Chapter-5

Urbanization-environment conflict and associated vulnerability

5.1. Land use alteration and habitat conversion

The urban areas have been situated within the low-lying littoral-coastal plain comprising with differential landscape setup. Therefore, the natural environment has been degraded due to the expansion of urban areas as well as the intensive urbanization. In that way, environmental conflicts have been increased concerning the physical stability of the urban landscape.

As mentioned earlier in chapter 2, the urban areas of Digha situated over the shorefront beach ridge dune surface along with the lowlands areas. The natural landscape has rapidly altered into the artificial land use due to the rapid growth of the infrastructural development in Digha urban fringes at present. Therefore, a massive level of habitat conversion has been observed in that area. Most of the built-up sites have been developed over the shore parallel dune ridges at Digha, Sankarpur and Mandarmani tourism sectors. The elevated dune ridges have been flattening for the preparation of suitable land for the construction of tourism infrastructures. Moreover, the shoreline retreat has been intensively active and the pressure of mass-tourism has also gradually increased in that coastal stretch. In such juxtaposition situation, the demand for further tourism infrastructures has tremendously increased in the tourism sites. Moreover, the natural increase of population is a common phenomenon which required lands for the construction of dwelling units and agricultural fields for their livelihood. Therefore, the problem of land sharing among the stakeholders for their different life-supporting activities is continuously increasing in the coastal areas. In this contrast, the agricultural land, forest land, wetlands and dune landscape are converted into the dwelling units and tourism infrastructures. Moreover, the indigenous species of dunes and wetlands are endangered and or extinct from those areas of the coastal environment.

Almost a similar kind of landscape (wetlands and lowlands) conversion has been found in the Haldia municipality area. The estuarine floodplain and natural levees have been entirely occupied by the urban-industrial infrastructural developments. The recently formed tidal swamp and mud-bank areas have intensively utilized as the brick kiln field in the estuarine bank of Hugli (Plate 2.15). The agricultural land and other natural wetlands have been converted and occupied for the urban infrastructures. The industrial waste and effluents are deposited in the surrounding areas of the industries. Also, most of the effluents are directly mixed with estuarine water. Therefore, the habitats, as well as the species of the land and estuarine environments are degraded violently.

The dune ridge and surrounding lowlands of the Contai municipality area are intensively utilized for the dwelling and urban infrastructures, and agricultural practices. The dense natural vegetation of dune ridge is entirely wiped out and only remain in the fringe areas. Also, with due effects of intensive urbanization, the entire top surface dune ridge has been utilized and the people are compelled to construct their dwelling units in the arable agricultural land and wetlands. Therefore, the natural habitats of dune and wetlands are continuously degraded in that municipality area.

5.2. Scarcity of water

The water scarcity is an important criterion to intensifying the environmental conflict in the study areas. To assess the water scarcity, long-term temperature and rainfall variability of the urban centres of Digha (1982 – 2017), Contai (1949 – 2017), and Haldia (1982 – 2017) have been analysed along with the level of groundwater depletion during 1996 – 2015. The trend of temperature and rainfall has a great significance in the water demand and scarcity in conjunction with groundwater depletion. In this context, before assessing the water scarcity, these three aspects have been analysed in this study.

5.2.1. Rainfall and temperature variability

The long-term mean monthly variations of maximum temperature show an increasing trend of temperature at Digha in the months of January (0.03), May (0.74), and September (0.62) which respectively represents the seasonal trend during the winter, summer and late summer periods (Fig. 5.1). At the site of Contai, the trend of temperature is increasing during summer (0.63) and late summer (0.56), whereas, it is decreasing during the winter (-0.30) periods (Fig. 5.2). The similar situation observed in case of the Haldia urban area with an increasing trend of temperature during the winter (0.11), summer (0.63) and late summer (0.77) periods (Fig. 5.3). Alongside the temperature, the rainfall variability is also analysed for these three sites. The average rainfall of winter (December – January), pre-monsoon (March – May), monsoon (June – September) and post-monsoon (October – November) seasons and the mean annual rainfall has been analysed in the three sites. The slightly increasing trend of annual (0.09) and monsoonal (0.05) rainfall is observed in the Digha site (Fig. 5.4). However, the slightly decreasing trend is observed in the other two sites of Contai and Haldia (Fig. 5.5, 5.6).

All over India, the micro-climatic variation has been observed with the land use and land cover change which reflects the declining trend of summer monsoon rainfall (Paul et al., 2016). In the Medinipur littoral-coastal tract, there have some influencing factors of coastal weather in the local and regional weather phenomenon, mostly associated with the depressions, deep depressions, and other cyclonic storms. Digha is located at the seaside position of the

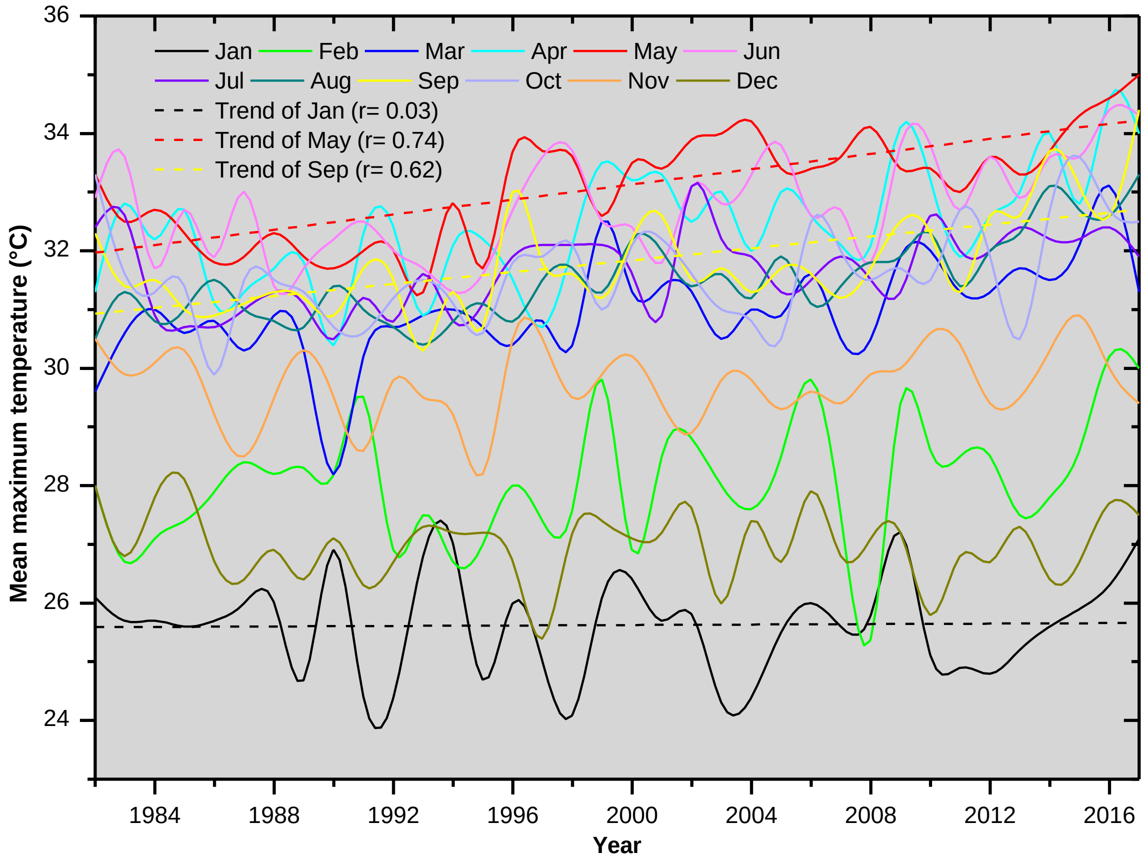

Fig. 5.1: Mean monthly variation of maximum temperature at Digha during 1982 – 2017.

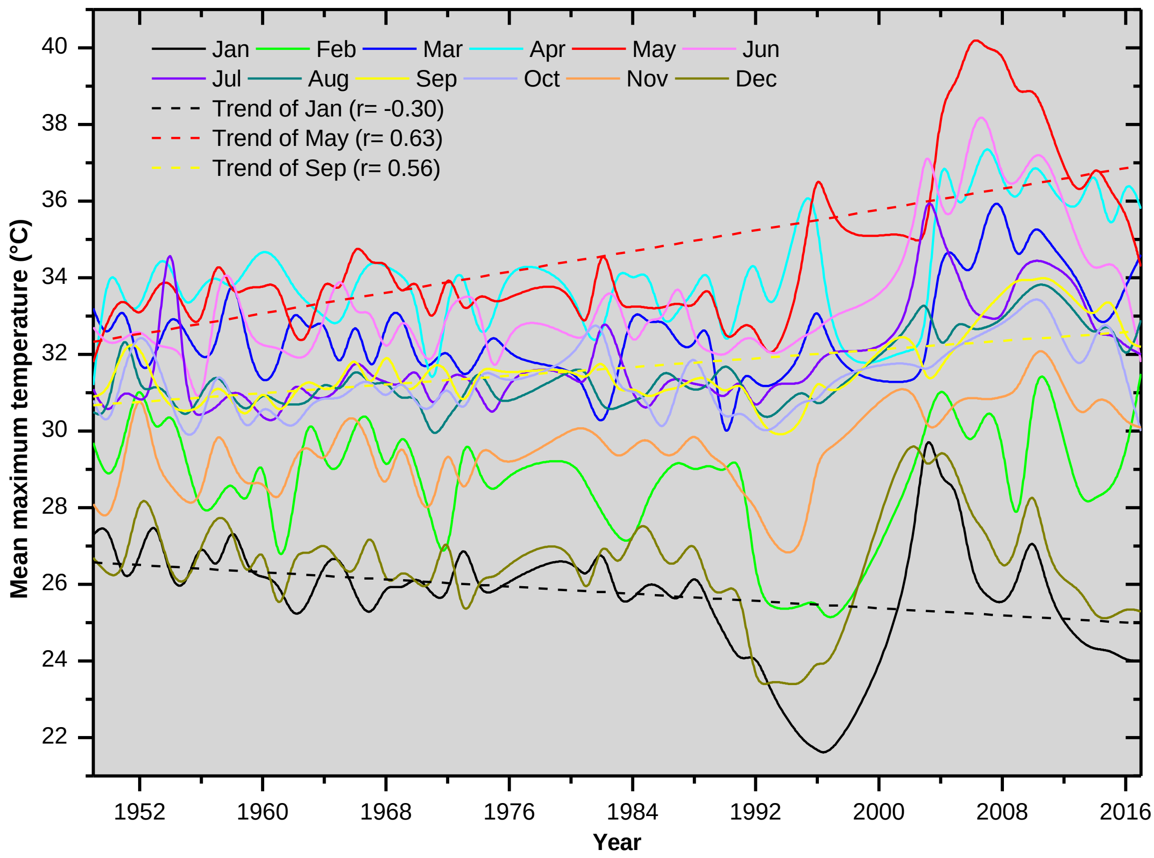

Fig. 5.2: Mean monthly variation of maximum temperature at Contai during 1949 – 2017.

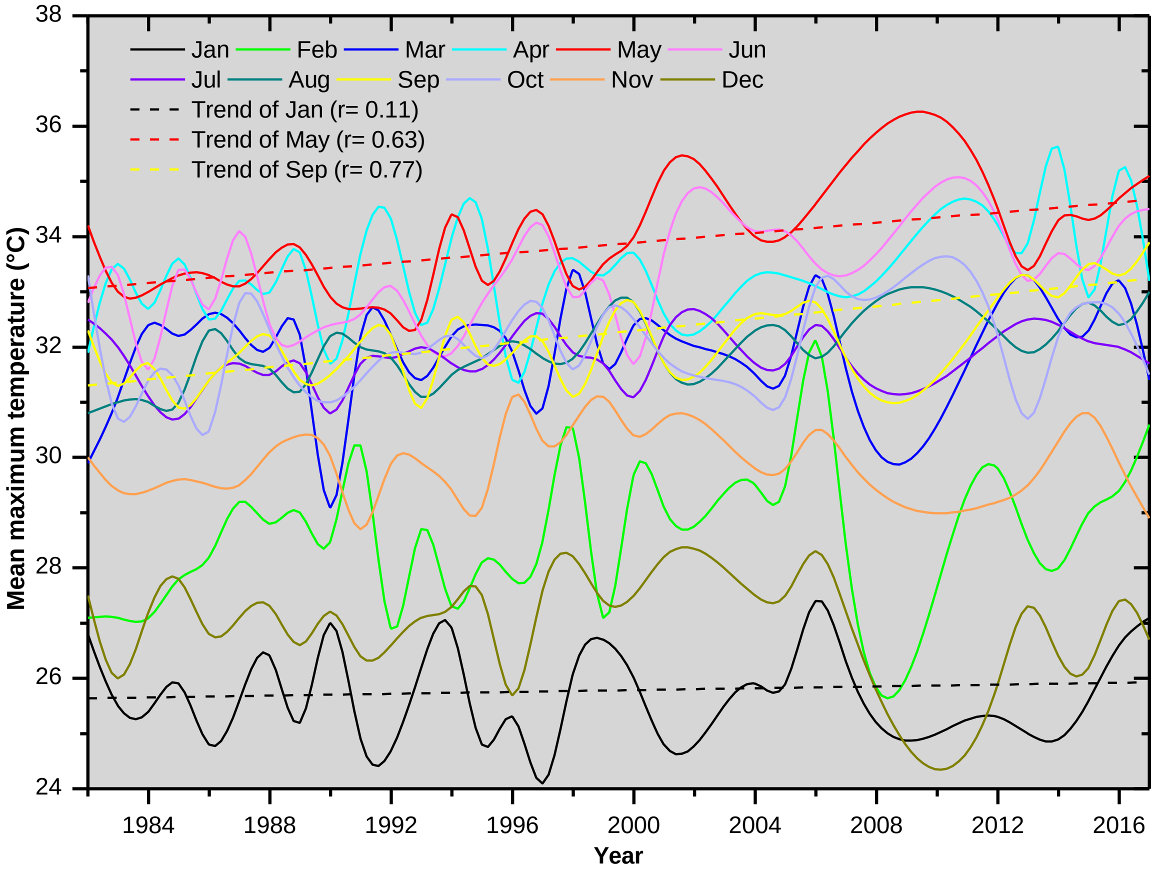

Fig. 5.3: Mean monthly variation of maximum temperature at Haldia during 1982 – 2017.

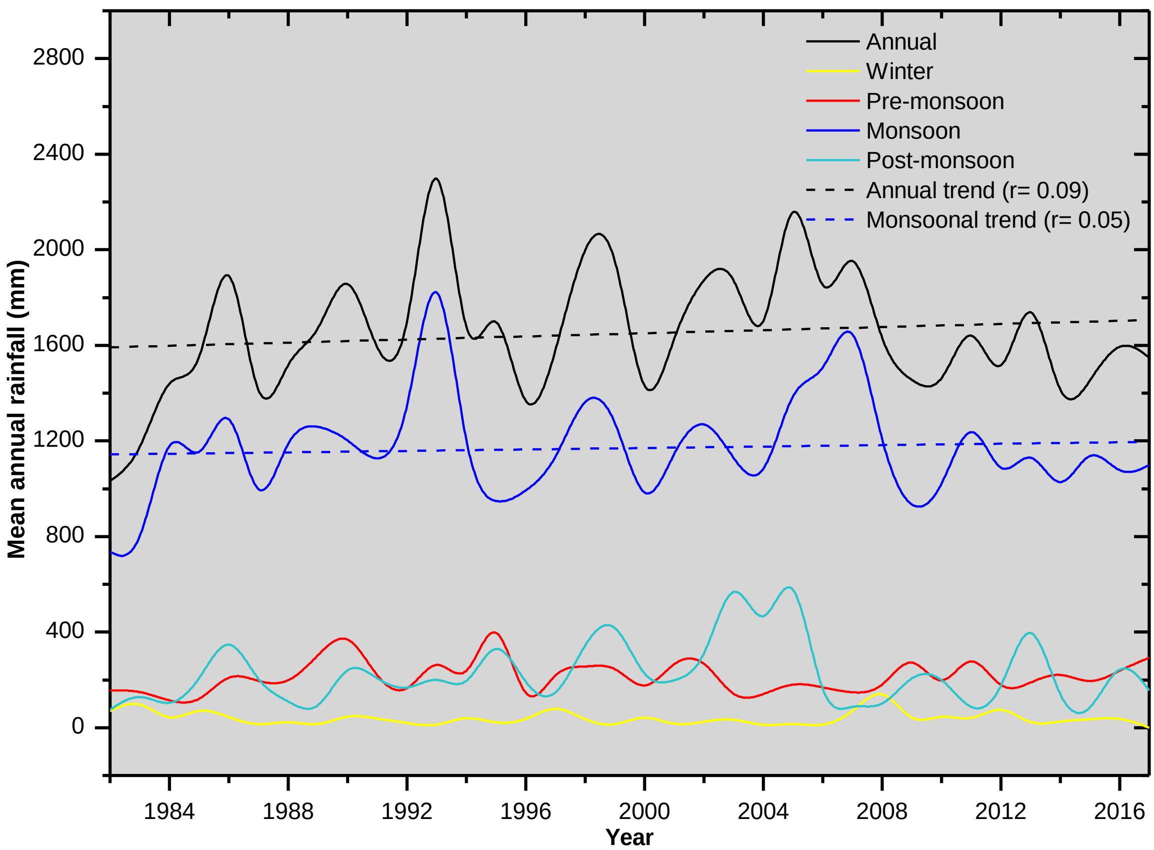

Fig. 5.4: Seasonal variation of rainfall at Digha during 1982 – 2017.

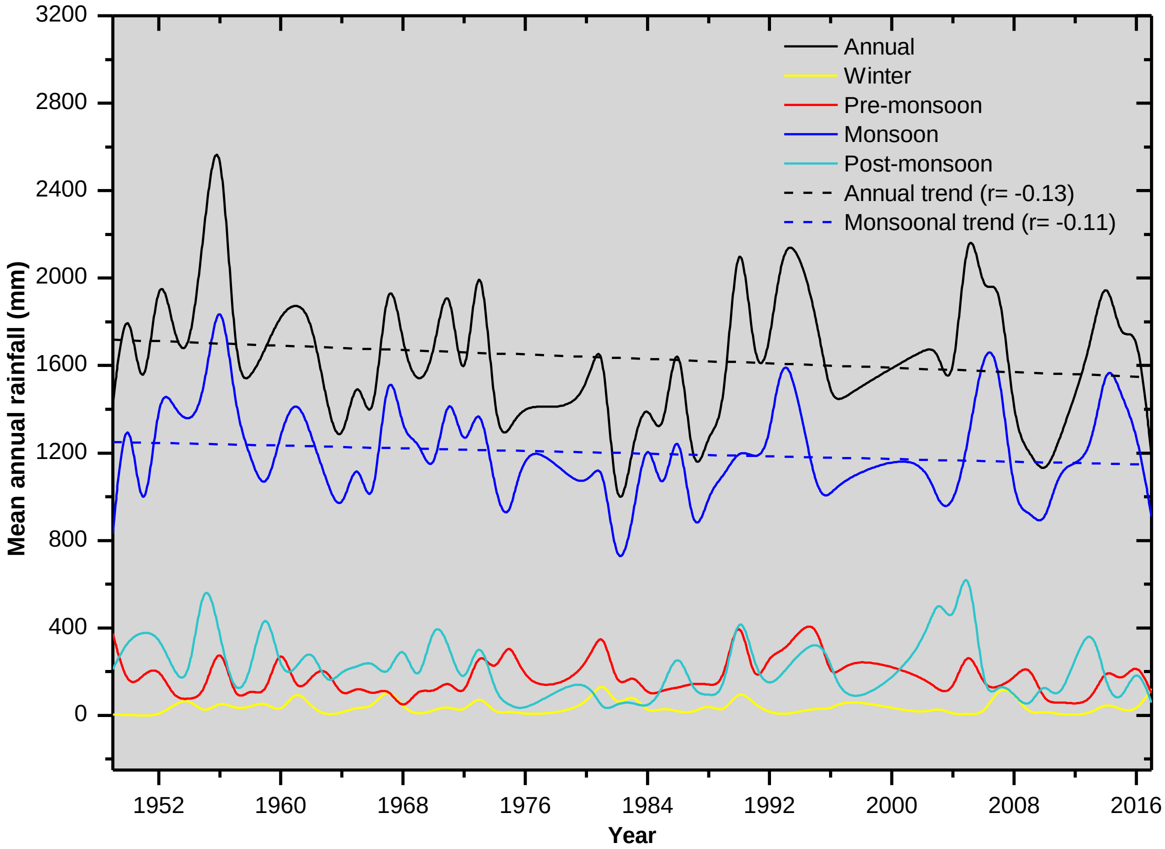

Fig. 5.5: Seasonal variation of rainfall at Contai during 1949 – 2017.

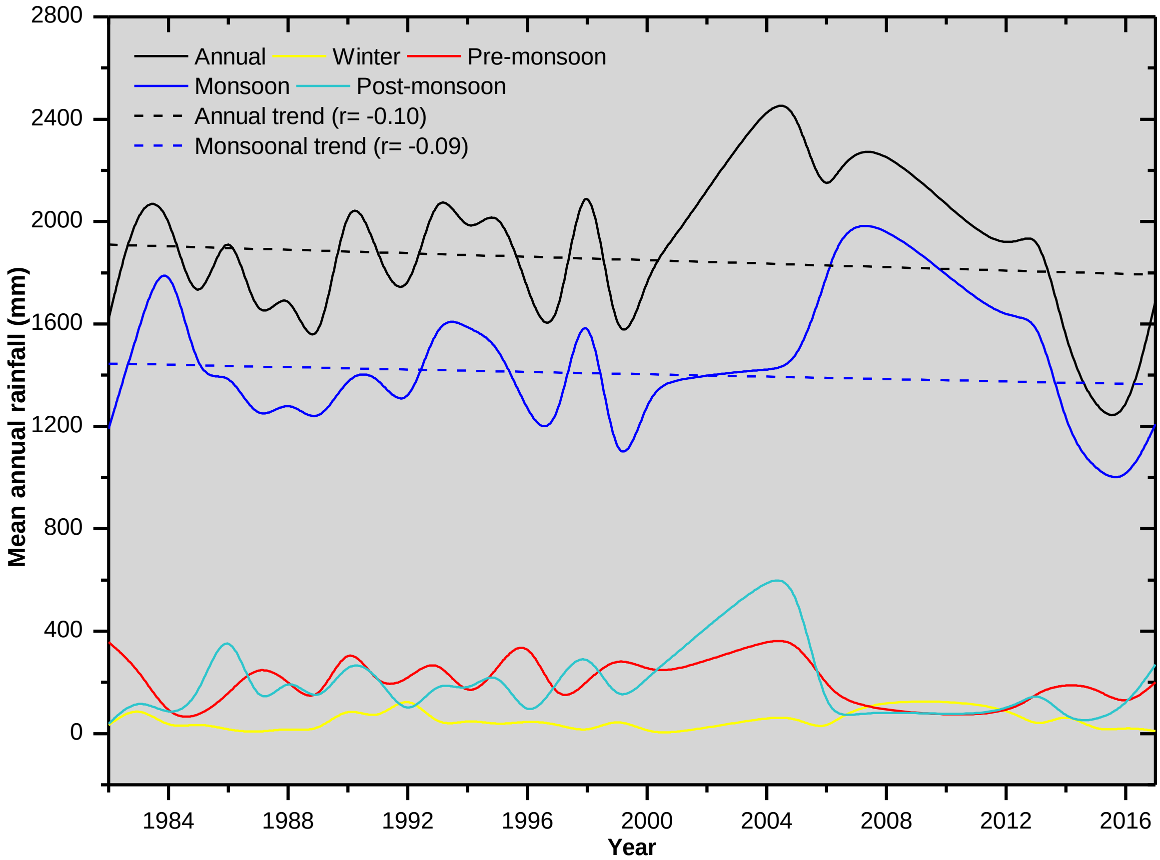

Fig. 5.6: Seasonal variation of rainfall at Haldia during 1982 – 2017.

Bay of Bengal sea, whereas, Contai situated about 10 km inland position away from the seashore and Haldia situated in the estuarine environment about 75 km inland position from the Digha (about 50 km inner part from the open sea). Therefore, there have some micro-climatic variability in the local and regional weather pattern and resultant rainfall distribution within this littoral-coastal tract (Paul et al., 2016).

5.2.2. Groundwater depletion

The demand of groundwater has tremendously increased with the immense population pressure and growth of population in the coastal urban areas (Shah, 2005; Chinnasamy & Agoramoorthy, 2015; Michael et al., 2017; Bate et al., 2018). The conventional alterations in the livelihood patterns and life-supporting occupations amplify the extraction of groundwater for multipurpose uses like drinking water, water for household activities, irrigation, and importantly for the fisheries sectors (Hossain, 2014; Gangadharan & Vinoth, 2016; Singh et al., 2016; Marwah, 2018). Therefore, the groundwater table depleted in tremendous rate year by year. Moreover, the tendency of monsoonal rainfall has decreased at a significant rate (Paul et al., 2016). Such kind of contrasting situation creates a conflict among the stakeholders regarding the sharing of groundwater.

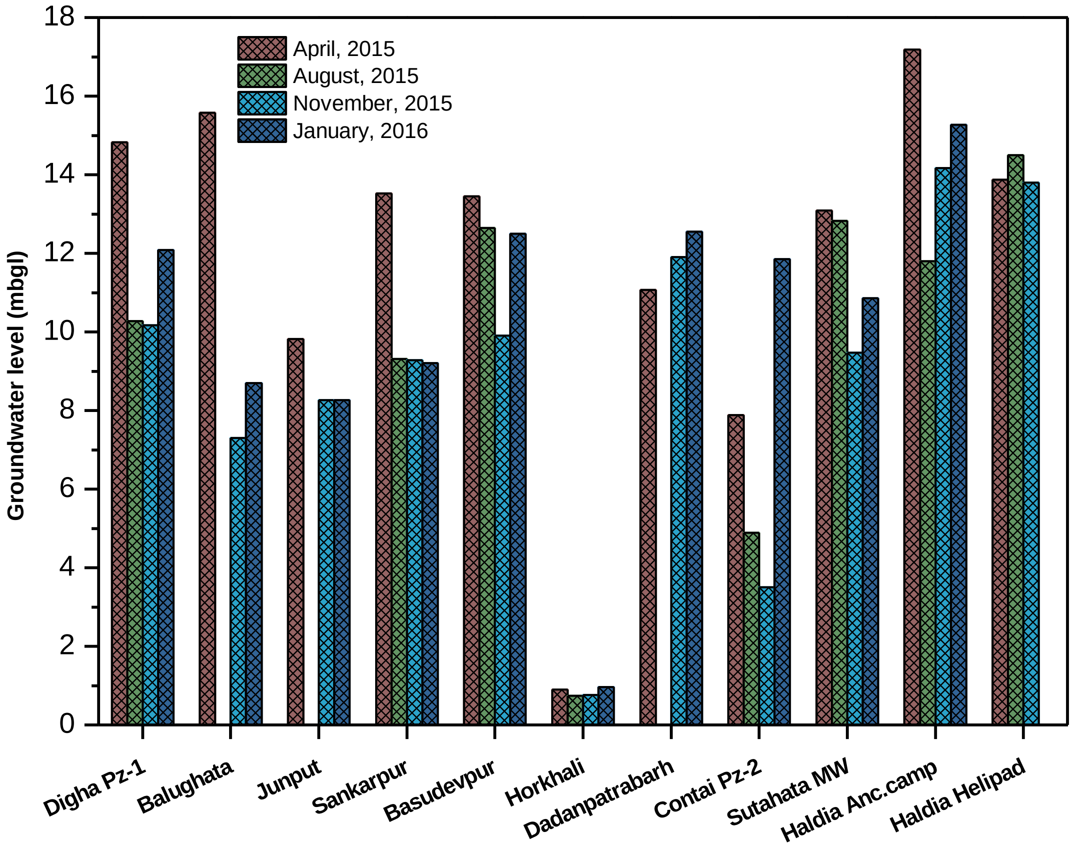

Fig. 5.7: The nature of seasonal groundwater level at different coastal stretches of Medinipur littoral tract.

In the different sites within the study areas, the level of the groundwater table remains at various depths, also the seasonal groundwater table varied significantly (Fig. 5.7) (CGWB, 2016). Moreover, the long-term (1996 – 2015) net depletion of groundwater table reveals a threatening condition in all the coastal urban centres of Digha, Contai and Haldia. As the demand of groundwater requirements is rapidly increased in Digha and Sankarpur coastal stretch by large scale tourists inflow (due to easy access from the city of Kolkata), the net groundwater uses have been also increase. The groundwater depletion is recorded as highest in Digha-Sankarpur coastal tract where the mass-tourism process exists at a higher level (Fig. 5.8) in compare to other areas. More importantly, the nearshore coastal areas resulted in more groundwater depletion than the other inner part of the study area. The moderate level of depletion is observed at the Mandarmani tourism area. The maximum and minimum level of depletion resulted as 10.02 m and 5.02 m, respectively at Digha urban centre (Fig. 5.8). In the Contai urban centre, a very minimum range of groundwater depletion is observed which varies from 7.59 m to 7.15 m (Fig. 5.9). The groundwater depletion level is higher in the densely populated areas at the central part and its surroundings of the Contai municipality (Fig. 5.9). The water scarcity is tremendously increased due to over-extraction of groundwater year by year without estimating the water budget. The highest level of groundwater depletion (10.68 m) is observed in the Haldia urban centre among the three sites. The utmost percentage of urban areas of Haldia remain under a higher level of groundwater depletion (Fig, 5.10). At Haldia urban centre, the maximum and minimum level of groundwater depletion is observed as 10.68 m and 6.74 m respectively (Fig. 5.10). The overall analysis of the maximum level of groundwater depletion reveals that the higher level of depletion in the Haldia (10.68 m) and Digha (10.02) urban centres, whereas, the lower level (7.59 m) in the Contai urban centre (Fig. 5.11). The minimum level of depletion observed as 5.02 m (Digha), 6.74 m (Haldia), and 7.15 m (Contai) (Fig. 5.11). Such variability of groundwater depletion reveals that the urban centres are to be more fragile and vulnerable concerning the degree of water scarcity.

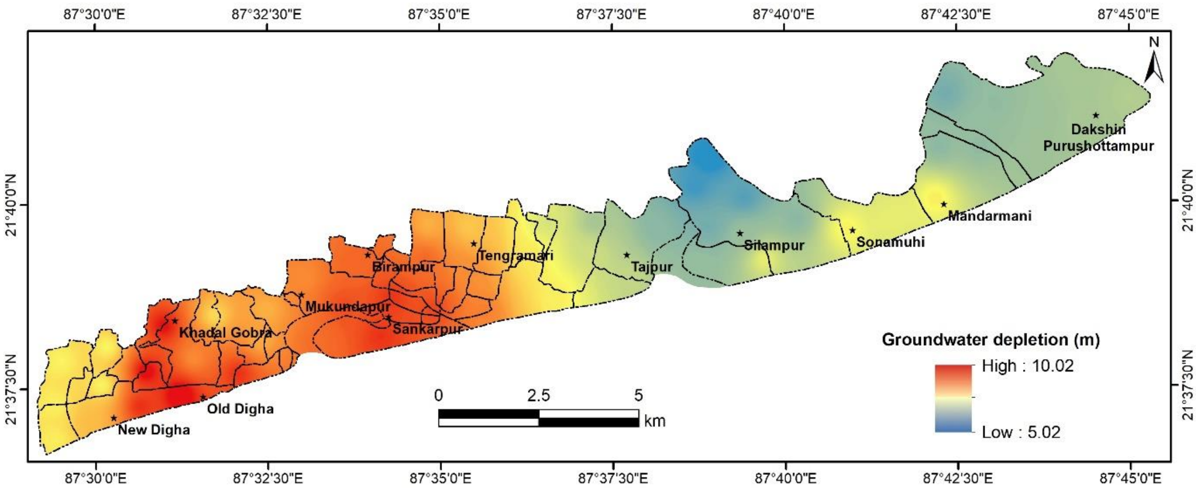

Fig. 5.8: Net depletion of groundwater level (mbgl) at Digha during 1996 – 2015.

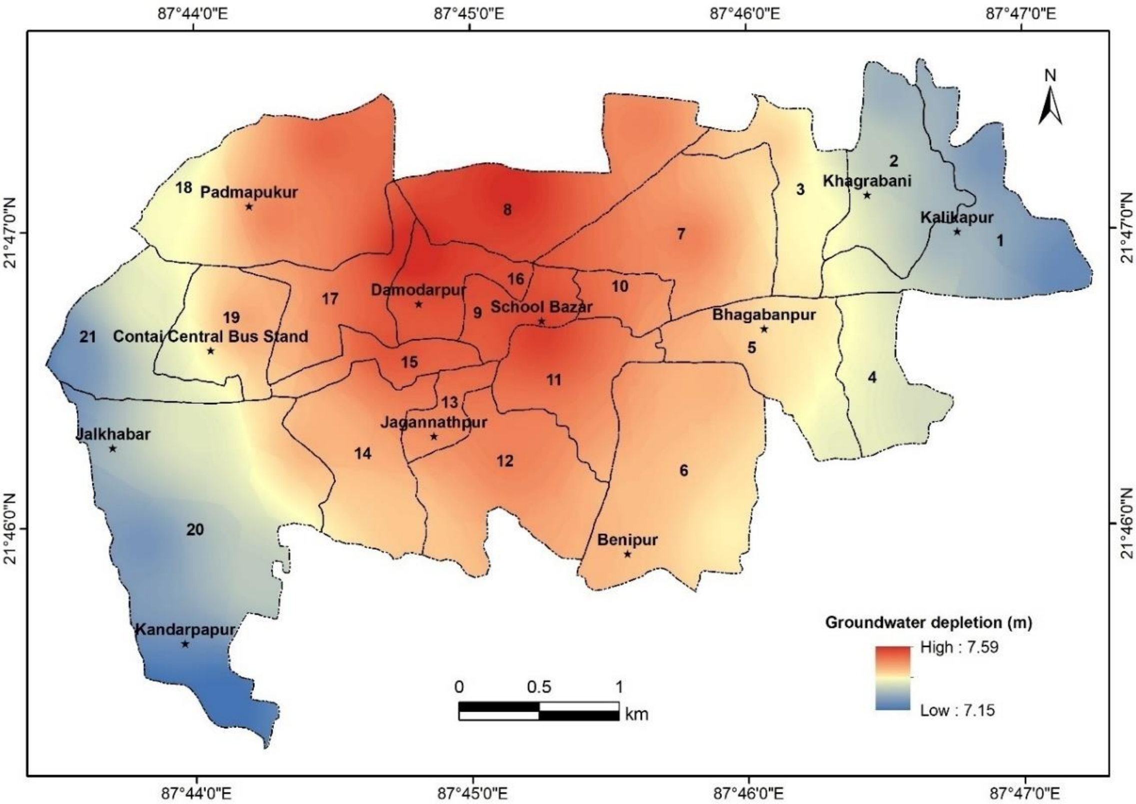

Fig. 5.9: Net depletion of groundwater level (mbgl) at Contai during 1996 – 2015.

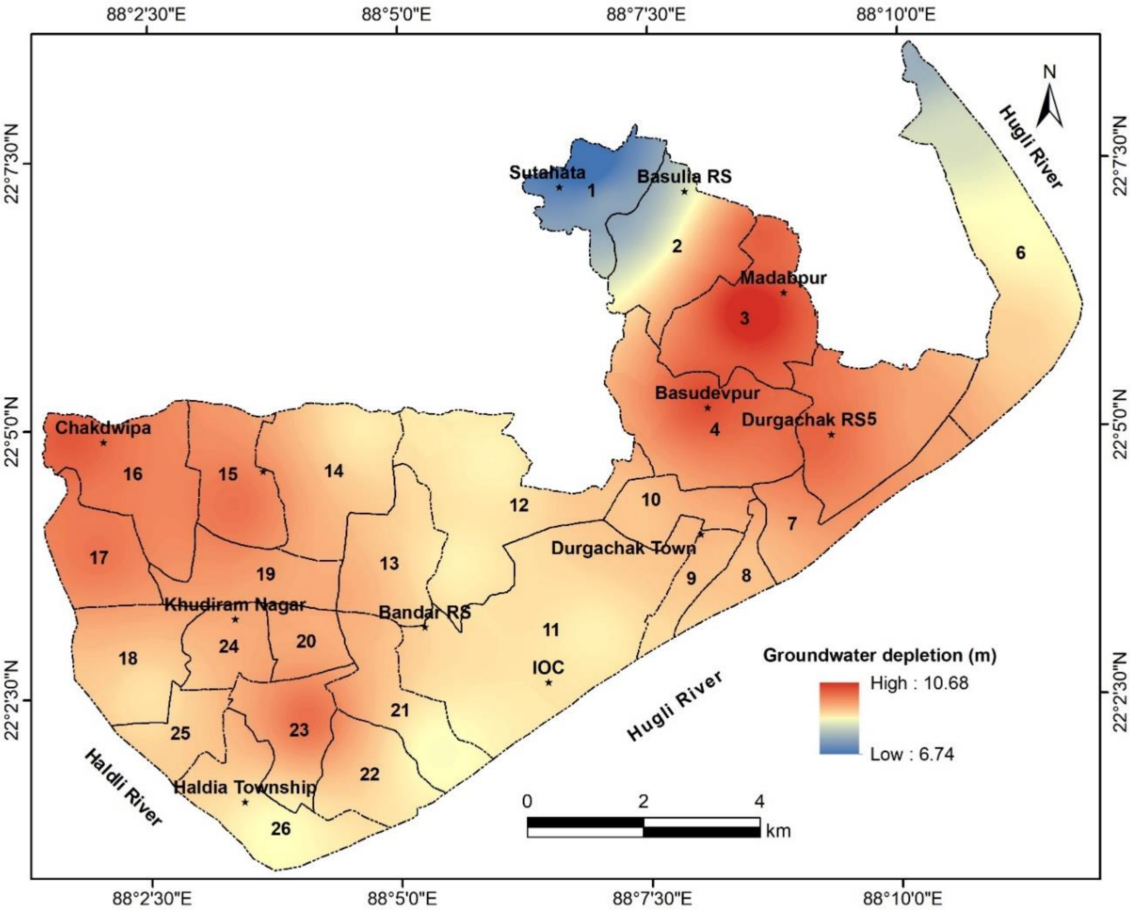

Fig. 5.10: Net depletion of groundwater level (mbgl) at Haldia during 1996 – 2015.

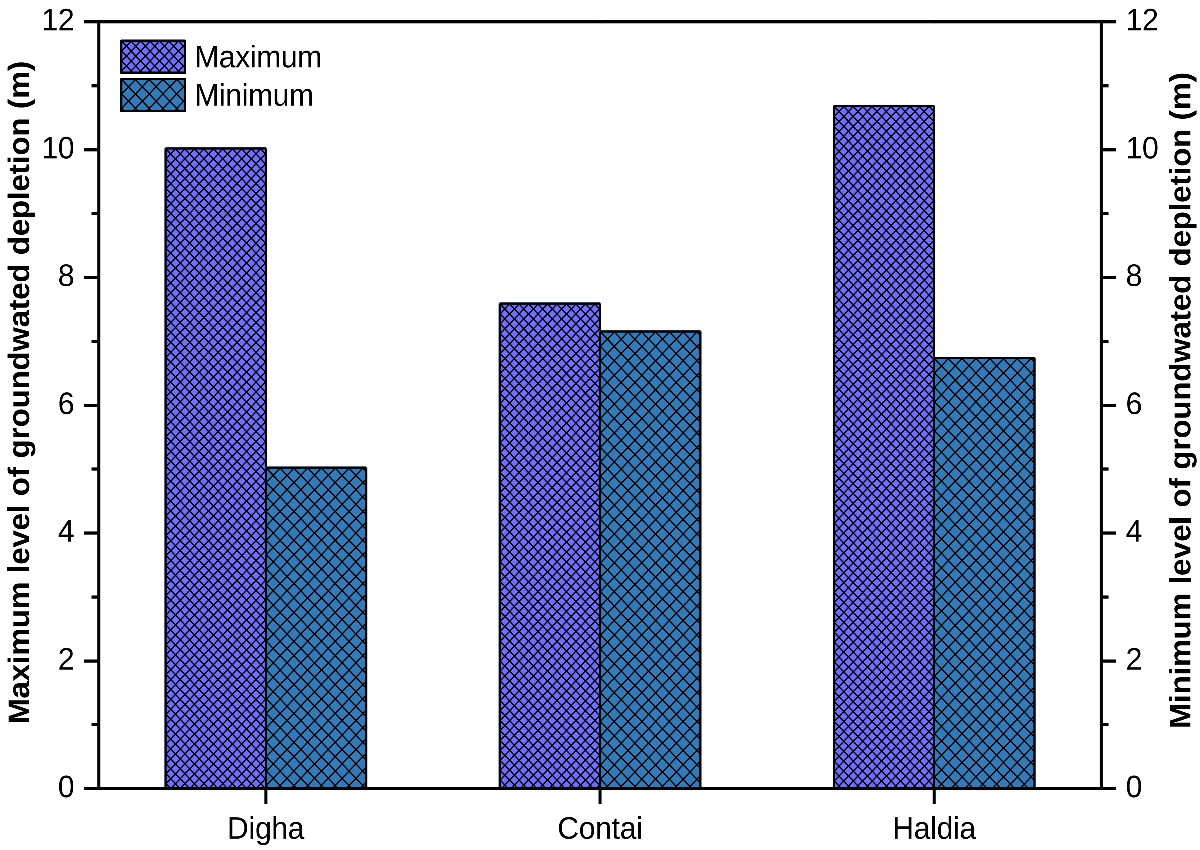

Fig. 5.11: Maximum and minimum levels of net groundwater depletion (mbgl) at three different sites during 1996 – 2015 (showing vulnerabilities).

5.3. Sand mining, wetland conversion and lowland filling

The Digha and Contai urban centres are situated over the sand dunes and low-lying areas, and Haldia in the estuarine floodplain area. Most of the elevated sand dunes have been converted into the urban infrastructural areas in Digha and Contai. The undulated dunes and its ridges are flattening for the preparation of suitable land for building constructions (Plate 2.10, 5.1). The dune sands are mined and transported towards the interior low-lying areas of wetlands for lowland-filling to prepare more suitable and profitable land utilization (Plate 5.2). In Haldia, the urban-industrial wastes are somehow dumped in the lowlands and open space. Moreover, the industrial pollutants and effluents are deposited in the surrounding land and depression areas. Therefore, the productivity of land has deteriorated and not further utilized for the agricultural purpose. In this consequence, such kinds of land-unit are eventually acquired by the industrial and or urban infrastructural entrepreneurs (Plate 2.8). Moreover, the natural wetlands have been converted into the fisheries in the backwaters of Digha-Mandarmani coastal region (Plate 2.1a) that can degrade the indigenous species of flora and fauna (Rodrigues et al., 2011; Das, 2014b; Das et al., 2018).

Plate 5.1: Dune cutting (b) and flattening (a) for housing construction in Contai.

Plate 5.2: Wetland filling for construction of hotel at Mandarmani.

Plate 5.3: Bare soil under the floor of Casuarina trees at the dune top across the wind passes in Digha.

The natural dune habitats and associated species are progressively disappeared with dune effects from the dune landscape degradation and land use alterations. The indigenous dune vegetation species have also been wiped out by the stakeholders through the introduction of more profitable plant species as an alternative (Plate 2.5b, c, d). Moreover, the casuarina trees are widely adopted as a dune plant all along the coastal areas to protect the sand dune from erosion, although, the dune erosion rate cannot be controlled in any sense (Paul & Bandyopadhyay, 1987; Roy & Datta, 2018). However, the other bushes and shrubs species are wiped out from the dune surface under the coverage of casuarinas which leads to dune erosion (Plate 5.3). In association with the flora, the faunal species were also extinct from the dune landscape (Das, 2014b).

5.4. Solid wastes

The urban areas of Digha, Contai and Haldia are formed based on tourism, dwelling household and industrial activities. The volume and types of solid wastes are also different in one site to another. At Digha, the volume of solid wastes mainly generated from the tourism-based activities. It is observed that the ten various types of solid wastes are dominated in the Digha tourism area (Fig. 5.12). Among those, the organic waste mixed with sand, organic waste, coconut shell and plastic dominates all over the area. The plates (used for food service) made by leaves, paper and thermocol are also a significant source of waste in Digha area. The worst impact of mass-tourism activities is observed with respect to the comparison of solid waste volume in the normal and peak tourist days (Fig. 5.13). The volume of solid waste in different sectors i.e. domestic, commercial, coconut sellers, hotel and restaurants, sweeping, and market are tremendously amplified (more than double) in peak tourist days (Fig. 5.13).

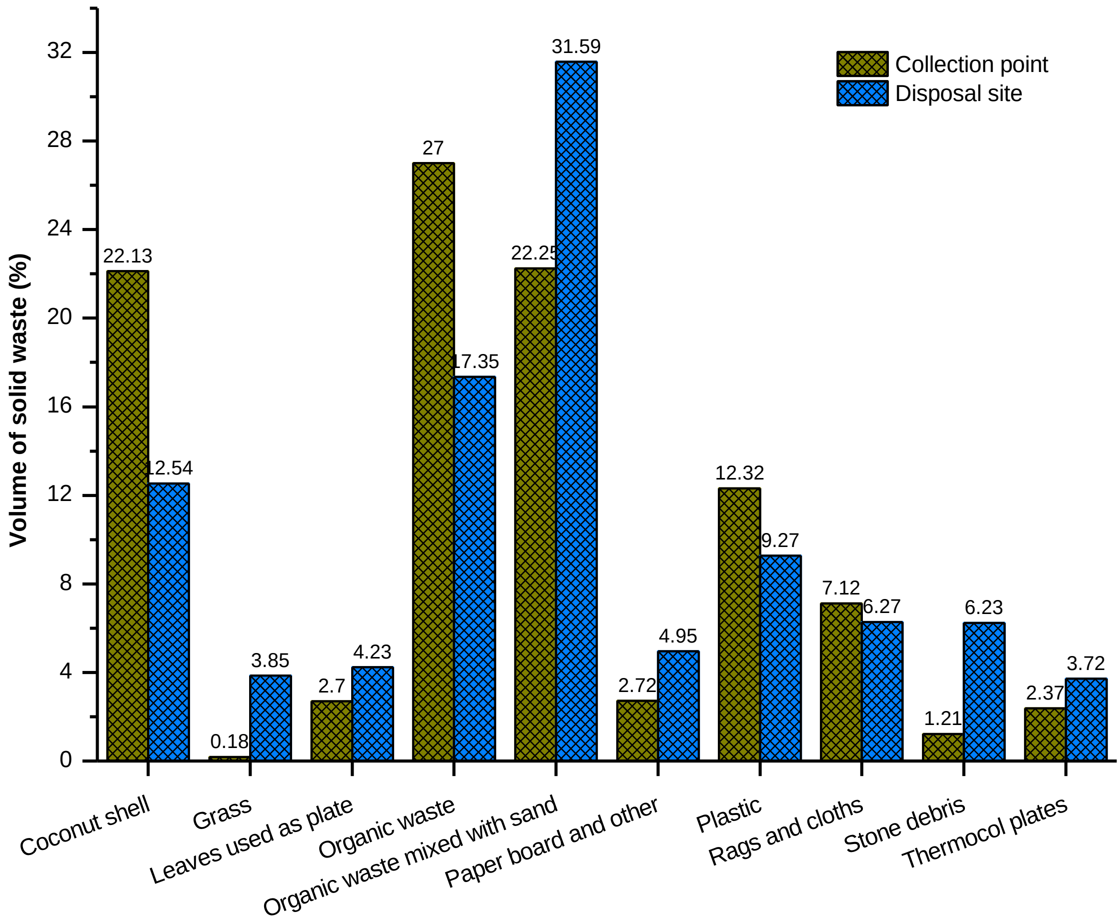

Fig. 5.12: Different types of solid waste at Digha Township Area (during field survey in 2016).

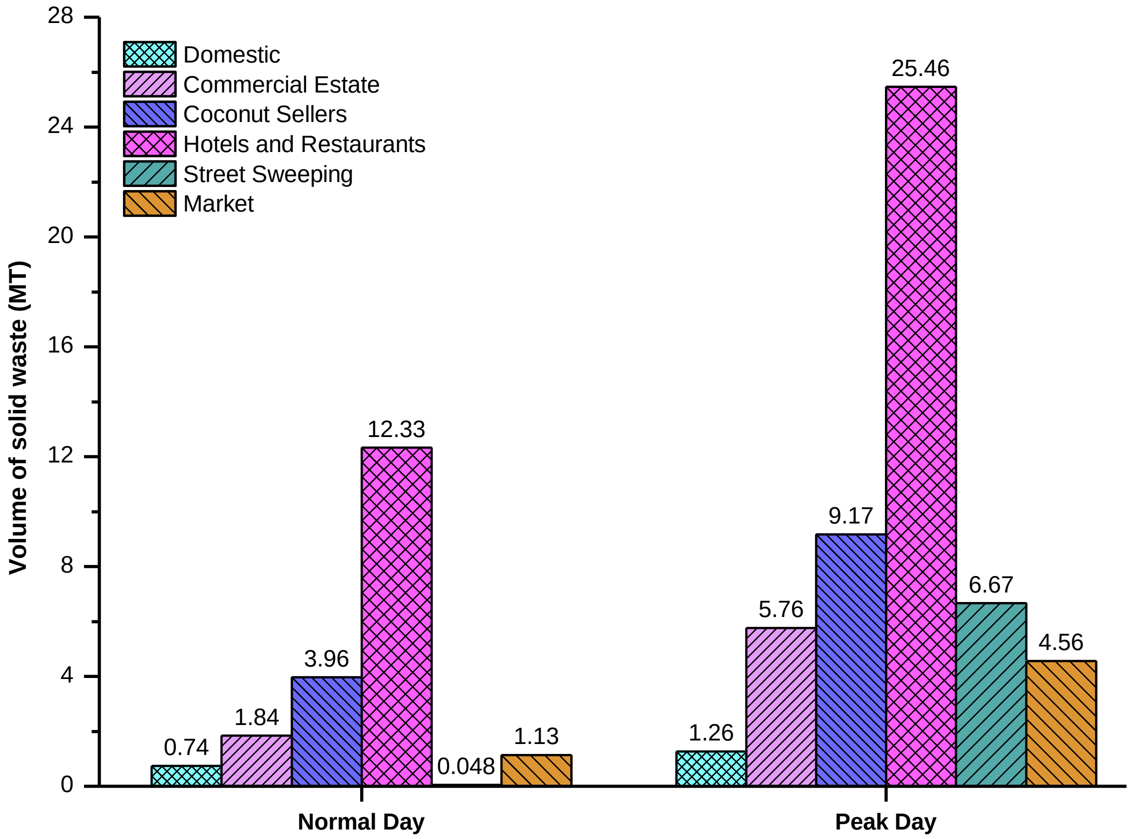

Fig. 5.13: Sources of solid waste at normal days and peak tourist day at the Digha Township Area (during field survey in 2016).

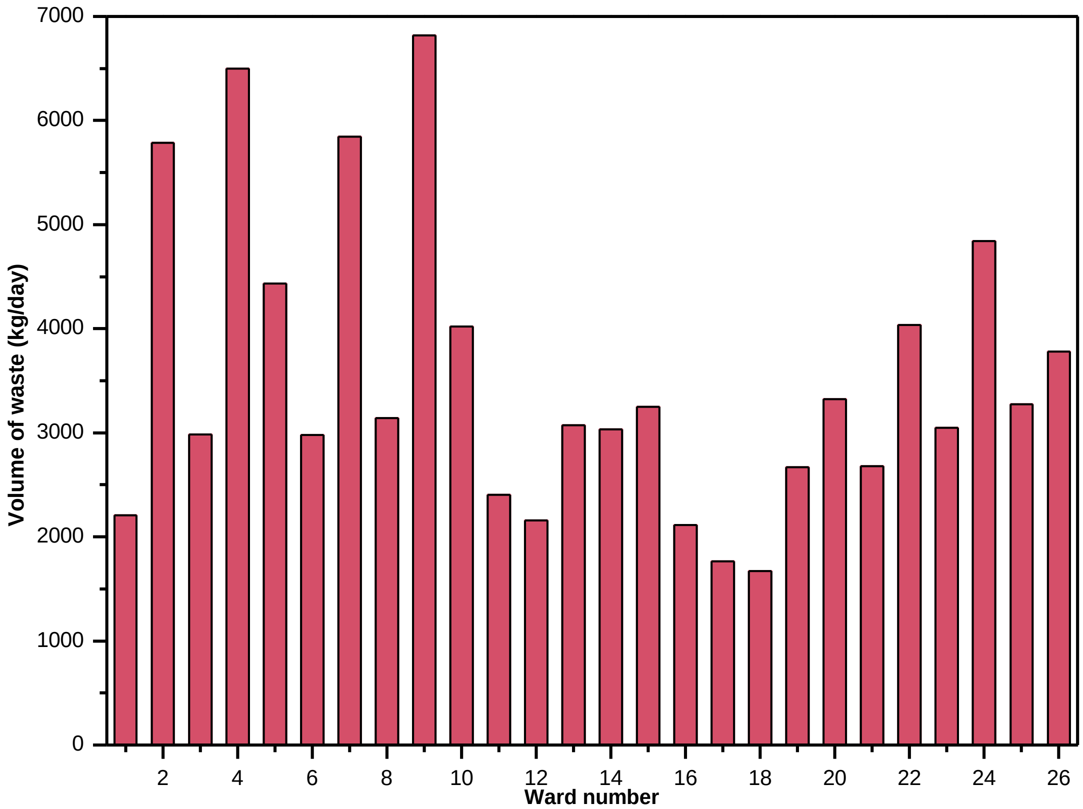

Fig. 5.14: Ward-wise production rate of solid waste at Haldia municipality area (during field survey in 2017).

In Haldia, the solid waste volume varies according to the wards (Fig. 5.14). The production rate of solid waste is very high in ward number 2, 4, 7, and 9 in compared to others (Fig. 5.14). Due to the increase of built-up areas and associated household-industrial activities, those wards have the highest rate of waste production. Moreover, all the other wards generate grossly about 2250 kg/day solid waste (Fig. 5.14). The waste collected by the municipality is varied year to year (Fig. 5.15). During 2012 – 2018, the municipality collects 16295 ton of solid waste where the maximum (24138 ton) and minimum (8987 ton) respectively during 2012 – 2013 and 2015 – 2016. After 2015 – 2016, the collection system has been strong enough and gradually increasing the volume of waste collection (Fig. 5.15). Among the total waste collected by the municipality all over the area (Fig. 5.16), mostly dominated with organic waste (47.24 %), and the others important wastes are plastic (26.48 %), paper (10.45 %) and inert materials (7.04 %). However, the waste collection from the residential sector (Fig. 5.17) is dominated with the plastic (46.49 %), paper (25.36 %), glass (6.55 %), metal (2.16 %) and other waste like organic material, inert etc. (19.43 %).

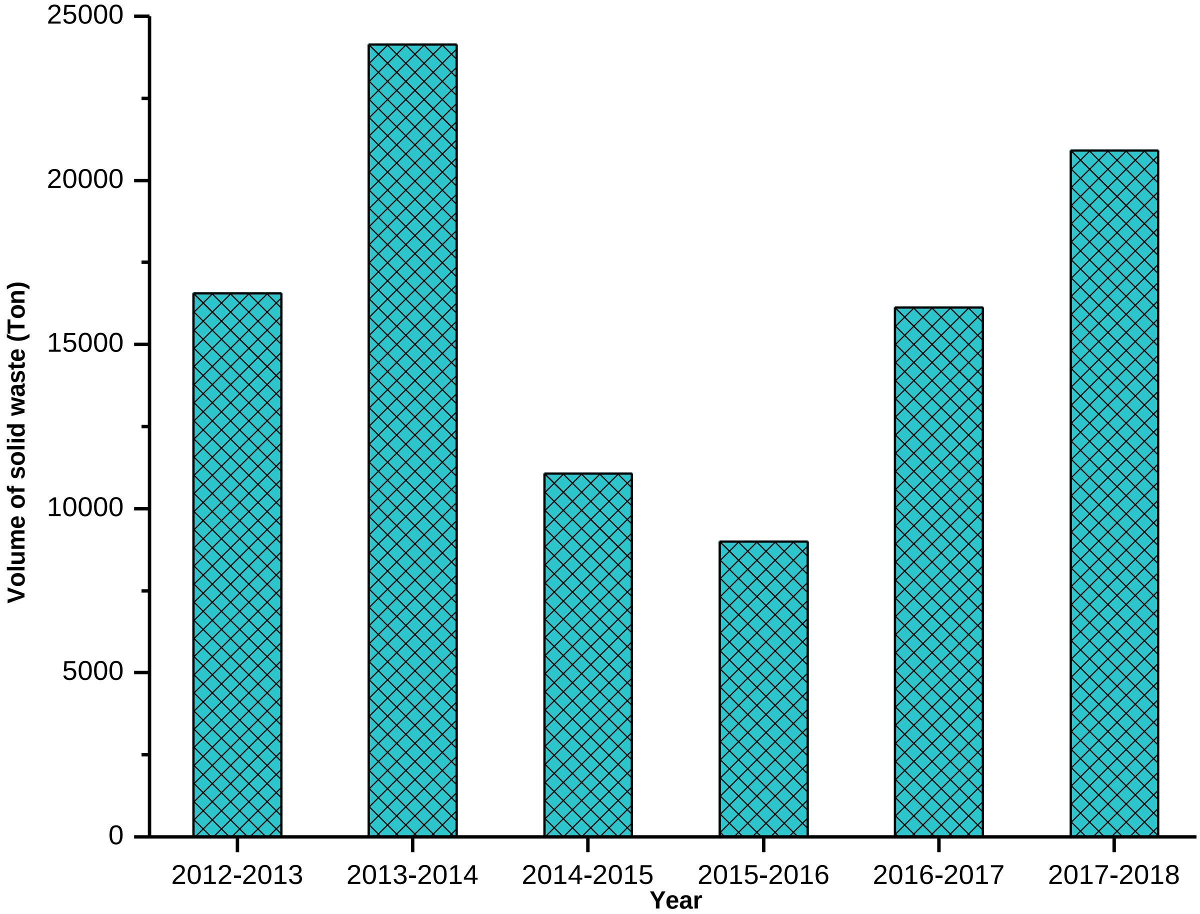

Fig. 5.15: Year-wise volume of solid waste collected by plant at Haldia municipal area (data collected from Haldia municipality).

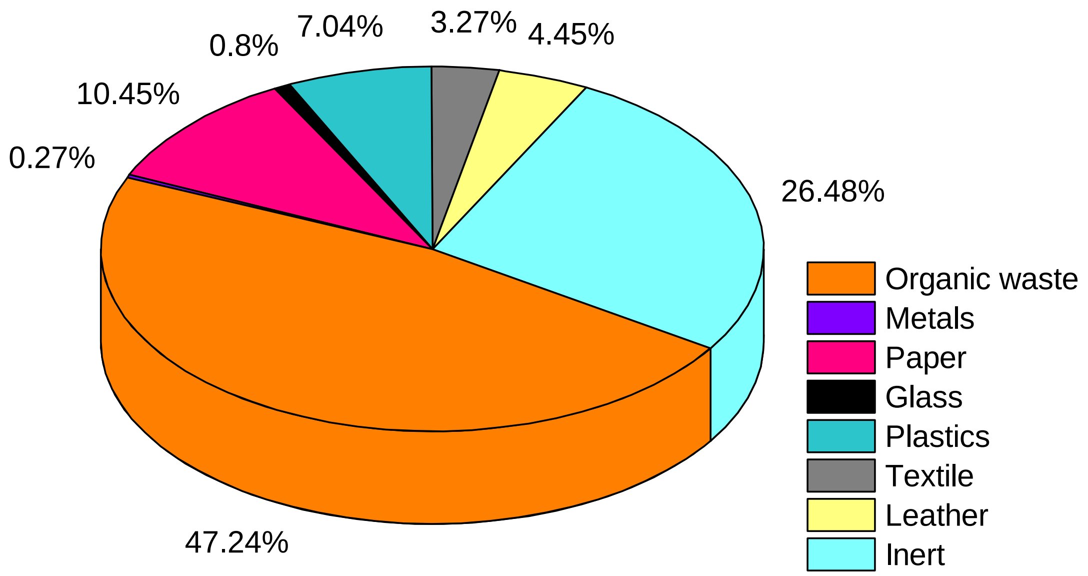

Fig. 5.16: Physical composition of solid waste at Haldia municipality area (based on field survey in 2017).

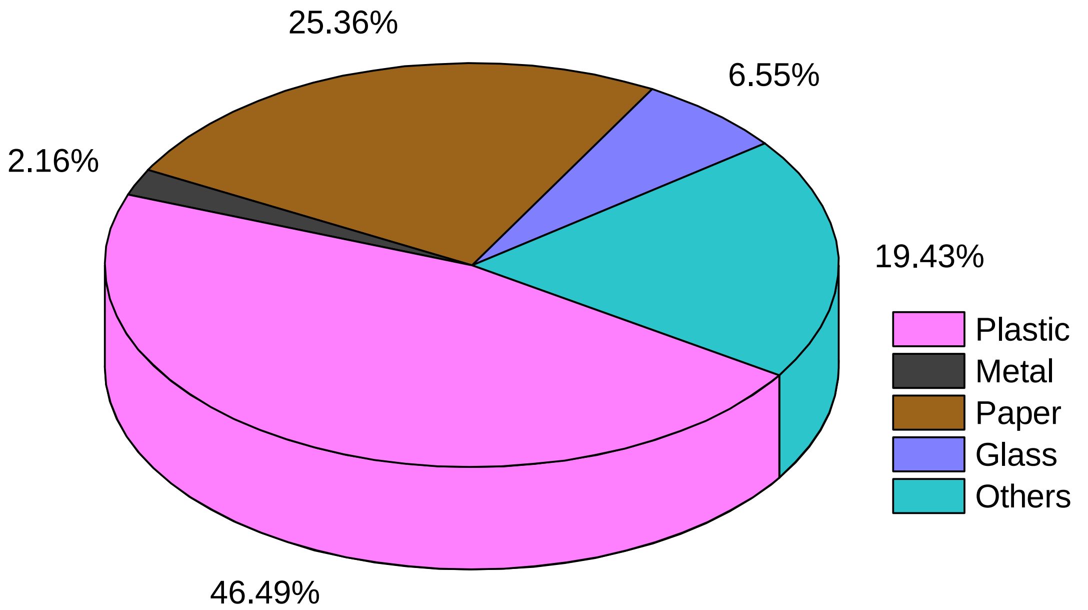

Fig. 5.17: Composition of solid waste collected from the residential sector at Haldia municipality area (data collected from field survey in 2017).

Plate 5.4: Different types of waste dumped into the ponds and open lands of Haldia municipality areas.

In the Contai municipality area, the volume of waste production is relatively less compared to Digha and Haldia. The wastes are generated from the residential and market sectors. The ward number 9, 10, 15, 16 and 17 are mostly populated areas, where most of the wastes are generated as organic, inter and plastic (Plate 5.4). The plastic waste is the major problem in the congested areas of market and residents.

Plate 5.5: Solid waste collection by the municipality authority (a) which is managed by the WBWML (b) in Haldia at present.

The voluminous solid waste is creating severe problem related to land and water pollution. The dumping areas and its surroundings are harshly affected by the waste materials and residential environment is significantly affected by it. The plastic creates the water-logging problem mainly during the rainy season. However, in the Haldia municipality area, the urban and industrial wastes are collected and decomposed by the West Bengal Waste Management Limited (WBWML) (Plate 5.5).

5.5. Water quality

Groundwater quality is a major concern in urban residential areas. The assessment of groundwater quality has been done based on the data of seven sites within the study areas (Fig. 5.18). In most of the sites, the water quality parameters of pH, Electrical conductivity, Total hardness, Calcium, Magnesium, Sodium, Potassium, HCO_3, SO_4, Chloride, SiO_2, and PO_4 are remain under permissible limit as per the World Health Organization (WHO) standard (Fig. 519; 5.20; Table 5.1). In all the sites the pH level in the groundwater is above the permissible limit (6.5) (Fig. 5.19a). Electrical conductivity remains above the permissible limit (1500 µS/cm) in the sites of Contai, Haldia Anc. Camp, and Sutahataand under the permissible limit at the rest of the site (Fig. 5.19b). At the sites of Contai, Basudevpur, and Haldia Anti Natal Clinic (Anc.) Camp the Total hardness; Calcium at Contai; Magnesium at Basudevpur; and Sodium at Contai remains above the permissible limit (Fig. 5.19; Table 5.1). The quality of Potassium at Sutahata, and Chloride at Contai, Basudevpur, Haldia Anc. Camp, Sutahata and Balughata remain above the permissible level (Fig. 5.20; Table 5.1). The HCO_3 remains just at the permissible level only at the Contai site. Other parameters remain under the permissible limit (Fig. 5.20; Table 5.1). Therefore, the status of groundwater quality reveals an overall good quality until now. However, with the over-extraction of the groundwater with due effects from the immense population pressure, the water quality may be declined in the near future.

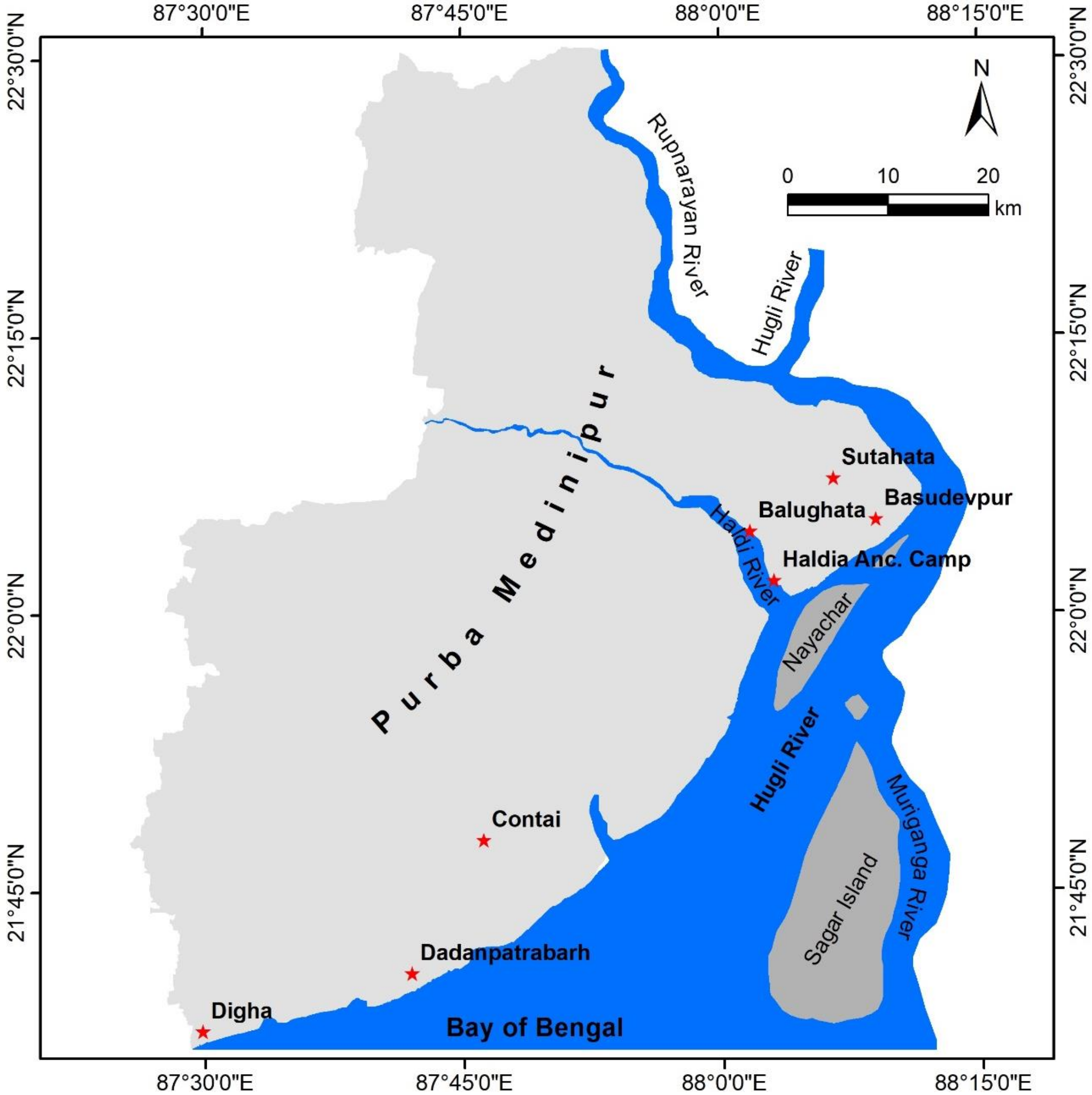

Fig. 5.18: Groundwater quality data at the different sites of the study area.

Table 5.1: Groundwater status and their quality of different parameters within the study area.

Sample site	pH	EC	TH	Ca	Mg	Na	K	Cl	HCO_3	SiO_2	SO_4	PO_4
Contai	8.2	4480	425	96	45	214	4.9	428	500	13	23	0.16
Basudevpur	7.9	1460	340	44	56	149	2.8	364	153	34	56	0.17
Digha	7.9	800	180	38	21	50	4.3	67	159	20	25	0.34
Dadanpatrabarh	7.4	1410	275	36	45	114	2.8	110	342	15	20	0.87
Haldia Anc. Camp	7.9	2790	320	52	46	125	4.4	404	305	11	8	0.17
Sutahata	7.6	2350	290	50	40	115	14.9	316	323	33	7	0.76
Balughata	7.5	1340	245	46	32	139	1.3	355	287	30	13	-

The WHO standard permissible limit of pH: 6.5; Electrical conductivity (EC): 1500 µS/cm; Total hardness (TH): 300 mg/l; Calcium (Ca): 75 mg/l; Magnesium (Mg): 50 mg/l; Sodium (Na): 150 mg/l; Potassium (K): 12 mg/l; Hydrogencarbonate (HCO_3): 500 mg/l; Sulphate (SO_4): 200 mg/l; Chlorine (Cl): 200 mg/l; Silicon dioxide (SiO_2): 120 mg/l; and Phosphate (PO_4): 2.2 mg/l.

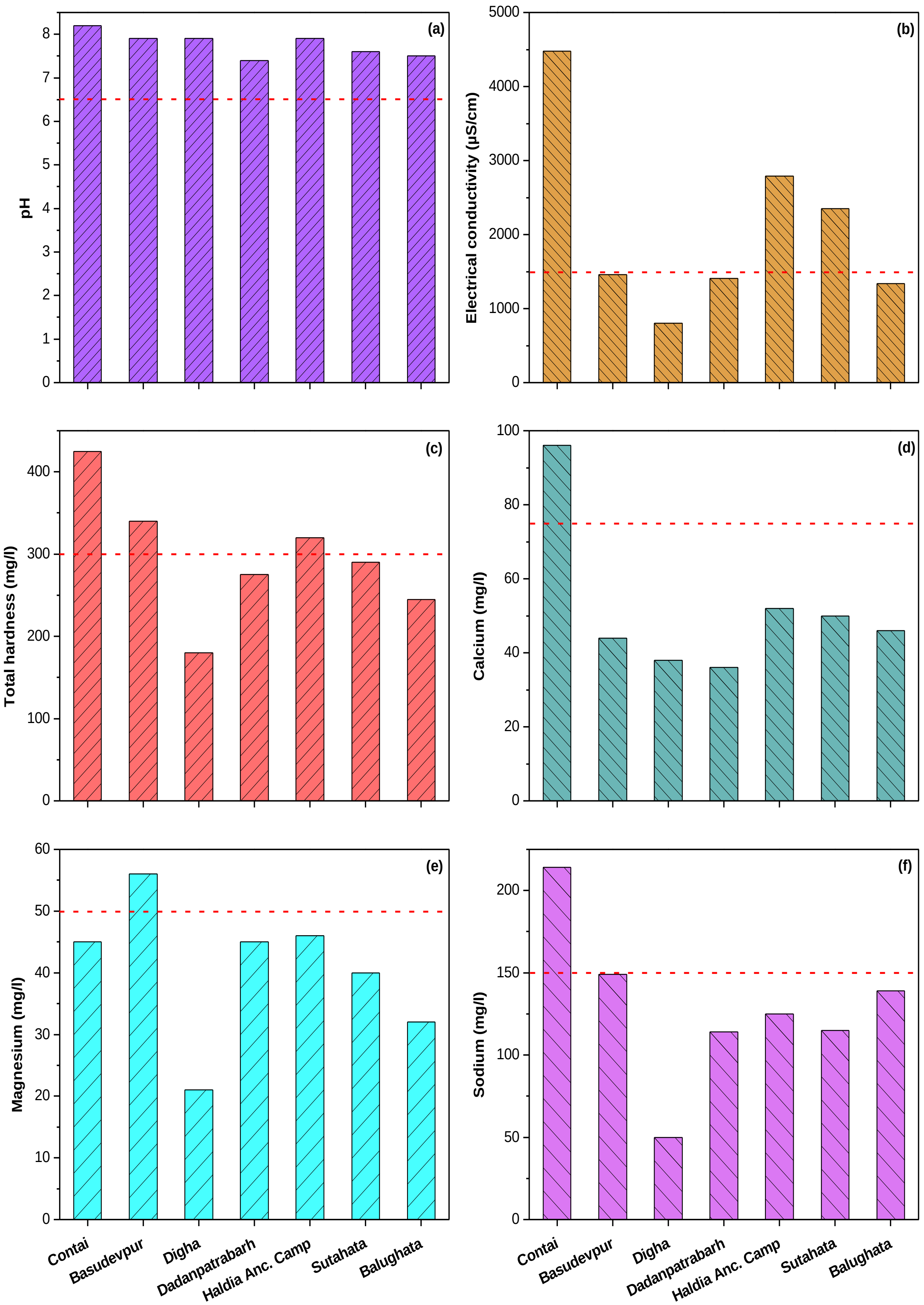

Fig. 5.19: Variation in groundwater quality of different parameters (a) pH, (b) Electrical conductivity, (c) Total hardness, (d) Calcium, (e) Magnesium, and (f) Sodium at the different sites. The red line indicates the WHO standard permissible limit.

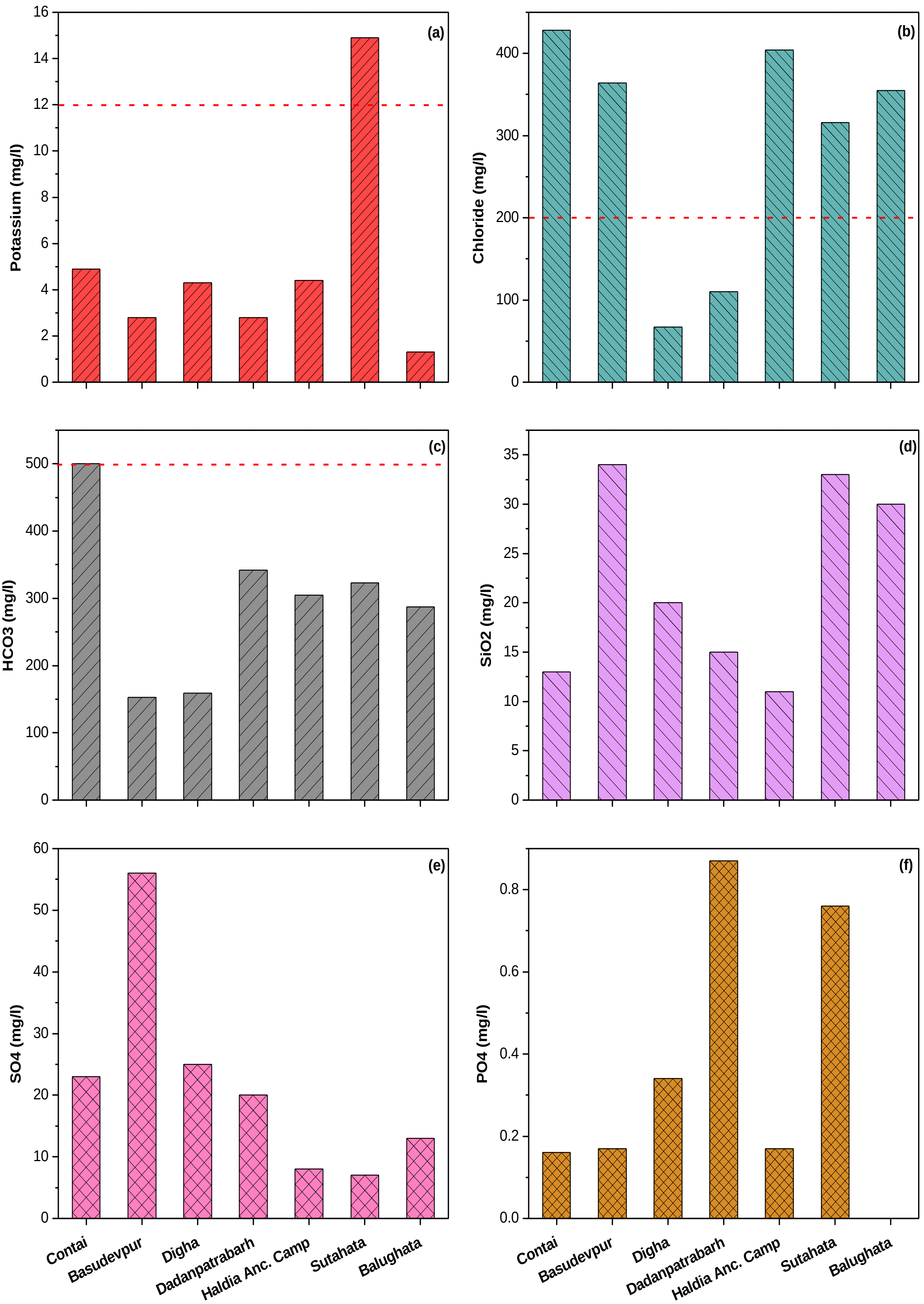

Fig. 5.20: Variation in groundwater quality of different parameters (a) Potassium, (b) Chloride, (c) HCO_3, (d) SiO_2, (e) SO_4, and (f) PO_4 at the different sites. The red line indicates the WHO standard permissible limit.

5.6. Air quality

The batter air quality is experienced in the coastal areas of Digha and Contai. Only the Haldia industrial areas are suffering from air pollution and several harmful gases, suspended particulate matter and respirable particulate matter in the air responsible for deteriorating the ambient air quality (Plate 5.6). The respiratory problem is the major concern in the Haldia industrial areas. The year-wise monthly variations of Suspended Particulate Matter (SPM) is remained above the permissible limit (200 μg/m^3) except the monsoonal months (Fig. 5.21a). The status of Sulphur dioxide (SO_2) remain under the permissible level (80 μg/m^3) during 1998 – 2007 (Fig. 5.21b). Whereas, the level of Nitrogen dioxide (NO_2) was above the permissible level (80 μg/m^3) during 2000 – 2002, however, it remains under the permissible level (Fig. 5.21c) after 2002. Moreover, the RPM, SO_2 and NO_2 level in ambient air at four different sites during November 2009 – May 2010 in Haldia urban centres (Supermarket, West Bengal Industrial Infrastructure Development Corporation (WBIIDC) building, Bhowanipur and Bhunia-Raichak) showing the monthly status of the parameters (Fig. 5.22; Table 5.2). Only the RPM remained above the permissible limit during December 2009 at the site of WBIIDC building and Bhowanipur (Fig. 5.22a; Table 5.2). Otherwise, all the parameters remained under the permissible limit at four sites (Fig. 5.22; Table 5.2).

Table 5.2: Ambient air quality at the different sites of Haldia municipal area during 2005-2006.

Parameter	Site	2005									2006		
		Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
SPM (μg/m^3)	Supermarket	237	147	114	58	90	96	143	271	379	455	285	263
	WBIIDC	256	181	125	67	90	106	138	287	358	457	282	314
RPM (μg/m^3)	Supermarket	68	46	41	23	39	33	48	118	203	224	106	81
	WBIIDC	63	54	50	25	36	37	45	118	162	248	95	94
SO_2 (μg/m^3)	Supermarket	7	7	6	5	6	6	7	7	8	9	9	9
	WBIIDC	8	8	7	6	6	7	8	8	9	13	10	10
NO_2 (μg/m^3)	Supermarket	31	32	29	26	28	25	30	34	44	60	47	45
	WBIIDC	37	34	32	29	31	27	32	32	47	58	49	48

The WHO standard permissible limit of Suspended particulate matter (SPM): 200 μg/m3; Respirable particulate matter (RPM): 100 μg/m3; Sulphur dioxide (SO_2): 80 μg/m3; Nitrogen dioxide (NO_2): 80 μg/m3.

Plate 5.6: Air quality is deteriorated at Haldia industrial area due to (a, c) untreated smoke and (b) somehow treated in few sites after the burning process.

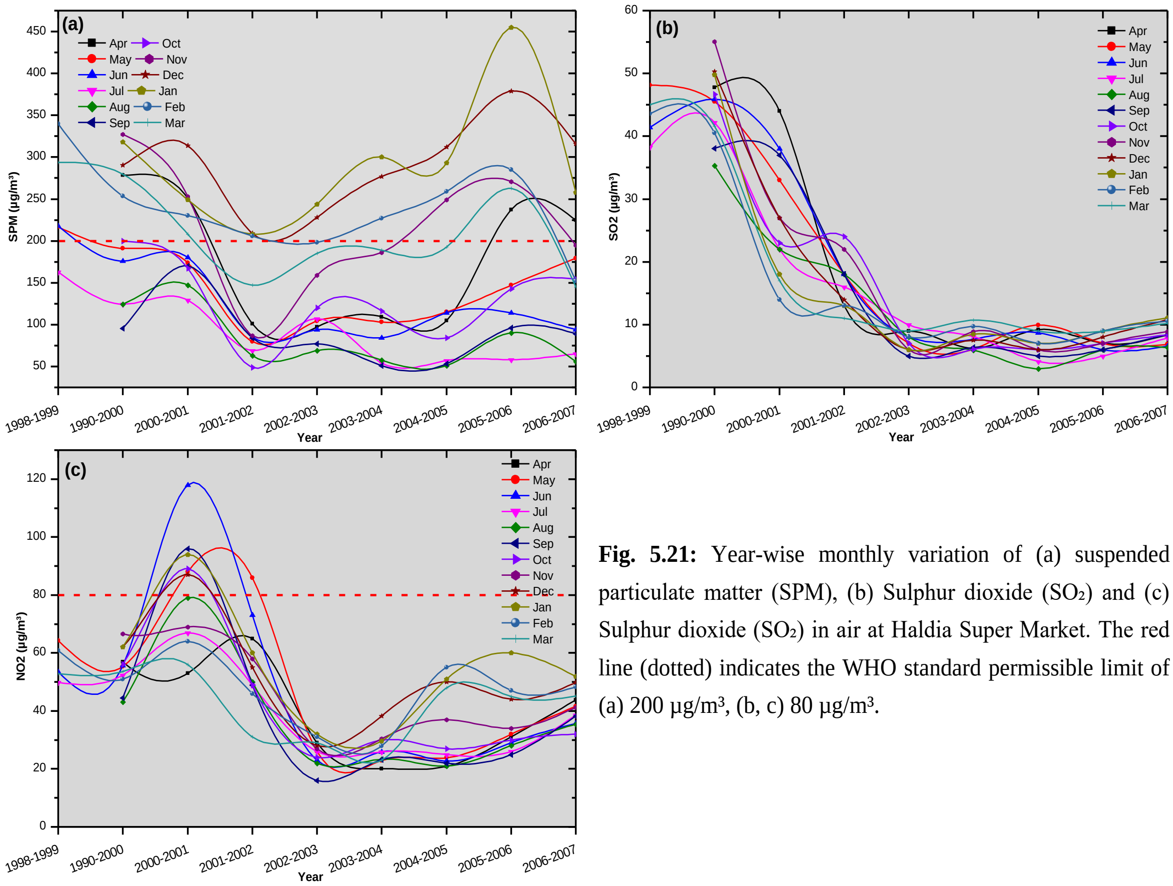

Fig. 5.21: Year-wise monthly variation of (a) suspended particulate matter (SPM), (b) Sulphur dioxide (SO_2) and (c) Sulphur dioxide (SO_2) in air at Haldia Super Market. The red line (dotted) indicates the WHO standard permissible limit of (a) 200 µg/m³, (b, c) 80 µg/m³.

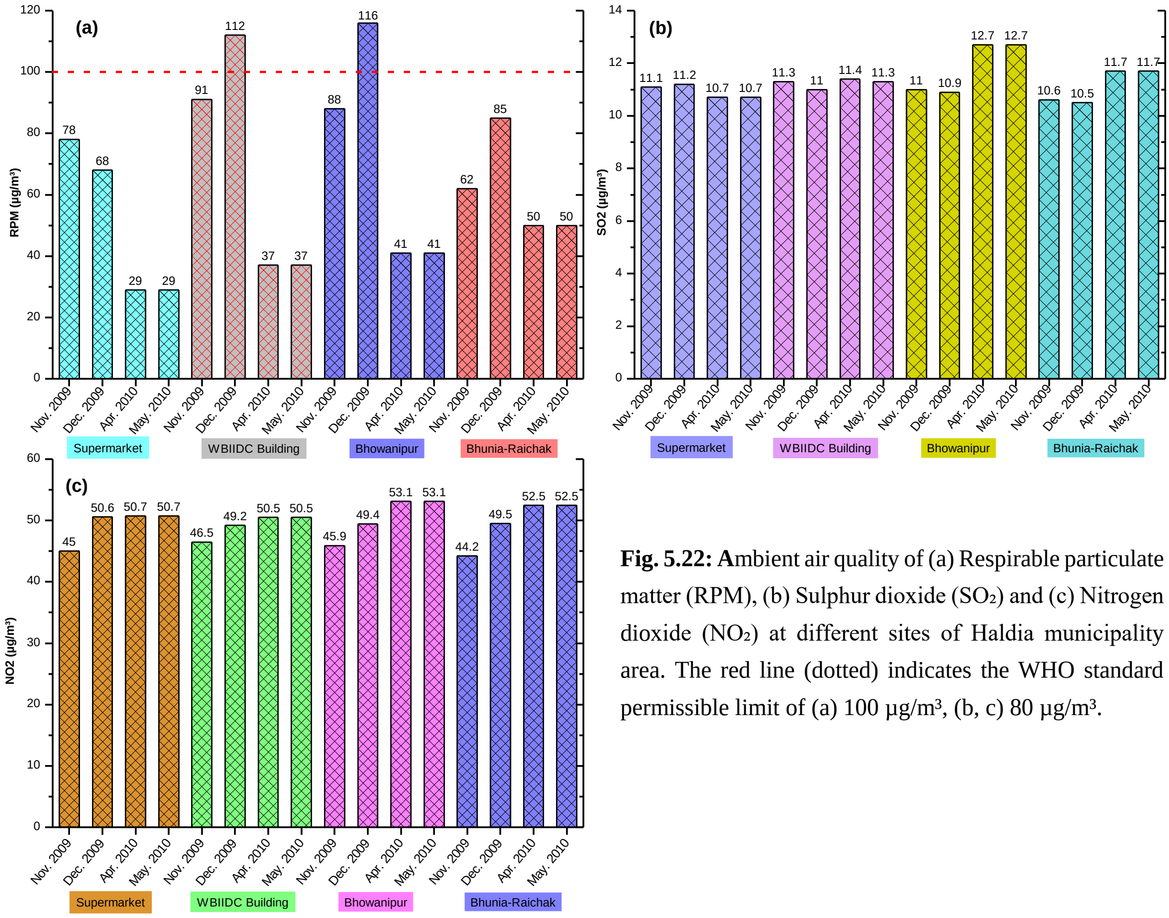

Fig. 5.22: Ambient air quality of (a) Respirable particulate matter (RPM), (b) Sulphur dioxide (SO_2) and (c) Nitrogen dioxide (NO_2) at different sites of Haldia municipality area. The red line (dotted) indicates the WHO standard permissible limit of (a) 100 µg/m³, (b, c) 80 µg/m³.

5.7. Violation of CRZ rule

The Coastal Regulation Zone (CRZ) rules were issued in February 1991 under section 3 of the Environment Protection Act, 1986 to promote sustainable development of the coastal areas (Ramachandran et al., 2005; Panigrahi & Mohanty, 2012; Krishnamurthy et al., 2014). Concerning the natural hazards such as the scenario of the Sea Level Rise (SLR) and global warming along with the immense pressure from the increasing population in the coastal areas, there have need to protect the coastal zone from the accelerated rate of degradations. Besides, the rules also seek to conserve and protect the coastal and marine environment, livelihood security to the fishermen communities and local level stakeholders. After the first implementation of the CRZ rules in India (1991), it modified in the year of 2011 and remodified in draft form in 2018 (DTE, 2019b). In this study, the coastal and estuarine areas of the Bay of Bengal and Hugli estuary remained under the CRZ. However, CRZ mapping has not done for the Haldia urban area as this area under the port-industrial development, therefore, there have some considerations in the development considering the CRZ rules. Only the mapping has done for the urban centre of Digha as it is directly situated in front of the Bay of Bengal coast. Moreover, the CRZ rules of 2011 have been considered for this study as the 2018 rule which is remained in draft form and yet not published in final form. Based on the CRZ rules (2011), the CRZ map has been prepared. As per the CRZ rules (2011), the coastal zones have been classified as CRZ-I (ecologically sensitive areas), CRZ-II (built-up areas), CRZ-III (rural areas) and CRZ-IV (water areas). Moreover, for protection of the islands of Andaman & Nicobar and Lakshadweep, a separate draft Island Protection Zone Notification (IPZN) was issued. The areas under different CRZs are as follows (CRZN, 2011; DTE, 2019a);

CRZ-I: (A) The ecologically sensitive areas and the geomorphological features i.e. mangroves, corals and coral reefs, sand dunes, biologically active mudflats, national parks, marine parks, sanctuaries, reserve forests, and other protected areas (salt marshes, turtle nesting grounds etc.) and the archaeological and heritage sites; and (B) the area between Low Tide Line (LTL) and High Tide Line (HTL) remain under CRZ-I.

CRZ-II: The already developed areas (built-up areas) in the landward side up to or close to the shoreline.

CRZ-III:(A) Under the rural areas with population density of 2161/km^2 which is extended HTL to 200 m inland side and not allowed any hard constructions considered as No Development Zone (NDZ), (B) the rural areas where the population density is less than 2161/km^2 containing the areas between the 200 m to 500 m.

CRZ-IV: (A) The water area from the LTL to twelve nautical miles toward the sea, along with the tide influenced water bodies having a salinity of 5 ppt in the driest season of the year.

Moreover, the *CRZ-V* has been implicated for the special considerations for the areas which have been already build-up like Greater Mumbai, Goa and backwaters of Kerala.

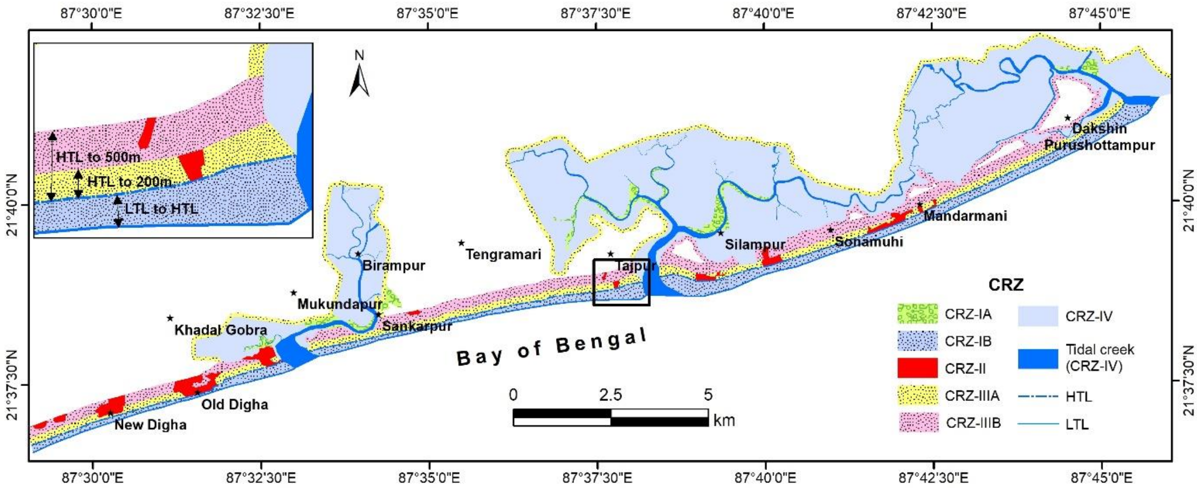

Fig. 5.23: Coastal Regulation Zones (CRZ) at Digha-Mandarmani coastal belt (based on 2011).

Table 5.3: Area under different CRZs in the Digha-Mandarmani coastal stretch as per CRZ-2011.

CRZs	Area (km²)
CRZ-IA	1.55
CRZ-IB	5.80
CRZ-II	1.48
CRZ-IIIA	9.17
CRZ-IIIB	7.30
CRZ-IV	35.83

In Digha, the rural fisherfolk communities and the tourism-based urban infrastructures had already been established before the implementation of the CRZ rule (1991). Within the diversified areas of Digha-Mandarmani coastal sector, all the five zones have been existed as per the CRZ rules (2011) (Fig. 5.23). About 1.55 km² area remained under the CRZ-IA including the mangroves and active mudflats (Fig. 5.23; Table 5.3). The beach areas (5.80 km²) between the HTL and LTL existed in the CRZ-IB. The already built-up areas (1.48 km²) of tourism infrastructures have remained under CRZ-II. About 9.17 km² area between the HTL and 200 m landwards side considered as CRZ-IIIA, whereas, 7.30 km² area between the 200 m to 500 m remained under CRZ-IIIB. The other tidewater inundation part in the margin and surrounding areas (35.83 km²) of tidal creeks and inlets remain under CRZ-IV (Fig. 5.23; Table 5.3). However, with the retreating shoreline positions, the distances of the different CRZs have been gradually changing the local level conflicts between the CRZ rule implementers and the local stakeholders. Such kind of conflict is observed in the most erosion-prone areas of the Mandarmani tourism sites. The hotels are now exposed at the HTL, however, those were constructed at the far distance from the HTL during the 2000s (Pahari, 2013). The dunes of the entire coastal stretch have been degraded and utilized for the tourism infrastructure. The wetlands have been filled up for the construction of hotels and other tourism infrastructures and remaining part utilized for the fisheries. Therefore, the CRZ rules have been taken to protect the coastal zones but it rarely followed due to lack of coordination between the regulating authorities and stakeholders.

5.8. Assessment of coastal vulnerability

In contrast with the urbanization and environment degradation, the coastal areas exposed to risk-prone in recent time and the risk will be accelerated in the near future. In this context, the assessment of coastal vulnerability is necessary. Therefore, the Coastal Vulnerability Index (CVI) based vulnerability has been assessed for the selected urban centres of Digha, Contai and Haldia depending on the different risk rising parameters.

5.8.1. Vulnerability of the Digha urban centre

In case of Digha urban centre, the 23 micro-zones have been demarcated (Fig. 5.24) on the basis of estimated physical characteristics of elevation, slope, drainage, wetlands etc. for the vulnerability assessment. The nine risk rising variable of average elevation, net shoreline erosion, length of sea-wall i.e. total shoreline, dune degradation of total area, inundation area of total area, groundwater depletion, wetland filling of total area, built-up area of total area, and production of wastes have been considered to assess the CVI for the Digha.

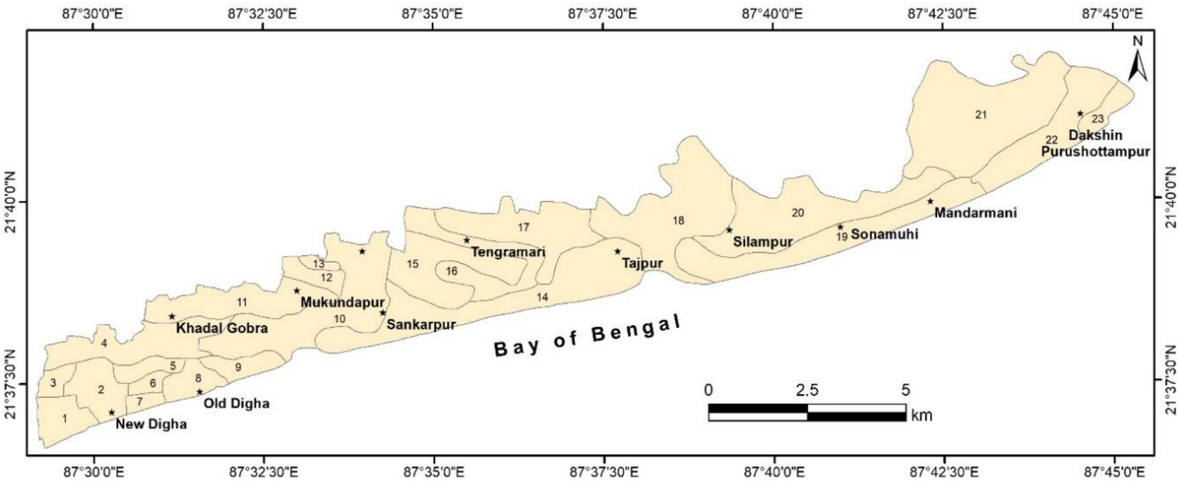

Fig. 5.24: The setting of micro-zonation for vulnerability assessment of Digha, based on estimated physical characteristics (i.e. elevation, slope, drainage, wetlands etc.).

Table 5.4: Risk variables and assigned risk rating for estimation of coastal vulnerability (index) of Digha.

Risk variables	Categorical risk rating				
	Very low (1)	Low (2)	Moderate (3)	High (4)	Very high (5)
Average elevation (m)	>8.5	7.0 to 8.5	5.5 to 7.0	4.0 to 5.5	<4.0
Net shoreline erosion (m)	>250	100 to 250	-50 to 100	-200 to -50	> -200
Length of sea-wall of total shoreline (%)	>90	80 to 90	70 to 80	35 to 70	<35
Dune degradation of total area (%)	<1.00	1 to 10	10 to 20	20 to 40	>40
Inundation area of total area (%)	<5	5 to 15	15 to 40	40 to 70	>70
Groundwater depletion (m)	<6	6 to 7	7 to 8	8 to 9	>9
Wetland filling of total area (%)	<1	1 to 3	3 to 9	9 to 15	>15
Built-up area of total area (%)	<1	1 to 5	5 to 10	10 to 15	>15
Production of waste (kg/d)	<100	100 to 200	200 to 1000	1000 to 9000	>9000

The five categorical risk rating scores have been considered mentioning the risks of very low (1), low (2), moderate (3), high (4), and very high (5) (Table 5.4) depending on the impacts of the risk rising factors of this area. The micro-zone wise vulnerability nature has been estimated, and the risk rating scores have been assigned against the zone wise vulnerability nature (Table 5.5). The scores have not assigned for the net shoreline erosion and length of sea-wall of total shoreline as those zones are situated in the interior part (Table 5.5). Also, the risk scores have not assigned in such zones where dune does not exist. The CVI has been estimated for each zone based on the Eq. 1.10, which is further standardized as CVIs following the Eq. 1.11. The vulnerability score varies from very high (0.95) to very low (0.00) (Fig. 5.25; Table 5.5). The vulnerability map (Fig. 5.25) reveals that the entire shorefront areas of the Digha-Mandarmani coastal stretch have a higher level of vulnerability, whether, the inland areas are relatively lower vulnerable. The very high vulnerable areas have already occupied by the worthy tourism infrastructures. Moreover, the natural habitats of sand dune and wetland have been entirely degraded and or converted into profitable land use practices. Also, the coastal villagers those are settled from the long period in those areas, they are facing severe problems for maintaining their livelihood. Therefore, concerning the social, economic and environmental perspective, the studied coastal stretch of Digha is severely vulnerable and will be more vulnerable or may entirely be ruined at least in an ecological and environmental perspective.

Table 5.5: Nature of vulnerability, assigned risk rating and Coastal Vulnerability Index (CVI) in different zones of Digha.

Zones	Risk variables	Average elevation (m)	Net shoreline erosion (m)	Length of sea-wall of total shoreline (%)	Dune degradation of total area (%)	Inundation area of total area (%)	Groundwater depletion (m)	Wetland filling of total area (%)	Built-up area of total area (%)	Production of waste (kg/day)	CVI	CVIs
1	VN	10.09	-200.28	100.00	8.13	0.24	7.80	3.14	4.57	125	6.32	0.05
	RR	1	5	1	2	1	3	3	2	2		
2	VN	8.61	-178.47	100.00	57.21	0.37	8.08	12.25	19.94	10250	29.81	0.42
	RR	1	4	1	5	1	4	4	5	5		
3	VN	8.08	–	–	1.54	0.29	7.70	1.75	1.47	75	2.65	0.00
	RR	2	–	–	2	1	3	2	2	1		
4	VN	4.79	–	–	–	50.20	8.49	0.12	0.70	110	4.62	0.03
	RR	4	–	–	–	4	4	1	1	2		
5	VN	7.86	–	–	–	4.27	9.24	7.64	3.50	450	5.48	0.03
	RR	2	–	–	–	1	5	3	2	3		
6	VN	9.97	–	–	40.56	0.00	9.42	2.14	8.40	300	8.02	0.08
	RR	1	–	–	5	1	5	2	3	3		
7	VN	8.60	-155.01	100.00	2.14	0.84	9.41	0.56	2.18	25	2.98	0.00
	RR	1	4	1	2	1	5	1	2	1		
8	VN	10.31	-117.59	100.00	34.62	1.05	9.43	4.18	20.42	9400	25.82	0.36
	RR	1	4	1	4	1	5	3	5	5		
9	VN	6.44	-211.56	100.00	18.35	16.16	9.10	2.94	15.99	1200	54.77	0.81
	RR	3	5	1	3	3	5	2	5	4		
10	VN	4.19	-125.00	0.00	2.15	63.22	8.94	0.00	1.59	0	23.85	0.33
	RR	4	4	5	2	4	4	1	2	1		
11	VN	6.16	–	–	–	5.88	8.63	2.11	3.33	250	6.93	0.06
	RR	3	–	–	–	2	4	2	2	3		
12	VN	4.73	–	–	–	38.54	8.84	0.00	0.23	0	2.83	0.00
	RR	4	–	–	–	3	4	1	1	1		
13	VN	5.82	–	–	–	8.04	8.83	0.00	1.69	50	2.83	0.00
	RR	3	–	–	–	2	4	1	2	1		
14	VN	8.34	-193.40	69.00	17.68	6.94	8.03	9.42	3.90	1400	64.00	0.95
	RR	2	4	4	3	2	4	4	3	4		
15	VN	4.08	–	–	–	73.26	8.69	0.00	0.52	0	3.65	0.02
	RR	4	–	–	–	5	4	1	1	1		
16	VN	5.75	–	–	1.23	18.55	8.22	0.00	1.50	150	6.41	0.05
	RR	3	–	–	2	3	4	1	2	2		
17	VN	3.96	–	–	–	74.56	7.40	1.04	0.67	0	5.00	0.03
	RR	5	–	–	–	5	3	2	1	1		

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Zones	Risk variables	Average elevation (m)	Net shoreline erosion (m)	Length of sea-wall of total shoreline (%)	Dune degradation of total area (%)	Inundation area of total area (%)	Groundwater depletion (m)	Wetland filling of total area (%)	Built-up area of total area (%)	Production of waste (kg/day)	CVI	CVIs
18	VN	4.08	-285.22	0.00	1.25	70.98	5.92	0.00	0.86	0	10.54	0.19
	RR	4	5	5	2	5	1	1	1	1		
19	VN	7.09	-233.34	6.00	19.26	6.18	6.87	21.76	7.17	1950	63.25	0.94
	RR	2	5	5	3	2	2	5	3	4		
20	VN	4.38	–	–	–	58.82	6.64	4.37	3.65	100	8.00	0.08
	RR	4	–	–	–	4	2	3	2	2		
21	VN	3.69	–	–	–	78.09	6.28	0.00	1.13	0	4.08	0.02
	RR	5	–	–	–	5	2	1	2	1		
22	VN	6.05	79.46	0.00	5.31	19.48	6.44	7.36	4.28	500	32.86	0.47
	RR	3	3	5	2	3	2	3	2	3		
23	VN	5.35	274.28	0.00	–	24.90	6.53	2.11	0.51	0	6.71	0.06
	RR	4	1	5	–	3	2	3	1	1		

Note: VN = Vulnerability nature, RR = Risk rating. The symbol of '–' are used where the risk variables are not applicable for the CVI and standardized CVI (CVIs) among those zones.

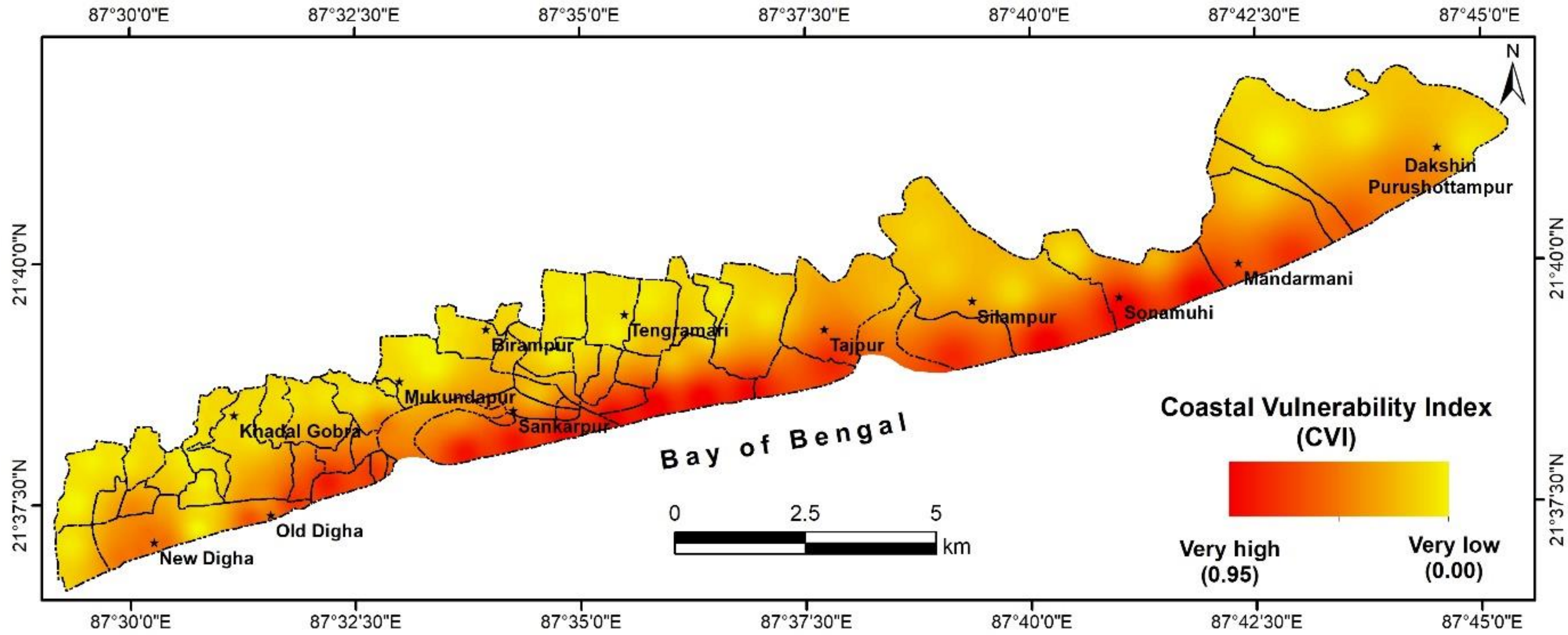

Fig. 5.25: The estimated standardized CVI based vulnerability assessment of Digha urban centre.

5.8.2. Vulnerability of the Contai urban centre

Likewise the Digha, the CVI and CVIs have been estimated for the Contai urban centre considering the 12 micro-zones (Fig. 5.26). In this case, the zones have been selected along the dune ridge, dune fringe and further low-lying areas on both sides of the dune fringe.

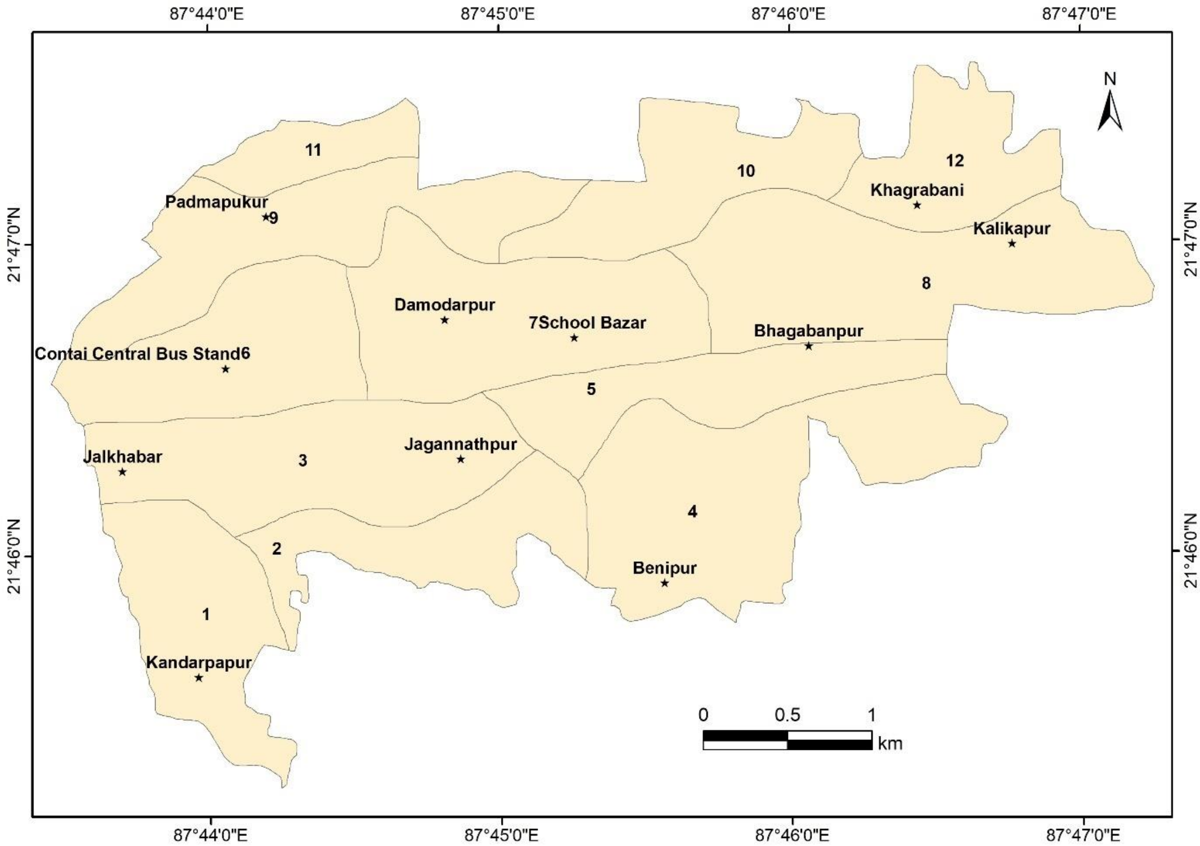

Fig. 5.26: The setting of micro-zonation for vulnerability assessment of Contai, based on estimated physical characteristics (i.e. elevation, slope, drainage, wetlands etc.).

Table 5.6: Risk variables and assigned risk rating for estimation of coastal vulnerability (index) of Contai.

Risk variables	Categorical risk rating				
	Very low (1)	Low (2)	Moderate (3)	High (4)	Very high (5)
Average elevation (m)	>13	11 to 13	9 to 11	7 to 9	<7
Dune degradation of total area (%)	<1.00	1 to 10	10 to 20	20 to 40	>40
Water logging area of total area (%)	<1	1 to 5	5 to 10	10 to 50	>50
Groundwater depletion (m)	<7	7 to 7.5	7.5 to 8	8 to 8.5	>8.5
Area affected by saltwater encroachment of total area (%)	<5	5 to 20	20 to 50	50 to 70	>70
Wetland filling of total area (%)	<1	1 to 5	5 to 15	15 to 25	>25
Built-up area of total area (%)	<3	3 to 10	10 to 15	15 to 20	>20

The CVI has been assessed based on the seven risk variables of average elevation, dune degradation of total area, water-logging area of total area, groundwater depletion, the area affected by saltwater encroachment of total area, wetland filling of total area and the built-up area of total area (Table 5.6). In the CVI estimation, the risk rating scores have not assigned in some zones. Those risk variables are not applicable for the respective zones or those variables do not exist within those zones. The CVIs varies from very high (0.69) to very low (0.00) (Fig. 5.27; Table 5.7). The result reveals that most of the areas remain under very high vulnerable in the low-lying areas in the northern part of the study area (Fig. 5.26). The central part of the Contai municipality and the low-lying areas in the southern part are moderately vulnerable, along with some dune fringe areas. The rest of the areas in the transitional parts of the dune fringe and lowlands remain under the very low vulnerability. The very high vulnerability in the ward number 18 and some parts of the ward number 8, and 7 is experienced due to the higher percentage of built-up in the lowlands areas after wetland filling which is prone to water-logging. In the eastern side (part of zone 8 and 12), however, a higher rate of dune degradation has resulted, but most of the land remained vacant (in the areas of Uttar Darua) due to the saline water encroachment into the groundwater table. Moreover, the seasonal and long-term groundwater depletion rate is significant for future vulnerability. From the overall analysis, it can be said that the entire dune area will be occupied by the anthropogenic activities and most of the wetland areas will be converted into the built-up areas in the near future which will responsible for further increase of risk and vulnerability.

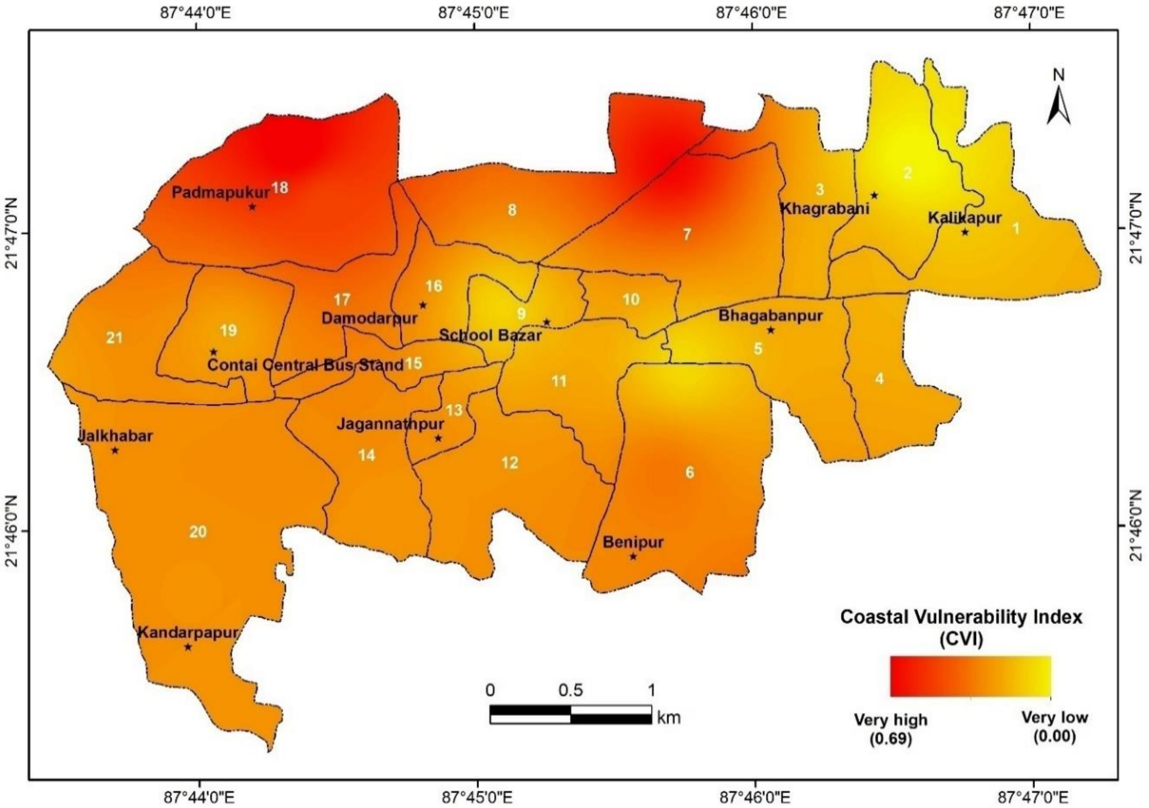

Fig. 5.27: The estimated standardized CVI based vulnerability assessment of Contai urban centre.

Table 5.7: Nature of vulnerability, assigned risk rating and Coastal Vulnerability Index (CVI) in different zones of Contai.

Zone	Risk variables	Average elevation (m)	Dune degradation of total area (%)	Water logging area of total area (%)	Groundwater depletion (m)	Area affected by saltwater encroachment of total area (%)	Wetland filling of total area (%)	Built-up area of total area (%)	CVI	CVIs
1	VN	6.78	–	68.23	7.3	–	3.24	4.23	6.32	0.27
	RR	5	–	5	2	–	2	2		
2	VN	7.21	–	47.89	7.49	–	5.16	5.72	6.2	0.26
	RR	4	–	4	2	–	3	2		
3	VN	9.4	–	6.41	7.52	–	22.35	14.71	6.57	0.29
	RR	3	–	3	2	–	4	3		
4	VN	5.96	–	86.51	7.49	23.16	1.79	1.14	7.07	0.34
	RR	5	–	5	2	3	2	1		
5	VN	9.52	–	4.76	7.55	42.15	4.89	1.37	4.24	0.08
	RR	3	–	2	3	3	2	1		
6	VN	13.43	44.24	1.26	7.5	–	3.56	43.51	5.77	0.22
	RR	1	5	2	2	–	2	5		
7	VN	13.68	37.21	–	7.59	7.21	0.97	49.12	4.47	0.10
	RR	1	4	–	3	2	1	5		
8	VN	13.67	51.16	–	7.49	89.78	–	14.52	5.48	0.19
	RR	1	5	–	2	5	–	3		
9	VN	9.86	–	3.64	7.58	–	48.48	15.1	8.49	0.47
	RR	3	–	2	3	–	5	4		
10	VN	9.79	–	6.49	7.57	61.31	8.91	3.6	10.39	0.64
	RR	3	–	3	3	4	3	2		
11	VN	6.91	–	51.18	7.52	–	4.69	17.01	10.95	0.69
	RR	5	–	5	3	–	2	4		
12	VN	12.01	6.35	0.88	7.38	76.42	1.37	0.7	3.38	0.00
	RR	2	2	1	2	5	2	1		

Note: VN = Vulnerability nature, RR = Risk rating. The symbol of '–' are used where the risk variables are not applicable for the CVI and standardized CVI (CVIs) among those zones.

5.8.3. Vulnerability of the Haldia urban centre

The CVI is also assessed for the Haldia urban centre based on the 12 micro-zones which are demarcated considering the relative existence of the relatively elevated natural levees (Hugli and Haldi river systems), low-lying areas and the areas in-between the levees and lowlands (Fig. 5.28). In this case, seven risk rising variables have been considered for the five categorical risk rating i.e. average elevation, water-logging area of total area, groundwater

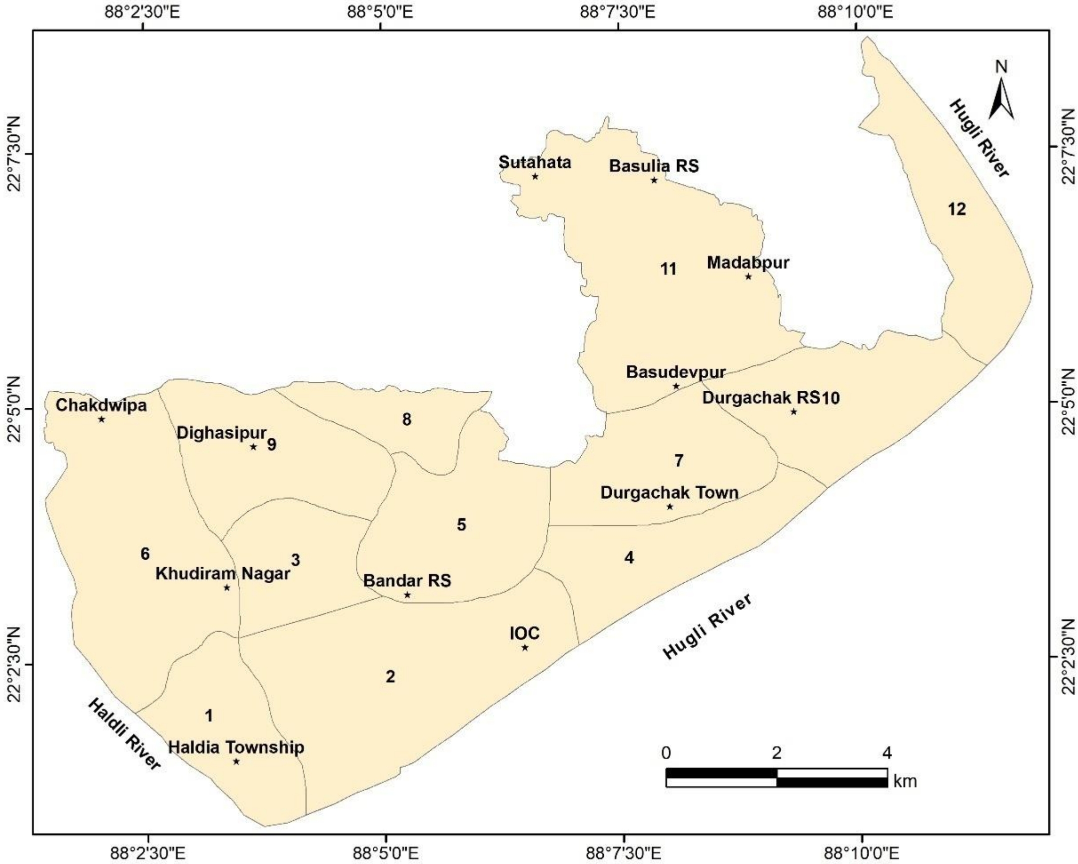

Fig. 5.28: The setting of micro-zonation for vulnerability assessment of Haldia, based on estimated physical characteristics (i.e. elevation, slope, drainage, wetlands etc.).

Table 5.8: Risk variables and assigned risk rating for estimation of coastal vulnerability (index) of Haldia.

Risk variables	Categorical risk rating				
	Very low (1)	Low (2)	Moderate (3)	High (4)	Very high (5)
Average elevation (m)	>11	10.5 to 11	10 to 10.5	9.5 to 10	<9.5
Water logging area of total area (%)	<5	5 to 10	10 to 20	20 to 50	>50
Groundwater depletion (m)	<9	9 to 9.5	9.5 to 10	10 to 10.5	>10.5
Wetland filling of total area (%)	<5	5 to 10	10 to 20	20 to 50	>50
Net bank erosion or accretion (m)	>100	100 to 50	50 to 0	0 to -50	>-50
Built-up area of total area (%)	<15	15 to 25	25 to 35	35 to 50	>50
Production of waste (kg/day)	<3000	3000 to 6000	6000 to 9000	9000 to 12000	>12000

depletion, wetland filling of total area, net riverbank erosion or accretion, the built-up area of total area and production of waste (Table 5.8). The erosion-accretion nature of the riverbank is only applicable to the river margin zones. Therefore, the risk rating has been given only for the zones of 1, 2, 4, 6, 10 and 12, and other zones remain empty (Table 5.9). The estimated CVI varies from very high (24.84) to very low (3.02) along with the respective CVIs (Fig. 5.29; Table 5.9). The very high to high vulnerable areas are the entire wards of 4, 8, 9 and 10, and some parts of the ward number 7, 11 and 12. Being the built-up areas the waterlogged, higher rate of wetland filling, and a higher rate of solid waste production are liable for higher vulnerability. The moderate level of vulnerability has been mainly observed in the low-lying areas. The very low vulnerability is experienced in the highly elevated river margin natural levees, which remain unaffected from the water-logging problems and relatively less density of built-up areas. However, the tremendous rate of increasing built-up areas (mostly over the low-lying areas after lowland filling in recent time) in terms of urban-industrial infrastructure development over the physically complicated estuarine landscape will prone to more risk and vulnerability alongside the complex consequences in recent future.

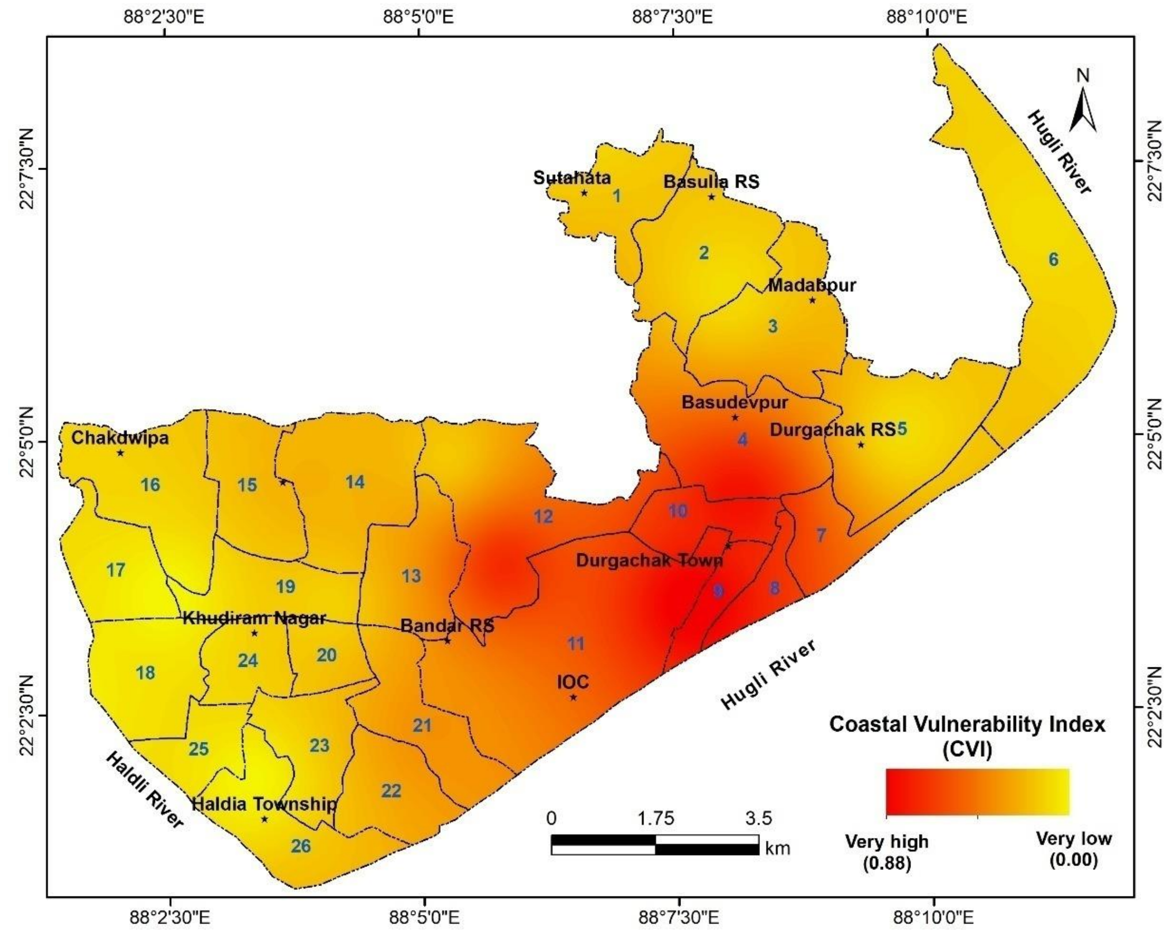

Fig. 5.29: The estimated standardized CVI based vulnerability assessment of Haldia urban centre.

Table 5.9: Nature of vulnerability, assigned risk rating and Costal Vulnerability Index (CVI) in different zones of Haldia.

Zones	Risk variables	Average elevation (m)	Water logging area of total area (%)	Groundwater depletion (m)	Wetland filling of total area (%)	Net bank erosion or accretion (m)	Built-up area of total area (%)	Production of waste (kg/day)	CVI	CVIs
1	VN	12.07	0.25	9.62	1.35	-18.88	24.56	7050	3.21	0.01
	RR	1	1	3	1	4	2	3		
2	VN	11.54	1.42	9.90	23.17	-22.39	54.07	10750	11.71	0.35
	RR	1	1	3	4	4	5	4		
3	VN	10.37	4.68	9.68	14.24	–	30.54	6100	6.36	0.13
	RR	3	1	3	3	–	3	3		
4	VN	9.89	6.15	9.77	15.33	23.42	42.40	15800	24.84	0.88
	RR	4	2	3	3	3	4	5		
5	VN	9.32	93.64	9.31	85.23	–	54.60	3700	20.41	0.70
	RR	5	5	2	5	–	5	2		
6	VN	12.28	2.16	10.11	6.16	307.83	13.26	9200	3.02	0.00
	RR	1	1	4	2	1	2	4		
7	VN	9.69	37.36	10.16	36.28	–	34.22	10500	22.63	0.79
	RR	4	4	4	4	–	3	4		
8	VN	9.15	100.00	9.30	17.25	–	12.38	2500	7.07	0.16
	RR	5	5	2	3	–	2	1		
9	VN	10.01	10.21	9.88	5.67	–	25.34	6150	9.00	0.24
	RR	3	3	3	2	–	3	3		
10	VN	9.98	2.22	10.07	7.69	140.68	31.12	4400	5.24	0.09
	RR	4	1	4	2	1	3	2		
11	VN	9.98	7.87	10.68	4.98	–	8.42	10900	5.16	0.09
	RR	4	2	5	1	–	1	4		
12	VN	9.62	33.14	9.13	1.06	5.25	21.89	2400	5.24	0.09
	RR	4	4	2	1	3	2	1		

Note: VN = Vulnerability nature, RR = Risk rating. The symbol of '–' are used where the risk variable is not applicable for the CVI and standardized CVI (CVIs) among those zones.

5.9. Major findings

The major outcome of this chapter is included as;

1. The trend of average annual rainfall over a 35 year period, though decreasing in all three urban centres of the coastal belt, but intensities of storm rainfall in a short period create coastal floods in the low-lying areas of the coast. However, the average annual temperature for the said periods is increasing significantly.
2. The groundwater is gradually depleted in the study areas which leading to saltwater encroachment into the aquifers. Moreover, the dumping of untreated wastes and associated problems and urban air pollution generate complex consequences of such alarming expansion of the coastal urbanization in the present study area.
3. The exiting CRZ rules, the effort of Integrated Coastal Zone Management (ICZM) activities, the participation of rural people in tourism development processes and multiple activities of Digha-Sankarpur Development Authority (DSDA) are not enough to reduce the conflicts between stakeholders and resource sharing activities and to tackle the advancing sea and climate variabilities of the vulnerable coastal environment fringed with northern Bay of Bengal and the Hugli estuary.
4. As the development of urban areas intensified or spread into vulnerable sites of the coastal belt, so the potential impact of hazards increased in Digha, Contai and Haldia at present.