Chapter-2

Growth of coastal urban centres

2.1. Environmental setup of the urban centres

Topography, substrate character, drainage condition and groundwater influences on the environmental setup of the urban centre of any places. The present urban centres remained over the coastal plain alluviums dominated by sand and clay materials. The surface elevation of the coastal plain is ranging from 3 m to 18 m above the Mean Sea Level (MSL) liable to flooding in the storm incidences and during heavy rains of southwest monsoon months. The urban centres are existing within three distinct landscape setup i.e. Digha in the shorefront beach ridge sand dune surface, Contai in the inland dune ridge surface and Haldia in the estuarine floodplain surface. The maximum elevations of the three urban centres are 18 m (Digha), 17.98 (Contai) and 15.37 m (Haldia) (Fig. 2.1). The drainage channels of the low gradient surface are also liable to siltation during the phases of Highest Astronomical Tide (HAT) and storm surges in the coast when the reverse hydraulic gradient of advancing seawater pushes sediments and saltwater into the inland channels of the region. The shallow groundwater aquifers of Digha, Contai and Haldia are liable to saltwater encroachment as the over-extraction of groundwater is continued in indiscriminate ways for municipality's water supply. Thus, the environmental setup of the three urban centres is very sensitive to the fragile condition of the alluvium coasts. Environmental conditions are discussed individually in the next section for each urban agglomeration of the coastal plain.

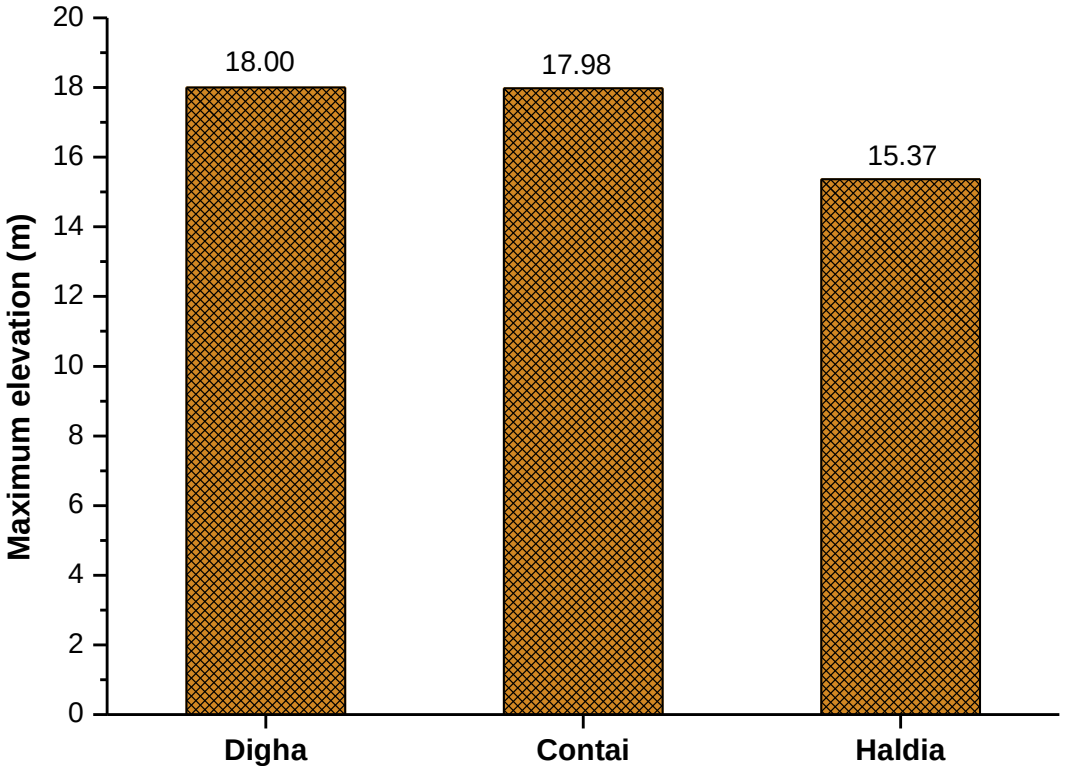

Fig. 2.1: Comparison of maximum elevation of three different urban centres.

2.1.1. Growth of Digha urban centre

Digha is a beach resort town which extends along the shoreline of the Bay of Bengal. Over time, the tourism centres are extended into different sections (Digha, Sankarpur-Tajpur, and Mandarmani) from 1950 to 2018 over the beach ridges and sand dunes. Also, the entire Digha-Sankarpur Development Authority (DSDA) area situated within the low-lying areas of wetlands. The elevation of the area varies from -0.74 m to 18 m (Fig. 2.2). The higher elevation observed along the shorefront dune ridges in the Digha, Sankarpur and Mandarmani coastal stretches, whereas, the lower elevation found in the wetland areas at inner parts. Geomprphologically, the coastal stretch situated within the distinctive geomorphic setup of sandy beach, beach ridge with dune, Holocene tidal deposit, mature swamp, recent tidal basin, and swamp (Fig. 2.3). Among those geomorphic features, most of the area occupied by the recent tidal basin (25.17 km²), Holocene tidal basin (15.62 km²), and beach ridge with dune (15.21 km²) (Table 2.1).

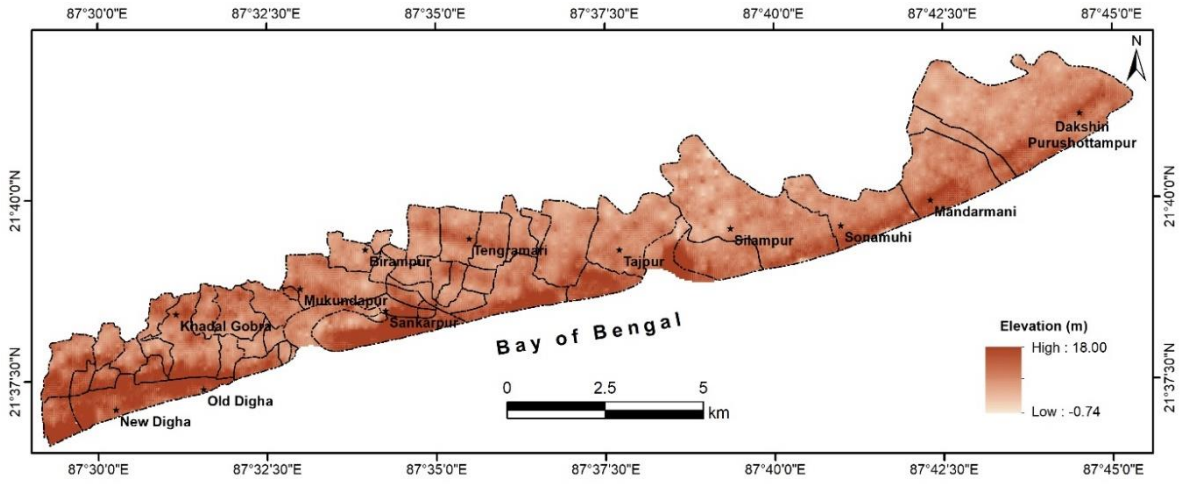

Fig. 2.2: Digital Elevation Model (DEM) of Digha-Mandarmani coastal stretch of Purba Medinipur district (showing the elevation differences of the administrative areas).

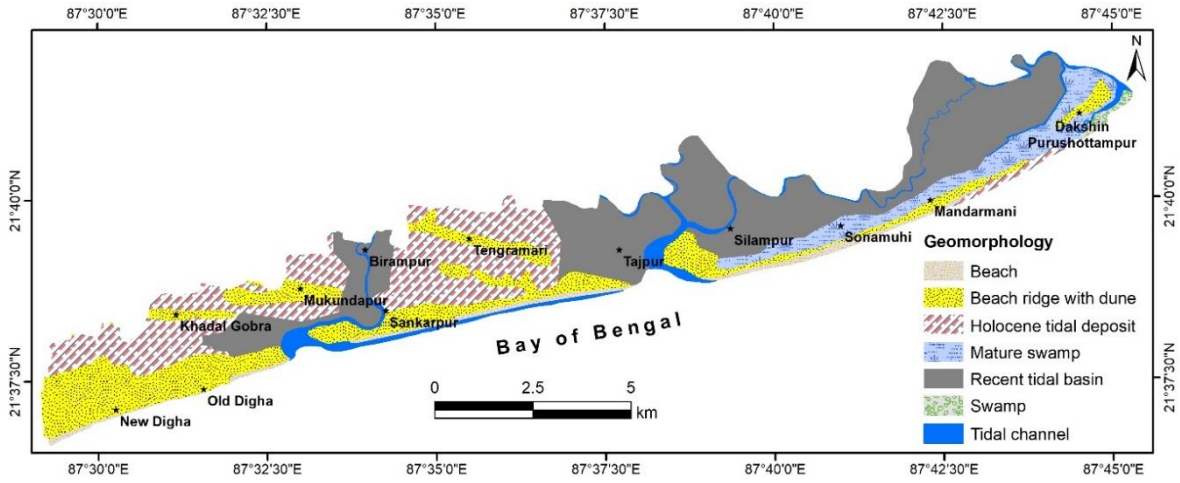

Fig. 2.3: Geomorphological diversities of Digha-Mandarmani coastal zones along the shore-fringe areas of the Bay of Bengal.

Table 2.1: Geomorphological diversities at Digha-Mandarmani coastal stretch.

Geomorphic features	Area (km^2)
Beach	2.06
Beach ridge with dune	15.21
Channel	3.30
Holocene tidal basin	15.62
Mature swamp	5.27
Recent tidal basin	25.17
Swamp	0.38

2.1.2. Growth of Contai urban centre

Contai or Kanthi is a municipality town of Purba Medinipur district. The urban centre is extended over the beach ridge sand dune complex of Kanthi peripheral sand ridge which is laying toward inland at 8 – 10 km distance from the present day's shoreline of the Bay of Bengal. The Contai municipality area situated over the Contai dune ridge and interdune low-lying swale landscape. The elevation of the entire area varies from 2.41 m to 17.98 m from the MSL (Fig. 2.4). Higher elevation exists over the dune ridge and the low elevation within the low-lying swale areas. The linear sand ridge of the region was formed by marine and aeolian deposition which took place about 7,000 Years Before Present (YBP) during the presence of active shoreline at the area (Maiti, 2013).

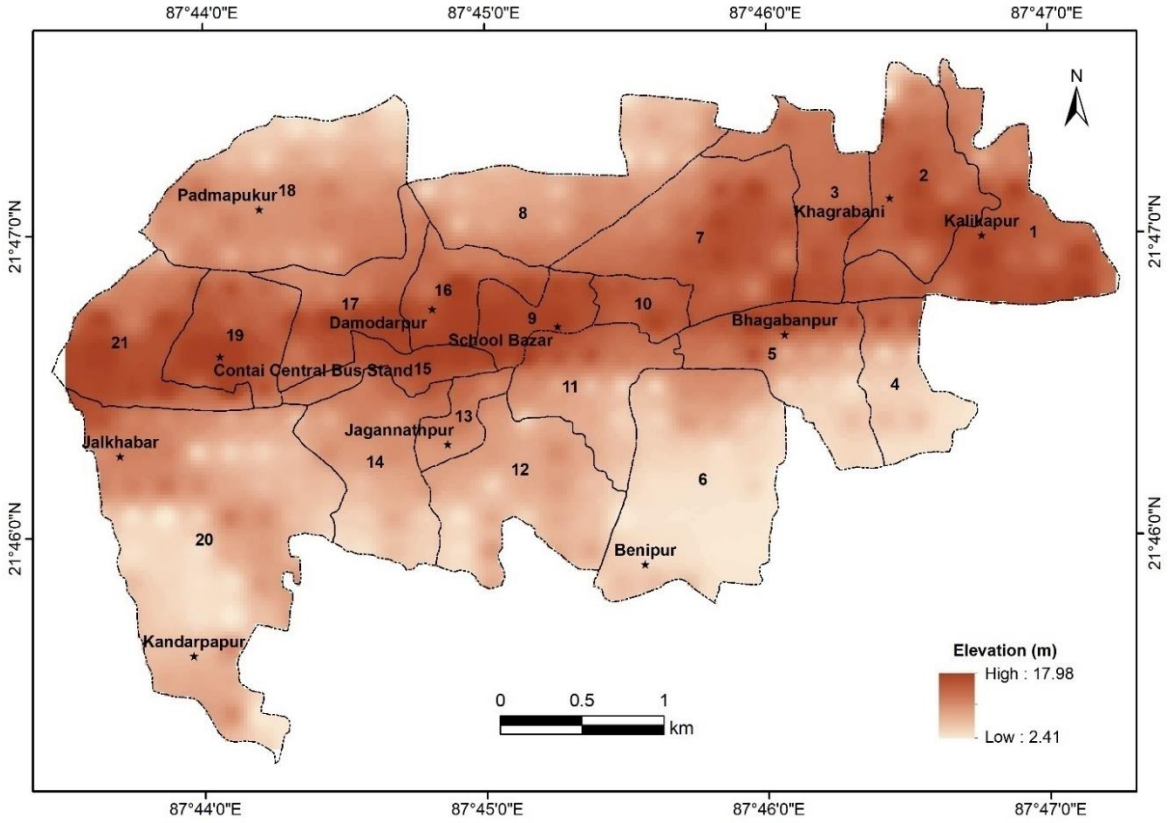

Fig. 2.4: Digital Elevation Model (DEM) of Contai Municipality areas in the littoral tract of Purba Medinipur district (showing the elevation differences of the administrative areas).

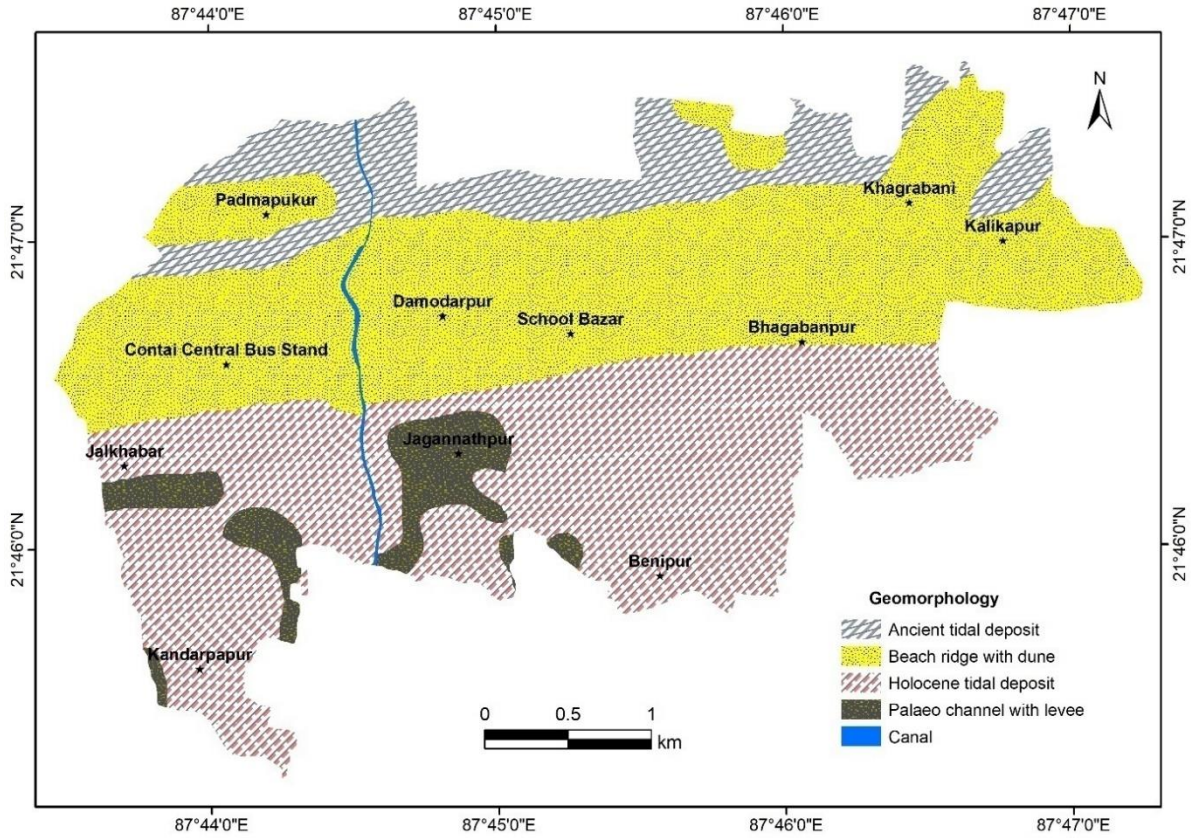

Fig. 2.5: Geomorphological diversities of Contai Coastal Plain with palaeo dune ridges in part.

Initially, the shore parallel linear sand ridges ware formed as a barrier spit in front of the wide and extensive backwater (Dubda basin) areas toward the north (Jana & Paul, 2019). Gradually, the beach ridges with overlying sand dunes were drifted toward inland by overwash process on the pre-existing lagoonal setting of the region at the early Holocene rise of sea level (Niyogi, 1975; Paul, 2002). The northward advancement of sand sheets with overlying sand dunes of that period (about 7, 000 YBP) provide the substrate condition for today's urban centre of Contai. The geomorphological diversities of Ancient tidal deposit, beach ridge with sand dune, Holocene tidal basin and palaeo channel with levee are observed within the area (Fig. 2.5). Most of the area has been occupied by the beach ridge with sand dune (6.28 km²) and Holocene tidal basin (5.40 km²) with the other geomorphic features of Ancient tidal basin (1.83 km²) and palaeo channel with levee (0.76 km²) (Table 2.2).

Table 2.2: Geomorphological diversities at Contai.

Geomorphic features	Area (km^2)
Ancient tidal basin	1.83
Beach ridge with dune	6.28
Holocene tidal basin	5.40
Palaeo channel with levee	0.76
Tidal channel	0.05

2.1.3. Growth of Haldia urban centre

The municipality town or the port-town of Haldia is situated on the estuarine bank margins of the river Hugli and Haldi in Purba Medinipur district. The elevation of this area varies from 8.47 m to 15.37 m (Fig. 2.6). The higher elevation found in the bank margin areas at the confluence of river Hugli and Haldi. The lower elevated areas remain in the inner low-lying areas.

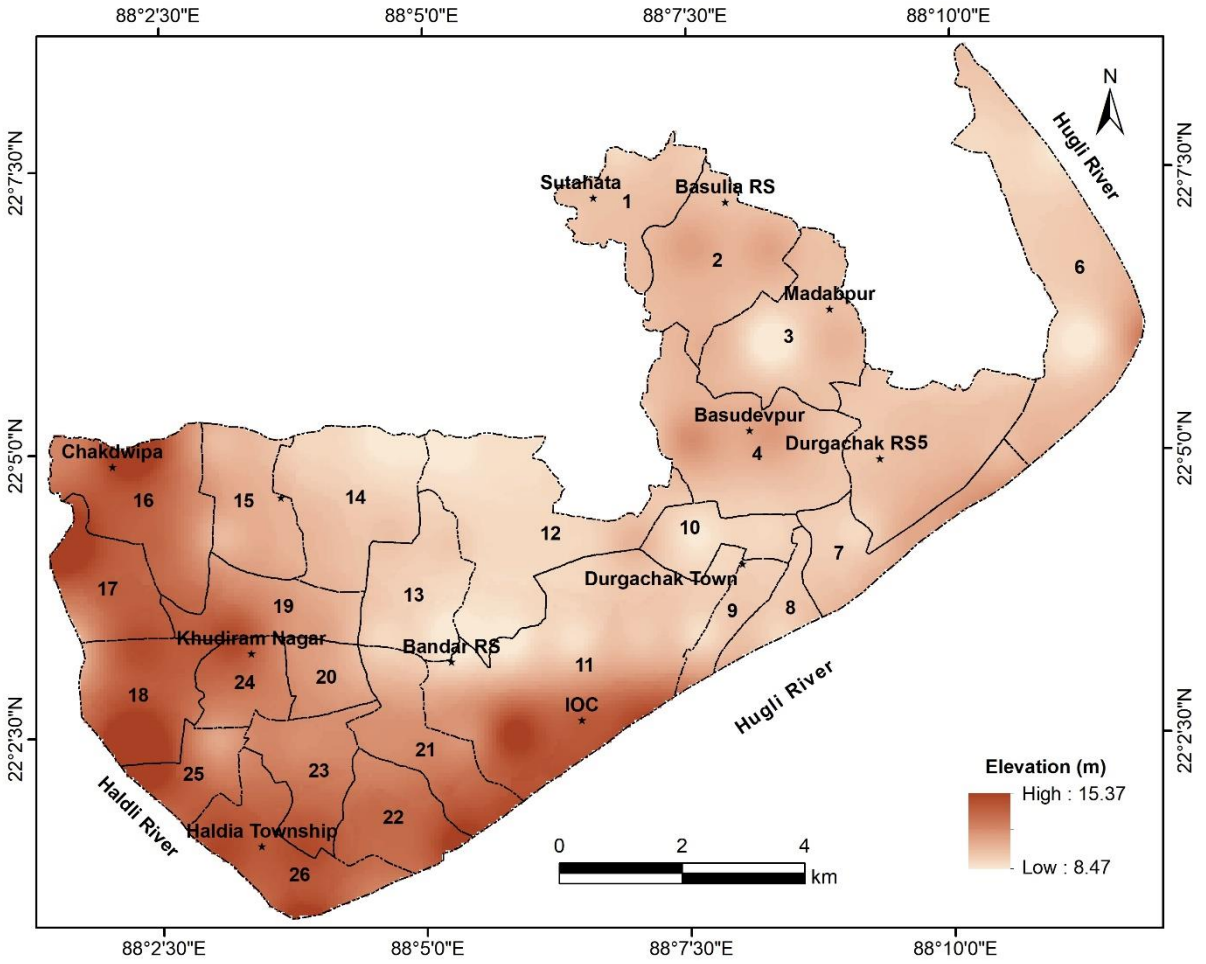

Fig. 2.6: Digital Elevation Model (DEM) of Haldia Municipality areas in the littoral tract of Purba Medinipur district (showing the elevation differences of the administrative areas).

Table 2.3: Geomorphological diversities at Haldia.

Geomorphic features	Area (km^2)
Ancient tidal basin	10.21
Holocene fluvial deposit	61.22
Mature swamp	6.62
Mudflat	1.66
Palaeo channel with levee	15.25
Swamp	2.86
Tidal channel	2.16

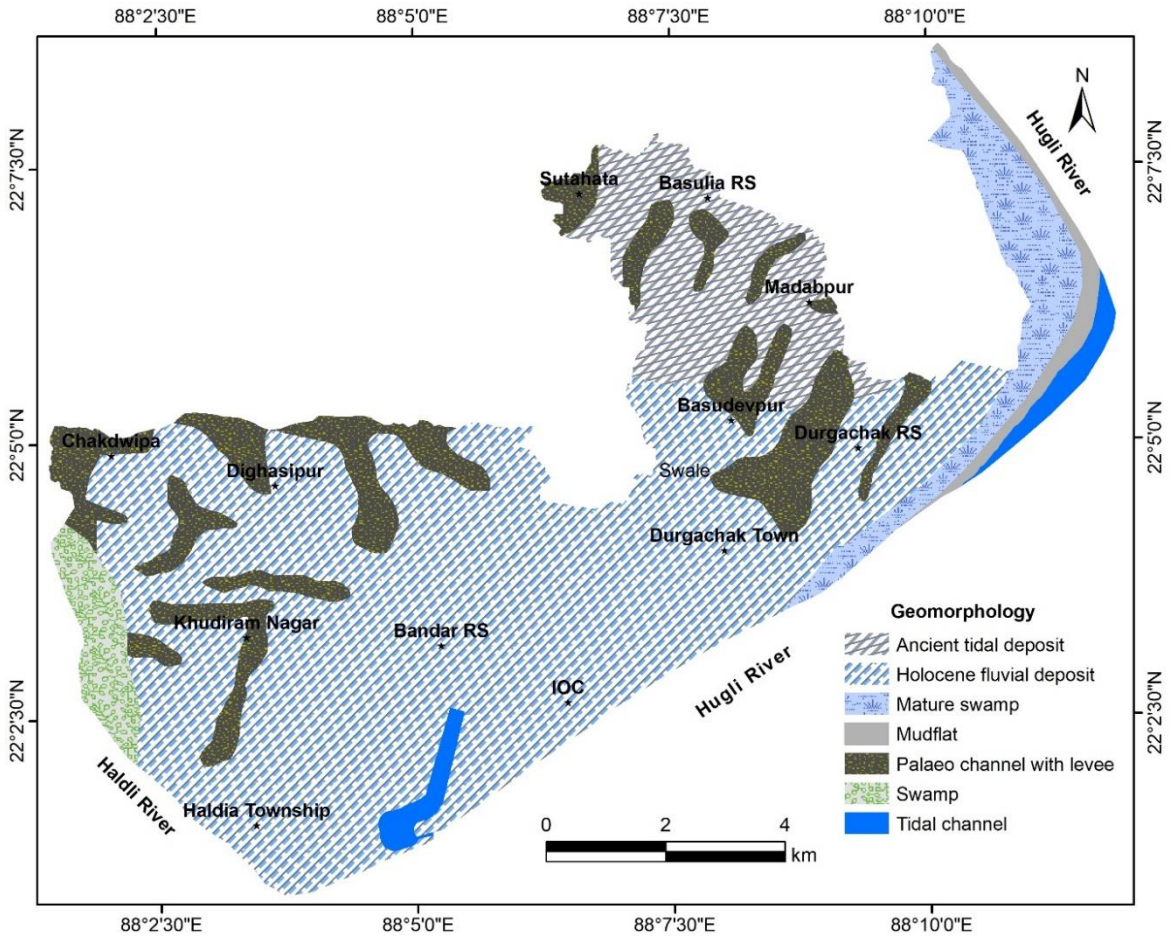

Fig. 2.7: Geomorphological diversities of Haldia urban centre along the Hugli-Haldi estuary complex (part of the inner littoral tract).

The six major diversified geomorphological features of Ancient tidal deposit, Holocene fluvial deposit, mature swamp, mudflat, palaeo channel with levee and swamp are observed within the area (Fig. 2.7). Most of the area has been formed as the Holocene fluvial deposit (61.22 km²), palaeo channel with levee (15.25 km²), and Ancient tidal basin (10.21 km²) (Table 2.3). Also, the mature swamp, swamp and mudflat surfaces have been occupied the areas of 6.62 km², 2.86 km² and 1.66 km² respectively (Table 2.3). The urban infrastructures are extended over the estuarine floodplain of basement clay and silty-sands across the tidal flats, wetlands and low-lying alluvial surfaces. Over-extraction of groundwater at an alarming rate is reflected in the rapid fall of groundwater depth in the region. Huge dumping of the urban wastes filled up the wetlands and lowlands along the bank margins of the river estuaries at present. The wide space of river bodies and extensive saltmarshes of Nayachar Island and Haldi estuary banks act as a good filter of emitted pollutants from industries and port areas in Haldia. The spread of the town may further occupy wetlands and may reduce the areas of pollutant trapping of the open marshes. Restoration of wetlands at the urban fringes will control the level of pollution in the inner township areas.

2.2. Expansion of urban centres

2.2.1. Expansion of Digha urban centre

In the present study, the Digha urban centre is considered as the area under the DSDA. The present form of DSDA considering the entire coastal tourism areas of Digha, Sankarpur and Mandarmani (LUDCP, 2015). The entire tourism area under DSDA is expanded with increasing tourists' demand in three different stages in the year of 1990, 1991 and 2004 (Fig. 2.8). The famous tourism area of Digha was initially established in 1956 with the formation of Digha Development Society (DDS). During 1990, the DDS modify the tourism area considering the 16 mouzas in Digha sector and established the Digha Planning Authority (DPA). Afterwards, in 1991, the Digha Development Authority (DDA) was established occupying the 42 mouzas and extended the tourism area up to the Sankarpur-Tajpur coastal sector. Finally, in 2004, the DSDA was formed occupying 51 mouzas extending up to Mandarmani coastal sector (Fig. 2.8).

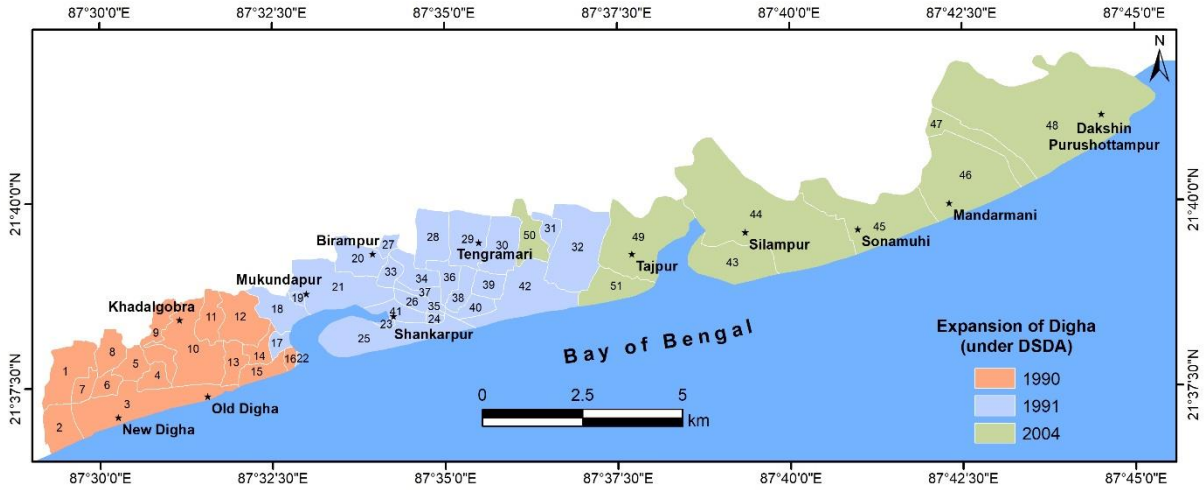

Fig. 2.8: Temporal and spatial changes in areas of Digha urban centre along the shoreline.

In the present form of the DSDA area, the coastal sand dunes, beach ridges, wetlands and lowlands are modified and converted into hotels, resorts, various offices and tourism infrastructures for ever-growing of the coastal resort town. As per the Census of India (2011), the Khadalgobra mouza is considered as the census town. The Digha, Sankarpur-Tajpur and Mandarmani tourism areas are situated as shore fringe beach-resort destinations under the development board of DSDA in Purba Medinipur district. The entire DSDA area is extended with time on the beach ridge sand dune complex and gradually occupy the marginal wetlands of mangroves, saltmarshes and foreshore beach plains. Digha estuary and Champa river delineate the northern and eastern boundary of Digha resort town. However, Tajpur-Sankarpur and Mandarmani sections are separated by Jaldah estuary and Pichaboni river (Shoula river)

further towards east particularly along the shorelines. Since 1950, the Digha-Sankarpur-Mandarmani tourism areas have been extended in different stages in different periods with increased tourist demand over the coastal sector. With the increase of tourism activities the spatial expansion has been continued likewise, during 1950 onwards the resorts were initiated at the Old Digha, 1980 onwards at New Digha, 1985 onwards at Sankarpur, 1990 onwards at Digha periphery areas, 2007 onwards at Mandarmani, and 2015 onwards at Tajpur area.

2.2.2. Expansion and reform of Contai urban centre

In 1958, the Contai municipality was established in the form of residential activities. This is the main urban centre and also the administrative town of the littoral-coastal tract. The municipality area expanded and reformed in different years (Fig. 2.9). During 1991, 14 wards

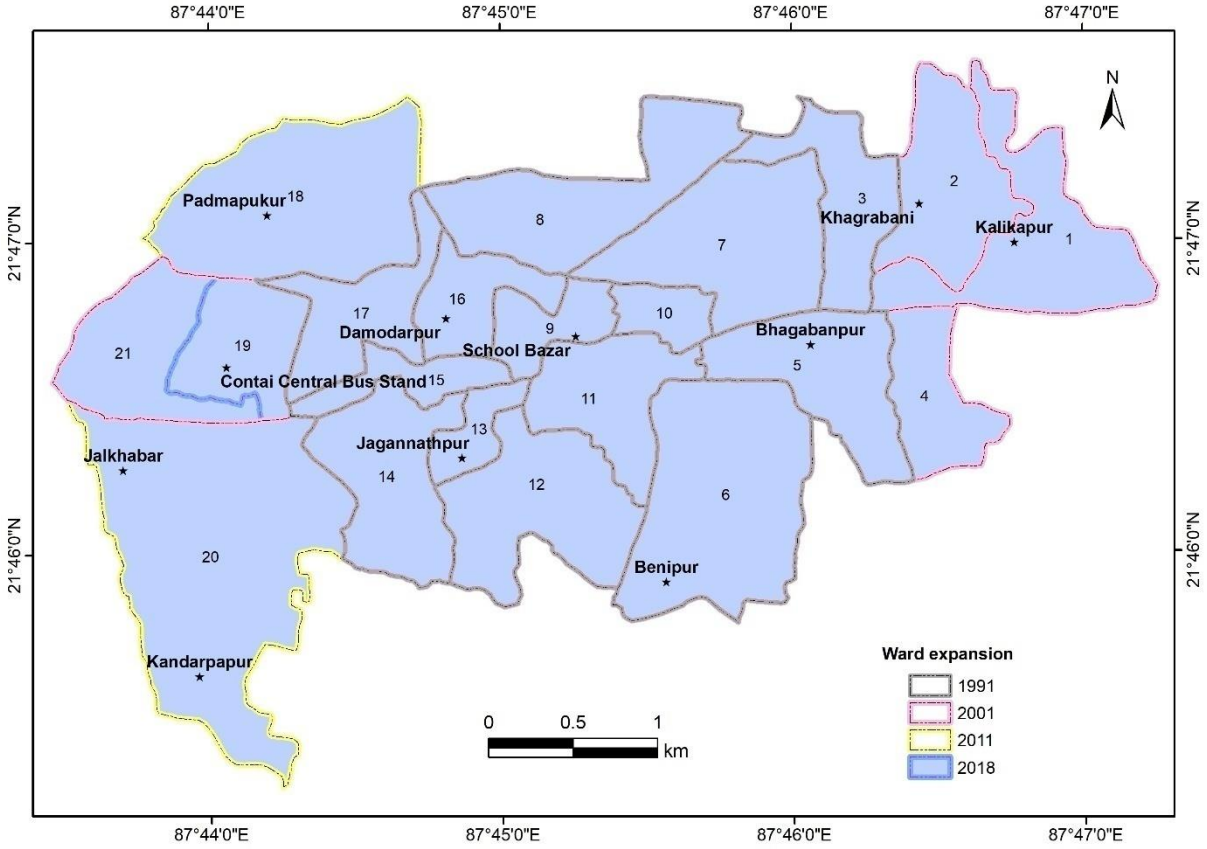

Fig. 2.9: Temporal and spatial changes in areas of Contai urban centre along the inner coastal dune ridges.

remained at the central part over the dune ridge and surrounding areas. In 2001, 4 new wards were incorporated under the municipality area. Among those, 3 wards located on the eastern side and 1 ward located on the western side of the earlier municipality area. In 2011, another 2 wards have been formed in the northwest and southwest side of the existing wards. Finally, in 2018, 21 wards exist within the Contai municipality. It is observed that most of the urban area

has expanded along the dune ridge, and a majority of the town area laid over the saline groundwater aquifer in the coastal plain. Over-extraction of groundwater for municipality water supply in the region may produce harmful effects of the shallow groundwater aquifer. Furthermore, the north and southward expansions of the town will occupy low-lying alluvial tracts of pasture lands, agricultural lands and wetlands. Extensive areas of Cashewnut trees and other indigenous vegetations of that region are alarmingly reduced due to urban infrastructural development.

2.2.3. Expansion and reform of Haldia urban centre

The Haldia municipality was established in 1997 compiling with 18 wards based on the port and industrial areas. After that, the municipality area has been expanded in terms of area and the number of wards likes, 23 wards in 1999, 24 wards in 2001, and 26 wards in 2011 (Fig. 2.10). Finally, in 2019 the municipality area and wards have been further expanded and

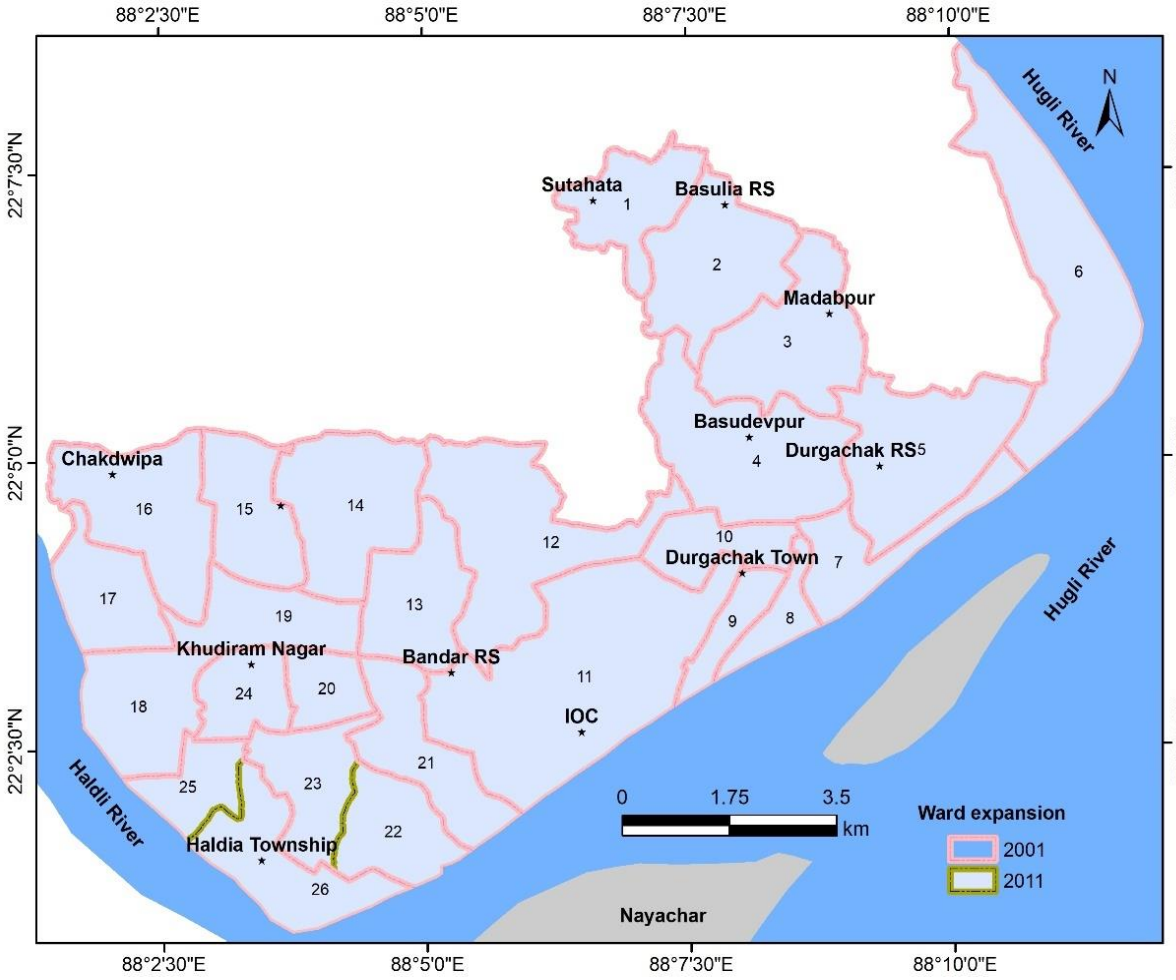

Fig. 2.10: Temporal and spatial changes in areas of Haldia urban centre along the estuarine floodplain of Hugli-Haldi confluences.

reformed with 29 wards. The municipality has not published any kind of final map of the new wards. As the current map of municipality is showing the boundaries of 26 wards (2011), the present work is also based on the similar map available from the municipality office in the present form (Municipality ward map of Haldia, 2011). It is observed that the urbanization has been initiated at the bank margin areas depending on the port and industrial activities. Afterwards, the municipality area has been expanded in the eastern and western side over the levees of river Hugli and Haldi. The suitable land has been occupied by the built-up areas, and people are compelled to build their settlement in the low-lying areas. Therefore, the newly expanded urban areas will remain in a vulnerable condition.

2.3. Scenario of land use and land cover change

The spatio-temporal assessment of land use and land cover (LULC) is very essential to establish the pattern of urbanization and urban growth. The natural landscape and land cover pattern have been converted into the comfortable areas for construction of settlement and other required infrastructures. The LULC change and their impact on the land can be assessed through analysis of the nature of vegetation cover, distribution of water bodies and wetlands, and distribution of impervious areas or built-up areas. Therefore, the LULC and their changing scenario have been assessed for the three urban centres (Digha, Contai and Haldia) considering the images of four different years (1991, 2001, 2011 and 2018).

2.3.1. Land use and land cover change in Digha

The LULC and their changing scenario have been assessed all along the entire area under the DSDA in four different temporal periods. After the initiation of tourism activities mainly in the Digha sector, the tourism supportive infrastructure requirement has increased for the benefit of tourists. The natural beach ridge and sand dunes have been altered into the built-up area at the cost of dune degradation and habitat conversion. During 1991, the tourism-based

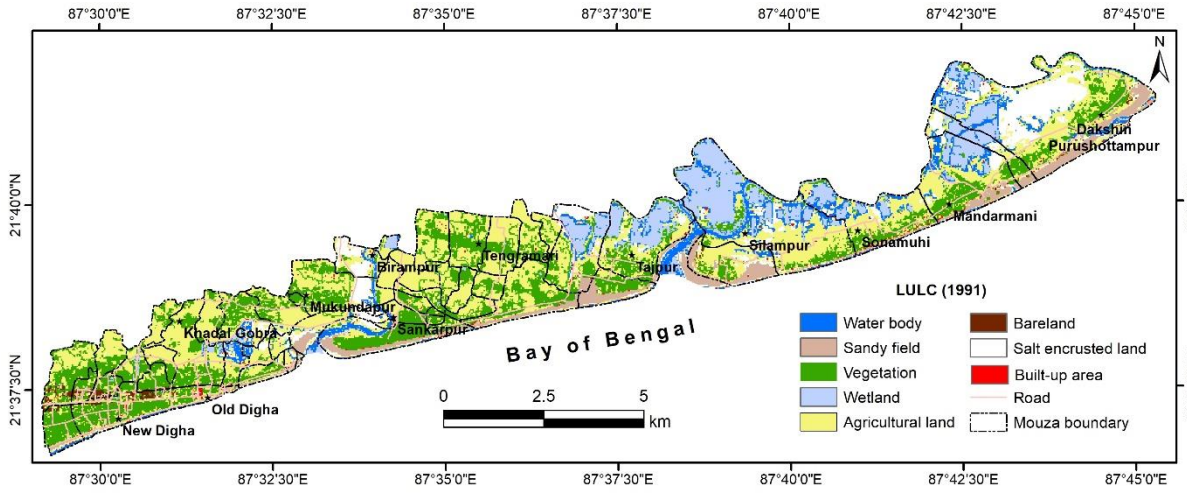

Fig. 2.11: Land use and land cover types of Digha (1991) urban centre.

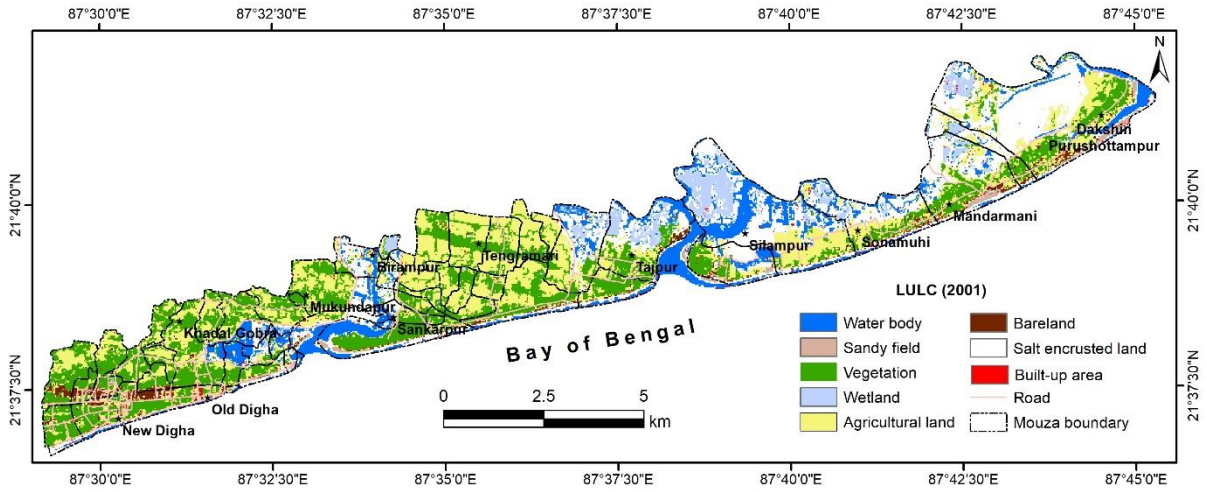

Fig. 2.12: Land use and land cover types of Digha (2001) urban centre.

Infrastructure development took place on the dune ridge surface at Old Digha and New Digha centres (Fig. 2.11). Even though, there has some bare land (0.56 km²) within the study area (Table 2.4) which is gradually occupying for the new constructions. Also other type of land uses of vegetation cover, agricultural land, wetland, salt-encrusted land, sandy tract, and water-body are distributed in the different parts of the area (Fig. 2.11). In this study, the wetland considered as the areas of fisheries and other natural marshy low-lying areas. The salt-encrusted areas are mainly concentrated at the low-lying part of the Dakshin Purushottampur mouza. This part of the mouza has utilized for the traditional salt processing field from the seawater (Plate 2.1b). The tourism areas are continuously increased along the shorefront part at the Sankarpur, Tajpur and Mandarmani sector in the latter half of 2000 (Plate 2.2). The LULC analysis of 2001 reveals that the built-up areas have increased along the shorefront stretch (Fig. 2.12). The salt- encrusted area has significantly increased from 6.27 km² (1991) to 16.05 km² (2001) (Table 2.4). In spite of the increasing built-up area, the bare land has also increased up to 1.50 km² in

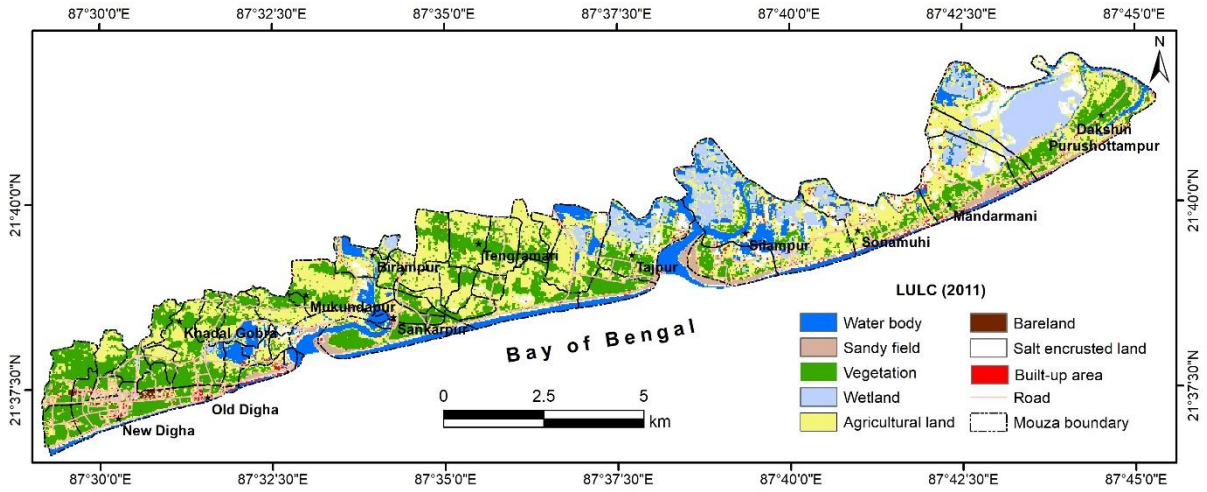

Fig. 2.13: Land use and land cover types of Digha (2011) urban centre.

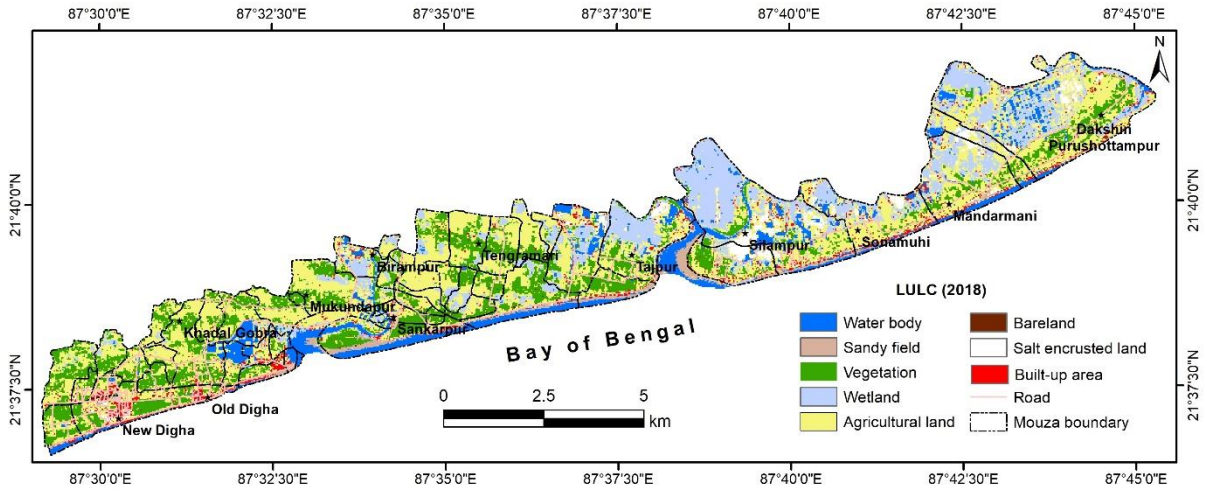

Fig. 2.14: Land use and land cover types of Digha (2018) urban centre.

Table 2.4: Changing pattern of different land use and land cover at Digha (1991 - 2018).

LULC	Year-wise area (km^2)			
	1991	2001	2011	2018
Water	4.99	8.27	8.42	6.63
Sand	3.92	0.65	2.39	2.28
Vegetation	17.19	18.15	17.73	13.31
Wetland	7.69	3.20	6.11	11.68
Agricultural land	25.88	18.51	26.87	28.21
Bare land	0.54	1.50	0.19	0.32
Built-up	0.56	0.71	1.26	2.51
Salt	6.27	16.05	4.07	2.12

2001. Moreover, the area of vegetation cover has increased in 2001 (18.15 km²) with respect to 1991 (17.19 km²). However, after 2001, the area of vegetation cover and bare land reduced in 2011 and 2018 at the cost of the gradual increase in the built-up area (Plate 2.3). The salt-encrusted area has been reduced from 16.05 km² (2001) to 2.12 km² (2018) (Table 2.4). The reduced salt-encrusted area is mostly converted into the wetland for the fisheries (Fig. 2.13; 2.14; Plate 2.1a). In 2011, the built-up area is found in both sides of the Champa river mouth for the construction of the fish market (Digha Mohona) and fish landing stations (Sankarpur)

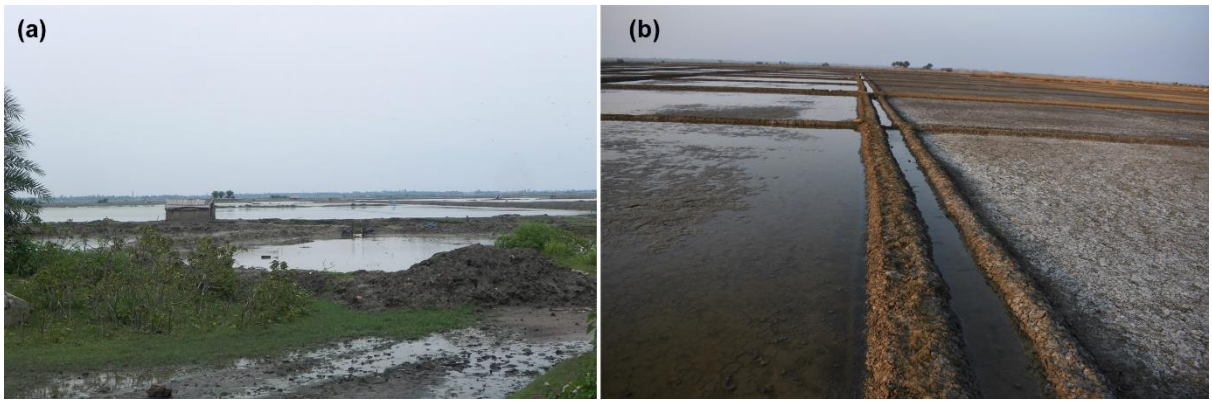

Plate 2.1: Earlier salt processing areas are mostly converted into the fisheries (a) and a few areas still utilized for salt processing fields (b).

Plate 2.2: Tourism infrastructural development extended along the shorefront areas of the Mandarmani (a), Tajpur (b), and Digha coastal belt (c, d).

(Plate 2.4). The settlement and hotels have also emerged after degradation of the natural landscape and vegetation cover over the degraded sand dunes in the shorefront areas of the Tajpur, Mandarmani and Dakshin Purushottampur mouza (Fig. 2.13). The existing built-up areas (2001) (Fig. 2.12) are clustered and expanded with the new construction of the hotels and other infrastructures for tourism development at present (Fig. 2.14). During 2018, the vegetated area has decreased compared to 2011. However, the areas of agricultural land continuously increased after 2001 (Fig. 2.13; 2.14). The eight different LULC classes and their areal distribution in four different temporal spans clearly indicates in Fig. 2.15. The significant level of LULC alterations is associated with the distribution of vegetation, agricultural land, wetland, salt-encrusted area and built-up area.

The conversions of LULC classes have been assessed during the overall period of 28 years (1991 – 2018) (Table 2.5). The eight different LULC classes have been categorized in the year of 1991, 2001, 2011 and 2018. Therefore, depending on the LULC classes of 1991 and 2018, the detailed LULC conversion has been estimated with their areal extensions in the different classes (Table 2.5), where a distinct bit of conversions have been observed in all the LULC classes. The agricultural land has mostly remained in the same type of land classes, with a significant level of conversions into the built-up area (0.77 km^2), salt-encrusted area (0.63 km^2), vegetation cover (4.04 km^2), and wetland (3.33 km^2). The bare land converted into the

Table 2.5: Land use and land cover conversion types during 1991-2018 in Digha.

Previous land use type (1991)	Converted land use type (2018)	Area (km^2)
Agricultural land	Agricultural land	15.30
	Bareland	0.10
	Built-up area	0.77
	Salt encrusted area	0.63
	Sandy field	0.41
	Vegetation	4.04
	Water body	1.31
	Wetland	3.33
Bareland	Agricultural land	0.31
	Bareland	0.01
	Built-up area	0.07
	Salt encrusted area	0.02
	Sandy field	0.01
	Vegetation	0.10
	Water body	0.01
	Wetland	0.00
Built-up area	Agricultural land	0.00
	Built-up area	0.40
	Salt encrusted area	0.01
	Sandy field	0.02
	Water body	0.09
	Wetland	0.03
Salt encrusted area	Agricultural land	2.26
	Bareland	0.00
	Built-up area	0.17
	Salt encrusted area	0.39
	Sandy field	0.29
	Vegetation	0.13
	Water body	1.18
	Wetland	1.85
Sandy field	Agricultural land	0.95
	Bareland	0.03
	Built-up area	0.27
	Salt encrusted area	0.10
	Sandy field	0.80
	Vegetation	0.36
	Water body	1.23
	Wetland	0.20
Vegetation	Agricultural land	6.84
	Bareland	0.17
	Built-up area	0.53
	Salt encrusted area	0.17
	Sandy field	0.44
	Vegetation	8.20
	Water body	0.23
	Wetland	0.61
Water body	Agricultural land	1.08
	Built-up area	0.16
	Salt encrusted area	0.27
	Sandy field	0.20
	Vegetation	0.19
	Water body	1.66
	Wetland	1.43
Wetland	Agricultural land	1.48
	Built-up area	0.13
	Salt encrusted area	0.53
	Sandy field	0.11
	Vegetation	0.30
	Water body	0.92
	Wetland	4.23
Total		67.04

Table 2.6: Temporal conversion types of land use and land cover areas of Digha.

LULC type	Year-wise land use conversion area (km^2)			
	1991-2001	2001-2011	2011-2018	1991-2018
Vegetation	0.96	-0.42	-4.42	-3.88
Agricultural land	-7.38	8.36	1.34	2.32
Bareland	0.96	-1.31	0.13	-0.22
Water body	3.29	0.14	-1.79	1.64
Wetland	-4.49	2.92	5.57	3.99
Salt encrusted area	9.77	-11.97	-1.95	-4.16
Sandy field	-3.27	1.74	-0.12	-1.65
Built-up area	0.16	0.55	1.25	1.95

Plate 2.3: Degeneration of dune habitats by the tourism infrastructural development at Digha.

Plate 2.4: Fish landing stations and fish market at the Sankarpur (a) and Digha Mohona (b) at the Champa river mouth.

agricultural land (0.31 km²) and vegetation (0.10 km²), and the other type of conversion is also observed into some extent in negligible level. The salt-encrusted area has mostly converted in agricultural land (2.26 km²), water bodies (1.18 km²) and wetland (1.85 km²). Most of the sandy field has been converted into the water bodies due to beach erosion. The significant level of vegetation area has been converted into the agricultural land. The year-wise LULC conversion has also been analysed in on the overall basis (Table 2.6). The result shows that the area of vegetation cover is gradually reducing from 2001 to 2018. The degradation of the vegetation cover is observed over the dune ridge at the Digha, Tajpur, and Mandarmani coastal stretch (Plate 2.3). The agricultural land is significantly reduced (7.38 km²) during 1991 – 2001 due to converted into wetland and a minimum area of bare land (Fig. 2.11, 2.12; Table 2.6). But after that period the area of agricultural land increased at the cost of vegetation to some extent. The built-up area has continuously increased as 0.16 km², 0.55 km², and 1.25 km² during the period of 1991 – 2001, 2001 – 2011, and 2011 – 2018, respectively (Table 2.6).

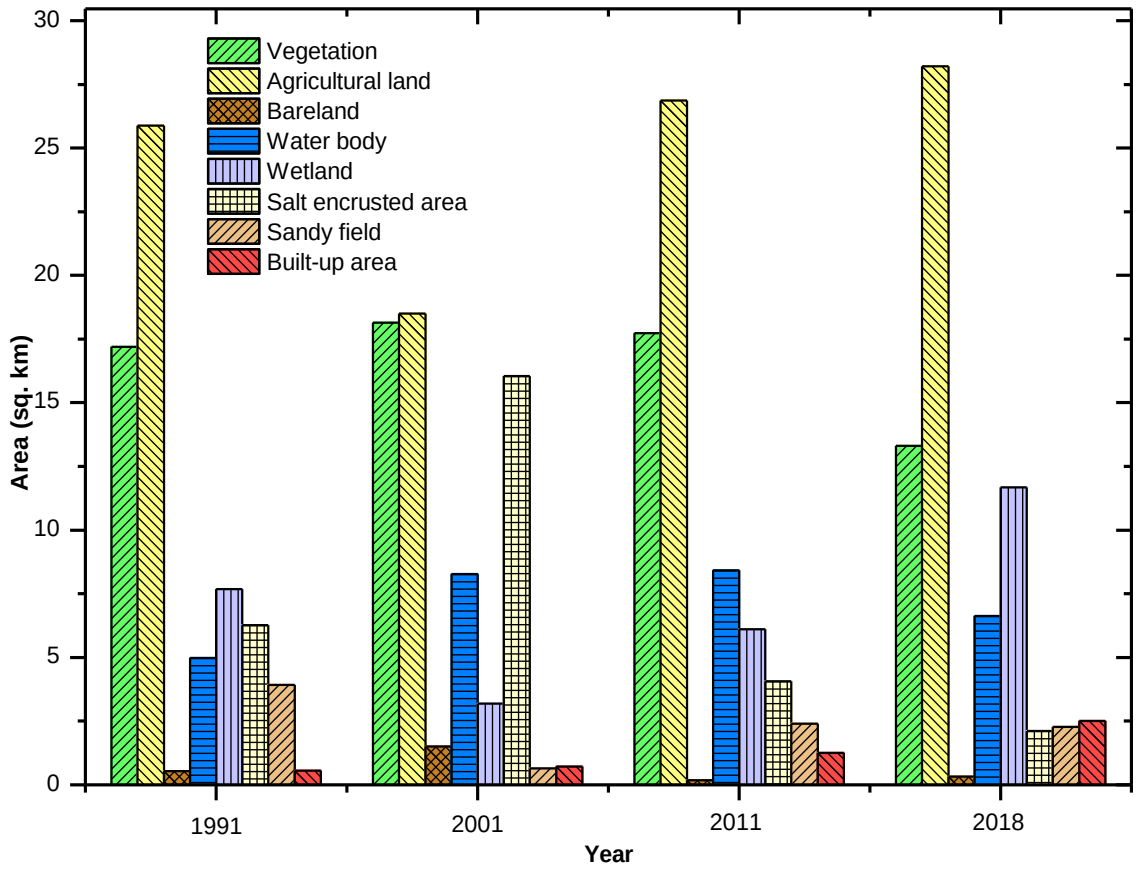

Fig. 2.15: Changing pattern of land use and land cover types of Digha (1991 - 2018) urban centre.

2.3.2. Land use and land cover change in Contai

In LULC classification, the entire Contai municipality area of 2018 has been considered for the LULC classification of 1991, 2001, 2011 and 2018. Although, the municipality area has

been differently distributed during those years, as mentioned in subsection 2.2.2. During 1991, the LULC analysis shows that most of the built-up area (0.61 km²) existed over the dune ridge

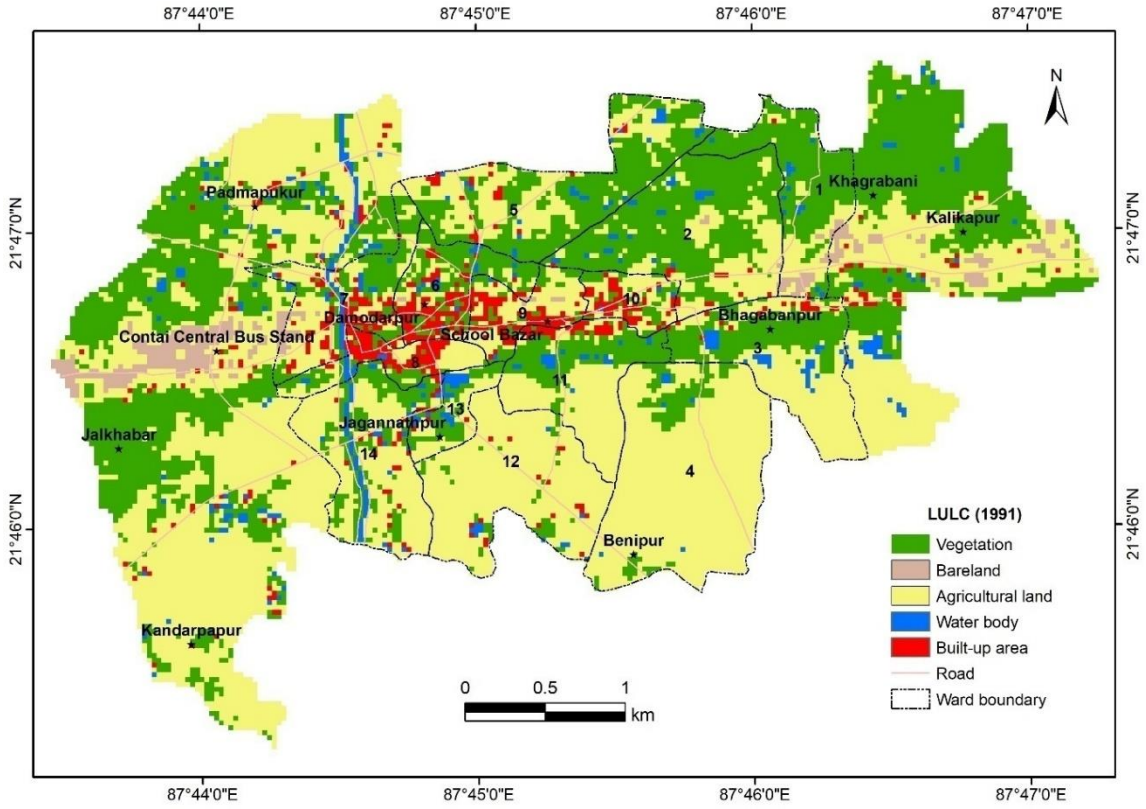

Fig. 2.16: Land use and land cover types of Contai urban centre (1991).

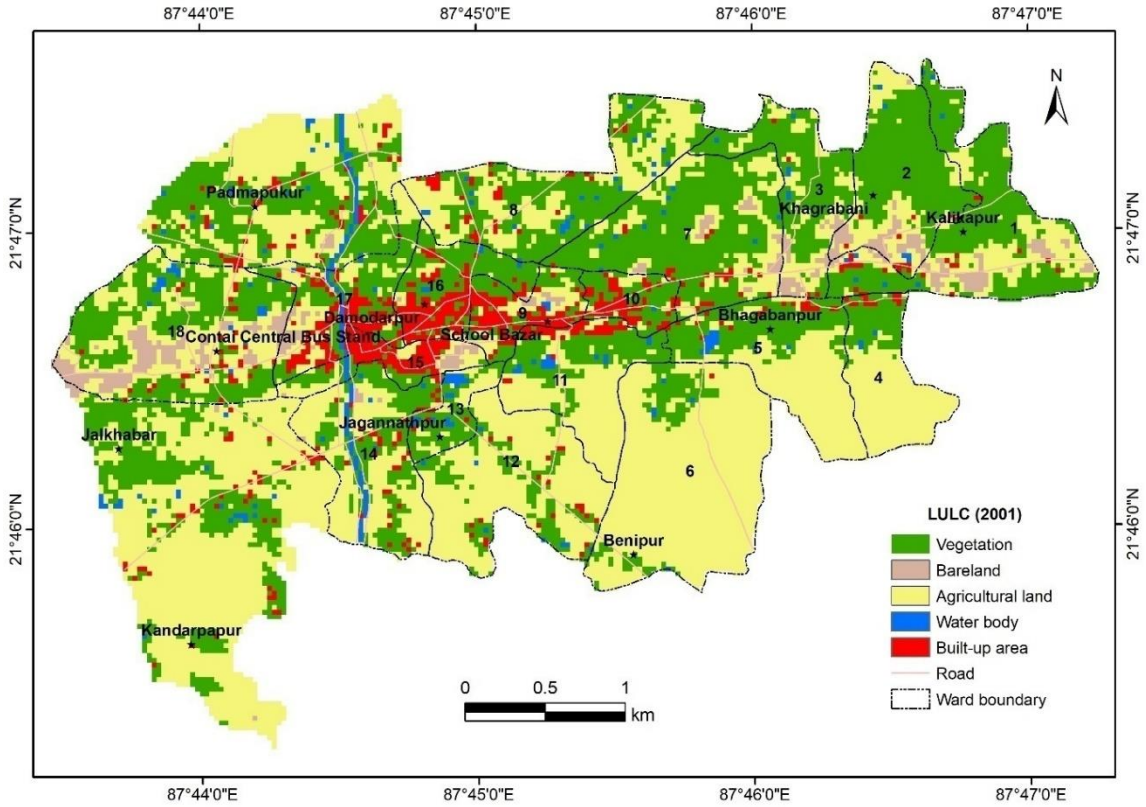

Fig. 2.17: Land use and land cover types of Contai urban centre (2001).

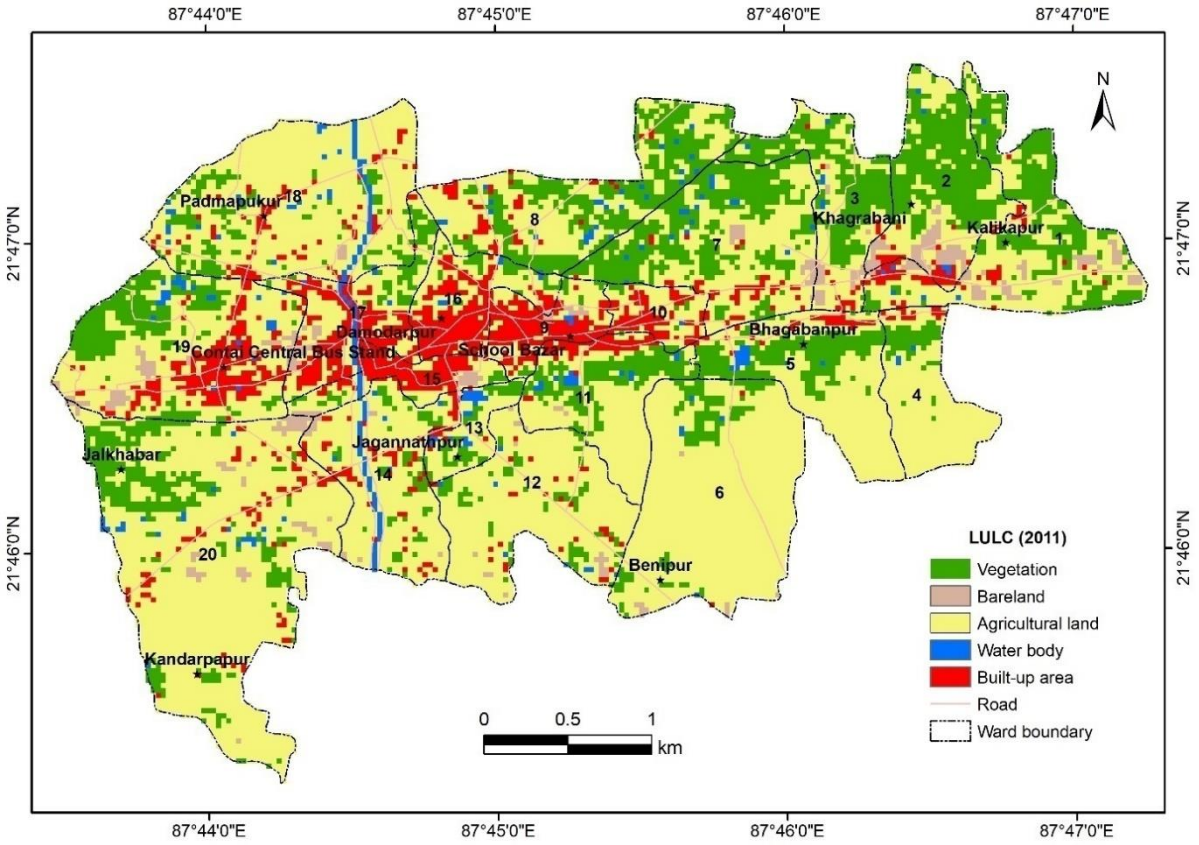

Fig. 2.18: Land use and land cover types of Contai urban centre (2011).

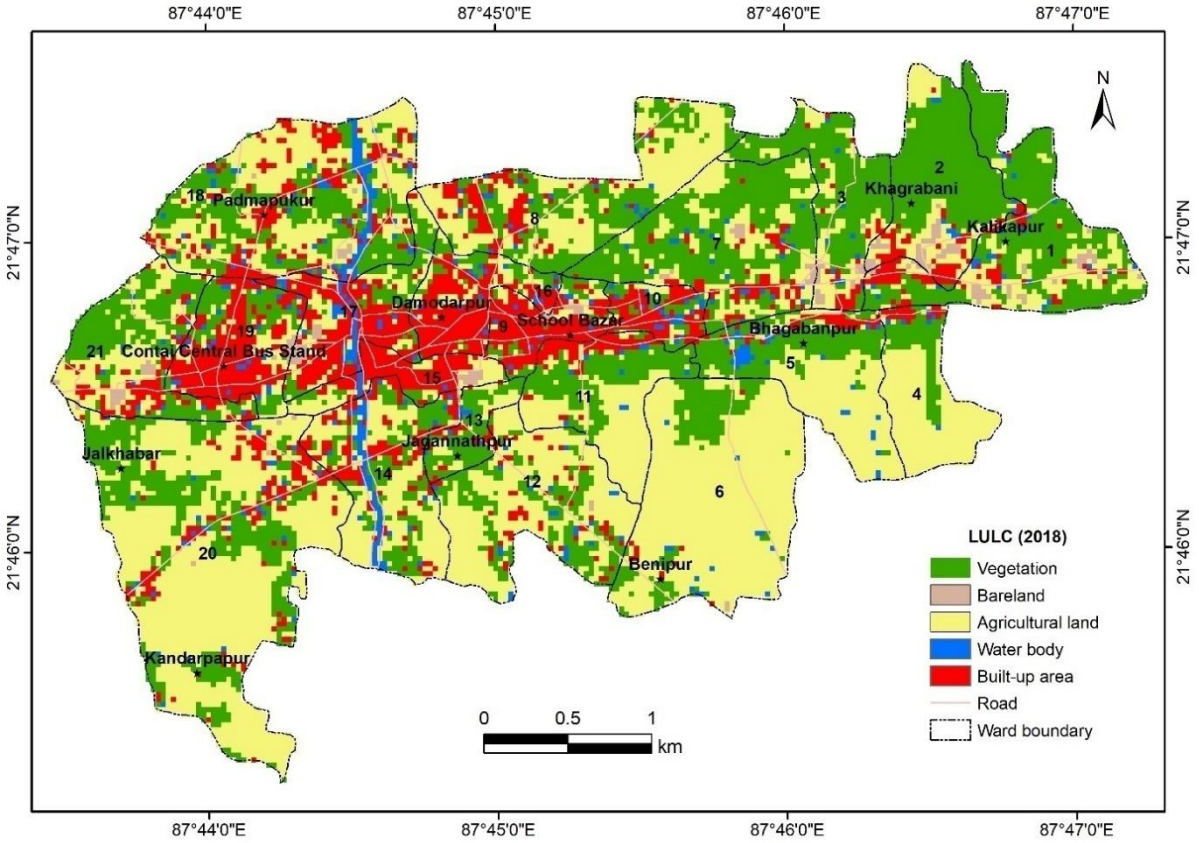

Fig. 2.19: Land use and land cover types of Contai urban centre (2018).

at the central part of the Contai municipality (Fig. 2.16; Table 2.7). The other part of the dune ridge has been utilized for the agricultural land (7.77 km²) along with the low-lying areas. The remaining part of the dune ridge has remained as bare land (0.34 km²). The area of vegetation cover (5.21 km²) exists in the dune fringe areas and somehow in the low-lying parts (Plate 2.5a). In 2001, the built-up area has nucleated over the existing areas (Fig. 2.17) as observed in the previous year of 1991 (Fig. 2.16). During 2001, the overall built-up area (0.84 km²), bare land (0.42 km²) and vegetation cover (5.58 km²) have been increased, whereas, the agricultural land (7.24 km²) and water bodies (0.26 km²) decreased within the entire area (Table 2.7).

Plate 2.5: Natural vegetation at dune fringe areas (a), habitat restoration process by afforestation programme (b) and nursery (c, d) on the older sand dunes of Contai.

Table 2.7: Changing pattern of different land use and land cover types in Contai during 1991 – 2018.

LULC type	Year-wise area (km^2)			
	1991	2001	2011	2018
Vegetation	5.21	5.58	3.18	4.90
Bare land	0.34	0.42	0.35	0.17
Agricultural land	7.77	7.24	9.14	6.60
Water	0.42	0.26	0.28	0.46
Built-up	0.61	0.84	1.40	2.21

The LULC analysis of 2011 shows that the built-up area (1.40 km²) has been increased towards the eastern and western part of the dune ridge (Fig. 2.18; Table 2.7), mainly, over the earlier

bare lands (Fig. 2.17). Therefore, the area of bare land (0.35 km²) has reduced and again it comes closer to the area (0.34 km²) of 1991 (Table 2.7). The vegetation coverage has significantly reduced compared to the previous year of 2001. It is observed that most of the vegetation covers of dune fringe and some part of low-lying areas have converted into the agricultural land (Fig. 2.18). During 2018, the built-up area is extended in the northern and southern side of the area, mainly, beside the roads (Fig. 2.19). Also, the compactness in the built-up area over the dune ridge has observed during 2018. The built-up area (2.21 km²) is almost fourth times greater than the areas of 1991 (0.61 km²). The most significant result is that the area of vegetation cover is increased (4.90 km²) compared to the area (3.18 km²) of the previous year (2011) (Table 2.7). The on-field survey and observation reveal that after the adaptation of the tree plantation programme in 2000, the bare land has been utilized for nursery (Plate 2.5c, d). The agricultural land has also been decreased (6.60 km²) with increasing of the vegetation cover (Table 2.7). In 1991, the water bodies were higher than the year 2001 and 2011 by existence of natural ponds and others watershed. But, in between 1991 to 2011 the water bodies squeezed by the landfilling and rapid contraction for new build-up. Finally, the water bodies have significantly increased after 2011 due to renovation and new construction of the ponds (Table 2.7). The length of the road is gradually increased with the increasing population pressure and built-up areas.

Table 2.8: Land use and land cover conversion types during 1991-2018 in Contai.

Previous land use type	Converted land use type	Area (km²)
Agricultural land	Agricultural land	5.07
	Bare land	0.10
	Built-up area	1.07
	Vegetation	1.34
	Water body	0.20
Bare land	Agricultural land	0.12
	Bare land	0.07
	Built-up area	0.12
	Vegetation	0.03
	Water body	0.00
Built-up area	Built-up area	0.61
Vegetation	Agricultural land	1.34
	Bare land	0.00
	Built-up area	0.39
	Vegetation	3.34
	Water body	0.14
Water body	Agricultural land	0.08
	Built-up area	0.03
	Vegetation	0.19
	Water body	0.12
Total		14.35

The LULC conversions have been analysed based on the four classified images of 1991, 2001, 2011 and 2018. The overall conversion nature during the 28 years (1991 – 2018) reveals

that the five major LULC classes have been converted in the different type of land uses (Table 2.8). The agricultural land has significantly converted into the built-up area (1.07 km²), and vegetation cover area (1.34 km²) (Table 2.8). The bare land has significantly converted into the built-up area (0.12 km²), and the same area of agricultural land (Table 2.8). The major conversion has observed of vegetation cover areas into the agricultural land (1.34 km²), built-up area (0.39 km²) and water bodies (0.14) (Table 2.8). The year to year LULC conversion shows that during 1991 – 2001 the vegetation cover, bare land and built-up areas have increased with an areal expansion of 0.38 km², 0.08 km², and 0.23 km², respectively (Table 2.9). Whereas, the agricultural land and water bodies reduced as 0.53 km² and 0.16 km², respectively. However,

Table 2.9: Temporal conversion types of land use and land cover areas of Contai.

LULC type	Year-wise land use conversion area (km^2)			
	1991-2001	2001-2011	2011-2018	1991-2018
Vegetation	0.38	-2.40	1.72	-0.31
Agricultural land	-0.53	1.90	-2.54	-1.17
Bareland	0.08	-0.07	-0.17	-0.16
Water body	-0.16	0.02	0.19	0.05
Built-up area	0.23	0.56	0.81	1.60

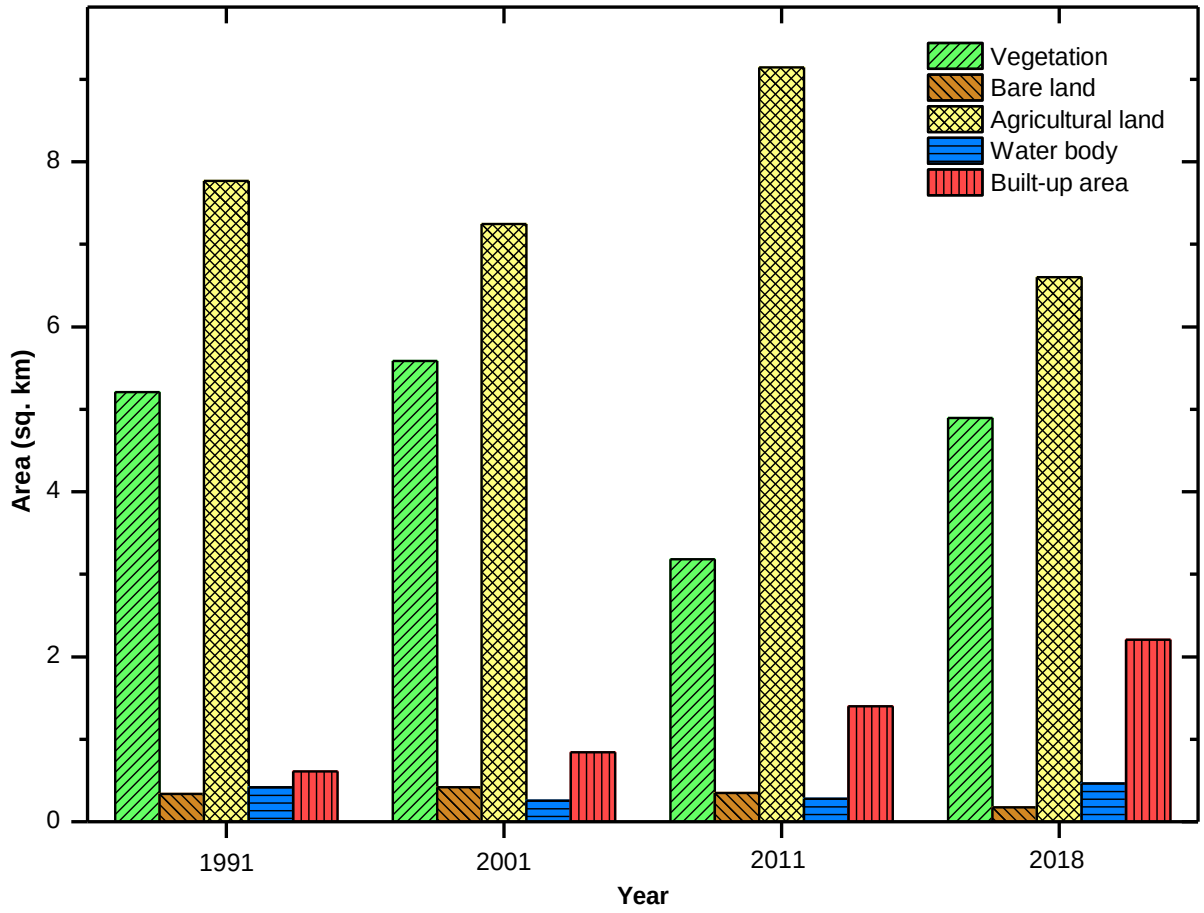

Fig. 2.20: Changing pattern of land use and land cover types of Contai (1991 - 2018) urban centre.

during 2001 – 2011, the areas of vegetation cover (2.40 km²), and bare land (0.07 km²) have reduced, and the other LULC has increased as 1.90 km² (agricultural land), 0.02 km² (water bodies), and 0.56 km² (built-up area). During 2011 – 2018, the areas of vegetation cover, water bodies and built-up have been increased, whereas, the agricultural land and bare land has decreased (Table 2.9). The overall condition of conversion (1991 – 2018) reveals a significant decreased in areas of vegetation cover, agricultural land and bare land with an increase of water bodies and built-up areas (Fig. 2.20; Table 2.9).

2.3.3. Land use and land cover change in Haldia

The LULC has been classified of the Haldia municipality area for the same periods likewise the Digha and Contai. Although the municipality has been established in 1997, the LULC of 1991 has also been considered to understand the nature and comparison of LULC changes among the three different sites of Digha, Contai and Haldia. The LULC classification of 1991 reveals the built-up areas have mainly remained in three parts near the Durgachak,

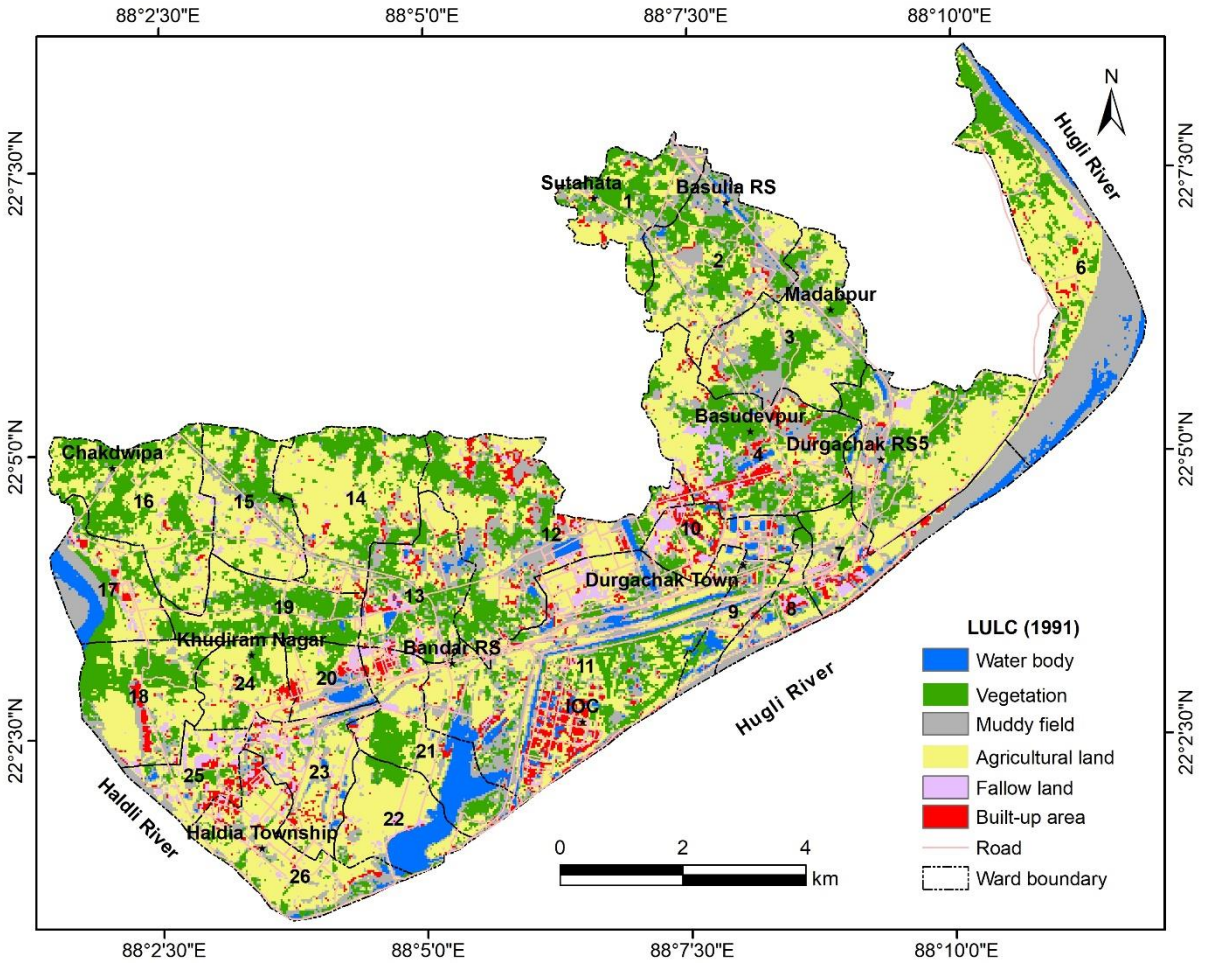

Fig. 2.21: Land use and land cover types of Haldia urban centre (1991).

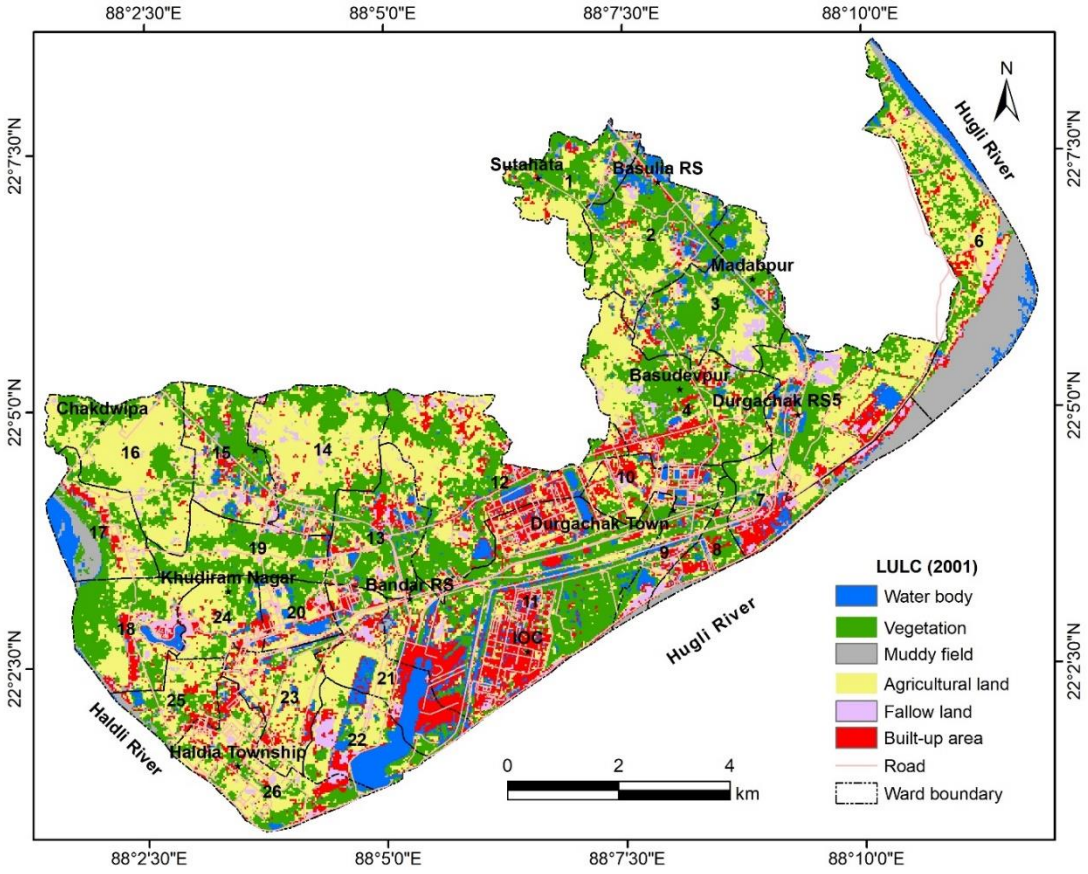

Fig. 2.22: Land use and land cover types of Haldia urban centre (2001).

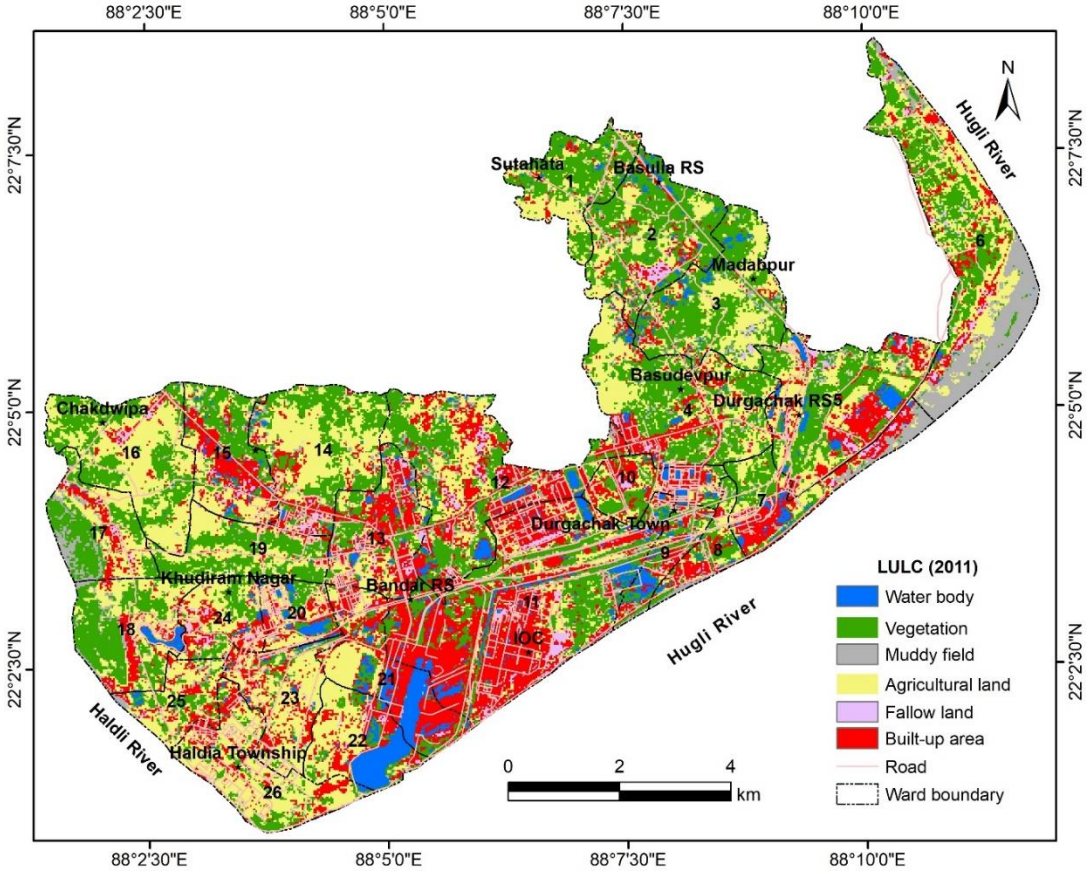

Fig. 2.23: Land use and land cover types of Haldia urban centre (2011).

Indian Oil Corporation (IOC) complex, and Township areas in a patchy form (Fig. 2.21) with an area of 4.72 km² (Table 2.10). Also, scattered distribution of built-up areas has been observed in different areas. Other five type of LULC classes are water bodies (4.68 km²), vegetation (22.56 km²), muddy field (20.78 km²), agricultural land (43.83 km²) and fallow land (3.39 km²) (Fig. 2.21; Table 2.10). In the case of Haldia, ward number 6 is situated in the bank margin of the river Hugli. The major part of this ward is inundated during the high tide.

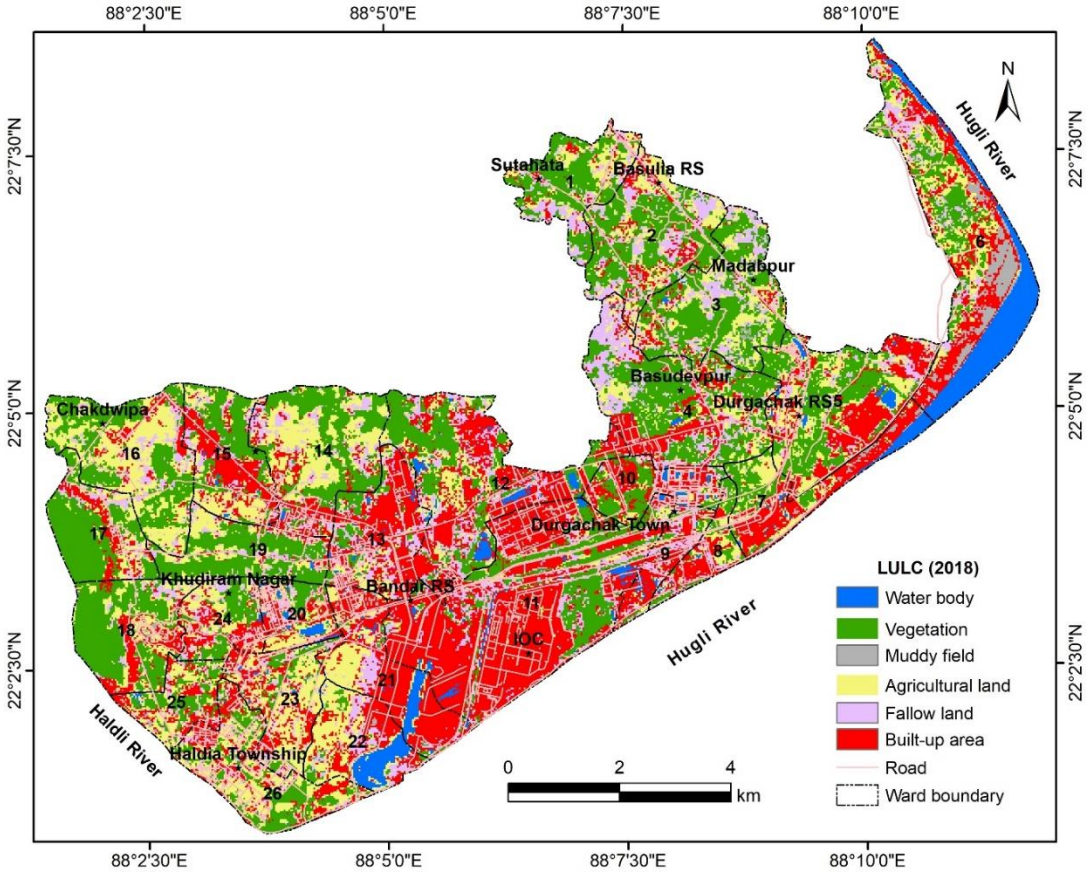

Fig. 2.24: Land use and land cover types of Haldia urban centre (2018).

Table 2.10: Changing pattern of different land use and land cover types at Haldia during 1991 – 2018.

LULC	Year-wise area (km^2)			
	1991	2001	2011	2018
Vegetation	22.56	31.47	31.03	29.81
Agricultural land	43.83	36.00	31.35	20.70
Fallow land	3.39	3.93	2.13	14.39
Mud	20.78	8.04	8.33	1.63
Water	4.68	7.27	4.43	4.08
Built-up	4.72	13.25	22.71	29.36

Therefore, depending on the tide level the area of the muddy field and water bodies (Plate 2.6) has been significantly changed in the different LULC classification maps. Moreover, the municipality area has been situated in the Holocene fluvial deposit, mature swamp and mudflat

areas. The muddy field has also been observed in the interior part. During 2001, the dramatic enhancement of the urban growth has observed which is reflected in the expansion of the built-up areas (Fig. 2.22). Within only 10 years, the built-up area increased (13.25 km²) almost fourth times with respect to the areas of 1991 (Table 2.10). It is observed that most of the built-up areas have been established over the inland muddy fields. The muddy fields have dramatically decreased (8.04 km²), although there has almost the same situation in the muddy filed areas of Hugli riverbank in both LULC maps of 1991 and 2001 (Fig. 2.21, 2.22). The areas of vegetation cover are increased during 2001 but the agricultural land area is decreased (Table 2.10) in the same period. During 2011, the compactness of the built-up area (22.71 km²) the linear and scattered form of settlement is observed (Fig. 2.23). The linear settlement observed along the major roads, mainly in the western side of the municipality area. Finally, in 2018 the exponential growth of built-up area (29.36 km²) has observed in the central part and in the bank margin areas of Hugli and Haldi river (Fig. 2.24). The image of 2018 was collected during the high tide. Therefore, the muddy field almost absent in the bank margin part of the river Hugli (Fig. 2.24). From the overall analysis of the four different periodic LULC classifications, it is observed that new land area emerged with the significant level of mangrove vegetation (Plate 2.7) in the western part of the municipality area of the Haldi river margin (Fig. 2.21 – 2.24).

Plate 2.6: Mudflat at the right bank of Hugli river in Haldia municipality area.

Plate 2.7: Halophytic grasslands on the Haldi estuary bank margin tidal flat arresting mangrove seeds for the growth of new habitats.

The LULC conversion during 1991 – 2018 shows that the six different LULC types are converted into a different kind of land uses (Table 2.11). Mostly the agricultural land has been converted into the built-up area (12.58 km²), fallow land (8.20 km²) and vegetation cover (9.07 km²). The fallow land converted into the built-up area (1.51 km²), agricultural land (0.83 km²), and vegetation cover (0.46 km²). Most of the areas of the inland muddy field has been modified as built-up areas (6.29 km²), agricultural land (3.02 km²), fallow land (3.19 km²), and vegetation cover (5.81 km²). The muddy field of the bank margin areas of the river Hugli remained in the same condition, but during the high tide condition, some part of this muddy field converted into water bodies (1.55 km²) (Table 2.11). Some areas of water bodies converted into built-up areas (1.11 km²) and other types of LULC. Therefore, it is clear that the urban area is now expanding over the agricultural land, fallow land, muddy fields, vegetation cover areas, and water bodies after land-filling.

Table 2.11: Land use and land cover conversion types during 1991-2018 in Haldia.

Previous land use type	Converted land use type	Area (km2)
Agricultural land	Agricultural land	13.11
	Built-up area	12.58
	Fallow land	8.20
	Muddy field	0.46
	Vegetation	9.07
	Water body	0.40
Built-up area	Built-up area	4.72
	Agricultural land	0.83
	Built-up area	1.51
Fallow land	Fallow land	0.45
	Muddy field	0.13
	Vegetation	0.46
	Water body	0.02
	Agricultural land	3.02
	Built-up area	6.29
Muddy field	Fallow land	3.19
	Muddy field	0.93
	Vegetation	5.81
	Water body	1.55
	Agricultural land	3.18
	Built-up area	3.14
Vegetation	Fallow land	2.38
	Muddy field	0.09
	Vegetation	13.62
	Water body	0.15
	Agricultural land	0.56
	Built-up area	1.11
Water body	Fallow land	0.18
	Muddy field	0.02
	Vegetation	0.85
	Water body	1.96
Total		99.97

The year-wise LULC conversion (Table 2.12) showing that the area of vegetation cover, built-up, water body and fallow land increased with an areal coverage of 8.91 km², 8.53 km², 2.59 km² and 0.55 km², respectively during the period of 1991 – 2001. With such increase, the area of agricultural land and muddy field decreased respectively as 7.84 km² and 12.74 km². During 2001 – 2011, the built-up area has significantly increased (9.46 km²) with an accountable increased of muddy field (0.29 km²) and the reduction of vegetation cover (0.45 km²), agricultural land (4.65 km²), fallow land (1.80 km²), and water bodies (2.85 km²). Similarly, during 2011 – 2018 the fallow land (12.26 km²) and built-up area (6.65 km²) are increased at the cost of reduction of vegetation (1.22 km²), agricultural land (10.65 km²), muddy field (6.70 km²) and water bodies (0.35 km²). The overall (1991 – 2018) scenario of LULC change reveals the reduced areas of agricultural land (23.14 km²), muddy field (19.15 km²) and water bodies (0.61 km²) converted into vegetation cover (7.25 km²), fallow land (11.00 km²) and built-up (24.64 km²). The nature of land conversion and changing pattern of LULC indicates that since 1991, a continuous reduction of agricultural land, and an inverse situation are observed in case of the built-up areas (Fig. 2.25; Table 2.12). Although the vegetation cover increased in the Haldi river margin areas of ward number 17 and 18 (Fig. 2.24; Plate 2.7), the area of vegetation cover has decreased due to dramatic expansion of the built-up areas in the central part and levee areas of river Hugli and Haldi. The area of fallow land has dramatically increased with due effects from waste deposition in wetland areas. The inland water bodies and wetlands are filled up which are further converted into the built-up areas (Plate 2.8).

Plate 2.8: Urban-industrial development over the wetlands after landfilling at Haldia.

Table 2.12: Temporal conversion types of land use and land cover areas of Haldia.

LULC	Year-wise land use conversion area (km^2)			
	1991-2001	2001-2011	2011-2018	1991-2018
Vegetation	8.91	-0.45	-1.22	7.25
Agricultural land	-7.84	-4.65	-10.65	-23.14
Fallow land	0.55	-1.80	12.26	11.00
Muddy field	-12.74	0.29	-6.70	-19.15
Water body	2.59	-2.85	-0.35	-0.61
Built-up area	8.53	9.46	6.65	24.64

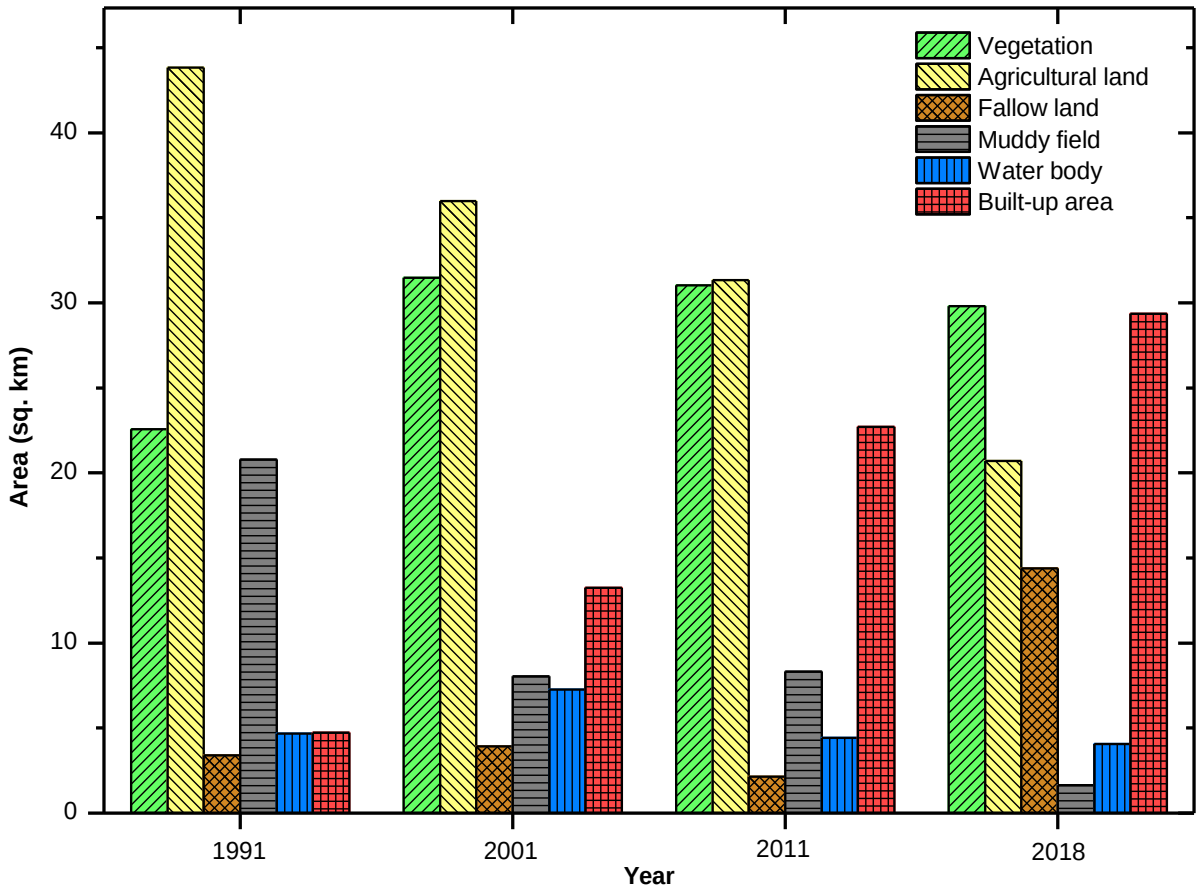

Fig. 2.25: Changing pattern of land use and land cover types of Haldia (1991 - 2018) urban centre.

2.4. Urban sprawling

The expansion of built-up areas of the urban centres is observed in the different form of compact, linear, patchy and scattered depending on the distinct landscape set up and urban activities. The urban sprawling is analysed through extracting the pixels of built-up areas of four phases (1991, 2001, 2011 and 2018) in Digha, Contai and Haldia urban centres (Fig. 2.26).

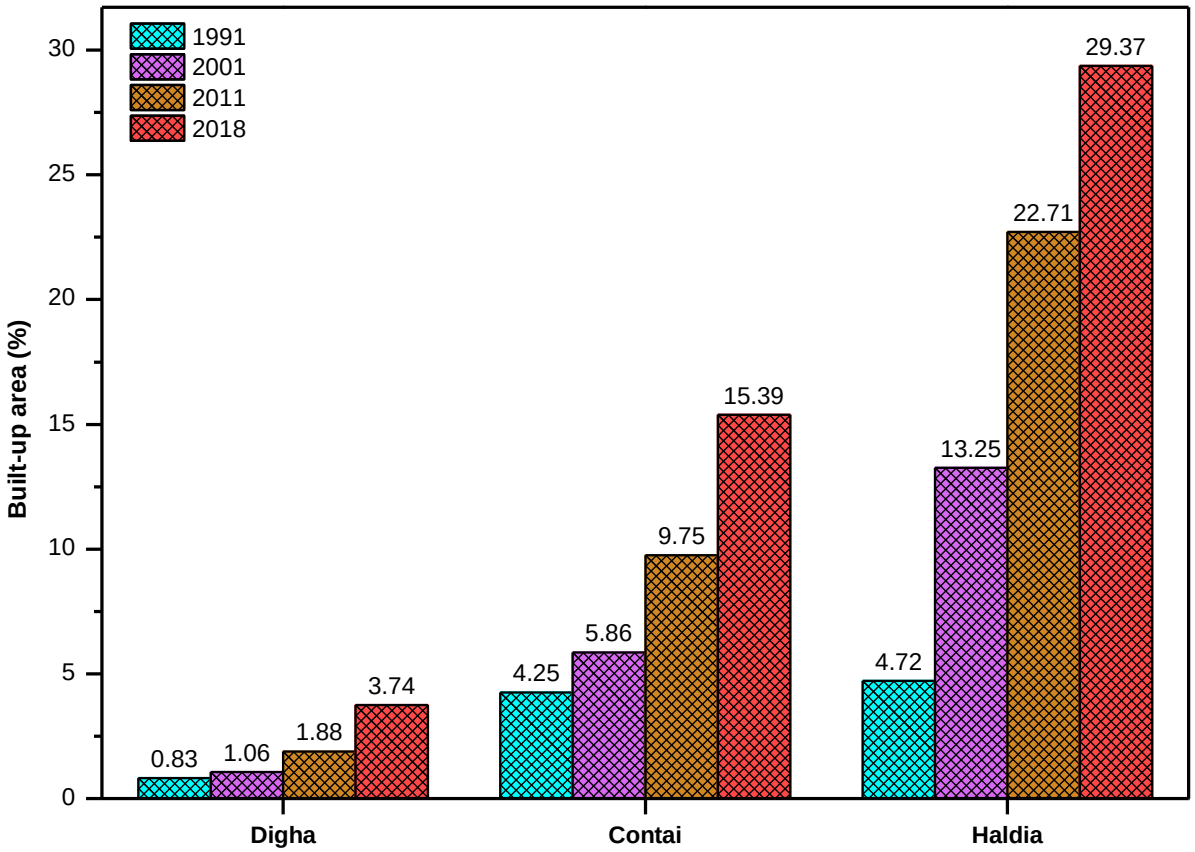

Fig. 2.26: Trend of increasing built-up area to the total area of three urban centres in Medinipur littoral tract.

2.4.1. Urban sprawling in Digha

The superimposed built-up areas of four periods in Digha (Fig. 2.27) depict the concentration of the built-up areas aligned along the shorefront dune ridge in a linear pattern. The urbanization and growth of built-up areas are influenced by tourism activities. The most compact pattern found in the New Digha and Old Digha tourist destination. The growth of built-up areas of the total area is very negligible compared to the other areas. But, it is more significant in terms of existence and risk of such kind of urban expansion. However, the trend of urban growth is increasing from 0.83% (1991) to 1.07% (2001), and from 1.88% (2011) to 3.74% (2018) of the total study area (67.04 km²) of Digha respectively (Fig. 2.26; Table 2.13). After the 2000s, the growth of built-up areas has significantly increased in forms of hotels, homestays, market areas, car parking sites, roads and other supporting accommodations in that area (Plate 2.9). As a result, such kind of drastic change is found within the built-up areas in Digha area. With such kind of infrastructural development, the natural landscape of the dune ridges are destroyed and sand is transferred to the low elevated parts for flattening of the land to prepare suitable land for infrastructural development (Plate 2.10). In the other shorefront areas like Mandarmani, the built-up structures have existed in the High Tide Line (HTL). The higher rate of shoreline retreat pushed the hotel structures in the interior part of the area after

wetland filling. Recently (2018), several built-up structures are constructed and observed in the far interior low-lying areas of the Mandarmani, Sankarpur and Tajpur coastal sector (Plate 2.11). Moreover, new tourist spot appears (e.g. Baguran Jalpai) in recent time with the more investment in tourism sector for best possible earning. The entire shoreline (Udaypur to Tajpur) is already concretized (Plate 2.12) to protect the shoreline retreat which shows as the built-up area (Fig. 2.27).

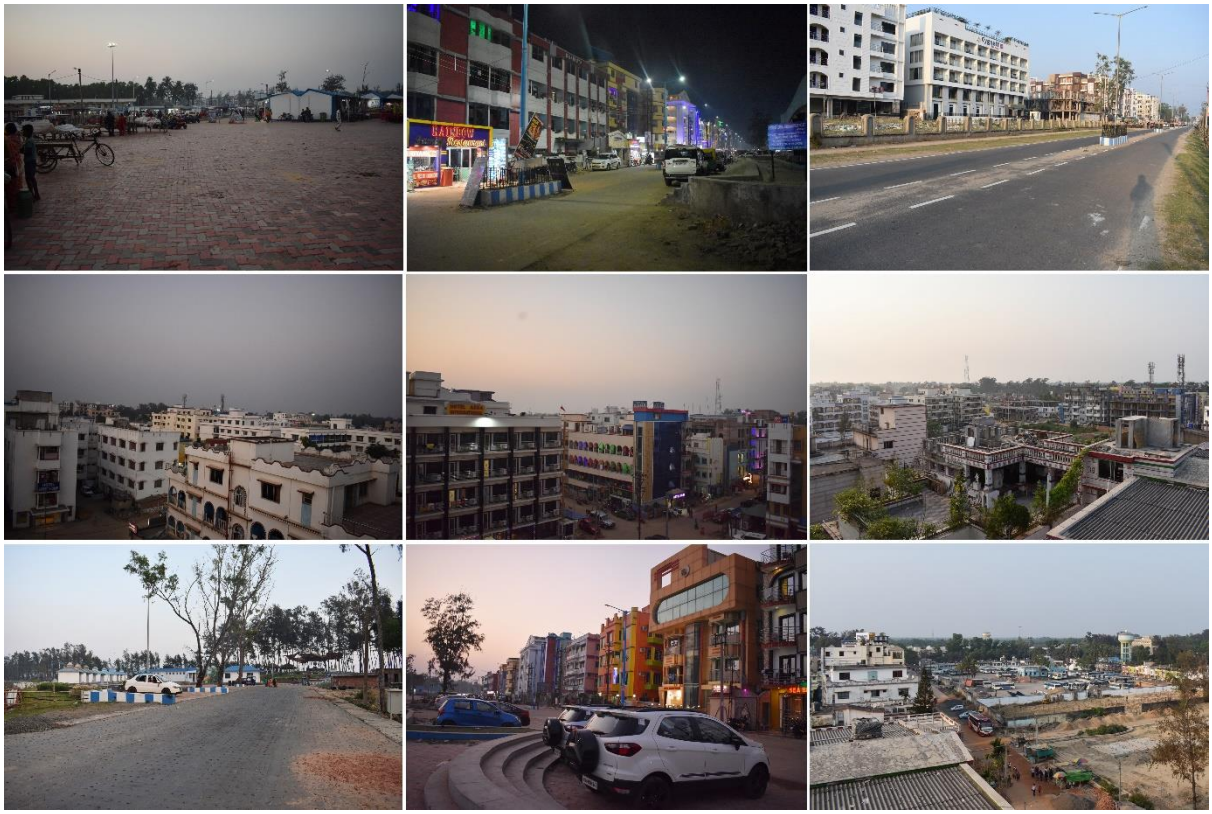

Plate 2.9: Intensive built-up areas at Digha coastal belt at present.

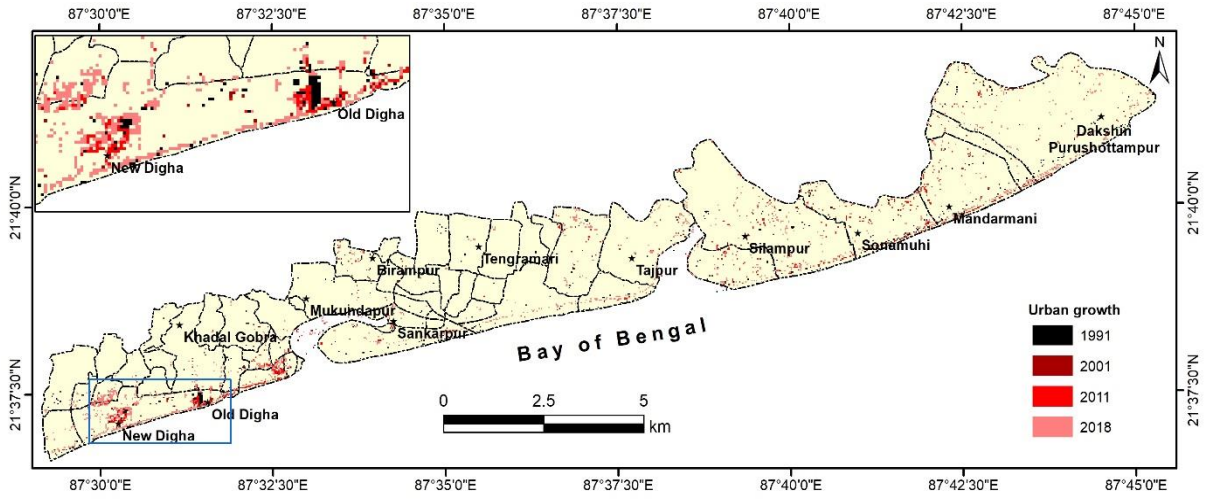

Fig. 2.27: Urban sprawling at Digha from 1991 – 2018.

Table 2.13: Urban sprawling at Digha during 1991 – 2018.

Year	Built-up area of total area (67.04 km^2)	
	km^2	%
1991	0.56	0.83
2001	0.71	1.07
2011	1.26	1.88
2018	2.51	3.74

Plate 2.10: Sand mining and dune flattening at the different parts of Digha coastal stretch.

Plate 2.11: Erosion and damages of the hotels by the storm effects at the shorefront areas (a-c) and new hotels are coming up at the backshore areas over the wetlands (d-f) in the Mandarmani coastal stretch.

Plate 2.12: Concretization of the shorefront areas at Tajpur-Sankarpur coastal stretch.

2.4.2. Urban sprawling in Contai

In the Contai municipality area, the urban growth is based on the residential, market and administrative activities. The Contai town is the main gateway to Digha and other tourism areas of the coastal zones. All kind of transport and communication, and accommodating supply systems in Digha – Mandarmani tourism area is provided through the Contai urban centre. Such kind of important diversified urban activities promotes to faster growth of that urban centre. As per the result of LULC change, the extracted built-up areas and their superimposition clearly indicate (Fig. 2.28) that the urban centre is mainly concentrated in the

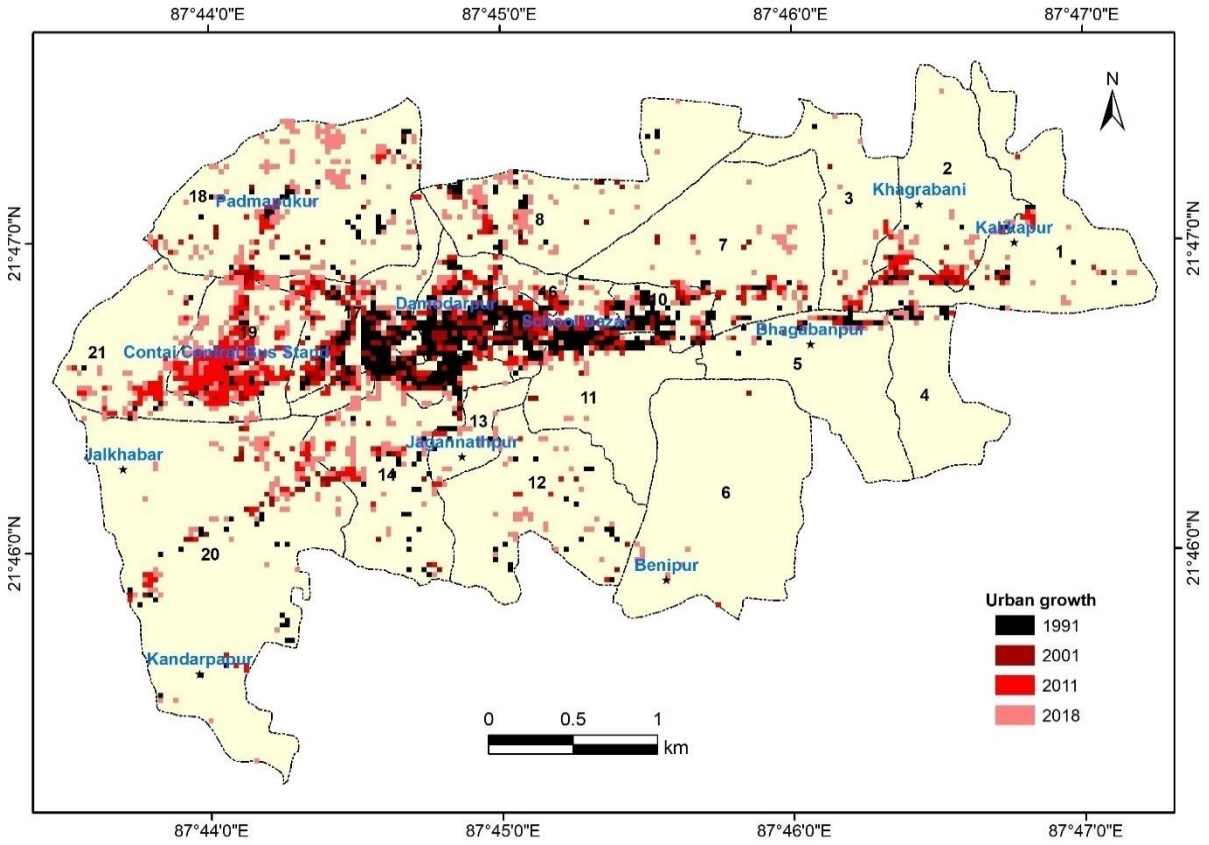

Fig. 2.28: Urban sprawling at Contai Municipality area from 1991 – 2018.

Table 2.14: Urban sprawling at Contai municipal area from 1991 – 2018.

Year	Built-up area of total area (14.35 km^2)	
	Km^2	%
1991	0.61	4.25
2001	0.84	5.86
2011	1.40	9.75
2018	2.21	15.39

central part of the municipality town (during 1991) over the dune ridge. After the 2000s, the built-up areas, as well as the settlements are grown in the eastern and western part, over the dune ridge and its fringe areas, also some settlement built along both sides of Contai-Digha main road (Fig. 2.28). In the later phase (during 2018) most of the settlements are built in the low-lying areas occupying the agricultural land and wetland filling in the northern and southern part of the main town (Plate 2.13). But, very interestingly the built-up areas are not grown significant level in the eastern side despite the more suitable land over the dune ridge (part of ward number 1, 2, 3 and 7) (Plate 2.14). The major problem of that area is the encroachment of saltwater in the subsurface and groundwater aquifer (CGWB, 2014). The land under the built-up area is growing likewise 4.25% (1991), 5.86% (2001), 9.75% (2011), and 15.39% (2018) to the total area (67.04 km²) of the Contai municipality (Fig. 2.26; Table 2.14). In the Contai urban centre also the urban expansion rate is significantly increased since the 2000s which is intensified during 2011 – 2018.

Plate 2.13: New construction over the wetlands (a) and in agricultural lands (b) of Contai.

Plate 2.14: Bare land at Uttar Darua in the Contai municipality area.

2.4.3. Urban sprawling in Haldia

The most dramatic change in the LULC pattern and in the built-up area took place in Haldia municipality centre during the years 1991 to 2018. The town initially developed as a port-industry based, afterwards, complete urban infrastructures developed coupling with residential and market complexes. In 1991, the urban built-up areas found in some scattered form mainly in the three sites (IOC, Durgachak, and Township areas)

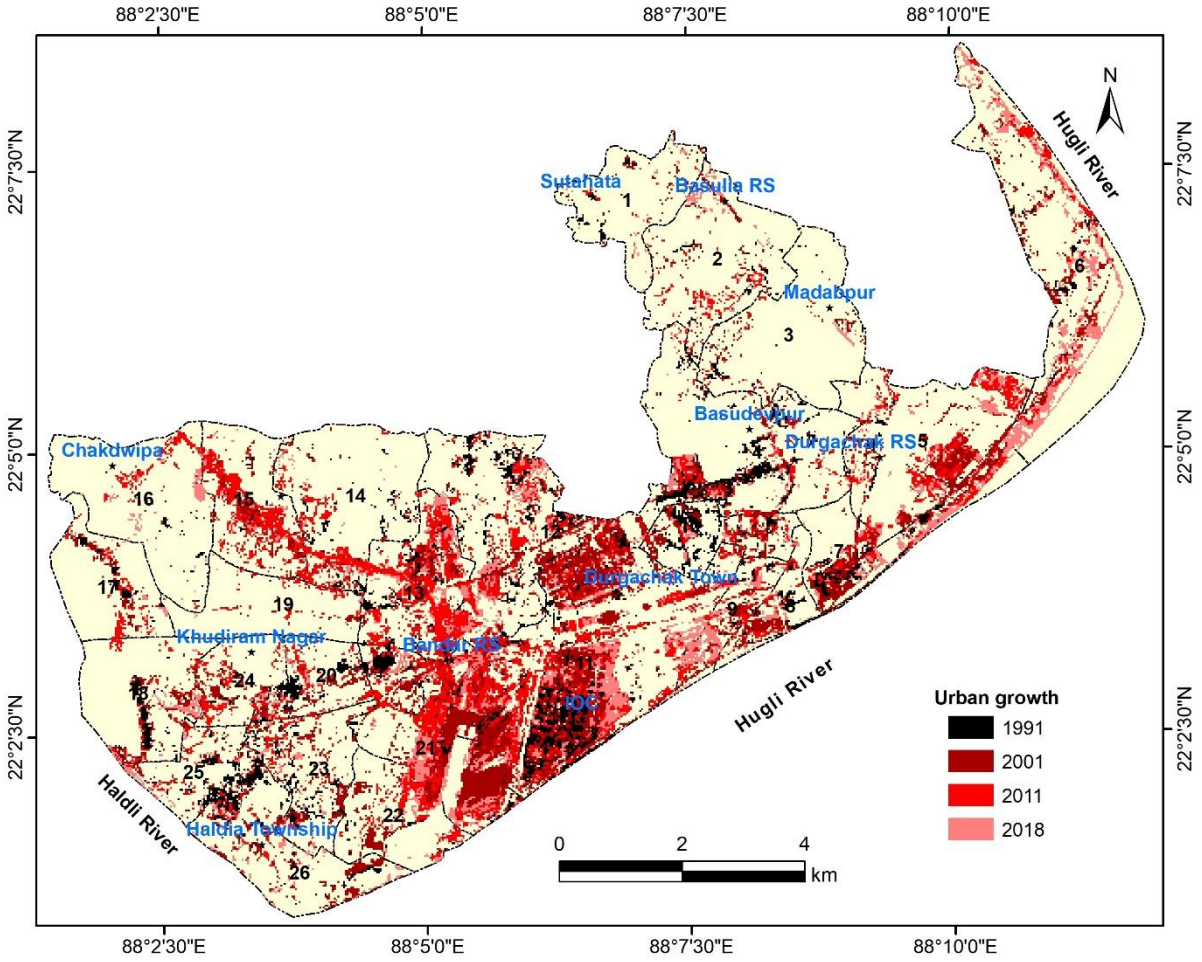

Fig. 2.29: Urban sprawling at Haldia Municipality area from 1991 – 2018.

Table 2.15: Urban sprawling at Haldia municipal area from 1991 – 2018.

Year	Built-up area of total area (99.97 km^2)	
	km^2	%
1991	4.72	4.72
2001	13.25	13.25
2011	22.71	22.71
2018	29.36	29.37

around the port (Fig. 2.29). In similar ways (as observed in the Digha and Contai) after the 2000s, the built-up areas significantly increased in the central part, western and eastern levee

side areas. In the eastern levee of the river Hugli, the brick-field or brick kiln areas have remained (Plate 2.15), which extracted as the built-up areas (Fig. 2.29). The settlements and some industries build in the roadside areas in the north-western side of the study area. After 2010, the settlements are mostly built-up in the low-lying areas in the central part through land-filling. Among the three sites, the highest percentage (29.37 %) of total land remains under the built-up area. The growth rate of urban areas is also highest in compared to the other two urban areas. Since 1991, the area under the built-up of the total municipal area is 4.72% (1991), 13.25% (2001), 22.71% (2011), and 29.37% (2018) (Fig. 2.26; Table 2.15). Such kind of urban expansion over the most risk-prone areas of the river banks, low-lying areas and wetlands after degrading the natural landscape, vegetation covers and agricultural land will create miseries to the urban dwellers in future.

Plate 2.15: Brickfield over the bank margin mudflat areas of Hugli river.

2.5. Major findings

The major outcomes of this chapter are as follows;

1. The urban centres have been expanded and redistributed depending on the number of population and administrative controls. The built-up area has been expanded in expanses of sensitive habitats (shorelines, sand dunes, wetlands etc.) of the alluvial coast over time and space such as Digha along with the shorefront dune ridges, at Contai along the dune ridge and lowland areas, and at Haldia over the natural levee and lowlands.
2. The built-up area has increased in the greater rate at Haldia in compare to Digha and Contai. The overall LULC conservations of Digha, Haldia and Contai include the dune ridge and lowland to built-up areas, coastal wetlands converted into fisheries, and

agricultural land with dune habitats converted into built-up areas during the considered period.

3. The rapid expansion of beach tourism along the littoral tract from New Digha to Mandarmani (24 km shoreline) has created a lot of environmental conflicts between tourism infrastructure development and modification of sensitive coastal environment in the region.