Chapter I

Foundation of the Research Work

1.1 Introduction

Beach morphodynamics is the interaction and mutual co-adjustment of intertidal beach-surf zone morphology, the hydrodynamic variables including the wind; beach gradient and sediment (Short, 1979). Beach stage dynamism is a model put forwarded by A. D. Short in 1979 on selected coastal stretches of Australia. Based on his model and also multifaceted attributes a beach stage dynamic model has been put forwarded in this work. However the formation and dynamism of sand dunes as a sedimentary depositional environment also behave differently in different parts of the land by process variables. Such continuous modification of sedimentary depositional environment over the time create or build up the specialized land surface supported by tropical floral structure and community pattern on the basis of available moisture condition and wind regime. The loss of vegetation from this natural built up surface increases the dynamism of surface stability of sand dunes. In the present study the dune features and their dynamism are identified to build up a dune stage morphodynamics model. Human processes with different livelihoods and tourism recreational activities enter into the process as modifying agent. The future of tourism development on the basis of local tourism products (beach and dune landscapes) depends on dynamic behavior of temporal and spatial change of the sedimentary depositional surface. The dynamic behavior of beaches and sand dunes as well a wet lands will produce the impact over the tourism and recreational development of the region, if the climate change induced coastal chaos increase steadily in the tropical coast in the near future.

The world's coastline comprises of 40% to be under 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 four highlighting determinants 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. The beach morphology is also 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 methods to record 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 method which can later be translated into a Digital Elevation Model (DEM) using computer software like Google Earth and ARC GIS (Geographical Information System). 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. In the present study, repetitive survey has been carried out in three seasons as much as possible to fulfill the task.

The thesis considers the adequacy of existing theories regarding beach stage model, dune dynamics, livelihood vulnerability and sustainable tourism development. In particular the thesis examines the difficulties for the growth of tourism sector and livelihood diversity against the backdrop of a morphodynamic model on beach and dune. So this assessment study is not only carried out to justify the title with its context, But also for understanding the processes of the coast to consider the better management options by the coastal managers and administrators in the dynamic coast.

1.2 About the study area

1.2.1 Physiographic settings of the study area:

The area selected for this study is the part of the extensive shoreline of Bay of Bengal along the West Bengal coast (157 km including islands), popularly known as Mandarmani Beach, a fast developing sea side resort village. In attempting to assess the reasons behind the risk in environmental change, geomorphic variability and livelihood diversities, it is particularly important to understand the physical setup of this coastal stretch. The coastal stretch extends from Jaldah estuary in the west to Pichhaboni inlet or Soula estuary in the east. It was argued to be the longest (14km) drivable beach in India. The latitudinal and longitudinal stretch of the coastline is about 21^{o} 38’34.40’’N to 21^{o}40’51.83’’N and 87^{o} 36’09.10’’E to 87^{o} 46’ 45.15’’E respectively (Figure 1.1). The administrative extent of the selected stretch is comprised mainly of 11villages viz., Dakshin Purushottampur, Mania, Dadanpatrabar, Sona Muhi, Silampur, Mandarmani, PatharMunha, Baichibania, Tajpur, Alampur and Junbani (based on 2011 census). Out of 11villages former 8 villages fall under Ramnagar II Block and last 3 villages come within Ramnagar I Block of the Contai Subdivision of the District of Purba Medinipur, West Bengal.

This is relatively flat beach with undulating upper and lower beach face 0.5 to 2.5m wave height with a strong easterly or south-west winds, but high energy storm wave height reaches upto 6m creating a significant deformity on the beach compactness and dune barrier (INCOIS- ODIS wave rider buoy for Digha and Mandarmani). Morphologically the beach has a high compaction with gently sloping gradient of 1^{o} to 5^{o} towards the sea. The tidal range is recorded to be 2-4.5m in this zone belonging to a meso-tidal regime with a fluctuation of spring tidal range. This juxtaposition of fluvial, tidal, marine and atmospheric influences continuously generates and degenerate the micro to macro level geomorphic features of the beach and dune. Backshore beach is featured by dune tail, undulating shallow dune depressions, marshy tract, low lying wetlands, back swamp etc.

However the present scenario is in a constant threat from three different influential perspectives. Firstly, the seasonal dynamism leads to a variation in beach and dune rhythmic features (Komar, 1976) viz., beach lowering, dune retro-gradation and dune advancement, sand encroachment, seasonal wave dynamics with rising high tides modifying the depositional environment over the sea face and inlet mouths, micro cusp generation, varieties of ripple marks creation, berm formation (dry season) and erosion (wet season), rip channel and ridge and runnel topography and sediment circulation cell development. Secondly, the episodic events like the tidal waves flooding the shore front and backshore region, high intensity storms and cyclonic disturbances pressurize the seasonal to and fro and hazardous erosional and accretional dynamism become prominent. Dune lowering, dune cliffing, sand spraying by strong winds, tidal mud exposure on the beach face, over wash deposition, etc. are the striking signatures. Lastly the influences from human interference through livelihood variability and tourism development create more pressure on the natural processes of dynamism and more destruction of rich and lustrous environment. It's really a controversial legislative issue whether the tourism development shall be promoted or it will be stopped from further progress and in what way. Evidences of the conversion of the original landscape are dune flattening, wetland filling, diminishing or weakening dunes as physical barrier, groundwater lowering by over extraction, saline water intrusion and further encroachment of the saline water to the freshwater aquifers. The vegetation plays a very crucial part in protecting the dune and back dune environment. Mangrove and salt marshes of wetland areas of the back shore and tidal embayment and dune floral community over the sandy surface are playing stability factor for the unconsolidated sediments. So the unscientific exploitation and removal of this green layer is showing to be a more vulnerable condition inviting more extreme environment in the near future. In particular the thesis examines the difficulties for the growth of tourism sector and livelihood diversity against the backdrop of a morphodynamic model on beach and dune.

Coastal zones are one of the most dynamic units on the earth surface. Here per unit energy flux is very high. India is blessed by a continued shoreline water locked peninsula from East, South and West. Compared to the western part, the eastern coast of Indian Sub-Continent experiencesa lot of dynamism in terms of coastal stability. West Bengal has a substantially long coast line of almost 325 kilometers (including island) characterised by great diversity in floral and faunal species, diversity in geomorphic feature and anthropogenic intrusions. Topographical and physiographical outlook are controlled by geographical aspects of processes and responses.

Mandarmani is almost 180 km from Kolkata Airport on the Kolkata - Digha route. It was the longest drivable beach in India (driving was restricted after 2016 accidents). The study area has relatively shorter waves than nearer tourist beaches of Digha, Tajpur and Sankarpur. After the discovery of this beach it was at first named Mandarboni and also Madar Mani but with evolution of time the name became Mandarmani. Known for its scenic beauty, adjacent to Sankarpur Beach, another rising tourist spot is a regular fishing harbour.

Purba Medinipur district is part of the lower Ganga Plain. Topographically, the district can be divided into– (a) undulating flat plains and (b) the coastal plains of the south (Contai Coastal Plain). The vast expanse of land is composed of younger deltaic alluvim and coastal alluvium. The elevation of the district is within 10 meters above mean sea level. The district has a long coastline of 65.5 km constitutes five coastal CD Blocks, namely, Khejuri II, Contai II (Deshapran), Contai I, Ramnagar I and II.Cyclones, storm surge and tidal floods are quite regular in these five blocks. The major rivers dissecting the platform are Haldi, Rupnarayan, Rasulpur, Bagui and Keleghai, flowing mostly in north-west to south-east direction. The district has a low forest cover (899 hectare), which is 0.02% of its geographical area.

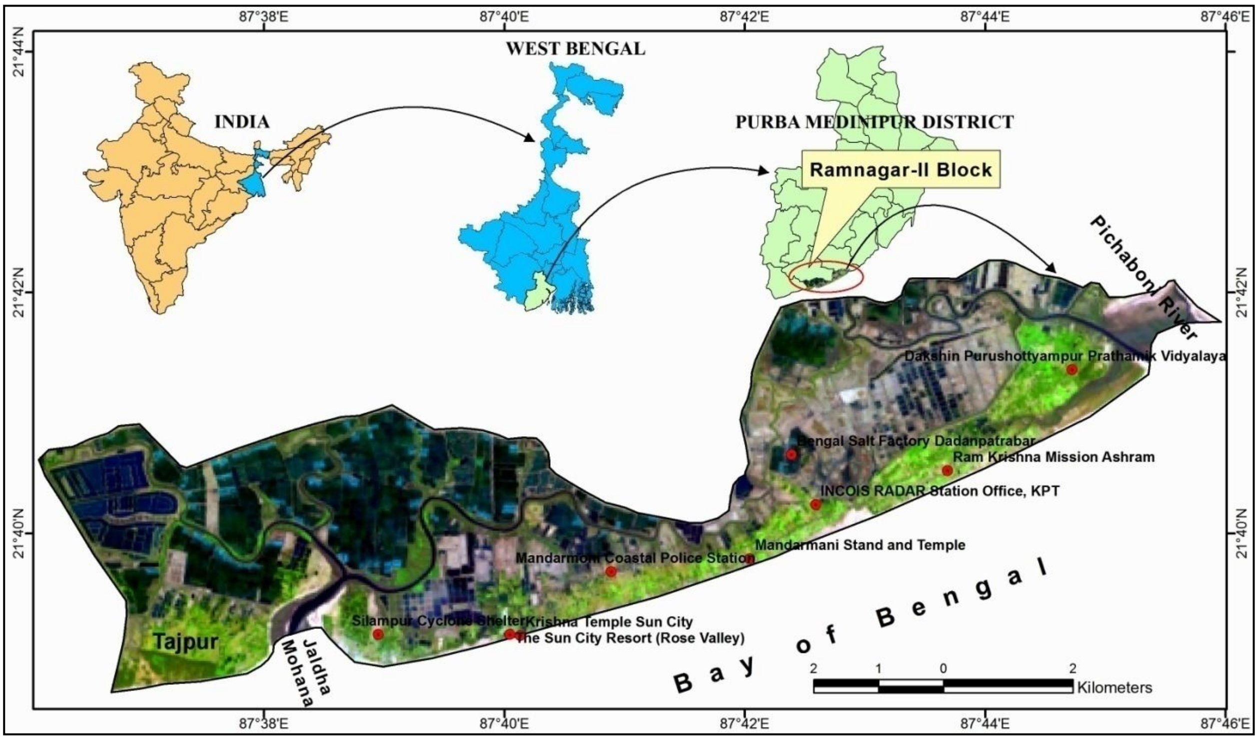

Figure 1.1: Location map of the study area

Ramnagar II CD Block is surrounded by Egra II and Contai I CD Blocks in the north, in the east Contai I CD Block, southerly limit by Bay of Bengal and Ramnagar I CD Block in the west. It is 89 km away from Tamluk, the district headquarter. Ramnagar II Block with an area of 163.27 km^2 has 137 mouzas and 134 inhabited villages. Headquarter of the CD Block is at Bara Bankuya. Gram panchayats of Ramnagar II are: Badalpur, Balisai, Depal, Kadua, Kalindi, Maithana, Paldhui and Satilapur. According to Census 2011 information the location code or village code of Mandarmani village is 347093. Mandarmani village is located in Ramnagar II Tehsil of Purba Medinipur district in West Bengal, India.

Tamluk and Baisai is the district & sub-district headquarters of Mandarmani village respectively. Digha is nearest town to Mandarmani which is approximately 23km away.

1.2.2 Late Holocene Geomorphology of the Study Area

The Mandarmani coastal plain is situated within the delta region of Subarnarekha River and extends from Jaldah estuary in the west to Pichhaboni inlet or Soula estuary in the east. Sedimentation from Hugli River Estuary is also a prominent influence on its mechanism. The geological history of the coast is comparatively short and it dates back to not more than 2900B.P. i.e. the Holocene Epoch (Maiti, 2013; Rao et al, 2020). During this period Mandarmani coast experienced with few stages of sea level rise with gradual sediment deposition over the lower beach ridges to form elevated dune ridges.

Most of the sediments are deposited within these sand dunes which are carried along by long shore currents during strong monsoon period from shallow sea of the Subarnarekha river mouth areas. Sand dunes are formed with material contents of medium grained semi-compact grey sands. Sandy beach is composed of very fine, white to grey sands mixed with clay particles.

So many research works resulted with shoreline shifting concluded that a negative rate of shoreline shifting is observed during 1973 to 2003 with a rate of -19.98m/y as highest and -11.10m/y as lowest within Mandarmani coastal stretch (Maiti& Bhattacharya, 2009).

The geomorphological consequences of this transition zone areunder the influence of fluvio-tidal and marine processes superimposed upon the geological events of Holocene epoch of marine transgression and shoreline progradation. This beach having almost east-west extension has to face vagaries of atmospheric and marine events of the North Bay of Bengal.

1.2.3 Relationship with geology and physiography

The local alluvium coast has evolved during and after the Late Holocene stage. There are mainly two types of deposition. One is Marine Alluvium and another one is Fluvial Alluvium which is controlled by sea level rise and fall. According to age of formation, there are mainly three categories – 1) 6500-7000 years (Contai formation), 2) 3500-5500 years (Sezua formation) and 3) 1000-2900 years (Digha formation). Mandarmani is related to the recent Digha formation. The typical formation of the district is laterite, which veiled nearly the entire country in the north and west, but the younger alluvium of the Gangetic delta wraps the south and east. The beach mainly contains sand, shells, and very small grains. The red lateritic rocks envelop a hefty area, but the only variety detectable on the surface is a gravelly and nodular rock. Frequently the detrital or nodular laterite is like loose gravel, each nodule being separate, but not uncommonly it has been cemented into a solid mass, which can be quarried like any other rock. This gravelly laterites or *moram* are noticeable as exposed mounds or even used for building cart tracts at rural arears. In very few places the actual contact of the laterite with the underlying rocks can be traced. The soft and clayey mass with sharp angular pieces of quartz is also available and they are cemented by peroxide of iron into a mass closely resembling the ordinary laterite of the country.

1.2.4 Climatic characteristics

Climate in the study area is variable in character. There is a wide range of variation in temperature, rainfall noticed. April, May, June, July is the hottest months when the day temperature reaches to the highest point. The minimum temperature is found in December to January which is coldest months. Rainy season extends from June to November. South-west monsoon and north-east monsoon blows blow alternatively throughout the year. However, the wind velocity and direction of the coastal wind system are also affected by the influence of land breeze and sea breeze. Climate extremes are followed by the attack of tropical cyclones in the monsoon season and Nor'wester in the pre-monsoon season. These cyclonic storms clubbing up with high tides may render in overtopping of natural protective embankments or coastal dunes, thereby spoiling the standing crops and rendering soil salinity.

1.2.4.1 Rainfall

In the cold weather months of November and December very small amount of rainfall occurs monthly, if any rain happens that is due to the northward movement of cyclonic storms, from the south of the Bay of Bengal. From the end of December with the north-east trade making the foot hold, cold season storm commences by shallow depressions, whose sources are mainlynear north- west Bay of Bengalwhich moves eastward. They produce light showers from cirrostratus clouds. These depressions persist during the blazing hot months, but after the monsoonal winds have commenced, thunderstorms are as frequent a feature as they are the reverse in cool months. Local sea breeze commencesat the end of January or the beginning of February. They increase their velocity and strengthto extend their influence further inland as the temperature rises again completing the cycle. Occasionally during the scorching months of April, May and June, periods of atmosphere disturbance are of most importance with local hot weather storms usually called nor'westers. These thunderstorms are generally accompanied by heavy showers. The annual rainfall varies from 1400mm to 1600mm. Kanthi littoral part receives high rainfall which gradually decreases towards the northwest of the district. During the monsoon season the weather condition in Ramnagar are very much the same as in other parts of South-West Bengal.

1.2.4.2 Temperature

The average temperature of the study area is 26.5^{o} C having broad variation of temperature. Generally temperature starts to rise rapidly from about first half of the March. The maximum temperature is observed during April to early part of the June and very often rises up to 35^{o} C to 38^{o} C. The temperature starts to drop down by approaching of rainfall upto the month of September. During monsoon the temp remains more or less static showing between 25^{o} C to 28^{o} C. Afterwards as Sun moves southward temperature simultaneously drops. The coldest month is January the average winter temp is 15^{o} C.

1.2.5 Drainage and water body

The principal drainage system of the study area is the Pichaboni River. The river has been passed through North West to South east direction in the north and south part of the study area. Several gullies have been noticed along the bank of the river. Several ponds with small areal extend have located in the residential area which have been used for domestic purpose. Jaldha Inlet is in extreme south-west corner of the block and another tributary river Nalguna has passed through almost from middle of the block to south-west corner and joined the Jaldha Inlet (Figure 1.2).

1.2.6 Soil

The soil is mainly alluvium in nature with salt encrustation and the texture is mostly sandy so the water holding capacity is very low.The soil is also influenced by saline water encroachment from the sea. The study area is characterized by Aquic Ustipsamment (Kamila, 2019) type of soil which is a mixture of deep layered, well sorted; gentle sloping beach formation and Pansuka formation.

1.2.7 Vegetation

The natural vegetation of the area comprises of mixed varieties of coconut, cashew nut, bamboo grooves, scattered all over the area, because of ridge spread afforestation schemes undertaken by the department of forestry. Vast stretches of casuarina plantation prevail along the entire study area. Towards the interior, the vegetation is mixed deciduous in nature. As a result continuous sea breeze shows an impact upon them. In this area vegetation shows an inclined alignment landward because of the wind effect.

1.2.8 Communication and transport

Ramnagar I & II blocks are connected to Kolkata (186 kms by road) via State Highway-4, National Highway-41 and then NH-6. The alternative access to Ramnagar(Digha) is to travel along NH-6 up to Kharagpur and take the road to Digha via Egra and Depal (SH-5). From Digha or Contai Bypass in order to reach Mandarmani by car (Figure 1.2) one must turn from Chawolkhola stoppage (12 km away from Mandarmani Bus Stand). Other parts of the state like Barddhaman, Durgapur, Asansol, Bankura, Birbhum and Purulia and beyond come to Kharagpur by State Highways and major roads making Kharagpur (falling in Paschim Medinipur district) an important hub for Ramnagar block. The recent improvement in road connectivity due to four-lane of NH-6 and NH-41 has shortened the journey time to Digha-Sankarpur to a great extent. One can travel by car from Dum Dum Airport through highways and expressways and reach Digha within 4 hrs (Figure 1.2). By Rail With the opening of railway line between Tamluk and Digha under South-Eastern Railway Division, this Planning Area now has a railway station at Digha linking it by rail to Kolkata and Kharagpur and there from to the southern, northern and western parts of India.

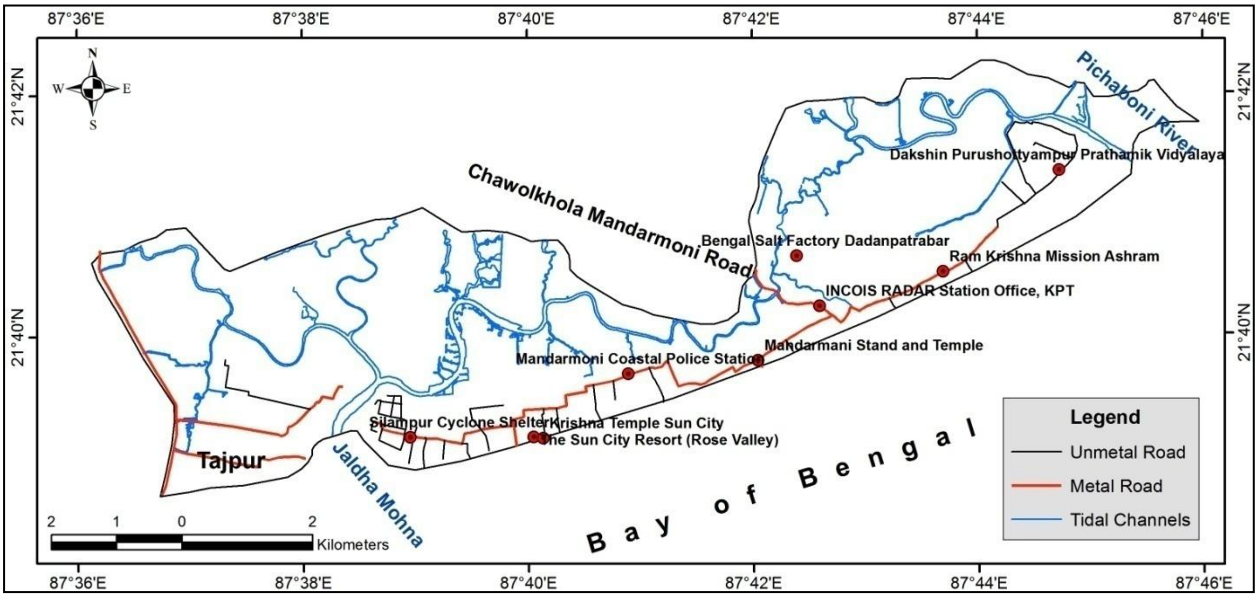

Figure 1.2: Drainage and Transport map of the study area

1.3 Literature Review

From the literature review it can be anticipated that a vivid and varying outcomes are expected to be gained. Previously similar works have been done on the coasts of other countries but this research work can well be implemented on the coasts of India. According to the Coastal Regulation Zone (CRZ) Notification, dated 19th February 1991, or amended upto 3rd October, 2001, under the Environment Protection Act (EPA) 1986, no construction should be done in the area falling between the Low Tide Line (LTL) and the Highest High Tide Line and even in the area falling within 500m of the landward side of the HHTL (Ministry of Environment & Forest or MOEF, 1991). This Act had been totally violated and hotels have been set up within the reach of high tidal water since 2007. The government's coastline protection measures are also been implemented to reduce coastal erosion process (Santra, 2013). But according to Sahoo (2016) Mandarmani is an area influenced by hydro graphic and anthropogenic activities and with development in tourism industry. Mandarmani is threatened by erosion of beaches and front dunes and over washed by high tide which resulted shifting of shoreline, uprooting of casuarina trees and capturing the agricultural land with invasion of salt water. This case study can prove to be a very good awareness program for common people or the individuals as well as the Hoteliers, Managers and Administrators of the coastal development projects because clear selection of stable zone and unstable zone can be delimitated over the stretches of coastal area of Mandarmani.

Beaches, along with the accompanying dunes and shore face environments were established after stabilization of sea level less than 3,000 years. The coastal dunes behind beaches and the shore face regime seaward of the beach are tied together as a beach system with each of these features having unique difference. Accumulations of unconsolidated sand or gravel that extend from mean low tide to the uppermost extent of wave impact are known as Beach. The beaches best develops on low lying alluvial coasts and typically more than a third of the world's coastlines are beach environments. (Dolan, 1972)

The beach has three major parts: beach face, berm and back beach. The beach face is themost active zone of dynamism. This slope depends on both grain size and wave energy which are again interdependent. The major factors governing the slope of the beach face and the movement of grains on the slope are: wave height, wave period/length, and grain size of the particles. Grain size is major controlling factor of percolation of water into the sand and thereby the amount of water in the surface backwash and the amount returning through the beach sediments. This in turn sorts the beach foreshore gradient as the amount of surface return flow is anaspect in the movement of sand grains. Coarse sand beaches associated with high degree of percolation have steeper gradient than fine sand beaches because of the less backwash effect and therefore minor movement of the grains towards sea. Under conditions that allow beach growth, the berm develops at the top of the beach face. Excepting very flat beaches, the berm shows a well-defined crest at the seaward edge. Energy is spent in a swash of water carrying sand upward, as each wave moves up the beach face. Since some part of the water returns through the beach sand, the backwash is reduced and sand is supplied to the berm at the crest. The back beach behind the berm has variation in width and character. In the back beach sands are generally fine-grained and well-sorted compared to the beach face. The back beach and dunes merge into one another and for this the line of demarcation may shift.

Entrainment and transportation of sediments by wind follows similar patterns to those initiating sediment movements in water. Particles move when the shear stress from the wind exceeds a critical value that is related to grain size, density and slope. Because of the large differences of density between sand grains and air, transportation by suspension is relatively unimportant in coastal dunes. A dune’s sand movement is generally by bed-load creep and saltation. Removal of sand from the windward face and is transported to the lee face, where it is deposited and accumulated at the angle of repose.

The conditions for formation of coastal sand dunes are supply of sand, a place for the sand to accumulate, anda wind to move it. Dune accumulation arisesstarting above the spring high-tide line and extended backward, while the back beach formations are the seaward limit of the dunes which is the main supplier of sediment (Illenberger and Rust, 1988). Goldsmith 1985 classified dunes as migratory transverse dunes or vegetated dunes. The vegetated dunes form anchored ridges parallel to the beach. These are usually a series of dune ridges formed during the accretional history of the coastline. Transverse non-vegetateddune ridges have stable ground, and generally move to and frowithrhythm of the prevailing winds (Kocurek, 1992). Under storm conditions, these dunes may show dramatic encroachment over the landward side. Non-vegetated dunes are especially common in arid climates where there is a plenty supply of sand and a lack of vegetation.On open sandy coasts, the shore face is of concave in slope between the surf zone and the continental shelf floor.The shore face varies in width, depth, shape and long shore extent, and it may not be well developed in many locations (Liu and Zarillo, 1990).

The texture of beach sediments 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 the sediments. The dominant mineral groups are biogenic shell debris (carbonates), quartz and feldspar minerals derived from granitic igneous rocks, dark minerals from basic igneous rocks, and igneous rock fragments from basaltic igneous rocks. The most widespread beach material is mainly quartz, but biogenic carbonate grains are also importantin tropical regions. The processes that act upon the beach are recorded within the sedimentary structures signatory beach face. Cross-bedding may develop where old berms have been eroded and new foreshore sediments deposited. The presence of dark layers form as a result of larger waves concentrating heavy minerals. Migrating shores and cross bedding formation illustrates a beach that is in the process of building out under the influence of fair-weather waves and developing cross-bedding. Cross-bedding is also a basic feature of the internal structure of dunes. Variation in the bedding planes is the showcase of advances and retreats of dune faces, presence of vegetation, and wind shifts, leading to cross-bedding and erosional unconformities. Low-angle cross-beds develop as sand accumulates around the dune vegetation, which acts as a baffle, trapping the wind-blown sand.The beach gradient and sediment texturedistinguish beaches in terms of dissipative and reflective beaches. (Wright and Short, 1983) The beach profiles are different, and the types of wave-breaking and near shore circulation patterns are different from reflective to dissipative beaches. Dissipative beaches form under high wave conditions when there is an adequate supply of medium to fine sand. Spilling breakers form and proceed as bores across the surf zone, which is quite wide and has a fairly uniform slope. Dissipative beaches have a wider upper and lower beach face with a slope less than five degrees, and usually lack berm development. (Short, 1983; Smith, 1990)

Reflective beaches develop during low to moderate wave conditions when the waves break by plunging or surging followed by strong wave swash up the beach face. The steeper reflective beach face (>10 degrees) transitions to less slope offshore. In higher-energy reflective beaches, there is a berm crest, upper and lower beach face, step and deeper near shore. Low-energy reflective beaches have only a beach face, steep and near shore zone. The berm remains in the transition from higher to lower wave energy, but it becomes wider with lesser slope. According to Bryant (1982), beaches may have seasonal shifts from reflective to dissipative in response to storm and swell conditions. Regardless of wave conditions, a beach of coarse grains may remain reflective and of a fine-sand may remain dissipative.

The material of the Contai coastal tract is generally siliciclastic and quartzo-feldspathic (Al-Rawi, 1967) in composition, will well shorted medium to fine sand in the Contai coastal tract. (Jana, A. and Bhattacharya, A. K.-2013). The beach face is smooth almost flat, gently sloping 1:55 to 1:75 towards sea. Width of the beach face is different in different place. The sediments are sand, greyish white to yellowish white, very fine to fine, sub-angular to sub-rounded, moderately well sorted, nearly symmetrical, mesokurtic, to leptokurtic.

Several types of beach ripples develop on the foreshore. Backwash ripples form on fine sand beaches because of the backwash of waves setting up turbulent motion. As water flowsperpendicular to the beach during low tide large ripples form within the runnel between the ridge and the beach face. Rip channels and strong tidal current channels have large current ripples. Current ripples are of asymmetric shape that shows the direction of the flow of current. Wave ripples with oscillatory motion are symmetric and sharp. A combination of long shore current ripples and approaching wave oscillation ripples may produce a pattern of cross ripples. Aeolian ripples, which have a similar shape to current beach ripples, develop on all parts of the dunes and upper beach.

Transformation of wave energy across the shelf, near shore, and surf zone and the action of onshore winds in transporting wave deposited sand landward are part of a single system of sand input, storage, and loss. The effect and control of each process differs with the environment, and has aspects that are unique to each. The dune, beach, and shore face sand transport is by different forces, but all combine to exchange sand over the combined system.

Beaches are continually being influenced by the forces of waves and by fluctuations of water lines because of tide. They are capable of undergoing catastrophic changes in morphology within a short time scale that ranges between nearly instantaneous to seasonal or longer. During high energy events, such as large storms or tropical cyclones, waves increase in size and therefore are more capable of eroding sediment from a beach and transporting it either farther offshore or along the shoreline to a new location in very short periods of time. During longer time periods, a similar result can occur even during fair weather when low energy waves are affecting the beach. Most often the impact of sea breeze is felt because of the wave field that is excited by the breeze in shallow areas near the coast. (Neetu, S. et. al., 2006). In general, however, most beaches undergo the most substantial erosion and loss of sediment during storm events and then experience a period of recovery to regain a cross sectional profile that is in equilibrium with the wave and tidal conditions.

Many previous works are done on this topic like hydrodynamism, morphodynamism, aerodynamism etc. the detailing of these topics can be reviewed by driving into the intricate systems of each dynamics. According to John Pethik (1984) the driving force behind almost every coastal process is due to waves. The transformation of solar energy into the mechanical energy of the wind is subsequently converted into wave potential energy by the deformation of still water sea surface. Or in other way turbulent pressure fluxes in the moving airstream set up under surface resonance, manifest as small wave-like deformations of the surface. Surface irregularities and wind, resulting in a pressure drop at the crest which allows the wave to peak up. Wave size gets varied by the fetch (the distance over which the wind blows), wind velocity and wind direction (Carter, R.W.G.-1995). The power of a given wave is approximately proportional to its amplitude squared and to its period (Polinder, H. et. al. 2007).On the other handwave energy increases as the square of the wave height; thus the ability to mobilize coastal materials is a function of wave height. So those coastal areas of high wave height are considered as more vulnerable coasts and vice versa (Kumar, T. Srinivasa 2010).The dominant portion of the spectrum in terms of energy is associated with the surface waves ranging from 1 to 30 second (gravity waves). Two types of gravity wave in the ocean are wind waves due to local wind and swells generated elsewhere due to remote wind systems and propagating over large distances. The gravity waves, along with the coast of India, mainly depend on wind conditions (Kumar, et.al, 2013).The whole Mandarmani beach tract extends about a 14 km stretch of the shoreline from Jaldah estuary to Pichhaboni River with dune barrier of low height and back-dunal wetlands capturing the maximum part of the study area fringed by a flat and wide beach plain. According to Paul, A.K. (2002,2012) a barrier bar setup with back water areas, wide sandy tract, multiple beach ridges with high dune platforms fringed by extensive beach plain surface was existing in the previous centuries (1800,1900 A.D.) in the region from Digha Estuary to Pichhaboni Estuary of the Kanthi Coastal Plain.

The beach foreshore may have a step just seaward of the swash zone. This is a sudden drop in the foreshore profile that takes place at the point where the wave swash flowing back down the beach meets the next incoming wave. The step has changes in sand texture, being marked at the top by an assemblage of coarser sediment than the rest of the beach face. Steps are mostly developed where tidal ranges are low and the foreshore slope is steep; as a result they are usually associated with reflective beaches. Cusp-shaped points are common along beaches. These features grade in size from miniatureforms of beach cusps to larger cuspate forelands. Ideal sites for the development of cuspate forelands include those locations where a major change in coastline direction occurs. Many cuspate forelands have been built by the progradation of a series of beach and dune ridges as sediments are deposited in the slack water zone between two coastal eddies. Eddies commonly develop inside a major current that flows along the coast, such as the Gulf Stream. Some small cuspate forelands are formed by progradation of beaches on the inside of small islands or other obstructions. Carbonate beaches are subject to rapid cementation in the foreshore environment compared to siliciclastic beaches. This leads to the rapid development of seaward dipping slabs of beach rock. Beach rock, a lithified beach sand (calcarenite) which is either precipitated from marine water of freshwater influence in banded structure along the intertidal zone of the world's tropical and subtropical beaches. Most carbonate dunes are deposited adjacent to high energy beaches in warm climates where abundant carbonate grains are present. These dunes develop in a manner similar to siliciclastic dune formation and few differences are found between quartz and carbonate dunes in either the developmental processes or in the resulting dune forms. Dune sands expose skeletal and non-skeletal sediments supplied by the beach face and fossils of terrigenous organisms. During the wet season, calcium carbonate from the shell fragments undergoes chemical change. During the long dry season, the calcium carbonate precipitates, forming cement, which will produce a distinct type of lithified coastal rock, referred to as an eolianite or fossil dune accumulation. Generally eolianites are cross-bedded and well-sorted deposits which preserve all of the characteristics of an unconsolidated dune. However, the modern dunes and sea beaches of the present coast are highly unconsolidated and partially vegetated.

1.4. Research Problems or Gaps

If we talk about the previous research works on Mandarmani Coast, there is a huge gap of data on both physical and socio-economic sector of this region. Some authors like Santra Mitra (2013), Sahoo(2016) and others have tried to estimate the shoreline shift in a temporal scale at this dynamic coastline but only considering the physical aspect and also in a 2dimensional view point. But shoreline change detection is not enough from a broader respect. This is the reason the development work is taking place in an unscientific manner which is creating a negative impact on the economy and also the environment.

Moreover if a definite model on beach and dune has to be generated then the sediment budget has to be estimated and loss and influx of sediment volume have to be calculated at the same time. As Mandarmani Beach is a fast rising tourism sector so the development strategies and options have also to be taken under consideration. We have to keep in mind the overall sustainable management of the whole environment. In order to do that the dune plant ecological dynamics can never be overlooked because these are the binding agents of the unconsolidated dune system. If dune system stability can be reached then further beach lowering can be stopped and in the back shore region a developed and sustained tourism can flourish.

These types of beach modeling have been done in other parts of the world mainly Australia, New Zealand and some beaches of Europe and USA. But dune has never been a factor for consideration in these rhythmic dynamisms of fore shore and backshore region of the coast. In case of Mandarmani beach, dune is a highlighting base for protection of the back dune wetland areas and the flourishment of coastal development projects. Not only is that as this research an applied research so the anthropogenic influence should be another parameter for consideration. This research is not to declare that tourism or livelihood dependency on the coastal landform is not an option for development but this study is to guide the individuals and the administrators and hoteliers to reach a sustainable management of the overall coastal tract.

1.5. Objectives

The research study is designed to assess the following objectives in order to superimpose a socio-economic scenario over a physical backdrop. The specific objectives for the thesis are as follows:

- To demarcate the erosion-transportation-accretion pathway of sediment and regenerate a beach stage model on the basis of micro zonation of depositional features driven by hydrodynamic parameters.
- To prepare the dune stage model going by the dune morphodynamics and spatial and temporal variation of adjacent beach.
- To understand the livelihood related constraints developed by beach stage and dune stage morphodynamics within the system.
- To recommend a sustainable measure for a better coastal development project and tourism flourishment of the region.

1.6. Methods and materials of the study:

For this micro level survey of beach and dune morphodynamics few parameters are selected: Pre-existing morphology, Gradient of the beach and the dunes, Sediment texture, Beach-surf zone hydrodynamics, Dune ecological community, Beach faunal community (Figure 1.3).

This spatial survey is then again compared temporally after three years time span. This varying survey has been carried out for 4years in order to prove the research model. Tidal data and meteorological data are also collected and implemented. Moreover, large-scale episodic events which create a major change in the coastline of Mandarmani are also taken into consideration and analysed.

After this on-field survey many analysis like temporal analysis of the morphology of the region; identification of various micro- terrain features; preparation of DEM and applying various morphometric techniques on it have to be done which can ultimately divide the whole coastal area of Mandarmani into many zones of erosion prone area, depositional area and equilibrium area of erosion and accretion. An ideal model of beach dynamism is recreated and a dune dynamic model is generated based on the series of analysis. Other socio-economic surveys also been done like household perception survey on the existing villages, hotel survey for the verification of CRZ rules and population pressure on the study area and also tourist and hotel survey to know the demand and supply of the resources of the region and their expectations and grievances. This research will definitely help the sustained growth of tourism industry keeping in mind the livelihood security of the local people and also following the regulations of CRZ.

The modern shoreline systems are modified and processed with the effects of alternate wet and dry seasons and events of storms. Sediment transportation paths along the shore fringes are guided by effective monsoon currents (Northeast and Southwest monsoon drifts) in the region. Therefore, survey profiles are conducted in a repetitive manner in monsoon and in non-monsoon moths.

Understanding the dynamic process is immediately needed to estimate and to manage the coastal resources of the sedimentary depositional environment.

List of materials utilised during the process of research work:

a. SOI Topgraphical Map (1970 Topo Sheet No. 73O/10, 73O/14; 1962 Topo Sheet No. NF 45-11)
b. Satellite imageries (SRTM DEM, Landsat8)
c. Google Earth Image
d. Instruments (Total Station, GPS, Tape, Staff, Clinometers, Prismatic compass, handmade grid, zip pouch, spade, Anemometer, etc.)
e. Census Data 1991, 2001, 2011
f. Other Secondary Data
g. Questionnaires

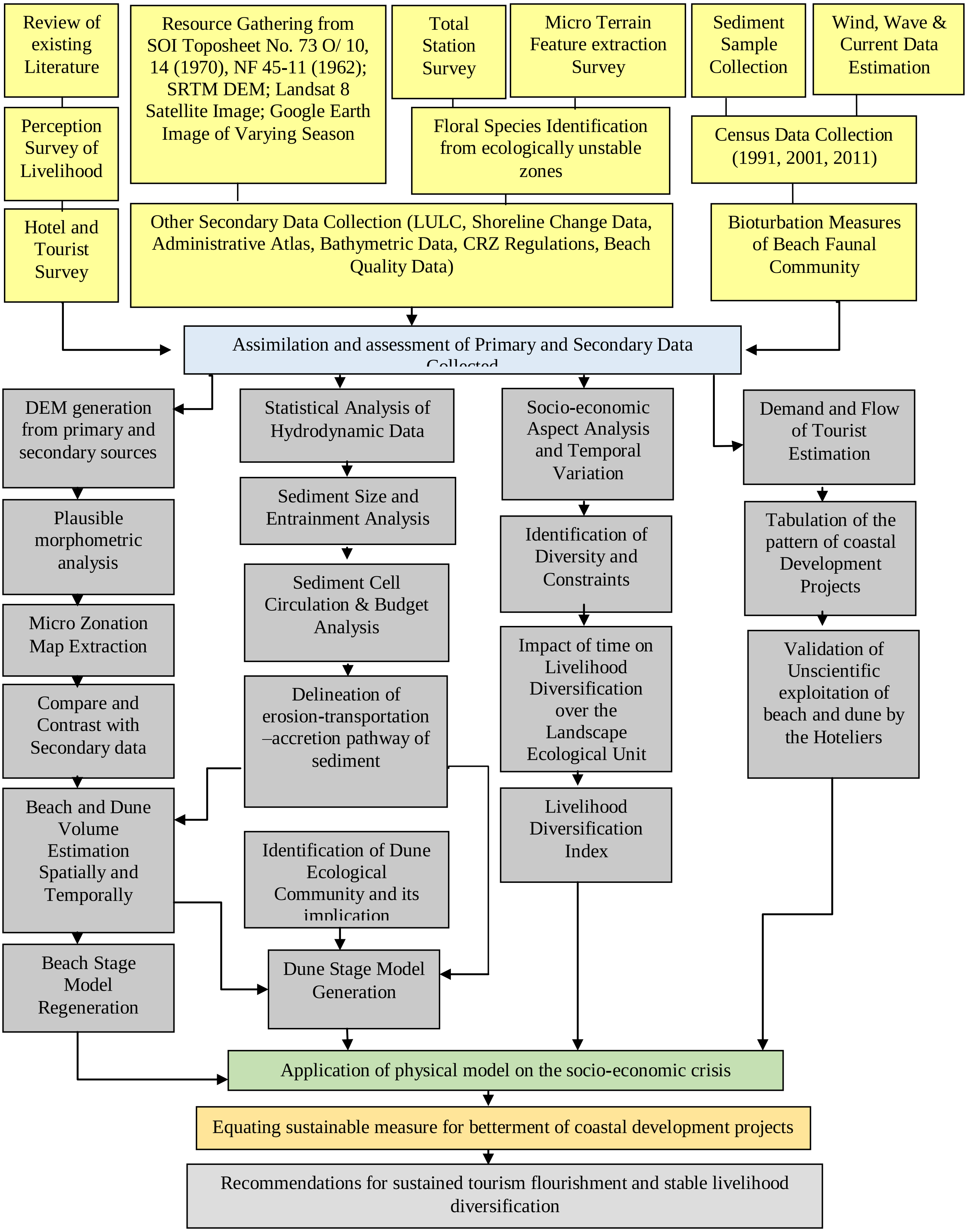

Figure 1.3: Methodological flowchart

1.7.Research Design

I have conducted an application based research or implied research and it is a case study and has mainly a quantitative approach with some descriptions according to relevance. From a vivid **study of the existing literature** and finding out the **gaps of research** it was the first and foremost work to arise with the **research questions and justify its importance** to the society. As it has already been explained that this is a geomorphic model with a perspective of get fitted on the anthropogenic influences for the fast development of that area. So the question arises is this sort of Coastal Development Projects scientific or not. Whether this socio-economic changes is ethical or not? Is this balance between livelihood and tourism exerting an imbalance among the landform, environment and ecology? Thus the **title of the research** truly presents us to a depth of the past, present and future of the study area – "Assessment of Beach Stage and Dune Stage Dynamisms for the Sustainable Management of the Coastal Development Projects- A study at Mandarmani Coast". Thus the research questions arisen gave a clearer understanding of the picture and selection of the proper **aims and objectives** for the research work. 4 objectives clearly showing 4 chapters of study so the **methods and materials** to be chosen should also be from 4 directions. So the **plan of action** is in such a way that it should include a repetitive instrumental surveys temporally and spatially for the data collection of morphology, hydrodynamisms, sediment volume movement pathways, etc., sample survey collection for sediment texture analysis, floral varieties and faunal influences, perception survey for livelihood diversities of the individual residing in the villages, questionnaire survey for the anthropogenic influential data mainly by the hoteliers and tourists and also the administrative effects for the coastal development. This data hub has then been tested, rectified and processed and put forward for **analysis, mapping, evaluation and interpretation.** Finally the reporting stage depicts the **major outcomes, limitations and future scope of the study and also the recommendations** for implementation. This research work covers a time period of 5years but the previous secondary data are also superimposed in order to predict a future trend and a plan of action.

In the next part of the thesis, beach and dune stages are modeled to understand the shoreline morphodynamics of the present study area over which the tourism recreational infrastructures are widely expanded since the year 2007.