



Dynamics of Urban Growth and Spatial Transformation in Dhulian Urban Cluster, West Bengal

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Abstract

In recent decades, Dhulian town and its surrounding areas in Murshidabad district, West Bengal, have experienced rapid urban growth and extensive spatial transformations. Consequently, investigating urban growth and quantitatively assessing land use and land cover (LULC) transformation have emerged as critical areas of study. This study examines the trends, patterns, and processes of urban growth and associated spatial transformations in the Dhulian Urban Cluster. Landsat imagery from 1991, 2001, 2011, and 2023 has been used to generate classified LULC maps employing the Maximum Likelihood method and the Supervised Classification technique in ArcGIS 10.8.2 software. Classification error has been minimized through the use of high-resolution Google Earth Imagery, while Post-Classification Comparison Change Detection Techniques have been applied for mapping and monitoring the temporal land transformations. Furthermore, statistical analyses and thematic mapping have been conducted using secondary data to assess the urban growth and its spatial and temporal variations. The findings indicate rapid urban expansion and spatial transformation within the study area, primarily driven by the increasing population pressures, growth of census towns, expansion of non-farm economic activities, and infrastructural development. During 1991-2023, built-up areas accelerated at a rate of approximately 373.9 percent, while the extent of agricultural land and open or fallow land declined significantly. Urban areas have expanded through horizontal extension along the corridor between the Ganga River and the National Highway. Understanding the urban growth pattern and its impact on surrounding areas may contribute to formulating micro-level planning strategies for urban development.

Keywords: Urban Growth, Population Densification, Spatial Transformation, Land Use and Land Cover Change, Change Detection

Introduction:

Urbanisation is a universal phenomenon and one of the most transformative processes of the 21st century. It refers to the transformation of rural settlements into urban areas and the increase in the percentage of the population living within urban centres (Pacione, 2009). In recent decades, rapid urbanisation has emerged as a dominant global trend, particularly in developing countries. According to the *2018 Revision of World Urbanization Prospects*, it is projected that approximately 2.5 billion additional people will be added to the urban areas by 2050 due to the combined impact of urbanisation and the world's population growth.

Concurrently, roughly 68 percent of the world's total population is expected to reside in urban areas, with nearly 90 percent of this increase occurring in Asia and Africa. Apart from demographic factors, other aspects, such as economic growth, infrastructure development, and socio-spatial complexities, continue to influence the nature and pattern of the urban growth process in developed and developing countries (Wang & Liu, 2017).

In India, the process of urbanisation has acquired distinctive characteristics over the last two decades, primarily manifested through the rapid emergence of census towns (CTs) alongside statutory towns (STs). Statutory towns are governed by municipal authorities, whereas census towns, despite fulfilling the criteria of census town as per the Census of India- such as a minimum population of 5,000, a density of at least 400 persons per square kilometre, and more than 75% of male main workers engaged in the non-farm activities - are still governed by the Gram Panchayats (Samanta, 2014, Zerah & Denis, 2017; Roy & Samanta 2018; Guin, 2019). According to the Census of India (2011), only 242 new statutory towns and 2,532 census towns have emerged in the previous decade, and approximately 31.16% of the total population resides in urban areas. This shift highlights a contemporary trend in Indian urbanisation, with census towns emerging at a much faster rate than the statutory towns.

Several Scholars have conceptualized this emerging pattern of urbanisation from different perspectives. Samanta (2012) described the growth of such settlements as "Non-recognized Urbanisation", which have been declared as urban by the Census but not officially recognized as statutory towns by the State. Pradhan (2013) further termed this phenomenon as "Unacknowledged Urbanisation," emphasizing that census towns contributed nearly 186 percent of the urban population growth in the last decade, whereas statutory towns contributed only 6 percent. Furthermore, he noted that around 66 percent of the newly emerged census towns are developed beyond the influence of the metropolitan cities. Similarly, Denis et al. (2012) introduced the concept of "Subaltern Urbanisation" to explain the autonomous growth of urban settlements driven by local market dynamics, historical influences, and which emerged far from metropolitan cities without relying on large, historically significant cities or being a part of planned cities.

Urbanisation is fundamentally a socio-economic and spatial process characterized by demographic concentration, behavioural transformations, and structural economic change (Lampard, 2013). In this process, demographic change refers to an increase in population concentration within urban areas, whereas behavioural transformations indicate the alteration of the social life patterns, and structural economic change denotes the shift from an agrarian economy toward industrial and service-oriented activities. As a consequence of these transformations, urbanisation leads to the physical expansion of urban areas through spatial growth of settlements and increasing built-up density (Berry, 1970). In Murshidabad district, the population density reached approximately 1334 persons per sq. km in 2011, indicating increasing pressure on land resources and the gradual transformation of rural areas into residential or built-up areas. In relation to this transformation, the spatial distribution of the census towns in Murshidabad district reveals that the maximum concentration of census towns has developed within Jangipur subdivision, particularly along the transportation networks and the Ganga River. Previous studies have demonstrated that urban sprawl and the transport networks development in

the suburban areas accelerate the conversion of agricultural and other land cover categories into built-up areas (Bhat et al., 2017; Obiahu et al., 2021).

In this context, the Dhulian Urban Cluster (DUC), situated between the Ganga River and the National Highway, represents a significant example of a rapidly changing peri-urban area. The urban expansion pattern of the DUC is linear in nature, shaped by the transportation network and environmental constraints. In recent decades, the spatial structure of the DUC has undergone a substantial transformation through the rapid expansion of built-up areas. This transforming land use and land cover (LULC) pattern has been shaped by both anthropogenic and natural factors, including population pressure, non-farm economic growth, various infrastructural developments, and riverbank erosion (Hassan et al., 2016; Roy & Samanta, 2018; Naiko et al., 2020; Paul & Bhattacharji, 2023). Therefore, the quantitative assessment of LULC changes has become essential for understanding and managing the process of land transformation. This study attempts to analyse the trends, patterns, and processes of urban growth in the Dhulian Urban Cluster in Murshidabad district, West Bengal, during the time period from 1991 to 2023. It focuses on demographic aspects of the urbanisation process and also assesses spatio-temporal changes in LULC with special emphasis on urban growth during this period. Understanding the dynamics of urban growth and its impact on surrounding areas may contribute to formulating micro-level planning strategies for urban development.

Materials and Methods:

Study Area

The study area for this particular research is the Dhulian Urban Cluster in Jangipur subdivision of Murshidabad district, West Bengal, and has a linear urban concentration. It has been selected because this area faced rapid urban transformation and dynamics of land use changes in recent decades. The study area consists of 1 Municipality, 14 Census towns and 4 inhabited villages: Dhulian (M), Arjunpur (CT), Sibnagar (CT), Mamrejpur (CT), Paranpara (CT), Mahadeb Nagar (CT), Jafrabad (CT), Anup Nagar (CT), Kankuria (CT), Uttar Mahammadpur (CT), Kohetpur (CT), Jaykrishnapur (CT), Basudebpur (CT), Chachanda (CT), Dhusharipara (CT), Jigri Kulgachi, Sikdapur, Loharpur and Jaladipur (Census, 2011). The DUC spreads over an area of 46.77 sq. km, located between 24°43'27"N to 24°37'22" N latitude and 87°54'03" E to 88°0'59" E longitude (Figure 1). As per the Census of India (2011), the DUC has a total population of 318352 with an average population density of 7325 persons/sq.km.

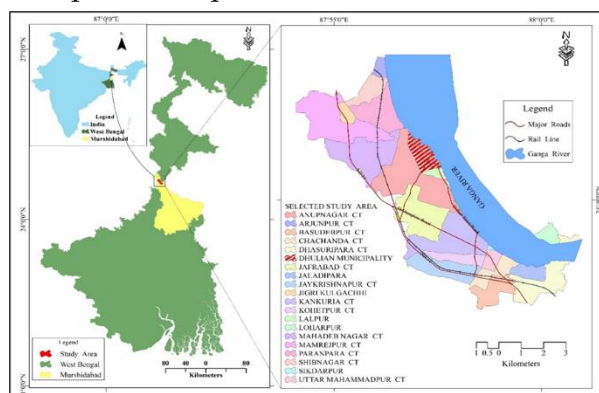


Figure 1: Location Map of the Study Area

The DUC is situated on the western bank of the Ganga River and the NH34 and is highly vulnerable to riverbank erosion due to its geographical location. Urbanisation along the Ganga River is one of the most important phenomena. As per the 2001 census, there were only 6 towns (1 statutory town and 5 census towns). But, in 2011, the figure had increased to 15, which includes 1 statutory town and 14 census towns. This increase in the number of towns indicates that altogether 9 villages have been transformed into census towns in a decade (2001-2011), registering an increase of over 180 per cent. From the above analysis, it is clear that despite a steady increase in the population, the number of statutory towns has remained the same. At the same time, the number of census towns has increased considerably in the last decade. Therefore, it is crucial to understand the dynamics of urban growth and spatial transformations of the DUC using geospatial techniques.

Database and Methodology:

The study is mainly based on secondary data sources. The secondary data have been obtained from various official records, Magazines, newspapers, books, journals, theses, and related Websites. The demographic and socio-economic data have been collected from the District Census Handbook and Primary Census Abstract, published by the Office of the Registrar General and Census Commissioner, India. To examine the process of urban growth in terms of demographic aspects from 1991 to 2011, the decadal growth rate of population, population density, household density, and non-farm activities of each urban centre have been computed and analysed. Furthermore, to gain a comprehensive understanding of the urban growth process, the growth of a new urban centre and the class-wise distribution of the town have also been analysed. The study area maps have been collected from the website of the District Land and Land Reforms Office, Murshidabad (<http://dllromsd.org/>).

To identify the LULC changes of the study area, it is necessary to detect the status of the present and the past LULC. For the LULC mapping and change analysis for the period of 1991-2023, four multispectral remote sensing images from the same season of each study year have been used. The data has been collected from the USGS Earth Explorer. Table 1 shows the details of the satellite data used. High-resolution Google Earth images have been used for the validation of the classified images and visual interpretations.

Table 1: Details of the Satellite Data

Satellite	Sensor	Path/Row	Date/Month/Year of Acquisition	Resolution	Source
Landsat 5	TM	139/43	23-10-1991	30m	
Landsat 7	ETM	139/43	26-10-2001	30m	U.S.
Landsat 5	TM	139/43	15-11-2011	30m	Geological
Landsat 8	OLI/TIRS	139/43	29-11-2023	30m	Survey

In this study, the maximum likelihood method and supervised classification techniques have been used to classify the Landsat images into five major classes, i.e., Agricultural land (AL), Vegetation/Plantation (V/P), Built-up area (BUA), Water Body (WB), and Open/Fallow land (O/FL). The classification error has been reduced by reclassifying the generalized images and cross-verified with the help of the high-resolution Google Earth images. Post-classification Comparison Change Detection Techniques have been used for

mapping and monitoring of the LULC changes from one land type to another during the period 1991 to 2023 in the DUC. To assess the spatial transformation associated with urban growth, the temporal changes in Agricultural land, Vegetation/Plantation, Built-up area, Water Body, and Open/Fallow land have been analysed.

The collected data have been analysed using different statistical techniques and cartographic representations. Microsoft Excel 2020 and ArcGIS 10.8.2 have been utilized for thematic mapping and visualizing the temporal dynamics and spatial variation of urban growth.

Result and Discussion:

Urban Growth Dynamics in the Dhulian Urban Cluster

Growth of the New Urban Centres (Census Towns)

The growth of new urban centres is one of the most important aspects of urbanisation in the DUC. As per the 1991 census, there were only 1 statutory town and 2 census towns in this area (Figure 2). Dhulian town is the only statutory town, while other urban units are Chachanda and Dhusaripara, which are located far away from the statutory town. According to the 2001 Census, Anup Nagar, Kankuria, and Uttar Mahammadpur were designated as census towns. In 2001, the total number of towns had increased from 3 to 6 (1 statutory town and 5 census towns). It has been observed that the growth rate of the urban centres was remarkably high in 2011, at the figure of 15, including 1 statutory town and 14 census towns, indicating a rapid rural to urban transition within this area (Figure 2). The urban units are Dhulian (Statutory town), Arjunpur, Sibnagar, Mamrejpur, Paranpara, Mahadebnagar, Anup Nagar, Jafrabad, Kankuria, Kohetpur, Uttar Mahammadpur, Jaykrishnapur, Chachanda, Basudebpur, and Dhusaripara. During this time period, a significant number of census towns developed in the proximity of the statutory towns and along the national highway, indicating that the DUC has undergone rapid urbanisation over the last two decades.

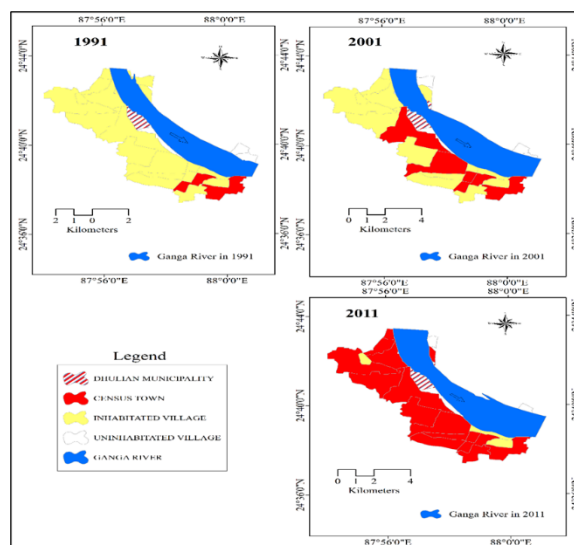


Figure 2: Growth of Census Towns within the Dhulian Urban Cluster, 1991-2011

Class-wise Distribution of Towns

The size class of towns is a major component in the continuum of urban growth, Because of the fact that urbanisation is closely linked to the size of the urban population (Hugo, 2017).

The volume of the urban population per unit of the urban centre is used to estimate this size. The Census of India has classified towns into six categories based on population size: Class I (100,000 or more), Class II (50,000-99,999), Class III (20,000-49,999), Class IV (10,000-19,999), Class V (5,000-9,999), and Class VI (less than 5,000).

In 1991, there were only two Class-V towns, i.e., Chachanda and Dhusaripara, in the DUC (Table 2). In 2001, out of the 6 urban units, Dhulian belonged to the category of Class-II town; Kankuria was included as a Class-III town; Chachanda and Dhusaripara were in Class-IV town category; and Anup Nagar and Uttar Mahammadpur were both identified as Class-V towns. Based on the 2001 census, Dhulian was upgraded from Class-III to Class-II town category, and two census towns were upgraded from Class-V to Class-IV town category (Table 2). In 2011, with the emergence of 9 new census towns in the DUC, the total number of towns had gone up to 15. Most of the newly emerged census towns in the study area belong to the Class-III town and the Class-V town categories, while only Jaykrishnapur CT belonged to the Class-IV town group. Anup Nagar happens to be the sole urban unit to be upgraded from the level of class-V town to class-IV town in 2011 (Table 2). The data clearly show that the study area had a dominance of class-III, class-IV, and class-V towns in 2011, demonstrating the predominance of small and medium-sized urban units within DUC. From 1991 to 2011, the continuous expansion of towns and the emergence of new urban centres marked a highly significant phase of the urbanisation process, reflecting trends of urban growth and population concentration.

Table 2: The
Classification of Towns from 1991 to 2011

<i>Name of the Town</i>	<i>Status</i>	<i>1991</i>	<i>2001</i>	<i>2011</i>
Dhulian	M	III	II	II
Arjunpur	CT			V
Sibnagar	CT			V
Mamrejpur	CT			V
Paranpara	CT			III
Mahadeb Nagar	CT			III
Anup Nagar	CT		V	IV
Jafrabad	CT			III
Kankuria	CT		III	III
Kohetpur	CT			V
Uttar Mahammadpur	CT		V	V
Jaykrishnapur	CT			IV
Chachanda	CT	V	IV	IV
Basudebpur	CT			V
Dhusaripara	CT	V	IV	IV
Total Urban Units		3	6	15

Source: DCHB Murshidabad 1991-2011, Census of India

The study area did not belong to the Class-I town category during 1991-2011, but in 2022, according to the Solid Waste Management Survey of the Dhulian Municipality, it has a population of 121,41. This figure suggests that the Dhulian town has now attained the

status of a Class-I Town. This transformation reflects increasing population density within the municipal area, an expansion of urban functions, and an accelerated trend of urban growth.

Densification of the Population:

Population density is defined as the number of people living in an area per square unit. The Census of India considers a population density of 400 persons per square kilometre as a criterion for classifying an area as urban. The overall population density of the DUC was 3950 persons per square kilometre in 1991, 5125 persons per square kilometre in 2001, and 7325 persons per square kilometre in the 2011 census year. This continuously increasing trend of population density means an increase in the concentration of population in the DUC. The population density has been categorized into 5 groups (Figure 3): very low (below 1000), low (1001-4000), moderate (4001-7000), high (7001-10000), and very high (above 10000).

In 1991, there were 9 urban centres with low population density (1001-4000), which later got decreased to 7 by 2001 and further to 3 by 2011. Meanwhile, the number of urban centres with a medium population density (4001-7000) has increased from 5 in 1991 to 7 in 2011. Urban centres with high population density (7001-10000) have ascended from just 1 in 1991 to 4 by 2001. In 1991, there were no urban centres with a very high population density (above 10,000), but by 2011, this number had grown to 4 (Figure 3). The data show a clear trend of a growing population in the urban centres over time. From 1991 to 2011, the number of low-density urban centres has steadily decreased, while the number of medium, high, and very high-density urban centres has surged significantly. This shift suggests that urban areas are becoming increasingly compact in settlement within the study area, reflecting broader patterns of urbanisation and population concentration.

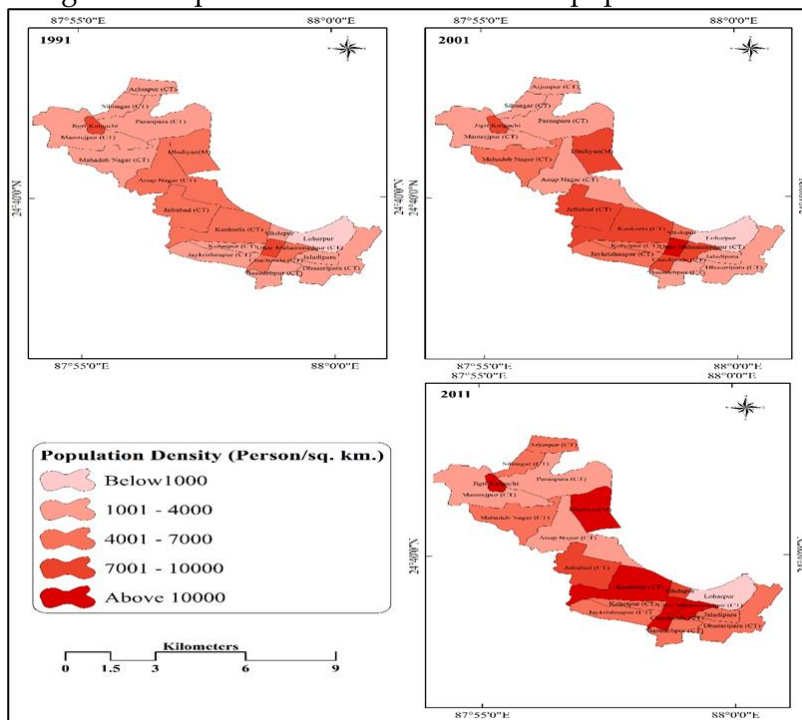


Figure 3: Population Density of the Dhulian Urban Cluster

Decadal Population Growth Rate:

The growth rate of the population is considered an important demographic indicator for determining the urbanisation of an area (Bhatta, 2012). Decadal growth rate refers to the percentage by which the population has increased over the past ten years (Sarkar & Samanta, 2023). During the period 2001-2011, the average decadal growth rate of the DUC was 31.52 percent, which is higher than the average decadal population growth rate of India (17.70%), indicating a rapid pace of urbanisation within the study area. The percentage of decadal population growth for the last three decades has been calculated and classified into five categories (Figure 4): very low (below 10%), low (10-20%), moderate (20-30%), high (30-40%) and very high (above 40%).

During 1981-91, more than 30% decadal growth had been recorded in all the urban centres of the DUC. Moreover, 7 out of 15 urban centres, namely Arjunpur, Sibnagar, Jafrabad, Kankuria, Uttar Mahammadpur, Chachanda and Dhusaripara, had exhibited the highest decadal growth of population (above 40%). During the period 1991 - 2001, the highest decadal growth rate was recorded in the Dhulian town (119.49%). The annexation of a part of the Anup Nagar mouza by the Dhulian Municipality during this period and the rural-urban migration due to river bank erosion are the main reasons behind such high growth. Conversely, the two urban centres, Anup Nagar (-67.90%) and Sibnagar, had experienced negative growth rates during this period.

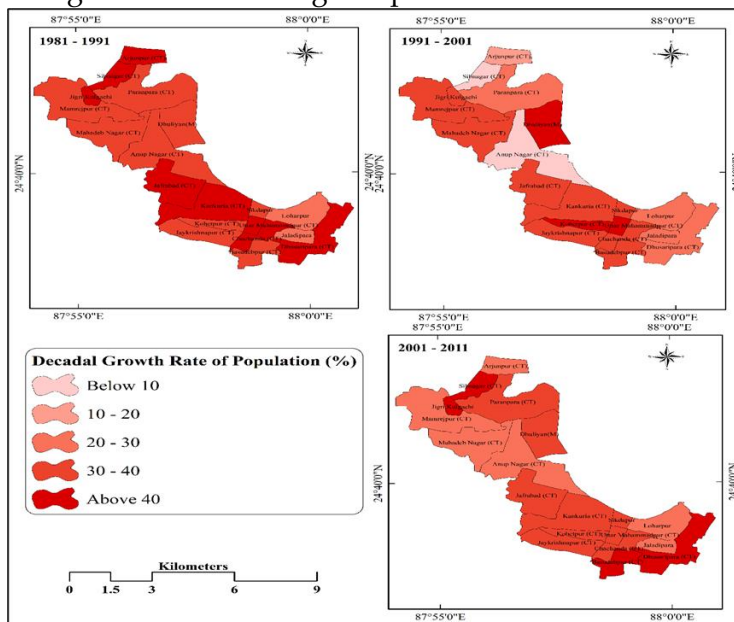


Figure 4: Decadal Population Growth Rate of the Dhulian Urban Cluster

During the 2001-11 decade, 3 urban centres, i.e., Basudebpur, Dhusaripara, and Sibnagar had displayed a very high decadal growth rate (above 40%) among all the 15 urban centres, from which two of them are spatially located in the southern part, and one is in the northern part of the DUC. Furthermore, a high decadal growth rate (30-40%) was recorded in 7 out of 15 urban centres, namely Paranpara, Jafrabad, Kankuria, Uttar Mahammadpur, Kohetpur, Chachanda, and Jaykrishnapur. A moderate growth rate (20-30%) was found in Arjunpur, Mamrejpur, Mahadeb Nagar and Anup Nagar. Overall, the growth trends indicate that while some urban centres within the DUC have experienced

rapid expansion, others have seen slower growth or even population decline. These patterns reflect the complex dynamics of urbanisation in the study area, influenced by factors such as annexation, migration and geographical location.

Household Density:

The Household density states the relationship between the number of households and the occupied area per square kilometre or square mile. The collected data on household density from 1991 to 2011 have shown a clear shift towards higher household concentration within the DUC (Figure 5).

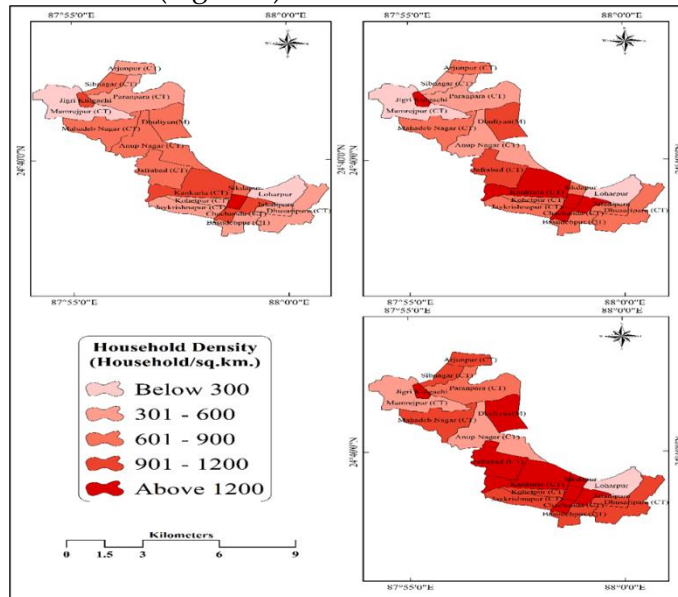


Figure 5: Household Density of the Dhulian Urban Cluster

In 1991, 6 urban centres had a low household density (301-600), but this number had decreased to 3 by 2001 and further to 2 by 2011. Similarly, urban centres with a medium household density (601-900) had also declined, from 5 in 1991 to 1 in 2011. On the contrary, the number of urban centres with a high household density (901-1200) had increased significantly, from just 2 in 1991 to 7 by 2011 (Figure 5). The shift from low and medium household densities to high and very high household densities across the urban centres, which reflects a significant population growth as well as an increase in the settlement concentration and compactness over the two decades.

Growth of Non-Farm Activities:

Non-farm activities and the level of urbanisation are interlinked. The Census of India also employs this parameter as an essential criterion to identify urban areas. In 1991, 6 urban centres had less than 80% non-farm activities; by 2011, this number had decreased to 1. Conversely, the extent of non-farm activities (90-95%) in urban centres increased noticeably, rising from 3 in 1991 to 8 by 2011 (Figure 6). In 1991, Dhulian was the only urban centre where a capacious extent of non-farm activities was noticed (above 95%). By 2011, 5 urban centres had started to participate in above 95 percent of the non-farm activities, indicating a substantial shift towards non-farm economic activities over the two decades (Figure 6).

The acquired data show an increasing trend of participation in non-farm activities within the DUC, which in turn reflects the expansion of the urbanisation process. The economic transformation of the area can be highlighted by the overall growth in the extent of non-farm activities, driven by a shift from farm activities to more diversified urban-based economic activities. This trend has acted as a catalyst for urban growth, settlement expansion, and the emergence of new urban centres in this study area.

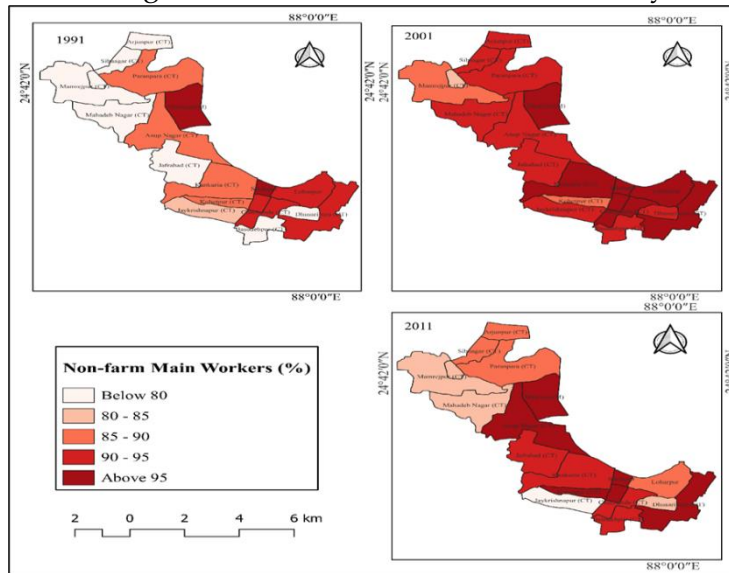


Figure 6: Non-Farm Activities of the Dhulian Urban Cluster

Spatio-Temporal Dynamics of the Land Use and Land Cover Change:

The LULC changes are a significant concern in the context of global environmental changes. The term 'land use' refers to anthropological activities on the land surface, while the 'land cover' refers to natural elements such as vegetation, water bodies, soil, and other natural features of the land (Verburg, 2000; Macarringue et al., 2022). Population growth, along with growing economy, industrialization, and urbanisation, imposes extreme strain on the existing natural resources. As the population increases, the demand for land resources intensifies, which alters patterns of land use (Dhas, 2008; Ahmed et al., 2020). Through the analysis of the LULC and the change detection process, it becomes easier to assess how various land uses evolve with time.

The LULC changes across the referenced periods have been studied, considering the existing land area within the DUC in 1991 as the base area. The DUC has undergone substantial land use changes from 1991 to 2023. The LULC maps of the different periods showcase the changes in different land use categories (Figures 7, 8, 9 and 10). There has been a significant increase in the magnitude of built-up areas and water bodies, along with a decline in the spread of agricultural land and open/fallow land. All land use categories have changed, although with varying percentages and rates. Tables 3 and 4 summarize the results of LULC classification for the years 1991, 2001, 2011 and 2023.

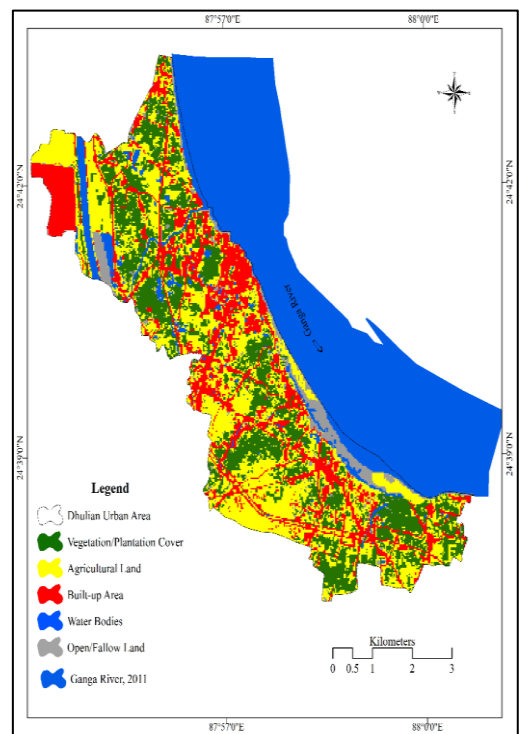
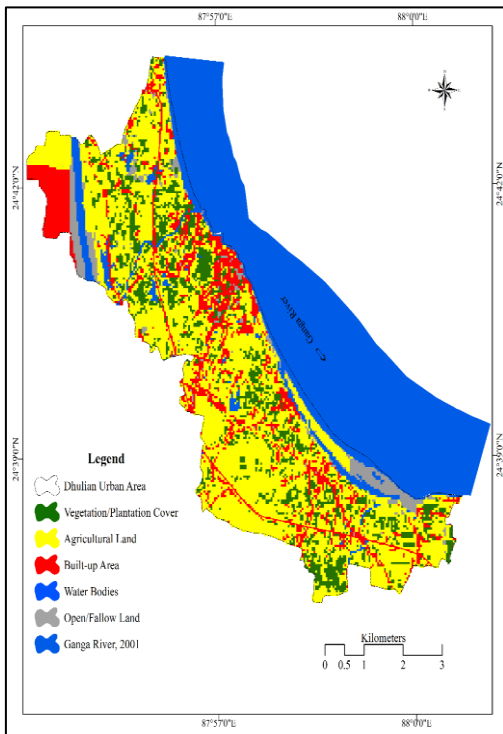
Table 3: Changes in the Area of Different LULC Classes (1991-2023)

Land Use Land Cover Categories	1991		2001		2011		2023	
	Area (sq.km)	Area (%)	Area (sq.km)	Area (%)	Area (sq.km)	Area (%)	Area (sq.km)	Area (%)
Agricultural Land	17.83	48.16	21.03	56.77	13.20	35.68	3.46	9.36
Built-up Area	3.40	9.17	5.89	15.91	8.77	23.71	16.08	43.47
Open/Fallow Land	3.16	8.53	1.83	4.94	1.96	5.28	1.63	4.41
Vegetation/Plantation Cover	11.05	29.84	5.56	15.01	10.46	28.27	11.97	32.37
Water Bodies	1.59	4.29	2.73	7.36	2.61	7.06	3.84	10.38

Source: Computed after Land use Classification, 1991-2023

Figure 7: LULC of Dhulian Urban Cluster in 1991

Figure 8: LULC of Dhulian Urban Cluster in 2001



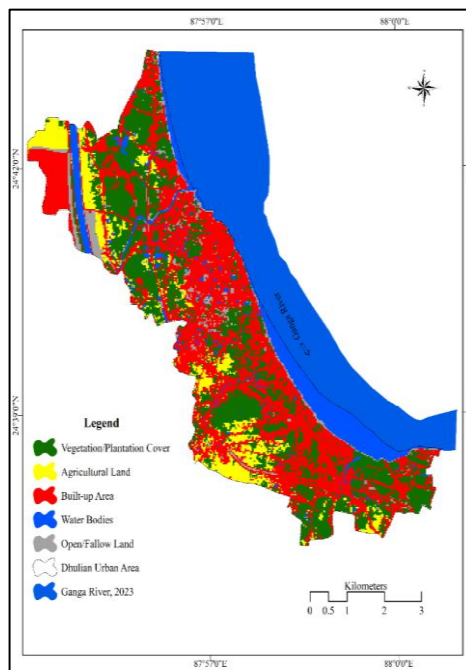


Figure 9: LULC of Dhulian Urban Cluster in 2011 Figure 10: LULC of Dhulian Urban Cluster in 2023

Agricultural Land and the Changes:

This transformation in the built-up areas and vegetation/plantation cover has primarily been at the cost of agricultural land, the extent of which has decreased by 80.56% (14.36 sq. km) from 1991 to 2023. Agricultural land, which used to cover around 48.16% of the total area, covering a total area of 17.83 sq. km in 1991, had increased to 21.03 sq. km, covering only 13.20% of the total area in 2001. The main reason behind such an increment was that during this period, the vegetation/plantation cover was cleared and converted into agricultural land. However, during 2023, a further reduction was recorded, where the spread of agricultural land went down to 3.46 sq. km, covering around 9.36% of the total area (Table 3). The rate of decrease in the area of agricultural land has been in correspondence with the increase in built-up areas and water bodies. The area had increased by 3.20 sq. km (17.88%) between 1991 and 2001. From 2001 to 2023, a negative growth has been seen, as the agricultural land area has decreased by 37.16% (7.83 sq. km) between the years 2001 and 2011, and by 73.76% (9.74 sq. km) in the period 2011-2023 (Table 4).

Built-up Areas and the Changes:

The built-up area has significantly increased in all the selected periods (Table 3). There has been an overall increase in built-up areas by 373.9% in a span of 32 years, from 1991 to 2023. The area has increased from 3.40 sq. km (9.17% of the total area) in 1991, to 5.89 sq. km (15.91%) in 2001 (Table 3). From 2011 to 2023, the area has increased from 8.77 sq. km (23.71% of the total area) to 16.08 sq. km (43.47% of the total area). The increase in the built-up areas may be attributed to the increase in population, the increase in public facilities, and structural changes due to developmental activities.

The built-up areas have exhibited a positive change in their growth in every decade, with 73.44% in 1991-2001, then an increase of 49.01% in 2001-2011, and a further 83.36% Volume-XII, Issue-III

increase in 2011-2023 (Table 4). In a span of 32 years, from 1991 to 2023, there has been an increment by 373.90% (Table 4). The expansion of the built-up areas has occurred in the form of residential areas and infrastructure development.

Open/ Fallow Land and the Changes:

Open/fallow land mainly comprises uncultivated land, river sandbars, and temporary vacant fields, which are unsuitable for settlement or any sort of economic activity. Similar to the agricultural land, a negative change has been witnessed in open/fallow land, which has been converted into built-up areas and water bodies. The expansion of open/fallow land has decreased from 3.16 sq. km (8.53%) to 1.63 sq. km (4.41%) in the period 1991-2023 (Table 3). Its area has reduced by 48.29 percent from 1991 to 2023. It has changed at a rate of -42.03% in 1991-2001, 6.87% in 2001-2011 and -16.52% in 2011-2023 (Table 4).

Vegetation/plantation Cover and the Changes:

Vegetation/plantation cover had decreased from 11.05 sq. km (29.84% of total area) to 5.56 sq. km (15.01% of the total area) during 1991-2001. Because of the fact that the vegetation/plantation cover were cleared and converted into agricultural land during this period, it has increased from 10.46 sq. km (28.27% of the total area) in 2011 to 11.97 sq. km (32.37%) in 2023 (Table 3). A negative change in vegetation/plantation cover was observed for the period 1991-2001, which was 49.71%, and its area had increased by 88.34% and 14.52% during 2001-2011 and 2011-2023 respectively (Table 4). The overall vegetation/plantation cover changes, in terms of area, for the period 1991-2023 were 8.47% (Table 4).

Water Bodies and the Changes:

During 1991, the water bodies were recorded to have a spread of about 1.59 sq. km (4.29% of the total area), which had increased to 2.73 sq. km (7.36%) in 2001. It has further increased from 2.61 sq. km (7.06% of the total area) in 2011 to 3.84 sq. km (10.38%) in 2023 (Table 3). The water body area has increased by 71.71% and 47% between 1991-2001 and 2011-2023, respectively. However, around 4.08% of the water bodies that had dried up during the period 2001-2011 have been converted into agricultural and open/fallow land (Table 4). In a span of 32 years, from 1991 to 2023, it has seen an increment of about 142.10%, mainly due to riverbank erosion (Table 4).

Table 4: Rate of Areal Change in the LULC (1991-2023)

Land Use Land Cover Categories	Rate of Change (1991-2001)		Rate of Change (2001-2011)		Rate of Change (2011-2023)		Rate of Change (1991-2023)	
	Area in sq. km	Area in %	Area in sq. km	Area in %	Area in sq. km	Area in %	Area in sq. km	Area in %
Agricultural Land	3.20	17.88%	-7.83	-37.16%	-9.74	-73.76%	-14.36	-80.56%
Built-up Area	2.50	73.44%	2.88	49.01%	7.31	83.36%	12.69	373.90%
Open/Fallow Land	-1.33	-42.03%	0.12	6.87%	-0.32	-16.52%	-1.53	-48.29%
Vegetation/Plantation Cover	-5.49	-49.71%	4.90	88.34%	1.51	14.52%	0.93	8.46%
Water Bodies	1.14	71.71%	-0.11	-4.08%	1.23	47.00%	2.25	142.10%

Computed after Land use Classification, 1991-2023

Land Cover Contribution to Built-up Area Expansion (1991-2023):

Change detection refers to monitoring the changing behaviours of land cover over a period of time. This helps to demonstrate the patterns of land cover transformation from one type to another over time. According to data computed from the LULC Change Detection Maps for 1991-2001, 2001-2011, and 2011-2023, a significant amount of vegetation/plantation (49.95%), agricultural land (33.71%) and open/fallow land (31.96%) have been converted for the sake of urban land use from 1991 to 2023 (Figure 11, 12, 13 and 14).

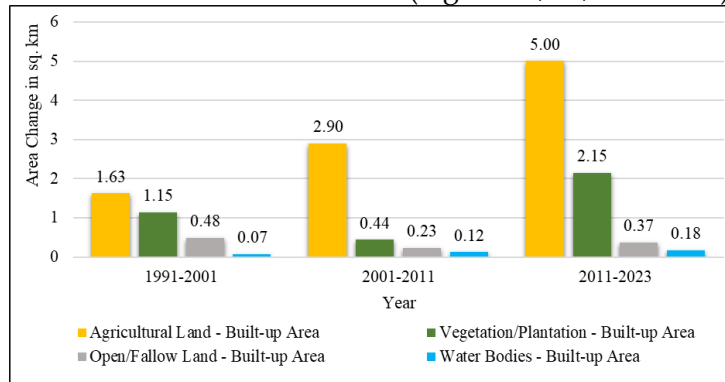


Figure 11: Land Cover Contribution to the Built-up Areas (1991-2023)

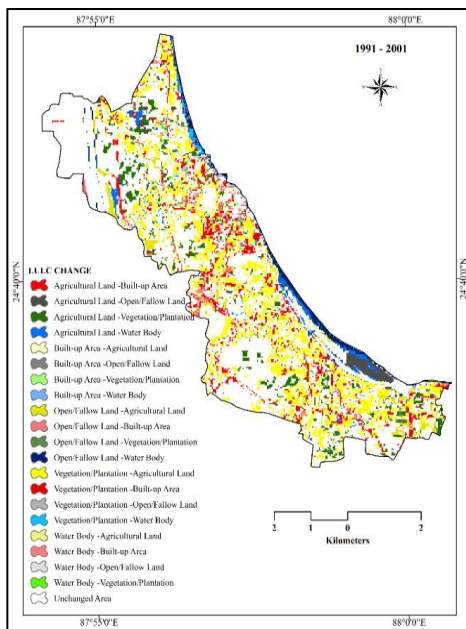


Figure 12: Changing LULC Map (1991-2001)

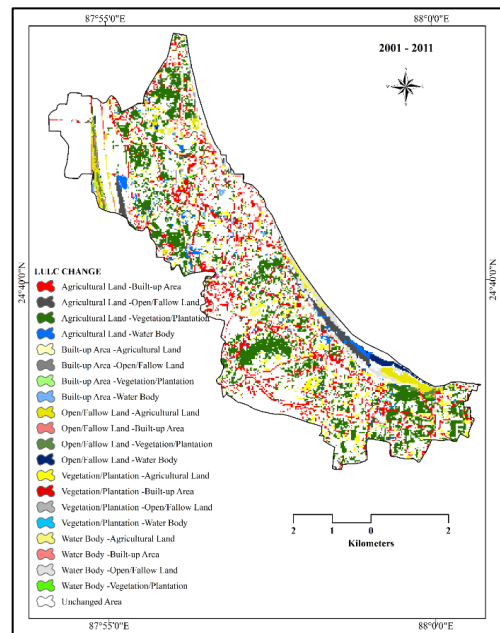


Figure 13: Changing LULC Map (2001-2011)

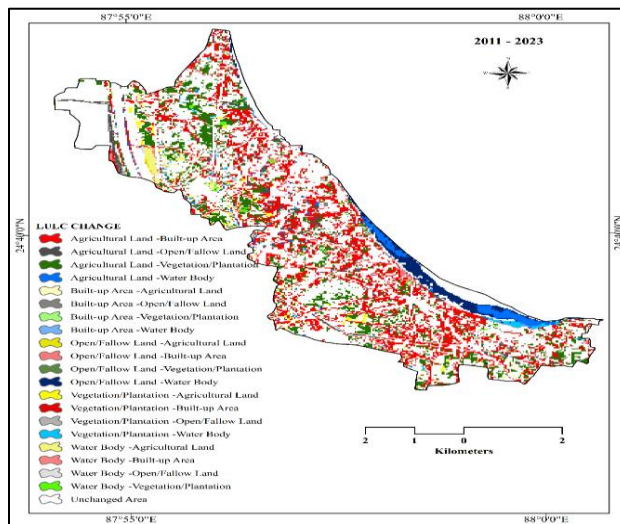


Figure 14: Changing LULC Map (2011-2023)

In 1991, about 9.14% (1.63 sq. km) of the agricultural land out of the total area was converted into built-up areas. This has resulted in about 73.44% increase in the total built-up areas. Around 10.37% (1.15 sq. km) of the vegetation/plantation cover and 15.30% (0.48 sq. km) of the open/fallow land have also been added to the built-up areas to increase its total area to 5.89 sq. km (15.91% of the total area). Similarly, there has been a significant transformation (4.51%) of the water bodies into built-up areas (Figure 11).

The area has increased from 5.89 sq. km (15.91% of the total area) in 2001 to 8.77 sq. km (23.71% of the total area) in 2011. This increase is attributed to the transformation of about 13.80% (2.90 sq. km) of agricultural land and around 7.97% (0.44 sq. km) of the vegetation/plantation cover into built-up areas in 2001. Similarly, a significant area under open/fallow land (12.47%, 0.23 sq. km) has been intruded by built-up areas (Figure 11).

The built-up areas have increased at a much faster rate from 2011 to 2023. With the increasing rate of urbanisation, nearly 37.90% (5 sq. km) of the agricultural land that existed in 2011, has been transformed into built-up areas. Similarly, a significant area under vegetation/plantation cover (20.51%, 2.15 sq. km) has been encroached upon by the built-up areas (Figure 11). Around 18.73% (0.37 sq. km) of the open/fallow land and 6.90% (0.18 sq. km) of the water bodies have also been added to the built-up areas, in turn, increasing the total area to 16.08 sq. km (43.47 % of the total area). Most of the pre-existing water bodies have now been filled up for built-up expansion.

Overall, the result suggests that the urban growth has primarily occurred through the continuous conversion of agricultural land and vegetation/plantation cover, highlighting the dominance of horizontal urban expansion within the Dhulian Urban Cluster. At the same time, it clearly underscores the accelerating process of spatial transformation and the emergence of a rapidly expanding peri-urban landscape in the study area.

Urban Growth in terms of Built-up Area:

The built-up area is typically used as a parameter for quantifying urban growth (Torrens et al., 2000). The built-up area of the DUC has been calculated from the LULC maps of 1991, 2001, 2011 and 2023, and these have become instrumental in measuring the urban expansion (Figure 15 and Table 5). The built-up areas of the DUC have increased from 3.40

sq. km (9.17% of the total area) to 16.08 sq. km (43.47% of the total area) during the period 1991-2023 (Figure 15 and Table 5). In the span of 32 years, from 1991 to 2023, built-up areas have increased by approximately 373.9% (Figure 15 and Table 5).

There has been a considerable increment in the extent of built-up areas between 1991 and 2001. During this time-frame, there has been an increment from 3.40 sq. km to 5.89 sq. km, marking an initial acceleration of urban expansion. However, during the period of 2001-2011, the expansion was from 5.89 sq. km to 8.77 sq. km. Finally, the built-up concentration has reached 16.08 sq. km in 2023 (Figure 15 and Table 5). The growth rate of the built-up areas was the highest during the most recent period (2011-2023) at 83.36%, followed by 73.44% in the period of 1991-2001, while the least growth rate was 49.01% in the 2001-2011 period (Figure 15 and Table 5).

Overall, a significant increase in built-up area during the study period clearly indicates that rural landscapes are progressively transforming into densely built-up areas, especially along major transportation corridors.

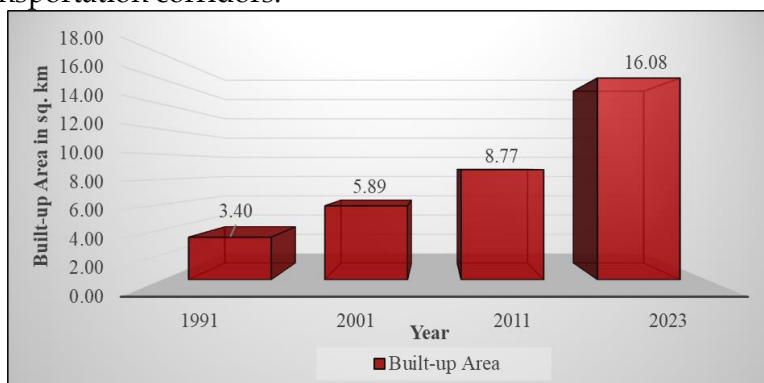


Figure 15: Trend of Built-up Area (1991 - 2023)

Table 5: Expansion of the Built-up Areas in the DUC

Year	Built-up Area (sq.km)	Built-up Area (%)	Changes in Built-up Area (sq.km)	Changes in Built-up Area (%)
1991	3.40	9.17	---	---
2001	5.89	15.91	2.50	73.44
2011	8.77	23.71	2.88	49.01
2023	16.08	43.47	7.31	83.36

Computed from the LULC Map, 1991-2023

Spatial Pattern of Urban Expansion (1991-2023):

DUC has seen a significant increase in built-up areas from 1991 to 2023 (Figure 16). Built-up areas in 1991 were mainly concentrated along the bank of the Ganga River and transport routes. During the period 2001-2011, urban expansion had become increasingly evident, with the initiation of the expansion of the built-up areas outwards from the town. This growth was particularly noticeable along the major roads and railways, indicating that transport networks have played a significant role in shaping urban expansion. This decade marked the beginning of the urban sprawl, as previously, separate urban areas had started to merge together. Especially from 2011 to 2023, the built-up area within the DUC has almost doubled, reflecting rapid urbanisation. During this period, the DUC has grown

in almost all directions, but the main growth has been towards the western and southern directions along the major roads, railway, and river banks. This pattern reflects a shift in land use from rural to urban, with agricultural and natural lands being converted into built-up areas to accommodate the growing population.

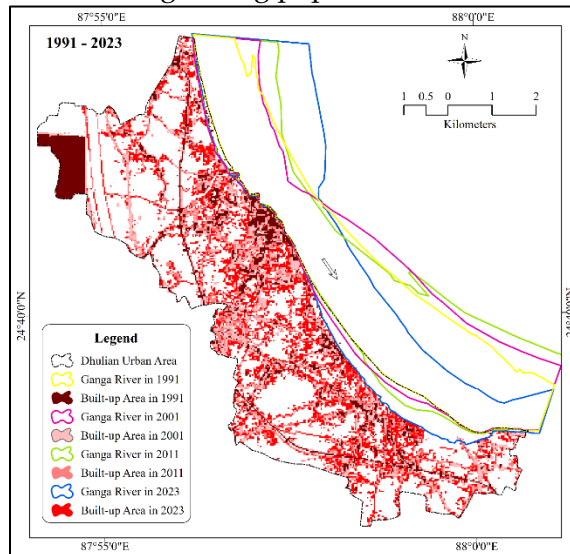


Figure 16: Urban Expansion of the Dhulian Urban Cluster (1991-2023)

Conclusion:

The present study reveals that Dhulian Urban Cluster has undergone a remarkable urban growth as well as spatial transformation from 1991 to 2023, with a particularly accelerated growth being observed between 2011 and 2023. The increasing population pressure, migration, economic transformation, and infrastructure development are the major driving forces behind the urban growth process within the study area.

The findings from the change matrix show that LULC changes in the DUC have mainly occurred through the significant growth of built-up areas, with the loss of agricultural land and open/fallow land, which in turn indicates increasing urban pressure on natural land resources. The results of the study indicate that the built-up areas have increased from 3.40 sq. km. to 16.08 sq. km. from 1991 to 2023, indicating an overall growth of about 373.9 per cent. This accelerated built-up area growth has been observed in the periphery of the Dhulian Town, due to its proximity to the town and the availability of facilities. Also, this growth has been noticed in places along the NH 34, major roads, and the western bank of the Ganga River, and this horizontal urban expansion has provided an elongated linear shape to the DUC.

This study strongly highlights the need for proper micro-level land use planning, conservation of agricultural land, control of haphazard built-up growth, and development of urban infrastructure to ensure balanced and environmentally sustainable urban growth within the Dhulian Urban Cluster.

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