Variability of Sand Spits at the Mouth of Estuaries: A Disastrous Impact Study of Phanase, Tambaledge and Tondavali of Sindhudurg Coasts

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Abstract
Numerous coastal landforms have been found in the parts of west coast of Maharashtra. The depositional coastal land forms like sand bars, sand dune and sand spits are continuously varying coastal landforms in the region. These coastal landforms are changing their characteristics seasonally due to the coastal and fluvial processes and also changes due to the human intervention. An attempt has been made to assess the size and shapes of sandspits of Phanase, Tambaledge, and Tondavali for the year 2003, 2011 and 2019.

The variations in the spits have also been evaluated periodically for the considered years. Every year the dimension of the sand spits has changed at these sites. The data variation in the shape, size and aerial extent of the sand spit has been procured from the Remote Sensing Technique and Google Earth Satellite Images. Besides this, a field survey with the in situ observation of sand spits at primary stage was also conducted at the coastal area of Phanase, Tambaledge and Tondavali.

Keywords: Coastal landform, Sand Spits, Sand bars, Satellite Images, Sea waves.

Introduction
Coastal landforms are formed due to equilibrium condition of erosional and depositional processes which are highly affected by the sea waves and tidal energy15. The formation process of sand spits and their altering uniqueness in terms of morphological change in shoreline landforms have been acknowledged by Johnson9 and Zenkovich18. It has been noted that west coast of Maharashtra comprised with coastal depositional features like beaches, sand dunes, sand bars and sand spits. In this areas sand spits are generally formed at the mouth of estuaries and tidal inlet.

Ganuzas - Monge et al16 have also studied the accumulation and formation of sand spits at the mouth of eastern Cantabrian estuaries6. A sand spit is a low leveled deposited sediment i.e. ridge type feature attached to land or beach at one end, with the other edge opening in estuary or sea water. The growth and variability of sand spits may be affected by artificial structures3.

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The estuarine mouth changes seasonally and depends on the geomorphological characteristics. The deposition of material, its shape and size vary due to their associated processes at the estuarine mouth with the contact of sea water. There is a strong relationship between coastal landforms, wind, sea waves and tidal currents6. During the low tide the sediment transport rate on the spit is higher than during the period of high tide, however sand spit level depends on bed topography and river stage16. Most of the population is intensely leaving along the coasts worldwide, many coastal landscape have been affected by the native people and natural disaster1. Numerous natural hazard may result in another disastrous effect on the locals in multiple form14.

Therefore, the study about the high risk zones due to natural disaster is significantly a need for proper management. According to many research scholars, the post-disaster assessment helps to reduce the disastrous impact. The affected area may rehabilitate with the proper protective measures8,13,17. Papathoma and Dominey-Howes12 in their study have attempted a new tsunami vulnerability assessment method for the two coastal villages in their study area that helps for the proper distribution of resources and disaster management planning.

On the basis of published tsunami risk maps, the research scholars have assumed that tsunami flood risk has usually the natural calamities within the expected flood zone in their study area5,10. But in their region they revealed that 'population and infrastructure within a given flood zone were not uniformly at risk' due to the predicted and potential risk zone, because of the in detail study about the flood prone areas11,12.

As discussed earlier, coastal population is increasing rapidly in the coastal area and settlements are threatened by disastrous events like storms, cyclones and coastal floods. Therefore, such erosion prone affected areas should be continuously monitored for accurate information in terms of variability in the coastal landforms and migration of shoreline features. Such comprehensive analysis of shoreline movement has also been attempted by the U.S. Geological Survey in their region. Mapping and analysis results of shoreline change may help in the concrete management of the coastal features7.

The affected and erosion prone sites of sand spit should always be protected that are essential for the preservation of
biodiversity which is significantly a need of conservation strategies\(^2\). In the study area, it is seen that continuous variability in such land forms is required for some strategic planning for their conservation. In view of this, it is true that the coastal resource management of degraded areas with significant ecological importance are essential for sustainable development\(^4\). Therefore, present study in terms of change detection and the shifts in location will help to protect the shifted margins of the sand spits.

Here, it is a study of the western coastal land across the Maharashtra State of India, which is underling towards the Western Ghats declared as UNESCO World Heritage Site having varied diversity of biological and geomorphological features with various coastal landforms. Coastal landforms are developed as a result of stabilized condition of depositional and erosional activity taking place at sea shore with the help of tidal energy over a period of time. A sand spit is a depositional landform emerging in where the re-entrance of water occurs due to linear accumulation of mixed sediments. The present research study portrays the geomorphological studies and its retrospective analysis with the help of remote sensing data through Google earth and field work.

Geographically, the coastal area of the Western Ghats is not a proactive part of the mainland of the state. But the recent study of sand spits at Phanase, Tambaldeg and Tondavali (tip) has shown that local coastal processes are dominant and play a major role in the agglomeration of geomorphic, geological, anthropogenetic and hydro-meteorological factors making a greater impact on the coastal landforms. Erosion and deposition are combined processes that take place in the study area. Resourceful practices should be undertaken for the conservation of such coastal landform.

**Methodology**

Major objective is to study the spits with the Remote Sensing images. Nowadays multi spectral images are available for good resolutions. The images are very costly and not available for each year. In Indian scenario LISS IV with 5.8m resolution is last option for these type of the study. So, use of Google Earth Images for change detections of the coastal spits is the most appropriate option. The specific image was cropped from Google Earth and took coordinates points for georeferencing purpose. Then all data has been imported in ArcGIS software and georeferencing the images. More than two images were mosaic in one image. The process has been adopted for all years i.e. 2003, 2011 and 2019. The spits were digitized and assessed. Google Earth Images are available from 2003 to till date. For the study of the spits Google Earth Images taken i.e. January 2003, February 2011 and February 2019. Selected spits are Phanase, Tambaldeg and Tondavali (tip).

**Results and Discussion**

The coastal line of the Maharashtra is noticeable with headlands, steep cliff, sand bars, beaches, sand spits, tombolo etc. Due to the destructive tidal currents and the strong monsoon winds at the western coast, the landforms are attacked inherently. The current shoreline sand spits at Phanase, Tambaldeg and Tondavali where the study conducted is under threat due to various factors discussed earlier. Primarily data from the fieldwork and then the google images were procured and analysis was carried out.

The development, shift and degradation of the sand spits at the coast of Phanase, Tondavali and Tambaldeg are studied through the satellite images captured in the year 2003, 2011 and 2019 respectively. It is observed that sand accumulation having one side towards sea and other towards the mainland has changed their shape and area with a gradual shift in their places.

![Figure 1: Location Map](Source: Based on survey of India)

**Phanase Spit:** This spit has changed very rapidly during the year 2003 to 2019. Specially its area in 2003 was 0.06 sq.km, it was increased by 0.08 sq.km in 2011. In year 2019 it was decreasing area and the area was 0.03 sq.km. This also shows that the circular bar was emerged towards the northern side of the spit. It is mainly viewed in the pursuit that the strong offshore currents and the south western winds it have occurred. The encroachment in the estuary also depicts the human intervention helping in the decline of the sand spit proving threat to the ecosystem of estuary.
There is a significant and rapid shift during 2011 to 2019. Especially, the area declined more than 50% i.e. up to 0.03 sq. kms. This drastic change observed in the sand spit and the rapid shift vertically towards the northern side showing a thumb like structure and again in opposite side towards the sea side i.e. 26.91 mtrs.

The spit has shifted to north side for a distance of 152.63 m from 2003 to 2011 and southern side shift was observed in year 2019. The eastern side shift was 64.41 m from year 2003 to 2019. West side of the spit shifted 91.32 m toward eastern direction. The west side gradually changed towards east side. Phanase spit looked like a thumb up shape in year 2019. The Phanase spit of 2019 was reduced in size i.e. half the size of 2011 spit.

The northern side continuously formed a narrow right side channel entry of phanase estuary mouth, but during 2019 the larger part has been occupied by the mouth of estuary with inundated water. Most of the mouth zone area and sea water have encroached toward the landward side of the mouth zone of estuary.

Here at this site it has been observed that human intervention in the estuarine system is the main cause of variability in the spit and associated landscape of Phanase site. Anthropogenic activities have also affected the supply of the sand material due to disturbance of mangroves in the upstream areas of the Phanase estuary. The slope of the deposited material at the mouth of Phanase estuary at spit side has drastically changed yearly and has also influenced on the water currents and its pattern that affects the erosion and depositional processes of the spit material.

**Tambaldeg Spit:** The north side of Tambaldeg spit has not shown any changes. The southern side was more changed. It was shifted 131.72 m from 2003 to 2019. West side shift has seen 32.19 m during the year 2003 to 2019, western side shift occurs for a distance of 22.87 m from 2003 to 2019. This spit was more and rapidly changed on southern direction. The area of this spit was 0.20 sq.km. in 2003, 0.16 sq. km in 2011 and 0.15 sq.km in 2019.
Table 1
Locations of the Sand Spits

<table>
<thead>
<tr>
<th>S. N.</th>
<th>Location Name</th>
<th>Latitude</th>
<th>Longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Phanase</td>
<td>16°26′35.19″N</td>
<td>73°21′25.32″E</td>
</tr>
<tr>
<td>2</td>
<td>Tambaldeg</td>
<td>16°16′43.02″N</td>
<td>73°24′39.41″E</td>
</tr>
<tr>
<td>3</td>
<td>Tondavali</td>
<td>16°05′19.16″N</td>
<td>73°27′43.67″E</td>
</tr>
</tbody>
</table>

Table 2
Area of the Sand Spits in Sq.km

<table>
<thead>
<tr>
<th>S. N.</th>
<th>Location Name</th>
<th>Area 2003 (Sq. Km)</th>
<th>Area 2011 (Sq. Km)</th>
<th>Area 2019(Sq. Km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Phanase</td>
<td>0.06</td>
<td>0.08</td>
<td>0.03</td>
</tr>
<tr>
<td>2</td>
<td>Tambaldeg</td>
<td>0.20</td>
<td>0.16</td>
<td>0.15</td>
</tr>
<tr>
<td>3</td>
<td>Tondavali</td>
<td>0.33</td>
<td>0.32</td>
<td>0.29</td>
</tr>
</tbody>
</table>

Tondavali Spit (tip): The spit was shifted 92.28 m to the western direction from year 2003 to 2019. Actually, this spit was shifted east to west side direction in southern area. It was shifted 54.78 m from 2003 to 2019 and again reduced at same direction. The west side was similar to year 2003 and 2019 but major changes have been seen in the year 2011. There is a shift of 75.92 m to west side from 2003 to 2019. The major change is shown towards estuarine side. The large-giant sand bags of different sizes with in situ sand should be used to defend the sand spit and beaches from the active wave action and minimize the erosion in the study area.

It has been observed that settlement and infrastructural properties of Tondavali are more vulnerable to the floods coming from the Gad estuary at the mouth zones; the disastrous impact trend is increasing at these sites and damages are increasing during high floods, high tides and cyclones.

Therefore, the assessments of periodic shifts and migration of sand spits and sand bars in the study area helps to identify the potential sites of high erosion. Such type of change detection study helps to mitigate from the natural disasters.

Conclusion
Sand spit is a linear accumulation of diversified sediments that is attached to land at one end and entered into sea or in the estuary at the mouth. Sand spits considerably protect the mudflats, coastal settlements and estuarine environments from the sea storms and attacking sea waves. It is observed that sand spits of Western Maharashtra have been generally formed at the mouth of estuaries and tidal inlets.

The size, shape and morphological characteristics of sand spits are more probably depending on the type and availability of sand, sediments, wind speed, wind direction, sea waves and sea currents. It is also seen that some of the sand spits of coastal Maharashtra are at a high risk during cyclones and tsunamis.

References


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