*Research Paper*

# Deciphering Urbanization and Spatial Disparity in South 24 Parganas District of West Bengal, India

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## Abstract

*Continuous urban-rural migration between 1991 and 2001 has caused significant land use land cover (LULC) changes around core urban areas in Indian Urban areas. These expansions, through outgrowths and developments in urban-rural fringe areas, significantly impact the environment; therefore, it is essential to monitor LULC changes to promote sustainable urban growth. It is also imperative to identify significant factors driving such LULC changes. This study explores land use changes and transitions occurring in India's South 24 Parganas district, which forms a part of Kolkata Urban Agglomeration (KUA) and surrounds the core city of Kolkata in the East and South. It is the largest district of West Bengal, located in a highly eco-sensitive zone of the country. The rising urbanization in the district makes LULC research important. Using spatiotemporal and network analyses, this study tracks LULC trends in South 24 Parganas from 1991 to 2021. The study examines urban growth in South 24 Parganas from 1991 to 2021, corresponding to major access roads and elevation from the Mean Sea level. The built-up area (BUA) increased by 716.63% between 1991 and 2021, causing a tremendous loss of agricultural and natural ecosystems. Significant urban growth has been observed along the east bank of the Hooghly River near Kolkata Municipal Corporation (KMC) in South 24 Parganas. Over the last 30 years, this transformation has defined the future of urban planning and legislation to promote sustainable growth. The study has found a positive association between urbanization and changes in BUA with land elevation and access through major roads.*

## Keywords

*Land Use Land Cover (LULC), Network Analysis, Spatiotemporal Analysis, Sustainable Urbanization, Urban Expansion*

## 1. Introduction

The growth of urbanization affects both people and the natural world. Converting once rural areas into urban landscapes alters the population, socioeconomic, and environmental mix of both urban and rural areas (UNDP, 2019; Majumdar, 2020). Through careful management of the urbanization process, economic agglomeration can be increased, while at the same time, environmental deterioration and other adverse impacts can be reduced (UNDP, 20116; Fei, 2019). Urban efficiencies and technical innovations have fostered the expansion of the economy and the accumulation of knowledge while also producing new sources of revenue and employment (Henderson et al., 2018; Zhu, 2019). The rapid growth of urbanization has seriously damaged the natural environment surrounding us. According to Seto (2012) and Halder (2021), urban growth primarily results in the extinction of native species, which is detrimental to the health of local ecosystems and the preservation of the environment. As a result, the level of urbanization can be understood to refer to the proportion of a country's total population that resides in urban regions. An enormous increase in the population and area of a city leads to urban expansion (Alam, 2021). The United Nations has projected an additional 416 million people's accommodation in Indian cities by 2050 (United Nations, 2018). Urbanization has become an inevitable process with the increasing urban population. It entails the loss of fertile croplands and natural vegetation to impermeable surfaces (Li et al., 2013). Thus, a better knowledge of urban development patterns is critical for reducing these consequences and promoting long-term urbanization (Dadashpoor et al., 2019; Liu et al., 2016; FAO, 2020). There is an unprecedented change in LULC across urban India. By 2050, cities will be home to about half of India's population (UN, 2012). In several areas in India, urbanization's adverse effects are observable in India (Gupta, & Kumar, 2006; Kantakumar et al., 2016).

On the other hand, urbanization promotes the economic growth of a nation. Instead of limiting or correcting unsustainable urbanization, the strategy should aim to prevent it. The proper utilization of accessible land areas contributes to the area's economy while reducing environmental damage (Huang et al., 2009; Kantakumar et al., 2016). A spatial-temporal, demographic, and network analysis are all needed to understand the complexity of how cities grow. We must look at the factors driving spatial and temporal land conversion processes. In many developed regions, the metropolitan population outside core cities has expanded faster than urban districts, showing a significant propensity toward urban sprawl (Angel et al., 2005; Martellozzo & Clarke, 2011). Whether urban expansion is resisted or encouraged, the formulation of appropriate laws and regulations primarily depends on detecting and predicting urban expansion. The outcomes of this study imply that urban growth is the extension of developed and residential regions caused by the urbanization of formerly rural areas. Those who advocate for limiting population expansion have referenced those who disagree with them regarding the detrimental effects of urban sprawl. There hasn't been much research done on the spatial and temporal processes of land-use transition in areas with low populations, even though almost everyone has witnessed the urban expansion and anticipated the positive and negative consequences it will have on their immediate surroundings (Bolstad et al., 1991; Huang et al., 2009; Bagch & Chatterjee, 2017; He et al., 2017). In the last two decades, remote sensing and image processing have led to various digital change detection approaches for land use modelling (Dietzel et al., 2005; Devan & Corner, 2013; Dong et al., 2019). Advanced Remote Sensing (RS) techniques are integrated with GIS and landscape metrics to conduct the study. This inquiry employs a dynamic geographical territory-based technique with the following objectives in mind:

- Monitoring the spatiotemporal built-up area (BUA) dynamics corresponding to the study area's Digital Elevation Model (DEM).
- Analyzing demographic trends by examining the regional patterns and urban expansion processes using Census data and Network analysis.

## 2. Study Area

The Indian state of West Bengal's South 24 Parganas district is at the state's southernmost tip. The region is confined by the coordinates 21°29′N and 22°33′45′′N, and 88°3′45′′E and 89°4′50′′E. The district is relatively large, covering 9960 km$^2$ (Census of India, 2011). There are seven municipalities and twenty-nine CDBs throughout 5236.79 km$^2$. The Hooghly River borders it to the west, Bangladesh to the east, the Bay of Bengal to the south, and the Kolkata Municipal Corporation (KMC) and North 24 Parganas to the north (Fig. 1). In the last 30 years, it has seen unprecedented urban and industrial development (Census of India, 2011). The Sundarban Reserve Forest, protected by UNESCO, may also be found in this area. Natural disasters are more likely to occur because of the Bay of Bengal. The district of South 24 Parganas is the second-most urbanized region in all of India.

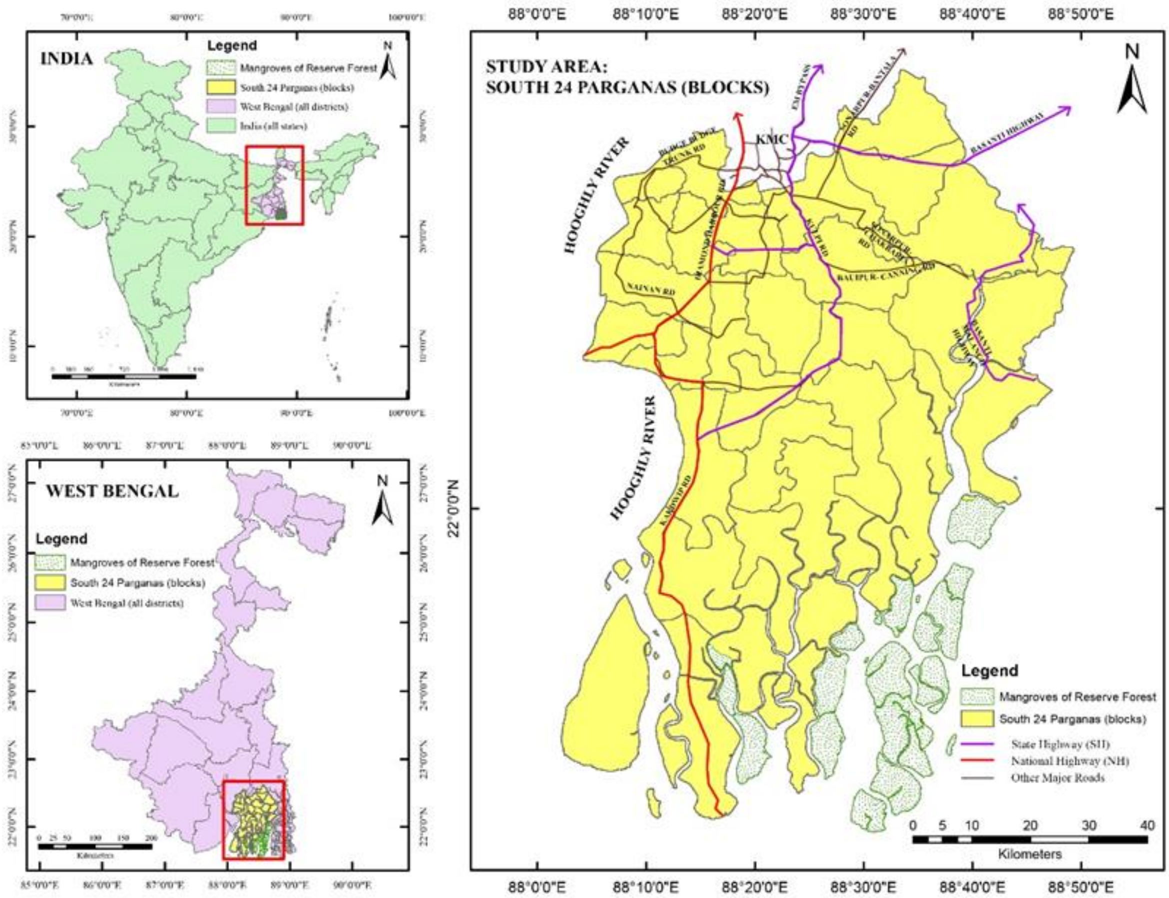


**Figure 1. South 24 Parganas and its geographic location in India, West Bengal. Source: Authors.**

However, the district's quality of life is under constant attack, despite its many inherent social, cultural, and economic benefits. Natural materials may be found in woods on both the mainland and islands. Human beings, agricultural outputs, seafood from both fresh and salt water, and domestic industrial outputs all count as socioeconomic resources. It's easy to see the differences between rural and urban environments. Deficiencies in resource use are a common cause of stagnation in progress (Bandyopadhyay & Basu, 2017; Chakraborty et al., 2021). The rate of human activity and population growth are both directly affected by urbanization. The study area is crossed by both interstate and state roads (WBTP, 2022).

3. Data and Methods

This study developed an empirical approach to evaluating recent geographical data obtained experimentally; all data is temporally continuous and has a global context. The study area uses space syntax to take cognizance of where and how people's network preferences change as the population does. Therefore, remote sensing, GIS, and network analysis are all crucial to the study's emphasis on an integrated approach (Fig. 2). Landsat data is utilized to map and analyze land-use changes. Long-term database access, medium spatial resolution, and uniform spectral and radiometric resolutions make LANDSAT data necessary. In 1982, LANDSAT-4's Thematic Mapper enabled the spectral (7 bands) and spatial (30 m) resolution for assessing urban expansion. We utilized cloud-free Landsat 4-5, 7 and 8 photos from 29 October 1990 to 21 December 2021 (https://glovis.usgs.gov) to examine urban growth in South 24 Parganas.

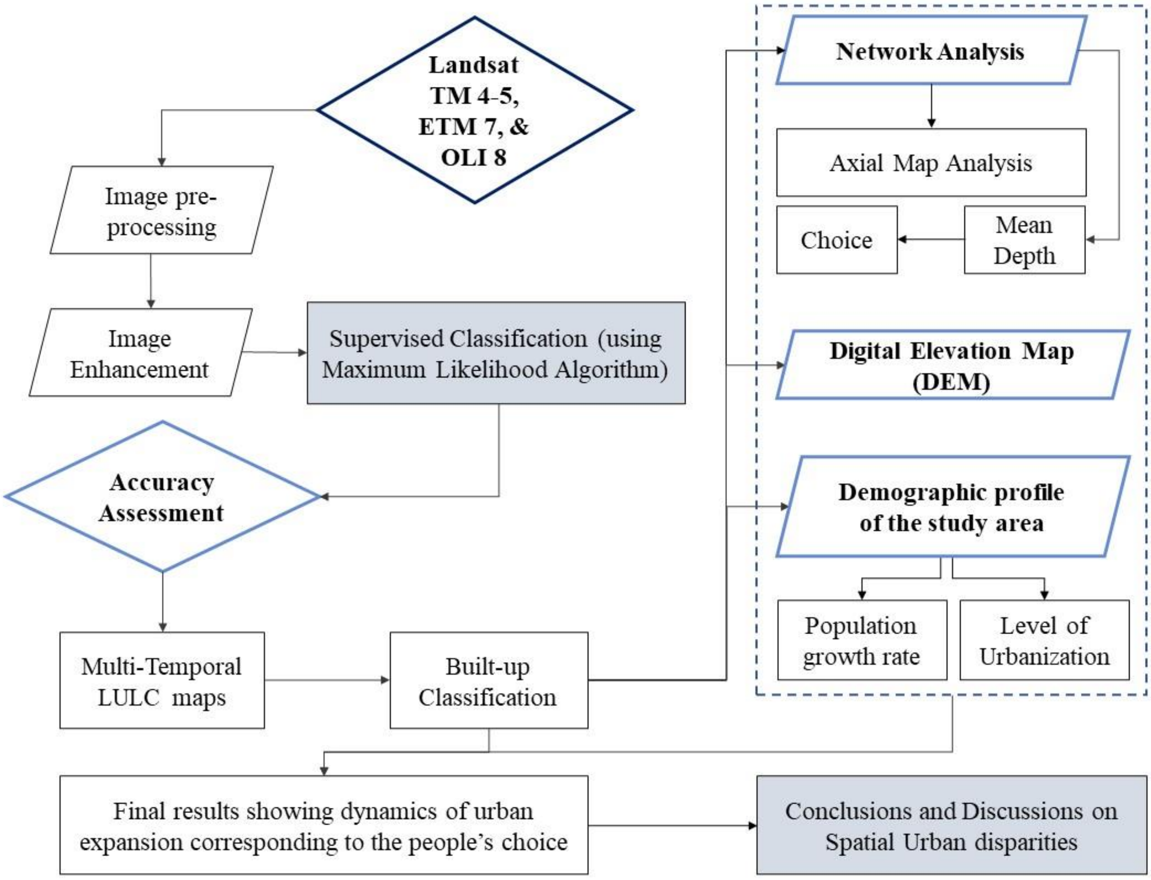


**Figure 2. Methodology workflow used in the analysis. Source: Authors.**

## 3.1. Image Classification

All images were processed by assigning per-pixel signatures and grouping the area into five categories based on distinct landscape components' DN. Built-up areas, croplands, mangroves, vegetation, and waterbodies were identified. Satellite imagery of training sample polygons acquired 60 spectral signatures for LULC classes (Gao, 2010; Mishra et al., 2012; Halder & Bandhopadhyay, 2022). The images were then processed and categorized using the Maximum Likelihood Method (MLM). The LULC change-transition matrix was created in ArcGIS using the overlay tool to quantify the area moved from one LULC class to another across the study period. The supervised algorithm used visual data and local knowledge. Visual interpretation improved LULC map accuracy. Change detection requires the categorization of data. Hence a precise evaluation of each classification is necessary (Owojori & Xie, 2005; Porta et al., 2006;

Rehman et al., 2022). Classification accuracy is often verified by comparing reference data with remote sensing data analysis (Congalton, 1991; Alam et al., 2022). Stratified random sampling was used to analyze LULC maps from satellite images to illustrate the research area's LULC classes. Eye perception and ground truth data assessed accuracy using 180 to 200 pixels in each category. Error matrix compares class values to field data. The non-parametric Kappa test considered diagonal and confusion matrix entries (Rosenfield & Fitzpatrick-Lins, 1986; Sateesh & Sandip, 2011; Follman et al., 2018).

### 3.2. Demographic profile classification

The current investigation consisted of two distinct parts. As a first phase, we carried out a detailed review of the existing literature on many elements of urbanization and economic development. These comprise conceptual underpinnings and case studies derived from the state of West Bengal, India, and other nations. The study retrieved data from the National Commission for Urbanization's Report (1988), the District Human Development Report of South 24 Parganas (2009 & 2018), and other relevant government records. Secondary data comes from the Indian Census and the Bureau of Applied Economics and Statistics. We used information from the Indian Census, the National Atlas, and the Thematic Mapping Organization to create dynamically scaled administrative and thematic maps. The second phase is acquiring and calculating data. The necessary maps and infographics were developed using the Geographical Information System and other technologies. Then, in the context of the South 24 Parganas, multidimensional data analysis, comparative study assessments, and verification of current urban-economic development theories were carried out. Analysis at the C. D. Block level has gotten much attention. This study used a regional socioeconomic classification of the district's blocks for debate.

## 4. Results and Discussion

### 4.1. Change Assessment

The average Kappa for the four categorizations is 86.3% which fulfils Anderson's 85% accuracy criteria. These results pave the way for further LULC investigations. Croplands and vegetation dominated LULC in 1991 when the duration of the study started. It was followed by mangroves, water bodies, and BUAs (35.5%). For each LULC, 2001, 2011, and 2021 trends differed. In 2021, BUAs dominated LULC, reducing croplands, vegetation, mangroves, and water bodies (Fig. 3). The LULC trend over three decades shows a general reduction in natural areas, including waterbodies (68.44%), vegetation (59.82%), mangroves (31.9%), and croplands (0.45%). Settlements show that human expansion and economic activity grew (716.63%).

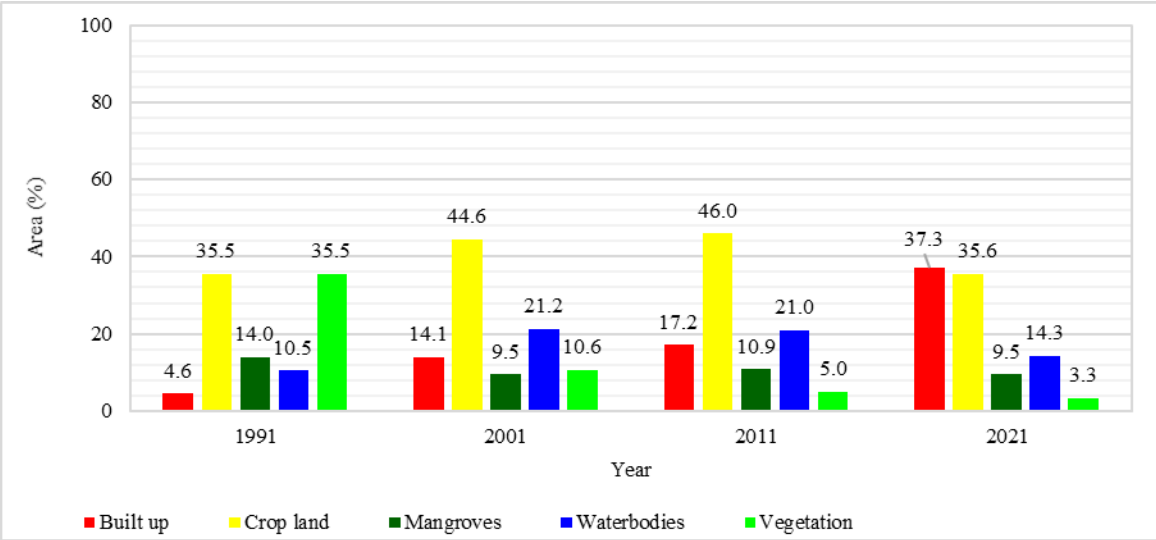


**Figure 3. Graph for change in LULC for 1991, 2001, 2011, and 2021 at South 24 Parganas. Source: Authors.**

Table 1 illustrates land use areas' transition and percentages from 1991 to 2021. It compares LULC class areas where over half of the investigation's BUAs and mangrove forests remained intact. A 50% agricultural transition preceded a vegetation shift, a 50% water body transfer, and a tiny, negligible mangrove forest transformed into built-up zones. The water area had the most excellent land-cover conversion rate in three decades, at 86.7%. Only 25% of mangroves and BUAs were natural.

**Table 1. LULC change Transition matrix at South 24 Parganas between 1991 – 2021. Source: Authors.**

| | LULC | | 2021 | | | | |
|---|---|---|---|---|---|---|---|
| | | **Unit** | **BUA** | **CL** | **MG** | **VG** | **WB** |
| **1991** | **BUA** | *km²* (%) | 132.95 (50.29) | 79.03 (29.89) | 0.35 (0.13) | 47.29 (17.89) | 4.73 (1.79) |
| | **CL** | *km²* (%) | 961 (45.86) | 783.12 (37.37) | 14.09 (0.67) | 323.14 (15.42) | 14.13 (0.67) |
| | **MG** | *km²* (%) | 83.48 (10.06) | 202.86 (24.45) | 410.84 (49.52) | 75.27 (9.07) | 57.23 (6.89) |
| | **VG** | *km²* (%) | 718.85 (40.16) | 751.31 (41.97) | 46.79 (2.61) | 262.18 (14.65) | 10.97 (0.61) |
| | **WB** | *km²* (%) | 194.01 (32.77) | 188.29 (31.80) | 58.46 (9.87) | 72.72 (12.28) | 78.61 (13.28) |

BUA-Built-up Area, CL-Croplands, MG-Mangroves, VG-Vegetation, WB-Waterbodies. The rows represent the former land cover (1991), and the columns represent the current land cover (2021).

From 1991 to 2021, much water and greenery disappeared, and many farmland and croplands were turned into concrete and steel. The water systems and vegetation also saw significant changes. The DEM and the change detection map (Fig. 4) show that the locations with the most significant elevation above the Hooghly River are where the most land has been converted to BUA (Fig. 4). Major inhabited regions typically sit between 8 and 10 metres above sea level. Since the main roadways have also expanded, the development has occurred on a ground elevation of 10 metres. Because of this, we may infer that the growth of the BUA is consistent with the DEM.

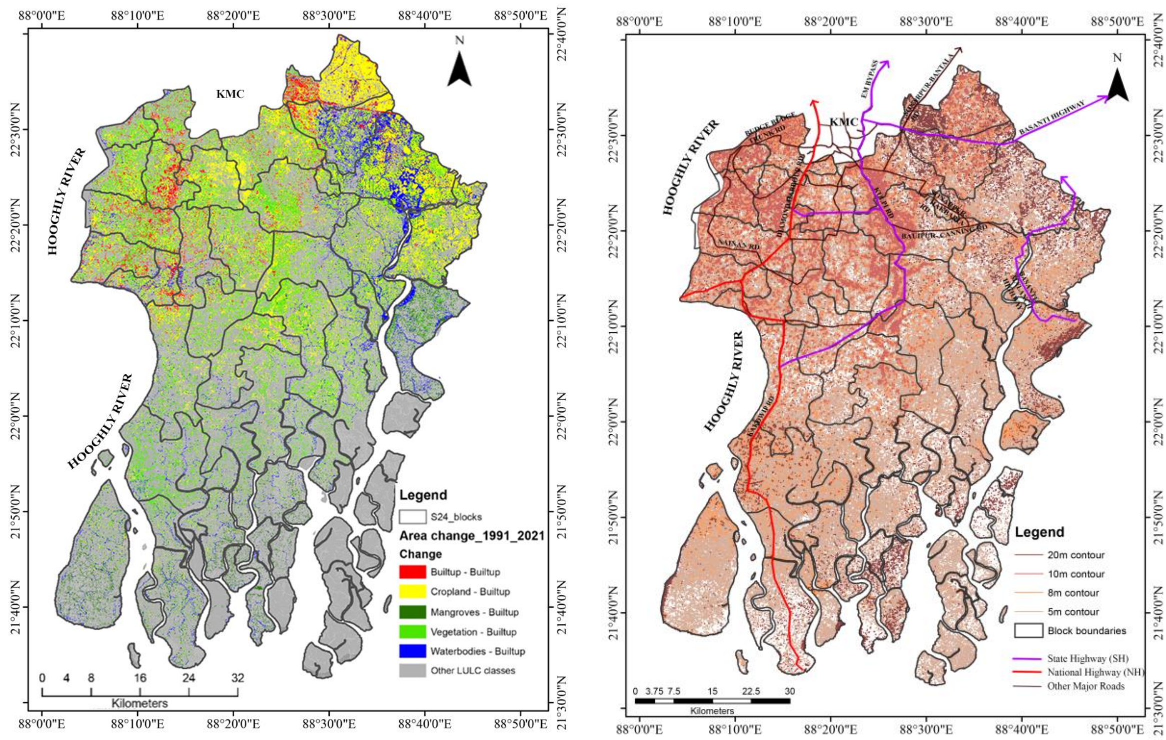


**Figure 4. The proportion of all land-cover classes transitioned to BUA between 1991 and 2021 at South 24 Parganas (left) and DEM with significant roads (right). Source: Authors.**

## 4.2. Network Analysis

The network metaphor in urban and territorial analysis has a long history, notably in land-use planning and economic geography. It entails tracking people's movements and creating lines of their paths. Most people's movements are predictable and constant (Telega et al., 2016). High control value means the line is a crucial connection for nearby lines (Baran et al., 2008). Figure 5 represents the network analysis in space syntax considering two parameters of the study area – 'choice ' and 'mean depth'. It shows that the network choice increases with a decrease in the mean depth value of the network. A higher mean depth value indicates segregation and network isolation, whereas a higher value of choice indicates the frequent choice of people and passing flow along with the specific network. Therefore, making some locations more frequently accessed by people than others within the region defines the region's future growth pattern and direction.

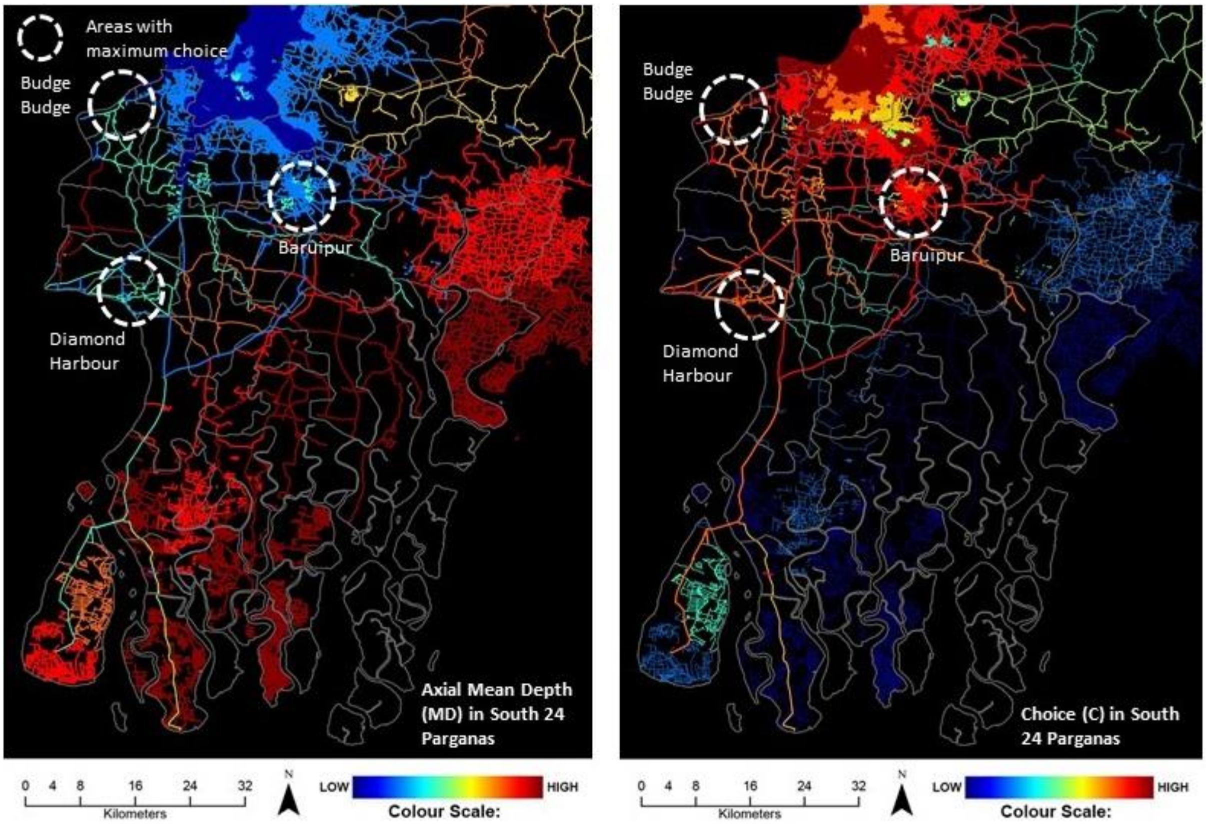


**Figure 5. Maps showing Mean Depth (left) and Network Choice (right) corresponding to the connectivity of streets in South 24 Parganas. Source: Authors.**

## 4.3. Population Dynamics

The network metaphor in urban and territorial analysis has a long history, notably in land-use planning and economic geography. It entails tracking people's movements and creating lines of their paths. Most people's movements are. An analysis was performed using the map statistics on the tendency of urban expansion in each urban spatial pattern contained inside the blocks. The data demonstrate that blocks on the eastern bank of the Hooghly and near the KMC boundary have shown positive population and urban growth. Thakurpukur-Maheshtala, Budge Budge-I, Sonarpur, Baruipur, Diamond Harbour, and Kakdwip are significantly affected. Due to changes in block areas during the previous years, most of the blocks during 1991-2001 saw early losses. This conclusion is consistent with data from the Indian Census (2011). South 24 Parganas saw a 39.40% population increase between 1991 and 2001, with growth slowing between 2001 and 2011. Very high growth rates were recorded in Tharkupukur-Maheshtala), Budge Budge-I, Sonarpur, Canning-I, and Diamond Harbour-I. At the same time, the seven municipalities within the region have shown significant growth in population, predominantly urban (Table 2).

**Table 2. BUA and population change between 1991 – 2021 across the district and its municipalities. Source: Authors.**

| Name | Area | BUA percentage | | | | Total Population | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1991 | 2001 | 2011 | 2021 | 1991 | 2001 | 2011 | 2021 |
| South 24 Parganas | 5236.79 | 4.57 | 14.05 | 17.16 | 37.28 | 5715030 | 6906689 | 8161961 | 9385426.5 |
| Maheshtala | 44.16 | 27.85 | 44.38 | 50.05 | 58.08 | 140240 | 385266 | 448317 | 602355.5 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Budge Budge** | 9.06 | 24.94 | 29.14 | 32.34 | 43.38 | 72951 | 75531 | 76837 | 78780 |
| **Pujali** | 8.32 | 14.78 | 23.68 | 27.28 | 35.94 | 10112 | 33858 | 37047 | 50514.5 |
| **Sonarpur** | 49.26 | 21.92 | 32.32 | 43.99 | 56.13 | 202941 | 336707 | 424368 | 535081.5 |
| **Baruipur** | 9.5 | 13.68 | 21.26 | 24.32 | 42.00 | 37659 | 44913 | 53128 | 60862.5 |
| **Diamond Harbour** | 10.36 | 6.56 | 11.58 | 29.83 | 37.45 | 30266 | 37234 | 41802 | 47570 |
| **Jaynagar** | 5.85 | 5.98 | 18.80 | 36.75 | 57.78 | 20217 | 23315 | 25922 | 28774.5 |

Municipalities and blocks near KMC and Hooghly River, like Maheshtala, had urban core expansion. Sonarpur, Budge Budge, and Pujali have no urban centre because of their isolation. These new municipalities saw tremendous population growth. Network analysis reveals land usage and population growth. Population growth and land use changes have occurred in areas with more network options and lower mean depth. Hooghly River and KMC border are important growing regions (Fig. 6). The neighbouring territories have crossed a threshold and are spreading towards Budge Budge, Baruipur, and Diamond Harbour. The network study also suggests a connection to Kakdwip, a rural village near Sagar Island, a famous religious tourism attraction. The Kolkata Urban Agglomeration (KUA) region comprises Thakurpurkur-Maheshtala, and Rajpur-Sonarpur is overpopulated.

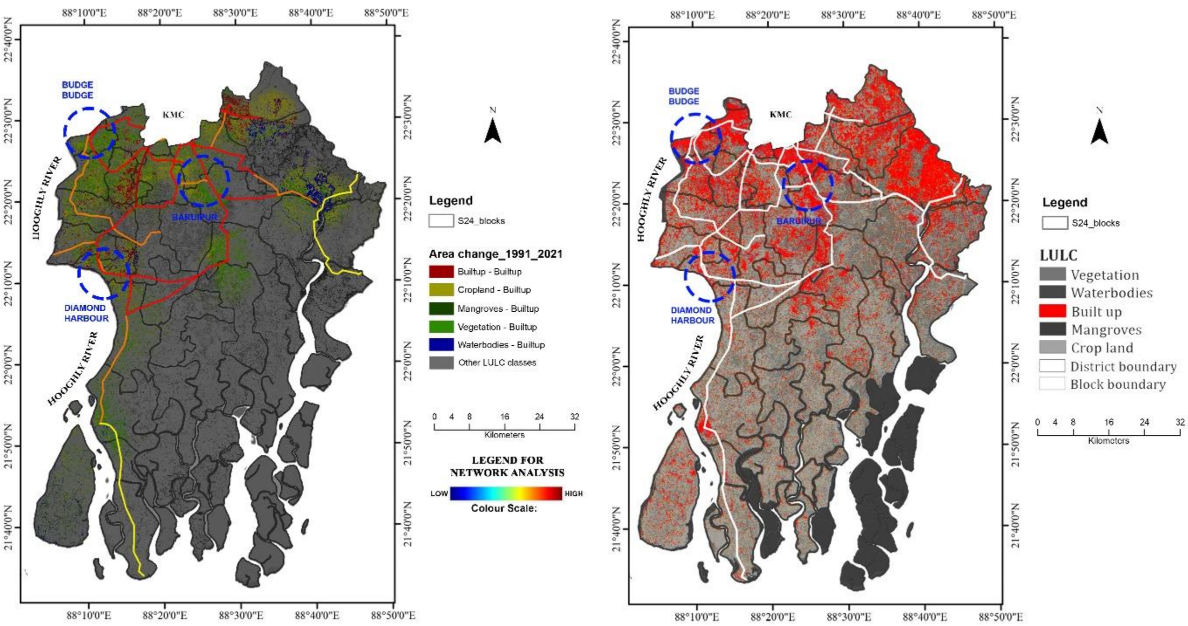


**Figure 6. Locations with the highest level of change in LULC (left) and locations with the highest level of population growth (right) correspond to people's network choices in the study area.**

According to this study, the South 24 Parganas includes three of the five basic ways to make a city healthier and more sustainable – Promoting urban agriculture, encouraging urban and peri-urban forestry, and reconnecting cities with the surrounding rural areas (FAO, 2022). Firstly, the region's current growth preserves the Sunderban Reserve Forest as a UNESCO World Heritage Site. It fulfils the criteria of encouraging urban and peri-urban forestry, where the reserve forest accounts for 9.5% of the region's habitable area (Fig. 3). The croplands have replaced the vegetation in most of the suburban areas in the past three decades. It promotes urban agriculture in the suburban areas and the newly urbanizing areas of the district. The current 35.6% of croplands are distributed along with the rural areas, but they also cover a small part of the peri-urban areas. Therefore, preserving the growth of the region can manifest the available resources.

## 5. Conclusion

The transition study uses a time series of maps to demonstrate land distribution changes. However, analyzing LULC trends in South 24 Parganas aids planning, management, and conservation choices. High-resolution multispectral satellite images may indicate more substantial area changes. LULC patterns changed significantly in the 1991, 2001, 2011, and 2021 Landsat assessments. From 1991–2001, most of LULC was transformed into agriculture. Population growth increased cropland, while agriculture remained a significant economic activity. While most of these constructions are on terrain 5-10 metres high in elevation, urbanization has encroached into low-lying areas on the western and southern boundaries of the district. The study also provided a method for examining urban land use patterns and urban growth in South 24 Parganas using network analysis for three decadal iterations (1991–2001, 2001–2011, and 2011–2021). Network analysis proves to calibrate regional urban spatial patterns and development trends adequately. From 1991–2001, the areas along the major roads (national and state highways) expanded faster than in 2001–2021. Blocks and towns around KMC multiplied. This expansion was attributed to urbanizing farmland. Population growth and rural migration in recent years have fueled development. Vacant and dilapidated lands were modified in the first phase (1991–2001), and good agricultural land in the second (2001–2021). The areas adjacent to the southern fringe of KMC, KUA and the eastern banks of Hooghly have a good rail and road network. Therefore, KUA's future population will be absorbed by South 24 Parganas. These outer zones allow urban expansion and planning. Future urban sprawl studies in developing countries should concentrate on spatial variation and resource flows. Urban growth dynamics and structure affect society, economics, and the environment. Remote sensing and GIS are used to assess urban development and geography. Land transformation strategies and management may benefit from the study's methodology.

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