INTERNATIONAL ASSOCIATION OF BIOLOGICALS AND COMPUTATIONAL DIGEST
International & Peer-Reviewed Journal
E-ISSN: 2583-3995

HEALTH ASSESSMENT MODELING OF MANGROVES: A CASE STUDY OF PURNA ESTUARY, GUJARAT, INDIA

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ABSTRACT

This paper quantifies the present status of Mangrove covers in the estuarine region of Purna River, Gujarat. Mangroves health assessment and change detection is modelled after contemplation of important health indicators such as canopy cover, drainage density, erosion and accretion, reclamation activities, and natural regeneration. The weightage of each parameter is given based on its relative importance in mangrove's health. The entire study area is overlaid with a uniform grid of 1 × 1 hectare, where each parameter is calculated and mapped using multispectral LISS-IV satellite imageries of different time frames between 2008 and 2018 along with the in-situ field measurements. Our analysis showed that the mangrove area of approximately 0.094 sq.km has been degraded from 2008 to 2018 and about 0.126 sq.km has undergone degradation. Whereas the mangroves present on island patches are showing an improvement especially observed along the creek. The area under the pristine health condition of mangroves has been reduced to 0.336 sq. km. One of the major reasons was the construction of aquaculture ponds, which was increased from 2.937 sq.km in 2014 to 7.659 sq.km in 2018. The secondary factor is the wave activity near the mouth of the estuary, which is causing severe erosion along the coast and thereby affecting the mangrove trees.

Keywords- *Health Model, Mangroves, Purna Estuarine, Optical remote sensing, Change detection*

INTRODUCTION

Mangroves swamp is the most productive ecosystem of a tidally influenced wetland. It serves a distinct number of wildlife species and acts as reservoirs for many small organisms. Therefore, it supports a large number of the local fishing communities associated with a coast. It stabilizes the shoreline position by trapping sediment and works as a barrier against natural calamities like stormsurge, tsunamis, etc. These social and ecological services of mangroves are well recognized in the literature. Besides this, the coastal areas are one of the most preferred sites for human development activities such as the construction of ports, aquaculture ponds, saltpans, embankments, etc. Unfortunately, directly or indirectly these human-induced activities are causing major threats to mangroves forests (Zhang et al. 2012; Makowski and Charles 2018; Spalding et al. 2014). These activities result in excessive sediment, lack of rainfall or freshwater, obstruction in natural flow can cause serious threats to mangroves. To overcome all these threats and to perform practices in the nearby areas, appropriate information related to its spatial distribution, structure, and composition is required (Satyanarayana et al. 2011; Walters 2005). Mangroves are generally termed under facultative *Halophytes* but some of its species cannot survive in the salinity more than 30 PSU. They need a freshwater flow for the dilution of salinity and enough tidal range (Parida 2010). Many studies demonstrated that resources like forest and some of its parameters are better mapped, characterized, and quantified by implementing advanced remote sensing techniques. It became an indispensable means to survey such a large intertidal area manually at a small scale (Kuenzer et al. 2011; Cracknell 1999). Some studies divulged that mangroves exhibit low reflectance value in SWIR region compare to any other non-mangroves forest

(Tamura and Kota 2008; Giri 2016).

The main objective of this study is to assess the current health condition and change detection of Purna mangroves swamp for a period of 2008 to 2018. Five major parameters have been identifiedsuch as canopy cover, drainage density, erosion and accretion, reclamation activities, and natural regeneration as indicators to measure the ecological health of mangroves. This paper provides themethod to analyse various parameters using multispectral satellite imagery. All the parameters are analysed on the grid of 1 × 1 hectare; the weightage value has been assigned for each segment of the grid as per their significance. The model used for simulation in this study is well putative in the Coastal Zones of India (Anon. 2012; Kannan 2014).

MATERIALS AND METHODS

Study Area

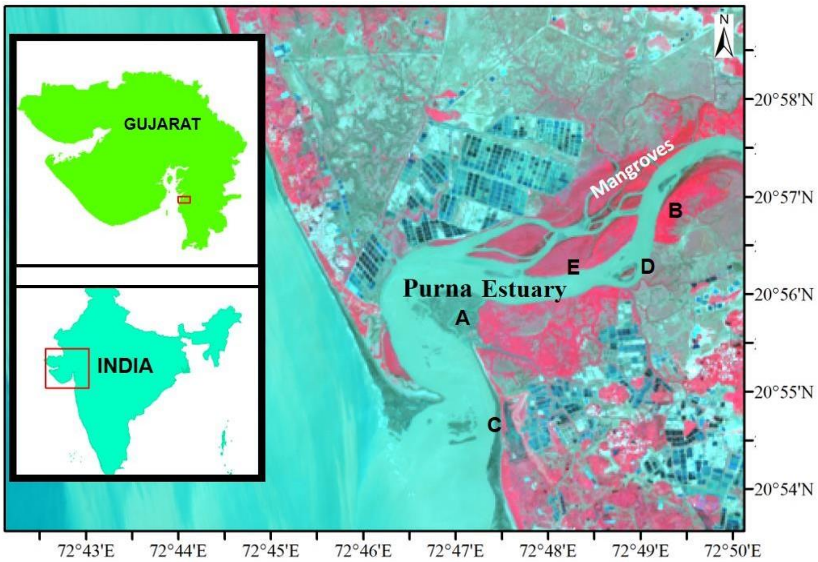


Fig. 1. Study area and location map of Purna Estuarine environment. The image shown is the False Colour Composite (FCC) generated using NIR, Green and Blue bands of LISS-IV satellite. The red region showing vegetation and bright red region corresponds to the mangrove region along the Purna River estuary. Locations A – E are points considered for in-situ measurement.

Purna mangroves are the least exposed forest of South Gujarat, west coast of India (Fig. 1). Most of the mangroves patches are located in the islands along the estuarine stretch. In 2009, a report was published by GEER foundation mentioned that 13 rare species of mangroves of height up to 10 m are found in south Gujarat. This area is surrounded by the fishing community which highly depending on them for their fuel and fodder. This is one of the areas rich in diversity of mangroves in Gujarat with tree height more than 5 m (Anon 2013; Singh 2006; Bhatt et al. 2009; Pandey andPandey 2009). Some of the identified species of mangroves during the field visit are listed in Table 1. *Avicennia marina* and *Ceriops tagal* are the most common species found here.

Table 1. Mangrove species found during the field visit are listed along with their location

Name of Species	Location (Lat/Long in degrees)
Rhizophora mucronata Lam.	20.96748; 72.81008
Avicennia marina (Forsk.)	20.94663; 72.81943
Aegiceras corniculatum (L)	20.94052; 72.79178
Acanthus ilicifolius L.	20.93767; 72.79678
Ceriops tagal (Perr.) C.B.	20.93943; 72.78637

Bruguiera cylindrica (L.) Bl.	20.93890; 72.78695

The multi-parameter mangroves health model follows a cell-based grid analysis for assessing mangroves health. Thus, the entire study area is divided into grids of 1 ha (100 m × 100 m) size. The methodology (Fig. 2) involves the analysis of mangroves health indicators, assigning the criteria and calculation of mangroves health. Following are the parameters critical in the mangrovehealth assessment model.

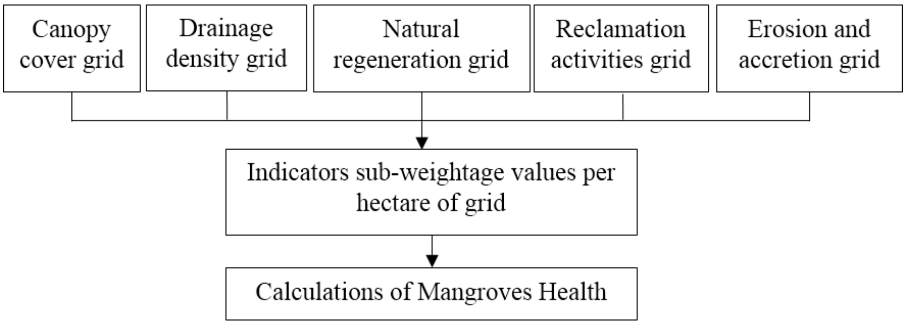


Fig. 2. Flow chart showing the methodology adopted to derive Mangrove health condition

(a) *Canopy cover:* This parameter is estimated by computing the pre-monsoon monthlysynthesis of the Normalized Difference Vegetation Index (NDVI). It is a normalized ratio of red and NIR spectral band ranging from 630 nm to 690 nm and 760 nm to 900 nm respectively as shown in equation (1)

$$NDVI = \frac{NIR - RED}{NIR + RED} \quad (1)$$

The value of NDVI varies from -1 to 1. Two composite data files were taken from each pre-monsoon months (January to April) of five years before to generate mean NDVI for 2008 and 2018. (Zhang et al. 2012; Tamura and Kota 2008) Then the natural breaks classification techniquewas applied to classify the entire image into four mangrove categories as very dense, dense, sparse,and mangroves (Gholami et al. 2015).

(b) *Drainage Density:* This map has been prepared by using Intensity Hue and Saturation (IHS) fusion technique between LISS-IV and Cartosat-2 data for the same period following Xu etal. (2008). The map of the width of a creek is prepared and overlaid on the grid. The criteria valueis assigned based on the percentage area of creek covered per hectare of a grid. The range of percentage creek area is given as if it is more than 20% the weightage value will be 100, for 10 – 20%, 5 – 9.9%, 1 – 4.9% and less than 1% the weightage values are 80, 60, 40 and 20% respectively.

(c) *Natural regeneration:* This parameter is derived from the field measurement during the post-monsoon season. The five major transects of the study region per square meter wereconducted to analyze the seedling. Approximately 100 seedlings per square meter are considered as 100% success in the natural generation. The criteria value for areas with a natural generation is100 and no natural regeneration is 10.

(d) *Erosion and accretion along the mangrove strand:* Erosion and accretion of mangrove strand are generated using the IRS-P6 LISS-IV satellite imagery. The lines are digitized along the periphery of the island for the years 2000, 2008 and 2018. The change in the area is then validatedwith the field measurements. Mangroves under stressed erosion are considered as unhealthy and the weightage assigned to it is 10; whereas for the accretion and stable condition it is considered as 80 and 100 respectively.

(e) Anthropogenic stress:

Changes in mangroves cover due to any other man-made activities such as the construction of aquaculture ponds, embankment, roads, etc. Villages present in the proximity of 5 km are also identified and buffer analysis has been carried out. Different weightages were assigned as per the distance and different reclamation activities observed in the study area. The polygon value in a grid is given as 100 for the area where no reclamation occurredas well as for the area 1 km away from the vicinity.

All the thematic layers were overlaid by assigning suitable weightages to each layer and used to assess the health of the mangrove. Weightage for each indicator are shown in Table 2.

Table 2. List of Parameters chosen for the assessment of Mangroves health and its respective weightages

Calculation of Model Output

$$\frac{\text{Map of each parameter (Rank)} \times \text{weightages}}{\text{the sum of weightages (39)}} = MH$$

The sum of weightages was done to bring the values in the range 1-100

Mangroves in pristine health are in the range of 80.1 - 100, Mangroves vulnerable to degradationare in 40.1 - 80, degrading mangroves are in 10.1 - 40 and degraded is 1-10 (Anon. 2012; Kannan 2014; Ramachandran et al. 1998).

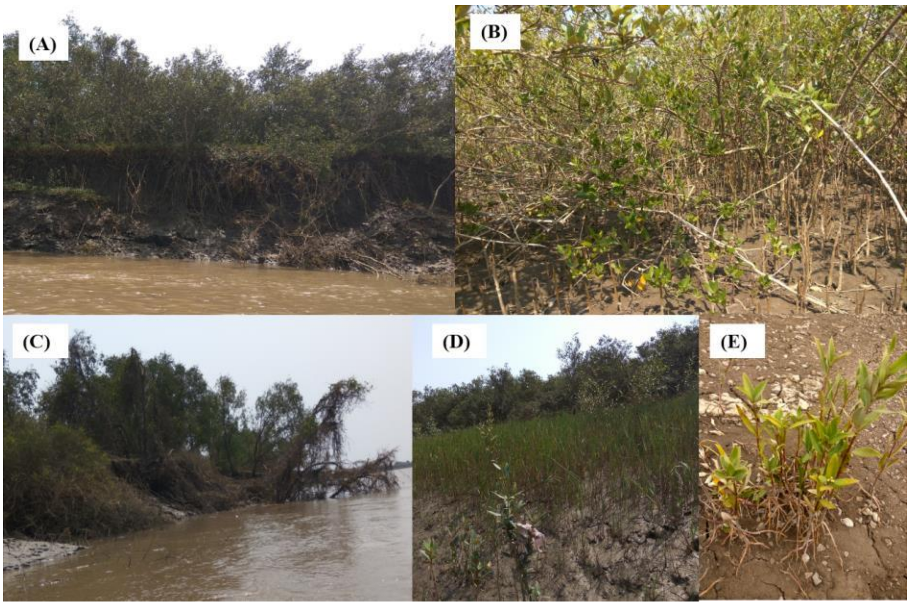
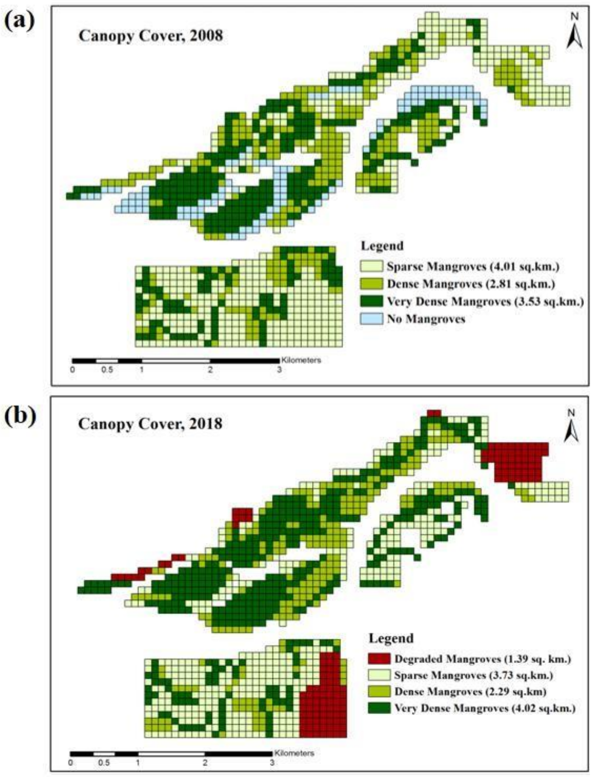


Fig.3. Photographs captured during the field visit: (A) a site photograph showing a severity of erosion along the edges of mangroves, (B) patch of dense mangroves, (C) uprooted mangroves due to erosion and high wave action, (D) conversion of mangroves patch into other halophytes and (E) a newly regenerated mangroves.



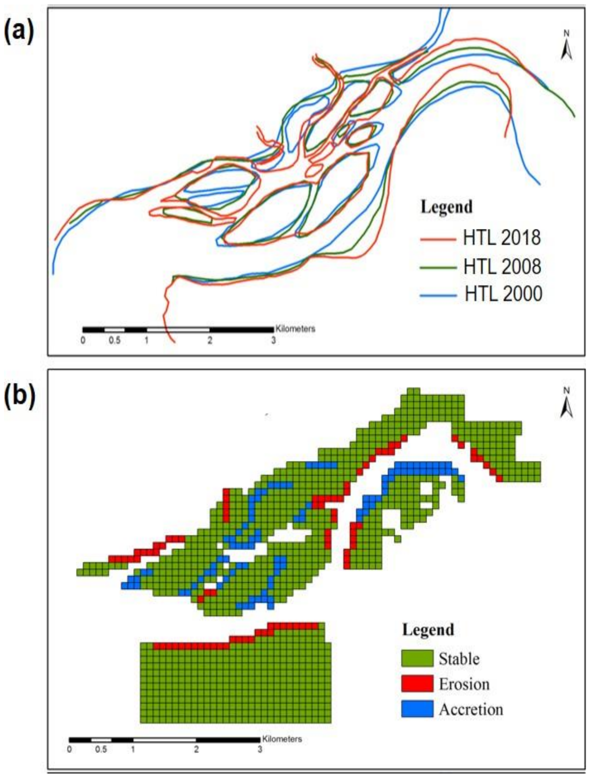


Fig. 3. Canopy cover of the mangroves during (a) 2008and (b) 2018

Fig. 5 (a) High Tide Line (HTL) extracted from satellite imageries of 2000, 2008 and 2018; (b) Erosion and Accretion map

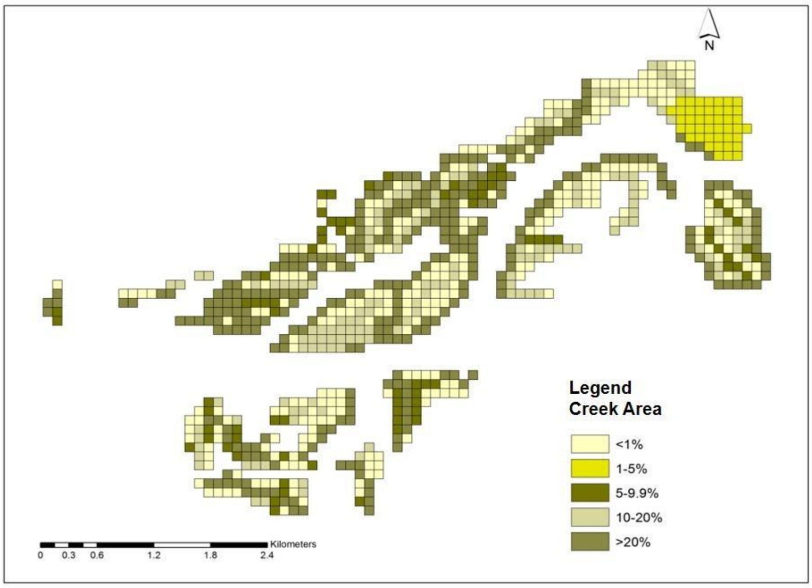


Fig. 4. Drainage density represented by creek area (%) in the study region.

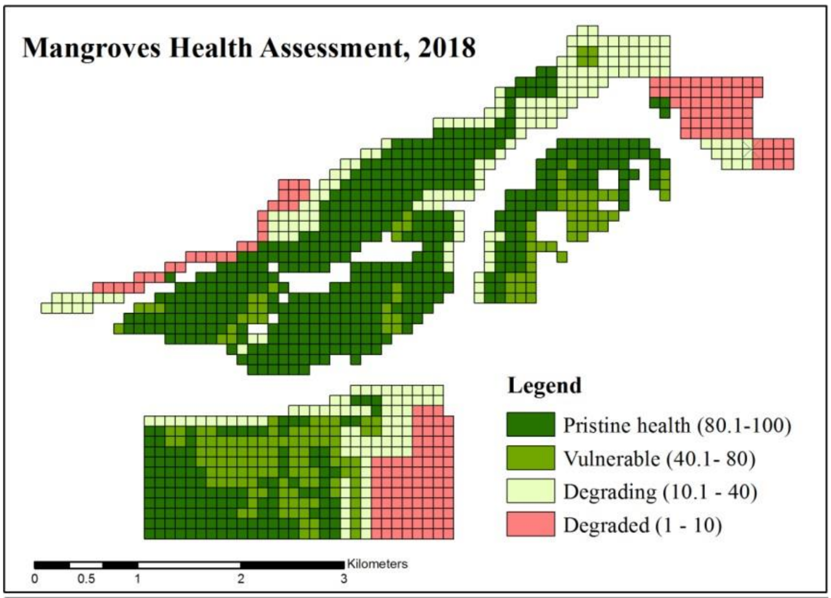


Fig.5. Mangroves Health assessment output generated in this study for 2018

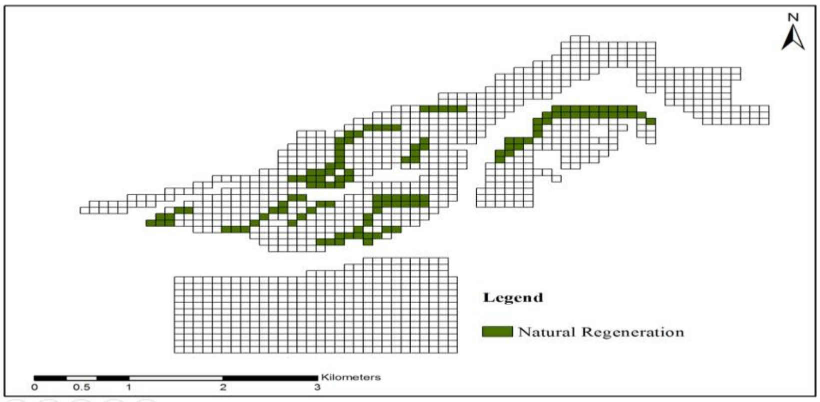


Fig. 6. Natural regeneration of Mangroves obtained from field survey in post-monsoon of 2018

RESULTS AND DISCUSSION

It has been observed that many of the smaller islands in the Purna region have extensive mangrovesfringing cover good diversity. During the field survey by boat, we have observed a variety of stagesof development and a mixture of species around the islands. Some of the pictures (Fig. 3) taken during the field measurements and validation of the model. The thematic maps have been preparedfor the parameters mentioned above divulged the major indicator resulting for declination in the health of mangroves. Canopy cover maps of the swamp (Fig. 4) are estimated by computing NDVI. The NDVI value for the same pixel of mangroves varies from 0.3 to 0.7. The NDVI low and highvalue for the year 2008 are 0.3 to 0.5 and for the year 2018 is 0.4 to 0.7. Out of all categories, thelarge portion of the dense area is converted into a sparse area. The mangroves present on small islands fall into the dense category from the very dense category.

It has been observed that many of the new small islands are constructed naturally due to the siltation and the mangroves have started growing on it. On the other side, severe erosion has beenobserved (Fig. 5) along the edge of Island because of high wave action results into the uprooted of mangrove trees. The meandering of the river could also be a major factor. Mangroves are the salt-tolerant plants but they need freshwater to grow. Construction of dam and irrigation reduce or diverse the flow of freshwater and increases the salinity level of coastal waters. This can also leadto mangroves drying out. The generated map (Fig. 6) the percentage of creek area per hectare of agrid.

Aquaculture farms were mapped at a resolution 5.8 m using IRS-R2 LISS-IV shows rapid construction. Out of 765.27 ha of the patchy pond located in the vicinity of mangroves about 472.2ha are constructed in the year of 2018 in a village Macchiwad, Navsari. Approximately, 15.508 ha of dense mangroves area and 32.02 ha of sparse mangroves area has been reclaimed. Earlier, theseponds were 1 to 2 km away from the mangroves but recently they were shifted as close as 10 m from the dense mangroves. According to the local villagers, they used these mangroves woods forthe construction of roofs of their houses.

Model Output

Health Assessment Modelling for Purna mangroves is done by gathering the information that hasbeen generated using satellite imagery as well as from the field measurements. The study area wasvisited twice a year during pre and post-monsoon for the collection of samples and validates the model. No leaf litter is observed on the sediment surface or presumably has been removed by the tide. It provided valuable input to prepare and overlaying the five indicator maps. Health index values are ranked in a specific range (Fig. 7). The results show that from 2008 to 2018 the mangroves cover near the Purna estuarine area is reduced. After the analysis of all parameters, theoverall output of the model discloses that the mangroves present on mid of island are sustaining well because of no erosion, no anthropogenic intervention, and good drainage network. It seems that an area where the mangroves diminish have on proper drainage and facing high reclamation activity. Severe erosion is observed along the edge of all islands because of that many of the mangroves trees especially *Avicennia Marina* got uprooted and washed away. Erosion at the upstream of the riverbank leads to deposition or construction of a new island. No other activities are noted so far. About 1.2 sq.km of the area is regenerated nearly since 2008 (Fig. 8). The total changes in the area for different categories are mentioned in Table 3.

Table 1. Changes in an area of Purna Estuary Mangroves

Categories	2008 (sq.km.)	2018 (sq.km.)	Change (sq. km)
Degraded Mangroves	0.053	0.147	+0.094
Degrading Mangroves	0.174	0.300	+0.126
VulnerableMangroves	1.608	1.685	+0.077
Pristine Mangroves	5.096	4.760	-0.336
Total	**6.931**	**6.892**	-0.039

CONCLUSION

After applying the model for five parameters, the overall outcomes reveal that the mangroves present in the middle of an island are in very good condition. However, the mangrovestowards the edge of mudflats are being vanished out because of high wave action, which causes severe erosion along the edge of islands. The mangroves on the island are having good density, diversity as well as 4-5 m of height could be because of its considerable distance from the mainlandand thus no apparent human-induced pressure noticed. Some of the mangroves patches are totallydegraded due to the construction of the aquaculture ponds. Mangroves along the creek are in a good health condition. However, mangroves towards the upward side of high mudflat are showingsparse behaviour. The study recommends that anthropogenic activity should be under control. Because these are the area where mangrove swamps can be grown potentially. Such studies can give us an accurate idea of the depleting mangrove health and further, the reasons and causes of this may be worked out to sustain these resources for a long-lived.

Acknowledgment: We thank our funding institution Space Applications Centre (SAC), Ahmedabad. The authors also express their sincere gratitude to the Director, SAC (ISRO), Ahmedabad and Dr. Raj Kumar, Deputy Director, EPSA, SAC (ISRO), Ahmedabad and Dr. A. S.Rajawat, Group Director, GHCAG, SAC (ISRO) for their overall support.

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