



# Land-use–land-cover change detection and application of Markov model: A case study of Eastern part of Kolkata

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## Abstract

Land-use change of a region acts as an indicator of human impact on the landscape. Increasing urban growth has induced adverse landscape alterations which need to be predicted and controlled, especially in the urban areas and ‘rurban’ fringes, to prevent the trends of urbanization from engulfing the ecology. The present discussion makes an attempt to address this issue by assessing the present and predicting the future spatio-temporal dynamisms in land use and land cover along the urban and rurban fringe area of eastern Kolkata, stretching from the Eastern Metropolitan Bypass to Bhargar areas in West Bengal, India. For the fulfilment of the work, Landsat imageries of 1991 and 2016 have been chosen to depict the present urban growth, following which the results have been predicted and validated to show how the various land-use categories might change, using the Markov model. The study has depicted that urban growth continues to shift eastwards, resulting in greater number of urban patches in eastwards. The validation of positive and negative growth of respective land-use patterns with Markov model is within 10%. So, if the current reclamation activities continue, the original land cover shall decrease by 70% of the study area and these shall be replaced by urban areas.

**Keywords** Land-use change · Urban growth · Rurban fringes · Spatio-temporal dynamism · Markov model application

## 1 Introduction

Detection of land-use change of a region is considered to be an outcome of dynamic nature of landscape change. Since anthropogenic activities bring about the dynamism between land use and land cover (LU/LC), any change in the attributes of the landscape reflects the socio-economic character of a region. Monitoring of such changes, therefore, becomes a

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prime subject of study for landscape scientists as well as ecologists. As the attributes of the landscape are coerced to conform to human requirements, the environment gets adversely affected (Hoek 2008). Such unscientific land utilization techniques associated with unsustainably in nature primarily, and these need to be controlled if nature's balance needs to be upheld. Thus, predicting such future developments is imperative for conservation activities to thrive.

Change detection helps to identify the landscape diversity and spatial changes. For understanding the impact of urbanization on the landscape change, scientists worldwide have begun to concentrate more on land-use and land-cover changes and its predictability since 1990. Various scholars such as Lambin and Ehrlich (1997) and Johnson and Kasischke (1998) have addressed this changing landscape as a result of urbanization in their research. Lambin and Ehrlich (1997) studied land-cover change in the African continent during the time period from January 1982 to December 1991. They concluded that although vegetation changes were found to be just a fraction of the total change detected in land cover, they might have a significant effect on ecosystems and sustainability of livelihood. In recent years, to achieve a greater accuracy in detecting land-use and land-cover changes, remote sensing, in conjunction with geographic information systems (GIS), has been widely applied and recognized as a powerful and effective tool (Ehlers et al. 1991; Méaille and Wald 1990; Treitz et al. 1992; Westmoreland and Stow 1992; Harris and Ventura 1995; Wegener 1994; Yeh and Li 1996, 1997, 1999; Klosterman 1999; Agarwal et al. 2002; Weng 2001). Using this technique, Johnson and Kasischke (1998) studied the change through vector analysis of multispectral monitoring of land-cover and land-use conditions. Similarly, Liu et al. (2005) used the same technique for exploring change of cropland across China for the time period of 1990–2000, while Jabbar et al. (2006) applied a computerized parametric methodology to estimate vegetation change in the Letianxi Watershed of western Hubei Province, China. Other than these, some studies have also identified that transformation of agricultural lands into shrimp farms and the consequent land-use and land-cover changes of coastal areas can also be monitored through remotely sensed data (Dewalt et al. 1996; Flaherty et al. 1999; Ali 2006).

The Markov technique as an advancement to land-use change studies has begun very recently in the twenty-first century (Bell 1974). After its initiation by Andrey Markov, a mathematician from Russia, it resulted as a random probability model, which is now used to demarcate present LU/LC changes of areas and forecast the behaviour of the same areas, considering their old characteristic features (Baker 1989). Wijanarto (2006) found that it is possible to predict the probable changes in land use in the future using the Markov model, wherein the LU/LC change in Banten Bay has been depicted, once encroachment issues are faced near the coastal areas. The same calculation was used by Kumar et al. (2014), for the Tiruchirappalli town of Tamil Nadu, a state in India, where the Markov chain was combined with GIS to analyse the changes undergone by landscapes over time—a phenomena consequent to urbanization. With more study on the predictability of landscapes, a modified approach of the Markov model was successful in a study conducted in the western coastal desert areas of Egypt (Halmy et al. 2015).

In India, the land required for urban growth has similarly resulted in the conversion of agricultural lands due to urban expansion (Fazal 2001; Chadchan and Shankar 2012). Such a change is the result of the growing urban sprawl which tends to capture the natural cover and build a habitable built-up landscape. Since land is finite and no land conversion laws exist uniformly over the Indian sub continent, which may be punishable by law, such conversions are increasing day by day leading to an unsustainable landscape. Thus, it is essential that studies in this regard are conducted to predict future LU/LC changes.

The present research is concerned about the detection of land-use and land-cover changes with an attempt to link satellite remote sensing and GIS to stochastic modelling methods that affects the urban sprawl area, respectively. This missing linkage has hindered through modelling and assessing the dynamics of land-use and land-cover changes, and significantly impeded progress towards understanding of earth–atmosphere interactions, biodiversity loss in respect of global environmental change. Moreover, unlike the pre-established predictability models, the Markov procedure takes into account the parameters which imbibe changes, and predicts future transformations for every individual category of land use. Additionally, it even helps to validate the growth of such categories if the matrices are overlapped on the classes undergoing growth. In recent years, other models have developed, but they are capable of only tracing how one particular category might change, considering the trends in the observed timeline. Such intricate study of category-wise change detection and predicting the validity of future events is essential for determining the trends of urban ecology. Till date, the use of Markov models has taken place in social studies, but limited number of researches has connected it to land use and hence its inclusion in the present study.

The present research makes an effort to present a robust and detailed assessment of spatio-temporal trends in urban land-cover change in Kolkata, India, specifically from the eastern part of Kolkata from the Eastern Metropolitan Bypass to Bhangar areas in West Bengal and to understand the transformation of land-use pattern in a selective time span (1991–2016). In connection with this, we have attempted to predict the nature of growth scenario of 2016 through Markov model where data of 1991 have been considered as base. For this, the study has identified the following objectives:

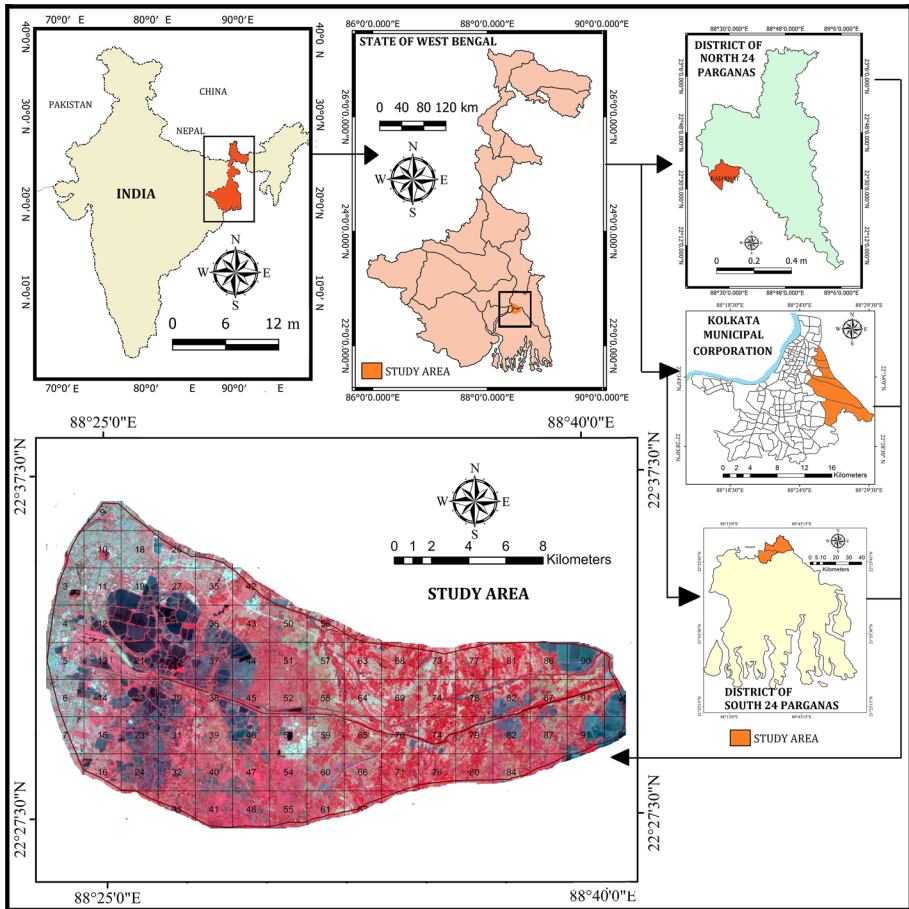
- (a) Land-use and land-cover change detection and growth analysis using satellite imageries of 1991 and 2016.
- (b) Change prediction of each land-use pattern of 2016 by Markov model considering the 1991 as base to validate the nature of growth.

## 2 Study area

The study area extends from  $88^{\circ}23'E$  to  $88^{\circ}41'46.43"E$  longitudes and  $22^{\circ}28'N$  to  $22^{\circ}32'28"N$  latitudes and comprises parts of Bhojerhat, Kheyada, Bhangar, Belegkata, Salt Lake area, Bantala and the deteriorated settlements of Duttabad dotting the western boundary of Salt Lake City (Fig. 1). The study area is a mixture of various types of settlements. These areas along the eastern stretch of Kolkata, i.e. along the Eastern Metropolitan Bypass, have experienced vast real estate growth, i.e. land-cover change, precisely in the last 18 years. Alongside these, Bhojerhat, Kheyada and Bhangar have remained predominantly rural areas wherein substantial land-use changes have not yet taken place. Since this stretch of land has witnessed a growth of high rises and wetland reclamation, there has been a vast change in land use and land cover making it suitable for the present research.

## 3 Methodology

The detection of land-use and land-cover changes and the application of the Markov model are assessed by using two sets of Landsat imageries: one acquired in 1991 and the other in 2016 (acquired on the 20 January and the 26 January, respectively). These were subjected

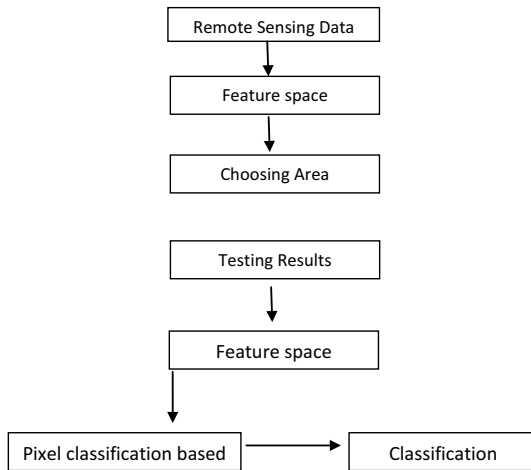


**Fig. 1** Location map of the study area. *Source:* Authors' own elaboration

to land-use change analysis to detect which categories of land use have experienced negative or positive growth over the selected span of 25 years. Following this, the Markov chain model has been used for predicting the change in each land-use type and validated for each grid over a period of 25 years. Since the change can be validated using the Markov model, this paper attempts to find out whether the positive change in these categories corresponds with the Markov prediction or not.

### 3.1 Positive and negative growth analysis of land use and land cover (1991–2016)

Identification of land-use categories and detection of their individual changes has been done using the Landsat imageries of 1991 and 2016, which were acquired on the 20 January 1991 and the 26 January 2016, respectively. These have been classified and have been subjected to the change detection technique in ERDAS IMAGINE 14.0. The classified images were then subdivided into grids using the Fishnet technique in ArcGIS 10.2.22, wherein each grid represents a 4 km<sup>2</sup> area. For each grid, the change in each land use and land cover has been calculated.



In the process of detecting changes in the landscape according to the grids, the resultant values have been assessed and divided into classes depending on their positive to negative nature of amplitude from mean value. Firstly the total number of land-use categories has been calculated for each grid and individual mean values have been calculated accordingly. Eventually by grouping these values, respective classes have been framed, so as to distinguish the growth as being highly positive, moderately and least positive or even negative sets of data series.

### 3.2 Application of Markov model for predicting and validating the growth of each land-use types

Markov chain model, devised by Andrey Markov, a mathematician from Russia, was created to identify present LU/LC changes of complex areas and tried to predict the behaviour of the same areas, concerning their pre-existing characteristics (Baker 1989; Weng 2002; Fortin et al. 2003). In this study, this model has been used for validating the existing changes by overlapping the Markov matrix on the change detection map. The Markov equation has been constructed using land-use growth data of 2016 ( $M_t$ ) and at the end ( $M_{t+1}$ ) of discrete time period as well as a transition matrix (MLC) representing the land-use change that occurred during that period. The matrix cell values are derived directly from the classified Landsat images and expressed as proportions. Under the assumption of the representative region, these proportional changes become probabilities of land-use changes over the entire sample area derived from the transition matrices. The three matrices created above were then assembled to form a link in the Markov chain using the following equation:

$$N_{t+1} = N_t * P \quad (1)$$

where  $U_T$  represents the probability of any given point being classified as urban at time  $T$  and  $LC_{ua}$  represents the probability that an agricultural point at  $T$  will change into urban land by  $T+1$  and so on (Ye and Bai 2007).

$$M_{LC} * M_t = M_{t+1} \quad (2)$$

$$\begin{bmatrix} LC_{uu} & LC_{ua} & LC_{uw} \\ LC_{au} & LC_{aa} & LC_{aw} \\ LC_{wu} & LC_{wa} & LC_{ww} \end{bmatrix} \begin{bmatrix} U_t \\ A_t \\ W_t \end{bmatrix} = \begin{bmatrix} U_{t+1} \\ A_{t+1} \\ W_{t+1} \end{bmatrix}$$

Iteration of these matrix equations derives the equilibrium matrix  $Q$  which by definition occurs when the multiplication of the column vector (land-use distribution) by the transition matrix yields the original column vector  $M_{LC} + M_1 = M_{t+1} = M_1$ .

In this first-order homogeneous Markov chains model, the behaviour of any selection time can be completely predicted if the transition probability matrix  $[P_{ij}]$  and the initial distribution vector  $N$  are known (Chakraborty et al. 1995). The  $s$ -step transition probabilities  $P_{ij}^s$  are obtained as the elements of  $P_s$ .

Following this, the Markov values of each of the grids have been depicted using hachures within the grids of the Fishnet. The Markov value for each category was then overlapped on the land-use change maps of the same category (shown in shades of blue, green, red and grey) and compared to find out whether the trend of changes in the choropleth maps is reflected in the Markov indices. The same is given in Sect. 4.2 later on to find out how similar the two values are going to be in future.

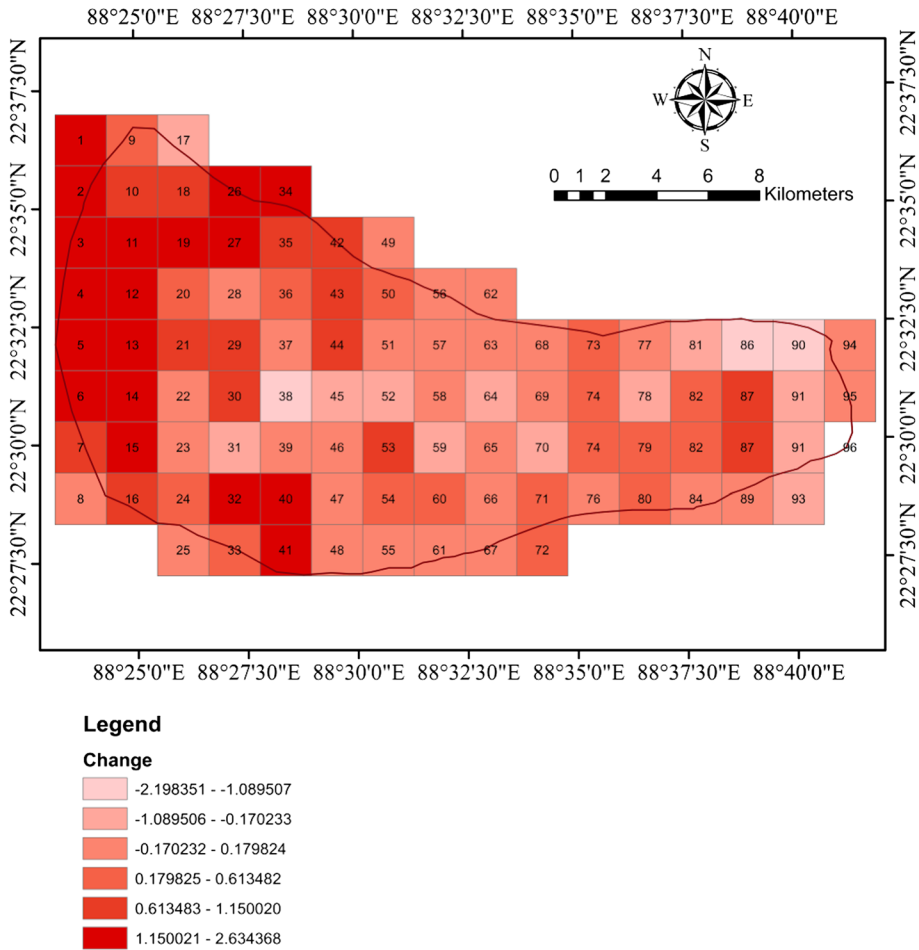
Thus, the calculated data have been used to prepare and predict changes of land use and land cover of the studied area and such observations also validate the growth analysis of each land-use pattern.

## 4 Results and discussion

### 4.1 Assessment of the positive and negative growth of each land use and land cover

Land-use and land-cover changes in the eastern Kolkata fringes have gradually been transforming over time. With increasing hotel chains, apartments, complexes and high-rise buildings, this area has undergone rapid development in a minimum span of time. To study this change, the appropriate Landsat imageries have been extracted from the USGS Earth Explorer website. Following this, a pair of composite images was created using the layer stacking of the individual bands. To enhance the image, techniques like data scaling and histogram equalization were also performed on each image. Lastly, the satellite images were rectified with the help of pre-referenced topographical sheet by the image to image rectification process using geographic coordinate system (latitude/longitudes), spheroid—Everest Datum-1830, using the ERDAS IMAGINE software.

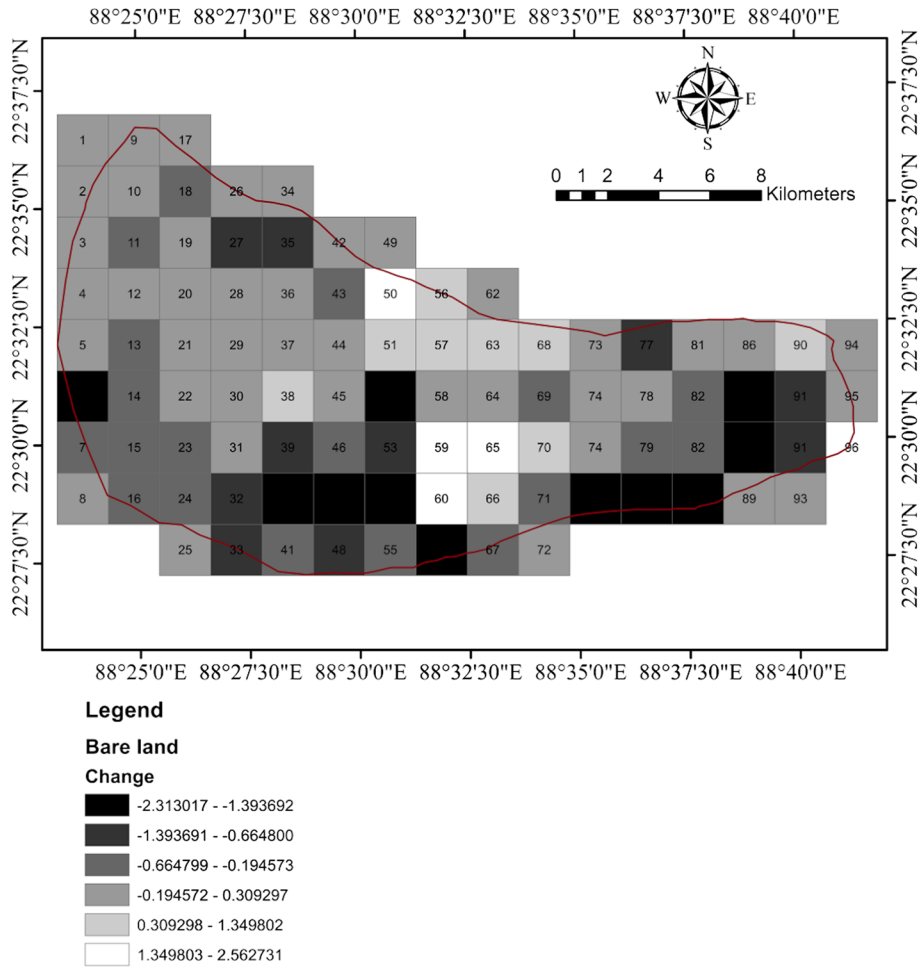
The images which evolved showed a varied pattern of changes. To find out the spatial entity of positive or a negative growth in the urban patches, a distinct comparison has been done by subtracting the land occupied by settlements in both years for each grid falling within the study area and its immediate adjacent portions (Fig. 2). If the computation gives a negative result, it is inferred that the growth has been negative, which means settlements have decreased in these grids and vice versa. Accordingly, six suitable classes have been selected and re-classed again. Highest positive change is depicted by the darkest red patches, while the lowest negative change in growth is shown by the lightest shade of red. The rest of the grids depict a moderate change in settlements. Towards the eastern part of the study area near the canals and the Kulti River, fewer-storeyed buildings exist. The people who reside here are primarily fishermen who depend on the wetlands for



**Fig. 2** Change in settlement growth over a period of 25 years *Source: Landsat 7 and 8*

their livelihood. With respect to the changing pattern of the settlements over time, it has been found that after 1990 high-rise buildings have continuously increased within the study area, particularly near the Eastern Metropolitan Bypass. Towards the western, northern and eastern boundaries of the map grid nos. 7, 30, 35–38, 41–43, 62 and 92 shows highly positive urban growth. Grid nos. 3, 8, 26, 27, 30, 56, 68, 85 and 89 show moderately positive growth of settlement, while the rest of the coloured portions of this map display low positive growth of settlement. Negative growth of urban settlement is also found in the study area, especially in grid nos. 52 and 90 which shows a highly negative urban growth, i.e. settlements have shrunken up, and at times, the land use has changed in the grids completely, turning previous residences into vegetated areas or other uses. This situation is found more towards the fringe areas. Grid nos. 34, 40, 45, 60, 65, 73–78 and 80–84 show moderately negative urban growth.

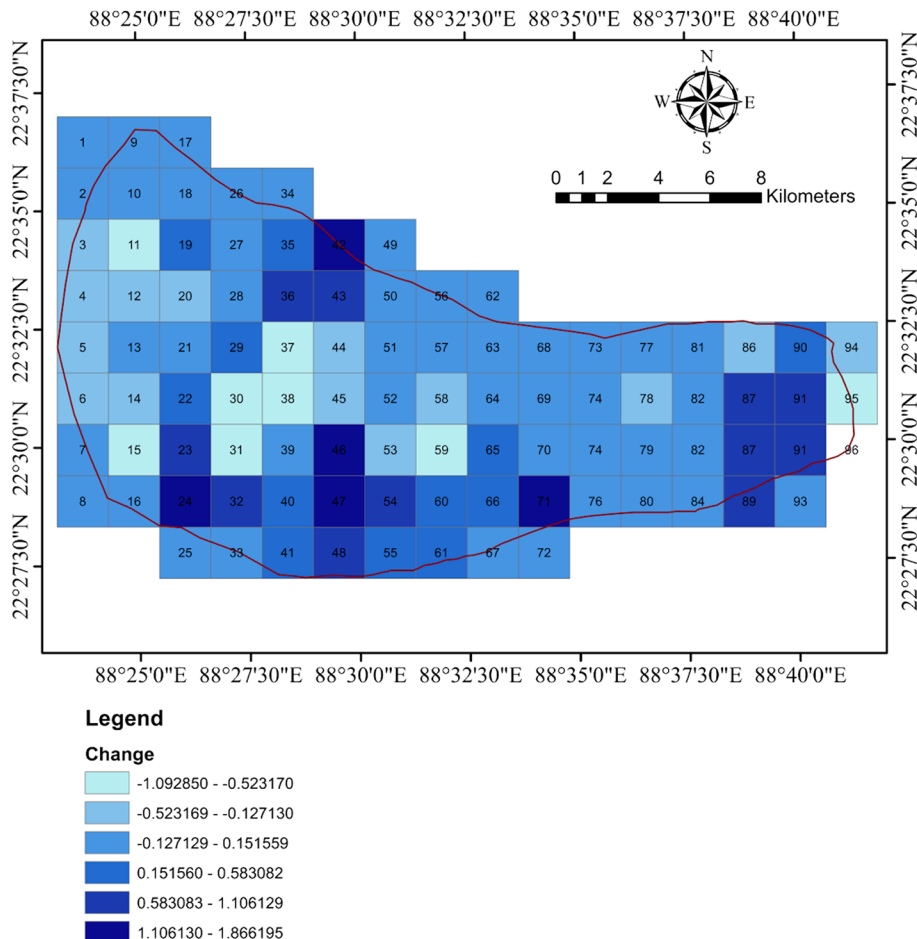
The growth of bare land follows a similar pattern. Change of bare land portions have been depicted by black to grey shades (Fig. 3), where the lowest level of negative growth in



**Fig. 3** Change in bare land growth over a period of 25 years *Source:* Landsat 7 and 8

bare land is found to be concentrated along the boundary of the study area, while the lowest amount of positive growth is found towards the left of the study area. This distribution indicates that towards the southern section of the map, amount of bare lands has hugely decreased, as a result of rampant land conversion of these portions into settlements. This continuous process of transformation might lead to instances where bare land may vanish over time and areas under cultivation might reduce drastically. The grids 50, 57, 63, 88 and 91 show high positive growth of bare land, while grid nos. 30, 65 and 68 show moderately positive growth, while the rest of the light grey shaded parts of the map represent a low positive growth of bare land. Highly negative bare land growth is found in grid nos. 3–10, 11–20, 41–44, 76–78, 88 and 89. In grid nos. 63, 64 and 68, the grids depict moderate bare land growth, whereas low-negative bare land growth zones are found unevenly distributed in patches within the map. The reason behind such a pattern of bare land development is the inclement weather, urban floods or anthropogenic disturbances on land as a result of constructional activities.





**Fig. 4** Change in water bodies over a period of 25 years *Source*: Landsat 7 and 8

The maximum change in water bodies and canals has been noticed in the southward section of the study area (Fig. 4). These areas which have suffered from the reclamation activities are mainly noticed in both the western and eastern portions of the map boundary and act as an indicative of all those places which have had experienced conversion of wetland into urban spaces. Towards the south, a greater percentage of increase has been observed regarding space occupied by water bodies over the selected years. This is a positive change determining the influence of fishermen and their dependence on water bodies for their livelihood. In the middle part of the study area, towards the northern and southern boundary, there exist grids which have a highly positive to a low positive rate of water body growth. This indicates minimum land conversion activities, and wetland fishing units or ‘bheries’ along with fishing activities are much higher in these zones. Such blue shaded grids increase towards the eastern section of the map, while conversely opposite patterns are found towards the western sections. Here also there are grids which indicate a sudden increase in the changes in land use, i.e. either conversion of wetlands into vegetated areas or wetland infilling and land conversion activities as a result of urbanization.

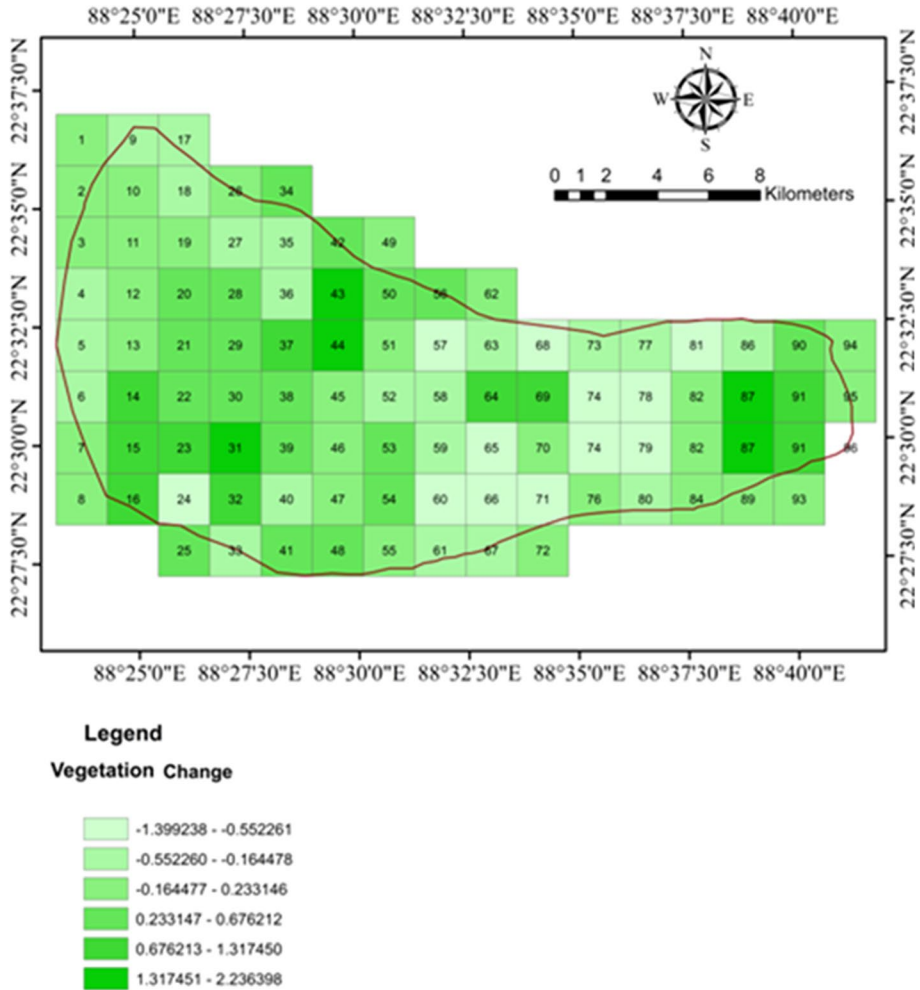


Fig. 5 Change in vegetation over a period of 25 years *Source:* Landsat 7 and 8

The change in vegetation, on the other hand, for the same years has been segregated with the help of light green shades, where the lightest green depicts the lowest negative growth in vegetation, while a darker shade of light green indicates the maximum positive growth in vegetation (Fig. 5). In places where lightest shades exist, there is a direct effect of urbanization, and vegetated areas have been replaced by urban settlements. In the middle and eastern portions of the area vegetation has increased, inferring the result of afforestation. Vegetation decrease is more concentrated towards Bhangor, Kamalgazi and far eastern fringes of the map. This proves the fact that land-use change activities are highest in these high-negative to low-negative vegetation growth zones. The probable reason behind this is clearing of vegetation for agricultural or residential purposes, which is the reality of these far eastern fringes of Kolkata.

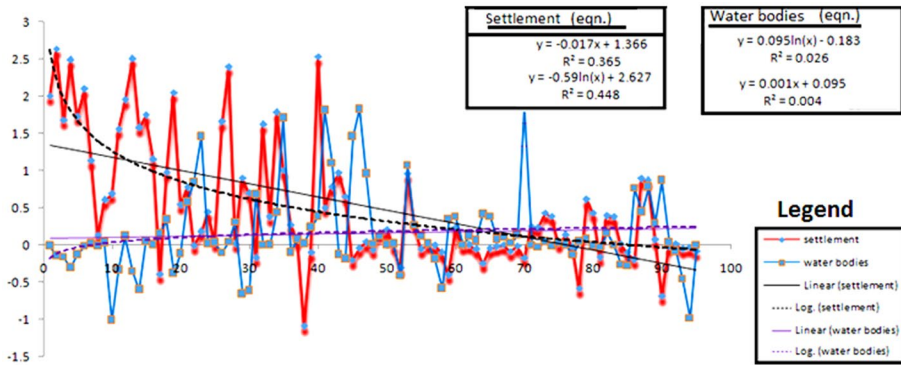


Fig. 6 Co-relation analysis between settlement growth and bare land creation

Hence, it may be inferred that the area under study has had rapid changes in land utilization over time, due to the change of transportation networks, residential patterns and natural space. This is further shown in Figs. 6 and 7, where the changing pattern of other land uses may occur if one category of land use alters over time. Accordingly, from these two diagrams it can be assumed that it is a gradual process of change. This can be explained by instances where water bodies are converted into bare land areas, after which settlements develop by replacing the bare lands over time. Such is evident in Fig. 7. In Fig. 6, where the logarithmic scale of water bodies and settlement have been shown, it predicts that this trend shall increase in time. This change requires adequate attention so as to maintain its balance with the natural systems.

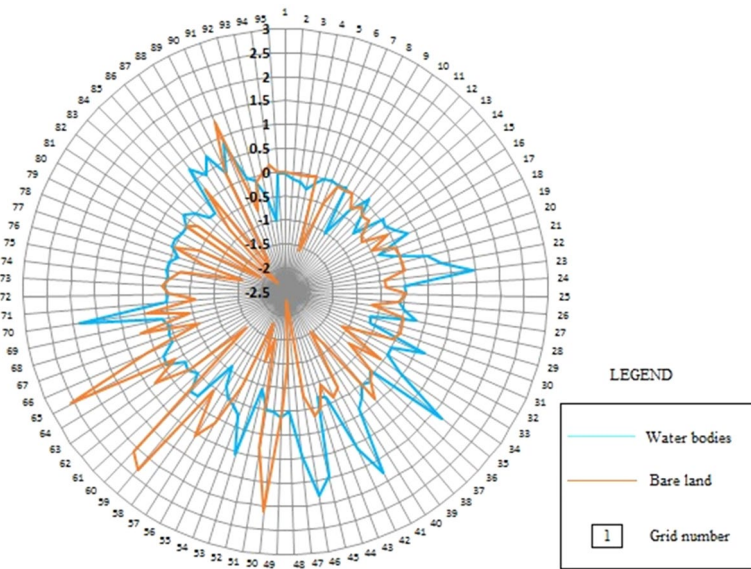


Fig. 7 Composition of water bodies and bare land growth

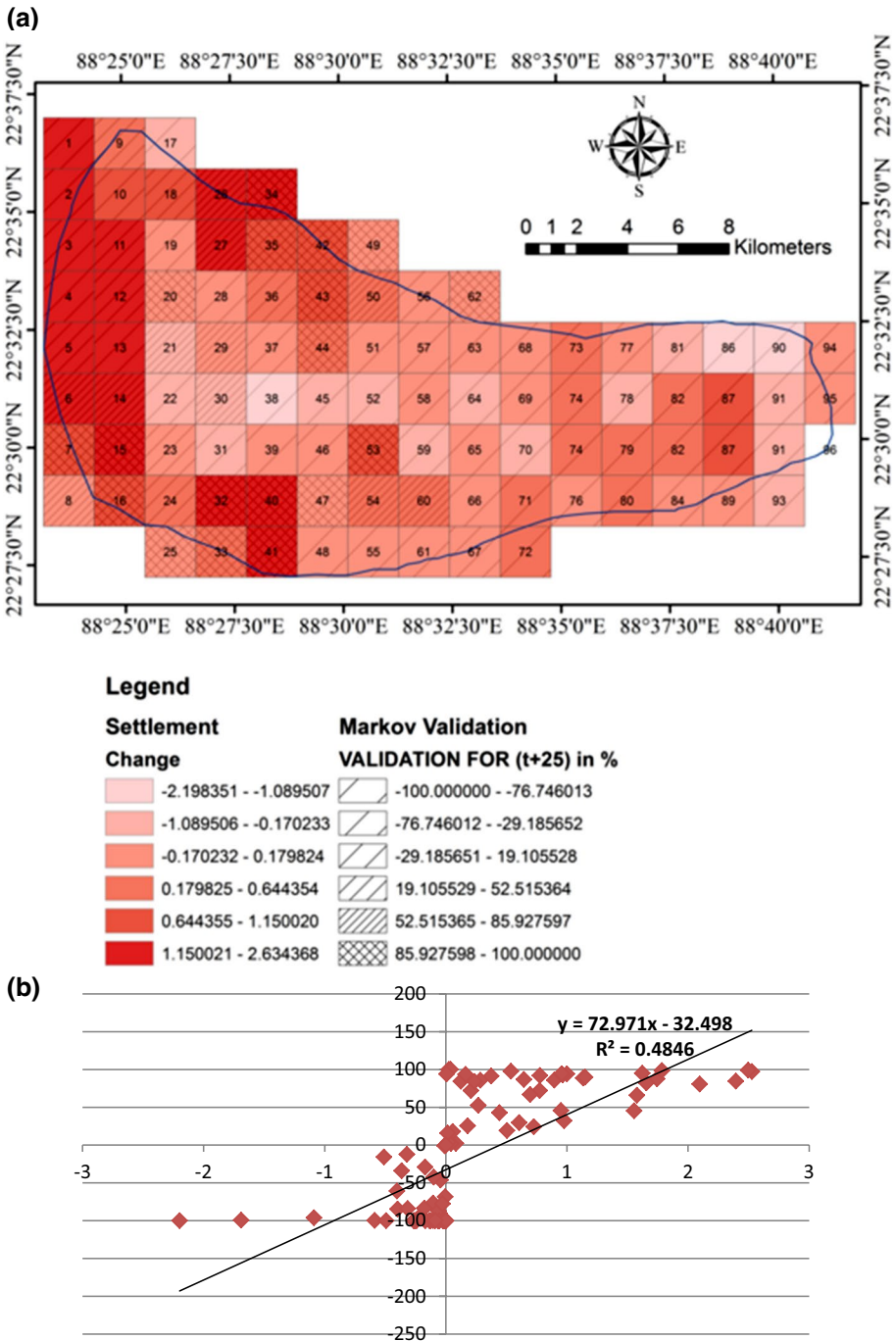
## 4.2 Prediction of the magnitude of change in each land-use type using the Markov model

The Markov model is one of the best tools for predicting future changes of land-use parameters. With the help of this formula, each land-use category and its subsequent change over time have been studied, which reveals that if the same trends of land-use change exist, in future, i.e. in about the next 25-years, what would be its change. This formula has hence been used for grid-wise prediction of changes that take place for both the years 1991 and 2016. The same has been spatially correlated with the changing land-use categories.

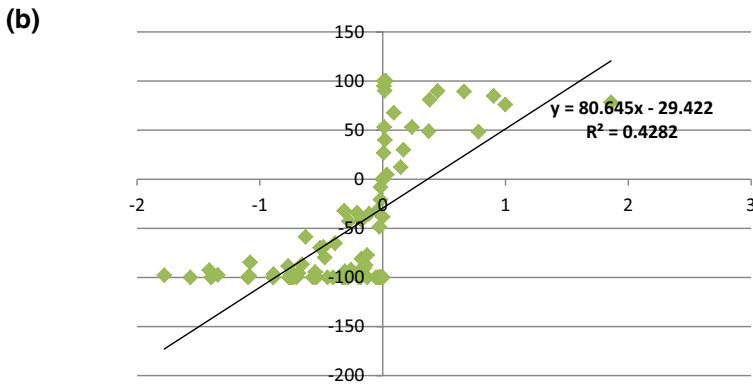
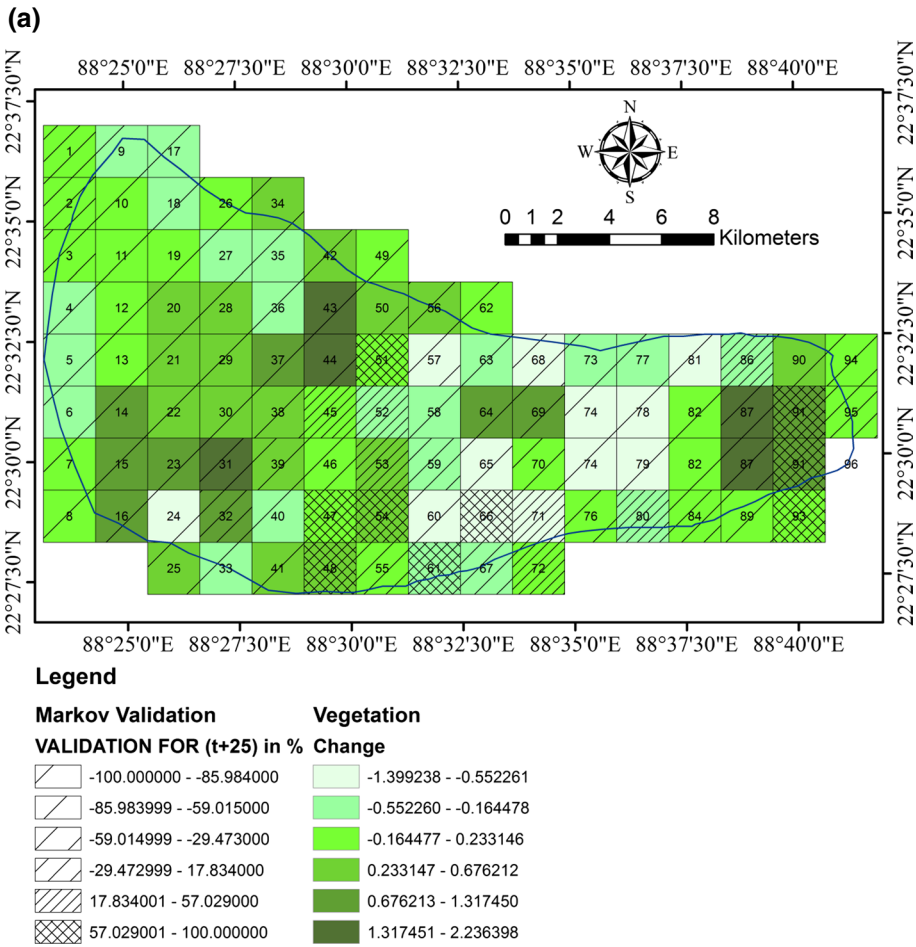
Considering the pattern of the land use (1991 and 2016), urban areas have been concentrated more towards the western half of the map (Fig. 8a). The probabilistic Markov model in the same situation infers that these dark red patches will retain its rate of positive growth 25 years later towards the eastern side, especially in grids 1–4 and 9–10. But the Markov prediction predetermines that the direction of urban growth shall be towards the eastern half of the study area where the grids are marked with the denser hachures. This predicts that all the grids in 1991 which were interspersed with vegetation, bare land and water bodies shall get converted into an urban landscape. Conversely, those with lighter red to peach-coloured urban patches with the denser hachures depict that these patches will experience the highest conversion into urban spaces. These portions are found towards the eastern section of the map. Validating the two datasets of changing urbanization and Markov prediction of the same, an 88–100% validation is found in some grids. The resultant correlation depicts that as urban patches experience a positive change, the Markov data follow suit and vice versa (Fig. 8b).

The nature of vegetation characteristic and patterns have changed through 1991 and 2016, and as is evident, vegetation is predicted to decrease all over excepting in around ten grids which are spread towards the centre of the study area. Considering the total number of grids, almost around 20 of them will exist in the same state if the trends of land-use change continue, while the rest of the 75 grids will face a 100% chance of facing a depletion of vegetated patches (Fig. 9a). Over time, on correlating the two datasets, a remarkable change is visible (Fig. 9b). Unlike the previous section, more number of grids in this case has negative change in vegetation during 1991, followed by a similar negative trend in 2016 predicted by Markov model.

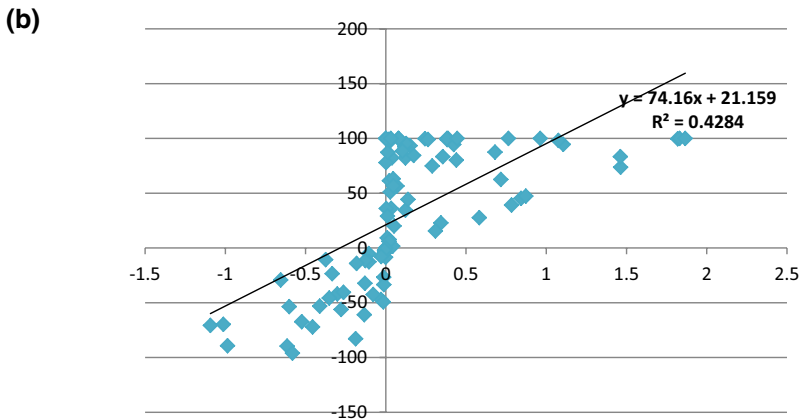
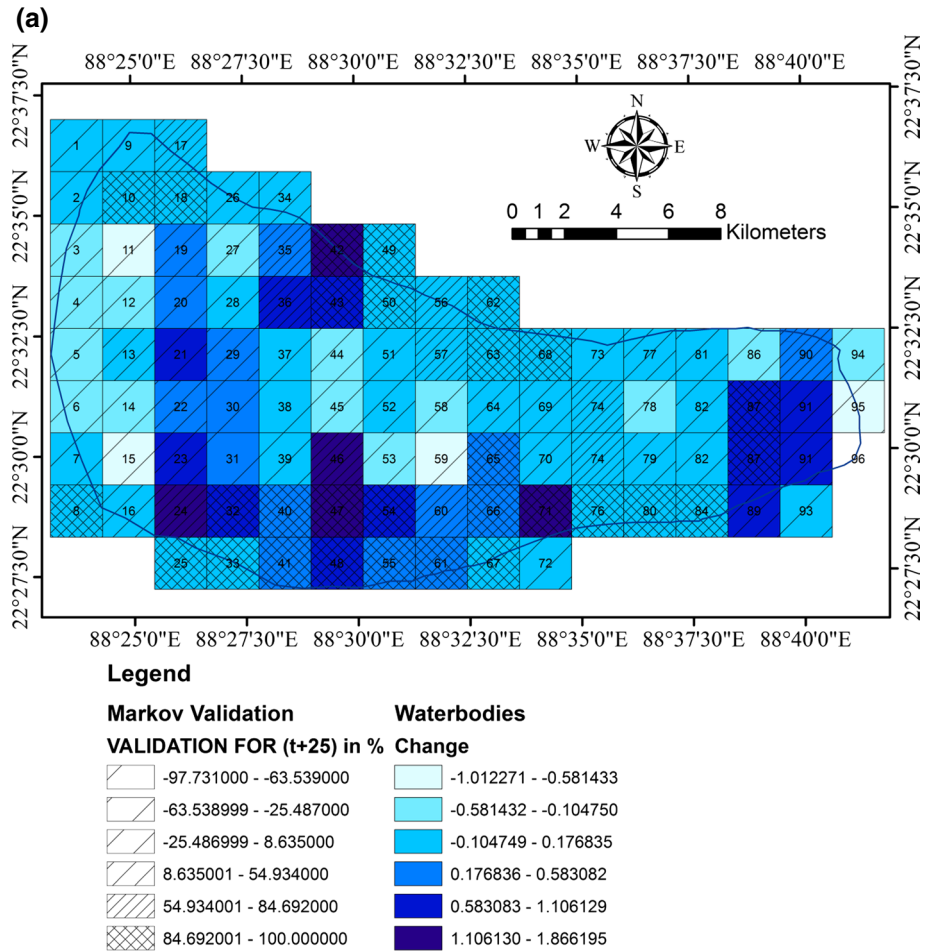
Transformation of water bodies is also varied for both 1991 and 2016. Almost 60 grids within the study area have faced negative change in water bodies, while the rest have not. While analysing with the help of Markov chain, it is evident that the water bodies in future shall reduce greatly in almost 70% of the total area; if the trends as seen in 1991 and 2016 remain the same, the concentration of water bodies shall shift towards the bottom of the study area where fisheries exist and fisher folk reside nearby (Fig. 10a). Similarly, in Fig. 10b it is observed that areas with lesser positive change in water bodies have a 10–100% chance of preserving water bodies, while areas with greater negative change have a greater possibility of being reclaimed for urbanization or other purposes. These preservation activities shall be in the Tardaha and Kheyada villages within the southern portions of the map. The northern section of the study area, which is gradually being occupied by new age townships, shows a complete 97% chance of facing a decreased rate of water bodies, if the present trends of land-use change keep stretching into the eastern fringes of Kolkata. In case of the bare land proportions, mostly the darkest grey shaded grids with a positive growth during 1991 and 2016 have the highest probability of being intensely occupied by bare lands. Excepting grids having a resemblance to grid no. 25, the rest of the grids have experienced



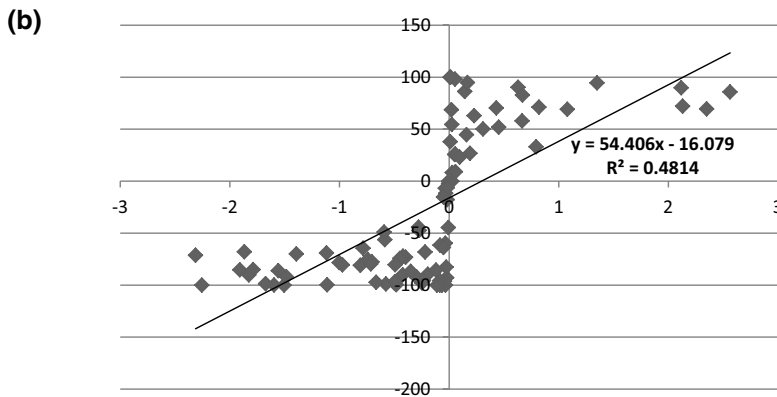
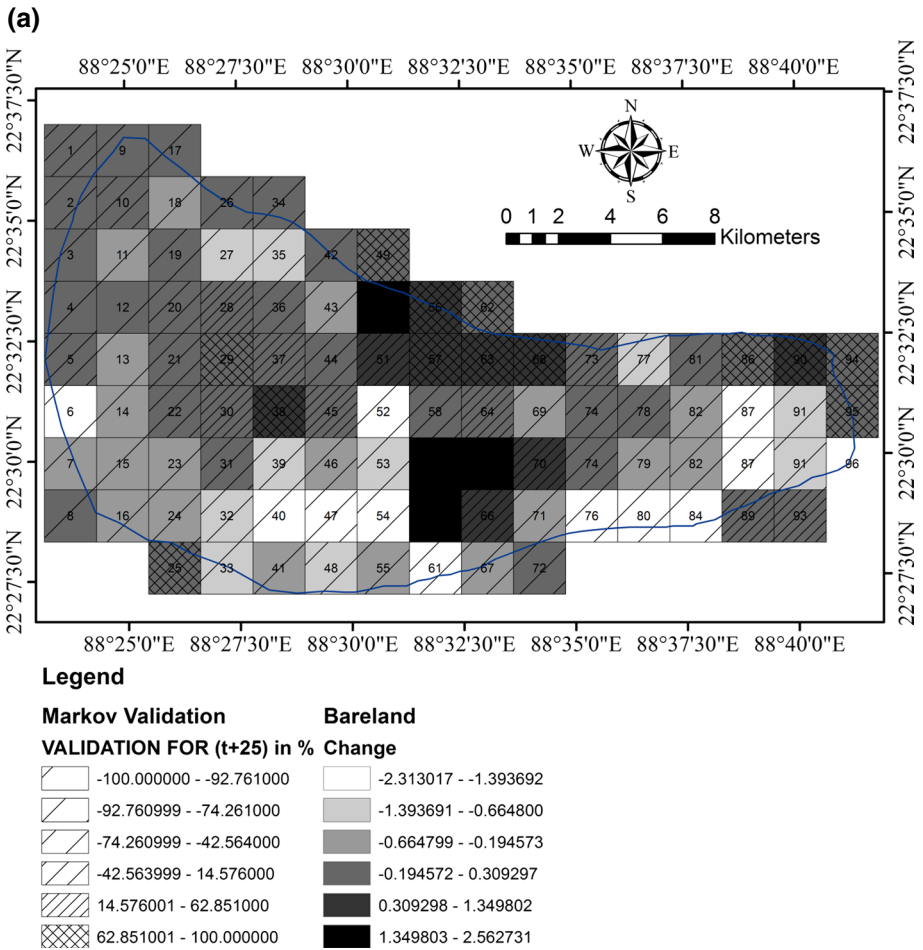
**Fig. 8** **a** Urban area growth (2016) and Markov prediction for 1991–2016 and **b** positive relation between growth and Markov prediction. *Source:* Landsat 7 ETM+ and 8 author's own elaboration



**Fig. 9** **a** Vegetation change (2016) and Markov prediction for 1991–2016 and **b** positive relation between growth and Markov prediction. *Source:* Landsat 7 ETM+ and authors' own elaboration



**Fig. 10** **a** Water body change (2016) and Markov Prediction for 1991–2016 and **b** positive relation between growth and Markov prediction. *Source:* Landsat 7 ETM+ and authors' own elaboration



**Fig. 11** **a** Bare land change (2016) and Markov prediction for 1991–2016 and **b** positive relation between growth and Markov prediction. *Source:* Landsat 7ETM+ and author’s own elaboration



negative growth and as per the Markov model, they have a lesser chance of being absolutely converted into bare lands and a greater chance of being converted into vegetated landscapes or water bodies. The grids with darker shades of grey with denser hachures depict that there shall be a 20–100% chance of the areas to be converted into bare land if the changes follow the 1991 patterns (Fig. 11a). Again if these two values of bare land change and Markov are correlated, as shown in Fig. 11b, maximum number grids seem to lie in the negative quadrant. This means that 80% grids within the study area will face a conversion of the landscape from bare lands to other land-use categories.

From the previous maps, we can conclude that growth of settlement is gradually taking over other land uses and is changing the landscape in such a manner that recovering their native natural attributes shall be very difficult. Thus, as larger water bodies shrink, bare lands shall take their place, and further, as bare lands are occupied by urban patches, bare land areas shall decrease rapidly until urban patches become the dominant category of land use. The study of correlation between growth and predicting values of Markov model also narrates the positive relation that ensures the accuracy of growth analysis in every land use, respectively (Figs. 8b, 9b, 10b, 11b).

The outcome of the overall analysis bespeaks the transformation of wetland areas into bare lands, which with time become occupied by settlements (Fig. 7). The trend analysis of settlement and water bodies shows a certain distinct finding; The coefficient of variation ( $R^2$ ) was found to be 0.365 (linear) and  $R^2$  0.448 in the logarithmic scale, indicating the continuity of land transformation process. Regarding the negative growth of water bodies, the recorded linear  $R^2$  value 0.026 and the logarithmic  $R^2$  value 0.0048 depict that water bodies shall decrease in its spatial distribution with time. The discussion also portrays that the growth analysis and Markov validation for each land-use pattern have a positive relationship. This is clearly evident when the results of the growth analysis are pitted against the Markov results. ( $R^2$  values are 0.484 for settlement, 0.428 for vegetation, 0.428 for water bodies and 0.481 for bare land, respectively.) With regard to the positive relationship between growth and Markov prediction, the difference is less than 10%, proving that the prediction accuracy even for 2041 is high. (Table 1). Attention needs to be drawn to those areas which have been foreseen to face both positive and negative growths. Here preservation of the wetlands and reuse of bare lands needs to be done in a systematic and scientific manner for the betterment of human lifestyle.

**Table 1** % of area covered in growth analysis and Markov model

Land-use pattern	% of predicting area	Difference (%)
Positive nature of change		
Settlement growth (2016)	50	
Markov prediction (2041, based on 2016)	46	4
Negative nature of change		
Natural vegetation (2016)	81	
Markov prediction (2041, based on 2016)	78	3
Negative nature of change		
Bare land (2016)	83	
Markov prediction (2041, based on 2016)	76	7
Negative nature of change		
Water body (2016)	75	
Markov prediction (2041, based on 2016)	68	7

## 5 Urban policies to prevent rapid land conversion

All in all, the present study essentially validates that land-use and land-cover changes and its resultant pattern are an essential element of study if future changes in landscapes and its direction have to be predicted. Post-1990s, following the economic liberalization within the Indian economy, private real estate owners were given the freedom to increase the supply of residential complexes and work in tandem with public enterprises so as to give an impetus to the infrastructure development in locales away from the city proper. Thus, the urban fringe was evicted of the urban poor by these private developers, who had a greater purchasing capacity. Today, with the increase in migrating populations and their demands, the need of the hour is to provide residential units for these in-migrants (Mitra et al. 2013). But due to the shortage of open or unused spaces in the city major, the most opted alternative today is land-use conversion in the peripheral areas (Mitra et al. 2013). This is true even in the context of the present study in the eastern peripheries of Kolkata, where trends of land-use conversion have been such that wetlands/water bodies have witnessed a transformation into bare lands which ultimately translated into urban spaces. A similar pattern of change is evident in the pre-existing vegetated landscape, which typically morphs into a bare land, before becoming an urban unit. These reclamation/conversion strategies, just for the sake of urbanization, not only disfigure the natural ecology of the area but threaten the very existence of man.

As artificiality dominates as a result of infrastructural advancement, natural systems destabilize and in turn pollute the living spaces. A similar study in this context showed this very aspect; that is, multiplicity of man-made living spaces resulted in greater 'individual ecological footprints', or in other words, consumption patterns, thereby degrading environmental health (Banerji et al. 2018). For such a step towards sustainable urban development, planners need to prevent wetlands from being converted into wastelands and wasteland conversion into built-up areas through detailed government-laid urban policies. Such policies should state rules so as to help planners categorize which areas to be chosen for urban development and which to be left untouched. Agencies within the government both public and private should cooperate with one another and abide by the land utilization norms. Smaller areas with local municipality or corporations should coordinate central land policies with local ones. To adequately implement land policies and follow the government rules, trained and technologically sound staff is required. As far as possible, compact of urban development needs to be emphasized and decentralization of the city needs to be restrained (Bardhan et al. 2011). Lastly, the residents of the concerned locales need to be both informed and made inclusive in carrying out plans so as to address the needs of society without adversely affecting the environment (Inam et al. 2012).

Further, since these changes can be predicted through the Markov rule, urban planners might be able to utilize the same, so as to prevent illogical urbanization trends and strike a balance between the nature and infrastructure development.

## 6 Conclusion

Land-use diversity is a significant tool to understand the trends of landscape changes and urbanization. With landscape change and the transformation in each component of land-cover/land-use categories experiences a growth or a reduction depending upon the type of urbanization. Thus, urbanization has the power to control the natural landscape. So it is essential to assess how the landscape is changing or how it might change in future. As the literature suggests, to analyse LU/LC change, satellite imageries and remote sensing

techniques are essential to monitor the changing dimensions of a landscape and to create an in-depth study of a particular stretch of land, if it has been suffering from tumultuous change in land use. Such rapid changes in a landscape are extremely detrimental to living beings as it implies the destruction of nature. So as cities grow and expand exponentially, the biosphere suffers extremely. Unsustainable activities begin, and eventually, dearth of essential resources results. Thus, if excessive consumption of resources in and around man's habitat needs to be reduced, these tendencies need to be monitored regularly and necessary measures need to be adopted so as to arrest the wasteful exploitation of the earth's valuable resources.

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