

# **Taluka level Environmental Sensitivity Index (ESI) and vulnerability mapping for oil spills: A Pilot study from Goa state, India**

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## **Abstract**

Coastlines are at risk when floating oil slicks reach the shoreline. Oil spill causes major stress on the marine environment. To deal with oil spill problem in the coastal area, Environmental Sensitivity Index (ESI) maps are prepared as a guideline to help contingency planning. These maps are prepared in advance of arrival of oil spill. They show the respective vulnerability of coast. Goa state is selected for a pilot study because of its beautiful beaches and rich biodiversity along its coast. The present study is carried out with the objective to map the vulnerability of the coast for oil spills up to taluka level using satellite images and field observations. Taluka is an administrative unit hierarchically above the local city, town, or village, but subordinate to a larger state or province. Goa is a small state which is located on the west coast of India. It occupies 100 km long. This coast is prone to the oil spill as it lies in the major traffic zone of oil transport. In the last decade, Goa coast experienced 4 spill incidents. Satellite images were used for the delineation of different shoreline types, mangroves, sand dunes, etc. Available existing marine ecological data and previous spill occurrence data along with Survey of India topographic sheet of 1:50000 were also used to prepare an ESI map (Fig 1). Several thematic maps were prepared based on NOAA guidelines. Accordingly, ranking was given on the scale of 1 to 10, where 10 are highly vulnerable and 1 is least vulnerable. As this study was carried out up to taluka level, it will be of immense help to initiate the preventive measures at local level decision makers in case of spill approaching the coast. It is necessary to have this kind of maps for all eco- sensitive coasts.

**Key words:** Goa coast, Environmental Sensitivity Index, Vulnerability, Oil spill

## **1. Introduction**

Oil spill now a days creating major environmental attention due to the sudden increase in the transportation through the sea. These spills occur due to the leakage in the oil super tankers, leakage in oil pipe lines, and also due to the off shore oil exploitation. Oil spill is having tendency to float over the water surface and it can easily reach the shore with the wave or tidal actions. Once this spill reaches the shore it creates major ecological damage. Shore line is rich in biodiversity. It is home of mangroves, sediment dwellers and estuarine ecology and of various other flora and fauna which are responsible for making balance between ocean and continental part. A major spill can disturb the coastal ecology which could potentially create long term problem. There are various oil sensitive organisms such as marine

birds, bottom dwellers and others suffer more when spills reach the coastal area.

## **2. ESI Mapping**

Environmental Sensitive Index (ESI) mapping is done prior to the oil spills. These maps represent the shore line in colour code which shows the vulnerability of shore line to oil spill. Shore lines are ranked on the scale of 1 to 10 in which 1 show the minimum vulnerability and 10 maximum. It has been an integral component of oil-spill contingency planning and response since 1979. Significant effort has been put for developing sensitivity mapping components of oil spill contingency plans around the world.

The Environmental Sensitivity Index (ESI) system is an international scheme that classifies and ranks the overall

sensitivity of different coastal habitats to oil spills. Several factors are used to determine the sensitivity of the coast including: substrate type (sand, mud, rock, mixed, etc.), exposure to wave action, slope of the shore, general biological productivity and ease of cleanup. Key to the rankings is an understanding of the relationships among physical processes, substrate type and associated biota that produce predictable patterns in oil behavior persistence and biological impact.

Shoreline Classification—ranked according to a scale relating to sensitivity, natural persistence of oil, and ease of cleanup.

Biological Resources—including oil-sensitive animals and rare plants; and habitats, which are used by oil-sensitive species or are themselves sensitive to oil spills, such as submersed aquatic vegetation and coral reefs.

Human uses resources—specific areas that have added sensitivity and value because of their use such as beaches, parks, marine sanctuaries, water intakes and archaeological sites.

Goa is situated along the western coast of India. It is highly vulnerable to the oil spill because Arabian Sea is having heavy transportation of oil super tankers and also there are off shore oil rigs active in it. Contrary to global scenario, oil incident along the Indian coast increased to 71% mainly along west coast because of heavy traffic in Arabian sea. A two year study of the Goa coast gives the result of 40 tones of oil tar deposition along the beaches of Goa. (B. S. Ingole and S. Sivadas, 2007). The occurrence of tar deposition become frequent phenomena on Goa beaches which happens to disturb tourism. In last 2 decades the state has experienced four major to minor oil spill incidents. Recently in may 2006 a bulk carrier MV Ocean Seraya was grounded was grounded in Oyster rock near to Karwar coast. (S. Sivadas, A. Gregory and B. Ingole, 2008) .The ship split in two and spilled oil reported on the major tourism significant beaches.

By keeping all development along the Goa coast, it is major task of environmental planners to come up with some concrete plan so as to tackle with the potential spill situation. ESI map which are prepared in advance of oil spill can give insight on the vulnerability of particular coast line.

Remote Sensing and GIS plays major role in the creation of ESI map. Remote Sensing can provide the fast, easy and cheap data collection regarding the shore line type identification, Geomorphology, geology, drainage, land use and land cover. It provides synoptic view of the area which can make data collection easy. GIS now becomes the backbone of ESI mapping as it gives the option of rigorous cartographic tool, updating of data .Updating data is the main feature of GIS, any change can be timely updated.

### 3. Study area

Goa is located on the West coast of India between the coordinates 14<sup>0</sup> 53' 57" North to 15<sup>0</sup> 47'59" North latitude and 73<sup>0</sup> 40' 54" East to 74<sup>0</sup> 20' 11" East longitude with a geographical area of 3702 sq.km. The coastline of Goa is shared by 5 Talukas of Goa state and estuary of Mandovi River touches far inland and makes part of another taluka in subject. In this study, six talukas of Goa state is mentioned, of which two falls under North Goa district and four under South Goa district. The area comprises bays, estuaries, rocky headlands, sandy beaches, creeks, cliffs, along the coastline.

### 4. Methodology for ESI mapping

#### Ecological Parameters

- Land forms :exposure of land form to the wave determines the amount of oil spill can accumulate on the shore line
- Oil sensitive organisms : some species are particularly sensitive to the oil spill like some birds ,which lose their insulative property of body due to the oil layer on their wings
- Tidal interference : The tidal fluctuation determines the amount of oil poured on the shore line
- Mangroves : mangroves are one of the most affected by oil spill
- Creeks: creeks are natural boundaries which can prevent the oil spill reaching on the shore.
- Estuary: estuary ecosystem contains many kind of flora and fauna .It is continuously facing tidal waves which make it vulnerable to oil spill.

### Geological parameter:

- Grain size of beach sand: Grain size determines the degree of permeability, and porosity of soil, if grain size is big than permeability will be more and hence oil accumulates into it.
- Geomorphology : It will give the general idea of land form present on the shoreline
- Slope of the shoreline : It is measure of the steepness of the inter-tidal zone between maximum and minimum at high and low tides, steeper the slope of inter-tidal zone, less would be affect of oil spill

### Land use land cover

- Man made features
- Another land use features such as agricultural land , aquaculture , tourism related spots
- Vegetation, wetlands , swamps , tidal flats , sandy beaches , mud flats , ( these mentioned land cover types are severally affected by oil spill)

### Biological parameter

- Number of species present along the shoreline area,; (shore line species are vulnerable to oil spill so classification of species is necessary in order to present a ESI atlas.
- Identification of major oil sensitive organism: (there are some species inhabiting the shoreline which are particularly sensitive to the oil spill, like some birds whose nesting, feeding, resting site is the shoreline area.)

Breeding, nesting, resting, feeding sites of some important organisms present around the coast

Initially satellite data and other spatial data such as topo map, geological map, and hydrological maps were acquired. These data has been geo-referenced and co registered in ERDAS software. From the topo-sheet base map of the study area is created. From the satellite map , through various digital image interpretation technique different land use and land cover type has been identified. Geological features, landforms, manmade features, habitats such as wetland habitat, mangrove, and estuarine habitat are identified.

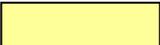
In the next stage these classified categories are overlaid on the base map. Extensive ground survey was carried out to collect the ground truth regarding the land form, ecology, species, and mangrove. The ground truth data has been taken into the GIS environment by using Arc GIS software. A GIS data inventory has been created for the collected non-spatial data and available data regarding flora and fauna present along the Goa coast.

## 5. Results and Discussion

**ESI 10**  Ranking 10 has been given to mangroves. Mangroves are most vulnerable to the oil spill. They are found along the course of Mandovi and Zuari River. Along the entire stretch of Cumbarjua canal which connects Mandovi and Zuari rivers, it has healthy growth. So these areas are ranked 10. East of Panjim city several swampy lands are present which fertile ground for mangrove vegetation is, they are also ranked 10 on the ESI scale.

**ESI 9**  Ranking 9 is assigned to tidal flats. In this study area Tidal Flats are found along the course of Mandovi and Zuari rivers. These areas are submerged in water at high tide time. If the spill will coincide with high tide than it may spread over tidal flat which can cause harm to the organisms taking shelter there.

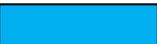
**ESI 8**  This ranking is given to sheltered rocky shore, sheltered man made structure. These areas are rare in this region. Only minute presence of sheltered rocky shore can be seen.

**ESI 7**  Ranking 7 is assigned for the exposed tidal flats. It is also high vulnerable area for oil spill. Tidal flats are present all along the major rivers flowing in the area. Mainly is can be seen along the Mandovi and Zuari river.

**ESI 6**  Ranking 6 is assigned for gravel beaches which has not been found in this area

**ESI 5**  Rank 5 is assigned to coarse sand to gravel beaches which are not found in this area

**ESI 4**  It is assigned for medium to coarse grained sandy beaches. In south Goa majority of beaches belong to this category. Beaches such as Bambolim, Bogmalo, Betul beach, Agonda beach, Palolem beach falls under rank 4 categories. The grain size analysis of sand suggests that these beaches are mainly made up of medium to coarse grain sand.

**ESI 3**  Rank 3 is given to medium to fine grained sandy beaches. South Goa is having one of the largest stretches of these kinds of beaches. There is 31 km long stretch of beach which is mainly composed of fine to

medium grained sand. Important beaches which fall in this category are, Colva, Majorda, Banaulim, Mobor, Verca, and Cansaulim Beach. Fine grain does not allow the oil to percolate. Cleaning operation is easier if oil does not percolate into the sand. Spread oil on the beaches are again taken into sea by the wave action.

So these beaches are low ranked in the ESI scale.

**ESI 2** Rank 2 is given to wave cut platform which are generally exposed. In the present study area wave cut platforms are rare.

**ESI 1** Rank 1 is assigned to rocky shore, cliffs, solid manmade structures. South Goa shoreline is made up of Rocky head land altering with sandy beaches. Important headlands are Vasco headland, Cape Di Rama headland. Except these there are some small headlands present there. In southern part shore line is mainly composed of headlands and cliffs. Rocky shore line reflects back spill and there is very less chance of accumulation of spill. So they are given minimum rank 1 in ESI index.

## 6. Conclusion

This study is of first kind in this region to have an integrated approach using remote sensing and GIS which gives a close look at the vulnerability of the Goa coast to oil spills. Remote Sensing and GIS can be effectively used for the preparation of ESI map. It provides fast and cheap way to find out the different classes of shoreline present in the coast. GIS provides powerful cartographic tool and data updating facility. Sensitivity of the Goa coast may be considered as medium to high. There are rocky head lands and pristine fragile beaches which attracts tourists from all over the world. Estuarine eco system will be most affected if the oil spill coincides with the high tide. These estuaries are having Mangroves which are rich in biodiversity. This ESI map means to support the environmental planners at the time of oil spill.

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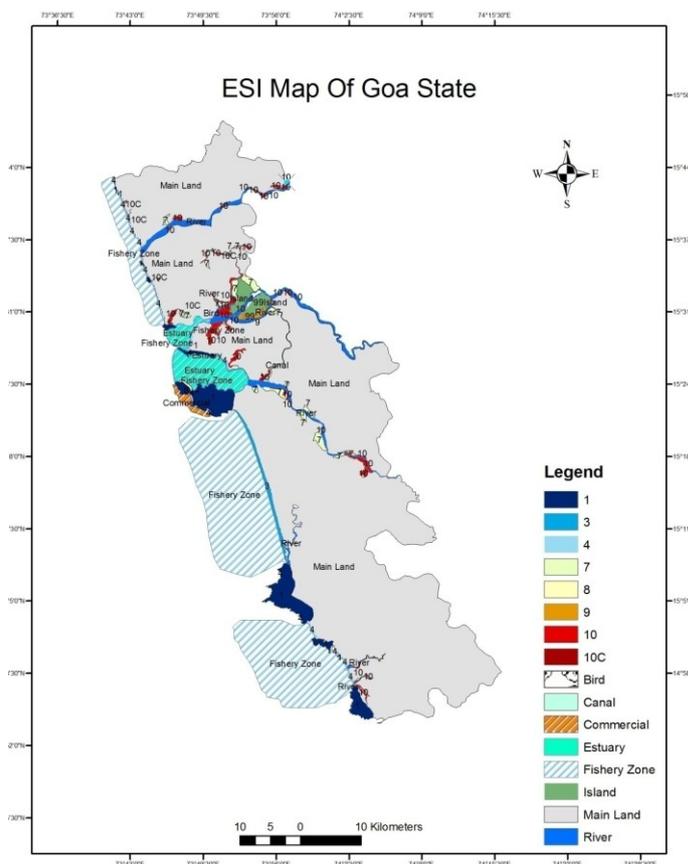


Figure 1. ESI map of Goa state