Analysis of Mangrove vegetation health index by implementing NDVI classification method based on Landsat image data: Case study from Zuari Estuary Goa, India

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Abstract

Mangrove ecosystems are among the most productive and biologically complex ecosystems in the world providing many ecosystem services for human wellbeing, hence they have an outstanding relevance ecologically and economically. Mangrove habitats are temporarily inundated and often located in inaccessible regions. In Goa, fringing mangroves are distributed in Zuari and Mandovi estuaries based on topography and environmental conditions. These estuarine regions are used as inland waterways for transportation of iron ore, tourism, infrastructure development like bridges, jetties, highways, resorts and hotels, residential apartments, restaurants, small roads etc. Zuari estuary is located at lat. 15°25'N and long. 73°59'E on the central west coast of India. The images were downloaded from United States Geological Survey website (USGS). The radiometric and geometric corrections were made to reduce the undesirable noise component and changes in the amount of incoming radiance from sensors.

Anderson level 1 classification was used for the classification purpose. The mangroves were digitized using hybrid classification method. For mangrove demarcation Google Earth Pro and visual interpretation techniques were used. Normalised Difference Vegetation Index (NDVI) analysis was adapted to perceive the health status of mangroves covers in the study area. The NDVI results were divided into three categories: (0.00-0.15 Stressed), (0.15-0.30 Moderately healthy), (0.30-0.47 Very healthy). Rhizophora and 01sp. each of Aegiceras, Bruguiera, Kandelia, Acanthus and Excoecaria along with mangrove associates like Acrosticum, Clerodendron, Salvadora, Ipomoea and Derris. Sonneretia alba and Avicennia marina were found to be dominating followed by Rhizophora mucronata. Stressed patches of mangroves can be attributed to the human interference from the surrounding regions, changes in water salinity, increase in pollution levels due to mining activities (transportation of iron ore from barges), infrastructure development etc. Moderately healthy and very healthy patches of mangroves may be associated with suitable ecological and natural conditions favouring healthy growth and also lack of anthropogenic interference and awareness about the importance of mangroves.

Keywords: Mangroves, NDVI, *Avicennia, Sonneracia, Rhizophora, Aegiceras, Bruguiera, Kandelia, Acanthus and Excoecaria.*

Introduction

Mangrove ecosystems are found at the interface between terrestrial and marine ecosystems and dominated by unique plant communities, that are adapted to a variety of alterable conditions of substrate, oxygen level, salinity and temperature[13]. India's mangrove cover extends over 4,975 sq km. including the coasts of Andaman and Nicobar and Lakshadweep islands as per the India State of Forest Report 2019[6]. The protection or restoration of blue carbon sequestered and stored over long timescales by mangrove forests is steadily gaining prominence as a key natural climate solution. They are most productive systems providing a unique habitat opportunity for many species and key services for human beings.

Mangrove habitats are regressing at an alarming rate due to direct anthropogenic impacts and global change, hence there is need to investigate the mangrove health[5]. Mangrove health-related literature, however, remains sparse and fragmented, in contrast with the situation regarding other terrestrial habitats[1].

The few mangrove reviews found have concentrated on ecological characteristics, economic value, impacts of environmental change on ecosystem resilience. The combination of remote sensing technology and spatial metrics, in particular, has made a powerful approach for analysing and managing mangrove degradation based on their distribution structures[7]. Remote sensing is an advanced technique due to its synoptic and repeated coverage and can provide historical and current information about the status of mangrove in large areas[4].

Many studies are conducted on mangrove ecosystems by using multi-spectral satellite data for determining spatio-

temporal change[9] by application of high-resolution multispectral satellites that can produce Normalized Difference Vegetation Index (NDVI)[10] or by mangrove vegetation stress with the Thematic Mapper (TM)/Enhanced Thematic Mapper (ETM) for the Landsat satellite[14]. Schultz et al[11] used multiple indices with the inclusion of the Enhanced Vegetation Index (EVI) and Normalized Difference Vegetation Index (NDVI). State of Goa is structured for administrative purposes into 11 talukas and is intersected by numerous rivers which can be navigated for different purposes. Most of the major rivers, which cut across hinterland formations, originate in the Western Ghats across the border. The two main rivers are Mandovi (61.6 km in length) and Zuari (92.4 km) with their interconnecting Cumbarjua canal (15 km) forming a major estuarine complex.

There are fringing mangroves present in this estuary and their distribution is based on topography and environmental conditions[8]. Goa has an average temperature of 25–30°C and the average annual rainfall is 2,848.7 mm and hence both these factors make it very conducive for mangrove growth. The composition and configuration of mangrove species in estuaries vary as per the salinity gradient which varies from the mouth of the river to upstream. This gradient decreases as one proceeds from the mouth to the upstream of the river and also varies from day to day due to the high tide–low tide phenomena.

Objective of this study was to enumerate the extent and location of mangrove forests distributed in Zuari estuary and to analyse the health of this vegetation using Landsat image data.

Study area

Zuari estuary is located at lat. 15°25' N and long, 73°59' E on the central west coast of India which is larger than the Mandovi. The 10 km stretch upstream from the mouth of Zuari is approximately 5 km wide and 5 m deep. It is known as Mormugao Bay. At the upstream end of the bay, the channel narrows to a width less than one km. The 30 km long channel of 50 km from Cortalim to Sanvordem narrows progressively.

Material and Methods

Data collection by Ground truthing and sampling: The fieldwork was conducted in September - October 2023. The site was pre-visited for geolocation of sampling points. Ground truthing included observation, photography, plant sample collection, along the walkway and by boat trip to the estuary. Species distributed towards Cortalim side extending from Loutolim, Raia, Borim, Shiroda, Panchawadi, Sanvordem and towards Agacaim side extending from Madkai, Durbhat, Borim, Shiroda, Panchawadi, Sanvordem were documented. Identification was carried out using available literature[2,3,12]. All these findings (ground inventory) were used to develop a final health vegetation assessment map for Zuari estuary.

Satellite Data and analysis: Remote sensing has surfaced as a sustainable tool for mapping and monitoring mangroves as it allows collection of information from places which are difficult to explore. Satellite data analysis along with the Geographical Information System (GIS) has become most popular manner to monitor the mangrove ecosystem on regular basis. For the mangrove health analysis, three different year Landsat satellite images were obtained i.e. for year 1992, 2002 and 2022 as seen in table 1.

The images were downloaded from United States Geological Survey website (USGS). The radiometric and geometric corrections were made as radiometric correction reduces the undesirable noise component and changes the amount of incoming radiance from sensors while geometric corrections rectify the distortions in an image and transforming it so that it has the properties of a map.

Study area was extracted using clip operation from these satellite images by overlaying study area shapefile in Arc GIS 10.8 software. Anderson level 1 classification was used for the classification purpose. The mangroves were digitized using hybrid classification method. For mangrove demarcation, Google Earth Pro and visual interpretation techniques were used. Normalised Difference Vegetation Index (NDVI) analysis was adapted to perceive the health status of mangroves covers in the study area (Fig. 1).

Results and Discussion

Mangroves and their associates recorded during study are tabulated in table 2.

The study site is dominated by *Avicenna officinalis*, *A. marina*, *S. alba*, *Sonneratia caseolaris*, *Rhizophora mucronata* followed by *Acanthus ilicifolius.*

NDVI is based on variation between maximum absorption of radiation in red due to presence of chlorophyll and maximum reflection of radiation in NIR due to leaf cellular structure. NDVI is vital model for generating density of mangroves which is useful for assessing their health status. Healthy vegetation has higher NDVI value as compared to that of unhealthy vegetation. The NDVI results were divided into three categories: (0.00-0.15 Stressed), (0.15-0.30 Moderately healthy), (0.30-0.47 Very healthy). The NDVI results for the three time periods 1992, 2002 and 2022 indicated health status of the mangroves respectively. Table 3 represents health status of mangroves in three time periods.

In 1992, the total area under mangroves was 4.52 km^2, out of which 1.46 km^2 area under mangroves was stressed, 2.12 km^2 area under mangroves were moderately healthy and 0.94 km^2 area under mangroves were very healthy. In 2002, the total area under mangroves was 6.73 km^2, out of which 1.62 km^2 area under mangroves was stressed, 3.21 km^2 area under mangroves was moderately healthy and 1.90 km^2 area under mangroves was very healthy.

Table 1
Data obtained from Landsat Satellite

S.N.	Satellite	Sensor	Resolution	Path & Row	No. of Bands	Date of Pass	Cloud Cover
1	LANDSAT	TM	30 M	146, 49	7	12/01/1992	0
2	LANDSAT	ETM+	30 M	146, 49	8	15/01/2002	0
3	LANDSAT	OLI	30 M	146, 49	11	30/01/2022	0

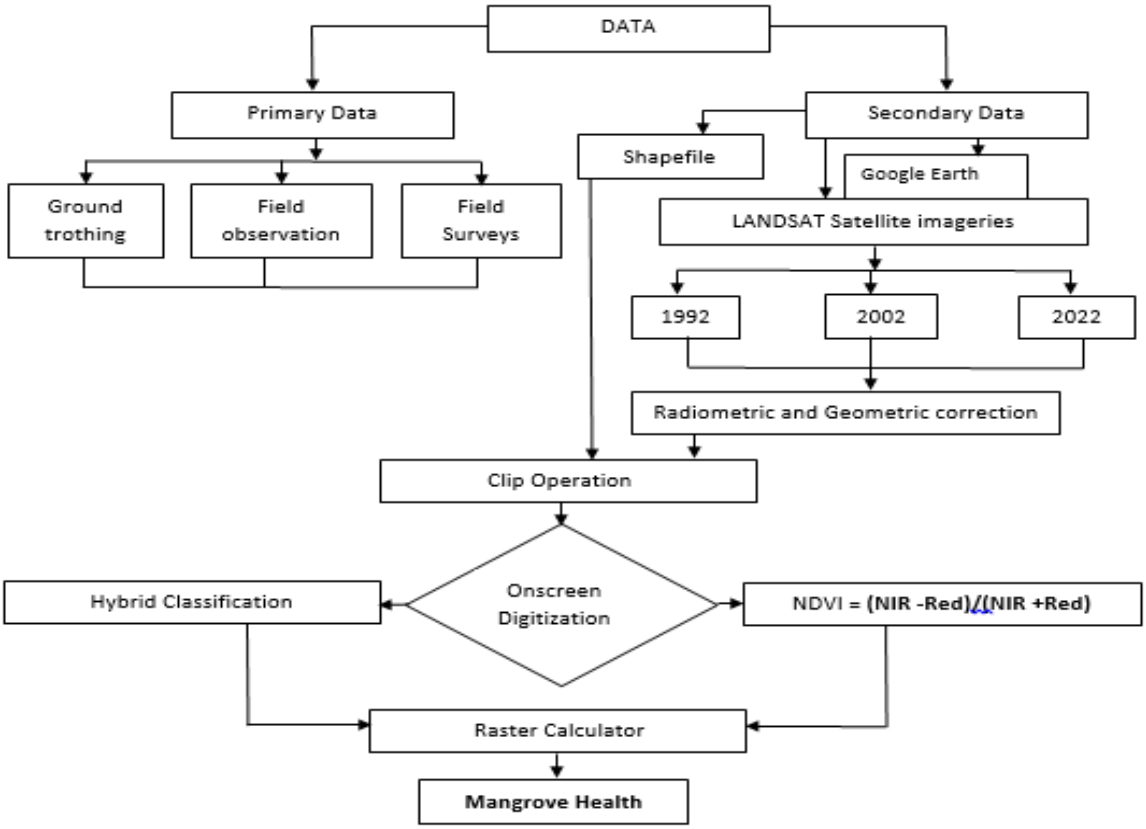

Fig. 1: Methodology Chart

Table 2
Mangroves and their associates documented during the study

S.N.	Botanical name	True Mangrove/Associate	Study site/s
1.	*Acanthus ilicifolius*	True Mangrove	All
2.	*Aegiceras corniculatum*	True Mangrove	All
3.	*Avicennia marina*	True Mangrove	All
4.	*Avicennia officinalis*	True Mangrove	All
5.	*Brugeira gymnorrhiza*	True Mangrove	All
6.	*Excoecaria agallocha*	True Mangrove	All
7.	*Kandelia candel*	True Mangrove	All
8.	*Rhizophora mucronata*	True Mangrove	All
9.	*Sonneratia caseolaris*	True Mangrove	All
10.	*Sonneratia alba*	True Mangrove	All
11.	*Acrosticum aurium*	Mangrove associate	All
12.	*Clerodendroninerme*	Mangrove associate	All
13.	*Derris trifolia*	Mangrove associate	All
14.	*Ipomoea pescapre*	Mangrove associate	All
15.	*Ipomoea tuba*	Mangrove associate	All
16.	*Salvadora persica*	Mangrove associate	All

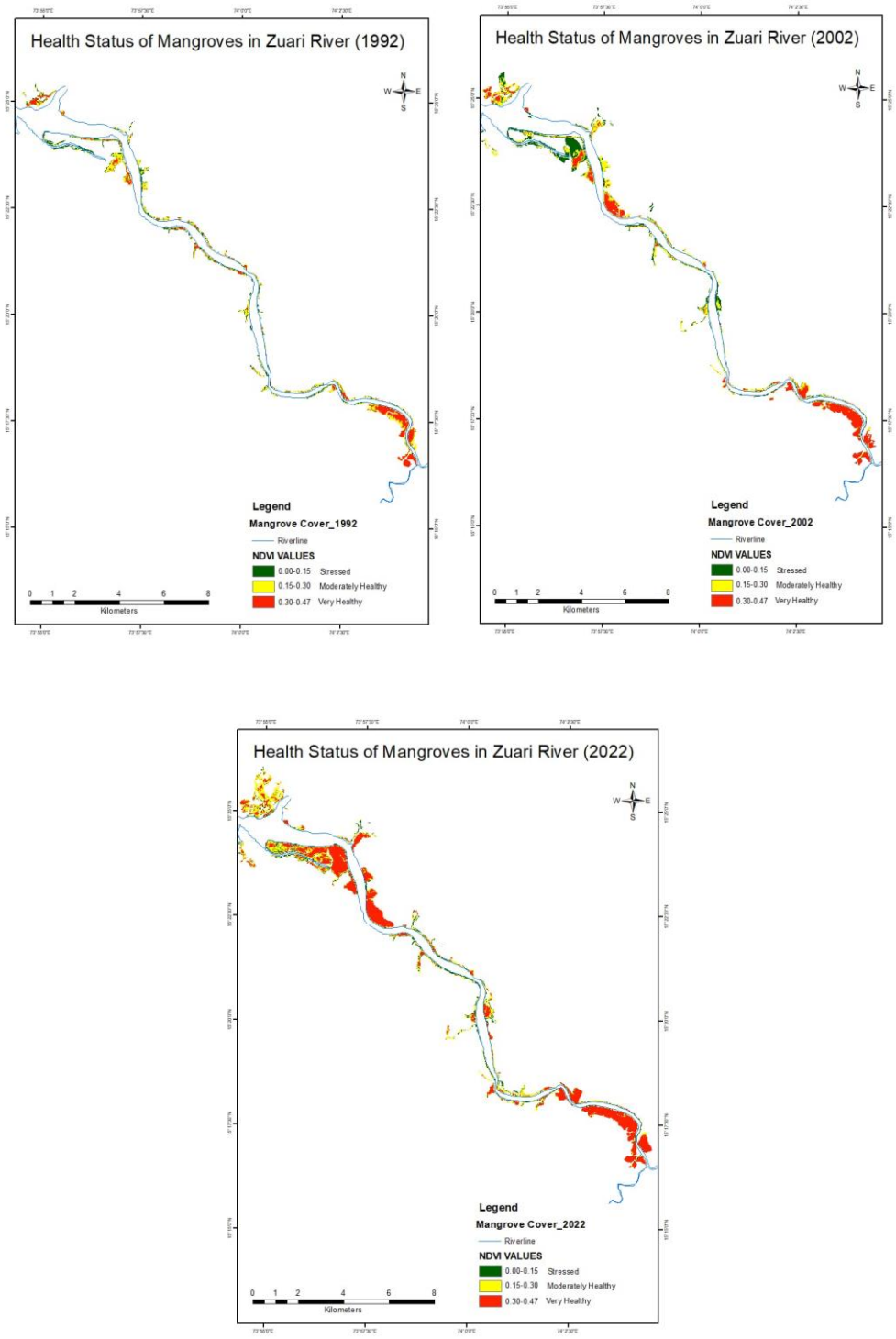

Fig. 2: Health wise mangrove distribution-1992, 2002 and 2022

Table 3
Mangrove Health Status

Year/ Mangrove health	**1992 (Area in km^2)**	**2002 (Area in km^2)**	**2022 (Area in km^2)**
Stressed (0.00-0.15 NDVI range)	1.46	1.62	1.15
Moderately Healthy (0.15-0.30)	2.12	3.21	4.28
Very Healthy (0.30-0.47)	0.94	1.90	6.02
Total area under Mangroves	4.52 km^2	6.73km^2	11.45km^2

In 2022, the total area under mangroves was 11.45 km^2, out of which 1.15 km^2 area under mangroves was stressed, 4.28 km^2 area under mangroves was moderately healthy and 6.02 km^2 area under mangroves was very healthy.

Stressed patches of mangroves can be attributed to the human interference from the surrounding regions, changes in water salinity, increase in pollution levels etc. Moderately healthy and very healthy patches of mangroves may be associated with suitable ecological and natural conditions favouring healthy growth and also lack of anthropogenic activities.

Conclusion

11 species of mangroves belonging to 08 genera were documented from estuarine region of Zuari comprising 02 spp. each of *Avicennia*, *Sonneratia*, *Rhizophora and* 01sp. each of *Aegiceras*, *Bruguiera*, *Kandelia*, *Acanthus* and *Excoecaria* along with mangrove associates like *Acrosticum*, *Clerodendron*, *Salvadora*, *Ipomoea* and *Derris*. *Sonneretia alba* and *Avicennia marina* were found to be dominating followed by *Rhizophora mucronata.* The NDVI results were divided into three categories: (0.00-0.15 Stressed), (0.15-0.30 Moderately healthy) and (0.3 0-0.47 Very healthy).

Natural conditions favouring healthy growth and also lack of anthropogenic interference and awareness about the importance of mangroves associates to healthy conditions of mangroves. While, changing salinity and human interference through deforestation, discharge of waste waters have lead to deterioration of mangrove health.

References

1. Chellamani P., Singh C.P. and Panigrahy S., Assessment of the health status of Indian mangrove ecosystems using multi temporal remote sensing data, *Tropical Ecology*, **55(2)**, 245–253 **(2014)**

2. Cook T., Flora of the Presidency of Bombay, Botanical Survey of India, Calcutta **(1967)**

3. Dhargalkar V., D' Souza R., Kavlekar D. and Untawale A., Mangroves of Goa, Mangrove Society of India, Goa Publication **(2014)**

4. Giri C., Observation and monitoring of mangrove forests using remote sensing: Opportunities and challenges, *Remote Sensing*, **8(9)**, 783 **(2016)**

5. Giri C., Ochieng E., Tieszen L.L., Zhu Z., Singh A. and Loveland T., Status and distribution of mangrove forests of the world using earth observation satellite data, *Global Ecology and Biogeography*, **20**, 154–159 **(2011)**

6. India State of Forest Report 2019 - Forest Survey of India. Dehradun: Forest Survey of India, Ministry of Environment Forest and Climate Change **(2019)**

7. Onesmus M., Introduction to Random Forest in Machine Learning, https://www.section.io/engineering-education/introduction-to-random-forest-in-machine-learning **(2020)**

8. Pawar T.A., Study of Mangrove flora along the Zuari River (Case study on Curtorim Village – Goa- India), *International Research Journal of Environment Sciences*, **1(5)**, 35-39 **(2012)**

9. Pham M.H.M. and Nguyen N.Q., An introduction of Random forest in the machine learning revolution and the application in satellite image classification, *Vietnam Journal of Geodesy and Cartography*, **39 (2019)**

10. Razali S.M., Nuruddin A.A. and Lion M., Mangrove Vegetation Health Assessment Based on Remote Sensing Indices For Tanjung Piai, Malay Peninsular, *Journal of Landscape Ecology*, **12(2)**, DOI:10.2478/jlecol-2019-0008 **(2019)**

11. Schultz M., Clevers J., Carter S., Verbesselt J., Avitabile V., Quang H.V. and Herold M., Performance of vegetation indices from Landsat time series in deforestation monitoring, *International Journal of Applied Earth Observation and Geoinformation*, **52**, 318-327 **(2016)**

12. Shukla S.R., Shashikala S., Panchpande S. and Sujata M., Handbook of Mangroves of Maharashtra, Nararaj Publishers, New Delhi **(2020)**

13. Sowah E.M.A., Graham N. and Watson N.M., Investigating mangrove-human health relationships: A review of recently reported physiological benefits, *Dialogues in Health*, https://doi.org/10.1016/j.dialog.2022.100059 **(2022)**

14. Zhang J. and Zhang Y., Remote sensing research issues of the National Land Use Change Program of China, *ISPRS J. Photogramm Remote Sens.*, **62(6)**, 461–472 **(2007)**.

(Received 09th March 2024, accepted 09th May 2024)