

Mapping of Environmental Sensitive Index (ESI) for the oil spills at Goa coast, India

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Abstract

Indian remote sensing satellite (IRS) data have been used to find out the Environmental Sensitivity Index (ESI) for the Goa coast which is situated in the west coast of India. It is one of the most sensitive environments in terms of its rich biodiversity and also due to its coastal geomorphologic features. It comprises of mangroves, creeks, Sandy as well as rocky beaches and cliffs. The shoreline is crenulated and segmented, with alternating headlands, cliffs, estuaries, bays, beaches, creeks and spits (Wagle. B.G, 1993). Marine and fluvial features are pre-dominant in this coast. Goa has been identified as one of the major tourist destinations of the world because of its beautiful beaches and associated recreational activities (Vethamony .et al 2007). The economy of Goa depends on tourism and any damage to its environment will badly affect its economy. . The aim of the study is to map and rank coastal areas of Goa on the basis of their sensitivity to oil spill using remote sensing and field data. Physical, geomorphic and biological environmental attributes have been used for the study area and respective sensitivity index for oil spills have been derived. These attributes have been used for classifying as well as to rank the sensitivity for oil spills. By using Geomorphology, Land use/ Land cover, Slope, Digital Elevation Model (DEM), part of the Goa coast have been classified and ESI maps are prepared. This map is very important and may be used for spill response contingency planning. The paper uses GIS and remote sensing techniques to achieve the task. The paper suggests the need for having a pre-validated ESI maps in response to action and contingency planning for oil spills in India. This study is of first kind in this region to have an integrated approach using remote sensing and GIS.

Key words: Goa coast, Environmental Sensitivity Index, GIS, Remote Sensing, IRS

Introduction

Oil spill is causing major stress on the marine environment at all over the globe. It is mostly caused by the oil super tankers which are the means of transporting the crude oil. There are other means of oil spill which include rupture in the oil pipe line crossing the ocean, spill from off shore oil rigs, industrial dump in the ocean. Global economic growth increases the demand for petroleum products which indirectly increases the risk of spills (Vethamony et.al, 2007)

These spills can create huge stress on marine environment. Marine organisms, birds, fish, seals, insects and bottom dwellers suffer short term and long term impact. Coastal zones are more sensitive to these spills as these areas comprise estuaries, wet lands, tidal flats, coastal plains, beaches. These areas are home of various plant species , mammals , bottom dwellers and plays important role in making balance between offshore and onshore environment. An oil spill can infuse long term impact on the coastal ecology.

To deal with this oil spill problem in the coastal area, ESI maps are prepared as a guideline to contingency planning. These maps are prepared in advance of arrival of oil spill. These maps are colour coded in which colour variation shows the respective vulnerability of coast. Ranking is given on the scale of 1 to 10 , in that 10 is given for the highly vulnerable coasts and 1 for less vulnerable .These ranking are based on three major parameters according to NOAA guidelines. They are shoreline type, biological resources and human use resources.

Goa has a 105 km large coast comprising estuaries, head lands, cliffs, creeks, beaches. The head lands are alternating with sandy beaches. There are seven major rivers which forms estuary at the mouth, Mandovi and Zoari estuaries are prominent among them.

Goa has versatile coastal ecology, it attracts tourists from all over the world. The economy in Goa is very much dependent upon these tourism activities. Other major socioeconomic feature is the fishing activity, which is active in all along the Goa coast. Except these, Goa people used to cultivate paddy and other crops in the coastal plains.

Our Indian coast is very much prone to the oil spills as they are in the major traffic zones of oil transport. In the last decade, particularly along the Goa coast 4 spill incidents occurred .Recently in May 2006 a bulk carrier MV Ocean Seraya was grounded on oyster rock in Karwar (S. Sivadas, et.al. 2008). The ship split into two and spilled oil was

reported up to Benaulim which is a famous beach in Goa .In august 2005 heavy deposit of tar balls were reported from the major tourist beaches of Goa. Keeping all these facts in mind, it is the need to prepare a ESI map which could be used for oil contingency planning and response if any spill incident occurs in near future.

Remote sensing and GIS plays very important role in the mapping of different classes of shore line and preparing different thematic layers such as coastal geomorphology, land use/ land cover, socioeconomic features, slope, etc.GIS is the best way to prepare a ESI map. In this case study, part of Goa has been used to classify different shore line classes, coastal geomorphology, land use land cover along the coastal area, coastal vegetation, slope, socioeconomic features etc. All the themes are taken into the GIS environment accordingly ESI map has been prepared by following the NOAA guidelines.

Oil spill along the Goa coast can potentially harm the estuarine ecology; it can damage the mangrove forest. The fishing activity can be hampered and it can make long term impact on the bottom dwellers, marine mammal, and sea birds. The white sandy beaches of Goa can lose its beauty and it can hamper the tourism business. There are examples which tell that tar balls are accumulated on the beaches of Goa and all of sudden tourist started to cancel their booking in hotels. A two year study gave a figure of 40 tones of tar balls along the Goa beaches (B. S. Ingole et.al. 2007). These all mentioned features makes it necessary to prepare a ESI map so that if any oil spill occur in future, environmental planners can plan the contingency and response properly . The objective of this study is to prepare an ESI map for the Goa coast using remote sensing and GIS

Study area

The study area (Fig.1) is part of Goa coast which starts from Mandovi Estuary and covers entire southern coast of Goa .The area falls under $73^{\circ} 46'10.794''E$ and $15^{\circ} 29'22.903''N$ to $74^{\circ}4'57.518''E$ $14^{\circ}54' 5.308''N$. This coast line of Goa is shared by 5 Talukas of Goa state and the estuary of Mandovi touches far inland and makes part of another Taluka. 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 . The estuarine ecology

constitutes swamps, mangroves, mudflats, river terraces and island.



Figure 1 Satellite image view of study area

Methodology

IRS P6 LISS-III satellite data have been used and digitally analysed with the help of ERDAS 8.6 soft ware. Land use/land cover classification has been performed on LISS-III data with various categories such as beaches, headlands, mangroves, wetlands, estuaries, build up land; barren land and agricultural land have been identified. The image has been used for the delineation of shore line types such as beaches, rocky head lands, cliffs, estuaries; wave cut platforms, creeks, mangroves. sand dunes. Available marine ecological data and previous spill occurrence data from National Institute of Oceanography Goa was used for the study. Survey of India topographic sheet of 1:50000 was also used to prepare a base map and for shore line identification. Several thematic maps have been prepared such as geomorphology map, slope map, shore line type map, coastal vegetation map , fluvio-marine formations such as Estuary ,Tidal flat , swamps etc . Finally following the NOAA guidelines, the shore line categories mapped has been matched with the shore line class index and accordingly ranking was given on the scale of 1 to 10 where 10 is highly vulnerable and 1 least vulnerable.

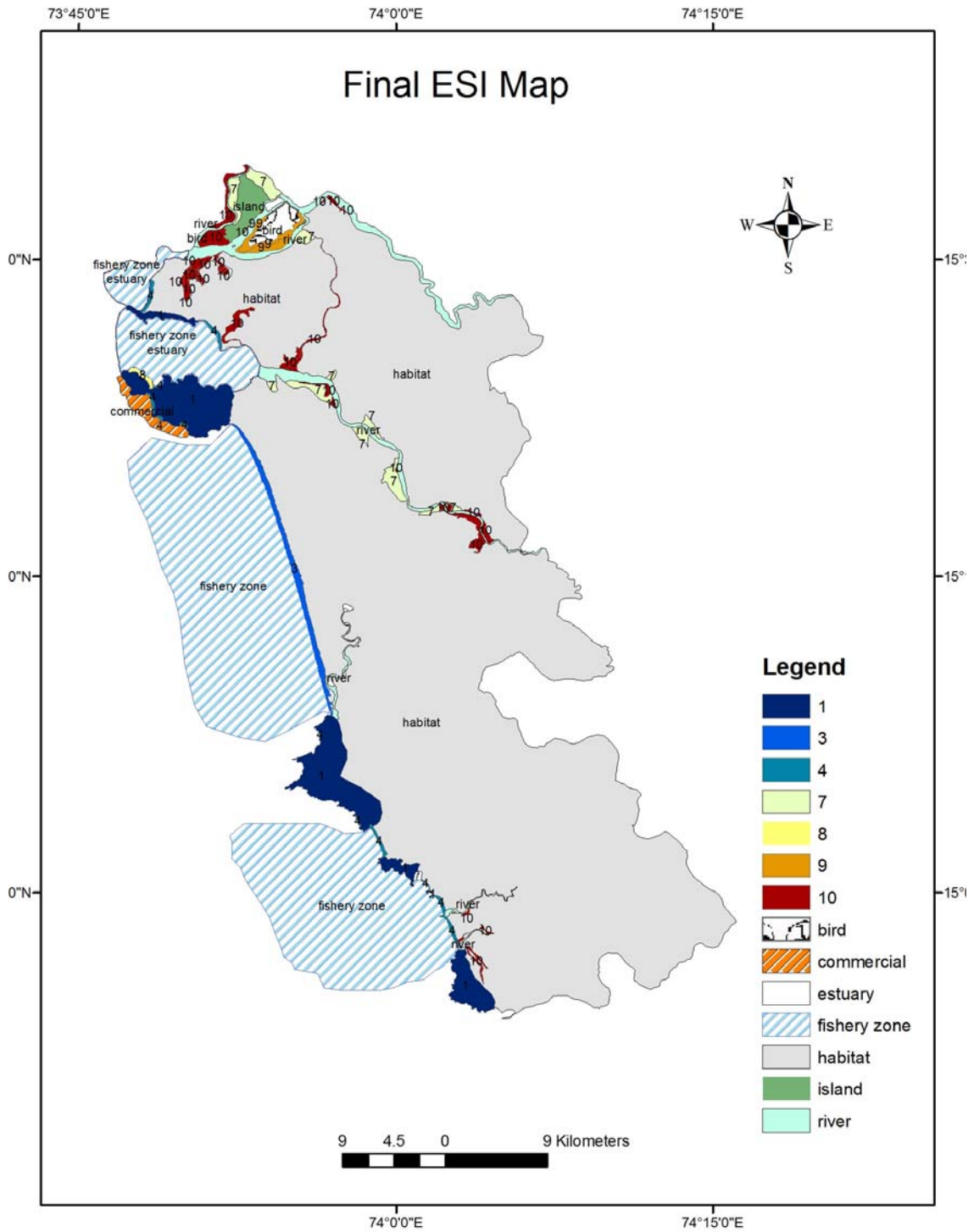


Figure 2 Environmental Sensitivity map of South Goa coast

Results and discussion

ESI map was generated in the GIS environment. It provided powerful cartographic tool. Proper colour coding is done for each shoreline type. For example in presenting the shoreline oil-sensitivity, warm colours indicate the most sensitive shorelines, and cool colours indicate the least sensitive. Wild life, Bird sanctuary, human use resources all are represented with proper symbol. The figure 2 shows the ESI map. The descriptions of the different indexes are as follows

ESI 10



10 ranking has been given to the highest vulnerable areas like Mangrove cover, Swamps, Freshwater marshes. In the study area, it has been observed at all along the Mandovi and Zuari estuaries. Other than that, it is observed along the Cumbarjua canal also. In the east of Panjim city, there is healthy growth of Mangrove. Two islands within the estuary are having mangroves which shelter many species and migratory birds. According to data from National Informatics Centre, 700 hectare of mangrove are present in the Mandovi estuary and 900 hectare present in Zuari estuary. Along the Zuari estuary several places are covered with thick mangrove cover. They all are at risk during oil spill if it coincides with the high tides. As data (Shetye et.al 2007) suggests that during high tide sea water reaches up to 40 km inside the rivers. There are some places inside Mandovi estuary where fresh water marshes are present.

ESI 9



Rank 9 has been given to sheltered tidal flats, Vegetated low banks. These area have been found in Mandovi estuary. Sheltered tidal flats are observed in the island within the Mandovi estuary. There are two islands inside Mandovi estuary where these sheltered tidal flats are present. They are mainly found in patches.

ESI 8



This ranking is given to the sheltered rocky shore, Sheltered, solid man-made structures. These types are very less in the study area. They are found in very small patches and major one which falls under this category is the Marmugoa port. It is some what sheltered because it has been established in the Zuari estuary.

ESI 7



This ranking is given to Exposed tidal flats. There are various places along the Mandovi and Zuari estuary where exposed tidal flats have been found. One of the major area is found in the Mandovi estuary. In the Zuari estuary tidal flats are more prominent. Near to Vasco there is a huge tidal flat area.

ESI 6



ESI 6 is given to the gravel beaches in which oil can percolate, once oil percolate than the cleaning operation becomes more problematic. This category is not found in the study area.

ESI 5



ESI 5 is given to the mixed sand and gravel beaches. Because of the mixing of sand in gravel, the oil percolation becomes less and hence oil spill may not create long term problem. This type has not been observed in the study area.

ESI 4



Coarse grain sandy beaches are ranked 4 in ESI map. In this study area, many shore line features falls under this category. Major beaches such as Miramar, Bambolim, Bogmalo, Velsao, Agonda, Palolem, Talpona, Galgibaga beach are having coarse grain sand. They all are ranked 4 in the ESI map.

ESI 3

Fine to medium grained sandy beaches (Antonio Mascarenhas, 1998) are falling under this category. In this study area this category extends from Velaso to Canaguinim. This entire stretch is of almost 31 km. This shore line type is ranked low because of less penetration of oil into it and the accumulated oil can be driven back from shore by the action of tides and waves.

ESI 2

ESI 2 rank is given to exposed scarps and steep slopes in clay. This category has not been found in the study area.

ESI 1

Rank 1 is given to exposed rocky shores, exposed solid man-made structures. In this study area, sandy beaches are alternating with rocky head land. The prominent are Marmugoa head land, Cape Rama and Agonda .There are many small hills with scrub to woody vegetation present all over the coast. In the north and south of the Zuari estuary, there are several rocky head land present. They all are ranked 1 because oil cannot accumulate on the rocky shores and it will be reflected back by wave action.

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. It is suggested to have pre-validated ESI maps for our Indian coast in response to action and contingency planning for oil spills in India. The coastline of

Goa which is having tidal variation of 2.4 m is at risk during the oil spill because of its estuarine ecology and fragile beaches. During the high tides, a potential spill may reach up to 30 to 40 km inside the river. This ESI map means to support the environmental planners at the time of oil spill.

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