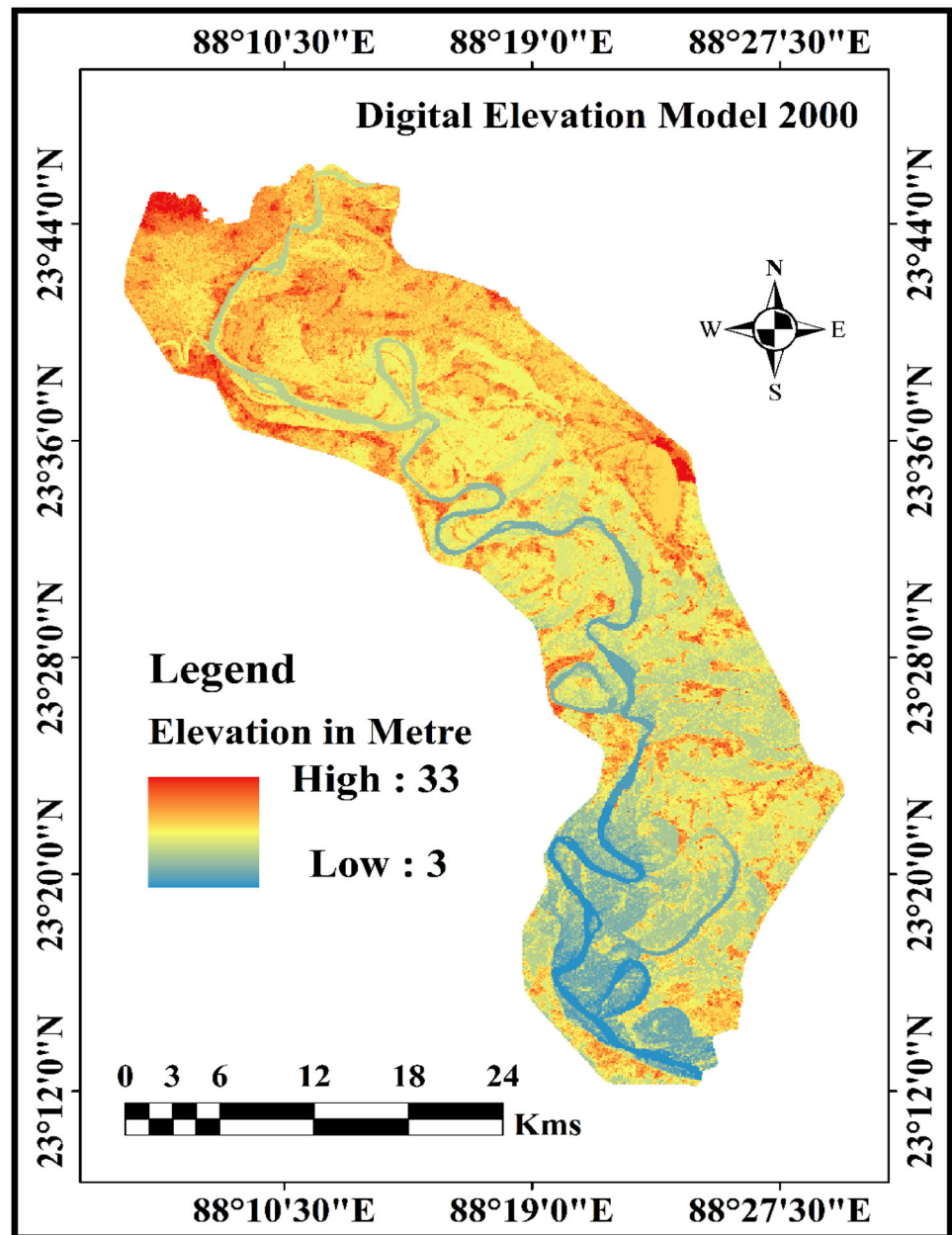


Table 1 Data used for the study and analysis

Reference system (path and row)	Satellite/sensor	Date of image	Spatial resolution/scale	Band numbers used
	SOI topographical map	1972–1973	1:50,000	
WRS_138 & 44	Landsat_7/ETM+	26.04.2001	30 m	1, 2, 3, 5
WRS_138 & 44	Landsat_5/TM	11.04.2010	30 m	1, 2, 3, 5
WRS_138 & 44	Landsat_8/OLI_TIRS	14.04.2017	30 m	2, 3, 4, 5
	SRTM DEM	11.02.2000	90 m	

Spatial data source: *USGS & SOI*

Semi-Automatic Classification Plugin (SCP) in QGIS 2.18.14. DOS is the methodology adopted over other methods because of its simplicity and good result. After

atmospheric correction, all the images are sub-sampled as per the demarcated study area boundary prepared on the Survey of India toposheet of 1972–1973.

2.3.2 Image classification

Maximum likelihood classifier scheme (MLS) with decision rule was used for supervised classification for land use and land cover classification (LULCC) in Erdas Imagine 2014. Maximum likelihood classification is widely used to detect the land cover classes. The supervised classification method is carried out using training areas and test data for accuracy assessment [2, 22]. Based on the field verification and necessary correction (Recode) were made. After classification of satellite images were prepared to land use and land cover (LULC) map. In this study, five land use and land cover classes were established as water bodies, agricultural land, agricultural fallow land, vegetation, and built-up areas. Delineation of these land use-land cover classes is presented in Table 2.

2.3.3 Accuracy assessment

Accuracy assessment is an important part of studying image classification and land use-land cover classification (LULCC) detection in order to understand and estimate the change accurately [2, 22, 23]. Accuracy assessment of the classified images was done by Erdas Imagine 2014. It had been referenced with processed satellite images (FCC images), field verification and Google Earth map respectively. Overall accuracy, Kappa statistics, User’s and Producer’s accuracies were acquired from the error matrices that represents the permission obtained after removing the symmetry of agreement that could be expected to occur by chance. The methodology of this research work is shown in the Fig. 3.

2.4 Markov model of LULC change

Models of landscape change are essential tools for understanding the forces that shape landscapes. Markov model is a convenient tool for simulating LULC change when changes and processes in the landscape are difficult to describe. A Markov process is one in which the future state of a system can be simulated purely on the basis of the immediately preceding state. Markov model will describe LULC change from one period to another and use this as the basis to project future changes [9].

A first-order Markov model comprises that to predict the state of the system at time $t + 1$, one need only know the state of the system at time t . The heart of a Markov model is the transition matrix P , which summarizes the probability that a cell in cover type i will change to cover type j during a single time step. The time step is the interval over which the data were observed to change (i.e., the time interval of the two maps). Markov models, while simple, have a number of appealing properties. In particular, they can be solved by iteration to project the state of the system. Writing the state of the system as a vector,

$$x_t = [x_1 \ x_2 \ x_3 \ \dots] \tag{1}$$

where x_i is the proportion of cells in type i at time t , a Markov model is projected:

$$x_{t+1} = x_t P \tag{2}$$

that is, the state vector post-multiplied by the transition matrix. The next projection for time $t + 2$ is continued:

$$x_{t+2} = x_{t+1} P = x_t P P = x_t P^2 \tag{3}$$

and in general, the state of the system at time $t = t + k$ is given by:

$$x_{t+k} = x_t P^k \tag{4}$$

where x_t is the primary condition of the map. Thus, the model can be projected into the future simply by iterating through the matrix operation [24].

2.4.1 Transition probability matrix

The transition probability is the probability of transitioning from one state to another state. It may be calculated through the annual average transition rate of a particular LULC class. The transition probability matrix has made based on landscape change from 2001 to 2010. The transition probability of a particular LULC class in 2001 converted into the same LULC class in 2010 was calculated in the following:

- (a) Divide each of the off-diagonal elements p_{ij} , $i \neq j$, by 9 (years in the data record)
- (b) Adjust the diagonal elements p_{ii} , to be $1.0 - \sum_j p_{ij}$. In other words, all rows must sum to 1.0. The matrix

Table 2 The land use-land cover classification scheme

LULC classes	Description
Water bodies	River, wetland/beel, pond, lake
Agricultural land	Areas with crops, cultivated agricultural land
Agricultural fallow land	Areas with no vegetation cover, uncultivated agricultural land, sand areas
Vegetation	Forest, trees
Built-up area	Residential, commercial, industrial, transportation infrastructures

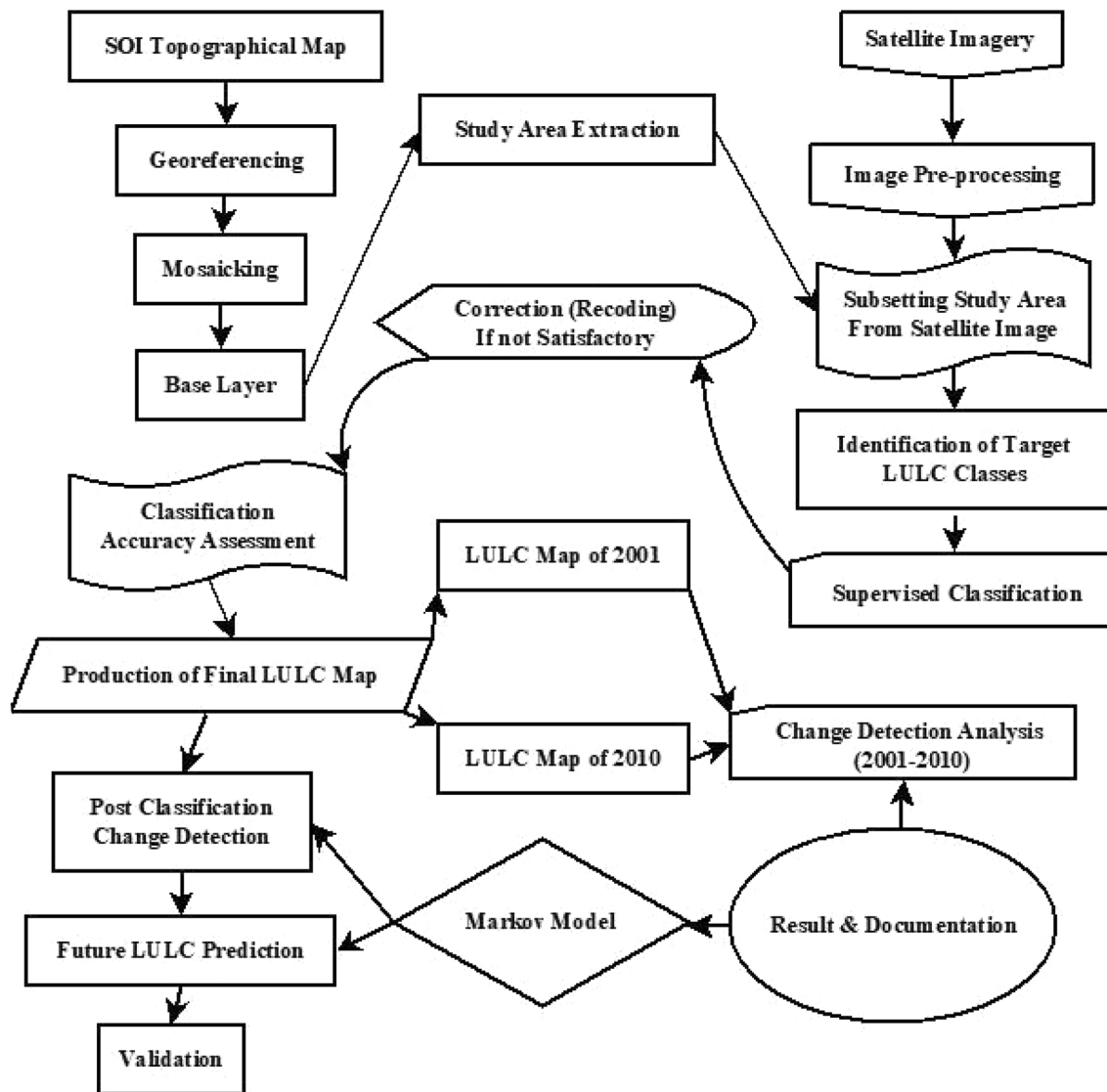


Fig. 3 The methodology adopted in this work

P is a complete description of the transfers in proportions of LULC classes over that time period.

The transition probability matrix P have constructed a simple model of landscape change by MOLUSCE in QGIS software 2.18.18. The 2001(time period) data has used as initial condition for the model and the data 2010 (second time period) data has used as a final condition (Table 3). The third time period (2017) has used to validate the model.

2.4.2 Future prediction in LULC change

Markov model is used to project in the trend of LULC types for one or more time steps. Equation (4) was used to find the change in the trend of LULC types in successive years. The MMULT function in EXCEL calculates the

matrix product of two arrays. The format of the function is MMULT (array1, array2). Where array1 and array2 are arrays of numerical values, representing matrices, where the number of columns in array1 is equal to the number of rows in array2. Using the function MMULT in EXCEL, through multi-step operation, the transition probability matrix P_{ij} was obtained and was thus used to simulate the changes for the future [9].

2.4.3 Validation of the Markov model

Validation of the model is an important part of the Markov model. It consists of the testing model against data that are not used to construct the model. For this, the LULC modeling is incomplete without validating the model with actual data. So, the simulated LULC areas need to be

Table 3 Transition probability matrix of LULC classes between 2001 and 2010

LULC classes	2010					Total
	Built up areas	Vegetation	Water bodies	Agricultural land	Agricultural fallow land	
2001						
Built up areas	0.30	0.21	0.01	0.09	0.38	1.00
Vegetation	0.04	0.64	0.01	0.13	0.18	1.00
Water bodies	0.01	0.03	0.69	0.06	0.21	1.00
Agricultural land	0.02	0.20	0.01	0.42	0.35	1.00
Agricultural fallow land	0.03	0.12	0.02	0.21	0.62	1.00

*Figures indicate the proportions of LULC classes

compared with actual areas interpreted from 2017 satellite image and result tested with actual values using Chi square test (χ^2 test) in order to ensure suitability of the model. The Chi square test (χ^2 test) is calculated by the following formula:

$$\chi^2 = \sum (O - E)^2 / E$$

where χ^2 is the Chi square test, O is simulated value, and E is actual value.

3 Result and discussion

3.1 Land use/land cover classification

Land use-land cover change is not uniform along the river Bhagirathi-Hugli between Nadia and Purba Bardhaman Districts. In the study area, five land use-land cover classes have been classified as built-up areas, vegetation, water bodies, agricultural land, and agricultural fallow land. The findings of land use-land cover classes are presented in Table 4. Areas of land use-land cover (LULC) varied from different years. It has shown that vegetation (8.21%), agricultural fallow land (3.12%) and built-up area (0.33%) have gradually increased but agricultural land (10.95%) and water bodies (0.71%) have decreased in the year 2001–2010 of Landsat data (LULCC) within the study area

(Table 4). It is observing that in the year 2001–2010, agricultural land (10.95%) and water bodies (0.71%) have converted into vegetation (8.21%), agricultural fallow land (3.12%) and built-up area (0.33%). Figures 4, 5, and 6 illustrate the classified LULC maps for the satellite images of the year 2001 and 2010 respectively.

3.1.1 LULC change detection analysis

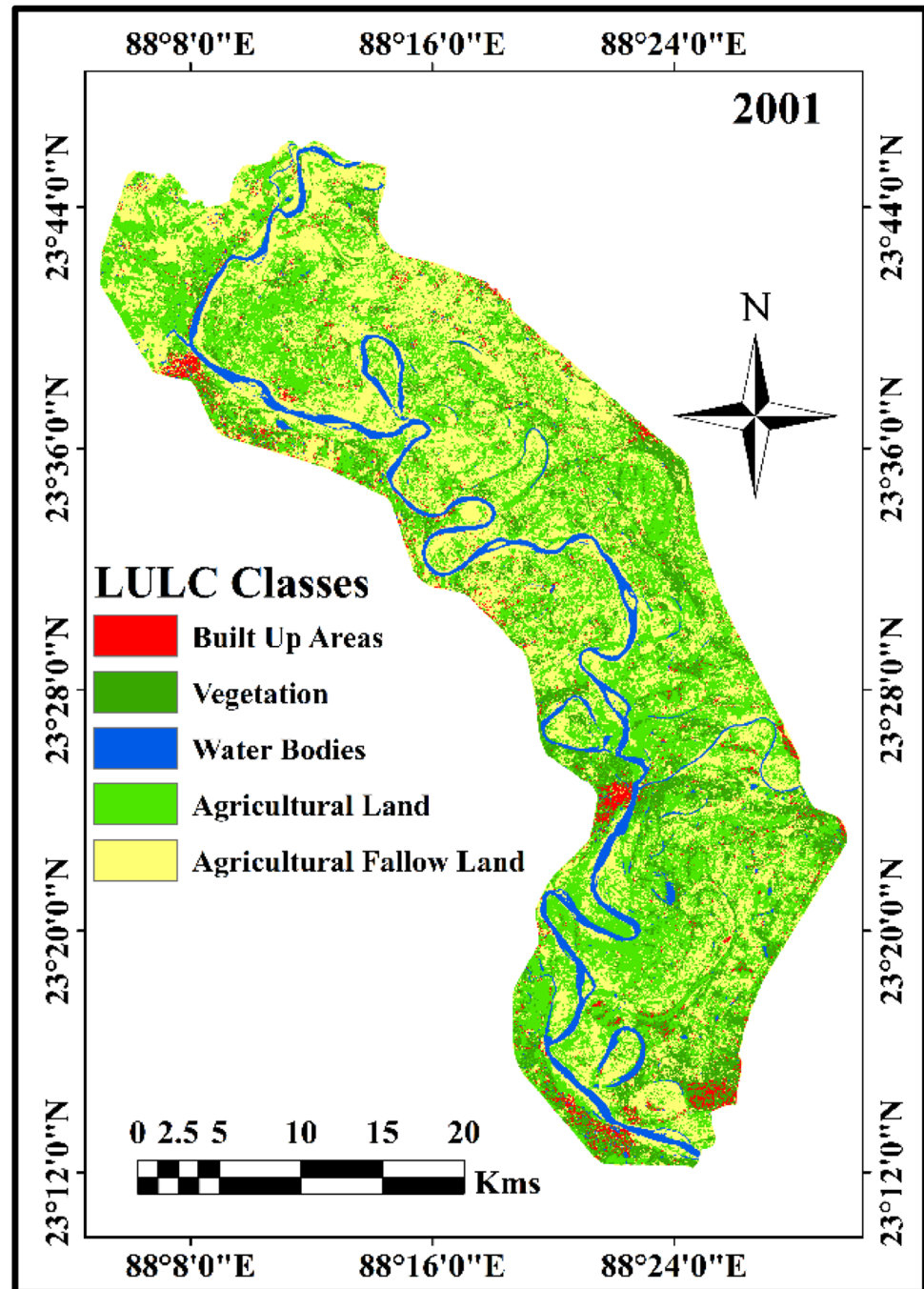
Land use land cover (LULC) maps of the year 2001 and 2010 are integrated into GIS and change matrix denoting “from-to” change class is given in Table 5. Each column of that table indicates how a particular LULC class in 2001 is converted to other classes in 2010. In contrast, each row represents how different LULC classes in the year 2001 are converted to a particular class in 2010. The values of diagonal in the change matrix indicate the unchanged area belonging to a particular class.

In the year 2001, out of 2.91% built-up areas in the study area, 1.11%, 0.62%, 0.27%, and 0.04% were converted to agricultural fallow land, vegetation, agricultural land, and water bodies respectively. Similarly, 1.06% under agricultural fallow land, 0.70% under agricultural land, 0.55% under vegetation and 0.05% under water bodies were converted to build up area in the year 2010 (Table 5). There was a significant conversion from agricultural fallow land to agricultural land (13.02%) and from agricultural

Table 4 Area transition for land use/land cover classes between the selected years

LULC class/area	2001		2010		Relative change (2001–2010)	
	km ²	%	km ²	%	km ²	%
Built up areas	27.85	2.91	31.02	3.24	+ 3.17	+ 0.33
Vegetation	133.81	13.97	212.45	22.18	+ 78.64	+ 8.21
Water bodies	61.77	6.45	54.99	5.74	– 6.78	– 0.71
Agricultural land	360.60	37.64	255.66	26.69	– 104.93	– 10.95
Agricultural fallow land	373.95	39.04	403.84	42.16	+ 29.89	+ 3.12
Total	957.97	100.00	957.97	100.00		

Fig. 4 LULC map for the year 2001

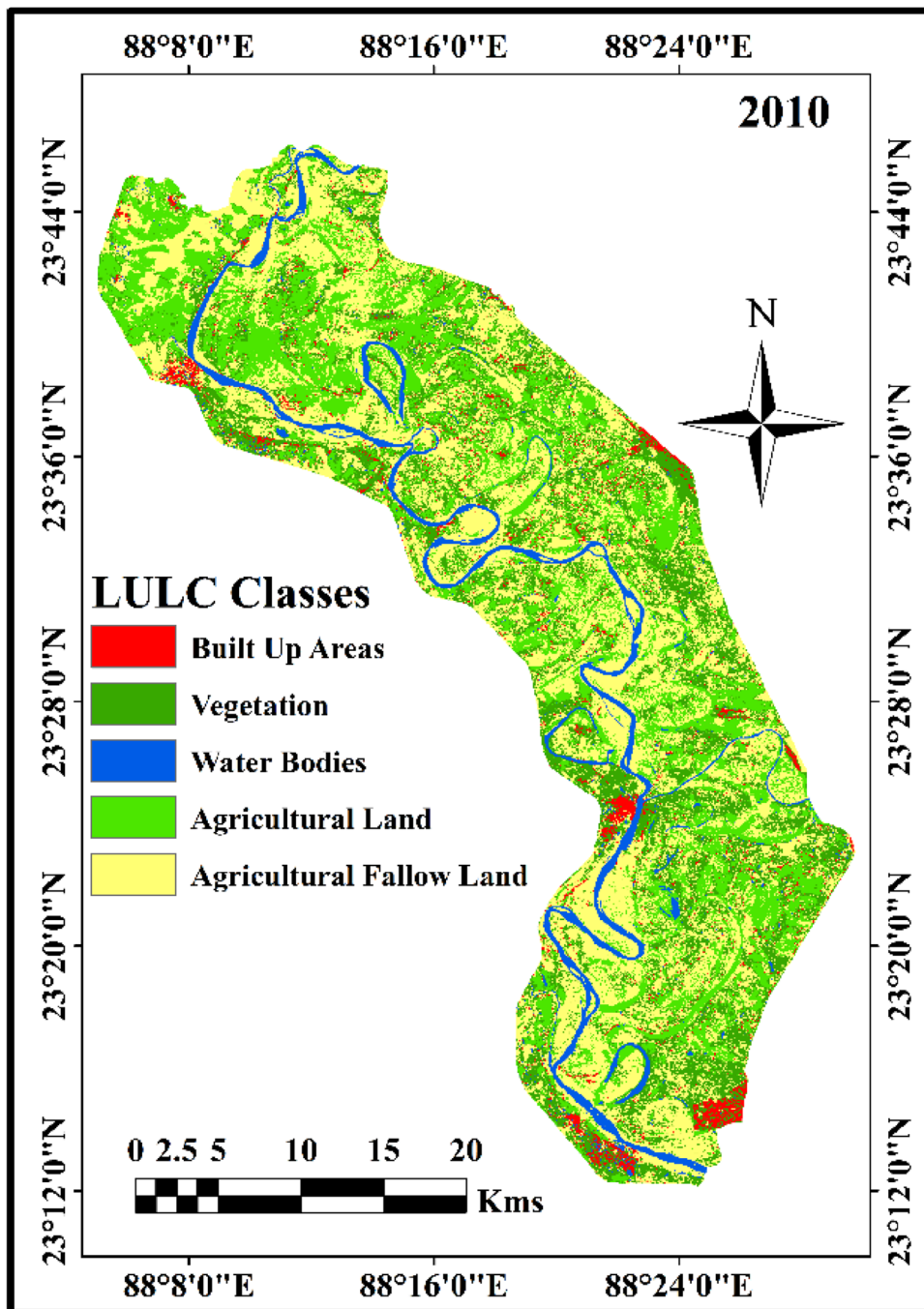


land to agricultural fallow land (8.31%). It is noticed that agricultural land and water bodies have reduced from 37.64 and 6.45% in 2001 to 26.69 and 5.74% in 2010. Vegetation and agricultural fallow land have tumid from 13.97 and 39.04% in 2001 to 22.18 and 42.16% in 2010 whereas the least amount of built-up areas (0.33%) has increased.

3.1.2 Accuracy assessment of LULC classification

All land use and land cover (LULC) map have compared to the reference data to assess the accuracy of the classification [25]. To run accuracy assessment total 100 samples have been taken from per image as ground truth points. Based on the ground truth data accuracy has been judged on the classified image. For all classified LULC maps overall accuracy is 81.00% in 2001, and 89% in 2010 respectively. This indicates a higher performance in class

Fig. 5 LULC map for the year 2010



wise image classification. Kappa statistics for all classified images are 0.76 in 2001 and 0.86 in 2010 respectively. The results of the accuracy assessment are presented in Table 6.

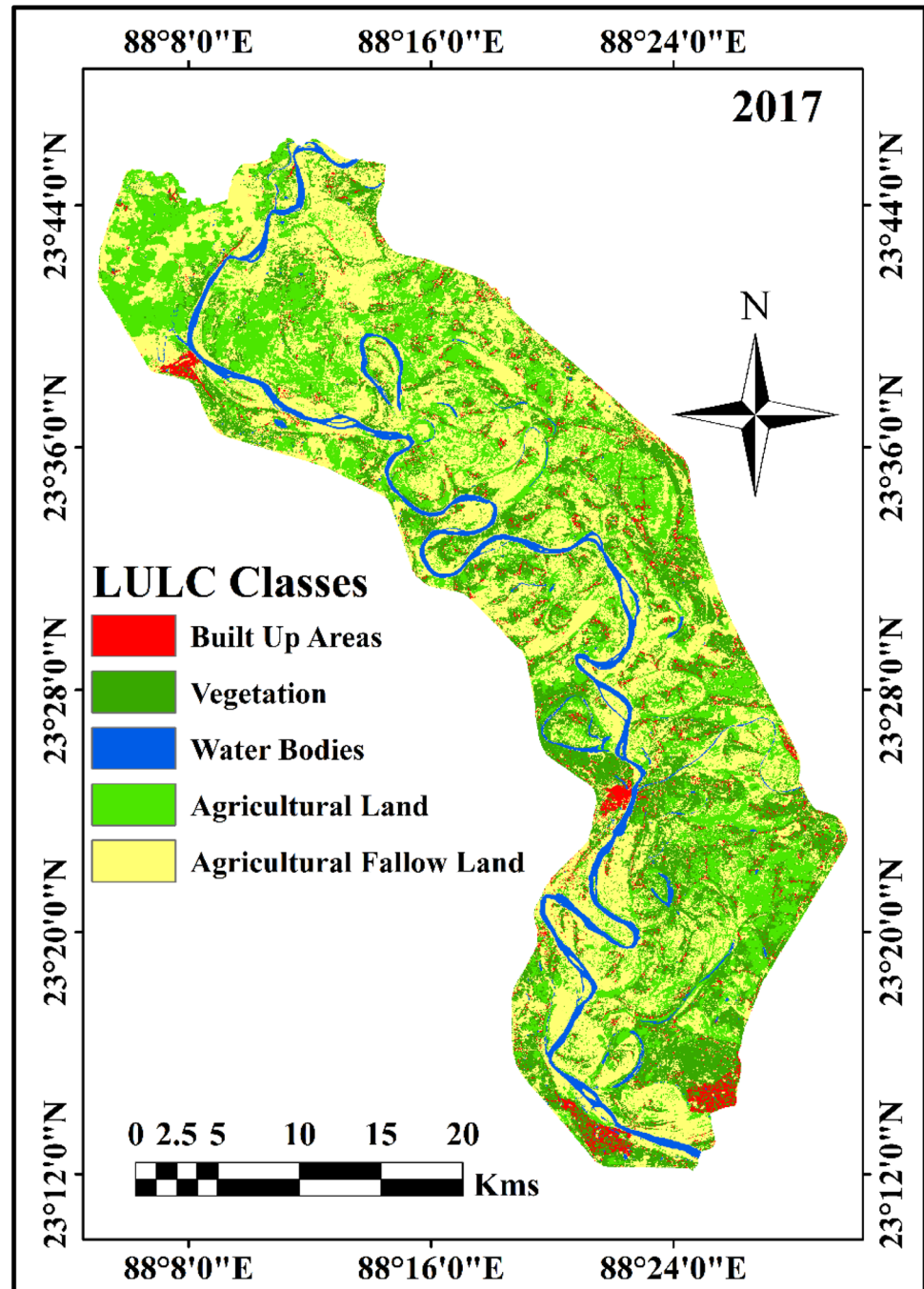
3.2 Markov modelling result

The transition probability matrix has been made based on landscape change from 2001 to 2010. The 2001 (time period) data has been used as the initial condition for the model and the data 2010 (second time period) data has been used as a final

condition (Table 3). On the basis of the transition probability matrix prediction of the LULC classes has been calculated for the next 18 years of the study area (Table 7).

The simulated results based on the Markov model indicate that the areas of built up and vegetation had increased from 2.91 and 13.97% in 2001 to 3.24 and 22.18% in 2010 and after the next time period in 2028, the area of built up and vegetation would have increased to 3.69% and 27.24% where agricultural fallow land has fluctuated in different times of this period. But the areas of water bodies and

Fig. 6 LULC map for the year 2017



agricultural land have decreased from 6.45 and 37.64% in 2001 to 5.74 and 26.69% in 2010 and after 18 years, those would have decreased to 4.90% and 23.01% in 2028. The change in LULC classes from 2001 to 2028 in the study area represents in the following Fig. 7 and the relative change of LULC classes from 2001 to 2028 has been seen in Fig. 8.

Figure 8 shows that the built-up areas, vegetation, and agricultural fallow land would have increased 0.79%, 13.27%, and 2.12%, but water bodies and agricultural land

would have decreased 1.54% and 14.23% from 2001 to 2028.

Water bodies are gradually reducing because of eutrophication in all the lakes and small water bodies, deposition of sediment, indiscriminate dumping of solid waste, fill up the pond/wetland for construction. Because of increasing industrial area mainly brickfield, loss of agricultural production due to natural calamity in every year, insufficient labour for cultivation, agricultural land has been decreased. Apart from these, the study area is a flood-

Table 5 Change detection matrix of 2001–2010

LULC classes	2010					Total
	Built up areas	Vegetation	Water bodies	Agricultural land	Agricultural fallow land	
2001						
Built up areas	0.87	0.55	0.05	0.70	1.06	3.24
Vegetation	0.62	8.92	0.18	7.68	4.78	22.18
Water bodies	0.04	0.09	4.45	0.41	0.76	5.74
Agricultural land	0.27	1.88	0.40	15.84	8.31	26.69
Agricultural fallow land	1.11	2.53	1.37	13.02	24.13	42.16
Total	2.91	13.97	6.45	37.64	39.04	100.00

The highlighted bold numbers define the unchanged land use area in different categories of 2010 compared to 2001

*Figures indicate the percentage of area

Table 6 Classification assessment report from the classified images in 2001–2010

LULC classes	2001		2010	
	Producer accuracy (%)	User accuracy (%)	Producer accuracy (%)	User accuracy (%)
Built up areas	87.5	70	88.24	75
Vegetation	76.19	80	88.89	80
Water bodies	100	85	90.91	100
Agricultural land	76.19	80	86.36	95
Agricultural fallow land	78.26	90	90.48	95
Overall accuracy	81.00	89		
Kappa statistics	0.76	0.86		

Table 7 Change trend of LULC classes simulated by the Markov model

LULC classes	Year				Relative change (2001–2028)
	2001	2010	2019	2028	
Built up areas	2.91	3.24	3.54	3.69	0.79
Vegetation	13.97	22.18	25.62	27.24	13.27
Water bodies	6.45	5.74	5.25	4.90	– 1.54
Agricultural land	37.64	26.69	23.83	23.01	– 14.63
Agricultural fallow land	39.04	42.16	41.76	41.16	2.12

*Figures indicate the percentage of area

prone and vulnerable region mainly river banks of Bhagirathi-Hugli. Agricultural Fallow land has fluctuated at different times of this period. Most of the converted agricultural fallow land has been transformed into agricultural land, vegetation, and built-up areas. There is an increase in vegetation gradually over the study period. The reason for this increase, a large amount of agricultural land and fallow land are transformed into vegetation and those have made different types of orchards or “Bagan”. This transformation is evidence of structural change in the agriculture from traditional sowing harvesting cropping method to semi-

permanent orchard based farming. Orchard-based farming is also less vulnerable to fluctuation related to the input of traditional agricultural practices such as monsoonal rain, fertilizer, labour, and pesticide etc. The growth of the built-up area is being due to the high growth rate of population and the development of infrastructure over the study period. The growth rate of the population in this study area was 12.56% in 2001, where it has been 20.39% in 2011. Therefore, the growth rate of population has increased rapidly from 2001 to 2011 [26, 27].

Fig. 7 Simulated LULC classes change from 2001 to 2028

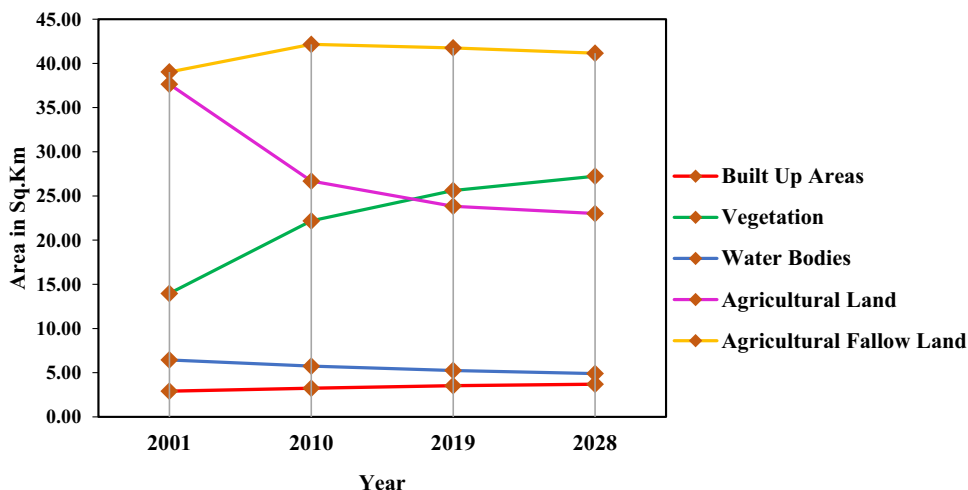
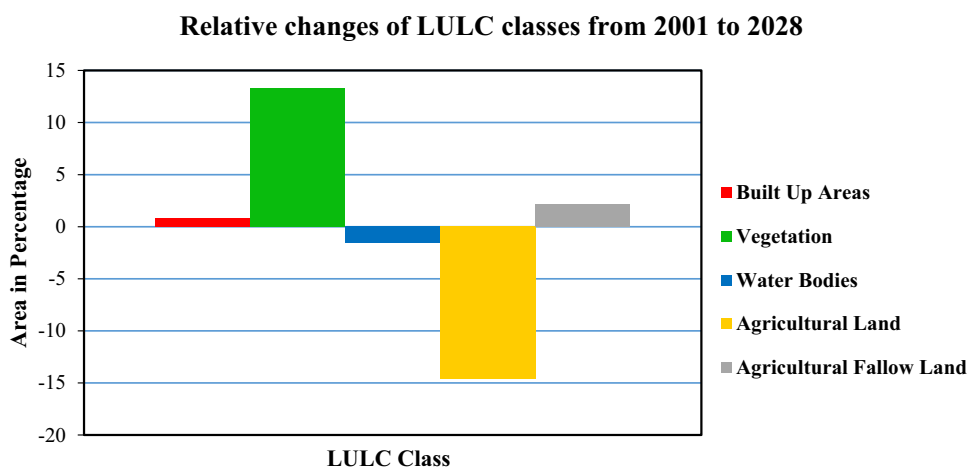


Fig. 8 Relative changes in LULC classes from 2001 to 2028



3.2.1 Validation of the Markov model

Validation of the model is an important part of the Markov model. It consists of the testing model against data that are not used to construct the model. For validation of the Markov model, Chi square test (χ^2 test) has been determined. The test results are as follows:

$$X^2 = \sum (O - E)^2 / E = 0.43$$

$$X^{20.05(4)} = 9.49$$

The Table 8 shows that there is no significantly great difference between simulated and actual values. The value of Chi square test or X^2 is 0.433 where the significance level of $X^{20.05(4)}$ is 9.49. Therefore, the Markov model of LULC change forecast in the study area can be used. The validation of LULC change forecast of the Bhagirathi-Hugli river catchment within the study area can be seen in Table 8.

4 Conclusion

The overall study shows that land use and land cover along the part of the catchment of the Bhagirathi-Hugli river of Nadia and Purba Bardhaman is going through a slow and progressive change. The study area is a flood-prone and vulnerable region mainly river banks of the Bhagirathi-Hugli. The simulated results based on a Markov model indicate that the areas of built up and vegetation had increased from 2.91 and 13.97% in 2001 to 3.24 and 22.18% in 2010 and over the next time period in 2028, area of built up and vegetation would have increased to 3.69% and 27.24% where agricultural fallow land has fluctuated in different times of this period. But the areas of water bodies and agricultural land have decreased from 6.45 and 37.64% in 2001 to 5.74 and 26.69% in 2010 and after 18 years, those would have decreased to 4.90% and 23.01% in 2028. This spatiotemporal model provided not only a quantitative description of LULC change in the past, but also the direction and magnitude of change in the future [9].

Table 8 Validation of LULC change forecast based on the Markov model

LULC classes	Simulated value (O)	Actual value (E)	(O – E)	(O – E) ²	(O – E) ² /E
Chi square test					
Built-up area	33.240	33.752	– 0.512	0.262	0.008
Vegetation	238.102	230.300	7.802	60.874	0.264
Water bodies	51.355	51.618	– 0.263	0.069	0.001
Agricultural land	234.401	240.550	– 6.149	37.815	0.157
Agricultural fallow land	400.863	401.756	– 0.893	0.798	0.002
$\chi^2 = \sum(O - E)^2/E = 0.433$, degree of freedom = (n – 1) and $\chi^2_{0.05(4)} = 9.49$					

The growth of the vegetated area for the loss of agricultural land marks a systematic change in the agricultural pattern in the study area. The growth in the built-up areas indicates the spread of urban growth in the study area. As the study area is mostly dominated by agricultural track, a major change in this land use type may hamper the food security of the area concern. So continuous monitoring of such areas is essential.

The above study also shows the capacity of the stochastic based Markov model to predict the future land use change in a given area. The applied model represents that it can be used in predicting the changing land use in flat low laying track. This prediction may help the decision maker to understand the future scenario of land use change of the study area and plan for sustainable resource management.

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Compliance with ethical standards

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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