International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 12 Issue 7 ǁ July 2024 ǁ PP. 246-262

An analytical study of urban expansion on the impacts of land use – land cover dynamics – A case study on Barasat Sub-division, North 24 Pargana

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Abstract
Urban expansion has become a serious concern in every part of India. Since independence, the North 24 Pargana district's urban areas have expanded significantly. According to data, the percentage of the population living in urban areas increased from 51.2 percent in 1991 to roughly 58.5 percent in 2021. This has brought about in a major growth of urban areas, which has led to an obvious transformation in land use and cover. The present study assesses the effects of urban expansion on the dynamics of land use and cover (LULC) on Barasat subdivision in North 24 Pargana district, during a 34-year period (1990–2024) by utilizing digital Landsat TM, ETM+, and Landsat OLI data till April of 2024. With a high classification accuracy, the LULC is divided into six classes. However, due to the impact of urban expansion on this entire region, urban settlement areas have grown by overall 30.35% (1990-2024), from 58.07 sq. km in 1990 to 270.0 sq. km in 2024, according to analysis. The majority of the lands transformed to urban settlement for this urban expansion are agricultural, vegetational and wet fallow lands, with very little encroachment on water bodies and dry fallow areas. To analyze the spatiotemporal dynamicity of LULC, this study utilizing the change index, transformation index, and temporal areal statistical method, to highlighting the other land use elements shifting trends to the urban land use in the Barasat subdivision landscape. Significant trends of LULC and urban expansion in Barasat subdivision for 34 years were strongly connected with population growth, technological advancement, economic development and other similar indexes.

Keywords: *LULC dynamics; Urban Expansion; Barasat Subdivision; change index; transformation index; temporal areal statistics.*

Date of Submission: 22-07-2024 Date of acceptance: 03-08-2024

I. INTRODUCTION

Over the past few decades, urban expansion—driven by urban growth—has been a common occurrence in emerging nations (Liu, Yue and Fan, 2011). Urban settlements grow and take up more space due to the rising of urban population. Urban development and densification are two possible ways that this expansion can appear (Angel, 2023). Global urban areas increased four times between 1970 and 2000, and estimates indicate that they will triple again between 2000 and 2030 (Seto *et al.* 2011and Seto *et al.* 2012). One of the most serious worldwide challenges, mostly affecting regions in Asia, Africa, and South America, is the rapid speed of urban expansion and the resulting changes in landscape (Chandel and Mathewos, 2023). Due to a variety of temporal and spatial scales, natural occurrences as well as anthropogenic activities have continuously altered the Earth's surface throughout history (Zhou and Chen, 2018). Natural landscapes are dramatically altered by urban expansion, with a variety of local and global effects (Patel, Verma and Singh, 2019), creating problems for the environment, ecosystems, and society. Loss of arable land puts the agricultural sector and food security at risk, while urban growth frequently results in a reduction in vegetation cover, disturbing regional ecosystems and reducing biodiversity (Bhat *et al.* 2017). The environmental implications are significant on increasing risks to populations' health, aggravating the effects of urban heat islands, and contributing to climate change. Along with increases the risk of air pollution, occupational threat, and traffic injuries clogged and badly maintained roadways due to urban expansion (Li *et al.* 2012).

India has seen an annual growth of urban areas of more than two percent since 2018 (timesproperty.com, 2024). Historically, West Bengal was one of the most urbanized states in the country, particularly in the early part of the 20th century (Ghosh and Chakma, 2014). Among its districts, North 24 Parganas ranked first in terms of the total population and ranked third in terms of urban population percentage, following Kolkata (first) and

Howrah (second) (Census of India, 2011). Urban areas have progressively moved towards surrounding rural and undeveloped areas as urbanization has rapidly increased. This trend is particularly evident in the North 24 Parganas district, where urban areas have rapidly expanded into surrounding suburbs. As a result of this movement, agricultural areas and natural ecosystems are under tremendous amounts of stress as they are being progressively encroached upon to make way for urban expansion (timesproperty.com, 2024).

Previous researches have mostly focused on the effects of urbanization, growth, expansion, or population dynamics on land use and land cover changes, typically within the boundary of a city or metropolitan assembly. (Mohan *et al.* 2011) analyzed the dynamics of urbanization and its impact on land-use and land-cover in the megacity of Delhi using urban growth parameters. To understand the impact of urbanization on land use and land cover changes within Pune Municipal Corporation (PMC) (Mundhe and Jaybhaye 2014) employed geospatial techniques. (Wu, Li and Yu, 2015) monitored urban expansion and its effects on land use and land cover changes in Guangzhou city, a major metropolitan area in South China, using remote sensing techniques. Where (Basu and Saha 2017) analyzed land use and land cover changes in relation to changing population scenarios in Barasat Municipality, North Twenty-Four Parganas, utilizing land use indices and statistical methods. The effect of urbanization on land use and land cover dynamics in Gombe Metropolitan, Gombe State, from 1976 to 2016, integrating remote sensing and Geographic Information System (RS/GIS) tools was examined by (Mbaya *et al.* 2019). On the other hand (Mishra *et al.* 2019) predicted the implications of urban expansion on land use and land cover in Mega Manila, Philippines, for sustainable development by 2030 using the Land Change Modeller. (Biswas and Sarkar 2019) studied sprawling urban growth in Barasat Municipal Town through geospatial technology. (Siddique, Ghosh and Roy, 2020) assessed urban expansion and associated spatial transformations in Chandannagar City using the Annual Growth Rate (AGR) and Land Use Integrated Index (LDI) to evaluate the rate, magnitude and nature of changes. The relationship between population dynamics and land use change in North 24 Parganas using geospatial techniques was analyzed by (Sen, Chatterjee and Das, 2021). To examined the impact of land use change and rapid urbanization on the urban heat island effect in Kolkata city, (Chatterjee and Majumdar 2021) employed land use indices and land surface temperature measurements. (Ray *et al.* 2023) conducted a quantitative analysis of land use and land cover dynamics in the Kolkata Metropolitan Development Authority (KMDA) area in West Bengal, using geoinformatics techniques and the Decision-Making Trial and Evaluation Laboratory (DEMATEL) methodology.

However, the aforementioned regions are primarily dedicated to big cities or municipalities. Research on the long-term impacts of urban expansion on land use and land cover dynamics within or beyond the boundaries of urban areas, such as suburbs, is extremely limited. Studies has mostly concentrated on city regions like KMDA or Barasat municipality in West Bengal (Basu and Saha ,2017; Ray *et al.* 2023), often overlooking quickly expanding urban areas towards suburban places such as the Barasat subdivision in North 24 Pargana. Because the effects of urban expansion on LULC in these suburban places might be different from those seen in larger cities, also there aren't a lot of studies examining the amount and nature of these LULC transformation to urban land use, despite evident urban expansion, this presents a major research vacuum. A more comprehensive understanding of the changes in land use and cover in the study regions can be obtained by applying geospatial approaches.

Conventional methods were previously used mainly to identify changing patterns in land use and land cover as a result of urban growth. But due to the enhancement of remote sensing and Geographic Information System (GIS), advance methodological techniques are used by the researchers to precisely identify and measure the areal statistics of various land use elements that have been transformed into urban landscapes. In this study also, some methodological techniques have been employed to analyze the Barasat subdivision, which encompasses both urban and rural landscapes. The research provides a detailed understanding of the impact of urban expansion on the dynamics of land use and land cover within the study region. which enables a more comprehensive and precise assessment of the scope and effects of urbanization.

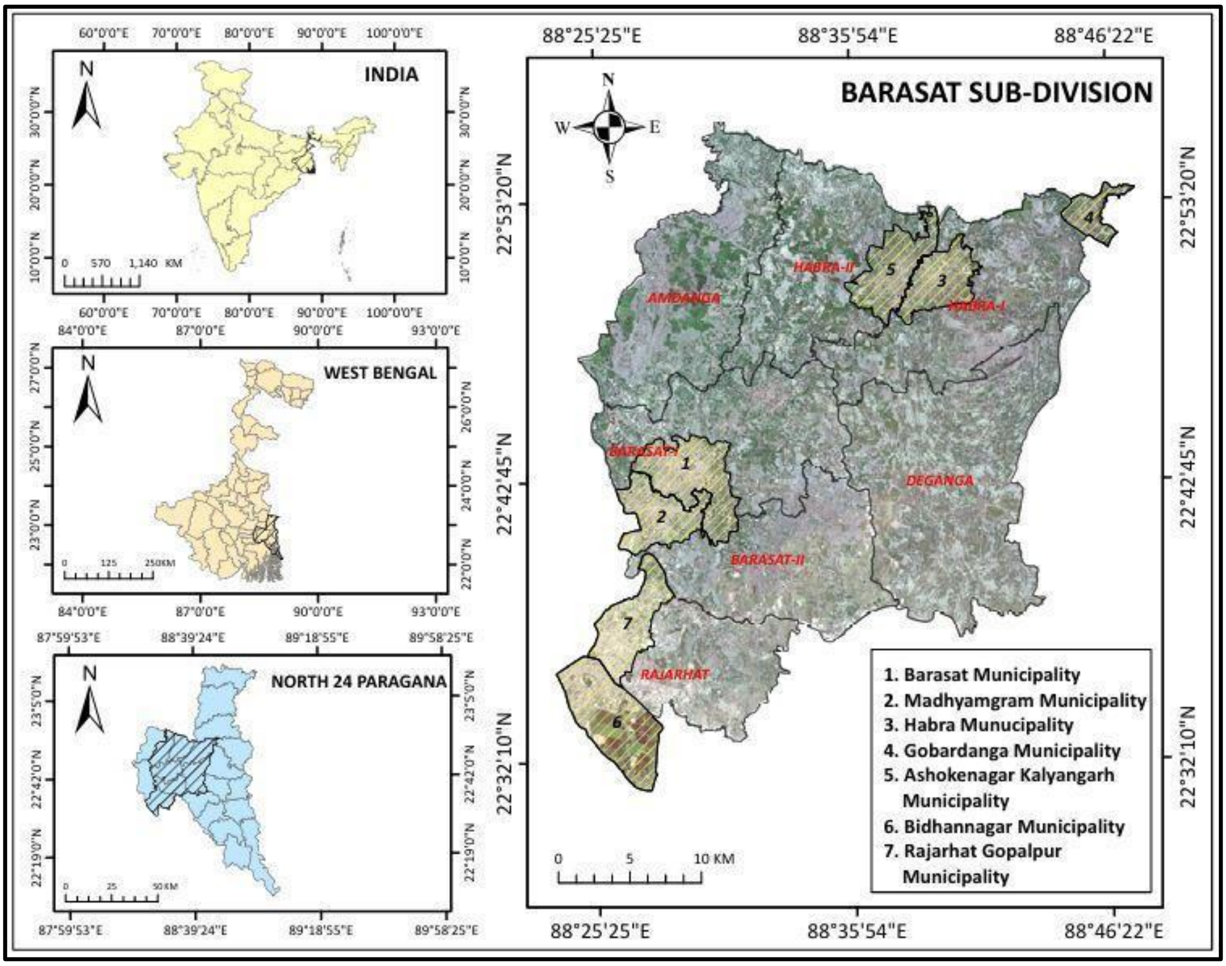
This study analysis the impact of urban expansion on land use and land cover (LULC) dynamics in the Barasat subdivision, North 24 Parganas, spanning the period from 1990 to 2024 (including 1990-2007 and 2007-2024). The research utilized multi-temporal Landsat remote sensing (RS) data integrated with Geographic Information System (GIS) approaches to achieve comprehensive analysis and accurate results. The study addressed the following research objectives: 1. To identify and quantify the temporal changes in various LULC elements in the Barasat subdivision over the last 34 years. 2. To investigate the transformation trend of each LULC feature, assessing the amount of loss/gain of the landscape. 3. To analyze the temporal areal statistics of each land use elements encroached upon by urban land use within entire study area.

II. MATERIALS AND METHODS

2.1 Study Area:

Barasat Subdivision is one of the administrative subdivisions of North 24 Parganas district, in the state of West Bengal, India. Bongaon, Barasat, Barrackpore, Basirhat, and Bidhannagar are the five administrative subdivisions that comprise the North 24 Parganas district. Barasat Subdivision is significant among these because of its high population density and the rapid urban expansion it has undergone, which has resulted in considerable alterations to land use and land cover (Census of India). Barasat Subdivision is located at latitude and longitude coordinates of 22.72°N and 88.48°E, respectively. Parts of the North Bidyadhari Plain and the North Hooghly Flat are included in the region. Within the lower Ganges Delta, these localities comprise two of the three primary physiographic regions of the North 24 Parganas district.

Figure 1: Location Map of the Study Area



The Barasat Subdivision covered 1,020.82 square kilometers in total area prior to 2015. The Rajarhat-Gopalpur Municipality and the Rajarhat Community Development Block were moved to the newly established Bidhannagar Subdivision as a result of an administrative reorganization, which also resulted in a reduction of Barasat Subdivision's total area to 889.55 square kilometers. There were 2,196,874 people living in the Barasat Subdivision as per the 2011 Census. Because of this large population and the smaller space, there are almost 2,500 people per square kilometer, which is a high population density. The subdivision's high level of urbanization and the ensuing pressure on its land resources are emphasized by its density. Over time, the administrative structure of this subdivision has undergone several changes. Barasat Subdivision comprised 7 community development blocks (Now 6), 7 panchayat samitis (Now 6), 58-gram panchayats (Now 52), 523 mouzas, 493 inhabited villages, 6 municipalities (Now 5), 1 municipal corporation (Bidhannagar), and 34 census towns (Now 25). After an administrative restructuring in 2015, the figures have been revised. The municipalities of Barasat, Habra, Gobardanga, Ashoknagar Kalyangarh, Madhyamgram, and Rajarhat-Gopalpur are located inside the Barasat Subdivision. However, the Rajarhat-Gopalpur Municipality was moved to the newly established Bidhannagar Subdivision after merging with the Bidhannagar Municipal Corporation in 2015. The part of the areas of Barasat (M), Madhyamgram (M), Rajarhat-Gopalpur (M), and Raigachhi (CT) within Barasat Subdivision are included within the jurisdiction of the Kolkata Metropolitan Development Authority (KMDA). The Barasat Subdivision and the entire North 24 Parganas area are administered from the Barasat Municipality, means all the district headquarters and other administrative centres are located from here. This strategic position enhancing Barasat subdivision's role as the district's centre of governance and administrative activity in the district (District Census Handbook, North Twenty-Four Pargana, Census of India 1991, 2011; Department of Urban Development & Municipal Affairs, 2021).

2.2 Data Source:

To evaluate the impact of urban expansion on land use/land cover changes in the specified study area, we obtained three cloud-free satellite images from the USGS Earth Explorer website (http://earthexplorer.usgs.gov). These images, taken from Landsat's TM, ETM+, and OLI/TIRS sensors, correspond to paths 138 and 44 rows and cover the years 1990, 2007, and 2024. The choice of Landsat images was driven by their availability and their medium to high spatial resolution, making them suitable for this analysis. Detailed information about the data can be found in Table 1. All three Landsat datasets are referenced to the Universal Transverse Mercator Projection (UTM Zone 45 N) using the WGS84 geodetic datum and have been corrected Landsat collection level-l (L1T).

Table 1: Details of Satellite Data Analyzed in the Study

Year	Sensor	Path/Row	Band Count	Resolution
1990	TM	138/44	7	Optical 30 m
				Thermal 120 m
2007	ETM+		8	Optical 30 m
				Thermal 60 m
				Pan 15 m
2024	OLI/TIRS		11	Optical 30 m
				Thermal 100 m
				Pan 15 m

Source: USGS (United States Geological Survey) Earth Explorer

2.3 Mapping of Land Use Land Cover Using Digital Classification:

The land use land cover classification for the FCCs (False Color Composition) with the best band combinations over the course of study period was produced by applying the maximum likelihood algorithm in conjunction with the hard classification approach in ERDAS Imagine (Dangulla et al., 2019). This method depends on the probability density of pixels that belong to a certain class and assumes equal probability densities for each class (Ahmad and Quegan, 2012). Like other supervised classification techniques, the maximum likelihood approach determines the spectral distance between the measurement vector for the candidate pixel and the mean vector for each signature within a pixel cluster (Chowdhury et al., 2020). This study selected and used six land use classes (settlement areas, wet fallow land, dry fallow land, agricultural land, vegetation, and water bodies) from 1990 to 2024. Maximum likelihood classification by figuring out each image pixel's discriminant function as follows (Richards, 1999):

$$g_i(x) = \ln p(\omega_i) - \tfrac{1}{2} \ln |\Sigma_i| - \tfrac{1}{2}(x - m_i)^T \Sigma_i^{-1} (x - m_i)$$

where:
i denoted as class
x is equal to n-dimensional data, where n is the total number of bands.
p(ωi) is the probability, considered to be the same for all classes, that class ωi appears in the image.
The covariance matrix determinant of the class ωi data is represented by |Σi|.
Σi-1 is inverse matrix.
mi is the mean vector.

The accuracy of the classified images was evaluated using a confusion error matrix, which compared the actual and predicted classifications. This matrix helped confirm the correct classification of pixels by comparing them to field data (Yesuph and Dagnew, 2019). Overall accuracy, user's accuracy (UA), producer's accuracy (PA), and the Kappa coefficient were calculated to determine the quality of the classification. The stratified random method was used for selecting 275 points for ground truth data (Seyam et al., 2023). For classification accuracy, an overall accuracy value of more than 70% is considered satisfactory (Gondwe et al., 2021). The degree of agreement between pixels used for categorization and ground truth is measured by the kappa (κ) coefficient. The kappa coefficient encompasses errors of omission and commission, in contrast to overall accuracy (Ouedraogo et al., 2023). When the kappa value is zero (0), there is no agreement, and when it is one (1), there is perfect agreement. A kappa value of greater than 0.75 is typically regarded as a high or very good agreement in most applications. This accuracy assessment is crucial for ensuring the reliability of land use/cover maps derived from satellite images. Kappa coefficient is computed in this way (Gondwe et al., 2021):

$$k = \frac{N\sum_{i=1}^{n} x_{i,i} - \sum_{i=1}^{n} P_i G_i}{N^2 - \sum_{i=1}^{n} P_i G_i}$$

where,
i = Class Number
N = Total number of classified pixels (classified in relation to ground truth)
$x_{i,i}$ = Number of pixels of ground truth class i
P_i = Total number of class i categorised pixels.
G_i = Total amount of class i ground truth pixels.

2.4 Change Detection of Land Use Land Cover Categories Over Time:

The study focuses on analyzing land use and land cover (LULC) changes, defining reconfiguration as the transition between different land use elements. It uses the land use type dynamic degree, or change rate index, to quantify and predict these changes over time (Chen *et al.,* 2017). The analysis employs GIS platforms and post-classification comparison techniques for their accuracy and cost-effectiveness. Remote sensing data from different dates are classified and compared to detect changes, with the post-classification comparison approach, particularly the MLC algorithm with Landsat data, proving highly accurate. Classified raster images are converted to vector layers to calculate and visually represent changes for each land cover type (Seyam *et al.,* 2023). The rate of change in LULC elements is a key measure of how quickly land use/land cover (LULC) elements are either expanding or encroaching. A larger positive rate indicates a quick expansion, while a higher negative rate indicates a significant area lost to incursion. If the rate of the LULC elements is exactly zero, or in the range of zero to one, they are considered to be stable or almost stable (Mawenda *et al.,* 2020). In this study, the rate of change in area for each land use/cover class is determined using the following formula (Ray *et al.,* 2023).

$$Ci = \frac{(Wei\ - Wsi)}{Wsi} \times \frac{1}{t} \times 100$$

where, Wei and Wsi represent the impervious surface area or percentage at the end to start of the study phase, respectively, and t is the study phase's length expressed in years. Ci is the rate of change of each land use elements during the study period.

The transferred index 'T_r' measures the fraction of area transferred from one land use type to others, considering the changed area within the study period. Whereas transformed index 'T_m' a numerical representation of fractional area converted from other LULC elements within the studied span to a particular LULC element. Here is the equation (Ray *et al.* 2023):

$$T_r = \frac{\sum_{i=1}^{n} (A - a_i)}{\sum_{i=1}^{n} a_i} \frac{1}{a_j} \frac{1}{t}$$

where, A represents the total area. a_i is the fractional area converted from the i^{th} Land Use/Land Cover (LULC) element at the beginning of the year to other LULC elements by the end of the year. j denotes the fractional area of LULC elements that remain unchanged by the end of the year.

$$T_m = \sum_{i=1}^{n} \frac{a_{ei}}{a_{bi}} \frac{1}{t}$$

a_{ei} and a_{bi} represent the fractional areas of various LULC elements that have reformed into a specific LULC element from the beginning of the year to the end of the year.

Finally, transformation change index T_C has been calculated as follows:

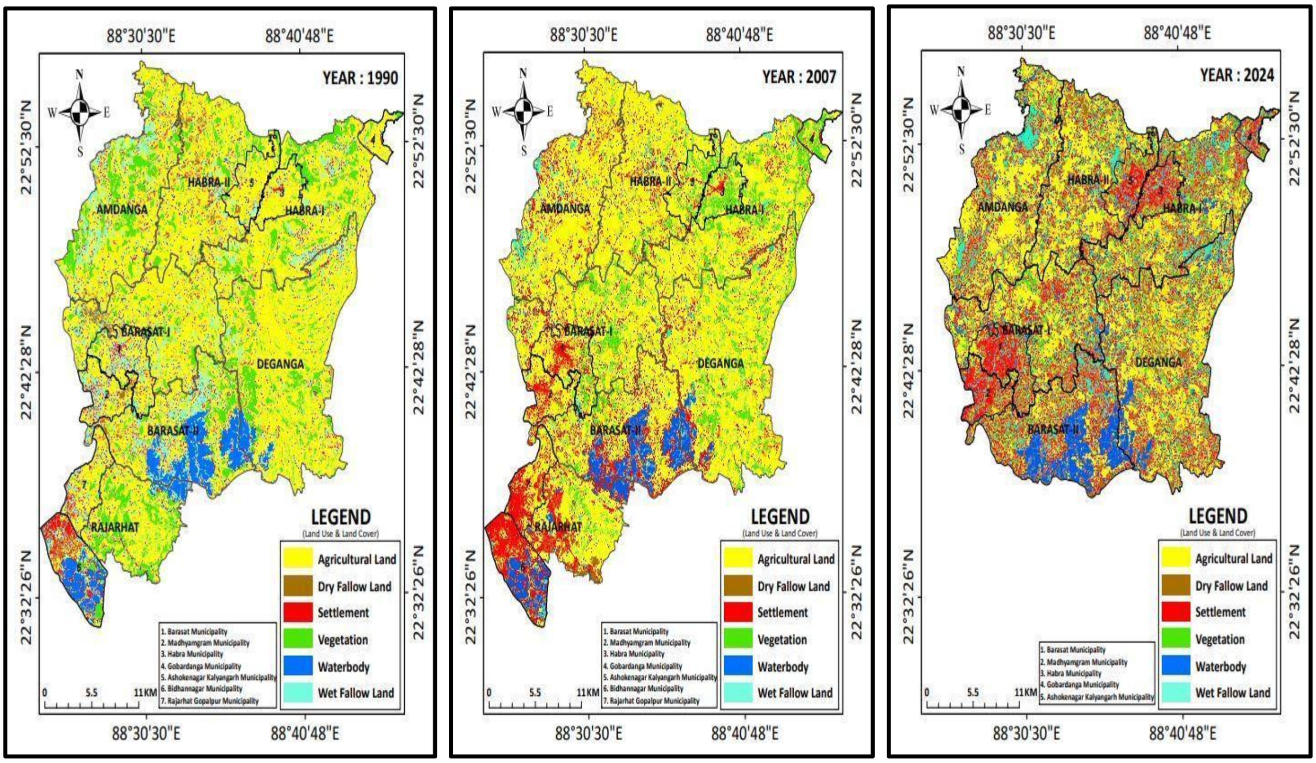
$$T_C = \frac{E}{R}$$

III. RESULT AND DISCUSSION

3.1. Land Use / Cover Classification:

Figure 2 shows the classified LULC maps of the study region for the years 1990, 2007, and 2024.

Figure 2: The Distribution of Land Use Land Cover for the years of 1990, 2007 and 2024



During the last 34 years, there has been a considerable variation in the distribution of land use and land cover elements in the Barasat subdivision. In three separate time periods the study area was divided into six distinct categories: vegetation, urban settlement, agricultural land, water bodies, dry fallow land, and wet fallow land. The achieved overall accuracies were 92%, 92%, and 94% respectively, and the kappa coefficients were 0.90, 0.89, and 0.91 for the classification of the 1990, 2007, and 2024 images, respectively, shows in Table 2, 3 and 4.

Table 2: Contingency Matrix of Land use Land Cover for 1990

Class Name	Agricultural Land	Vegetation	Urban Settlement	Waterbody	Wet Fallow	Dry Fallow	Row Total
Agricultural Land	7170	11	190	0	13	4	7388
Vegetation	127	8890	0	0	0	0	9017
Urban Settlement	252	0	2874	183	382	9	3700
Waterbody	0	0	1	5641	0	0	5642
Wet Fallow	2	0	948	0	2097	0	3047
Dry Fallow	57	0	104	0	0	308	469
Column Total	7608	8901	4117	5824	2492	321	29263

Table 3: Contingency Matrix of Land use Land Cover for 2007

Class Name	Agricultural Land	Vegetation	Urban Settlement	Waterbody	Wet Fallow	Dry Fallow	Row Total
Agricultural Land	4866	3	9	0	0	0	4878
Vegetation	74	52	0	0	0	0	126
Urban Settlement	0	1	8116	0	458	0	8575
Waterbody	0	0	0	1597	0	0	1597
Wet Fallow	0	0	484	0	1711	0	2195
Dry Fallow	0	0	0	0	0	132	132
Column Total	4940	56	8609	1597	2169	132	17503

Table 4: Contingency Matrix of Land use Land Cover for 2024

Class Name	Agricultural Land	Vegetation	Urban Settlement	Waterbody	Wet Fallow	Dry Fallow	Row Total
Agricultural Land	2761	35	135	0	0	0	2931
Vegetation	6	1209	63	0	1	0	1279
Urban Settlement	1	2	8802	0	707	0	9512
Waterbody	0	0	1	5195	0	0	5196
Wet Fallow	0	0	786	5	3043	0	3834
Dry Fallow	0	0	0	0	0	90	90
Column Total	2768	1246	9787	5200	3751	90	22842

Cohen proposed the following interpretation for Kappa statistics: values < 0.20 indicate poor agreement, 0.21–0.40 represent fair agreement, 0.41–0.60 signify moderate agreement, 0.61–0.80 indicate good agreement, and >0.80 represent perfect agreement (Henry et al. 2017). Therefore, according to Cohen's scale, the accuracy levels has surpassed the generally accepted benchmark for land use and land cover assessments.

3.2. Distribution Status of Land Use Land Cover:

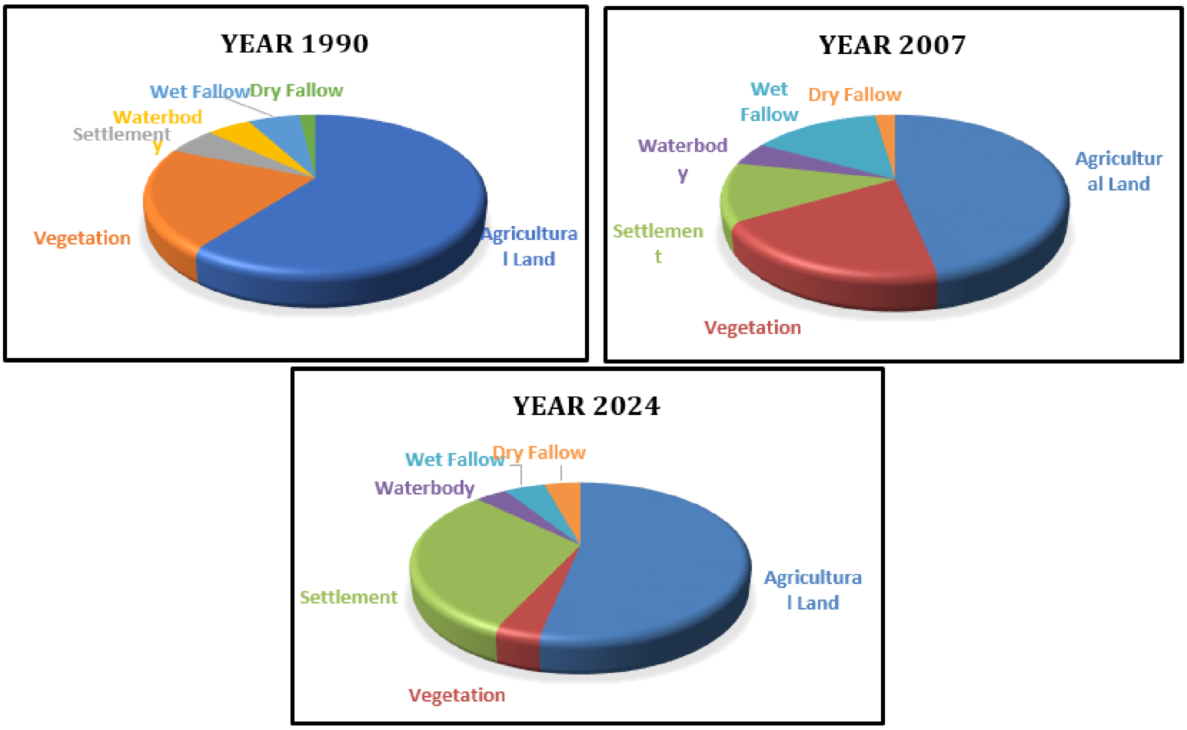
The distribution of land use land cover classification is summarized in Table 5.

Table 5: Land Use Land Cover Distribution from 1990 to 2024

Year	1990		2007		2024	
Class Name	**Area (sq.km)**	**%**	**Area (sq.km)**	**%**	**Area (sq.km)**	**%**
Agricultural Land	615.73	60.32	477.09	46.74	471.36	52.99
Vegetation	214.66	21.03	202.15	19.80	32.55	3.66
Urban Settlement	58.07	5.69	121.71	11.92	270.00	30.35
Waterbody	52.15	5.11	48.02	4.70	41.85	3.66
Wet Fallow	61.5	6.03	148.52	14.55	36.28	4.70
Dry Fallow	18.70	1.83	23.34	2.29	37.51	4.22

The Barasat subdivision's landscape in 1990's was mainly composed of agricultural land that was widely dispersed, as well as were numerous vegetative patches spread out throughout the research area, which added to the area's overall green cover. The urban areas were mostly found in the centre part of municipalities but in a very small amount. By 2007, patterns of land usage had changed significantly. Urban settlement areas had become more prominent and visible, encroaching other land use categories and extending beyond the core municipalities. This rapid urban expansion was shown by the outward expansion from the municipal centres (Figure 2). Now the region's agricultural and vegetation are started to decrease due to expansion of urban developments. However, by 2024, the dominance of urban settlement areas had become even more pronounced. Urban expansion had not only intensified within the municipalities but had also spread to smaller, scattered settlements throughout the Barasat subdivision (Figure 2). The dynamics of land use in the area have been considerably changed by the expansion and size of these urban settlements. At the same time, the region's agricultural land had continued to decline but vegetation cover and wet fallow land underwent a rapid decline (Figure 3). A trend towards more built-up areas and an associated decrease in natural and agricultural landscapes was reflected by the reduction of these green spaces (Table 5).

Figure 3: Area of Land Use Land Cover Distribution showing by Pie diagram (1990, 2007, 2024)



The distribution of land use and land cover in the study area is displayed in Table 5, where in 1990, approximately 60.03% (615.73 km²) of the subdivision was used for agricultural land, 1.83% (18.70 km²) was dry fallow land, 5.69% (58.07 km²) was settlement area, 21.03% (214.65 km²) was vegetation, 5.11% (52.15 km²) was water bodies, and 6.03% (61.53 km²) was wet fallow land. By 2007, the land use distribution changed as follows: about 46.74% (477.09 km²) was agricultural land, 2.29% (23.34 km²) was dry fallow land, 11.92% (121.71 km²) was settlement area, 19.80% (202.149 km²) was vegetation, 4.70% (48.02 km²) was water bodies, and 14.55% (148.52 km²) was wet fallow land Figure 3. Finally, in 2024, the area distribution was recorded as approximately 52.99% (471.36 km²) for agricultural land, 4.21% (37.51 km²) for dry fallow land, 30.35% (270.00 km²) for settlement areas, 3.66.10% (32.55 km²) for vegetation, 4.70% (41.85 km²) for water bodies, and 4.08% (36.28 km²) for wet fallow land.

3.3. Study on Land Use Land Cover Changes Detection and Loss/Gain Statistics:
3.3.1. Analysis of the Annual Rate of Change:

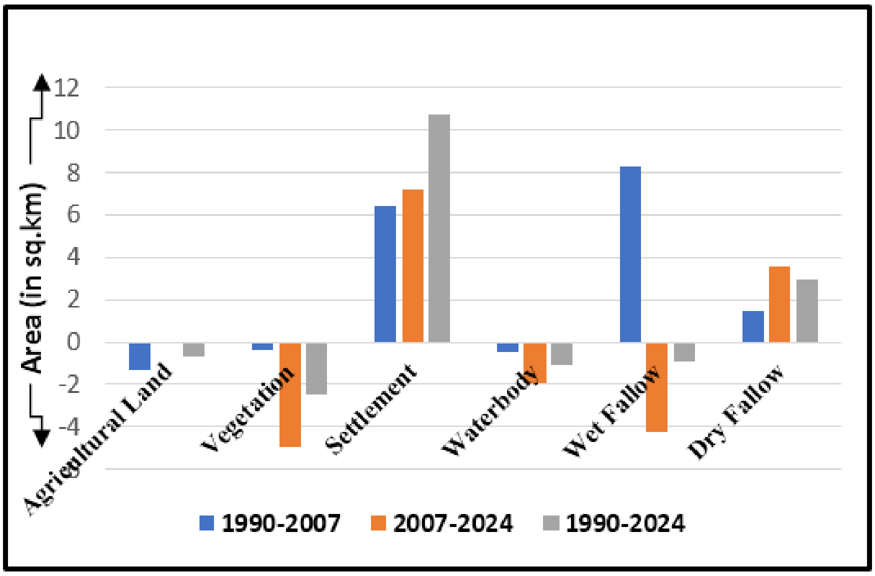
Table 6 shows that during a 34-year span, urban settlements and dry fallow land have seen the greatest area expansions. On the other hand, agricultural, vegetational, wet fallow and water bodies these lands have had a major decline. In the study region, some agricultural lands are act as dry and wet fallow land due to their moisture content of the land, resulting dryness or wetness.

Although significant changes in land use and land cover during 1990–2007, 2007–2024, and 1990–2024 are shown by the data (Table 6). The settlement area has increased significantly, which is consistent with urban expansion. In particular, the settlement area increased by 6.45 square kilometres between 1990 and 2007. From 2007 to 2024, there was a noticeable surge in this expansion, adding 7.17 square kilometres. The settlement area expanded by 10.74 square kilometres overall between 1990 and 2024 (Figure 4).

Table 6: Rate of Change (in %) of Land Use Land Cover

Year	1990-2007	2007-2024	1990-2024
Class Name	**Area (sq.km)**	**Area (sq.km)**	**Area (sq.km)**
Agricultural Land	-1.32	-0.07	-0.69
Vegetation	-0.34	-4.94	-2.50
Urban Settlement	6.45	7.17	10.74
Waterbody	-0.47	-1.89	-0.58
Wet Fallow	8.32	-4.22	-1.21
Dry Fallow	1.46	3.57	2.96

Figure 4: Land Use Land Cover Temporal Change (in %)



On the other hand, there were decreases in other land use groups. Between 1990 and 2007, there was a 0.34 square kilometre drop in vegetation cover; between 2007 and 2024, there was a further 4.94 square kilometre decrease, for a total decrease of 2.50 square kilometres. Waterbodies experienced a decline as well, contracting by 0.47 square kilometres in 1990-2007. In contrast, there was again a decrease of 1.89 square kilometres between 2007 to 2024, which led to a total decrease of 0.58 square kilometres between 1990 to 2024. Wet fallow land displayed a complicated pattern of change, growing by 8.32 square kilometres between 1990 and 2007 and then significantly decreasing by 4.22 square kilometres from 2007 to 2024. For the duration of the study (1990-2024), this resulted in a reduction of 1.21 square kilometres overall. The agricultural land decreased too with a huge decline of 1.32 square kilometres between 1990 and 2007, which continued to decrease by 0.07 square kilometres between 2007 and 2024, for a total reduction of 0.69 square kilometres between 1990 and 2024. At the very last, the area under dry fallow land grew by 1.46 square kilometres between 1990 and 2007 and by an additional 3.57 square kilometres between 2007 and 2024. From 1990 to 2024, the total area of dry fallow land increased by 2.96 square kilometres.

3.3.2. Assessment of the Temporal Loss/Gain of LULC:

A useful technique for measuring the alterations in land use and land cover (LULC) components across time is the transformation matrix, which is shown in Tables 7, 8, and 9. It is clearly determine the dynamics of areal gains and losses for each LULC category by analyzing these matrices.

Table 7: Transformation Matrix of 1990 – 2007

1990-2007	Agricultural Land	Dry Fallow	Urban Settlement	Vegetation	Waterbody	Wet Fallow
Agricultural Land	310.723	12.5104	63.2306	170.175	2.21569	56.875
Dry Fallow	10.8287	2.46222	2.61885	0.583893	0.340736	1.86248
Urban Settlement	14.4328	0.75436	17.8929	6.07469	1.99373	16.9186
Vegetation	125.294	6.98805	24.3291	18.688	2.97757	36.3814
Waterbody	0.936785	0.249594	0.751793	0.307493	39.0814	10.8224
Wet Fallow	14.8748	0.378397	12.8873	6.31935	1.40967	25.6566

Table 8: Transformation Matrix of 2007 - 2024

2007-2024	Agricultural Land	Dry Fallow	Urban Settlement	Vegetation	Waterbody	Wet Fallow
Agricultural Land	283.804	28.9645	94.74	13.2098	2.50861	15.5295
Dry Fallow	10.4109	4.60997	2.91562	0.192942	0.262329	0.484042
Urban Settlement	29.8451	1.42183	40.4355	0.951045	1.23059	4.6165
Vegetation	88.9729	0.799829	77.8907	16.7661	0.906746	2.48059
Waterbody	2.80725	0.185522	3.28368	0.033949	24.3019	0.527645
Wet Fallow	55.5154	1.52574	50.7418	1.39591	12.6381	12.6449

Table 9: Transformation Matrix of 1990 - 2024

1990-2024	Agricultural Land	Dry Fallow	Urban Settlement	Vegetation	Waterbody	Wet Fallow
Agricultural Land	305.368	27.9093	177.801	25.6957	5.52878	13.8001
Dry Fallow	9.36155	3.10097	3.53734	0.398686	0.464182	0.445339
Urban Settlement	14.7469	0.971272	20.4368	0.732208	2.51682	3.21983
Vegetation	120.079	4.44203	37.5081	4.97395	3.77909	10.4867
Waterbody	4.23803	0.376539	4.81326	0.028512	26.5776	0.76855
Wet Fallow	17.562	0.707329	25.9109	0.720696	2.98183	7.56274

Table 10: Areal (in sq.km.) Loss and Gain of LULC over the Study Region for 1990 – 2024

Class Name	1990-2007		2007-2024		1990-2024	
	Loss	Gain	Loss	Gain	Loss	Gain
Agricultural Land	305.01	166.37	154.95	187.55	250.73	165.99
Dry Fallow	16.23	20.88	14.27	32.90	14.21	34.41
Urban Settlement	40.17	103.82	38.07	229.57	22.19	249.57
Vegetation	195.97	183.46	171.05	15.78	176.29	27.58
Waterbody	13.07	8.94	6.84	17.55	10.22	15.27
Wet Fallow	35.87	122.86	121.82	23.64	47.88	28.72

It is possible to identify which land use features in the study region have lost the most area over the course of 34 years by using data from the transformation matrix, includes identifying which land use features have increased in area due to encroaching other land uses.

According to Table 10, agricultural land saw a significant decrease in area from 1990 to 2007. However, throughout the extended study period from 1990 to 2024, agricultural land has been rapidly regaining its area. In contrast, vegetational areas have also experienced a loss in land, but their recovery has been much slower. Meanwhile, urban settlement areas have only lost a small amount of land but have quickly expanded over the entire study period.

Here, "converted area" refers to land that has changed to different land uses over the time, while "transformed area" indicates other land uses that have transitioned to a particular land use due to its dominance in the region. Table 11 illustrates that 1990-2007, the largest converted areas were agricultural and vegetational land, with 0.503 and 0.323 sq. km., respectively. From 2007 to 2024, agricultural, vegetational, and additionally wet fallow lands were the most converted to other land uses, with areas of 0.306, 0.337, and 0.240 sq. km., respectively. In contrast, urban areas predominantly experienced transformation rather than conversion throughout the entire period from 1990 to 2024. The transformation rate was slower between 1990 to 2007, but it accelerated significantly from 2007 to 2024 (Figure 5).

Figure 5: Land Use Land Cover Conversion and Transformation (in sq.km.)

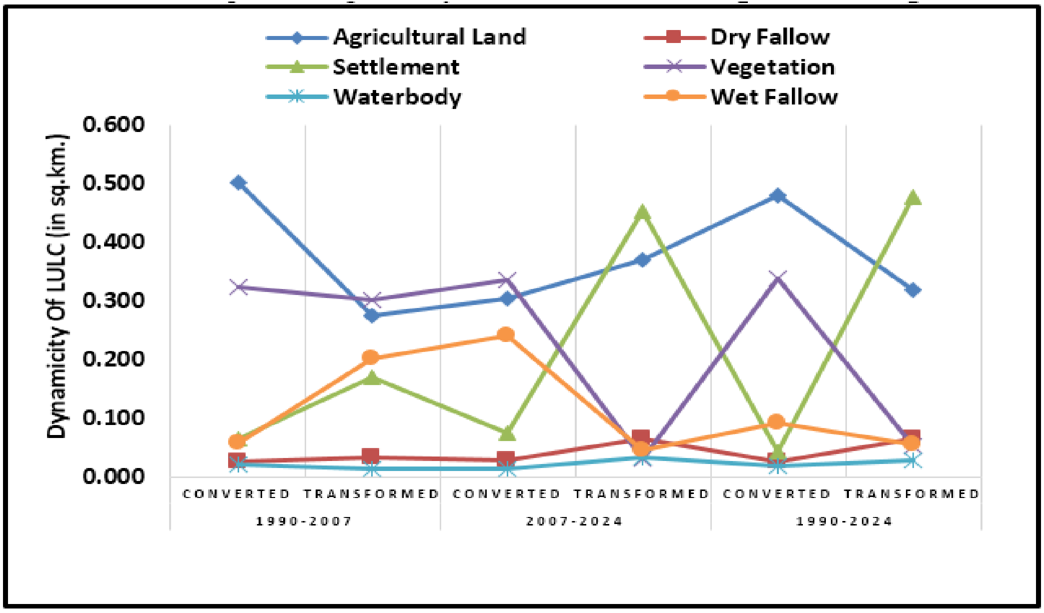


Table 11: Converted and Transformed Land Use Land Cover (in sq. km.) over the Time

Class Name	1990-2007		2007-2024		1990-2024	
	Converted	Transformed	Converted	Transformed	Converted	Transformed
Agricultural Land	0.503	0.274	0.306	0.370	0.481	0.318
Dry Fallow	0.027	0.034	0.028	0.065	0.027	0.066
Settlement	0.066	0.171	0.075	0.453	0.043	0.479
Vegetation	0.323	0.303	0.337	0.031	0.338	0.053
Waterbody	0.022	0.015	0.013	0.035	0.020	0.029
Wet Fallow	0.059	0.203	0.240	0.047	0.092	0.055

3.3.3. Analysis of Urban Expansion and Areal Statistics of Encroached Land Use Elements:

The study region experienced significant urban expansion during the course of the study period (Figure 7). In the beginning, between 1990 and 2007, most urban development took place inside each municipality's core, with limited outward expansion. But there was a discernible change in the trend of urban expansion between 2007 and 2024. Urban areas started to spread outside of the central areas, expanding onto the boundaries of every municipality (except Bidhannagar and Rajarhat-Gopalpur after merging Bidhannagar Subdivision in 2015). Urban expansion is fragmentedly growing into suburban areas within this time frame (2007–2024). This growth displayed more dispersed urban expansion as it encroached upon other land use elements (Figure 6). Over the course of the research period, the previously non-urban areas have become urbanized due to this fragmented growth pattern, drastically changing the environment

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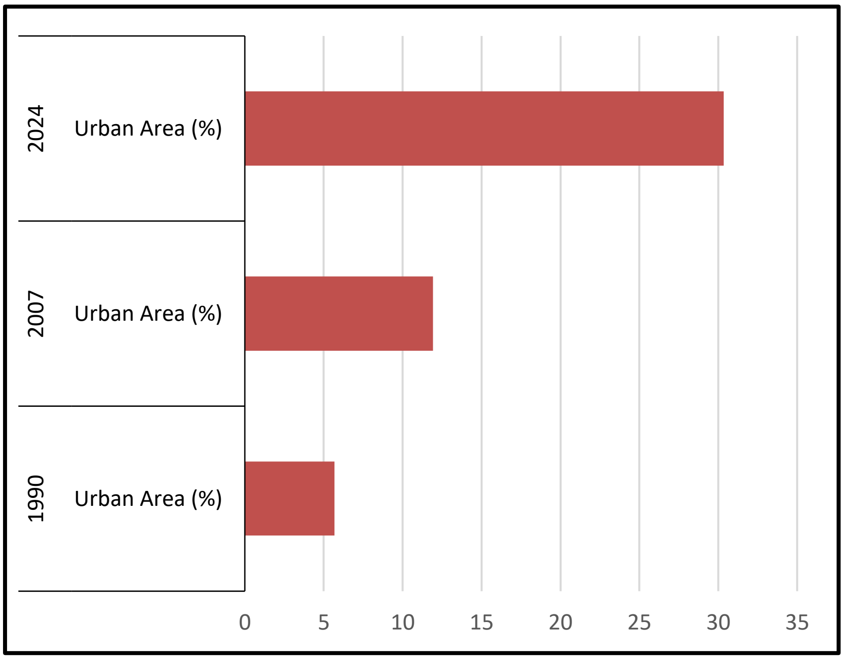
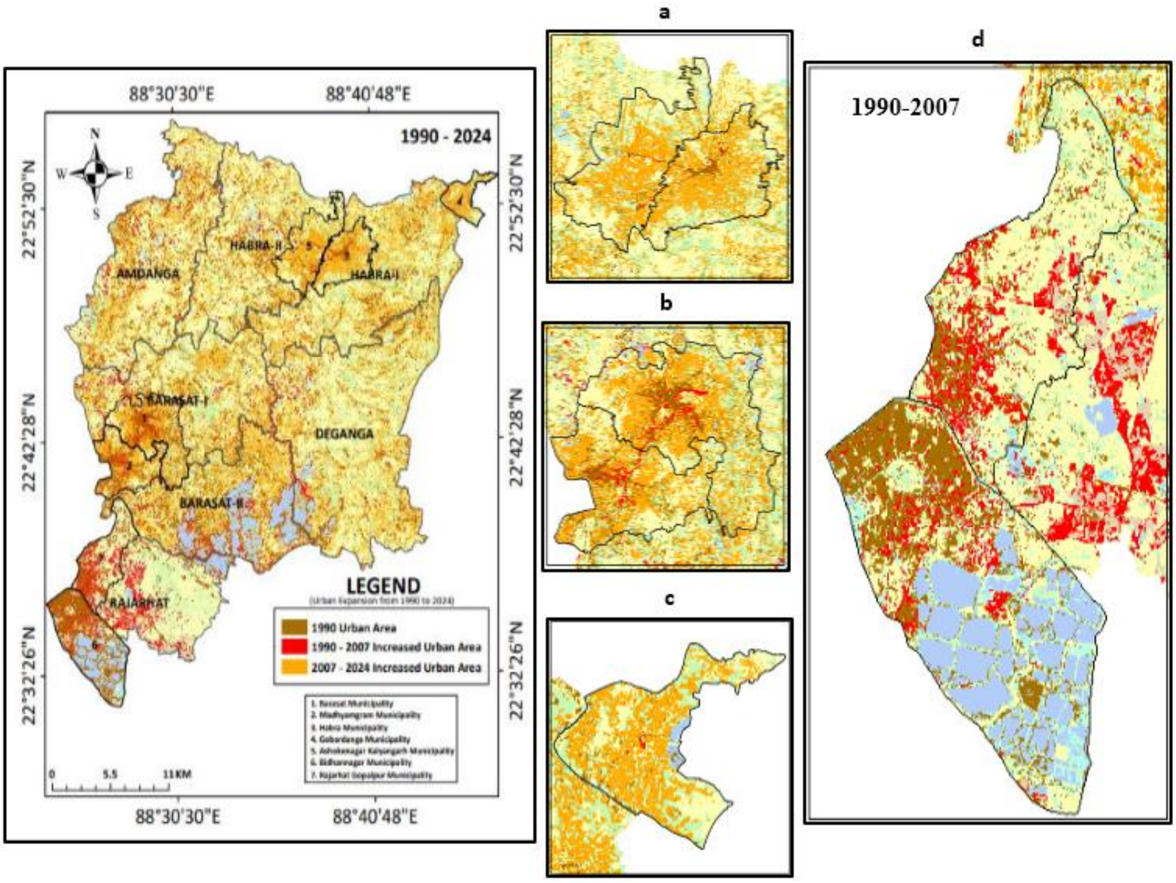


Figure 6: Temporal Distribution of the Urban Area (in %)

Figure 7: Urban Expansion from Municipalities to Entire Study Region



Barasat and Madhyamgram Municipality, b. Ashokenagar-Kalyangarh and Habra municipality, c. Gobardanga Municipality, d. Rajarhat-Gopalpur and Bidhanngar Municipality

As of now, this analysis has made it clearly apparent that, as various land use components have been encroached while urban areas have rapidly expanded throughout the study region from 1990 to 2024. So, it is possible to determine which area of land use has the greatest impact from urban expansion by using an areal statistical approach from transformation matrix analysis to depict the portion of the study area where a greater amount of other land use elements have been reformed to urban areas as a result of urban expansion. According to Table 12 the majority of the agricultural, vegetational and wet fallow land in this region has been switched to urban areas. While there is very little encroachment on dry fallow land and water bodies shown in Figure 9. Based on the information shown in Table 12, between 1990 and 2007, approximately 103.82 square kilometers of land within the total area of 1020.82 square kilometers were transformed from other land use types to urban areas.

Figure 8: Areal Statistics of Encroached Land use Elements to Urban Area

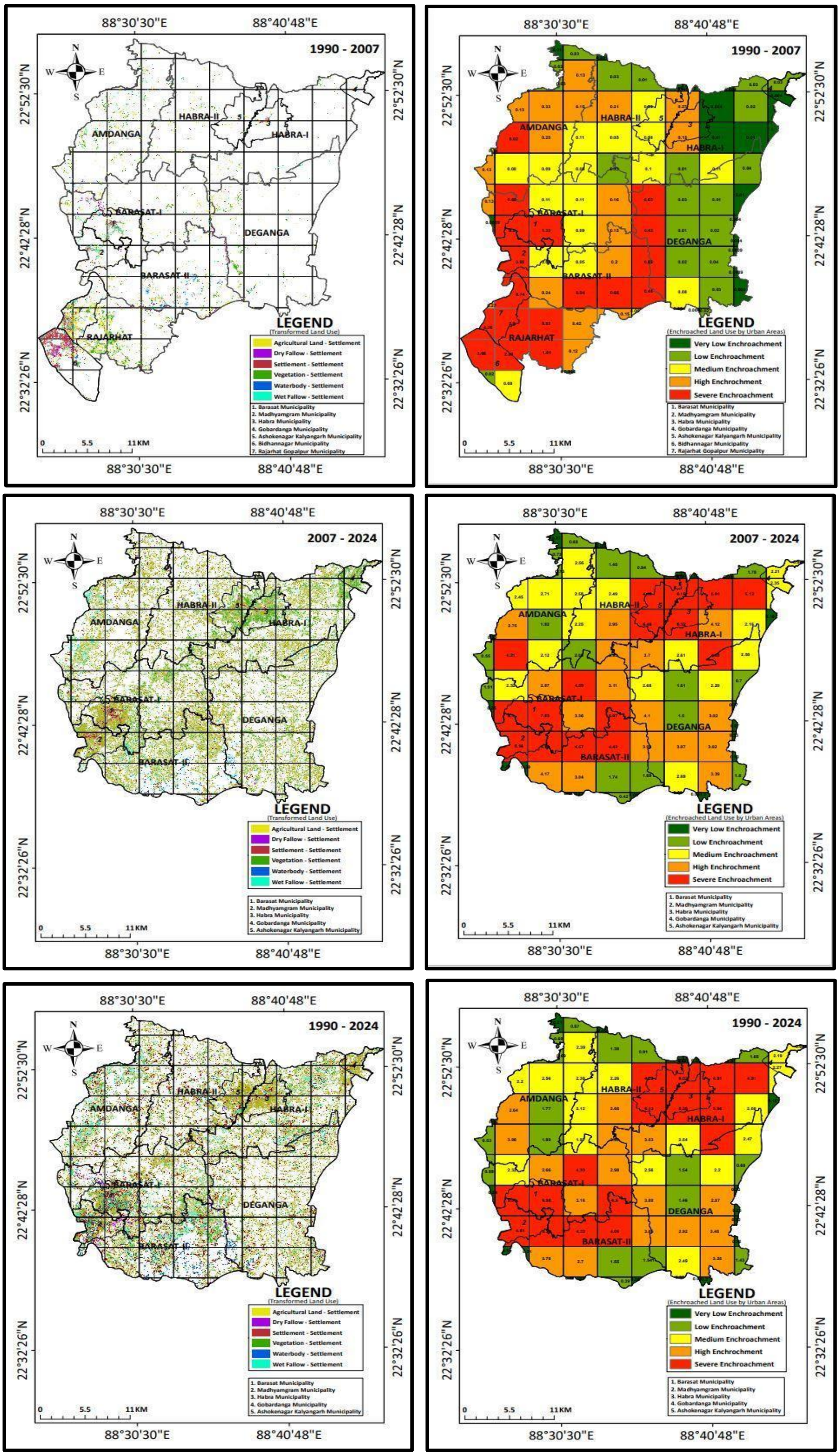


Table 12: Encroached Land use Land Cover (in sq.km.) by Urban Area

Encroached Land Use Land Cover	1990-2007	2007-2024
Agricultural Land - Urban Settlement	63.23	94.74
Dry Fallow - Urban Settlement	2.62	2.92
Vegetation - Urban Settlement	24.33	77.89
Waterbody - Urban Settlement	0.75	3.28
Wet Fallow - Urban Settlement	12.89	50.74

This indicates there was a considerable amount of urban encroachment during this period. On the other hand, from 2007 to 2024 indicates that, out of a reduced total area of 889.55 square kilometers, around 229.57 square kilometers were converted from other land use elements to urban areas. This significant increase of urban expansion emphasizes the serious impact on the dynamics of land use and land cover in the suburban sections of the Barasat subdivision during this period.

For every 4 square kilometers along the course of the study area, the areal statistical approach was computed, shows in Figure 8, where in four of the seven municipalities, there was significant encroachment of urban areas which converted other land use elements throughout the 1990s to 2007. More especially, the municipalities of Madhyamgram, Rajarhat, Bidhanangar, and Barasat. Gobardanga had the least amount of land use encroachment among the municipalities under study, but Habra and Ashokenagar municipality had medium to high levels of contamination. Basically, with the exception of the eastern portion of this suburban region, the remaining sections essentially displayed the convertional effect to urban regions. The encroachment trend changed from 2007 to 2024 in the same way that it occurred from 1990 to 2024. During this latter period, four out of the five municipalities faced severe encroachment, with Gobardanga shifting to a medium level of urban encroachment over other land use elements. This shift indicates a more pronounced and widespread impact of urban expansion during the later years of the study. The encroachment, which was initially concentrated within the municipalities, has now spread out to encompass the entire surrounding region. This spread signifies the expansive reach of urban growth, affecting the whole land use land cover in the suburban region. The results emphasize the substantial impact of urban expansion on land use and land cover dynamics throughout the study region that changed the region's spatial landscape over the 34-year time span.

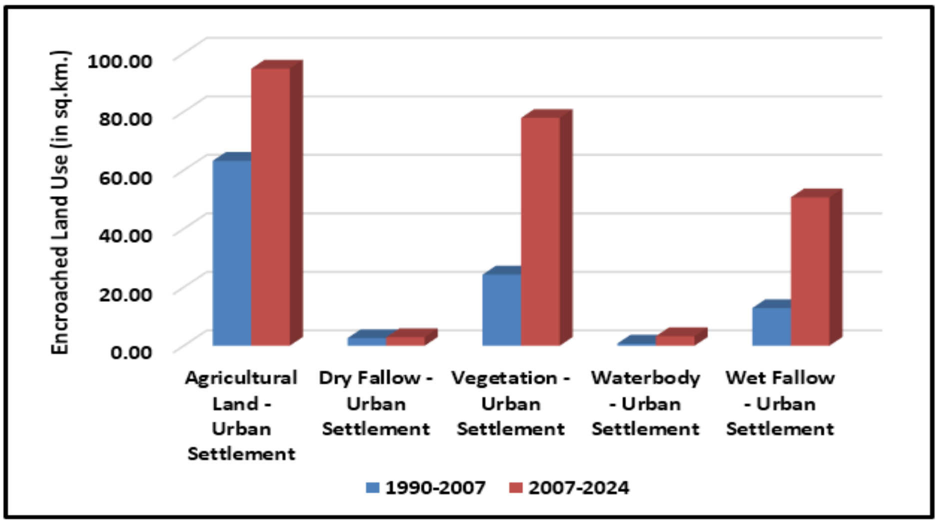


Figure 9: Temporal Urban Reformed Land Use Elements

IV. CONCLUSION

It is generally accepted that changes in Land Use and Land Cover (LULC) patterns are unavoidable as a result of urban development, based on various observations and existing literature on the subject. In every urbanized area, substantial changes in LULC are typically a consequence of the ongoing urbanization process along with the necessary infrastructure developments. It is clear from the entire study that throughout the 34 years, urban expansion has significantly changed the LULC in the Barasat subdivision region. The rise in urban built-up regions was the most noticeable trend, based on relevant quantitative assessments on the temporal LULC scenario. Initially concentrated in the central regions of the municipalities, the expansion gradually extended to the periphery and beyond the municipal boundaries into the suburban regions. The municipality regions had the greatest level of land use encroachment, whereas scattered instances were observed in the suburban regions. This trend indicates a substantial change in land use, with a considerable amount of previously undeveloped land now being utilized for residential purposes.

In this region, vegetative areas and agricultural land have been encroached upon the most for urban development. The transformation of these land use elements is significant, highlighting the extensive impact of urban growth on the natural and agricultural landscapes. To comprehensively understand the effects of urban expansion on LULC dynamics, the study adopts some quantitative methods, analyzing every transferred and transformed land use element across the entire study region. To balance the development of urban expansion with environmental preservation and socioeconomic well-being, urban planners and policymakers must have developed strategies by thorough understanding of the dynamicity of land use land cover.

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