Chapter 2

Beach Stage and Dune Stage Dynamism

2.1. Concept

Beaches may be described and differentiated by the character of the materials that comprise them or by the features found in their profiles. The most apparent characters are: texture - weather gravel, coarse sand or fine sand form the beach; the composition of the particles and slope of the beach.

The texture of the beach sediment provides a means of describing different beaches. The main distinction is between gravel or sand beaches, but fine, medium, or coarse grained sand also define the beaches. Gravel beaches may result from high wave energies and removal of fine sand through erosion. Beaches may also be grouped by composition of sediments. The dominant mineral groups are biogenic shell debris (carbonates), quartz and feldspar minerals derived from granite igneous rocks, dark minerals from basic igneous rocks and igneous fragments from basaltic igneous rocks. The beach slope and grain characteristics allow beaches to be described in terms of dissipative and reflective beaches (Short, A. D., & Wright, L. D, 1983).

Transformation of wave energy across the shelf, near shore and surf zone and the action of onshore wind in transporting wave deposited sand landward are a part of a single system of sand input storage and loss. The dune, beach and shore face sand transport is by different forces, but all combine to exchange sand over the combined system.

The 40% of world's coastline comprises of beach fringe area. Beach generally consists of an accumulation of loose and unconsolidated sediment, ranging from very fine sand to pebbles, cobbles and occasionally boulders often with shell fragments. Beaches are found in various environments with long and almost straight or gently curved shape, exposed to the open ocean or stormy seas whereas others are shorter and hidden as pocket beaches sheltered in bays/ coves or behind island or reefs or between rocky headlands.

The beach profile is shaped by various factors acting upon the coast mainly the energy of the wave, swash and backwash intensity and balance, sediment texture and compaction, wave generated currents, and wind speed. Convex profiles came out from constructive waves often creating one or more swash-built berms. On the other hand destructive waves cut out concave profile beaches with ridge and runnel topography and varieties of rill and swash marks.

There are varieties of field survey of a beach profile i.e. survey using graduated poles and a level, a theodolite, an electronic distance measurer, a global positioning system (GPS), a total station or a wheeled vehicle designed to register. Besides these conventional methods beach morphology can also be mapped by GPS in traverse which can later be translated into a Digital Elevation Model (DEM) using computer softwares like Google Earth. United States Geological Survey (USGS) mainly adapt techniques like remote sensing such as x-band radar, light detection and ranging (LIDAR) and airborne laser terrain mapping (ALTM). While we follow the crude method there is always a risk regarding the strong wave action because profiles should ideally extend from the dune, through the berm, down the beach and upto near-shore fringe area i.e. the breaker zone/s. In order to estimate the rates of change on a beach and theirs pattern a repetitive survey must be carried out along the fixed transects.

The four highlighting determinants (Figure 2.1) which shape the morphology of beach-surf-zone fringe area are associated with the dynamisms of incident wave and wave generated currents, and different reflective and resonant oscillation frequencies interacting with the sediment texture and also beach gradient along with the pre-existing morphologies. This is what we call it Beach- Morphodynamics.

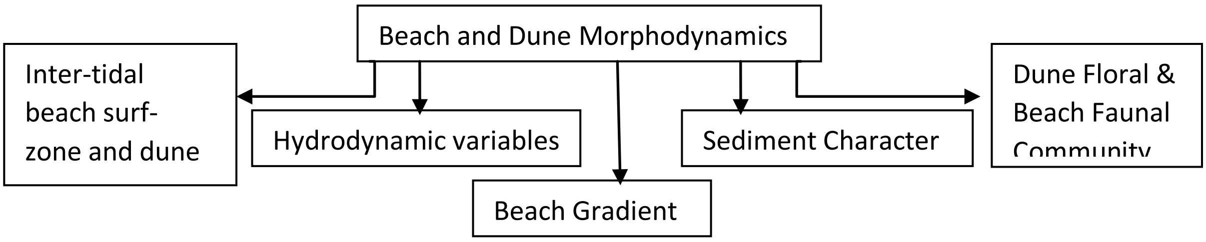

Figure 2.1: Circuit of the Chapter

If we discuss about the other characteristics of beaches then some are long and almost straight or gently curved; others are shorter, and include sharply curved pocket beaches in bays or coves between rocky headlands. Few beaches are exposed to the open stormy seas, while others are sheltered within bays or at the rear of islands or reefs. Beach systems deal with the interactions between beaches and the processes (waves, currents, tides and winds) that work on them.

Beach morphology is shaped by swash and backwash, spilling/plunging of waves on the shore, and varies in response to wave conditions. Beach sediments consist of sand or gravel particles of various sizes, the proportions of which can be determined by grain size (granulometric) analysis. Some are coarse, dominated by cobbles and pebbles, others finer, with various grades of sandy sediment, granules being relatively rare. Some are uniform (i.e. well sorted); others are more varied in texture, sometimes with contrasting zones of coarser and finer material along the beach face. Beach sediments are better sorted with high wave energy, swash dominant coast. Among the world's beaches quite a few are sandy, but coarser particles are often scattered across a sandy beach in patterns of cusps or ridges running parallel to the shoreline. These mixed beaches (sand and shingle) are highly variable, and the micro landform features may change within a few hours with response to the varying waves and tides. Sand and gravel particles may be angular or sub-angular in shape, but usually become rounded by abrasion. Collisions may result in pitted surfaces (percussion marks), but as sand and gravel are agitated by wave action the particles are worn smooth and gradually diminished by attrition. With continued process of attrition, sand grains become highly polished, while the upper facet of pebbles and cobbles tend to become slightly flattened, and thinner at right angles to their longest axis. The rate of wearing depends on the structure and hardness of the grains. Pebbles of dense, heavy rock, such as flint or basalt, are more slowly transported and reduced by attrition than those of softer sandstone. There are also pebbles and cobbles of soft material such as clay or peat, eroded from cliffs cut in fractured outcrops of these materials.

The rise and fall of the sea level during the past few million years show the existence of former coastlines with beaches at various levels above and below present mean sea level. Existing beaches are geologically of recent origin, having formed as the Holocene marine transgression slackened, or gave place to a sea level still-stand: on most coasts about 6000 years ago. Anyhow or the other sand and gravel from various sources reaches the beach in coves and bays along steep coasts, only excepting the shore which is too rocky and rugged with plunging cliffs to retain a beach. Roy et al. (1994) suggested that sandy beaches occur where the transverse gradient of the coast is between 0.1 and 0.8. The gentler gradient causes waves to shoal and form of barrier bars, while beaches with steeper gradients move sediment offshore and excessive erosion may cause exposure of bedrock. Beaches with steeper transverse gradients can have shingle as deposited sediment. Perched beaches form where swash deposits sand or shingle between mid-tide and just above high tide level, fronted by a rocky or boulder shore. There are many sandy beaches on high wave energy coasts where coarser sediment is unavailable, while alternate condition may arise at gravelly beaches with low wave energy. Beaches are absent altogether where there is no niche for deposition (as on plunging cliffs), where no sand or shingle has been supplied, or where they have been removed by erosion. A long shore current may not always drift the eroded sediments from one coastline and pass it to the next coast because the sediments are deposited on the sea floor instead. Some beaches remain slender with fringing cliffs and steep slopes, while others have wide extensions with the accumulation of successively formed backshore beach that may bear dunes crafted with sand winnowed from the shore. There are also relationships among patterns of refracted waves approaching the shoreline and its sediment characteristics. Where convergence of wave orthogonals indicates augmented wave energy (i.e. larger waves breaking on the beach) beaches become generally steeper, higher and better sorted; erosion is more severe and divergence of long shore currents causes sediment dispersal. Divergence of orthogonals signifies a low wave energy coast. If this condition reverses lower beach will be gentler, and with finer sediments and low level sorting reduces erosion or perhaps deposition and convergent long shore currents bring in beach sediment.

In case of our present study this is a sandy beach with low gradient and mesotidal effect and also with low to moderate energy of waves. The angle of wave approach is mainly from south-west. It has been proved by Santra Mitra (2013) that there is a constant rate of shoreline shift in this area. Hence proved that this could be an erosional beach but the eastern portion of the selected area is showing accretional features especially at the Soula River mouth. In order to know the region in three dimensional views we have to work on the field survey. Through field study we have deduced the morphometry of the dune and beaches, erosion-deposition concentration zone and its pathway of movement, the zonation of topographic highs and low, sediment texture analysis, hydrodynamism, aerodynamism, micro-features of the beaches, floral and faunal influence and lastly comprising the whole morphodynamic characteristics.

2.2. **Analysis**

The methodological flow can be understood by the following steps. All the primary data i.e. from total station and secondary data from SRTM DEM and Google Earth are formatted to form DEM of the study area. Then secondary source DEM data is generated for the whole study area and primary source DEM data are generated for four selected sample sites for repetitive survey on those spots in temporal scale. The DEM of the study area is undergone with plausible morphometric analysis. Comparing and contrasting with the estimated morphometric techniques and secondary data available, three micro-zonation maps were extracted. From the four selected sample site two year temporal DEM data is generated for Beach and Dune Volume Estimation spatially and temporally. On the other hand statistical analysis on hydrodynamic data, sediment size and entrainment analysis and budget analysis and delineation of erosion-transportation-accretion pathway of sediment are also estimated. All these analysis leads to the composition of Beach Stage Model. Moreover identification of beach-dune ecological community and its implication also results in the formation of Dune dynamisms. Finally, there has been application of these two physical models on the Socio-economic setup of the study area in the next chapters.

2.2.1. Sample site selection

From the DEM of the study area (Figure 2.2) it can be assured that the broad physiographic regions of the study area are – the Beach, the Dunes and the Back dune Wetlands. The beach lying at the southernmost part of the region has an elevation of 2m on an average and a slope of 1^0 towards the sea. The topographical highs i.e. the barrier dunes have a height ranging from 6m to 15m. The seaward gradient of the dunes is much steeper than the landward slope. The back dune wetlands with the tidal inlets are forming the lowest physiographic expression with some depressions having depth less than the mean sea level. These tidal depressions are the main source of moisture which again helps in the formation of dune on the shoreline on one hand and also restricts the extension of dune towards the back dune area. This is the reason for the low dunal rise in this particular tropical climatic condition with limited and local extent (Bird, 2008).

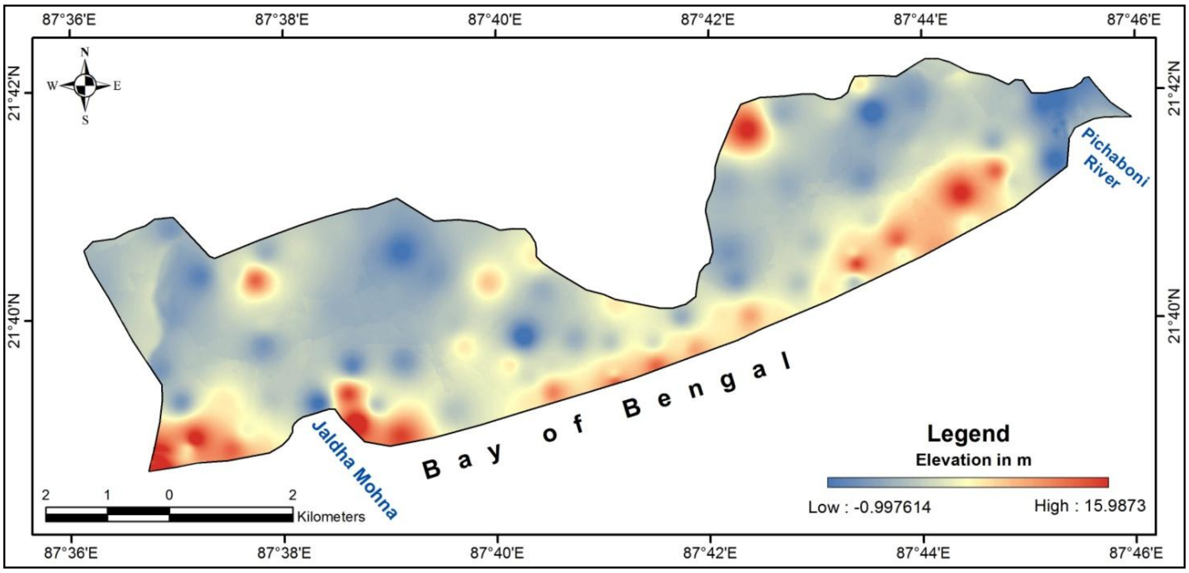

Figure 2.2: Digital Elevation Model (DEM) of the study area

The 50cm contour interval map is depicting another vivid layout of the morphogenetic zoning of the region ranging from less than sea level up to 15m elevation. This map (Figure 2.3) shows the extended dune belt garlanding the beach area and protecting the back-dune fringe area. Moreover there is a concentration of contour in the northern most frontiers but with variations. North-western concentric contours highlight the extension of the topographic highs of the Tajpur area adjusting and being dissected by the Jaldha Tidal Mouth and its associated creeks. The remaining concentrations are the deepest parts of the shallow wetland depressions both in the north-western and north-eastern parts except the northern topographic high in the eastern part of the map. This comes with the history of the formation of the whole Contai or Kanthi coastal dune, because this is argued to be the part of the extended Chenier belts of Kanthi Coastal Dune.

The contour map also vaguely portraying the location of Dune Blowouts and Breach Points in the recent past (within the research period) will be elaborated in the later part of this chapter with map showing micro-geomorphic features.

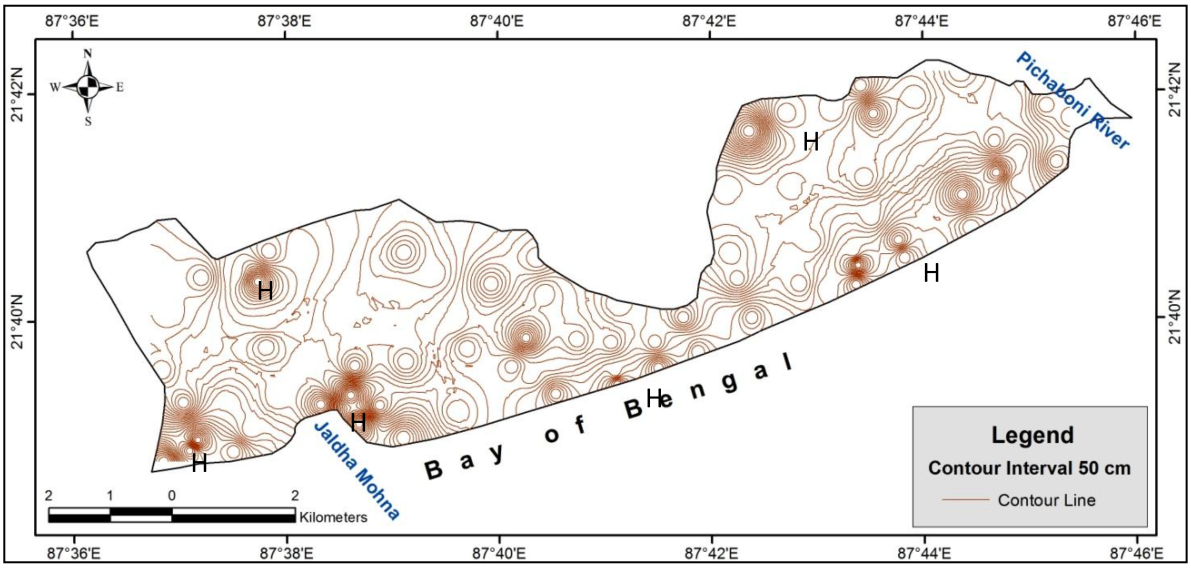

Figure 2.3: Contour map of the study area

The selected study area is a more or less flat surface (Figure 2.4) with low to very low slope not more than 2^{o}. The reason behind this is the level topography of the tidal flats, back dune marshy lands and estuary mouths of the tidal creeks and river inlets. The maximum slope ranges from 5^{o} to 15^{o} which concentrates mainly around the dunal slopes and inclinations of the deeper wetlands.

From the aspect map (Figure 2.5), the slope direction is the main information which we received. This down slope direction is the representation of the maximum rate of change in value from each cell to its neighbouring cell. If we took an intense view at this representation we came to find that at the eastern part of the map there is a clear saturation of three consecutive south and north aspect extending south-west and north-east. History can only justify this type of aspect ratio, which is the extended part of Chenier Dunes of Contai coastal belt. The remaining part of the area has another highlight of dunal shift or extension dune chains near the eastern part of Jaldha Mouth.

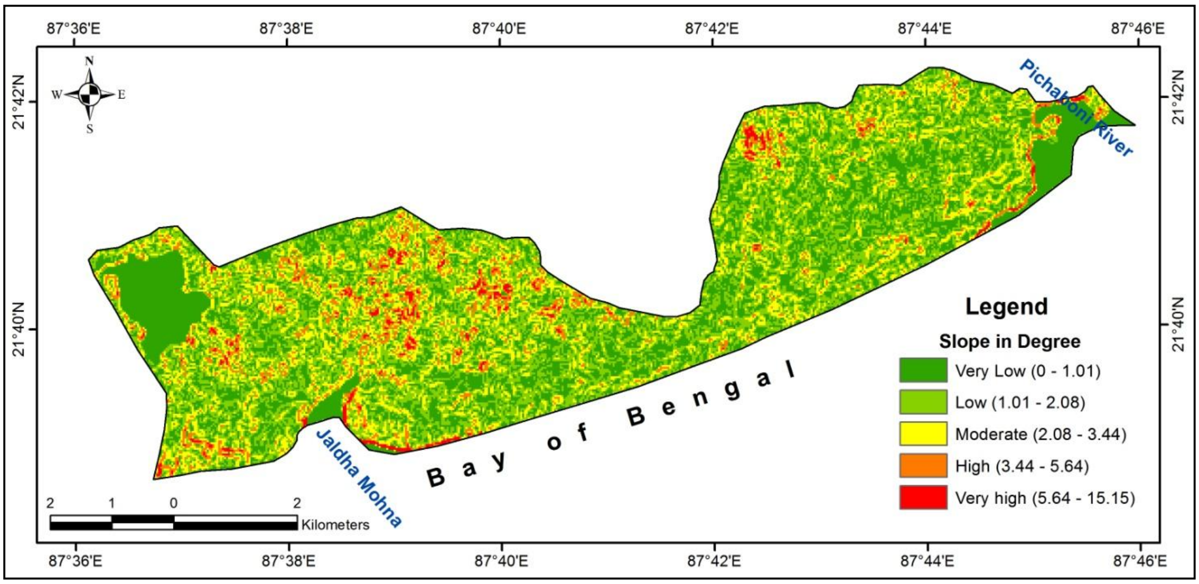

Figure 2.4: Slope map of the study area

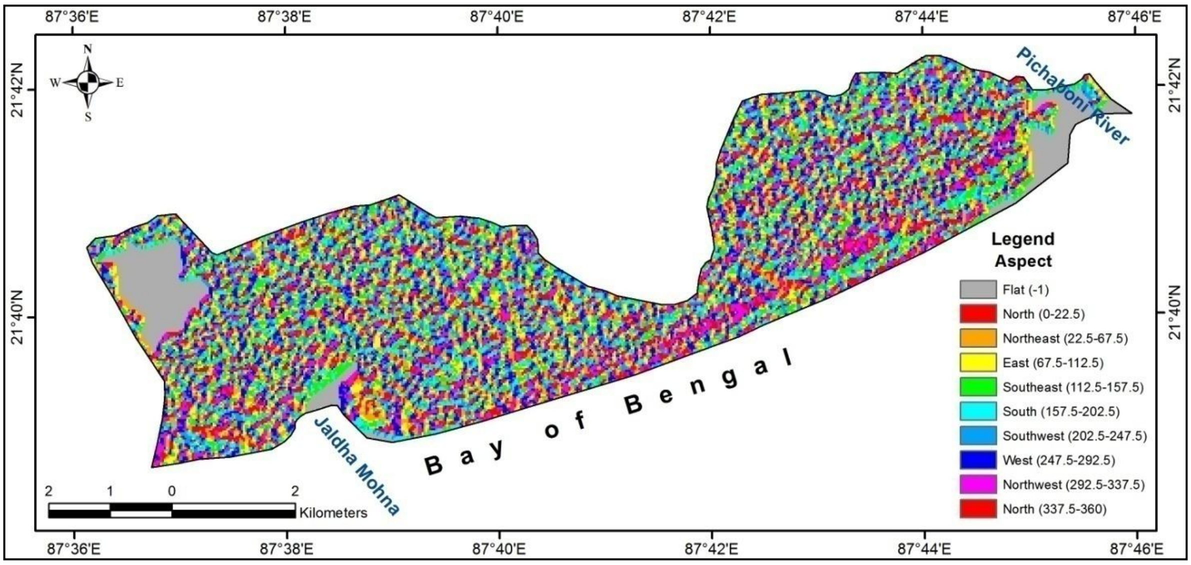

Figure 2.5: Aspect map of the study area

The total stretch of the land selected for the study has diversified characteristics in respect of selection of sample sites (Figure 2.6). For the purpose of beach and dune study mainly there are two types of influences, one is the morphodynamic impact and another one is the anthropogenic variations. Sample Site 1 i.e. the Jaldha at the Jaldha Mohona and Site 4 i.e. the Soula Mouth near the Pichaboni River Mouth are selected on the ground of morphological influence, hydrodynamism, aerodynamism, floral diversity, faunal presence etc. On the other hand Site 2 i.e. near Rose Valley or Sun City Resort is suited to fit the rapidly rising influence of Tourism Industry and gradual change of morphology, ground water, environment and ecological scenario and influence of it. Last but not the least Site 3 i.e. Khoti or boat anchoring ground for fishermen community of Dakshin Purushottampur village, reveals the character of the livelihood present at this vulnerable coastal scene and its impact on the physical setup of the beach and dune fringe area. The selection of these sample sites are really valuable because the research work is not only studying the physical setup but also the relationship between the existing community and the governmental regulation regarding the conflict between the expansion of territory for the native villagers or the outside tourism sector influencers.

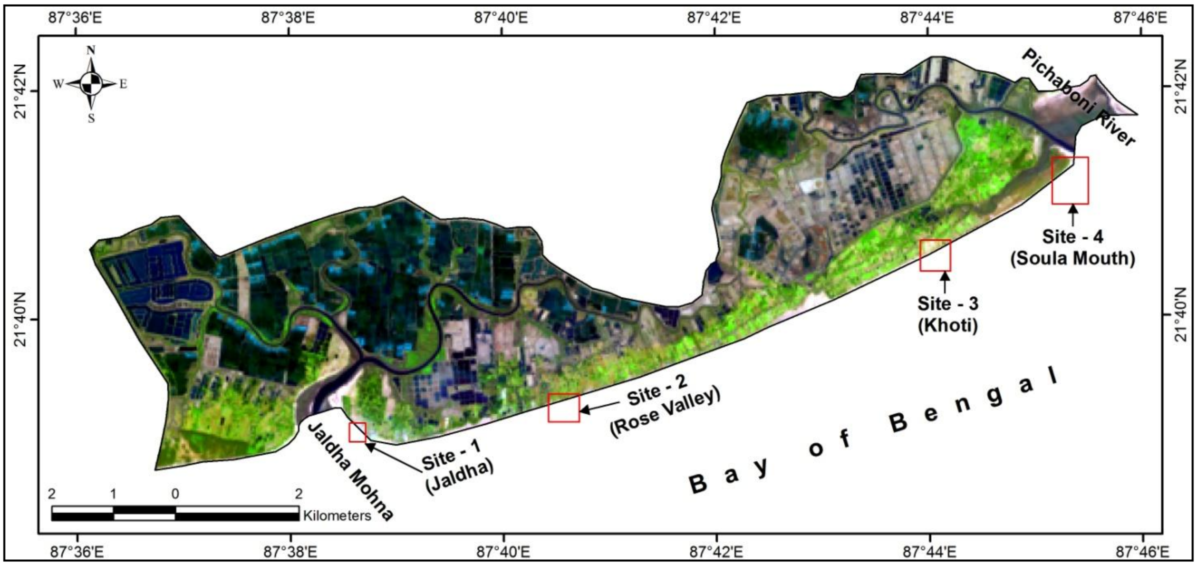

Figure 2.6: Sample site location map

The comparative survey at each sample stations is carried out between two years 2015 and 2018. As each of the Sample Site has its own characteristics for selection so each site has to be dealt with separate importance. This comparative survey is mainly done with the Total Station (TS) for estimation of the changes in morphology (Plate 2.1 & 2.2) and micro geomorphic features, rate of change and identification of the stage of the beach and dune. The total station survey is a more definite and modern tool for this kind of micro level surveys. On top of it, this time bound relative survey is the proper technique for estimation of erosion and accretion concentration area, calculation for sediment transportation volume and moreover evaluation for the rate of erosion per annum. So, these results can give us a clear picture of the physical setup of beach and dune fringe area and its variations due to morphodynamism or anthropogenic activities.

Plate 2.1 & 2.2: Total station survey

2.2.2. Estimation of Sediment Transportation Budget of Sampling Areas

The two TS DEM (Plate 2.3, 2.4) of Sample Site 1 from 2015 and 2018 has shown that a drastic change which has happened with 3years of time span (Figure 2.7). There are morphological changes with dune crestal peak concentration during 2015 whereas dune flattening is observed on 2018, 2015 shows pockets of dune blowout but 2018 has dune cliffing (Plate 2.5) characteristics, the ridge and runnel topography is prominent for 2015 and micro cusp feature overtook the lower beach face area during 2018. As from the past record it is quite evident that the region was formed in a tidal environment and the silty clay or mud is the main parent rock. These features are exposed at Site 1 and Site 2 where underlying muddy layers are also exposed at few pockets of beach (Plate 2.6). If we talk about the erosion aspect then it's definite that there is a huge reduction of elevation of nearly 3m concentrating mainly over the beach area. The dune has not drastically changed its elevation because this area is dominant with hydrodynamic character and has very little influence by human. But the erosion rate is high because of the tidal influence at the Jaldha Mouth, high wave energy and eastward moving long shore currents.

Plate 2.3 & 2.4: Total station survey

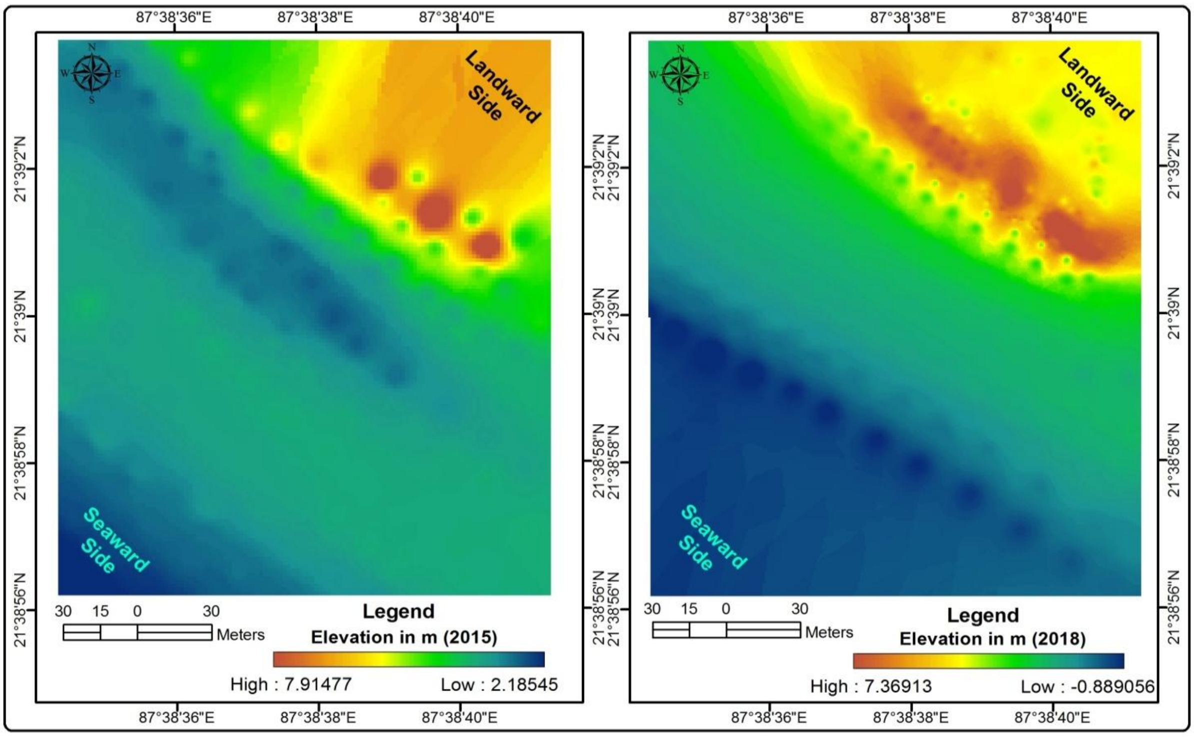

Figure 2.7: Digital Elevation Model for Sample Site 1 on 2015 and 2018

The zone of erosion is nearly 90% relative to the accretion zone in Sample Site 1. Following Jeanks' Natural Break Method, Volume Zonation has been done. These concentration zones are estimated by trend method through Interpolation techniques. The map (Figure 2.8) produced hereby shows that among five zones, which are delimitated according to topographic unit, four zones put up negative values i.e. Erosion and one zone has positive value which means concentration of Accretion. In this site total volume of sand transported (positive + negative) is 64142.51cu m within 3 years time span (2015-2018). However the net accretion is of much lower value i.e. 2409.19 cu m (3.75%) in comparison with net erosion 61733.32 cu m (Table 2.1). Thus, rate of erosion per year has been estimated to be 20,578 cu m which is a huge volume of sand being transported from the beach and dune fringe area. As it has already been mentioned the cause behind the erosion of the beach area but the reason for the accretion zone at the dune crest is due to dune flattening process. This means the peaks of the dune crests are lowered and the dune furrows are filled up by the sediments from the adjacent dune peaks. Otherwise this whole area is an erosive site with very few pockets of accretion.

Plate 2.5: Erosive beach of Site 1   Plate 2.6: Exposed underneath mud due to erosion

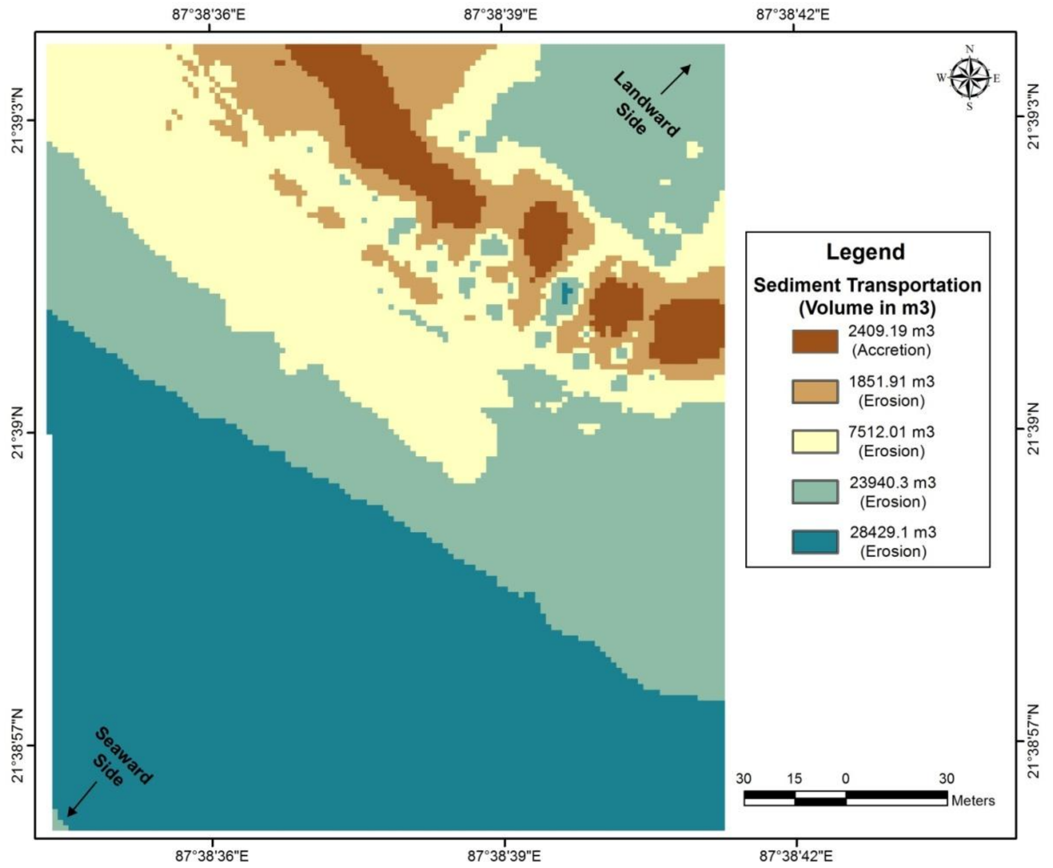

Figure 2.8: Volume zonation map of Sample Site 1

Table 2.1: Estimation of Change in Volume of Sand at Site 1 from 2015 to 2018

Sl.No	**Topographical Zone**	**Elevation in m**	**Area in Sq.m.**	**Volume of Sand in Cubic meter**	**Erosion/Accretion**	**Net Erosion cubic m**	**Rate of Erosion per year cu m**
1	Dune Crest	2.2572	1916.31	2409.19	Accretion	61733.32	20577.77333
2	Dune Slope	1.1603	1596.06	1851.91	Erosion		
3	Upper Beach Face	0.7569	9924.71	7512.01	Erosion		
4	Middle Beach Face	1.6592	14428.8	23940.3	Erosion		
5	Lower Beach Face	1.5393	18468.8	28429.1	Erosion		
Total		7.3729	46334.68	64142.51			

By comparing and contrast between two years (2015 & 2018) for Sample Site 2 it is evident that there is a reduction of 1m elevation (Figure 2.9). If we consider the deeper details about morphological aspect then it's very much clear that there is a spreading of dune sediment parallel to the shore. But that does not mean the accretion rate has increased, instead it means that the sediment has been washed out by the Highest High Tide (HHT) or the storm surge and re-deposited at the dune slopes and furrows. The presence of runnel at the fore dune base was prominent during 2015 but the runnel has spread its limit and has lowered the elevation of the upper beach face area.

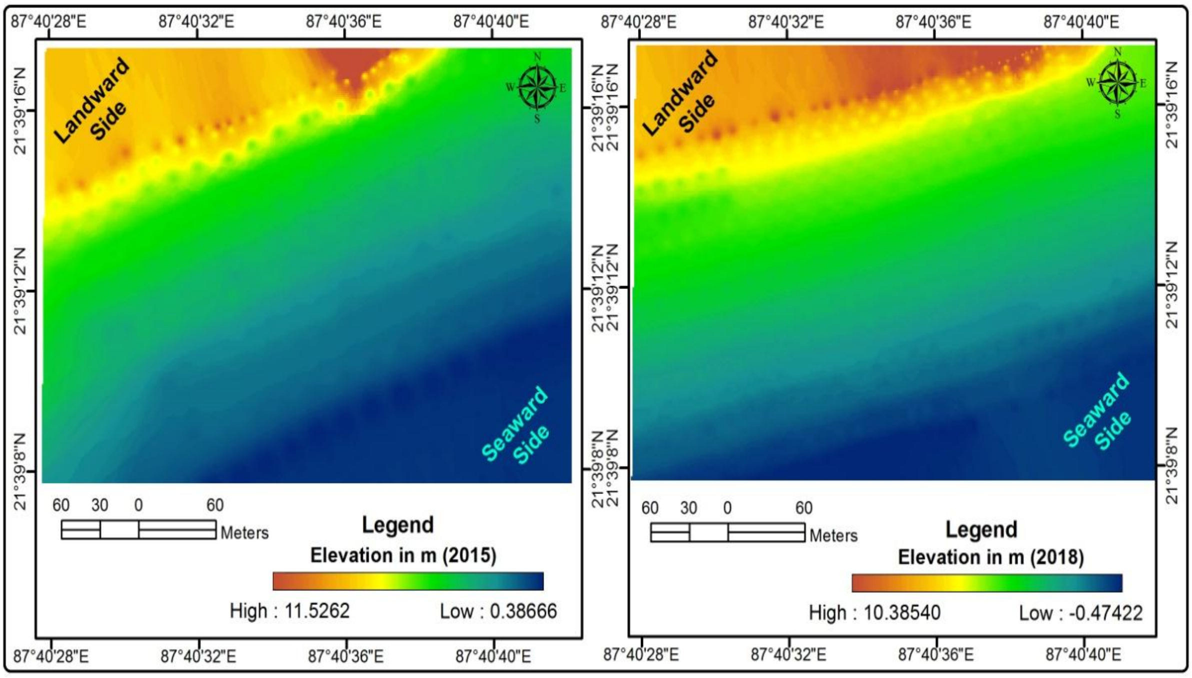

Figure 2.9: Digital Elevation Model for Sample Site 2 on 2015 and 2018

This is established that Sample Site 2 is erosion prone. The net erosion volume in 3years is 92238.97 cu m which is of much greater intensity compared to the previous site. Here the accretion volume is 3414.21 cu m (Table 2.2) which is only 3.5% of the total volume of sediment transported (95653.18 cu m). The accretion rate is lower than Site 1, which is an alarming situation because of the fact that this is a Tourism dominated site which supports thousands of tourists visiting the continuously flourishing scenic spot. From late 2009 the development of tourism sector had gradually accelerated and never retarded, so the beach and dune of that particular site must be quite supportive for this kind of establishment. But as the time passes the encroachment of construction and development sector overtakes the natural serenity of the Mandarmani Beach and especially the beach and dune of Silampur and Sona Muhi. Another alarming situation can be noticed from the figure 2.10 is that the western part of the Site has been excessively eroded. This is an alarming concern to think about because the topographic rise as dunes are totally washed off which can aggravate to coastal flood at each and every HHT and any kind of storm surge. The worst affected stakeholders are the villagers who are wholly and solely backing up the resorts and hotels and responsible for the economic growth of the tourism sector. Thus, the rate of erosion continues to remain nearly 30,746 cu m per year then all the dwellers and tourism area will be inundated regularly i.e. every spring tide and any high waves.

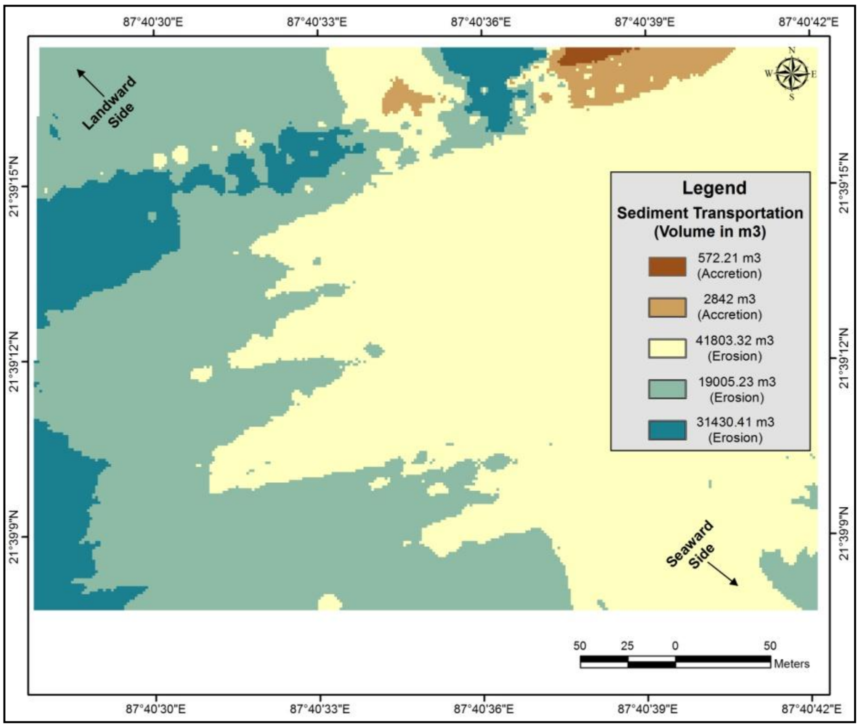

Figure 2.10: Volume zonation map of Sample Site 2

Table 2.2: Estimation of Change in Volume of Sand at Site 2 from 2015 to 2018

Sl.No	**Topographical Zone**	**Elevation in m**	**Area in Sq.m**	**Volume of Sand in Cubic meter**	**Erosion/Accretion**	Net Erosion **cubic m**	**Rate of Erosion per year cu m**
1	Dune Crest	3.2487	176.1354	572.21	Accretion	92238.97	30746.32333
2	Dune Slope	1.8877	1505.5383	2842	Accretion		
3	Upper Beach Face	0.8195	51010.7689	41803.32	Erosion		
4	Middle Beach Face	0.6768	28081.0152	19005.23	Erosion		
5	Lower Beach Face	4.873	6449.9106	31430.41	Erosion		
Total		11.5057	87223.3684	95653.18			

The Sample Site 3 (Figure 2.11) was selected to show the relationship of the intensity of utilization of resources by local inhabitants and quest for stability of the beach and dune against them. There is extreme reduction of volume of sediments form the beach, dune and back dune area, nearly 3.5 m height was cut off within 3 years over the dune and beach is showing a reduction of elevation for about 2 m (Figure 2.12).

The inhabitants of Dakshin Purushottampur utilize these kinds of back dune slope, dune crest, fore dune slope, beach face for various purpose of their livelihood like boat manufacturing, dry fish processing, livestock rearing, marine fish extracting etc. These man induced activities continuously turning the erosive coast of Mandarmani to much more erosive (Plate 2.7, 2.8). The total volume of sediment transported in 3years is 44762.32 cu m (Table 2.3). Yet we came to realize that the rate of erosion reaches near about 14920 cu m, which is the lowest among all the four selected sites. The photographic records can also show that the dunes are surprisingly flattened and upper beach face which produced micro berm like features has turned into eroded dune cliffs. So the question remains, why the rate of erosion is still lower than the previous two sites. Long shore current flowing eastward is the main reason behind this retarded rate of erosion. The sediments eroded from the coasts of western portion of the study area i.e. the coast near Jaldha Estuary are drifted towards the east and so the eastern part is much more accreted than the west. Moreover the Pichaboni River is also providing some sediment to the eastern portion which feed them with sand and help to reduce the erosion rate.

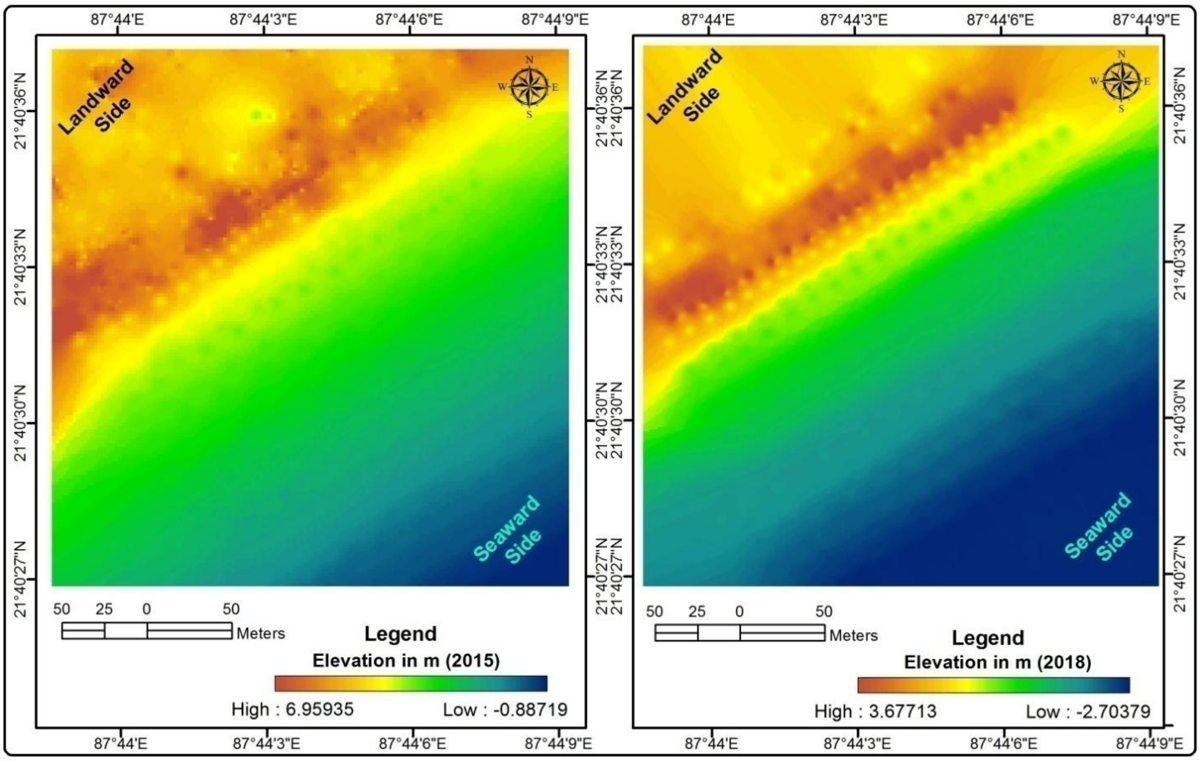

Figure 2.11: Digital Elevation Model for Sample Site 3 on 2015 and 2018

Plate 2.7: Beach during April month

Plate 2.8: Beach during October month

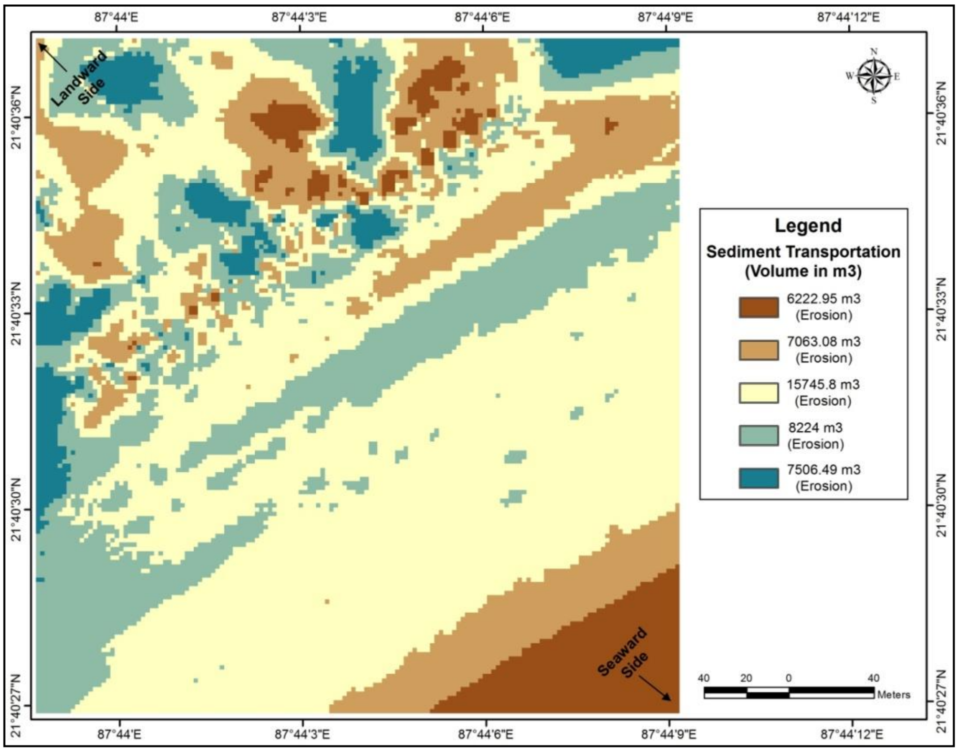

Figure 2.12: Volume zonation map of Sample Site 3

Table 2.3: Estimation of Change in Volume of Sand at Site 3 from 2015 to 2018

Sl.No	**Topographical Zone**	**Elevation in m**	**Area in Sq.m**	**Volume of Sand in Cubic meter**	**Erosion/Accretion**	**Net Erosion cubic m**	**Rate of Erosion per year cu m**
1	Dune Crest	1.0639	5849.19	6222.95	Erosion	44762.32	14920.77333
2	Dune Slope	0.4581	15418.2	7063.08	Erosion		
3	Upper Beach Face	0.3207	49098.2	15745.8	Erosion		
4	Middle Beach Face	0.3635	20899.6	8224	Erosion		
5	Lower Beach Face	1.4865	5049.78	7506.49	Erosion		
Total		3.6927	96314.97	44762.32			

The elevation (Figure 2.13) has reduced by 1m in the case of Sample Site 4 (Figure 2.14). The most important point is the location of this site, which is adjacent to the Soula Mouth. As eastern part of the coast is much more depositional in nature the estimation is also showing a smaller zone of accretion (785.03 cu m) and also less intensive erosion 47891.8537 cu m. This results to a rate of erosion of 15963 cu m (Table 2.4). The rate of Site 3 is still lesser compared to this region because here at the mouth of Pichaboni there is a tidal influence and also a very high hydrodynamic effects. Though this area whole coastline is an erosive coast but still the accretion rate is also balancing out with it.

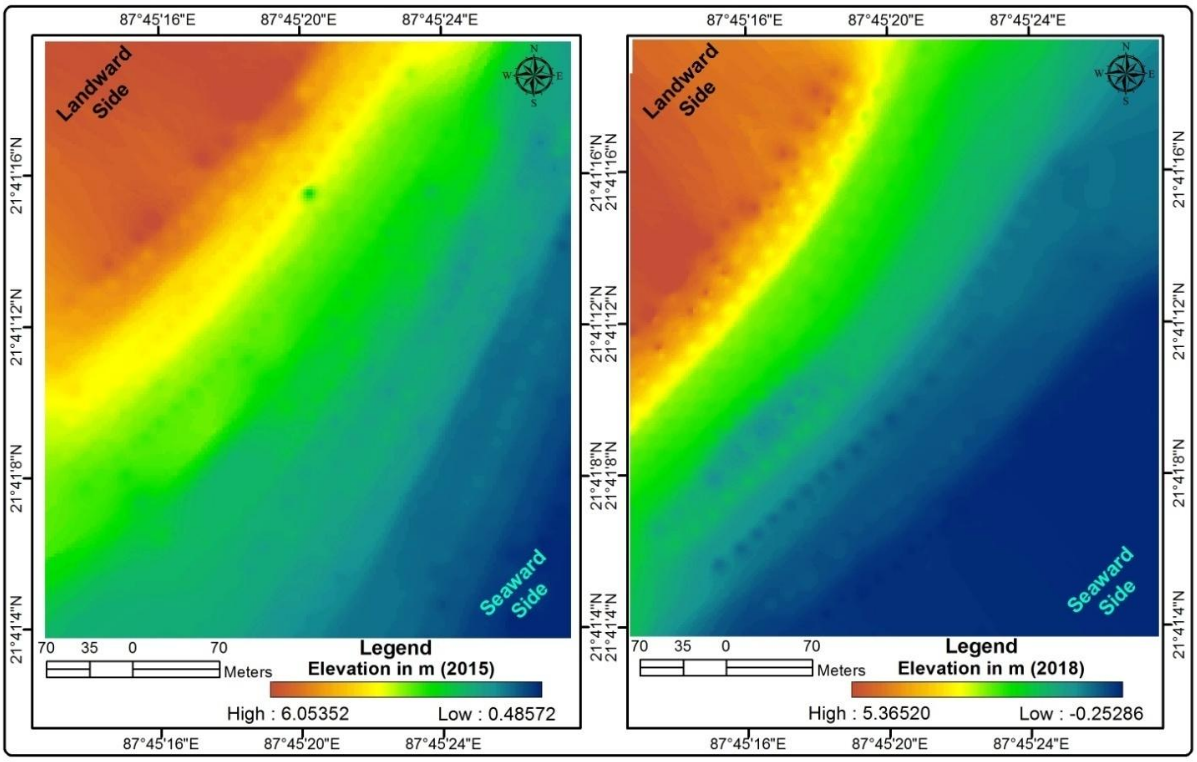

Figure 2.13: Digital Elevation Model for Sample Site 4 on 2015 and 2018

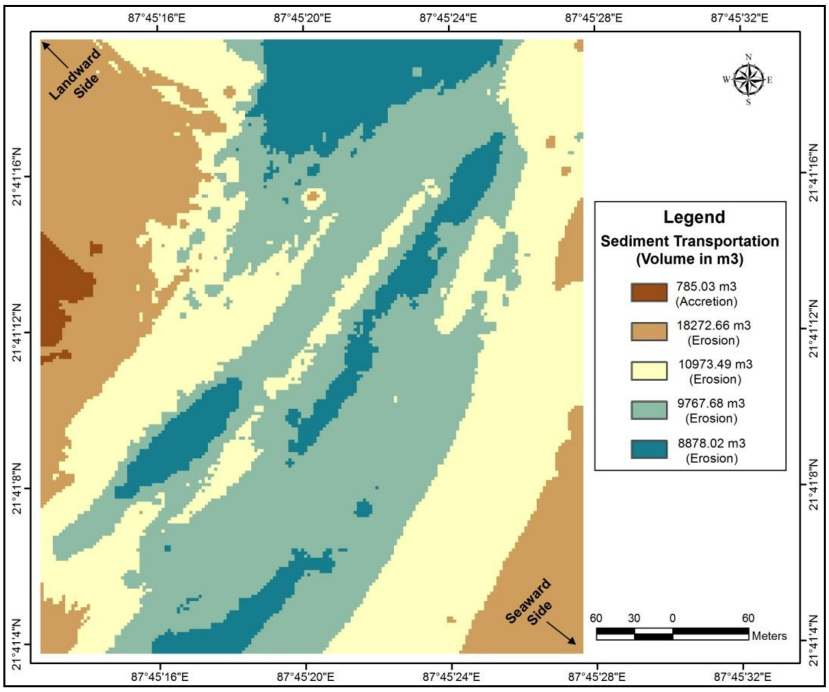

Figure 2.14: Volume zonation map of Sample Site 4

Table 2.4: Estimation of Change in Volume of Sand at Site 4 from 2015 to 2018

Sl.No	Topographical Zone	Elevation in m	Area in sq.m	Volume of Sand in Cubic meter	Erosion/Accretion	Net Erosion cu m	Rate of Erosion per year cu m
1	Dune Crest	0.7958	986.4635	785.03	Accretion	47891.8537	15963.95123
2	Dune Slope	1.0973	16652.3834	18272.66	Erosion		
3	Upper Beach Face	0.3786	28984.3998	10973.4937	Erosion		
4	Middle Beach Face	0.3366	29018.669	9767.68	Erosion		
5	Lower Beach Face	0.9677	9174.3544	8878.02	Erosion		
Total		3.576	84816.2701	48676.8837			

2.2.3. Sediment granulometric and stratigraphic analysis

There are many variations among the sediment structure that also has to be sorted out. Individually 6 sediment samples were collected in consideration of various morphological and hydrodynamic attributes viz. lower beach face, middle beach face, upper beach face, back dune area and also swash and backwash sediments respectively.

2.2.3.1. Sieve analysis

Sieve method or mesh method was carried out on the laboratory separately for each sample site. The mesh size or Ø value in mm or µm ranging from 1000 µm to 25 µm. Each mesh size leaves some sediment which are weighed and converted into percentage considering the total sample to be 100. There are various similarities and dissimilarities among the 4 sample sites intra or inter (Table 2.5, 2.6, 2.7, 2.8).

Table 2.5: Granulometric data for sample site 1

Micron	S-1 Backwash	S-1 Swash	S-1 Middle beach Face	S-1 Upper Beach Face	S-1 Lower Beach face	S-1 Back Dune
1000	0.08	0	1.6	0	2.67	0
850	0	0.18	28.47	15.87	40.02	0
500	3.58	0.04	61.46	74.96	42.12	0
250	6.35	62.23	7.17	3.35	1.22	2.44
125	89.36	16.66	1.3	5.82	13.97	67.03
75	0.63	20.89	0	0	0	10.34
63	0	0	0	0	0	18.82
38	0	0	0	0	0	1.34
25	0	0	0	0	0	0.03
Total (%)	100	100	100	100	100	100

Table 2.6: Granulometric data for sample site 2

Micron	S-2 Swash	S-2 Backwash	S-2 LB Face	S-2 Dune	S-2 UP Face	S-2 Back Dune
1000	0.05	0	0.21	0	0	0
850	0	0	1.11	0.8	2.5	0.04
500	1.94	48.79	80.46	85.69	19.65	0.25
250	19.64	4.55	5.02	5.04	5.84	1.59
125	77.45	45.89	13.2	8.47	48.6	65.75
75	0.92	0.77	0	0	19.69	10.08
63	0	0	0	0	3.62	20.97
38	0	0	0	0	0.1	1.31
25	0	0	0	0	0	0.01
Total (%)	100	100	100	100	100	100

Table 2.7: Granulometric data for sample site 3

Micron	S-3 Upper Beach Face	S-3 Dune Crest	S-3 Lower Beach Face	S-3 Swash	S- 3 Backwash	S-3 Back Dune
1000	0	0	0	1.25	0	0
850	0	0	0	25.35	0.1	0
500	22.52	0.98	0.31	46.24	0.92	0.01
250	1.1	3.36	0.56	15.42	1.8	0.51
125	71.9	93.38	94.34	10.49	59.2	74.94
75	4.48	2.28	4.79	1.25	34.14	10.18
63	0	0	0	0	3.84	12.01
38	0	0	0	0	0	2.34
25	0	0	0	0	0	0.01
Total (%)	100	100	100	100	100	100

Table 2.8: Granulometric data for sample site 4

Micron	S-4 Lower beach Face	S-4 Dune	S-4 Upper beach Face	S-4 Swash	S-4 Backwash	S-4 River basin	S-4 Back Dune
1000	0	0	0	0	0	0.14	3.56
850	0	3.86	15.41	5.8	4.7	0.03	4.88
500	48.33	85.1	78.21	23.2	26.5	1.54	13.64
250	9.34	2.25	1.91	10.6	8.43	4.97	9.56
125	34.04	8.79	4.47	51.28	51.48	41.02	12.77
75	7.91	0	0	6.62	7.64	19.91	12.12
63	0.38	0	0	2.5	1.25	31.57	40.87
38	0	0	0	0	0	0.81	2.57
25	0	0	0	0	0	0.01	0.03
Total (%)	100	100	100	100	100	100	100

2.2.3.2. Gradistat analysis

The GRADISTAT statistical programme was employed for understanding the nature of sediment depositional environment after converting the results of sediment weight (gm) retained by individual sieve into weight percentage distribution. The multiple sample statistics method has been applied for necessary results of mean, median, mode, sorting, skewness and kurtosis of grain size distribution to understand the influences of wave energy and beach morphology during their deposition on distinct beach environment.

Table 2.9: Statistical analysis for sample site 1

Methods	**Descriptions**	**Sample Name**					
	Sample Location	**S-1 Backwash**	**S-1 Swash**	**S-1 Middle beach Face**	**S-1 Upper Beach Face**	**S-1 Lower Beach face**	**S-1 Back Dune**
	Analyst and date:	AB, 2.8.2017	AB, 2.8.2017	AB, 2.8.2017	AB, 2.8.2017	AB, 2.8.2017	AB, 2.8.2017
	Sample type:	Unimodal, Well Sorted	Bimodal, Moderately Sorted	Unimodal, Well Sorted	Unimodal, Well Sorted	Unimodal, Moderately Well Sorted	Bimodal, Moderately Well Sorted
	Textural group:	Sand	Sand	Sand	Sand	Sand	Sand
	Sediment name:	Well Sorted Fine Sand	Moderately Sorted Medium Sand	Well Sorted Coarse Sand	Well Sorted Coarse Sand	Moderately Well Sorted Coarse Sand	Moderately Well Sorted Fine Sand
Method of Moments Arithmetic (µm)	Mean	216.2	287.4	707.5	676.3	685.3	158.8
	Sorting	99.98	120.7	183.2	163.6	267.2	61.07
	Skewness	3.676	-0.361	-1.175	-1.203	-1.084	0.382
	Kurtosis	16.32	2.910	5.746	5.870	3.121	4.970
Folk and Ward method (description)	Mean:	Fine Sand	Fine Sand	Coarse Sand	Coarse Sand	Coarse Sand	Fine Sand
	Sorting:	Well Sorted	Moderately Sorted	Well Sorted	Well Sorted	Moderately Well Sorted	Moderately Well Sorted
	Skewness:	Coarse Skewed	Very Fine Skewed	Fine Skewed	Fine Skewed	Very Fine Skewed	Very Fine Skewed
	Kurtosis:	Leptokurtic	Platykurtic	Mesokurtic	Very Leptokurtic	Very Leptokurtic	Platykurtic

Table 2.10: Statistical analysis for sample site 2

Methods	**Descriptions**	**Sample Name**					
	Sample Location	**S-2 Swash**	**S-2 Backwash**	**S-2 LB Face**	**S-2 Dune**	**S-2 UP Face**	**S-2 B ack Dune**
	Analyst and date:	AB, 3.8.2017	AB, 3.8.2017	AB, 3.8.2017	AB, 3.8.2017	AB, 3.8.2017	AB, 3.8.2017
	Sample type:	Unimodal, Moderately Well Sorted	Bimodal, Moderately Sorted	Unimodal, Moderately Well Sorted	Unimodal, Well Sorted	Bimodal, Poorly Sorted	Bimodal, Moderately Well Sorted
	Textural group:	Sand	Sand	Sand	Sand	Sand	Sand
	Sediment name:	Moderately Well Sorted Fine Sand	Moderately Sorted Coarse Sand	Moderately Well Sorted Coarse Sand	Well Sorted Coarse Sand	Poorly Sorted Fine Sand	Moderately Well Sorted Fine Sand
Method of Moments Arithmetic (µm)	Mean	232.9	433.2	596.9	620.6	291.0	156.5
	Sorting	97.69	239.2	177.3	149.0	231.7	66.15
	Skewness	2.295	-0.015	-1.664	-2.195	1.223	1.869
	Kurtosis	9.102	1.049	4.305	6.570	3.028	19.43
Folk and Ward method (description)	Mean:	Fine Sand	Medium Sand	Coarse Sand	Coarse Sand	Fine Sand	Fine Sand
	Sorting:	Moderately Well Sorted	Moderately Sorted	Moderately Well Sorted	Well Sorted	Poorly Sorted	Moderately Well Sorted
	Skewness:	Coarse Skewed	Fine Skewed	Very Fine Skewed	Very Fine Skewed	Very Coarse Skewed	Very Fine Skewed
	Kurtosis:	Leptokurtic	Very Platykurtic	Very Leptokurtic	Very Leptokurtic	Mesokurtic	Very Platykurtic

Table 2.11: Statistical analysis for sample site 3

Methods	Descriptions	Sample Name				
	Sample Location	**S-3 Upper Beach Face**	**S-3 Dune Crest**	**S-3 Lower Beach Face**	**S-3 Swash**	**S- 3 Backwash**
	Analyst and date:	AB, 4.8.2017	AB, 4.8.2017	AB, 4.8.2017	AB, 4.8.2017	AB, 4.8.2017
	Sample type:	Bimodal, Moderately Sorted	Unimodal, Very Well Sorted	Unimodal, Very Well Sorted	Unimodal, Moderately Sorted	Unimodal, Moderately Well Sorted
	Textural group:	Sand	Sand	Sand	Sand	Sand
	Sediment name:	Moderately Sorted Fine Sand	Very Well Sorted Fine Sand	Very Well Sorted Fine Sand	Moderately Sorted Coarse Sand	Moderately Well Sorted Fine Sand
Method of Moments Arithmetic (µm)	Mean	295.4	196.6	185.9	625.4	161.7
	Sorting	206.4	60.02	36.02	249.0	76.48
	Skewness	1.260	5.748	7.922	-0.597	3.942
	Kurtosis	2.666	42.34	111.2	2.437	29.92
Folk and Ward method (Description)	Mean:	Medium Sand	Fine Sand	Fine Sand	Coarse Sand	Fine Sand
	Sorting:	Moderately Sorted	Very Well Sorted	Very Well Sorted	Moderately Sorted	Moderately Well Sorted
	Skewness:	Very Coarse Skewed	Symmetrical	Symmetrical	Very Fine Skewed	Symmetrical
	Kurtosis:	Very Leptokurtic	Platykurtic	Platykurtic	Leptokurtic	Platykurtic

Table 2.12: Statistical analysis for sample site 4

Methods	Descriptions	Sample Name						
	Sample Location	**S-4 Lower beach Face**	**S-4 Dune**	**S-4 Upper beach Face**	**S-4 Swash**	**S-4 Backwash**	**S-4 River bank**	**S-4 Back Dune**
	Analyst and date:	AB, 5.8.2017	AB, 5.8.2017	AB, 5.8.2017	AB, 5.8.207	AB, 5.8.2017	AB, 5.8.2017	AB, 5.8.2017
	Sample type:	Bimodal, Poorly Sorted	Unimodal, Well Sorted	Unimodal, Well Sorted	Trimodal, Poorly Sorted	Bimodal, Poorly Sorted	Bimodal, Moderately Sorted	Unimodal, Poorly Sorted
	Textural group:	Sand	Sand	Sand	Sand	Sand	Sand	Sand
	Sediment name:	Poorly Sorted Coarse Sand	Well Sorted Coarse Sand	Well Sorted Coarse Sand	Poorly Sorted Fine Sand	Poorly Sorted Fine Sand	Moderately Sorted Very Fine Sand	Poorly Sorted Very Fine Sand
Method of Moments Arithmetic (µm)	Mean	433.2	635.0	686.0	354.5	359.0	148.3	238.6
	Sorting	241.7	154.0	147.8	251.8	250.7	101.0	261.0
	Skewness	-0.096	-1.991	-1.241	0.899	0.803	2.721	1.371
	Kurtosi	1.154	6.933	7.208	2.349	2.112	13.86	3.522

	s							
Folk and Ward method (description)	Mean	Medium Sand	Coarse Sand	Coarse Sand	Medium Sand	Medium Sand	Very Fine Sand	Fine Sand
	Sorting	Poorly Sorted	Well Sorted	Well Sorted	Poorly Sorted	Poorly Sorted	Moderately Sorted	Poorly Sorted
	Skewness	Very Fine Skewed	Very Fine Skewed	Fine Skewed	Very Coarse Skewed	Very Coarse Skewed	Coarse Skewed	Very Coarse Skewed
	Kurtosis	Very Platykurtic	Very Leptokurtic	Leptokurtic	Platykurtic	Platykurtic	Platykurtic	Very Platykurtic

2.2.3.3. Soil Stratigraphy collection

Soil strata of the exposed and covered surfaces tell us a lot about the composition and formation of the whole area. In order to do so a Hand Piston Auger, an instrument for burrowing soil surface were used. Two burrowing stations were on the beach face and on the wetland behind the back dune surface with grass field (Plate 2.9, 2.10, 2.11 & 2.12). The exposed dune cliff also showed a dynamic influence by the wave, current and tide.

Plate 2.9, 2.10, 2.11 & 2.12: Burrowing through hand piston auger

While working with hand piston auger anyone have to face limitations like we face in the beach area with sand coverage. It was possible only to burrow for 50 cm. but in case of the back dune wetland it was easier to carry out the task and hence a 2m hole (Table 2.13) can be generated through which underneath soil data has been extracted.

Table 2.13: Hand piston auger data showing soil stratigraphy

Layers	Thickness (cm)	Soil Type	Characteristics
S1	25	Mud	Colour – Blakish grey
S2	45	Sandy Mud	Colour – Brownish grey
S3	15	Sandy Mud	Colour – Brownish grey
S4	35	Liquid Sandy Mud	Colour- Yellowish grey Water bearing layer at 1m depth
S5	15	Muddy to Silty sand	Colour- Blakish to Dark grey Organic Mud with shell fragments ; Towards deeper part larger fragment of shell and forums; Presence of pottery fragments
S6	25	Sticky clay, Moderate liquid in character with compact mud	Colour- Blakish to dark grey
S7	40	Blakish clay layer with mica flex content very sticky and compact mud	Colour- Blakish

2.2.4. Estimation of wave hydrodynamics

Based on field observation, the geometrical properties of wave i.e., wave height of crest (H_c) and trough (H_t), wave breaking (H_b), water depth (d), wave length (L), surf zone width (W), run-up length of swash (L_s) and backwash (L_b), wave period (T) and frequency (f), angle of wave approach (α), along with wind speed (W_C) and direction were measured. Here, from those wave data other different wave hydrodynamic parameters were estimated through different empirical hydrodynamic equations (Pethik, 1984; Carter, 1995; Paul, 2002, Bird, 2008).

Wave Trough Height: Wave troughs are successive lowest parts of progressive sea waves which are alternated by wave crests such as wave crest – wave trough wave crest - wave trough and so on. It is, thus, clear that a wave trough is located between two successive wave crests, or a wave crest is located between two successive wave troughs. Height of trough from sea bed is called as trough height.

Wave Crest Height:	The successive higher parts of progressive sea waves are called wave crests which are the highest parts of the waves. The height of highest peak in a crest is called as crest height.
Breaking Height:	When the wave height increases to such extent that the wave cannot support the huge wave height, then the wave breaks and spills forward. One time the wave crest started to break when wave energy exceeds the wave speed. The height of wave when breaking is called as wave breaking height.
Wave Height:	Wave height (H) is the vertical distance between the crest and horizontal straight distance between two successive troughs distance of progressive sea waves. It is mainly implying the difference between crest and trough height. Mainly it is the indicator of potential energy.
Wave Length:	Wave length (L) is the straight horizontal distance between two successive wave crests or two successive wave troughs, which is expressed in terms of length unit of meters in the case of sea waves.
Wave Amplitude:	Wave amplitude (A) is the difference between crest height and average water label. Mainly the wave amplitude is the value of the half of the wave height. It is calculated by the formula of- $A=H/2$
Wave Depth:	Wave depth or water depth (d) is the vertical distance from mean water level of the seas. In the open sea the water depth is more and in shallow sea sometimes it is equal to wave crest height.
Wave Relative Height:	Wave relative height is the ratio between the wave height (H) and water depth (d). The formula for calculation is (H/d).
Wave Relative Depth:	Wave relative depth is the ratio between the depths of water and wave length. It is calculated by the formula of- (d/L).

Wave Velocity: Wave velocity (C) is the speed. Mainly wave velocity means the speed of waves to move per unit area. The wave velocity is measured by the ratio of wave length (L) and wave period (T). The calculating formula is- C= (L/T).

Wave Period: The time taken by a progressive sea wave to cover the distance of one wave length orb one wave cycle is called wave period (T), which is usually expressed as in time of unit seconds. This type of data was collected with the help of stopwatch. Mathematically wave period may be calculated. This formula is- T= (1/F)

Wave Frequency: The number of sea waves (one wave is equal to one wave length) passing through a certain point per unit time (usually one second and one minute) is called wave frequency (F). Wave frequency varies according to the wave lengths and of waves. There is inversely relationship between the wave length and wave frequency. This can be done by this formula – F = (1/T)

Wave Steepness: Wave steepness shows the ratio of wave height to wave length. The breaking of waves depends on the ratio of wave steepness. If the ratio is more than 1:7, then the waves break at plunge line and thus spills forward. Wave steepness is calculated by the formula of-W.S.=H/L.

Wave Energy: Wave energy (E) is proportional to that energy which is incorporated by mainly wind. Energy of wave is found mainly in the form of wave height and wave velocity where former indicates potential energy and later indicates kinetic energy. The amount of energy in wave is constant irrespective to location. In the study site the wave energy is calculated by the formula- E= 1/8pgH2

Average wave height (H), wave amplitude (a), and water depth (d) were measured as $H = H_c - H_t$, $a = H/2$, and $d = (H_c + H_t)/2$, respectively from initially observed wave geometric parameters. The geometric triplex has been understood from the ratios of relative water depth (d/L), relative wave height (H/d), and wave steepness during breaking (H/L), which describes wave environment, i.e., deep water (d/L> 0.5), transitional water (0.1 < d/L < 0.5) and shallow water (d/L < 0.1). In this study equations are adopted considering the shallow water environment. Also, the relative wave height at breaking (H_b/d) is measured depending on primarily observed field data. In addition, other hydraulic parameters like, wave phase velocity (C), wave crest velocity (C_b) (Van Dorn, 1978), wave energy (E), energy flux for each unit of wave crest (EC_n), breaking coefficient (h_b), and surf-scaling factor (ε) are estimated followed by Eq. 1, 2, 3, 4, 5 and 6 (Guza & Inman, 1975), respectively.

$$C = (gd)^{0.5} \tag{1}$$

$$C_b = (2gH_b)^{0.5} \tag{2}$$

$$E = 1/8\rho g H^2 \tag{3}$$

$$ECn = 0.5\rho g (H/2)^2 (gd)^{0.5} \tag{4}$$

$$h_b = (H/L)\tan^2\beta \tag{5}$$

$$\varepsilon = a_b \omega^2 / g \tan^2\beta \tag{6}$$

Where 'g' is gravitational acceleration (9.81 m/s^2), and water density (ρ) is estimated through laboratory analysis as $\rho = m/v$, when, 'm' is the mass of water and 'v' stands for volume of water. Also, 'a_b' is the wave breaker amplitude ($H_b/2$), and 'ω' incidents wave radian frequency ($\omega = 2\pi/T$).

Three consecutive observations (10mins each comprising 30mins) of wave hydrodynamic parameters in different tide levels (Rising tide, High tide and Falling tide) at each sample site (See appendix 2a,2b,2c,2d) confer a significant result on response to beach morphology and sediment distribution with spatio-temporal variation (Bird, 2008).

The observations of on-field wave parameters are also validated with the instinct results of equation derived measurement. The wave height (H) is expressed as $H = 0.36\sqrt{F}$, when F is fetch distance. Whereas, wave length (L) and wave frequency (f) is estimated by equation of $L = T(gd)^{0.5}$ and $f = 1/T$, respectively. The value of Root-Mean Square-Error (RMSE) lies between 0.015 m to 0.018 m for observed data and equation based computed results.

The length of both Swash (L_s) and Backwash (L_b) were also measured (Table 2.14, 2.15, 2.16, 2.17 & 2.18) along with the sediment carried on-shore and off-shore with them respectively was weighed. This would give a proper insight of the strength of the wave and current at each and every sample site. From this, it can be deduced that whether the waves are constructive or destructive.

Table 2.14 & 2.15: Swash and Backwash length of sample site 1 & site 2

Swash length(m)	Backwash length(m)
30	12
27	17.4
32	18
30	12.6
22	17.5
17	9.3
18.8	10.6
30	19.85
35	26.5
42	32
37	28.6

Swash length(m)	Backwash length(m)
35	22
28	17.2
25	18.6
15	8.3
36.2	22.5
37	24.6
35	18.75
25	15.85
27	10
30	14
27	17.3
35	30

Table 2.16 & 2.17: Swash and Backwash length of sample site 3 & site 4

Swash length(m)	Backwash length(m)
21	4.3
23	17.7
18.3	12.7
12.25	4.2
17	7.7
11.3	7.6
9.9	14.19
10.85	13.2
11.6	8.2
9.3	6
15	15.4

Swash length(m)	Backwash length(m)
27	5.3
19	2.7
32	6.1
22	3.2
17	4.5
29	3.3
23.5	5.9
28.6	3
21.4	4.7
30.4	2.2

Table 2.18: Sediment weights of swash and backwash current

Site No	Place	Weight of Swash Sediment (gm)	Weight of Backwash Sediment (gm)
1	Jaldha (Site 1)	672	622
2	Rose Valley (Site 2)	1240	1484
3	Khoti (Site 3)	545	578
4	Soula (Site 4)	722	185.48

2.2.5. Estimation of Aerodynamics

As the study area falls under the influence of monsoonal change and also being the coastal region so there is also effect of sea breeze and land breeze moreover the wave hydrodynamics most important parameter is the wind direction and velocity so the wind has to be measured. With the help of anemometer (Plate 2.13& 2.14) and prismatic compass the direction and the velocity of the wind were estimated.

Plate 2.13 & 2.14: Aerodynamic survey through anemometer

The four sample sites show a variation of wind direction mainly concentrating as Eastern wind. It varies between east, south-east and south-south east. Keeping parity with the 3consecutive observation of wave hydrodynamics, wind speed were estimated in 3 observations with 10mins of each observation.

Wind velocity ranges from 5-7m/sec to 11-13m/sec. Being a coastal region and having open sea ahead with varieties of unstable weather so the wind speed fluctuates very often. Site 2 and 3 having higher velocity of wind speed and site 1 and 2 are towards the lower range. This can directly affect the mechanics of the wave and current.

2.2.6. Estimation of Bioturbation influences on the beach morphology

Mandarmani as well as the adjacent area Tajpur are the habitat of red crabs (Plate 2.16 & 2.17), *ocypodidae fam*ily with one uniqueness being left claw larger than the right one. This place in local language is called *"laal kakrar desh"* meaning the land of red crabs. So this faunal community creates an important role to stabilize the morphology, ecology and biodiversity of the region. In short it can be said that they have a crucial role in restoring the beach or not that has to be analysed. For my study I have selected 9sample sites (Plate 2.15) for bioturbation study which are very close to the previously taken 4 sample sites for morphological and hydrodynamic study. As an example the method of collection of data for one sample (Grid A) is shown as follows.

Plate 2.15: Depiction of 9grid points

A 2x2 m grid has been generated for this survey method. The whole grid was divided in to 4 sub grid (A1, A2, A3 & A4). Then the diameter, depth, number of crab holes and the amount of sediment uplifted within the grid were collected carefully and weighed later.

The diameter of the large crabs holes ranging from 3-5cm (Table 2.19), diameter of medium crabs holes 2-2.6cm and small crabs holes 0.8-1.2cm.The vertical depth of the large crabs ranging from 38-45cm, depth of medium crabs holes 12-17cm and vertical depth of small crabs holes 4-9cm.Total no of crabs holes including large, medium and low is 57 in this grid (Figure 2.15). Amount of sediment lifted by the crabs 3.8kg in this grid.

Table 2.19: Attributes of bioturbation study for Grid A near sample site 4

Grid no	**Location (lat & long)**	**Diameter (cm) &no. Of frequency**			**Vertical depth(cm)**			**No. Of holes (per 4sq m)**	**Weight of sediments lifted by crabs(kg)**	**Remarks**
		Large	Medium	Small	Large	Medium	Small			
A1	(87°45'23.34"-87°45'23.40")e	5(3)	2.6(5)	1.0 (8)	45	15	5	57	1.8	Fossils and plant root
A2	&(21°41'21.47-21°41'21.54")n	3(6)	2.0(2)	1.2 (3)	41	17	6		0.85	
A3		4(5)	2.4(7)	1.0 (5)	38	12	4		0.65	
A4		4(3)	2.2(4)	0.8 (6)	44	12	9		0.5	

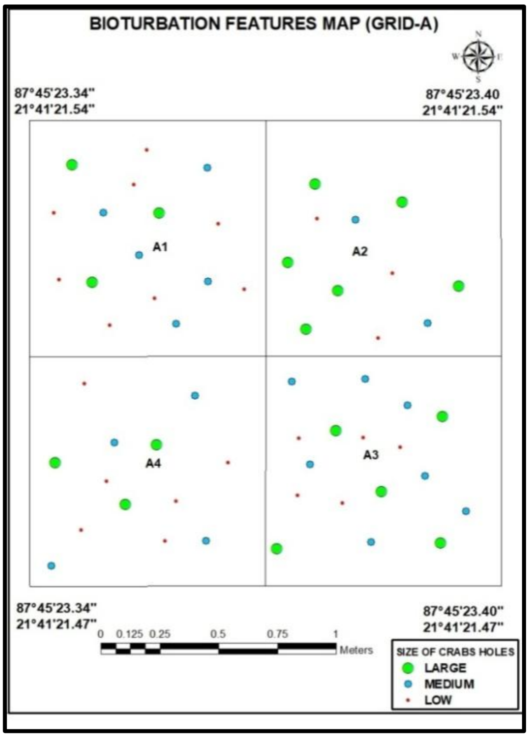

Figure 2.15: Distribution of crab holes in Grid A according to size

Plate 2.16 & 2.17: Habitat of red crabs

2.2.7. Dune floral community & Dune adjustment

Coastal sand dunes of the barrier bar are densely colonised by vegetation in the undisturbed areas along the shoreline nearly Pichaboni River Mouth .The coastal dunes are separated into two significant units such as shore parallel fore dunes and fore dune parallel beach dune. Their elevations and age of formation varies from place to place. In elevation the back dunes are ranging from 5m to 8m & they are relatively older in compare to the frontal sand dunes. The fore dunes are colonised by creeper plants & long rooted grasses with tussock forming vegetation (Paul, 2004).

The roots of these creepers play a vital role in arresting the dune at its place. In this research work more than 11varities of creepers (Table 2.20) were identifies and the horizontal and vertical extent of the roots were measured from the exposed surface of the dunes or with the help of a spade as a tool to expose the surface.

Table 2.20: Statistics of creeper's root (Horizontal & vertical)

Sl. No.	**Name of species**	**Length of stolons**	**Depth of rhizomes**	**Sand accumulation rate**	**Remarks (topography & significant**
1	*Launea sarmentosa*	>70	1	15cm	For dune significant
2	*Ipomea pes-caprae*	>500	>400cm	19cm	For dune significant
3	*Cyperus erythrorhizos*	-	>200cm	20cm/year	For dune significant
4	*Opuntia stricta*	-	>200cm	>12cm/year	Back dune significant
5	*Calotropis gigantea*	-	>300	>20cm/year	Back dune significant
6	*Lantana camara*	-	>200cm	>15cm/year	Back dune significant
7	*Pandanus tectorius*	-	>500	>30cm/year	Back dune significant
8	*Anacardium orientale*	-	>600	>30cm/year	Back dune signification
9	*Casuarina equisetifolia*	-	>300	Sapling stagy .20cm/year matured 15cm/year	Back dune signification
10	*Tamarix aphylla*	100cm	200cm	20cm/year	Back dune signification
11	Other species	15cm	30cm	10cm/year	Back dune signification

2.2.8. Micro geomorphic features

Micro geomorphology is evidently a crucial indicator for identification of the stage of a beach and the rhythmic nature of the beach and dune depends of the season change (Plate 2.18, 2.19, 2.20, 2.21 & 2.23). Beach mapping is the only method through which the micro features can be identified and located on the beach. Nowadays with improved level of technology it is quite easy to map a beach and recognize the micro features if enough funding is available. But due to lack of fund this mapping process is done through crude method of clicking photograph in a grid method. So an area at the sample site 4 is taken into consideration because this area received impact from 3elements- the morphogenetic factor or the influence of the wind, wave, tides, currents etc.; local inhabitants' impact and also pressure from tourism sector.

Pre-made grid was used with each grid having 1x1m area. Likewise 10 grid were plot in east-west direction i.e., parallel to the shoreline and in this way it was proceeded from land towards the sea. The time taken was during neap-tide in order to get lowest low tide and full expanse of the beach. In this manner a strip of land was photographed covering in total 1040sq m on the surface of the beach.

These photographs made into a strip was later cropped and merged and a micro feature identification map (Figure 2.16) of the beach area was formed through grid method.

Plate 2.18, 2.19, 2.20, 2.21, 2.22 & 2.23: Rhythmic nature of beach and dune

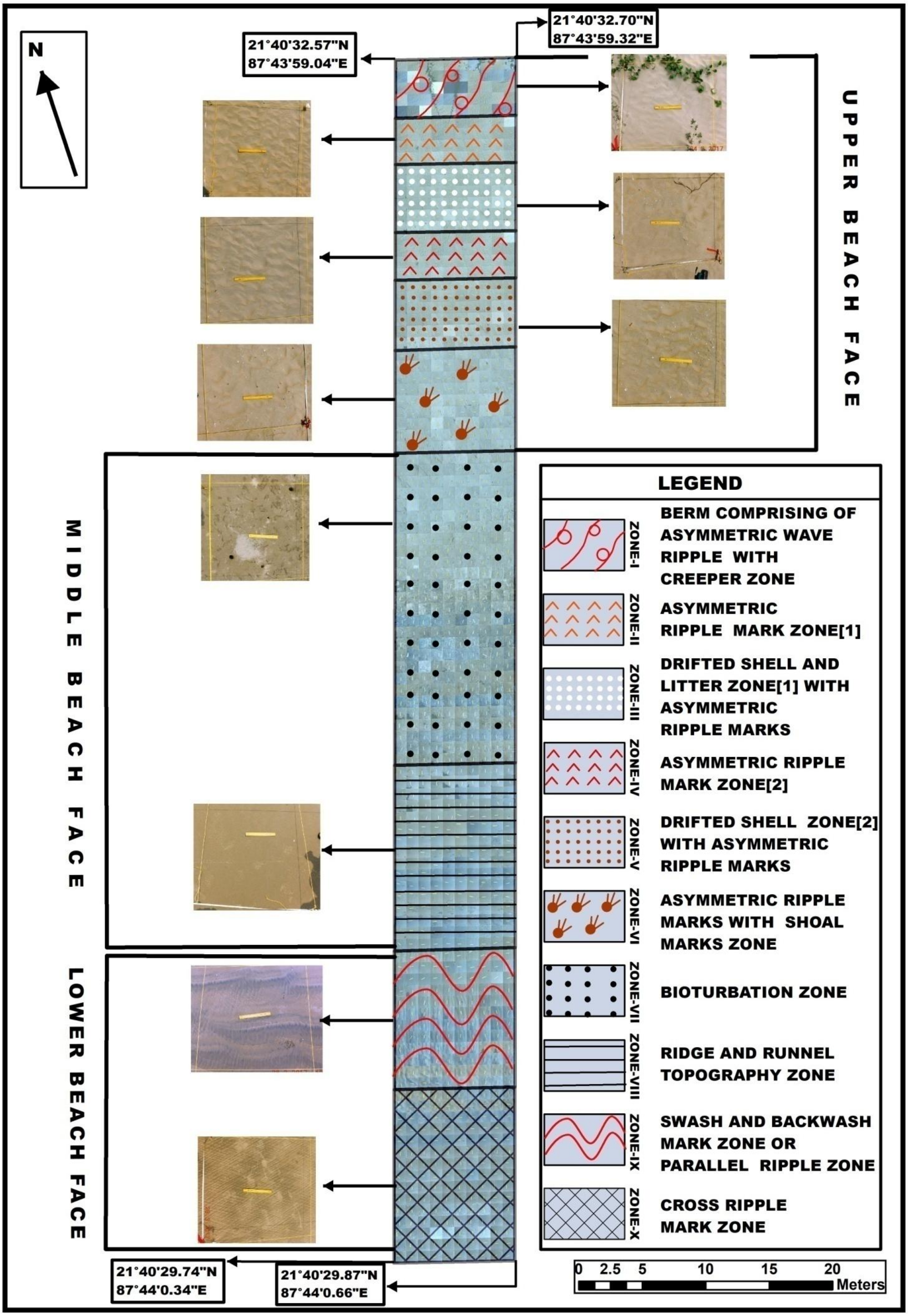

Figure 2.16: Beach mapping through grid method

2.2.9. Estimation of Beach-Dune Morphodynamism

All the above analysis and estimation leads to the final level of morphodynamism which includes all the factors, causes behind the factor, environmental influence, anthropogenic impacts. Now in Table 2.21 each sample site were graded and assimilated to deduce the final result of each of its condition and conclude the stage at which the beach-dune morphology is acting at present time.

Table 2.21: Morphodynamic Indices of the sample sites.

Sl. No.	Parameters	Site 1	Site2	Site 3	Site 4	Average
1	Month	August	August	August	August	
2	Inter- tidal width /m	250	180	175	200	201.25
3	R.L difference between HWL & LWL	4	3.5	4.2	4.5	4.05
4	Beach face angle (β)(degree)	5	2.5	3	2.8	3.325
5	Swash line bearing (degree)	23	34	36	30	30.75
7	Mean water depth /m	1.05	1.39	1.29	1.06	1.1975
8	Mean wave height(h) in m	0.47	0.55	0.53	0.79	0.585
9	Significant wave height (H1/3) in m	0.67	0.97	0.82	1.12	0.895
10	Mean wave period /s	6.5	10	12.6	14.9	11
11	Mean wave approach angle (α) in degree	292	247	290	242	259.6667
12	Velocity of longshore current / (m.S-1)	1.039	0.673	0.417	0.704	0.70825
13	Wave form velocity © in m/sec	1.03	0.98	1.25	1.36	1.155
14	Wave length (L) in m	9.45		23.87	8.88	12.5
15	Wave steepness/ (H.L -1)	0.5	0.43	0.2	0.95	0.52
16	Max. & Min. Wave height /m	0.75 & 0.29	1.05 & 0.25	0.92 & 0.27	1.19 & 0.45	0.97 & 0.35
17	Surf scaling factor /ϵ	39	59.99	46.87	52.65	49.6275
18	Breakers type	Spilling	Spilling	Spilling	Spilling	Spilling
19	Rate of sediment transport / (m.S-1)	21380.84	31884.39	14920	16225.62	21102.71
20	Wave energy (E) in /(J. M.S-2)	1228	1153	927	1407	1178.75

All these analysis leads the research to outcomes which have the final say about the physical setup of the region. Beach stage model and dune dynamism estimates have an immense effect on the livelihood options and expansions which has to be dealt in an inter-dependent manner. The beach or dune which has high risk from the stability point of view, there must be some preservation and also buffer zone to cope up with the crisis.

2.3Outcome

There are varied and vivid outcomes of this chapter which is the main foundation of the research work. These outcomes are depicted in a systematic manner keeping in parity with the analysis of the chapter. This outcome will also lead us to the final conclusion or the discussion part of this chapter.

2.3.1. Sample site selection

The DEM, the contour map, the slope and aspect map of the study area have given a broad view of the whole area. Being a very flat plain surface with average relative relief of 4 m and topographic highs of 15m and lows of less than sea level shows a complex and fragile physiographic depiction of the study area. Moreover this area is always in a constant threat from the monsoonal variations, maritime disturbances and fluvial sediment influx. So the selection of sample site has to be done very cautiously and intentionally. The 4 sample sites selected are very much representation of what problems and conditions the physiography is facing. The sample sites (Site 1 & 4) clearly cover both the physical influence from both the estuaries one being the tidal channel (Jaldha Mohona) and other the riverine system (Pichaboni River). On the other hand Site 2 & 3 shows the rage of human in the name of recreation and constant fighting of the locals with the vagaries of the environment respectively. Based on these 4sites all the other morphodynamic variables were estimated, computed and analysed to deduce the outputs.

2.3.2. Estimation of Sediment Transportation Budget

It can be deduced that as a whole the coastal region is an erosive coast. But sample site specifically demarcates the erosive area to be maximised at site 2 and the adjacent area (Figure 2.17). The reason is also clear that the two mouza Silampur and Sonamuhi are molded at its top by the tourism sector since 2009. Another output is that the eastern part of the coastal stretch has a trend of accretion relative to the others the reason being the serene beaches with adaptive locals who try to protect the nature not destroy it and one more point is that the long shore current is from the west to the east. So it’s natural that the nature also forces the sediment to drag from Jaldha to Pichaboni.

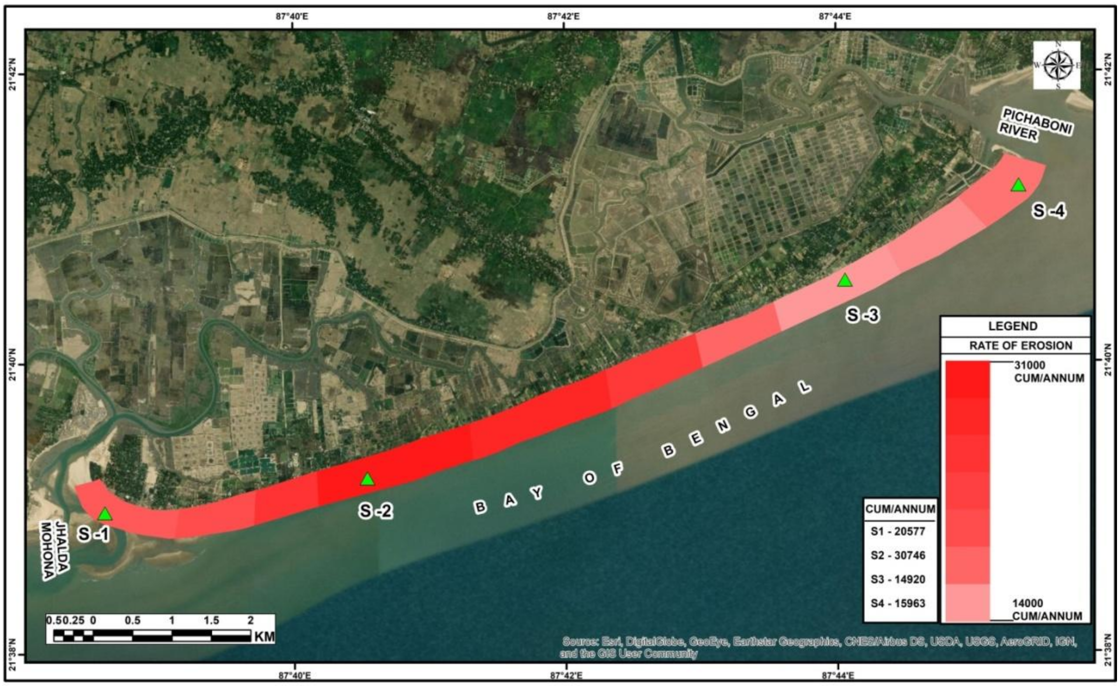

Figure 2.17: Zonation map showing erosive and depositional beach (according to sample sites)

The exchange of volume of sand at Site 2 i.e. at Sonamuhi mouza near Rose Valley or Sun City resort is 95,653.18 cu m of sediment (Table 2.22) and minimum is at Site 3, Dakshin Purushottampur at Khoti with 44,762 cu m of sediment. This leads to the prediction that the rate of transportation of sediment for beach-dune interface is 78,40,563.21 tonnes per year.

Table 2.22: Sediment transportation budget

Site No.	Name of the places	Total Change of Volume of Sand	Accretional Sand Volume cu m	Erosional Sand Volume cubic m	Rate of Erosion per year cubic m	Rate of Accretion per year cubic m	Area in sq m	Transportation Rate of Sediment per year cubic m	Transportation Rate of Sediment in tonnes per year
1	Jaldha Mohona (Silampur)	64142.52	2409.19	61733.32	20577.77	803.06	46334.68	21380.84	50906.7619
2	Rose Valley (Sonamuhi)	95653.18	3414.21	92238.97	30746.32	1138.07	87223.36	31884.39333	75915.22222
3	Khoti(Dakshin Purushottampur)	44762.32		44762.32	14920.77		96314.97	14920.77333	35525.65079
4	Soula Mohona (Dakshin Purushottampur)	48676.88	785.03	47891.85	15963.95	261.67	84816.27	16225.62667	38632.44444

Total	82208.81	2202.8	314689.28	84411.63333	200980.0794
Total Erosional/Accretional Rate in Cubic meter per year for the total Dune Coverage Area	2120551.44	56820.56	8117315	2177372.61	5184221.5
Total/Erosional/Accretional Rate in Cubic meter per year for the total Beach Dune Complex	3207100.79	85934.85	12276546	3293036.55	7840563.21
Total/Erosional/Accretional Rate in Cubic meter per year for the total Beach Shore Face	1086549.35	29114.29	4159231	1115663.94	2656342.71

The rate of erosion of sediment per cubic metre per year is highest at Site 2 (30,746.32 cu m) and the rate of accretion is also at its top at this site (1138.07 cu m). Though, there is a trend of healing with nourishment of sand by accretion process but the erosion rate is so high that it’s not able to compensate the preceding process.

Though anyone can misinterpret the map that the accretion rate is also high at the same zone (Figure 2.18) which means the region is depositional, but no, actually the accretion pockets are seen only as an area of sand refilling in the dune furrows which have been a prominent feature 3years ago. The beach or fore shore face have been so utilized with tourist activities like walking, biking, water sports (water bike, speed boat, paragliding, etc.), movement of jeeps and cars (now there is strict restriction against movement of transport over the beach due to few tourist accidents at the years 2015-2016) that the stability of the beach is also hampered.

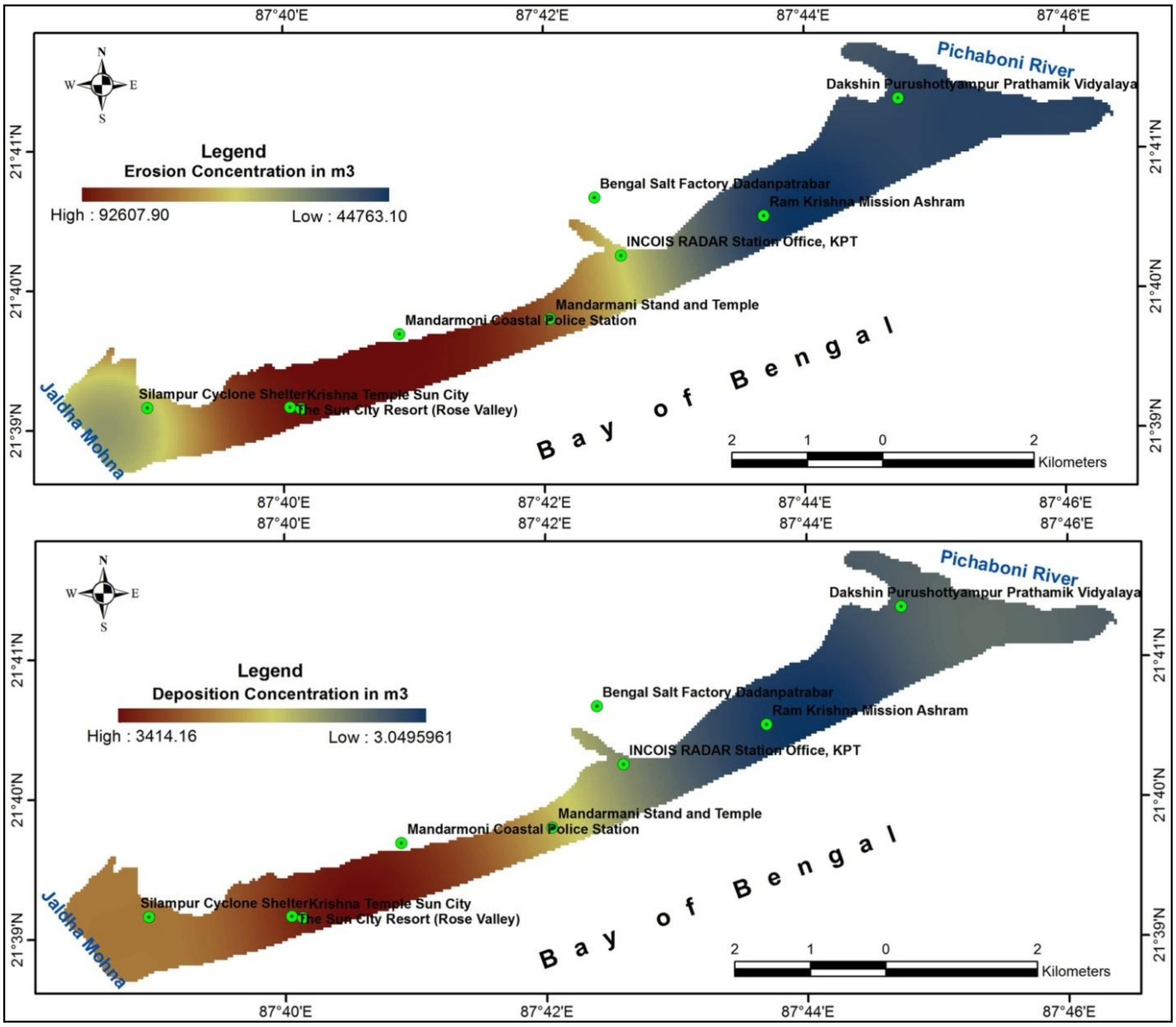

Figure 2.18: Erosion and accretion concentration zones along the beach-dune interface

2.3.3. Sediment analysis

Results of sediment grain size analysis suggest that maximum sediment particles have been deposited in the intertidal zone under diverse hydrodynamic circumstances. The cumulative weight percentage distribution of 25 samples illustrates the integration of particle size of different samples. These cumulative weights shows an interesting output i.e. most of the sediment samples collected are bi-modal (Figure 2.19, 2.20, 2.21 & 2.22) this means there is concentration of two sets of particle size most of them to be at 500 μm and 75 μm. The exceptions with unimodal distribution are Site 1 backwash (Medium sand), Site 1 middle beach face (Coarse sand), Site 2 swash (Medium sand), Site 3 dune (Medium sand), Site 3 lower beach face (Medium to Fine sand) and Site 4 upper beach face (Coarse sand).

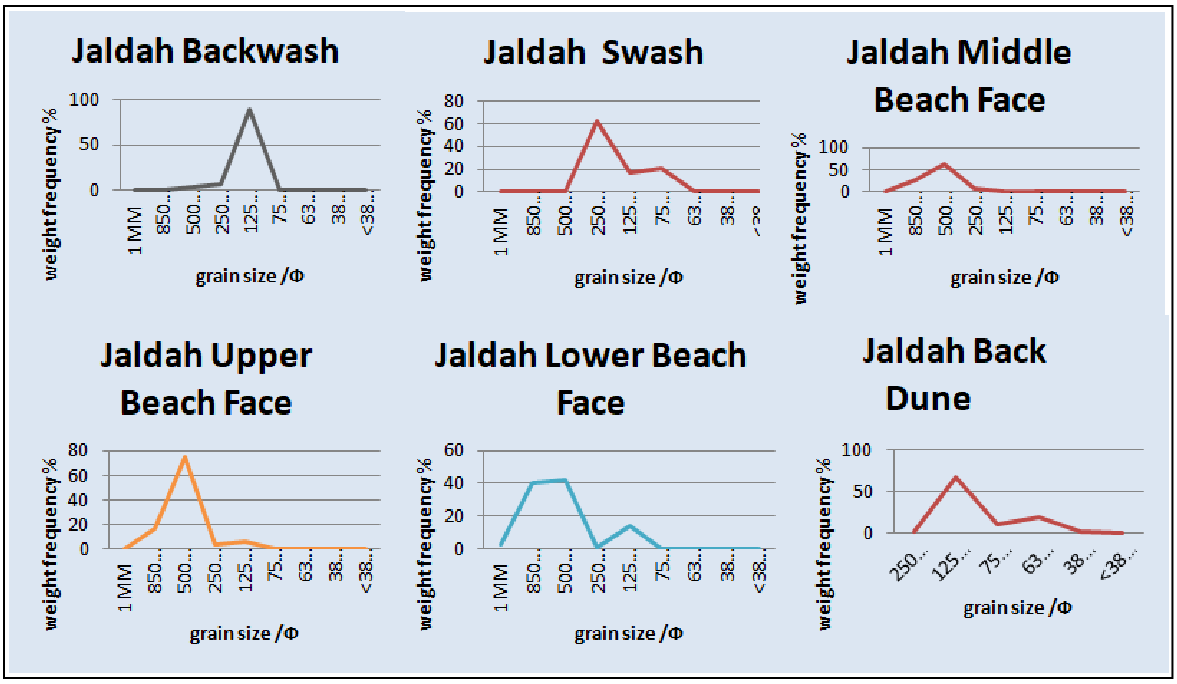

Figure 2.19: Grain size distribution of Sample Site 1

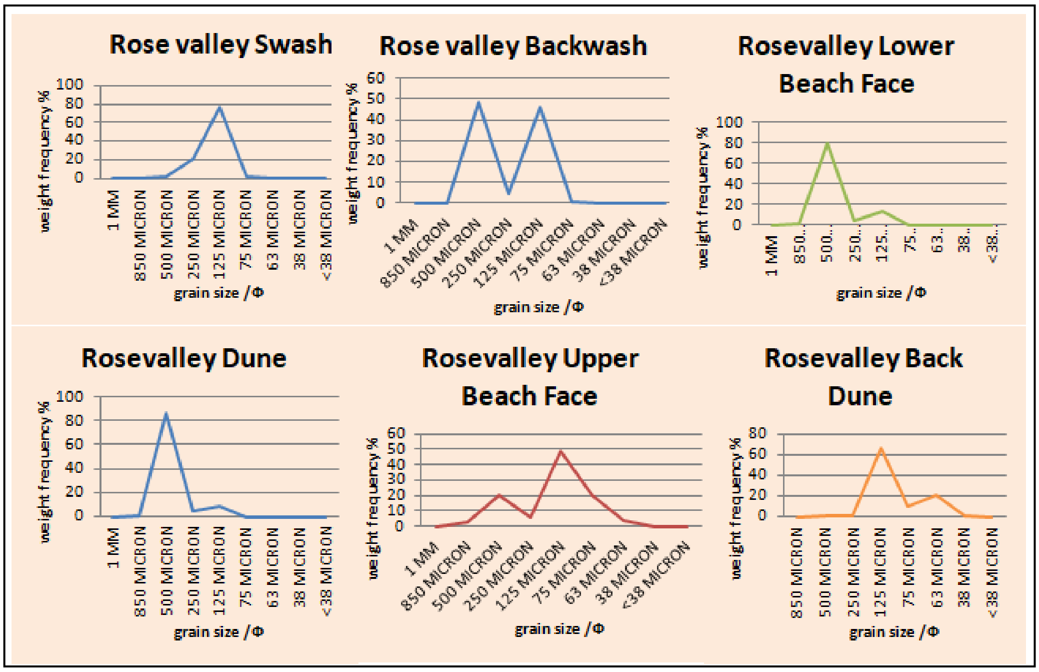

Figure 2.20: Grain size distribution of Sample Site 2

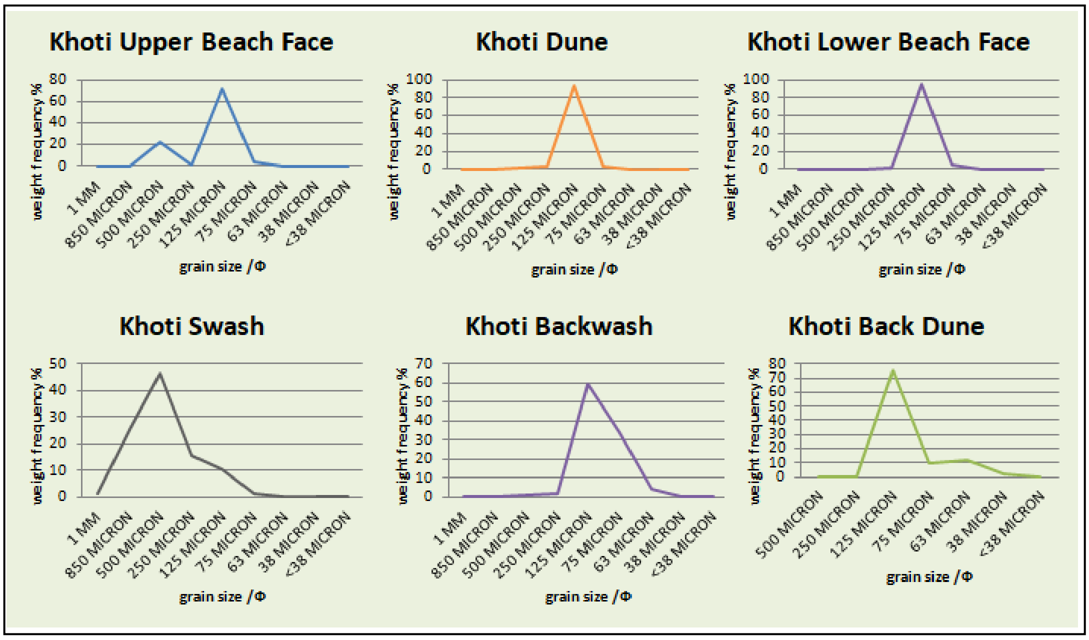

Figure 2.21: Grain size distribution of Sample Site 3

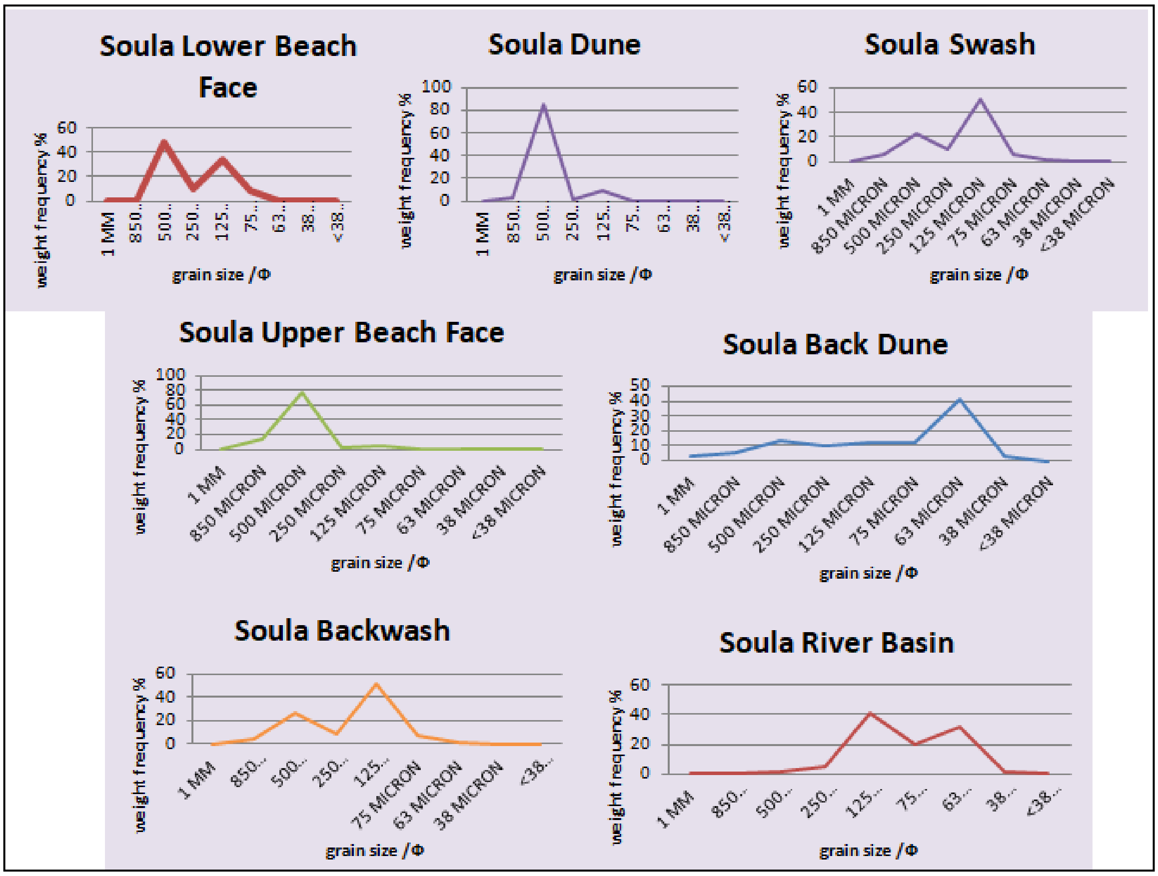

Figure 2.22: Grain size distribution of Sample Site 4

From the GRADISTAT analysis more detailed statistical results show that the samples range from all spheres of sand textures (Figure 2.23) from Very Fine Sand, Fine Sand, Medium Sand to Coarse Sand. Back dune swamp area and River bank are concentrated with Fine Sand and Very Fine Sand respectively. The Beach Face is practically loaded with Coarse Sand and Medium sand material. The dunal sediments are very well sorted and the lower beach face, swash sediment and backwash sediment are moderately or poorly sorted (According to Folk and Ward method).

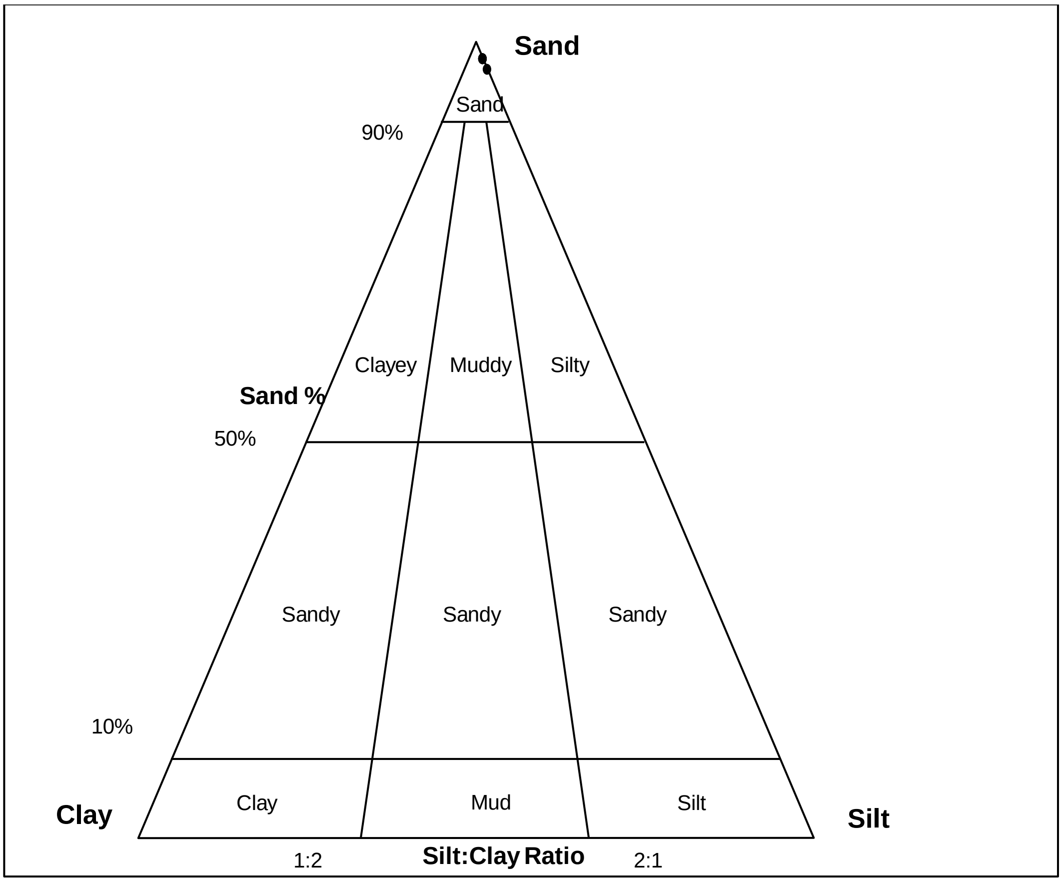

Figure 2.23: Ternary diagram showing concentration of sand particles

Plate 2.24: Collection sediment sample from lower beach face

A verbal classification for skewness suggested by Folk (1968) includes: from +0.10 to -0.10 as nearly symmetrical; -0.10 to -0.30 as coarse-skewed; and, -0.30 to -1.00 as strongly coarse-skewed. The samples with concentration of fine to very fine sand are nearly symmetric and the coarse sand is coarsely or very coarsely skewed. So the more skewed particles are found in the middle and upper beach face and also at the dune. Though there are variations in between each sample sit result for Kurtosis but there is definitely a link between finely sorted lower beach face (Plate 2.24), swash, backwash, back dune and river bank are mostly platykurtic and the remaining are to be either leptokurtic or mesokurtic. The relationship between each of the sample site is that the value of sorting of sand particles gradually decreases from Site 1 to Site 4 which represents the force of the long shore currents from west to east and accretion zone at Site 4.

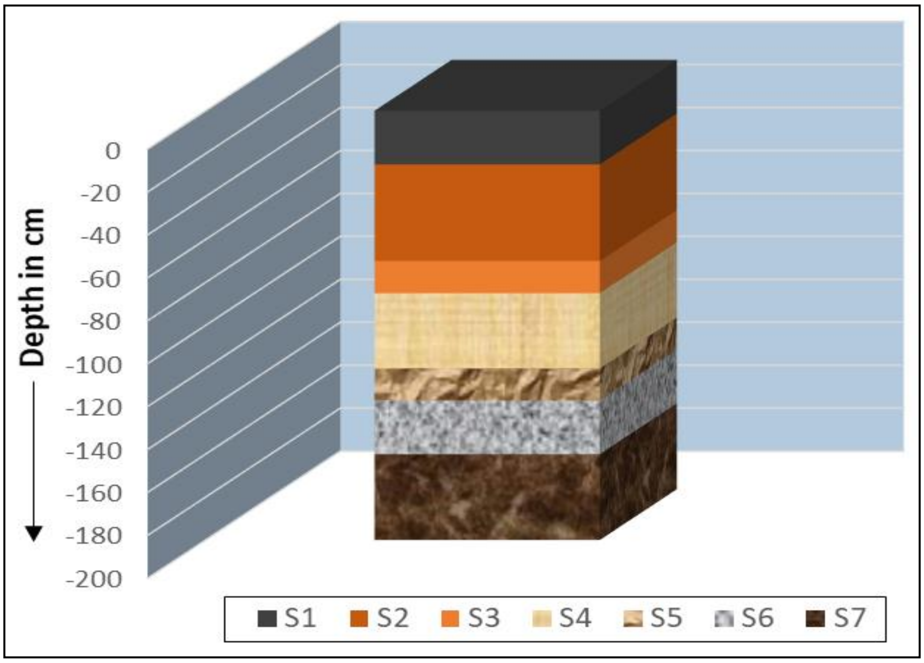

Figure 2.24: Stratigraphical representation of back dune fringe area

The 2 m stratigraphy of the back dune region (Figure 2.24) is a representation of tidal influenced accretionary layers in the soil structure. In between the muddy layers (S1, S6 & S7) of top and bottom there are sandy or sand mixed muddy layers (S2, S3, S4 & S5) caked inside. Another interesting excavation is the presence of pottery or brick like structure in the layer S5.

The burrow at the beach face made by hand piston auger showed a clear picture of the influence of both tide and wave in the accretionary process of beach. It shows a 20cm accumulation of fresh white sand at the top with finer sand particles which is mainly tidal influence. Below that level there are yellowish oxidised sand with moderate to coarser in size which is definitely wave deposited. The Dune cliff exposed the dune stratigraphy at various points along the beach.

2.3.4. Estimation of wave hydrodynamics

The relationship between each hydrodynamic attributes is the most challenging thing to understand**.** As this is a shallow environment so the wave dependent variable change according to the depth of the wave. There is a steady relationship between wave depth and wave amplitude, wave breaking height, wave height and wave relative height (Figure 2.25), which gradually and slowly diminishes as the wave depth increases. This negative relation is much stronger for Site 3 & 4 because the eastern part is much more accretion prone.

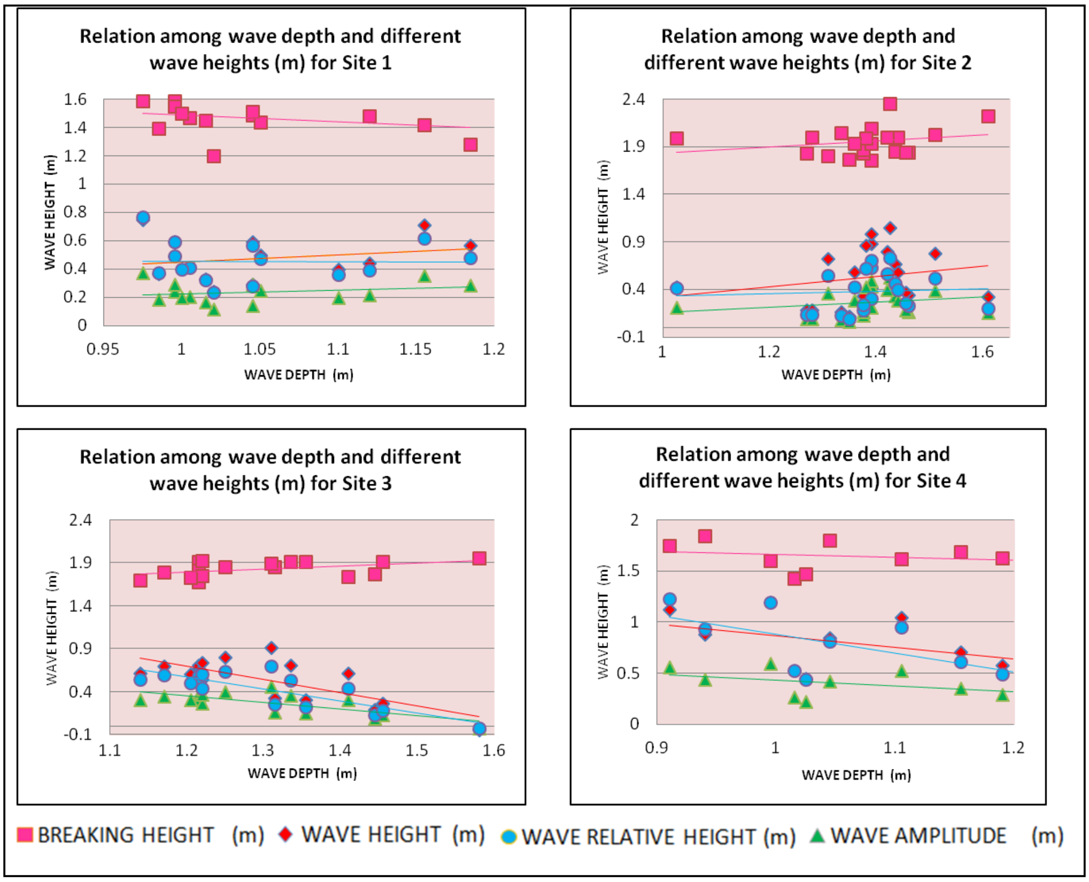

Figure 2.25: Relationship between various hydrodynamic variables

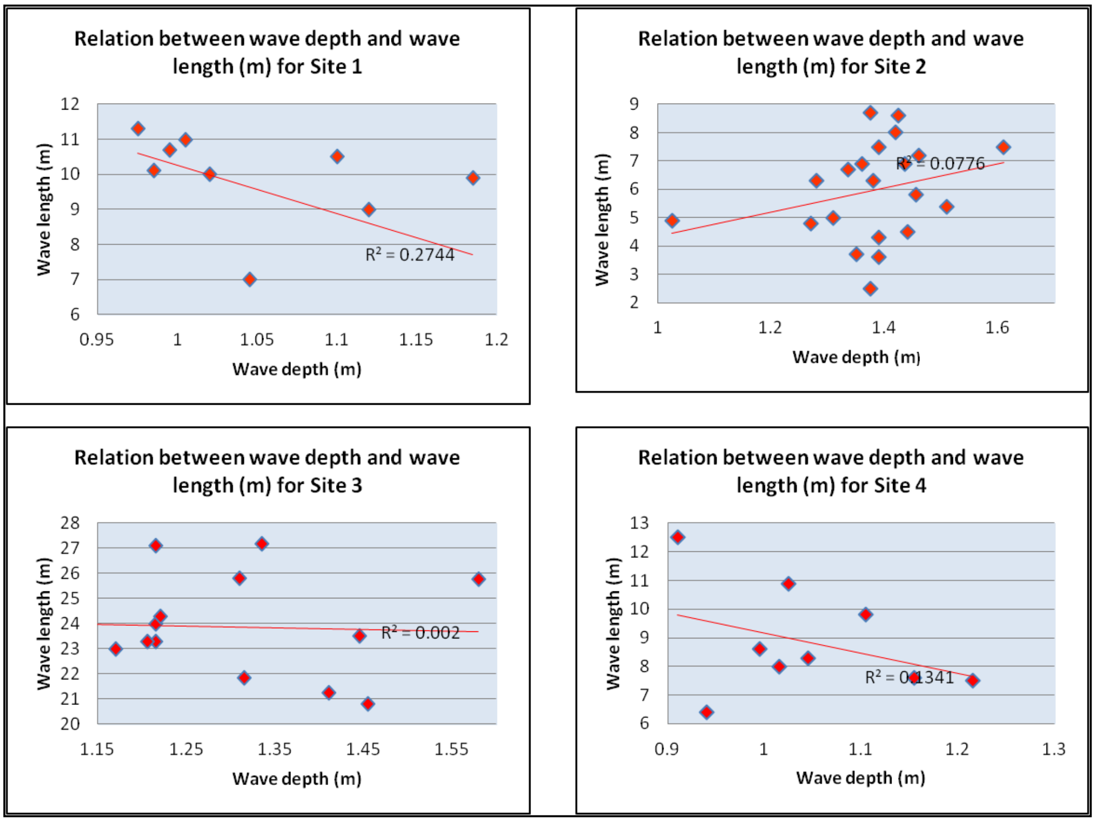

Figure 2.26: Relationship between wave length and wave depth

This is evident that there will be a negative relationship between wave depth and wave length but it is much flatter in case of Site 3 (Figure 2.26). This may be due to the near-shore bathymetry which is quite deeper in this case, that's why this site is used by the local fishermen for the boat landing station. But the exception is for Site 2 of course due to anthropogenic influences.

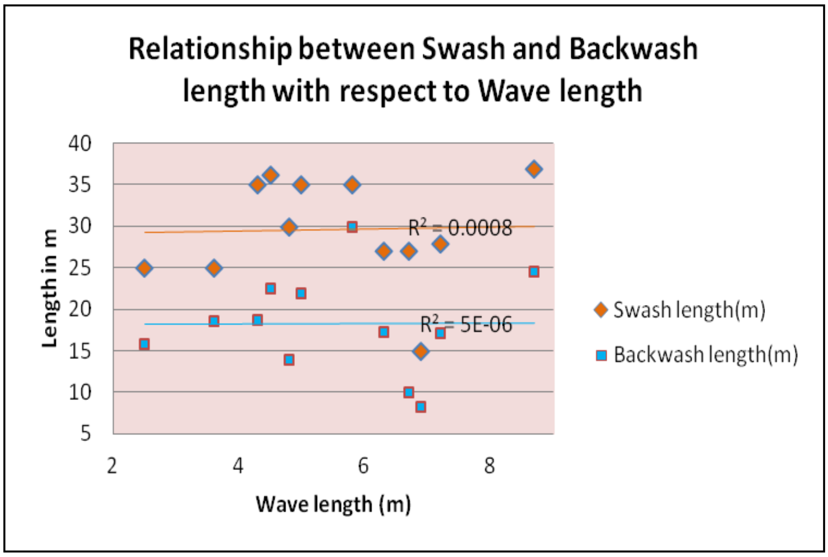

Figure 2.27: Relationship between swash and backwash length

The Swash & Backwash length data set is showing the fact that the Swash lengths are longer than the Backwash length (Figure 2.27), which means there is scope for accretion for this coastal stretch. But if we look into the mass of the sediments transferred by this circulation it is seen that for Site 1 and 3 the sediment brought in is compensated with the sediment washed out. In case of Soula the swash is much stronger than the backwash but for Site 2 backwash is quite stronger making the beach unstable inside out.

2.3.5. Estimation of Aerodynamism

It's the rule of hydrodynamics and aerodynamics that there be must a positive relation between wind speed and wave height and wave breaking height. In case of the selected area the same rule applies here also. But the striking feature is that the breaker height is much higher than the average height in case of Site 2 & 3 which is the tourism and fishing affected area (Figure 2.28). This is an alarming feature showing the rage of the breaker waves which can smash against any odds in front of them. Due to this character of the vertical cliff generated at the sample site shows the stronger backwash effect and gradually penetrating sea water landward.

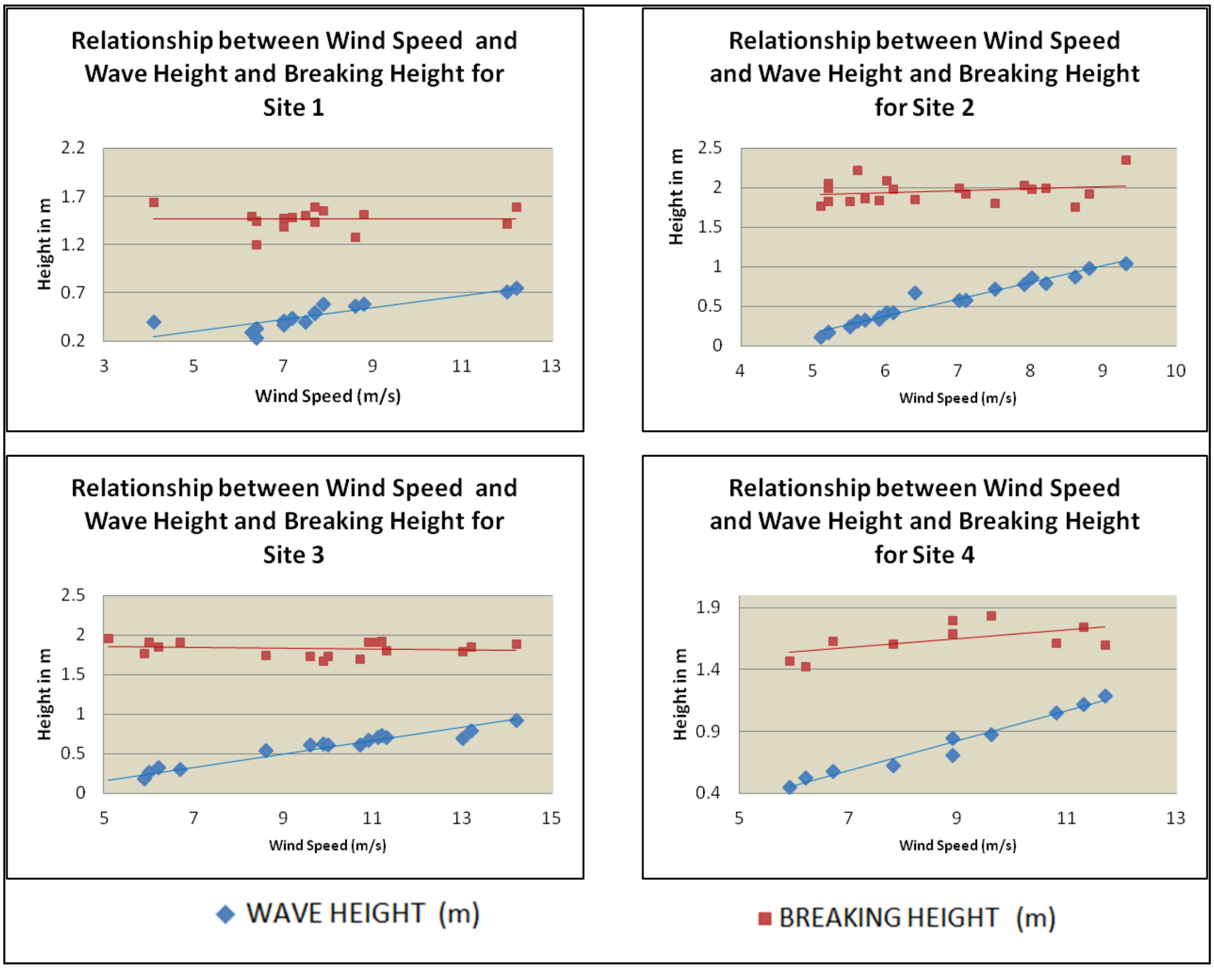

Figure 2.28: Relationship between wave height and wave breaking height with wind speed

The wave velocity is mainly guided by the wind speed so depending on the fetch length as the wind speed increases the wave velocity increases. This is a very direct and positive relation between the two (Figure 2.29). But the graph depicting the retarded wave velocity is showing either a phase of wind gap or a phase of counter current of wind from the land.

The value of Pearson's correlation coefficient of the relation is 0.44954319. The critical value of 't' at 60 degree of freedom is 1.67 (the hypothetical value). But the computed value of 't' is 3.930602 at 60 degree of freedom. As the computed value of 't' at 60 freedoms is more than the hypothetical value. So, therefore the null hypothesis is rejected at favour of alternative hypothesis. So the relation between wind speed and wave height is significant. So it is concluded that the wind is the only dominant control factor of wave parameters.

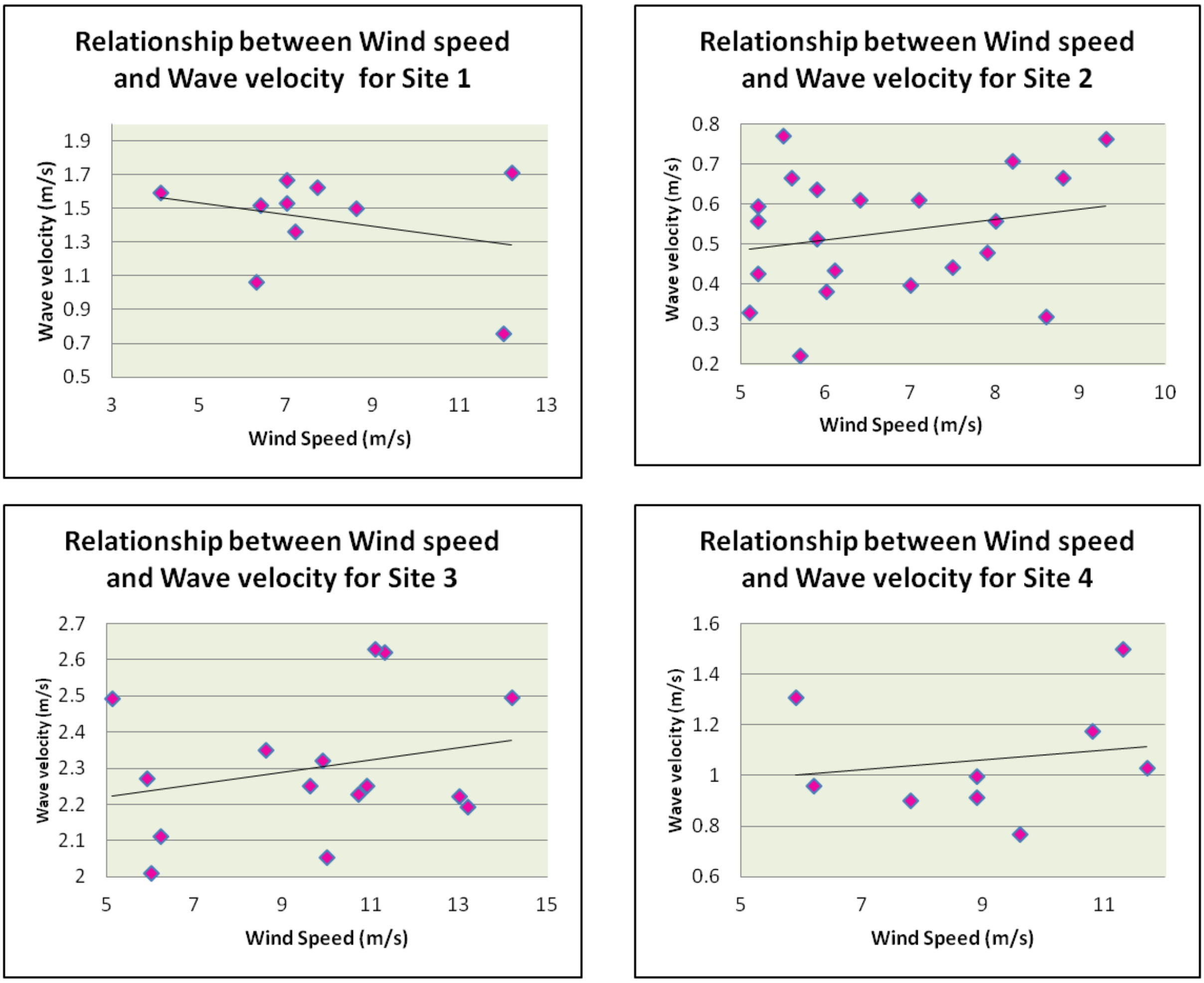

Figure 2.29: Relationship between wind speed and wave velocity

2.3.6. Estimation of Bioturbation influences on the beach morphology

In one of the 9selected bioturbation zone the grid map (Grid A) is showing the distribution of crab holes through Nearest Neighbour Index (NNI). It indicates the dispersed pattern of the crab holes. The first circle represents the number of crab holes lying in the 1Standard deviation and next big circle represents number of crab holes in the 2 standard (Figure 2.30). In this grid large crabs holes and their vertical depth is high due to the lack of human interference on the beach of this area as the site is situated beside rural livelihood.

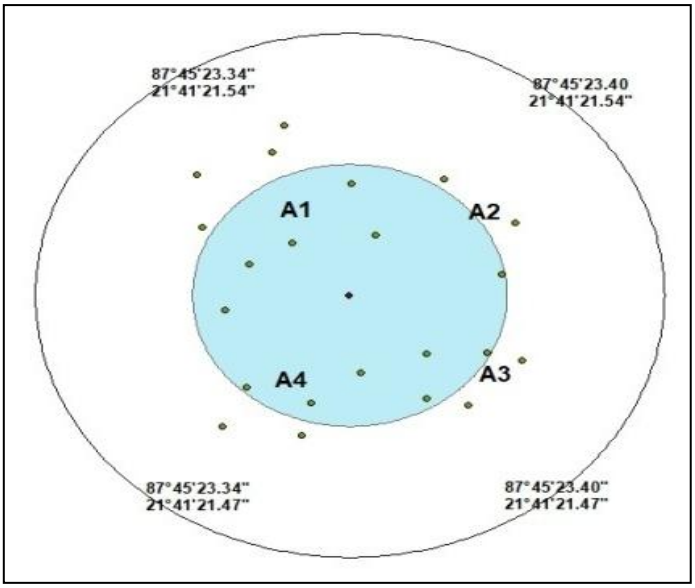

Figure 2.30: Nearest Neighbour Index

Plate 2.25: Large crab holes

It can be predicted that if in 4 sq m area 3.8 kg (Grid A sediment weighed in the laboratory) sediment is lifted by crabs, so 1sq km area can produce 950kg beach sediment.

Table 2.23: Attributes of beach bioturbation survey

Grid no	**Latitude &longitude**	**Diameter (cm)&no. Of frequency**			**Vertical depth(cm)**			**No. Of holes (per 4 sq m)**	**Weight of sediments lifted by crabs(kg)**	**Remarks**
		LARGE	MEDIUM	LOW	LARGE	MEDIUM	LOW			
1	21°41’21.54” N 87°45’23.34” E	4(17)	2.3(18)	1(22)	42	14	6	57	3.8	Fossil, root plant
2	21°41’11.41” N, 87°45’13.79” E	3.9(22)	1.8(11	.4(316)	31.5	7.5	7	350	2.3	Fossil, root plant
3	21°41’5.15” N, 87°45’4.6”E	3.6(37)	1.4(8)	.35(243)	28	6.2	4	288	2.9	Fossil
4	21°40’04.21” N, 87°42’53.97” E	3.9(27)	2.0(8)	.5(295)	21	20	7	330	7.6	Plant root ,fossil
5	21°40’0.35” N, 87°42’45.08” E	3.0(38)	1.5(4)	0.3(429)	13.5	7.3	6	471	4.7	Plant root, fossil
6	21°39’47.04” N, 87°42’20.72” E	0	.85(25)	0.32(368)	0	7.2	4	393	0.3	Fossil
7	21°39’43.77” N, 87°42’6.27”E	0	0	.4(597)	0	0	5.3	597	0.42	Fossil
8	21°38’54.66” N, 87°39’8.29”E	4.2(14)	1.7(31)	.4(553)	30	19	11	598	3.1	Roots of creepers
9	21°38’56.17” N, 87°38’57.02” E	3.4(27)	0	.2(27)	20.6	0	4.2	14	3.3	Floating material.

All the 9 grids computed together (Table 2.23) to impart a better knowledge about the bioturbation characteristics of the beach. According to the assumed diameter, 3 types of crab holes were found – large (>3cm), medium (1-3cm) and small (<1cm). But the percentage share among these 3 showed an interesting relationship with the beach morphology that large size crab holes (Plate 2.25) constitute only 5.8 % among the total and medium to be 3.3% and the remaining are small crab holes. So the nature is always trying to establish a balance in everything. If the large crab holes were found to be more then the sediment uplifted by the red crabs would be much more as the burrow hole up to a greater depth (ranging from 13-42cm).

But this phenomenon is replenishing the beach sediment and giving it a little stir and mix between the lower and upper layers of beach material.

2.3.7. Dune floral community & Dune adjustment

The extensive surface stolons and rhizomes of *Ipomaea pes-caprae* (Table 2.20) can accumulate the windblown sand particles from the wide sandy sea beaches in the dry period (Plate 2.26, 2.27, 2.28, 2.29, 2.30 & 2.31).The network of the creepers not only bind the soil surface but also can accumulate sand particles in this part of the study area. However, the back dunes are colonised by *Pandanus sp, Cyperus sp, Opuntia sp, Calotropis sp, Lantana sp.* etc (Plate 2.32, 2.33, 2.34 & 2.35) which can accumulate more sands in compare to the creeper plants. When the back dunes vegetations are partially colonised by the creepers under the shades of smaller trees & bushes they can also accumulate more sands and also stabilise the depositional surface jointly with the thick coverage of vegetation (see Appendix 2e). Ecologically the succession of the plants start from the colony of embryonic dunes and it achieves in the climax stage at the back dune area. However, in this case the climax vegetations are still absent in terms of small trees & large trees as geologically the present back dune area is younger in category.

Throughout the coastal stretches of 14km from Pichaboni to Jaldha, the shore fringe area was dominated by high dunes (8 to 22 m) with strong vegetation coverage in the previous decades (late 18th century). However, the fishermen communities occupy the dune belt for extraction of fresh waters & cultivation of vegetables with erection of temporary settlements during the decade of 1970's. The dunes were used by the local communities to grow multiple varieties of vegetables for continuous modification & transformation of soil character under dynamic environment. As the sand dune are standing over the base line clay surface and that was extended towards the inner part of the coastal wetlands, the windblown sand particles from the beach front & dune front positions accumulate over the wetland fringes to produce perfect loamy varieties of soil under azonal characters. This mechanism of the soil enrichment is known to the local people and they constructed the multiple pits over the dune top surface to accumulate the perched water table for irrigating their crops that also stabilise the soil surface of the dunal platform (3m to 8m) in place of the indigenous vegetations. Gradually the fertile areas of dunal belt were occupied by the tourism sector to develop beach tourism and nature tourism in and around the frontal villages of the coastal belt. Since 2007 the tourism sector occupied a large part of the sandy tract over the back barrier surface and wetland fringes and removed the local vegetations & settlements from the dune belts. Similarly the other villages of the coastal front positions around the Dadanpatrabar area the sand dunes are heavily utilised by the fishermen communities for fish drying platforms and wetland fringes were utilised for salt processing & fish farming activities in the present study area. However the natural landscapes are still preserved partially in the eastern part of Dakshin Purushottampur towards Pichaboni river mouth. After the incidences of Aila cyclone (2009) and other following cyclones the sand dunes of the coastal belt are modified into low height platform with significant cliffing at the seafront position by advancing sea.

Plate 2.26, 2.27, 2.28, 2.29, 2.30 & 2.31: Dune adjustment with floral community


Plate 2.32: *Opuntia stricta* Plate 2.33: *Tamarix aphylla*


Plate 2.34: *Ipomea pes-caprae* Plate 2.35: *Pandanus tectorius*

The degraded sand dunes and sea beaches are now unable to hold the advancing high tide water & storm tide water at different seasons and the entire shoreline is significantly affected by encroached over wash fan deposits across the beached and dunes. During the high phase of tides many areas of low lying surfaces are breached by high tide water and the back shore areas become inundated by salt water encroachment.

2.3.8. Micro geomorphic features

Though the dunes are acting as a topographic rise in this region but with the accelerated influence by the tourism flourishment few breach points and dune blowouts (Figure 2.31) are noticed through which saline water intrusions are happening.

It has been traced out with its morphological behaviour that this region has been developed in a back spit environment so the sediment filling processes are still going on. This process is also one reason for the filling up of the back dune wetland surface (Figure 2.32) and making the shallow depressions inhospitable for pisciculture other than the anthropogenic influences.

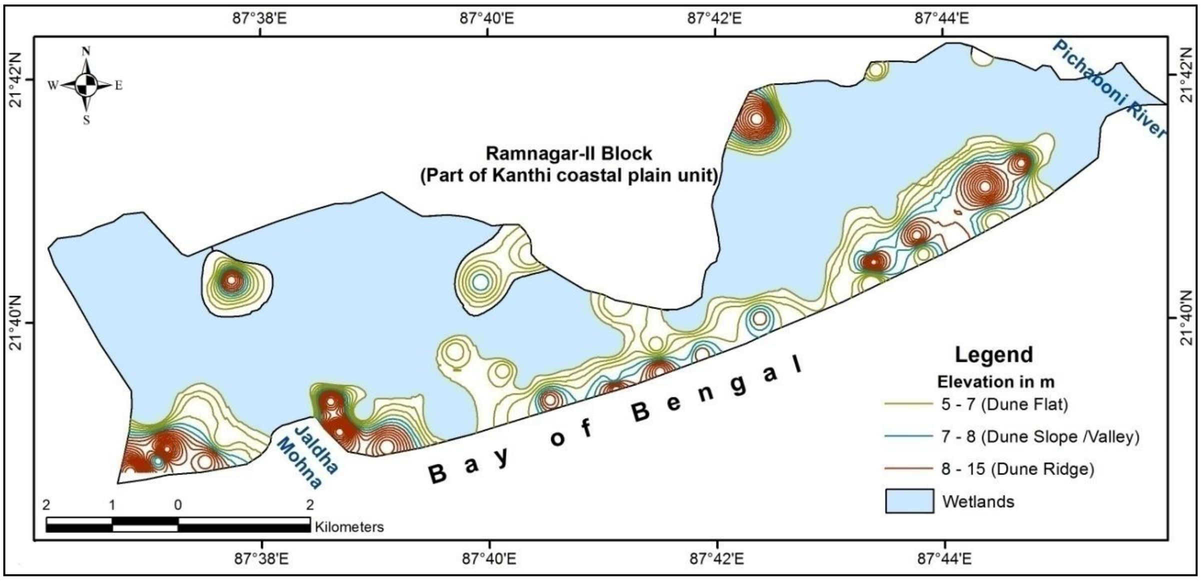

Figure 2.31: Micro geomorphic features of dune

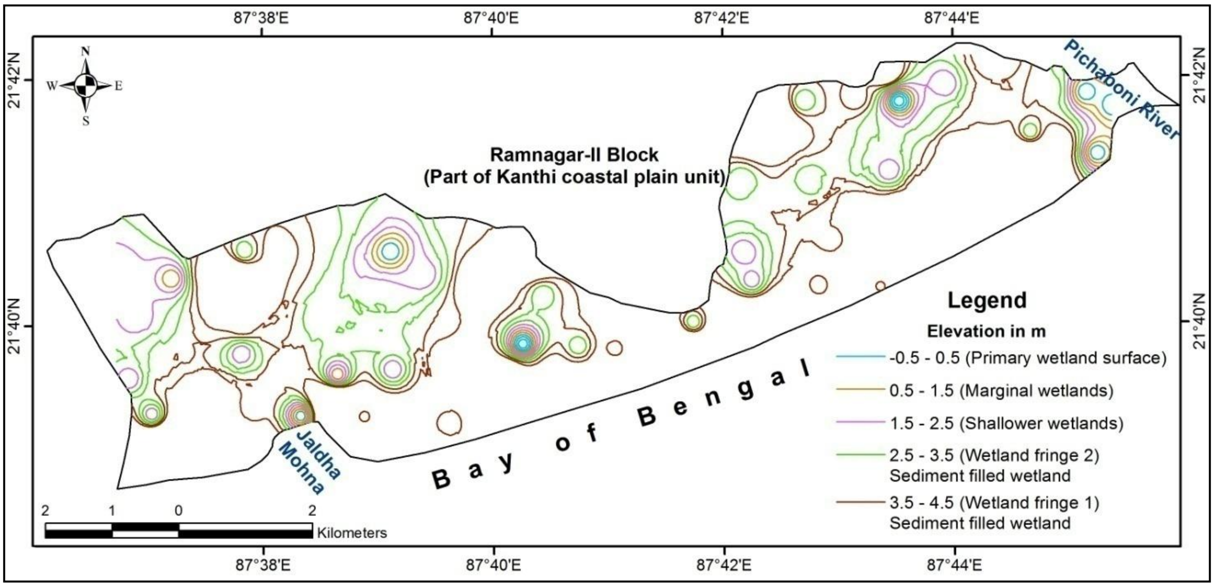

Figure 2.32: Micro geomorphic features of wetland

From beach mapping through grid method (Figure 2.16) the beach area is mapped to its extent. 10 zones were identified on the beach as well as during analysis. The adjacent dune region has an elevation of not more 2m from the mean sea level. The dune shape shifts from sharp cliff (Plate 2.36) with concave slope facing the sea during monsoon and post-monsoon season to a convex mound of sand during pre-monsoon phenomenon. This zone transits its position back and fourth from rainy to dry season respectively. This acts as a litter zone when the HTL touches its base. But in this map (Figure 2.16) the zones were identifies from the base of the dune. These 10 zones were again divided into 3beach faces- upper beach face, middle beach face and lower beach face. The upper beach face has characteristics like berm with creepers, asymmetric ripple marks, drifted shells, litter zone and shoal marks. Middle beach face comprises mainly with ridge and runnel topography (higher slope angle 6-8^{o}) and bioturbation zone. And the lower beach face (beach slope of 5^{o}) has alternate bands of swash and backwash marks (parallel ripples) or cross ripple marks meeting the near-shore bathymetry. Also there is a seasonal shift in between beature showing mainly in the lower beach face. During the heavy downpour from south-west monsoon strong and definite rip channels (Plate 2.37) generate here accelerating erosion process. But during the month of January to May alternate micro cusp and bay features are pretty much prominent. So the beach is showing a shift of features from dissipative to reflective beach type.

Plate 2.36: Dune cliff

Plate 2.37: Rip channels

2.3.9. Estimation of Beach-Dune Morphodynamism

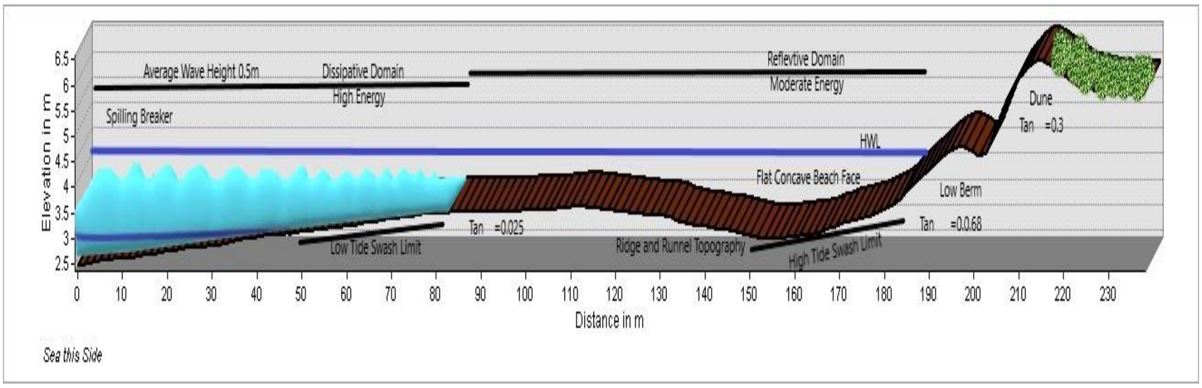

Figure 2.33: Beach-Dune Stage Model

All the analysis proves the fact that this coast is an admixture of dissipative and reflective beach (Figure 2.33). The beach and dune adjusts among themselves for their progression and also adjust with the high wave energy at the lower beach face and moderate wave energy at the upper beach face. The beach stage model can never be separated from the dune dynamism in case of Mandarmani coast because beach forms the dune and dune protects the beach and the back dune region. So all the attributes acting upon the landform is very much interlinked with each other. In between two tidal channels i.e. Jaldha tidal inlet and Pichaboni River lies the Mandarmani tidal system (Figure 2.35). Under this system there are four subsystems- Beach, Dune Barrier and Wetland. Further smaller subsystems are seen within Wetland subsystem- Channels, Mangroves, and Tidal Flats. These subsystems interact with each other and within themselves creating a morphodynamic setup of the whole tidal system (Figure 2.34). This interaction between system and subsystems made by all the hydrodynamic and aerodynamic attributes lead to the landscape evolution of the area. Moreover the system-subsystem setup are again influenced by external forces or the entropy i.e. the storm, sea level rise, fluvial influence (from the Hugli Estuarine system or Subarnarekha Fluvial system), geology and tectonics and also anthropologic pressures. All these characteristics lead to the adjustments of the equilibrium within the Mandarmani Tidal/Coastal System. Each entropy forces influences each subsystems individually and collectively which distorts the equilibrium condition. The recovery phase taken for adjustment of this equilibrium setup if took a longer period calling a positive feedback system, may take years or decades for balancing this imbalance. But if there occurs a negative feedback system among the entropy then the recovery phase will be smaller and equilibrium can be easily reinstated (Masselink, et.al. 2011).

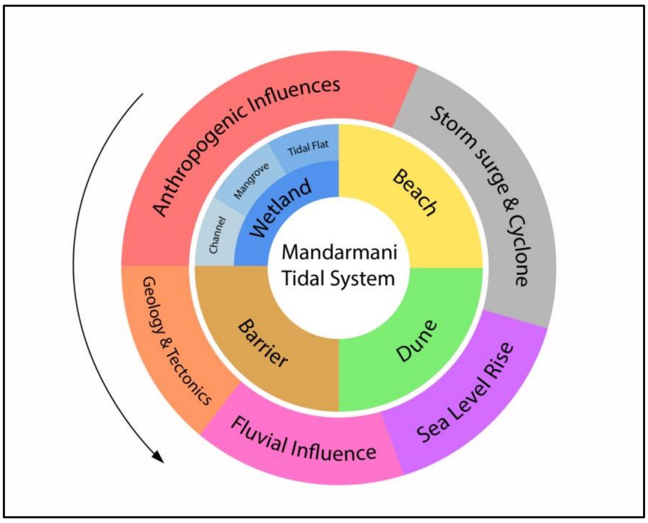

Figure 2.34: Relationships between the external forces and local morphological features and their interplaying processes.

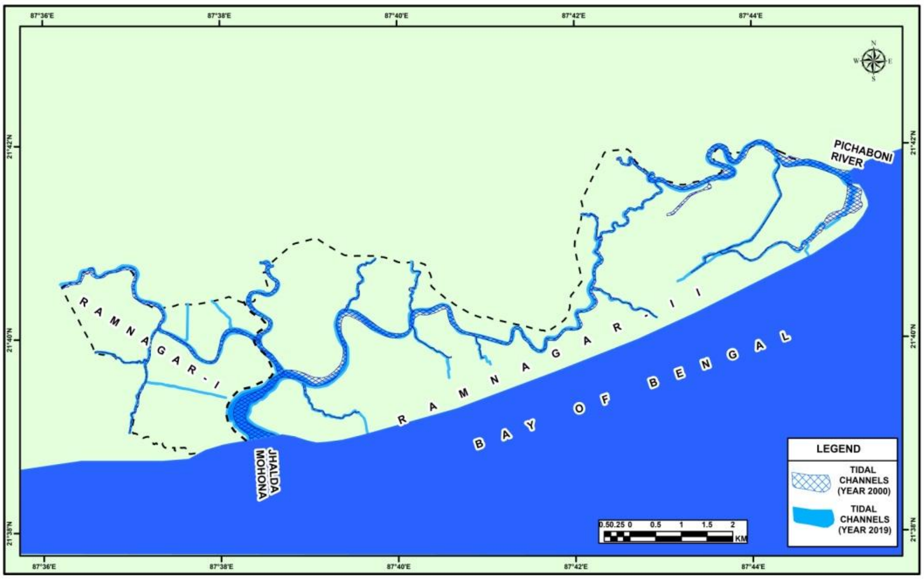

Figure 2.35: Tidal channels shifting through years

Plate 2.38: Destruction of fauna

Plate 2.39: Destruction of environment

Plate 2.40: Destruction of flora

Plate 2.41: Destruction of tourism

2.4 Discussion

From the Beach Stage Model (Figure 2.33) it is evident that the Mandarmani beach is in a dissipative stage but with seasonal fluctuation the character of the beach shifts from dissipative to reflective. Dune stability is interlinked with the beach status and the progradation and advancement of dune solely depends upon the moisture condition and the floral community. 7840563.21tonnes of sediment is being transported per year through the long shore current from west to east. The erosion and accretion concentration zone of the beach dune complex are both concentrated near the tourism sector. This is not a state of balance but an immense state of imbalance because this is the signature of dune flattening and deposition only in the dune furrow regions. The sediment sieving method is clearly showing that the sands are medium to fine grained and the fine grained percentage is gradually increase from west to east which also proves that longshore transport is more prominent from west to east with maximum effect on the coast. But keeping parity with the cell circulation system the long shore movement of sediment also transports from east to west during North-east Monsoonal wind. The two morphogenetic regions of dune and back dune wetlands are facing two different crisis situations with 4 breaching points and dune blow outs and sediment filling process in the shallow depressions. The hydrodynamics and aerodynamics are directly related but with changes in particularly the tourism sector. The *ipomea sp.*, *laurenia sp.*, *sessuvium sp* are the dominant floral species which try to stabilise the unconsolidated dune structure and arrest fluctuation. In situ and laboratory experiments show that the dimension of crab holes varies from 0.2 to 4.2cm in diameter and 4 to 42cm vertical depth and 2.3 to 7.6 kg weight of crab uplifted nodules. This bioturbation method is continuously replenishing the beach sediment and helping the stabilisation process. The *casurina* tree plantation is the most unscientific management strategy because this process totally hampers the dune structure and its free movement. Moreover it leads to dune cliffing, dune erosion in the shore front side and dune advancement in the lee side of the dune. Sometimes it generates the formation of dune blowouts and overwash deposits in the landward side. Here in the relation between wind speed and wave height is moderately positive relation.

The final result can be explained as, first outcome is considering mainly the excessive exploitation of coastal resources by the tourism industry through sand mining, constructing concrete buildings and roads within few metres of High Tide Line (HTL) clearing the natural forest cover, restricting the natural movement of sand dunes to and fro daily and seasonally, extracting ground water and lowering it immensely resulting on the salt water intrusion, etc. The second output shows that the eastern part of the coast is more protected and mainly a zone of accretion, which can be explained along with other results.

Understanding the dynamisms of shoreline processes of the local and external systems indicate there should be an well kept wide and open space immediately behind the shoreline and two active tidal streams to interplay the marine, coastal, tidal, aeolian and biological processes for natural adjustment with dynamic systems. Such dynamisms of coastal processes with climate variables and sea level variations will produce damages on the land and resources (erosion, inundation, salt water encroachment etc.) that can influence directly over the livelihood patterns and dynamic adjustments of the local people. In the next chapter of the thesis, an attempt is made to analyze the livelihood diversification and rapid adjustments made by people with changing physical conditions of the coast.