

# Coastal Sand Dune Systems: Location, Formation, Morphological Characteristics Analysis through Vegetation Processes Estimation

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## Authors' contributions

This work was carried out in collaboration between all authors. Authors AKP and SC designed the study, wrote the protocol and wrote the first draft of the manuscript. Author GB managed the literature searches. Author AK developed the portrait and sketch of the figures. Author NKB analyzed the study performed the spectroscopy analysis managed the experimental process and identified the species of plant. All authors read and approved the final manuscript.

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## ABSTRACT

Most of the beaches are covered by vegetated sand dumps called sand dunes, built up through dry beach sand blown inland and trapped by plants and other obstructions. As sand accumulates, the dunes become higher and wider. Stable sand dunes play an important role to protect the coastline. They act as a buffer against wave damage during storms, protecting the land behind from salt water intrusion. This sand barrier allows the development of more complex plant communities in areas protected from salt water inundation, sea spray and strong winds. Plants play a vital role in this process, acting as a windbreak and trapping the deposited sand particles. A characteristic of these

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plants is their ability to grow up through the sand and continually produce new stems and roots as more sand is trapped and the dune grows. To form the sand dune in the coastal belt and their morphological characteristics always depends mostly on three conditions like supply of sediments, bearing capacity of air and plant covering. The present attempt is to explore the formation and morphological characteristics of coastal dune in the estuarine part with massive deposition of sediments throughout the year in the shore, presence of wide beach and off-shore wind through the vegetation processes estimation which may significantly helps the nature to prepare the coastal sand dune.

*Keywords: Coastal sand dune; estuary; dune vegetation; dune morphology; floral habitat.*

## 1. INTRODUCTION

Sand dunes are developed along the coastal belt with three basic processes: supply of sand to the beach plain, aeolian sand transport from the beach to the backshore region and interaction between sand transport by the wind and vegetative growth or distribution [1]. However, low wind velocities, meso to macro-tidal ranges and damp sand conditions of the tropical humid coast prevent the maximum growth of sand dunes [2,3]. Only the dry weather situation of winter months as well as hot and humid summer months (mid February to mid June) of the pre monsoon season is favorable for aeolian sand transport in the coastal belt. The pre-monsoon summer months are also significant for their dominant onshore wind velocities. Vegetative cover on the bank of the beach initiates the dune formation and the growth of vegetation transforms with the accumulation of heaps of sand. Subarnarekha river with its peak monsoonal discharge, supply huge amount of annual sediment input into the shallow shelf region which again provide sands for the beach replenishment particularly in the fair weather wave energy conditions [4]. South west monsoon and the period of storms destabilize and dunes by winnowing sands from the immediate beach plain and backshore region and supply sediments to meet the demand of offshore and near shore regions [5,6]. Gentle slope of the extensive beach plain along with a large tidal range (>4 m) on the other hand providing wide areas of sands which usually dry at low tide are favorable for aeolian transport to built the dune. Most of the shore-fringed dunes are erosive in nature at present in the coast [7-9]. However, wide expanses of dry sand on the backshore and upper foreshore regions provide ideal condition for dune growth in certain places of deltaic coast [8].

## 2. THE STUDY AREA

Balasore coast is a part of unconsolidated alluviums originated by the huge sediments

deposition by the numerous rivers like Subarnarekha, Burahbalong, Dugdugi, Hanskara. The study area extending between 21°35'48" Northern Latitude and 87°27'17" Eastern Longitude. Balasore's coastal zone is endowed with a wide range of mangroves, salt marshes, estuaries, lagoons and a unique maritime flora and fauna with a series of parallel sand dunes. The area is a coastal alluvial tract with unconsolidated substrates and this stretch of the coastline is geomorphologically dynamic, rich in habitat diversity and prone to hazards such as tropical cyclone-induced tidal waves, storm surges and consequent coastal flooding. The estuary of the river Subarnarekha is 0.5 km to 1.5 km wide. Almost nine sand bars and one island are situated here. All the sand banks are linear by nature. The estuary of the river Subarnarekha and all the river of the study area such as Dugdugi, Burahbalong etc. are always very dynamic for long shore drift. The depositional bar of the Subarnarekha delta region increases rapidly for the agglomeration of the sediment carried by rivers and always alters the river mouths.

## 3. SALIENT FEATURES OF MAJOR COASTAL UNITS

Coastal landforms, any of the relief characteristics present along any coast are the result of an amalgamation of processes, sediments and the geology of the coast itself [10].

The coastal territory of the present study area is made up of a wide variety of landforms obvious in a spectrum of sizes and shapes ranging from gently sloping beaches to high cliffs yet coastal landforms are best considered in two broad categories: erosional and depositional [11]. In fact the overall scenery of any coast may be described in terms of one or the other of these categories. It should be noted that each of the categories have diverse types of processes and different kind of biological belongings which are always working for built up the coastal environment Fig. 1. The

present study area is also included several kinds of habitation unit which are highly inter-connecting and interact with each other, accordingly this individuals ecosystem build ups the vast coastal ecosystem [12].

### 3.1 Dune Provinces

Dune is a hill of sand built by either wind or water flow Fig. 2. Dunes occur in different forms and sizes formed by interaction with the flow of air or water. Most kinds of dunes are longer on the windward side where the sand is pushed up the

dune and have a shorter "slip face" in the lee of the wind [13]. The valley or trough between dunes is called a slack. A "dune field" is vicinity covered by widespread sand dunes. Some coastal regions have one or more sets of dunes running parallel to the shoreline directly inland from the beach. In most cases the dunes are significant in defending the land against possible deprecation by storm waves from the sea. Although the most widely distributed dunes are those related with coastal regions the largest multifaceted of dunes are found inland in dry regions and associated with ancient lake or sea beds.

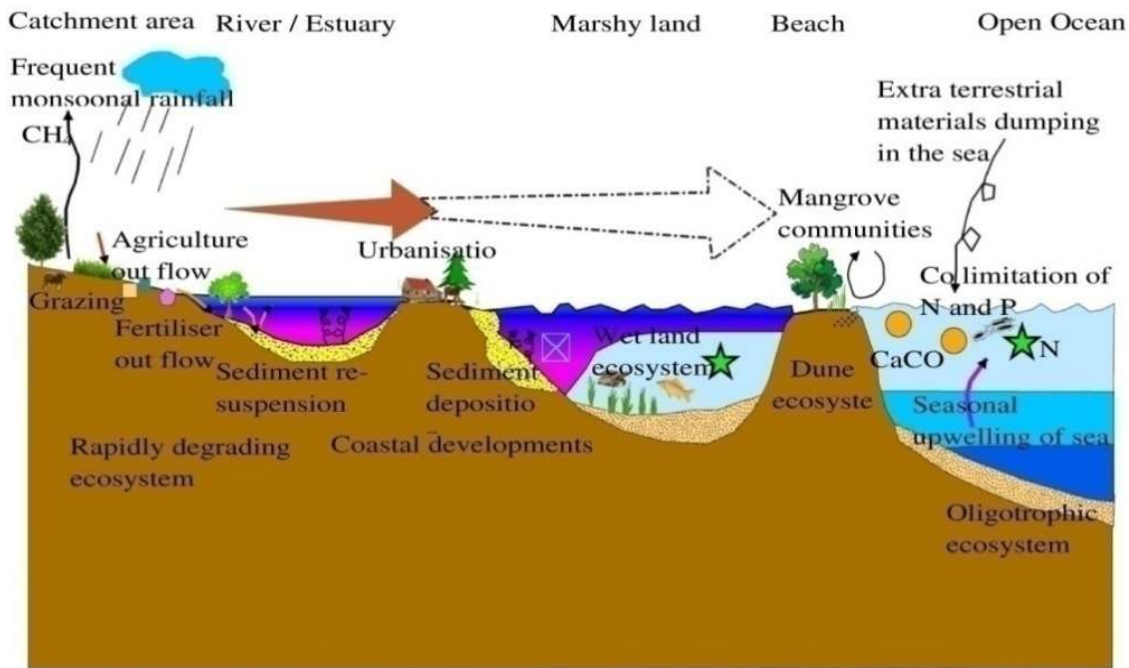


Fig. 1. Coastal landforms and their different types of processes, biological properties which are always working for built up the coastal environment in areal and sub-areal ecosystems

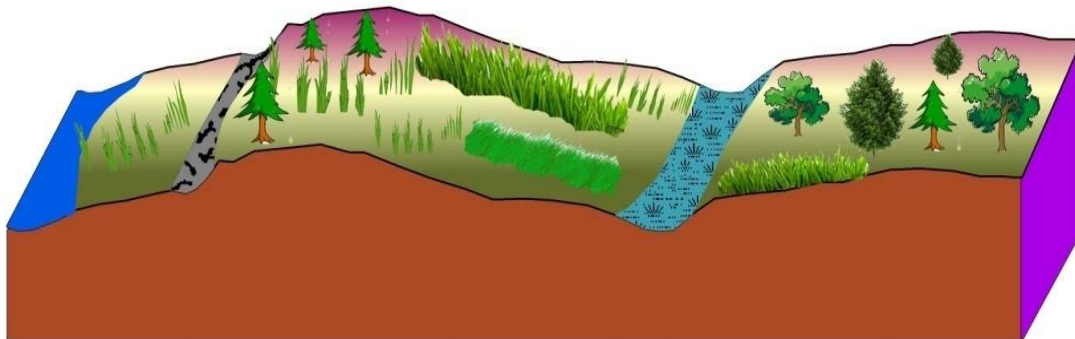


Fig. 2. Spatial configuration of dune provinces and protecting the land against potential ravages by storm waves from the seawards

### 3.2 Coastal Habitat at Sand Dune

Percentage of moisture in the sand dune of the coastal areas is higher than the sand dune situated in the other part of the world. So the importance of the floral habitat in coastal sand dune is immense [14]. To form the sand dune in the coastal belt three conditions are very essential these are i. supply of silt, ii. Bearing capacity of air and iii. Plant covering. In the present study area the river Subarnarekha river deposits massive sediments throughout the year in the shore then the wide beach, off-shore wind and presence of a lot of trees helps the nature to prepare sand dune.

### 3.3 Dune Formation with Relation to the Floral Community

In the end of summer and at the end of high tide coastal litter such as the remaining of the dead animals and plants, seeds, parts of the trees are sedimented on the beach [15]. Salt tolerant seeds are germinated here and the parts of the trees formed a barrier along the shore. As a result the sand carried by off-shore wind is obstructed by these plants induced barrier and creates low height fragmented sand dunes in many places parallel to the shore. In this way sand dune formation is started which is called incipient dune. Just after the formation of the incipient dune two kinds of plants namely - *Seuivium portulacastrum* and *Aleropus logopoides* grow here. They form a parallel plant colony to the sea shore on the incipient sand dunes and create barrier against the sand carrying sea wind. Consequently sand is deposited on the plant colony and height of the sand dunes gradually rises. Later when the plant colony grow up presence of more new plants like *Cynodon dactylon*, *Cyperus exalatus*, *Panicumrepens*, *Ipomia bioloba* etc. can be noticed on the dune [16]. During high tide the whole area go under water as it is still low. In this way some silt are deposited on the sand dunes. Later the roots of the trees holds the sand like hooks and the leaves of these trees create canopy on the sands and stability is generated and sand dunes with the height of 1-2 m are formulated. Such separated sand dunes are called 'embryo dune'. The roots of the plant species of the embryo dune gradually advanced towards the land and due to the deposition of sand carried by the sea wind, the sand dune gradually advance towards the land. Now some more new species like *Launia sermentosa*, *Ipomea pescarpa*, *Cyprus exaltatus* etc. grow

here [15]. Their roots make the sand dune stronger. In this way the sand dune stretches towards the land creates parallel dune row along with the shore line which are called 'fore dune'. These fore dunes are seen at the back of embryo dune and some grass species grow here and make it stronger. When the fore dune increases slowly, it turns into transverse dune gradually. At this time many plants such as *Calotropis gigantea*, *Pandanus tectoridis*, *Opuntia dilanic*, *Lantena cemera* etc. grow in the vegetation colony. For the spreading of the colony and for preventing on-shore wind energy the movement of the sand dune almost stops [17]. In this stage the dune formation completely stops, again dune start to break. The numbers of plant colony go up and the dune becomes fragmented. Due to moisture, level of nutrition, level of salt and above all presence of organic matter make these fragments permanent. For the presence of excessive organic matter in this stage this condition is called late yellow phase or grey dune phase. In this phase dune vegetation coverage decrease excessively. As a result fragmentation started and sand dunes are turned into low dune flat. It is generally found in back shore area.

### 3.4 Coastal Sand Dune and Their Vegetation Communities

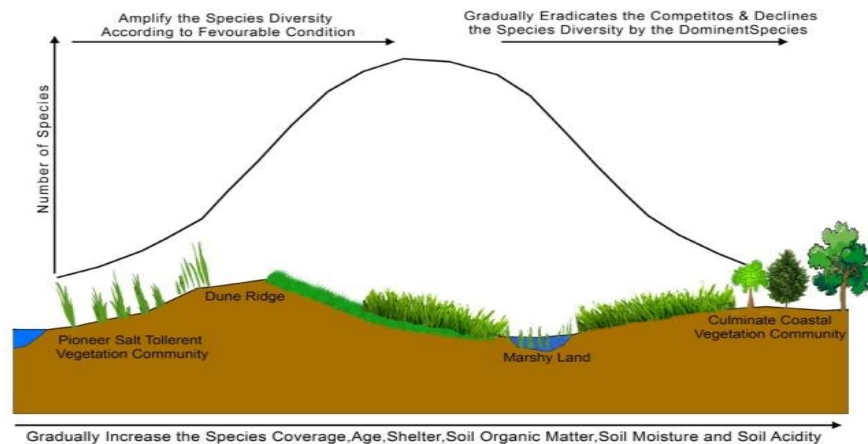
It is clear from the above discussion that sand dune is a remarkable example of floral habitat. Now we have to see which kind of species grow in the sand dune in which condition and which kind of plants grow plant colony by growing together Fig. 3.

### 3.5 Primary Salt Tolerant Colonizer

Primary salt tolerant colonizers generally built up colony where high tide ends. High tide carried out seeds, parts of the roots and builds up the colony with the help of accumulation of sea weeds like *Dhani ghas*, *Celecornia*, *Sesuvium portulacastrum*, *Soada*, *Aloropus logopoides* etc.

### 3.6 Creepers and Grasses

Generally two species mainly found to build up colony in the landward side of shore line. They are *Sesuvium portulacastrum* and *Aloropus logopoides*. Many long rooted species are found in the colony and increase the volume of the colony.



**Fig. 3. The functional relationship between number of species and dune configuration, varieties of species, age, shelter, physical and chemical properties of soil**

### 3.7 Creepers and Herbs

The creepers and herbs are generally stays in the interaction zone of dune and beach and build up their colony. In these colony new species like *Lania sermentosa*, *Ipomea pescarpa*, *Elipsa alba*, *Takphul* are present along with the old species. All these species make the colony larger and strengthen the stability of the sand dune.

### 3.8 Dune Shrubs

This dune shrubs are generally stays between dune top and base. Here *Lania sermentosa*, *Ipomea pescarpa*, *Cyprus exaltatus* usually grows and helps to strengthen the stability of sand dune. In addition to this the species like *Lantena camera*, *Cynodon*, *Calatropis gigantia* are noticed here frequently.

### 3.9 Park Land

When the numbers of dunes herbs are increased greatly over the sand dune then it is known as park land. The number of species like *Lantena camera*, *Cynodon*, *Pandanus tectoridis*, *Opuntia* increase largely and for this the sand carrying by the sea wind almost stops by the obstruction of these species.

### 3.10 Dune Meadow Land

The accumulation of organic matter increases considerably after the creation of the park land. Consequently, different species are grown here so that productivity of sand dune decreases and meadow land exposed in some parts. *Lania sermentosa*, *Vernonia ceneria*, *Agedectrin indica*, *Elipsa alba*, *Josia*, *Oldenlandia congmbosa* etc.

species are agglomerated in the dune meadow land.

### 3.11 Mixed Vegetation

From the top to the landward margin of the dune many kinds of species can be seen. Indigenous trees like *coconut* planted trees like *Casuarinas*, *Ucaliptus* and some salt tolerance trees like *keya*, *mollugo spergula* etc. are found here. The vegetation presents along the different parts of the dune are summarized into Table 1 (After Field Survey).

### 3.12 Colonization and Succession of Dune Vegetation at Deltaic Coast

Talsari beach has been taken as a sample unit an experiment has been made in the 204 m long and 24 m wide area from the sea water to back barrier dune and a phyto-geomorphological map Fig. 4 has been developed by dividing the area in 34 grids (Quadrate method – 12 mx12 m) to understand the zonation, colonization and succession of different types of floral species along with the faunal species.

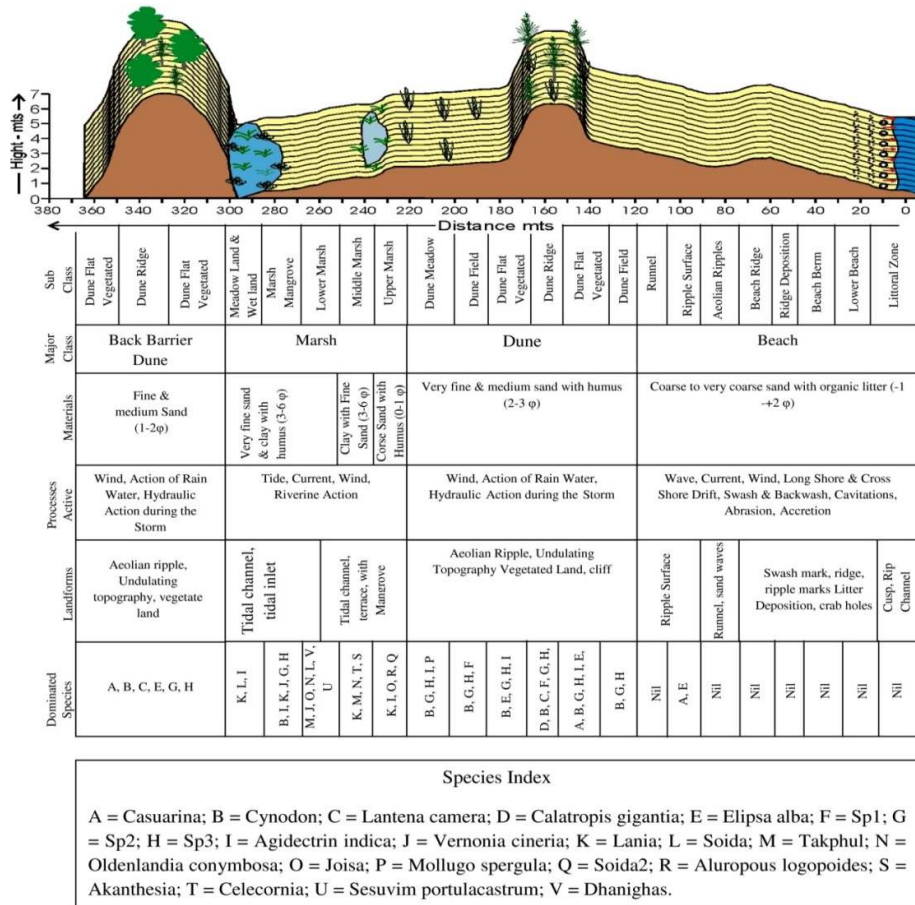
The phyto-geomorphological map shows that dune is highly vegetated than the beach. Dune meadow is covered by the *Cynodoa*, *Sp3*, *Sp4*, *Agidectrin Indica* and *Sp8* where as *Cynodon*, *Sp3*, *Sp4*, *Agidectrin Indica* and *Sp8* also along with the *Elipsa Alba*, *Casuria* and *Sp3* can be found in the dune flat and dune field. Dune ridge with a height of 4.5 m to 5 m is also very roofed with the colony of *Calastregis Gigantia*, *Cynodoa*, *Lantana Camera*, *Sp1*, *Sp2*, *Sp3* and *Sp4*. Now a day's dune row is used as fish drying ground and

also some times the place of fishing huts development, so the habitats of coastal sand dune are extremely degraded at the study area. These types of activities are mostly found at the Talsari

dune and the Kasaphal dune. So it is clear that the variation of colonization, zonation and succession depend on the height and the physical parameters of the coastal environment [18].

**Table 1. Physiographic unit of dune provinces and floral succession over it**

Division	Salient features of dune				
	Height (m)	Slope	Materials	Land form	Vegetation
Dune meadow	4	3°-4°	Coarse & fine sand	Tidal inlet, off lap on lap	B, G, H, I
Dune field	4	2°-7°	Fine sand	Aeolian ripple, undulating topography	B, G, H, F
Dune flat vegetated	5	6°-11°	Coarse & fine sand	Dune field with vegetations	B, E, G, H, I
Dune ridge	6	6°-32°	Fine sand	Aeolian ripple, vegetated land	A, B, C, E, G, H
Dune flat vegetated	5	6°-11°	Coarse & fine sand	Dune field with vegetations	B, E, G, H, I
Dune field	4	2°-7°	Fine sand	Aeolian ripple, undulating topography	B, G, H, F



**Fig. 4. Phyto-geomorphological zones developed on marsh, dune and beach face with some biogenic and morphological features**

### 3.13 Threats to the Floral Habitats at Sand Dune

The numbers of sand dunes in the present study area are under the gradual degradation by the frequent affects of tropical cyclone and allied extreme events. Dune vegetation community of sand dune is in trouble for this degradation. There are some reasons behind it which are discussed below.

1. The first and most important reason behind it is the gradual increase of anthropogenic activities and its concentration.
2. Different kinds of natural factors like- sea level change, wind regime, warm wind blow, dune migration, storm, climatic change, global warming etc. are destroying sand dune as well as floral ecosystem of sand dune.
3. Man made infrastructure in the coastal region like harbor, road, sand mining, waste disposal site, tourism centre, industrialization, beach resort, fish landing station etc. and allied pollution are destroying the sand dune.
4. The demand of fire wood is excessive and for this big trees are cut down. As a result vegetation as well as wild life habitat is hampered dangerously.
5. The coastal ecosystem is getting into problem due to frequent set up of coastal tourism centre.
6. Due to the construction of the stone fencing in the coastal area the nutrient carried by sea waves do not reach up to sand heaps, this affected badly the bio chemical cycle and microbial activities of the sand dune.

### 4. CONCLUSION

Beach and dune both interchanges materials between them as consequences of variables energy gradient and geomorphological change of land off-shore areas. The large tidal range of the Bay of Bengal coast provides a wide exposure of the tidal flat at low tide when landward aeolian sand transport is greatest on the low angle dissipative sandy beaches. Fore-dunes of such wide sandy beaches range from stable, well vegetated and laterally continuous to highly mobile and poorly vegetated forms. The sand dunes associated with dissipative beaches are potentially of much greater volume and dynamism. Thus the interactions between beach and dune are well recognized in the coast associated with continuous dune rows and low angle dissipative beaches.

On the other hand a large volume of tidal litter is found to be deposited on the upper part of the beach by wave pumping mechanism at the storm activities. The tidal litter is usually followed by bacterial decomposition on and within the beach and partially buried by blown sand. Thus organic debris of plant and animal origin in the hot sand bed of the seashore are usually converted to nutrients and supplied into the near-shore water by the current system at the high water level. In this way finally the water with high nutrient came into the close contact of sand dune during the astronomical phase which could have supplied the nutrients to the sand dune and prepared the favorable conditions to grow up the vegetation community.

### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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