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Research Article

# Evaluating the Dynamics of Urban Expansion and Land Use-Land Cover Change in the Inter-Urban Areas of Barasat and Barrackpore of West Bengal, India

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## Abstract

Urban expansion has predominantly occurred in peri-urban areas rather than within the urban core. It is mainly determined by unorganised growth, increased immigration, and rapid population growth in the urban fringe areas. The present paper analyses the trend of urbanisation, the land use and land cover change (LULC), and growth of built-up area in the Barasat-Barrackpore urban areas over the last four decades since 1990. The LULC change was prepared by using the Landsat images for the years of 1990, 2000, 2010, and 2020 by applying the maximum likelihood algorithm of supervised classification with the help of Remote Sensing and GIS techniques in ArcGIS. The four urban landscapes viz. urban core area, peri-urban area, scatter settlements, and open spaces were categorised using the NDBI sprawl matrix for analysing the magnitude and direction of urban growth. It is found that the urban population, urban area and urban units increased by 54%, 32%, and 42%, respectively in the period of 2001-2011. The built-up area increased in 102.50%, while agricultural, vegetation cover, fallow, and wetlands decreased in 23%, 59%, 60%, and 57%, accordingly. It is also known, by conversion matrix, that agricultural lands have been converted into built-up and fallow lands, vegetative cover into built-up, fallow lands and agriculture, fallow lands into built-up and agricultural, wetlands into fallow lands, agricultural and built-up area, respectively. This study may help the planners and policy-makers for sustainable urban development.

## Keywords

Urbanisation, Land Conversion, NDBI, Urban Core, Peri-Urban Area

## 1. Introduction

The unprecedented and haphazard urban growth and its consequences have become major issues in developing countries late twentieth and twenty-first. The spatial pattern and dynamics of urban growth along with change of land use and land cover are the important areas of research in contemporary urban studies. The urbanisation is a global phenomenon where the urban population expanded significantly from 62 million in 1951 to 377 million in 2011 (Census of India, 2011). The rapid growth of population in metropolitan cities has accelerated physical expansion of built-up areas in the peripheral regions. As a result, agricultural land, wetlands, vegetation cover, and fallow lands are being irreversibly converted to the

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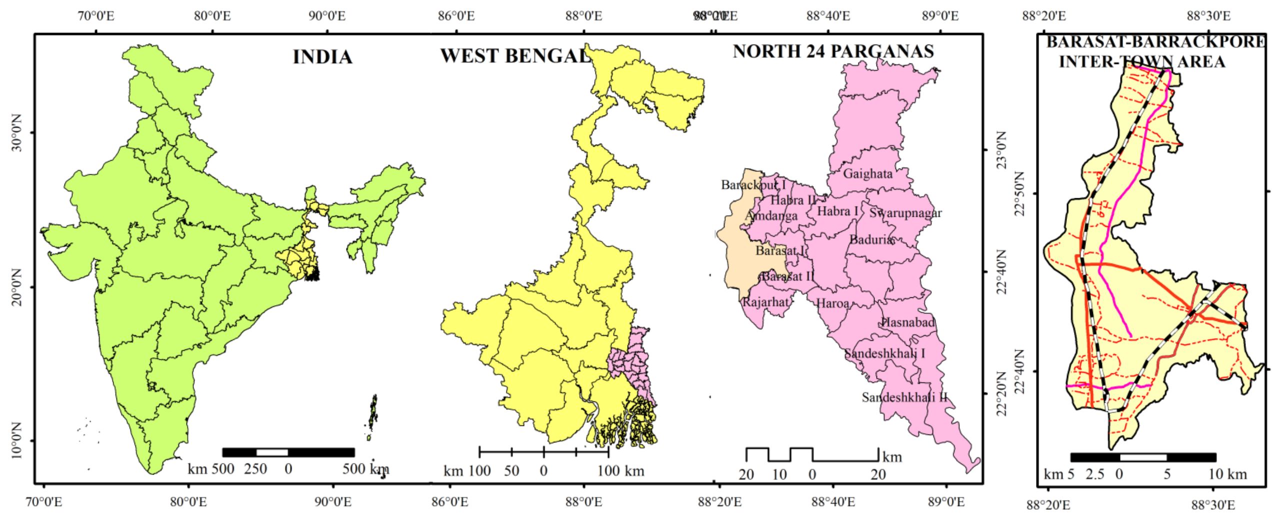
built-up areas, known as change of landscape pattern, occurring especially in the surrounding of the municipal urban areas between two towns. Rapid urbanisation and LULC changes are thought to be important contributors to environmental change [1].

The urban expansion is particularly important because it has significant effect on LULC change such as, agricultural lands and water bodies [2, 3]. The expansion of urban area requires more land and promotes the conversion of rural to urban LULC [4, 3]. Increasing human activity in urban areas has brought about profound changes in land use and landscape pattern at both local and global scales, and is having a marked effect on ecosystem structure, function, and dynamics, making urban areas fragile regions [5, 6]. The spatial metrics can be a useful tool for objectively quantifying the structure and pattern of an urban environment directly from thematic maps, e. g. from remote sensing mapping products [7]. In today's world, around half of the global population lives in urban areas, and by 2050, it is projected to increase to about 65 per cent [8]. It is worthy to mention that the eastern and northern parts of Kolkata are more sprawling than southern and western parts [9]. Similarly, the north-eastern and south-eastern regions of the Kolkata Urban Agglomeration area have experienced urban growth in their sub-urban fringe in the form of satellite towns [10]. The peri-urbanisation was taken place in the peripheral area of the municipalities, urban centres and daily commuters' zones of North 24 Parganas District [11]. Remote sensing and GIS techniques have been widely used for assessing and monitoring spatial patterns of urban growth during in the past few years [12, 13]. Remote sensing offers valuable multi-spectral data sets that cover both positional spatial detail and high temporal frequency [14].

The main objectives of this study are to analyse the trend and pattern of urbanisation, to assess the land use and land cover change detection, pixel-based transition of land use categories and growth of urban landscapes, to investigate the dominant factors and consequences of urbanisation, and to suggest suitable planning and land management strategies for sustainable urban development in the study area.

The most previous studies have focused on urban core area of Kolkata Metropolitan Area and Eastern fringes of Rajarhat areas. Although, several studies have examined urban expansion within the Kolkata Metropolitan Area, limited attention has been analysed to inter-urban transformation between Barasat and Barrackpore, particularly with respect to peri-urban land conversion dynamics. This study examines the dynamics of urban extension as well as LULC cover change and urban growth, particularly in the inter-town areas which is very significant contemporary issues in urban study. This transition zone is undergoing rapid transformation, influenced by adjacent of metropolitan, transport connectivity, employment opportunity, availability and affordability of lands and fragmented urbanisation. It integrates multi-temporal remote sensing data, GIS-based spatial analysis, and urban growth dynamics assessment to evaluate the pixel based transformation the study area. The study may assist policymakers, urban planners, and regional authorities in promoting sustainable land management, ecological conservation, and infrastructure planning in the study area.




Source: District Census Handbook, West Map Atlas, 2011

***Figure 1.*** *Location of the study area*

## 2. The Study Area

Barasat-Barrackpore urban area is located in the south-western part of North 24 Parganas District and is an extended part of the Kolkata Metropolitan Area (KMA). It lies between 22°35'45"N and 22°57'25"N latitudes and 88°19'45"E and 88°33'40"E longitudes (Figure 1), covering an area of 369.70

km$^2$, including Barrackpore- I & II and Barasat-I & II Community Development blocks. Barasat is the administrative headquarters of the district, while Barrackpore town is a military and administrative town since the British colonial period. As per the census of India, 2011, the study area has 19 municipalities out of which 27 municipalities, 37 Census towns out 78 CTs, 4 out growth and one Cantonment Board in the North 24 Parganas District. Level of urbanisation in these blocks is above 80%, indicating that Barasat- Barrackpore urban region is one of the most highly urbanised areas in the North 24 Parganas District. The study area is located in the lower part of the Ganga–Bhagirathi deltaic plain, bounded by the River Hugli to the west and the River Suti to the east. The climate is tropical wet and dry, characterised by high summer temperatures, heavy monsoonal rainfall, and high relative humidity during the monsoon season. The deltaic plain is predominantly composed of younger alluvial soils, ranging from sandy deposits along the riverbeds to sticky clay in the interior, with silty sediments in silted-up streams and muddy soils in swampy areas. The vegetation cover mainly consists of homestead plantations, which are widely distributed throughout the study area.

## 3. Databases

The secondary data on urbanisation were calculated from *District Census Handbook* and *District Census Statistical Handbook* (Census of India, 2001 and 2011). Cloud-free and geometrically corrected Landsat satellite images were acquired from the USGS Earth Explorer. These included a Landsat 5 Thematic Mapper (TM) image (Path 138, Row 44) acquired on 14 November 1990, a Landsat 7 Enhanced Thematic Mapper Plus (ETM+) image (Path 138, Row 44) on 17 November 2000, a Landsat 5 TM image (Path 138, Row 44) on 6 February 2010, and a Landsat 8 Operational Land Imager (OLI) image (Path 138, Row 44), and on 2 February 2020 along with spatial resolution of 30 m × 30 m.

## 4. Methods

### 4.1. Land Use Classification and Change Detection

Land use and land cover (LULC) classification was prepared by using the Maximum Likelihood Algorithm under the supervised classification method in ArcGIS 10.2. Change detection analysis is a highly effective approach for identify and quantifying the changes in different classes of landscape categories, like increase in urban built-up area or decrease in vegetation cover etc. Post-classification change detection has been employed as it reduces the possible effects of spectral resolution and sensor differences between the multi-temporal images [19]. The change detection can be expressed using the following formula:

$$Change(\%) = \frac{LA_{Finalyear} - LA_{Inttialyear}}{LA_{Inttialyear}} \times 100 \quad (1)$$

### 4.2. Accuracy Assessment

Accuracy assessment requires a reference map or 'ground truthing' data to validate image classification results. The producer's accuracy, user's accuracy, overall accuracy, and Kappa coefficient (κ) were computed by applying confusion matrices to evaluate the accuracy assessment of the classified LULC maps. Classification accuracy is usually measured by Kappa Index [15]. Cohen's Kappa index is a multinomial sampling model widely used to measure the accuracy [16]. Kappa values are characterized as <0 as indicative of no agreements, and 0–0.2 as slight, 0.2–0.41 as fair, 0.41–0.60 as moderate, 0.60–0.80 as substantial and 0.81–1.0 as an almost perfect agreement [17, 18]

$$Kappa(\kappa) = \frac{P_0 - P_e}{1 - P_e} \quad (2)$$

where $P_0$ is the observed proportion of agreement and $P_e$ is the proportion of agreement that may be expected to occur by chance.

### 4.3. Transition Matrix of Land Use and Land Cover Classes

The cross-tabulation matrix or transition matrix was used to assess the landscape characteristics conversion/transition by following obtain maps from time 1 and time 2 [20] pairs of components as follows,

***Table 1.*** *Cross-tabulation matrix for comparing two maps from different points in time.*

| Time 1 | Time 2 | | | Total Time 1 | Loss |
|---|---|---|---|---|---|
| | Category 1 | Category 2 | Category 3 | | |
| Category 1 | $P_{11}$ | $P_{12}$ | $P_{13}$ | $P_{1+}$ | $P_{1+} - P_{11}$ |

| Time 1 | Time 2 Category 1 | Category 2 | Category 3 | Total Time 1 | Loss |
|---|---|---|---|---|---|
| Category 2 | $P_{21}$ | $P_{24}$ | $P_{23}$ | $P_{2+}$ | $P_{2+}$ - $P_{22}$ |
| Category 3 | $P_{31}$ | $P_{32}$ | $P_{33}$ | $P_{3+}$ | $P_{3+}$ - $P_{33}$ |
| Total Time 2 | $P_{+1}$ | $P_{+2}$ | $P_{+3}$ | 1 | |
| Gain | $P_{+1}$ - $P11$ | $P_{+2}$ - $P_{22}$ | $P_{+1}$ - $P_{33}$ | | |

Source: [20]

The transition matrix follows the format (Table 1) in which the rows represent the categories of time 1 and the columns categories of time 2. The $P_{ij}$ indicates the proportion of the landscape that determines the transition from category *i* to category *j* where the number of categories is *J*. The entries on the *diagonal indicate persistence*, thus $P_{jj}$ represents the proportion of the landscape of category *j*, while e*ntries off the diagonal indicate* a transition from category *i* to a different category *j*. In the *Total column,* the $P_{i+}$ denotes the proportion of the landscape in category *i* in time *1*, which is the sum over all *j* of $P_{ij}$, while in the *Total row,* the $P_{+j}$ denotes the proportion of the landscape in category *j* in time 2, which is the sum over all *i* of $P_{ij}$. The additional column on the right denotes the gross loss of category *i* between time 1 and time 2, while the additional row on the bottom gross gain of category j between time 1 and time 2 in the proportion of the landscape. The matrix was analysed using a chi-square test [20] (Pontius et al. 2004), which compares the matrix of observed values to a matrix of expected values. The chi-square test estimates the expected values by assuming that each total, $P_{i+}$ and $P_{+j}$, is given a priori. The expected proportion of the landscape pattern that experiences a transition from category i to category j due to random chance is $P_{i+}$ times $P_{+j}$, where N is the number of grid cells in the map. The equation can be expressed as follows,

$$X^2 = \sum_{i=1}^{j} \left\{ N \times \frac{\left[P_{ij} - (P_{i+} \times P_{+j})\right]^2}{\left(P_{i+} \times P_{+j}\right)} \right\} \quad (3)$$

The transition matrix is prepared using cross tabulation technique in ArcGIS 10.2 and Microsoft Office. It provides detailed information on the major changes in LULC classes in the study area.

## 4.4. Normalised Difference Built-up Index (NDBI)

NDBI has been used to differentiate the built-up and non-built-up areas, which is validated by classified LULC maps for the year of 1990, 2000, 2010, and 2020. It is derived by using the following formula [21].

$$NDBI = \frac{SWIR - NIR}{SWIR + NIR} \quad (4)$$

where, SWIR denotes the Short Wave Infrared band and NIR the Near Infrared Band. The Normalised Difference Built-up Index (NDBI) was calculated using Band 5 (SWIR) and Band 4 (NIR) of Landsat TM, and Band 6 (SWIR) and Band 5 (NIR) of Landsat 8 OLI. The value of NDBI varies from - 1 to + 1. Values between 0 and +1 generally indicate built-up, while the values nearer to 1 indicate high density of built-up areas. Urban sprawl matrix is used to quantify the urban landscape pattern, and to analyse urban expansion [22]. Urban spatial pattern is categorised in four classes based on the spatial matrix function of urban pixels (Table 2).

***Table 2.*** *Categories of urban spatial patterns of the study area.*

| Urban spatial pattern | Criteria |
|---|---|
| Urban core area | The highest contiguous group of built-up pixels in which at least 50% of the surrounding neighbourhood is highly built up |
| Peri-Urban area | Built-up pixels that have neighborhoods with 30 -50% built-up |
| Scatter Settlement | Built-up pixels that have neighborhoods that are less than 30% built-up and not belonging to a ribbon development |

| Urban spatial pattern | Criteria |
|---|---|
| Open space | The non-urban patches surrounding urban core and peri-urban areas |

Source: Prepared by authors

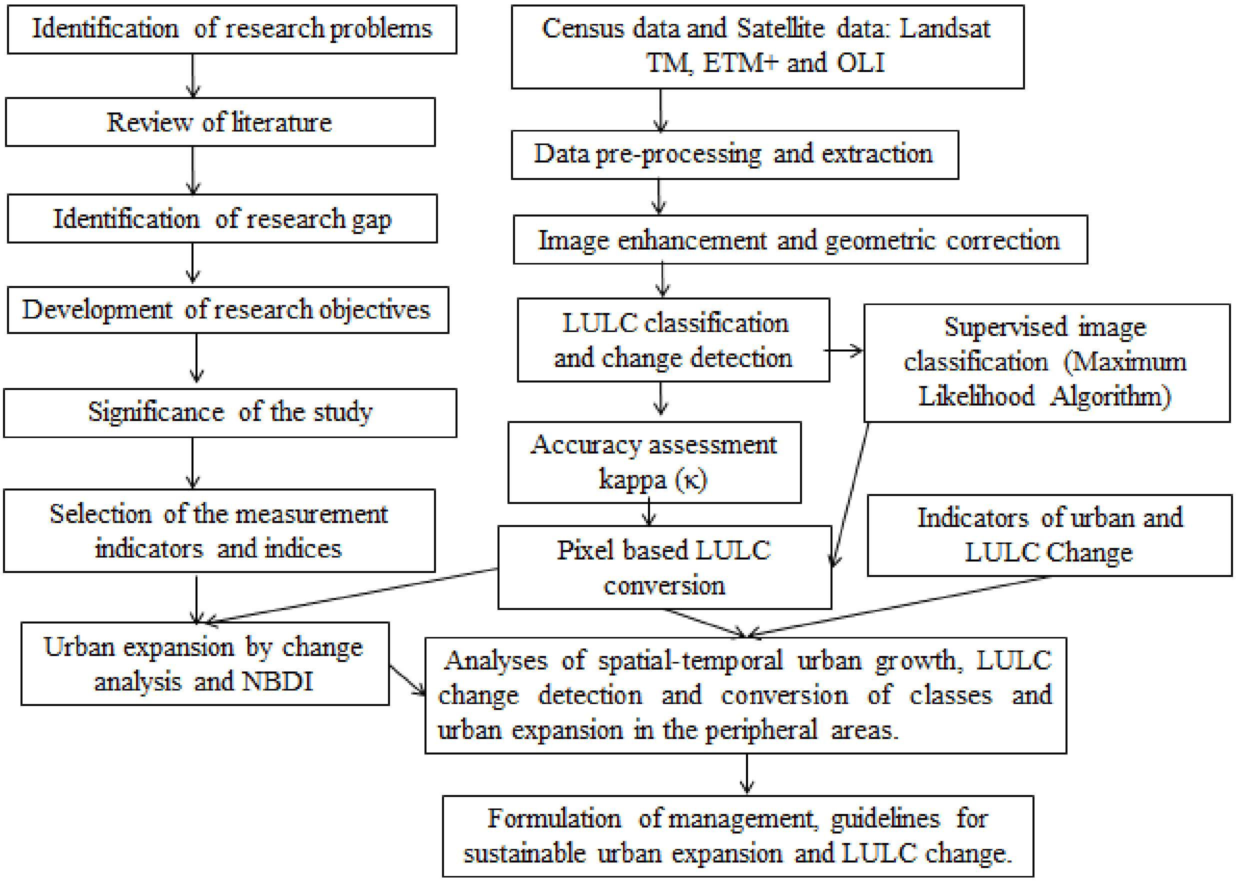
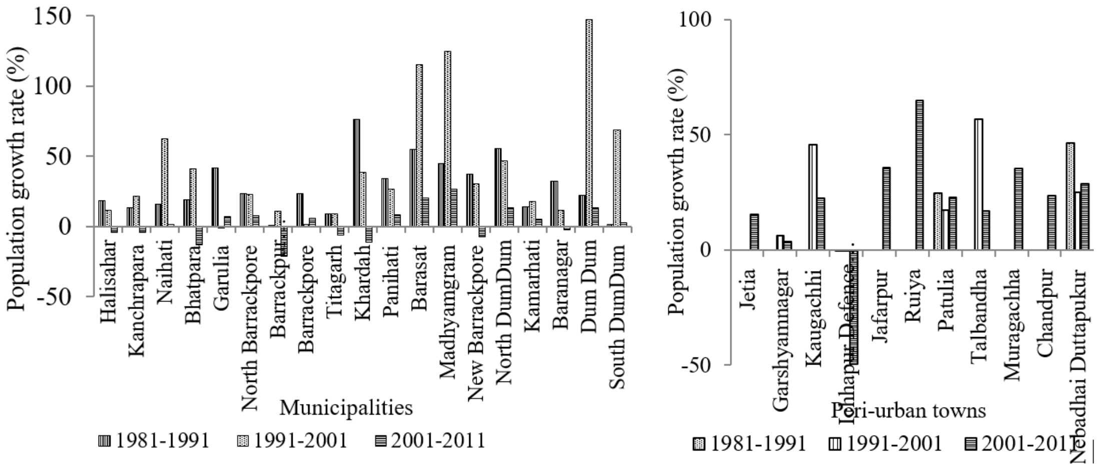



***Figure 2.*** *Methodological Framework of the study.*

## 5. Results and Discussion

### 5.1. Assessment of Urbanisation

North 24 Parganas District is one of the highly urbanised districts in West Bengal. The percentage of urban population to total population is 57.52%. The Barasat- Barrackpore urban agglomeration, an extended part of Kolkata Metropolitan Area (KMA), is situated in the south-western part of district. The share of urban population in Barasat and Barrackpore region accounts 72% of the total population, of which 70% resides in municipalities and 47% in census towns. The region has experienced significant urban growth, recording an increase of approximately 23% during the period 2001–2011. Similarly, urban households belong to 72%, while growth rate of urban household reached approximately 30% during the same period. The share and growth rate of urban units were around 54% and 80%, respectively. Notably, the census towns increased remarkably nearly 236%, which determines the rapid process of urban expansion in the study area. Furthermore, the study area experienced a substantial population growth rate of approximately 24.35% during the period 1991-2011. This demographic expansion can be basically recognised by in-migration, including cross-border immigration from Bangladesh since 1971, as well as the continuous influx of population from adjacent rural and peri-urban areas. Consequently, this study area has emerged as one of the most dynamic region within the Kolkata Metropolitan Area, characterised by rapid demographic change, built-up expansion, and LULC change.




Source: District Census Handbook, Census of India. 2011

***Figure 3.*** *(a) Trend of population growth in munipalities towns (b) Trend of population growth in peri-urban towns*

The very high population growth rate, exceeding 50%, was observed in South Dum Dum, Nahati and Dum Dum municipalities, while negative population growth was experienced in Bhatpara (-13.2%), New-Barrackpore (-7.3%), Titagrah (-6.2%), Halisahar (-4.3%) and Kanchnapara (-4.2%) municipalities during the period 2001- 2011(Figure 3a). These contrasting demographic patterns indicate the population redistribution within the study area. The patterns of demographic restructuring particularly concentration of population growth has found in the selected municipalities and peripheral towns, while older industrial municipalities exhibited demographic decline [23].

The growth of urban households was comparatively moderate around 25% in municipal urban areas rather whereas census towns (CTs) exhibited a comparatively higher rate of household expansion. Furthermore, negative growth in urban households was observed in municipalities such as Titagrah, Khardah, and Panihati municipalities reflecting the the decentralisation of residential houses in some of the older centres. On the other hand, the peri-urban towns experienced the considerable population growth in the urban fringe area. The population growth rates recorded above 25% in the peri-urban towns such as Jafarpur, Chandpur, Ruiya, Talbandha, Muragachha and Kaugachi during 2001-2011(Figure 3b). So, the trend of urbanisation is almost static or negative in municipal urban areas, whereas it was very increasing in the census town at the peri-urban areas. It reflects the increasing of residential development, driven by the availability and affordability of lands and transportation connectivity in the Barasat-Barrackpore urban area.

Therefore, it is stated that the pace of urbanisation has become relatively stagnant or, in some cases, negative in municipal urban areas, whereas the census towns have emerged as the urban growth centres located in the peri-urban areas. This trend determines the continuous process of peri-urbanisation and spatial redistribution of population from the municipal urban core towards the peripheral areas [24] in the study area. So, the outward movement of population and rapid expansion of peri-urban towns may build the new frontiers of urban development within Kolkata Metropolitan Area (KMA).

## 5.2. Classification of LULC Map

The land use and land cover pattern of a region is an outcome of the underlying natural and socio-economic factors. Changes of urban land use are a man-induced phenomenon in any urban region, especially in urban fringe areas, where dynamic of land use are the significant and challenging issues to the urban planner and policy makers. The change detection analyses describe and quantify the differences among LULC classes with the same spatial units over different time perods. This analysis is very much helpful to identify various changes in various land-use categories, such as the expansion of built-up areas and the decline of vegetation cover, agricultural land, and other land-use classes between 1990 and 2020 (Figures 4a–4d) in the study area.

In 1990, the built up area covered 103 km$^2$, while agricultural land, fallow land, vegetative cover, and wetlands occupied 126.60 km², 10.88 km², 103.37 km², and 14.63 km², respectively (Figure 4a). Similarly, the built up area had increased to 119.76 km$^2$, accompanied by the growth in agriculture 133.12 km$^2$ and fallow land 14.26 km$^2$, while vegetation cover and wetlands declined to 79.25 km$^2$ and 12.25 km$^2$, respectively in 2000 (Figure 4b). During, 2010, the built up area expanded significantly to 169.60 km$^2$, whereas the agriculture land, vegetation cover, fallow land and wetlands have gradually declined to 120.02 km$^2$, 55.90 km$^2$, 5.72 km$^2$, and 7.40 km$^2$, respectively (Figure 4c). Finally, the built-up area has reached 208.96 km², while agricultural land decreased to 97.30 km², vegetation cover to 41.72 km², wetlands to 6.21 km², and fallow land to 4.27 km², respectively in 2020 (Figure 4d; Table 3). Therefore, it is revealed that the built-up area covered approximately two-thirds of the total area. The continuous growth of built-up areas denotes the rapid urbanisation and peri-urban growth, reflecting the increasing of urban landscape and its socio-economic activities in the study area.

*Table 3. LULC classification and change detection and accuracy assessment of classified images.*

| **LULC Class** | **LULC classification ($km^2$)** | | | | **LULC Classification (%)** | | | | **Change of LULC (%)** | | | **Total Change (1990-2020)** | **Avrage Rate of Change (1990-2020)** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **1990** | **2000** | **2010** | **2020** | **1990** | **2000** | **2010** | **2020** | **1990 - 2000** | **2000 - 2010** | **2010 - 2020** | | |
| Agricultural | 126.6 | 133.1 | 120.0 | 97.3 | 35.3 | 37.1 | 33.5 | 27.1 | 5.2 | -9.8 | -18.9 | -29.2 | -23.1 |
| Fallow Lands | 10.9 | 14.2 | 5.7 | 4.3 | 3.0 | 4.0 | 1.6 | 1.2 | 30.6 | -59.7 | -25.4 | -6.6 | -60.8 |
| Built-up | 103.2 | 119.7 | 169.6 | 209.0 | 28.8 | 33.4 | 47.3 | 58.3 | 16.0 | 41.7 | 23.2 | 105.8 | 102.5 |
| Vegetation | 103.4 | 79.3 | 55.9 | 41.7 | 28.8 | 22.1 | 15.6 | 11.6 | -23.3 | -29.5 | -25.3 | -61.6 | -59.6 |
| Wetlands | 14.6 | 12.3 | 7.4 | 6.2 | 4.1 | 3.4 | 2.1 | 1.7 | -16.3 | -39.5 | -16.2 | -8.4 | -57.6 |
| Overall Accuracy (%) | 85.51 | 88.49 | 86.25 | 87.21 | | | | | | | | | |
| Kappa Co-efficient (*k*) | 0.86 | 0.88 | 0.86 | 0.87 | | | | | | | | | |

Source: Prepared by authors

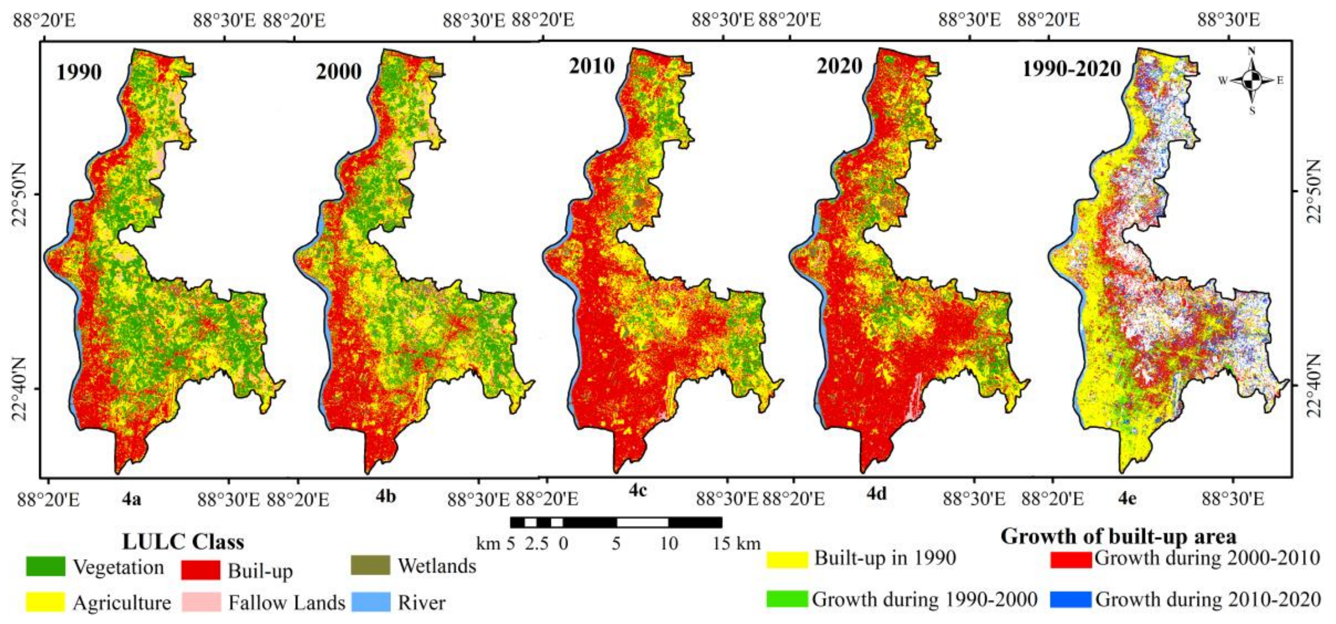



*Figure 4. (a- d) Classification of land use land land cover maps (e) Growth of built-up area in the study area.*

The five categories of land use and land cover classes have been delineated with a minimum of 250 reference points for each category to find out the classification of accuracy. The reference data has been collected by considering the stratified random sample points, the field knowledge and Google Earth Pro. The Global Positioning System (GPS) receiver is used to identify the exact position of the place by considering of latitude and longitude and visual observation. The overall accuracy of classification for years 1990, 2000, 2010, and 2020 were 85.51%, 88.49%, 86.25% and 87.21%, respectively with corresponding kappa (κ) statistics of 0.86, 0.88, 086 and 0.87 (Table 3). An overall classification accuracy of 85% or higher is commonly considered sufficient for a remote sensing data product [25].

### 5.3. Change Detection of LULC Map

The analysis of land use and land cove change reveals the significant transformation in the study area from 1990 to 2020 (Figure 5). The agriculture, fallow lands and built-up areas have increased in 5.18%, 30.59%, and 16%, whereas vegetative cover and wetlands have reduced in 23.33% and 16.26%, respectively during the period 1990-2000 (Table 3). It indicates the primarily urban expansion, accompanied by adjustments in agricultural practices and the transformation of natural land covers. During 2000-2010, the built-up area has increased in 41.68%, while agriculture has decreased in 9.8%, fallow land in 59.7%, vegetation cover in 29.5%, and wetlands in 39.5%, respectively in the study area. This period, the built-up areas have significantly increased converting from other LULC, reflecting developmental of urbanisation associated with population growth, infrastructural development, and the outward spread of urban activities. Lastly, the built-up area has increased 23.21%, while the agricultural land, fallow lands, vegetative cover and wetlands have reduced in 18.91%, 25.45%, 25.35%, and 16.19% respectively in periods of the 2010-2020. The continuous increase in built-up land demonstrates the sustained process of urbanisation and peri-urban growth within the study area.

So, during the last three decades, the built-up has increased in approximately 105.96 km², more than doubling its original extent and accounting for nearly one-third of the total area at an average rate of 26.44 $km^2$ per decade, while the agriculture land has reduced in 29.24 $km^2$ at an average rate 7.31$km^2$ per decade, fallow lands in 6.61 $km^2$ at an average rate of 1.65 $km^2$ per year, vegetative cover in 61.65 $km^2$ at an average rate of 15.41 $km^2$ per decade and lastly wetlands in 8.42 $km^2$ at an average rate of 2.10 $km^2$ per decade respectively (Figure 6). It clearly indicates that urban growth has occurred largely at the expense of agricultural land, vegetation cover, and wetlands, resulting in significant landscape transformation within the study area. The urban fringe areas experienced the rapid urban expansion through the transition of non-built up land uses into built-up areas, particularly in zones characterized by lower built-up density and greater land availability [26].

Urban expansion can be determined by several criteria, including population growth, availability of socio-economic facilities, and expansion of transport networks. In particular, the development and expansion of major transport corridors, such as the Kalyani Expressway and Belghoria Expressway, have significantly enhanced regional accessibility and stimulated urban growth along the routes in the study area. These infrastructural developments have influenced the conversion of non-built-up lands into residential, commercial, and industrial land uses. Furthermore, the spatial process of urban expansion exhibits a strong relationship with proximity to major transportation connectivity and distance from established urban centres, which indicates that the roads have being taken the most important driver for urban expansion of the study area.

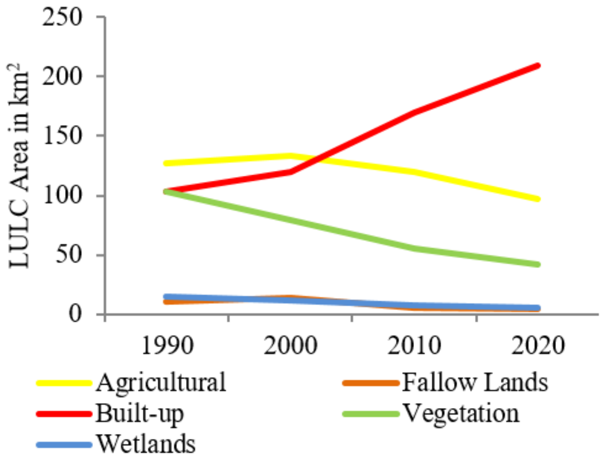



*Figure 5. Trend of LULC class from 1990 to 2020.*

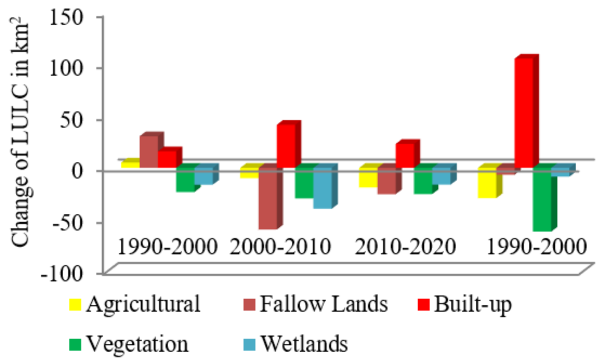



*Figure 6. Change detection analysis of LULC classes from 1990 to 2020.*

### 5.4. Conversion of LULC Classes

Analysis of land use and land cover transition is an important approach for identifying the extent and direction of transformations among different land-use categories over time. The transition matrix provides comprehensive information of the gains, losses, and persistence of each individual land-cover classes for explaining the spatial dynamics of landscape transformation [20]. It provides detailed information on how specific land-cover classes are converted into other categories and quantifies the corresponding area involved in such transitions. Cross-tabulation analysis helps as an effective tool to determine the magnitude and pattern of conversions from a particular land cover to another land cover category in certain duration. The nature and dynamics of the changes of different LULC classes can be examined through land use and land cover transition matrices based on post classification comparison techniques [27]. These transition matrices determine for identification of dominant land-use transitions and landscape transformation processes within the study area, presented in Tables 2, 3, and 4.

### 5.4.1. Conversion of LULC Classes from 1990 to 2000

The transition matrix of landscape pattern was prepared to understand the increase and or decrease in different LULC classes during the period 1990-2000 (Table 4). Agricultural lands have increased to133.23 km$^2$ in which 74.88 km$^2$ agricultural lands in 1990 was remain agriculture land in 2000. This land was increased by converting from 6.14 km$^2$ fallow lands, a major part of 33.12 km$^2$ vegetative cover, and a smaller portion of 0.66 km$^2$ wetlands (Figure 10a). These changes were mainly observed in the eastern rural and non-municipal urban areas of the study area (Figure 7a). The gain of fallow lands have increased in 3.33 km$^2$, by converting from 6.41 km$^2$ agricultural lands and 0.399 km$^2$ vegetative cover, while converted into 3.39 km$^2$ built-up (Figure 10b), happing in the urban fringe area of the study area (Figure 7b). The built-up area has increased to 119.76 km$^2$, by converting from 22.97 km$^2$ agricultural, 11.90 km$^2$ vegetative cover, 8.50 km$^2$ wetlands (Figure 10c), occurring in the sub-urban region of Barasat and Brrackpore (Figure 7c). Vegetative cover has declined to 79.25 km$^2$, with 19.17 km$^2$ converted into agricultural land, 5.01 km$^2$ into built-up land, and 0.89 km$^2$ into wetlands (Figure 10d). These transformations were mainly observed in Jetia, Nanna, and Khalishakota regions (Figure 7d). Similarly, wetlands have reduced to 12.25 km$^2$ in which it has transformed to 2.50 km$^2$ agricultural, 1.39 km$^2$ built-up and 3.82 km$^2$ vegetative cover (Figure 10e) in the eastern part of the study area (Figure 7e).

Agricultural lands increased because it provides maximum economic returns from cultivation more than other land use categories. Similarly, the fallow lands increased as building developer, industrialist and educational enterprises acquired the agricultural land, vegetative cover, and marshy land at relatively low prices along the major road connectivity. The built-up areas namely brickfield and industries at Jagatnathpur, Chak Barbaria, and Deara etc. in Barasat as well as Palladah, Jetia, Babanpur, and Jafarpur in Barrackpore have been converted into fallow lands during this period.

The built-up areas have increased due to the construction of residential apartments, real estate and individual houses, industrial establishments, and commercial building in the Barasat and Madhyamgram outskirts area, and road junction area at Warless Gate, Jetia, Patulia, Ruiya and Paltapara etc. In addition wetlands were reclaimed and converted into built-up land by developers and real estate promoters. Therefore, transition matrix of land use and land cover (LULC) indicates that urban expansion has occurred primarily through the shifting of agricultural land, vegetation cover, wetlands, and fallow land into built-up areas during 1990-2000. This transformation reflects the urban expansion and landscape restructuring characterised by urban encroachment into rural areas.

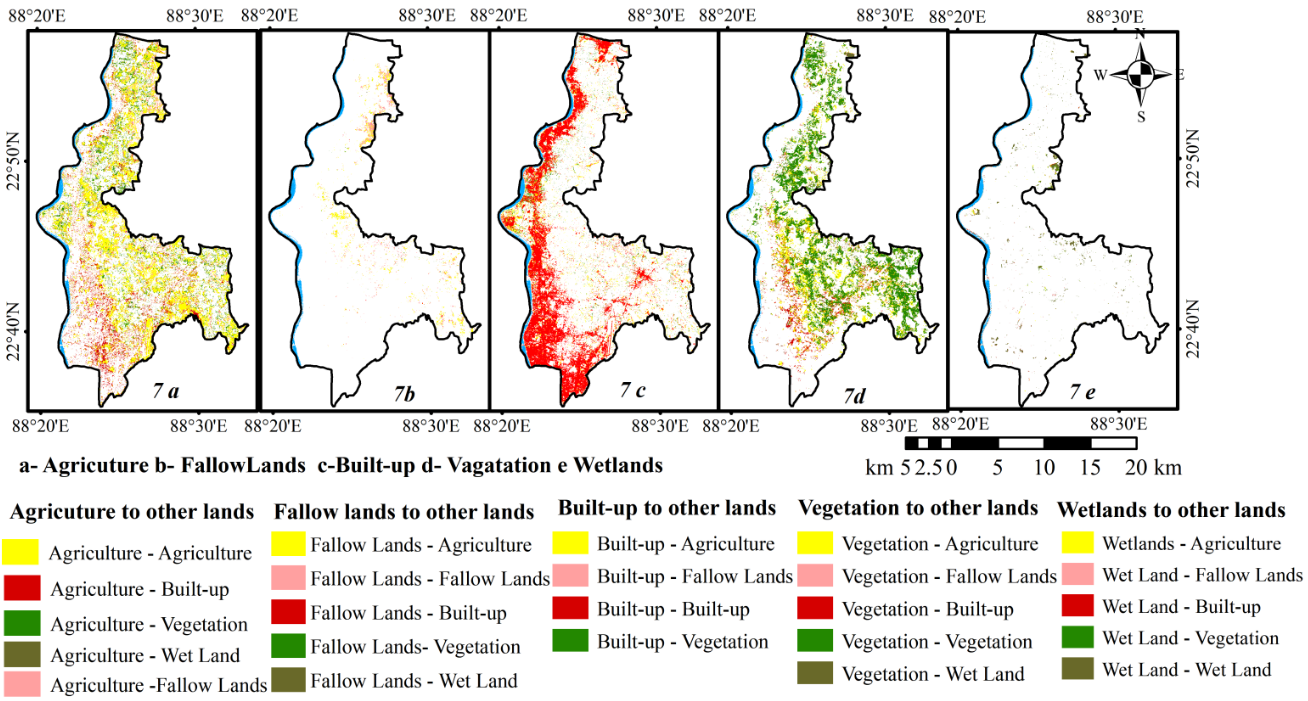



*Figure 7. Pixel-based conversion of LULC classes during 1990-2000 (a-e).*

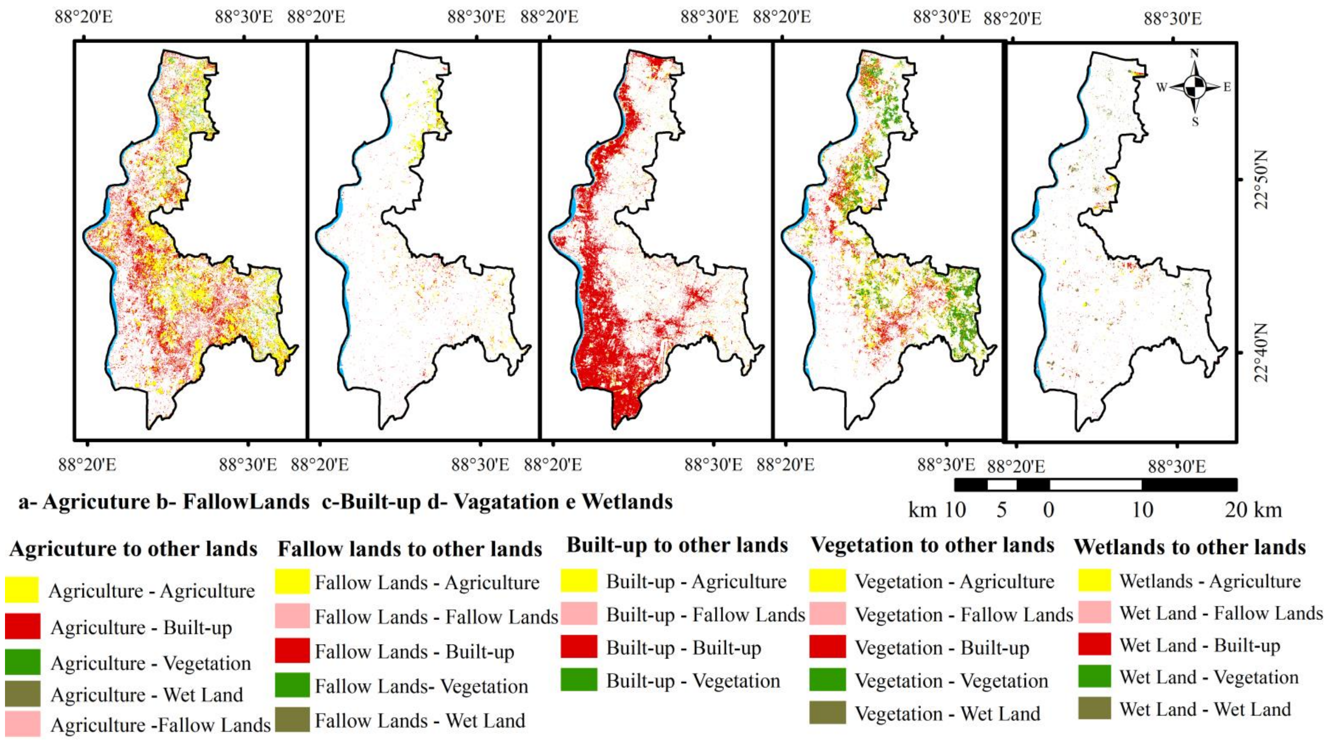



***Figure 8**. Pixel-based transformation of LULC classes during 2000-2010 (a-e).*

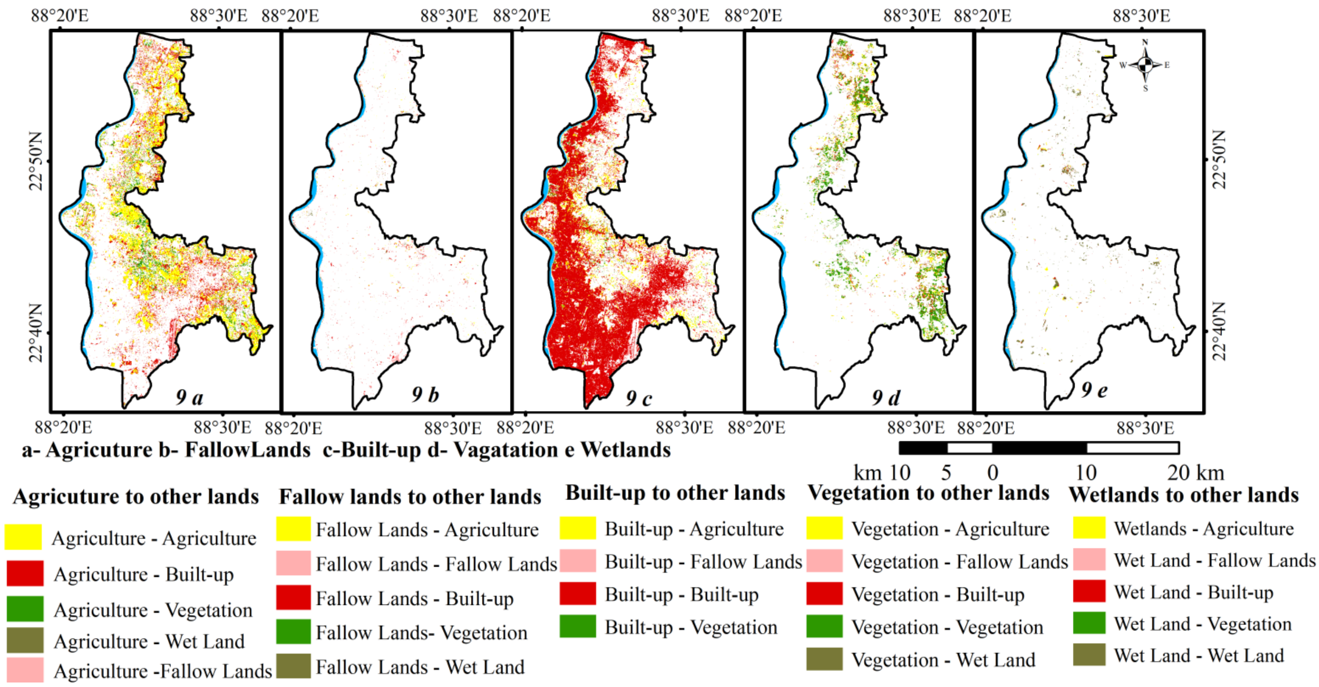



***Figure 9**. Pixel-based transition of LULC classes during 2010-2020 (a-e).*

*Table 4. The conversion matrix of LULC change from 1990 to 2000.*

| | LULC Classification | LULC Class-2000 Agriculture | Fallow Lands | Built-up | River | Vegetation | Wetlands | Grand Total |
|---|---|---|---|---|---|---|---|---|
| LULC Class-1990 | Agricultural | 74.88 | 6.41 | 22.97 | 0.07 | 19.71 | 2.5 | 126.56 |
| | Fallow Lands | 6.15 | 4.03 | 0.51 | 0.02 | 0.16 | 0.05 | 10.89 |
| | Built-up | 17.56 | 3.36 | 75.72 | 0.06 | 5.12 | 1.39 | 103.19 |
| | River | 0.01 | 0.03 | 0.1 | 10.33 | 0.01 | 0.69 | 11.13 |
| | Vegetation | 33.86 | 0.39 | 11.91 | 0.01 | 53.38 | 3.82 | 103.37 |
| | Wetlands | 0.67 | 0.02 | 8.49 | 0.76 | 0.89 | 3.81 | 14.64 |
| | Grand Total | 133.12 | 14.22 | 119.71 | 11.22 | 79.26 | 12.26 | 369.77 |
| | Change ($km^2$) | 6.57 | 3.33 | 16.51 | 0.09 | -24.12 | -2.38 | |
| | Change (%) | 5.19 | 30.59 | 15.97 | 0.81 | -23.33 | -16.26 | |

Source: Estimated by authors

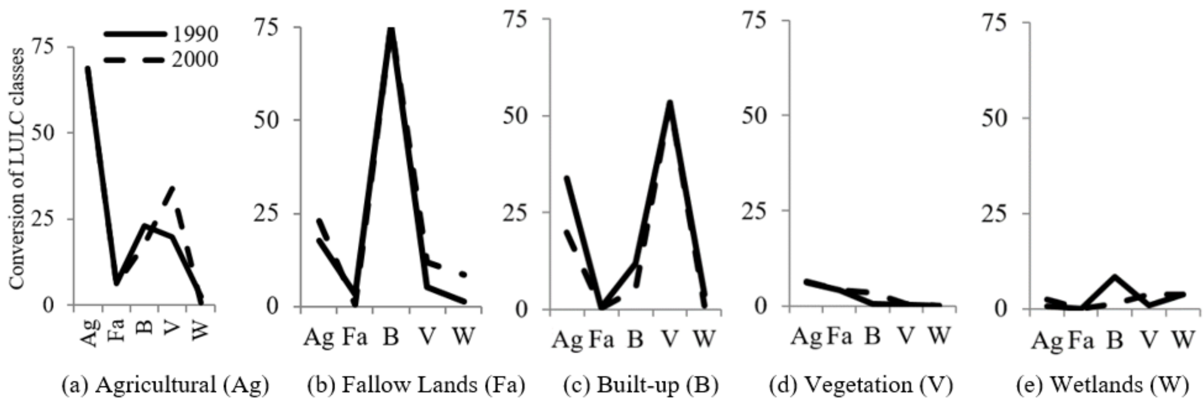



*Figure 10. The trends in conversion of land use and land cover types in the period of 1990-2000.*

### 5.4.2. Conversion of LULC Classes from 2000 to 2010

The land use and land cover conversion relationships became more direct and proportionate during the period 2000-2010 (Figure 8 and Table 5). Agricultural land declined by 120.02 km², of which 7.63 km² was converted into fallow land, 8.75 km² into built-up land, and 31.16 km² into vegetative cover (Figure 11a). These transformations were mainly observed in the southern, eastern, and northern parts of the study area (Figure 8a). The fallow lands also decreased by 5.72 $km^2$ in which 1.92 $km^2$ agricultural converted into agriculture land, 1.38 $km^2$ into vegetative cover, and 1.58 km2 into built-up areas, particularly in the north-eastern part and in the urban fringe areas of Barasat and Madhyamgram (Figure 8b and 11b). The built-up area has drastically increased to 49.89 km², by converting from 39.93 $km^2$ agriculture land, 4.39 $km^2$ fallow lands in, 21.89 $km^2$ vegetative, and 3.43 $km^2$ wetlands (Figure 11c). These changes were particularly evident in Jetia, Palladaha, Jagatnathpur, and Khalishakota (Figure 8c). Vegetative cover declined by 55.89 km², with a major portion (20.53 km²) converted into agricultural land in Sortribati and Mamudpur of Barrackpore-I, and 8.89 km² converted into built-up land in the Barasat region (Figure 11d and 8d). The wetlands have been reduced to 7.40 $km^2$, converting 1.31 $km^2$ into agriculture in Palladah and Poltapara, 0.65 $km^2$ into built-up in Wireless Gate and Muragachha, and 1.12 $km^2$ into vegetative cover in Mamudpur and Bartir Bill areas (Figure 11e & 8e).

Agricultural and fallow lands have both reduced because of th building developer, industrialist, and educational entrepreneurs have established their own projects on those lands by taking advantages of the following the well-connected transportation network in the study areas during 2000-2010. In addition, many local residents and migrants who preferred to settle in the peri-urban areas rather than in overcrowded urban area. The marshy or low-laying lands have also been extensively converted into built-up land, mainly in the Barasat and Madhyamgram outskirts and around major road junctions such as Wireless Gate, Jetia, Patulia, Ruiya, and Paltapara etc.

***Table 5.*** *The conversion matrix of LULC change from 2000 to 2010.*

| | LULC Classification | LULC Class-2010 | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | **Agriculture** | **Fallow Lands** | **Built-up** | **River** | **Vegetation** | **Wetlands** | **Grand Total** |
| LULC Class-2000 | Agricultural | 69.41 | 1.92 | 39.93 | 0.02 | 20.54 | 1.31 | 133.12 |
| | Fallow Lands | 7.63 | 1.35 | 4.37 | 0.01 | 0.81 | 0.05 | 14.22 |
| | Built-up | 8.77 | 1.52 | 99.76 | 0.15 | 8.86 | 0.66 | 119.71 |
| | River | 0.2 | 0.05 | 0.22 | 10.04 | 0.22 | 0.48 | 11.22 |
| | Vegetation | 31.17 | 0.38 | 21.89 | 0.1 | 24.59 | 1.12 | 79.26 |
| | Wetlands | 2.85 | 0.51 | 3.43 | 0.81 | 0.88 | 3.78 | 12.26 |
| | Grand Total | 120.02 | 5.73 | 169.6 | 11.12 | 55.89 | 7.41 | 369.77 |
| | Change (km$^2$) | -13.1 | -8.49 | 49.89 | -0.09 | -23.37 | -4.85 | |
| | Change (%) | -9.84 | -59.71 | 41.68 | -9.3 | -29.48 | -39.54 | |

Source: Estimated by authors

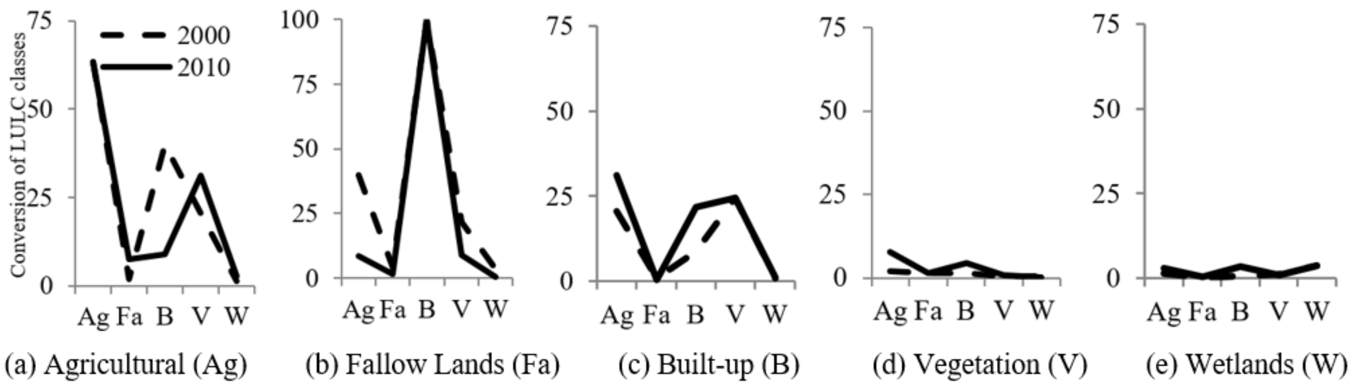



***Figure 11.*** *The trends in conversion of land use and land cover types during 2000-2010.*

### 5.4.3. Conversion of LULC Classes from 2010 to 2020

In the periods of 2010-2020, the different types of land categories have been transformed shown in Figure 8 and Table 6. The loss of agricultural land has reduced to 97.32 km$^2$, of which 12.59 km$^2$ was converted into built-up land, 12.96 km$^2$ into vegetative cover, and 1.04 km$^2$ into fallow land (Figure 12a), happening in the eastern parts in rural and non-municipal urban areas, including Mamudpur, Dogachia, Chhoto Kanthalia, and Surjapur (Figure 9a). The reduction in agricultural land was primarily driven by increasing pressure from developers to purchase farmland, higher market land values than the government-assessed land value, and the growing dependence of the younger generation on non-agricultural occupations. The fallow lands has decreased by 4.27 km$^2$, with a major portion (2.33 km$^2$) converted into built-up, while smaller portions were transformed into agricultural and vegetative cover (Figure 12b), occurring at Palladah Sotribati, and Jetia in the northen part, Telenipara and Mohanpur in the eastern part, and Airport, New Barrackpore, Sajirhat, and Madhyamgram in the southern parts of the study area (Figure 9b).

The expansion of real estate development, driven by developers and promoters purchasing fallow land for construction projects, has been a major factor contributing to the decline of fallow land. The built-up area has remarkably increased to 206.96 km$^2$, of which 34. 67 km$^2$ agricultural, 2.25 km$^2$ fallow lands, and 18.37 km$^2$ vegetative cover has been converted into built-up area (Figure 12c). These transformations were observed in the rural areas of Telenipara, Jafarpur, and Mohanpur in the eastern part, as well as Madhyamgram, Badu, and New Barrackpore in the eastern and south-eastern parts of the study area (Figure 9c). Rural-urban migration, the higher land values in core urban area compared with peri-urban areas, de-urbanisation in core urban area, and the movement of population from the urban core to the peri-urban fringe were the major influencing factors to the rapid expansion of the built-up area.

*Table 6. The LULC change matrix from 2010 to 2020.*

| | LULC Classification | LULC Class-2020 Agriculture | Fallow Lands | Built-up | River | Vegetation | Wetlands | Grand Total |
|---|---|---|---|---|---|---|---|---|
| LULC Class-2010 | Agricultural | 69.28 | 0.33 | 34.68 | 0.02 | 13.64 | 0.09 | 118.02 |
| | Fallow Lands | 1.04 | 1.51 | 2.28 | 0.02 | 0.05 | 0.84 | 5.73 |
| | Built-up | 12.95 | 2.34 | 150.81 | 0.01 | 3.42 | 1.08 | 169.6 |
| | River | 0.01 | 0.03 | 0.1 | 11.01 | 0.03 | 0.05 | 11.12 |
| | Vegetation | 12.96 | 0.05 | 18.37 | 0.01 | 24.44 | 0.05 | 55.89 |
| | Wetlands | 1.07 | 0.03 | 0.83 | 0.23 | 0.15 | 5.11 | 7.41 |
| | Grand Total | 97.32 | 4.27 | 206.96 | 11.29 | 41.72 | 6.21 | 369.77 |
| | Change (km2) | -22.71 | -1.46 | 39.37 | 0.16 | -14.17 | -1.2 | |
| | Change (%) | -18.92 | -25.44 | 23.21 | 1.46 | -25.35 | -16.2 | |

Source: Estimated by authors

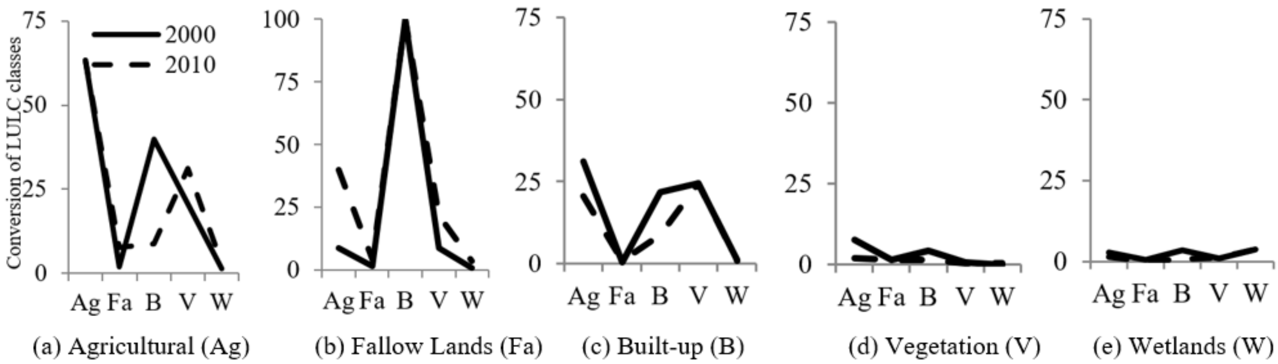



*Figure 12. The trends in conversion of landuse and land cover types in the period of 2010-2020.*

The vegetative cover has reduced to 55.88 km$^2$, transforming to 13.63 km$^2$ agricultural, 3.42 km$^2$, built-up, and 1.05 km$^2$ fallow lands (Figure 12d), observing in Piragacha, Bara, Tentulia, Chandigori, and Kirtipur of Barasat-I in the eastern part of the study area (Figure 9d). Agricultural land offers higher economic returns than vegetative cover, while single family dwellers have purchased relatively low price land for residential purposes in the peri-urban areas. Similarly, wetland area reduced to 6.02 km$^2$, of which a major portion approximately 1.08 km$^2$ has converted into built-up areas, while and small portions into agricultural, vegetative cover, and fallow lands (Figure 12e), observing at Berunanapukuria (West Bengal State University), Jagatnathpur and Barberia in Barasat-I, Palashi and Nagdah Barrackpore-I, and Muragacha, Teghari and Chandpur Barrackpore-II C. D. Blocks (Figure 9e) in the study area.

In this period, the agricultural and fallow lands have been converted into built-up area, particularly for developments such as Adamas Knowledge City, Adamas University, and the Anandabazar Newsprint House at Jaganathpur along the Barrasat- Barrackpore Road, B. T. Road, Kalyani Expressway, Jessore Road (NH6) and Krishnanagar Road (NH34). Similarly, built-up areas have increased substantially through the shifting of marshy land to built-up area, mainly in Barasat – Barrackpore urban outskirt. In contrast, wetlands remained largely unchanged, reflecting increased public awareness and consciousness of ecological importance of wetland in urban areas. In addition to urban wetland conservation and management, it was emphasised on the creation of new ponds under the "Jal Dhoro and Jal Bhoro" project initiated by the West Bengal Government in the year of 2010- 2020.

## 5.5. Urban Expansion in Inter-Towns Areas

The spatial expansion of urban areas was analysed using the Normalized Difference Built-up Index (NDBI), one of the most widely used spectral indices in remote sensing for identifying and monitoring built-up areas. The spatial growth patterns, including the urban core, peri-urban areas, scattered settlements, and open spaces, are presented in Table 7. In 1990, scattered settlements occupied a larger area than the urban core, peri-urban areas, and open spaces within the study area (Figure 13a). However, these spatial patterns changed considerably over time. The peri-urban area increased rapidly between 2000 and 2020, whereas the extent of scattered settlements and open spaces gradually decreased (Figures 13b–13d). In contrast, the urban core expanded at a comparatively slower rate than the peri-urban area. These findings indicate that scattered settlements and open spaces were progressively transformed into peri-urban areas, reflecting the outward expansion of urban development within the study area.

*Table 7. Change of urban built-up area in different urban areas from 1990 to 2020.*

| Urban landscape pattern | Area in in km$^2$ | | | | Change in km$^2$ | | |
|---|---|---|---|---|---|---|---|
| | 1990 | 2000 | 2010 | 2020 | 1990- 2000 | 2000-2010 | 2010-2020 |
| Urban core Area | 85.34 | 95.84 | 102.14 | 106.88 | 10.5 | 6.3 | 4.74 |
| Peri-Urban Area | 56 | 71.74 | 124.79 | 165.3 | 15.74 | 53.05 | 40.51 |
| Scatter Settlement | 189.86 | 173.6 | 113.23 | 85.11 | -16.26 | -60.38 | -28.12 |
| Open Space | 38.36 | 29.37 | 20.43 | 15.3 | -8.99 | -8.94 | -5.13 |

Source: Calculated by authors

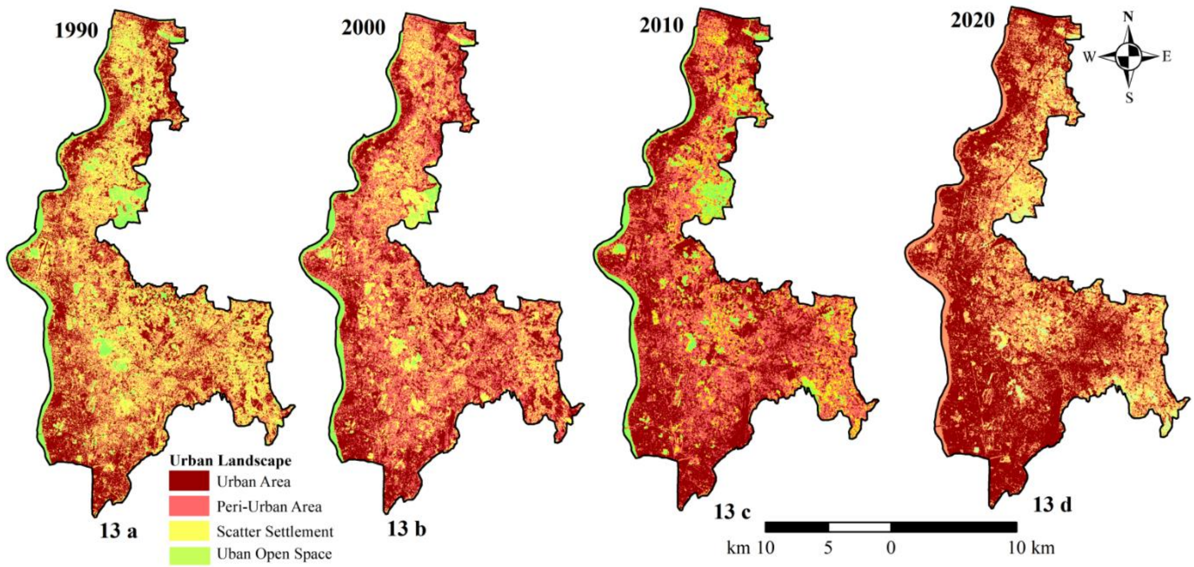



*Figure 13. Temporal dynamics of urban built-up areas from 1990 to 2020 (a-d).*

The urban core area has increased to 10.5 km$^2$, primarily concentrated within the municipalities located on the eastern bank of the River Hugli, extending with an average 1.5 km radial distance in the northern region of Halisahar, Kanchnapara and Naihati and 2.5 km in the southern part, extending from north to south during 1990-2000. Peri-uban area has also increased to 20.74 km$^2$, located in the boundary areas of the municipalities extending with an average outward extension of approximately 1.0 km in the southern region. Meanwhile, scattered settlements and urban open spaces declined to 16.25 km$^2$ and 8.99 km$^2$, respectively and were distributed across agricultural and fallow lands between the urban centres towards the eastern part of study area. Therefore, the process of urbanisation was basically concentered within the municipal urban core urban areas due to the availability of infrastructures and job opportunities associated in the Barrackpore industrial belt. Urban sprawling began to emerge in the southern region at Matkal, Badra, Bisarpara, Sultanpur, and Talbandha from Dum Dum to Barasat, and Kaugachhi, Sathirpara, Narayanpur, and Jafarpur along the Dum Dum-Barrackpore corridor. This expansion was mainly driven by the availability and affordability of land and the proximity of these areas to Kolkata.

Similarly, during 2000-2010, the urban core area increased to 10.50 km$^2$, becoming more agglomerated in the northern part of the study area, with a radial distance of approximately 2.0 km, while extending up to 3.5 km in the southern region. The sub-urban area has also drastically increased to 53.04 km$^2$, extending approximately 1.0 km in the northern part and 2.0 km in the southern region (Figure 13b). Although the extent of the urban core area remained relatively stable, and the process of de-urbanisation began after 2000, while the peri-urban areas continued to expand towards eastern part in the southern region of the study area. A distinct elongated or linear shaped urban expansion flourished extending from Dum Dum to Madhyamgram and Barasat. Meanwhile, scattered settlements and urban open spaces reduced to 60.37 km$^2$ and 8.99 km$^2$, respectively in the city area. Consequently, the urban growth is seen in inter-towns urban areas at Muragachha, Chandpur, Patulia, Ruiya, and Garshyamnagar, where edge expansion and outlaying urban growth patterns have found in the intermediate towns of Barasat and Barrackpore. A ribbon urban growth pattern has found along the Barasat-Barrackpore Roads and Kalyani Expressway in the study area.

Lastly, the urban core area has increased to 4.74 km$^2$, located between the municipalities' urban areas. However, the radial distance remained the same as previous during the period of 2010-2020, indicating an infilling pattern of urban landscape growth. The peri-uban area has also increased to 40.51 km$^2$ during this period. Meanwhile, scattered settlements and urban open spaces have reduced to 28.11 km$^2$ and 5.13 km$^2$, respectively and were located in agricultural and fallow lands towards the eastern part of the study area. It is known that urban built-up area looks like an elongated, blanket or carpet-like pattern extending from the south to north-east part across the peri-urban region, with a radial distance of approximately of 3.0 km in the northern urban area and about 6.5 km in the southern part between B. T. Road and Kalyani Expressway. The Barasat–Madhyamgram municipal urban agglomerations have been extensively expanding in all directions, following the Jessore Road (NH35), Taki Road, and Krishnanagar Road (NH34).

Consequently, the leapfrog pattern of urban growth has been observed in areas such as Barberia, Nilganj, Jagatnathpur, Muragachha, and Mohanpur, primarily driven by the existing roads and transports connectivity. It indicates the outward expansion of urban development beyond the contiguous built-up into the surrounding peripheral regions. The rural landscapes of Jatia, Nanna, Dangadhila, Dopere, Surjyapur, Jagberi, and Badai are likely to undergo substantial land-use transformation and become integrated into the expanding urban agglomeration due to continuous processes of urbanisation, development of infrastructures and increasing job opportunities in the study area. Peri-urban sprawling is highly occurring rapidly in the place of roads junction areas of Kalyani Expressway at Muragachha, Talbanda and Mohanpur regions, expanding from southerly to northerly across the Barrackpore subdivisions [28]. These trends reflect the increasing influence of infrastructural accessibility on the spatial dynamics of peri-urban growth and urban sprawl.

## 6. Causes and Consequences of Urban Sprawl

Urbanisation is termed as the shifting of from rural society into urban society, driven by social, economic and political developments. Urban growth and land use change are influenced by the economic, political, and social dynamics urban areas in comparison with rural areas. Peri-urban areas have been undergoing rapid transformation, especially in terms of spatial development, owing to their proximity to urban centres and availability and affordability of lands.

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### 6.1. Causes of Urban Sprawl

Urban amenities and facilities are primarily concentrated in municipal urban areas and are increasingly developing in peripheral urban areas, excepting in the rural areas within metropolitan region. Various forces, whether induced or autonomous, top-down or bottom-up, push and pull factors, simultaneously shape and reshape the peri-urban landscape into a distinct type of space [29]. Urban civilization offers a higher standard of living, better transportation, communication facilities, improved career prospects, greater access to education, and health services [30].

The Barasat–Barrackpore inter-town areas have wide scope for urban expansion due to the availability of fallow lands and one crop agricultural land along the Barrackpore Trunk Road (B. T. Road) and Kalyani Expressway, extending from Birati in the south to Knachanapara in the north. Urban expansion has primarily occurred towards the eastern part of the region because the western part is bounded by Hugli River, while river bank has long been characterised by dense settlement, old urbanisation and industrial development. As a result, recently negative population growth has been noticed in the municipal core urban areas (Figure 2), whereas the high positive population growth rate has been observed in the peri-urban areas (Figure 3). Similarly, another urban corridor has emerged in the north- eastern part of the KMA (9, 10), extending from Dum Dum to Barasat along the Jessore Road. The rate of urban expansion has been particularly rapid in the Barasat-Madhyamgram urban area due to availability of lands close proximity to the city, fallowing the road connectivity. Many villages surrounding Barasat namely, Sikdeshpukuria Jirat, Kashimpur, Kanthalia, Mandalganti, Bahera, Bara, Kadambagachhi have been converted into census towns, accompanied by an increase in built-up areas with a dispersed pattern.

The land value was relatively lower in the peri-urban areas and around the city than in the urban core. Land prices ranged from Rs. 2-3 lakh per katha (1 katha = 720 sq. ft. or 66.89 sq. m.) in the peri-urban areas, compared with Rs. 8–15 lakh per katha in the urban core of the study area in the year 2011 [31]. Consequently, the developer, building planners and commercial investor have preferred low-cost marshy lands for urban development. These lands were available along the Belghoria Expressway, Kalyani Expressway, and Basarat- Barrackpore State Highwasy. The Barasat and Madhyamgram urban areas have been preferred for residential purposes by low and middle income groups who have been buying the low price land close proximity to the city. As a result, urbanisations along with urban sprawl such as leapfrog patterns are developing at Noapara, Chotobazar and Nabapally, while ribbon patters are developing along the Barasat-Barrackpore Road (SH2), Barasat- Krishnagar (NH34), Jessore (NH 35) and Taki Road (SH2) in Barasat-Madhyamgram urban area. The rapid transformation of land, indicating urban “hotpots,” has been noticeably changed during the past 27 years in Barasat-Barrackpore urban area, located in the south-western part of the district [32].

Population growth was the significant factor of urban expansion and LULC change in the peri-urban areas rather than in the municipal core urban area. Rural to urban migration has been especially observed in the Barasat-Madhyamgram towns for residing and searching of job opportunities. In contrast, labour migration from Bihar and Jharkhand has been concentrated in the Barrackpore industrial areas. Consequently, local residents have been gradually relocating from the densely populated core urban areas to the surrounding peri-urban areas.

B. T. Road, Belghoria Expressway, Kalyani Expressway, Barasat-Barrackpore (SH12), Barasat- Krishnagar (NH34), Jessore (NH 35), Taki Road (SH2), and the connecting roads in inter-town areas namely Birati Road, Madhyamgram-Sodepur Road, Barrast-Barrackpore Road, Nilganj-Habra Road, Naihati-Habra Road, and Kanchanapara-Harighata Road are taking significant role of urban expansion and land use and land cover change in the urban fringe areas. Similarly, the Sealdah-Krishnagar Railways, Sealdah-Bongaon Railways and the proposed Noapara-Barrackpore Metro Railways (Pink Line) and Noapara-Barasat Metro Railways via Kolkata Bimanbandar (Yellow Line) are also extending urban expansion LULC change in the surrounding peripheral urban areas. The rapid urban growth has increased the demand of infrastructures, including highways, parking facilities, water supply, and electricity, contributed to increase pollution and shifting of agricultural and open lands into urban built-up areas [33].

## 6.2. Consequences of Urban Sprawl

The consequences of urban growth and land use and land cover change may have both positive and negative impacts. The positive implications of urban growth comprise higher economic growth, increased employment opportunities, improved livelihood, better infrastructure and enhanced public services, as known in Barasat and Barrackpore, and its surrounding transition areas. Rural-urban migration occurs in the peri-urban towns of Barberia, Muragachha, Mohanpur, and Bandipur, where these implications are significantly observed in the study areas.

On the other hand, the negative impacts of urban growth, including uncontrolled, uncoordinated, and haphazard urban expansion are generally more prominent than its positive impacts. Urban sprawl is a consequence of income and population growth, transportation systems, diverse user preferences, and increasing competition for land. However, it can also facilitate the expansion of essential public services such as transport connectivity, water supply, and sewerage systems, as well as other specialised services including better educational and health care facilities for the larger section of population [9]. These benefits have become increasingly evident in the peripheral areas of Poltapara, Srotribati, Ruiya, Mohanpur, and Bandipur within the study area.

Therefore, it is very essential to control the unchecked population growth, which contributes significantly to land use and land cover (LULC) change in the study area. A green belt is a land-use policy in which an area of agricultural or other vegetation land surrounding an urban area is preserved to restrict the outward urban expansion, which has been widely adopted in Britain [34]. Exclusive agriculture zoning methods have also been developed for conservation of farmlands in Oregon and Hawaii [35]. Annexation is another strategy for protecting the non-urban peripheral areas by preventing open-space annexation to the city [36]. Furthermore, the conservation of urban vegetation, urban wetland management, promotion of vertical urban growth, and control of rural-urban migration can contribute to the sustainable unban environment. The Smart City Policy also promotes compact pattern of urban development and redevelopment of existing built up areas. Finally, understanding the potential transformation among different the land use classes can provide valuable information for sustainable land resource management, appropriate land use planning, and identification of areas for potential urban development.

## 7. Conclusions

The transformation of land and urban sprawl matrix has provided a more efficient and accurate information of LULC change and urban expansion. De-urbanisation has been found in the towns of Titagrah, Bhatpara, Baranagr, and Khardah within the core urban area, where no further urban expansion is limited due to scarcity of available and affordable of lands. In contrast, rapid urbanisation has flourished along the Dum Dum, Madhyamgram and Barasat urban areas during the period 2000-2020. Agricultural and fallow lands have increased in some locations due to land acquisition by the promoters and developers for future urban development. The growth of urban core was higher than that of the peripheral urban region during 1990-2000. On the other hand, the built-up areas have drastically increased during 2000-2020 through the transforming the agricultural land, vegetative, fallow land, and wetlands to sub-urban fringe areas.

The exponential growth rate of population, improvements in transport networks and communication, the expansion of urban facilities, increasing job opportunities, and the availability and affordability land in the peri-urban areas have been the principal driving factors of LULC change and urban agglomeration in Barasat and Barrackpore inter-town areas. The urban expansions of Beijing and Tokyo cities occurred predominantly along radial corridors particularly major traffic and railway lines extending from the centre of the cities [37]. Similarly, the heterogeneous spatio-temporal patterns of urban expansion have been observed in the National Capital Territory (NCT) of Delhi and its peri-urban areas [26]. The rapid conversion of land, expansion of infrastructure, and real estate development have significantly altered land use and patterns, often leading to environmental degradation, loss of agricultural land, and the fragmentation of wetlands and open spaces in the Kolkata Metropolitan Area (KMA) [38]. Likewise, peri-urban growth in Bengaluru is strongly influenced by land markets and speculative urban development, where agricultural lands have been rapidly transformed into residential layouts and commercial zones [39]. But, urban expansion in the Barasat–Barrackpore inter-town area has occurred in a largely haphazard and often unplanned manner along the B. T. Road, Kalyani Expressway, Jessore Road, and the Sealdah–Krishnanagar and Sealdah–Bongaon Railway lines.

It is observed that an important area of investigation is land suitability analysis for the site selection of future urban expansion, considering both physical and socio-economic criteria for effective urban land use planning. Future research may also examine how changes of demographic pattern and change of landscape pattern would transform the socio-cultural and economic patterns in the study area. Finally, incorporating field-based validation and participatory approaches would strengthen the consistency of remote sensing and GIS-based analysis that would be helpful to prepare the proper land use map for sustainable urban growth and policy-relevant urban planning.

Therefore, the present research demonstrate that remote sensing and GIS techniques are effective for analysis of changing pattern of LULC, monitoring urban growth, and urban spatial patterns. Based on the observed trends in population growth, pattern of land conversion, and changes in the urban landscape, it is predicted that the population of urban core area would be migrated to the peri-urban fringes in the future. These peri-urban areas may likely to offer new opportunities for planned urban development and sustainable growth. So, appropriate urban planning and effective land use policy should be implemented for sustainable urbanisation in the inter-towns of the study area.

## Abbreviations

| | |
|---|---|
| GIS | Geographic Information System |
| LULC | Land Use and Land Cover |
| USGS | United States Geological Survey |
| NDBI | Normalized Difference Built-up Index |
| NIR | Near-infrared |
| SWIR | Short-Wave Infrared |
| TM | Thematic Mapper |
| ETM+ | Enhanced Thematic Mapper Plus |
| OLI | Operational Land Imager |

## Author Contributions

**Madhusudan Pramanick:** Conceptualization, Data curation, Methodology, Formal Analysis, Software

**Lakshminarayan Satpati:** Conceptualization, supervision, Investigation

## Conflicts of Interest

The authors declare that there is no conflict of interest.

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