Monitoring Mangrove Status using Remote Sensing and Geo-informatics in Piram Island, Gulf of Khambhat, Gujarat State, India

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Abstract—Piram is a living witness to the ancient disturbances of nature, changes in flora and fauna over millions of years and centuries of tides and ebbs. It is unique because there are very few islands of the Indian West Coast, which are so easily accessible. In the present study, Indian remote Sensing Satellite (IRS-P6) LISS-III and LISS-IV digital data covering Piram Island for the period of 2007, 2010 and 2013 have ben analysed for mapping mangrove. The LISS-III and LISS-IV data have been interpreted visually and the mangroves have been classified into two density classes namely, dense mangroves and spares mangroves based on the intensity of pink tone observed on the Satelllite data. Field Survey was carried out for mangrove density identification with the help of GPS measurements at various places in the Piram Island. During field visit soil samples were also collected for physical chemical analysis. Remote Sensing data was analyzed using ENVI Software and the mangrove density classes were delineated using the Quantum GIS software. This study aims to monitor changes in mangrove vegetation, in Piram Island using multi-temporal Indian Remote Sensing satellite data in GIS environment. The physico-chemical properties of soil of various sites in the Piram Island were also studied.

The results of this study on change monitoring of mangroves in the Piram Island indicate that mangrove area has been consecutively declining from 0.74 to 0.23 sq km in the Piram Island during the period from 2007 to 2013. Change detection study was carried out for monitoring mangrove status in Piram Island and results were compared with the mangrove estimates carried out by the Department of Ocean Development (DOD), Government of India, 2002. DOD carried out the mangrove mapping using the satellite data of 1987 and 1999 covering Piram Island and the results indicated that the mangrove area has decreased from 0.74 to 0.57 sq km. The results of present study on change monitoring revels that mangrove area is consecutively declining from 0.74 to 0.23 sq km in the Piram Island. Previous studies showed that mangrove forests has been significantly denuded owing to cutting down trees for firewood, charcoal making, construction materials, construction of salt pan and Aquaculture. (Bhavsar et al, 2013).

Soil samples were also collected and analyzed for parameters like pH (8.6), Electrical Conductivity (8.6 mΩ), Bulk Density (1.5 w/v), %Organic Carbon (3.6%) and Soil Organic Carbon (12.65 kg C m-2). The organic carbon and soil organic carbon is greater at 30 cm depth. The correlation between parameters is also discussed in detail. The mangrove area has very high potential to sequester the carbon which can be increased further in future by conserving or protecting the mangrove areas in the Piram Island. This study gives clear idea to land managers in implementing conservation initiatives for mangroves as well as protection of Piram Island.

Index Terms—Indian Remote Sensing Satellite (IRS), LISS-III & LISS-IV digital data, Mangrove mapping, Change detection, One way ANOVA, Land use classification, Weightage Analysis, Physical & Chemical analysis of soil sampls.

1 INTRODUCTION

Gujarat State enjoys the distinction of having the longest coast line in the country. It is more than 1650 kms and extends right from Jakhau in Kachchh District to Umargam in Valsad district. There are two prominent indentations in this stretch namely the Gulf of Kachchh and the Gulf of Khambhat. The coastal environment of India plays a critical role in the economy of the nation by virtue of its resources and ecosystems such as mangroves, coral reefs, salt marshes, sand dunes, estuaries etc. Gujarat coast has about 1.6 lakh sq.km on the continental shelf. The coast, due to its varied physiographic features, geomorphology, coastal processes and river discharge into the sea, provides a wide variety of coastal features. Based on the distinct variation in the land form categories, the Gujarat coast has been broadly classified into five regions:
(i) The Rann of Kachchh, (ii) Gulf of Kachchh, (iii) The Saurashtra Coast, (iv), The Gulf of Khambhat and (v) The South Gujarat Coast. The coast lines of the Gulf of Khambhat and Kachchh together form about 65% of the coast line of the state (Singh, 2000).

1.1 Piram Island in Gulf Cambay

The tidal range at Gulf of Khambhat is the largest along the Indian coastline on account of that world's biggest Ship breaking yard is present (Sanil Kumar, et al, 2010). The Gulf has many small Islands at present. Among them Piram is unique because there are very few islands of the Indian West Coast, which are so easily accessible. It is unique also due to the fact that it is privately owned and has a size, which is just right to savor the experience of sea all around.

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1.2 Flora and Fauna of Piram Island

Piram is a living witness to the ancient disturbances of nature, changes in flora and fauna over million of years and centuries of tides and ebbs. All of this history is evident in the layers of rock that make this island. This island is rich in history, marine and archaeological wonders and an exclusive place waiting to be developed for its variety of potentials. Island comes under the effect of the Delhi-Mumbai Industrial corridor (DMIC). Island has evidence of pre-historic periods evolving over millions of years and a recorded history of more than 5000 years. Authenticated by the Gazetteer of Piram has a history of all faiths: Hindu, Buddhist, Jain and Islam. It is an inhabited island showing the roots of the four main religions of India. It reflects the coexistence and respect for one another true secularism. (Anonymous, Piram Island, 2009 and Guar, A.S.,2010). Island has good mangrove vegetation and also nesting site for two endangered Species of Sea turtle. Mangrove ecosystems play a dual role and provide two important environmental services: as carbon sink and as buffer to protect the terrestrial ecosystem from adverse effects of climate change (Loffoley et al., 2009, Bunting et al., 2007). Piram Island has high density of mangrove vegetation (Anonymous, 2013).

Realizing the ecological importance of mangroves this study was carried out using Satellite Remote Sensing and GIS Data along with detailed field surveys. However, no detailed studies have been conducted that will give a general picture of the Piram Island to guide land managers and policy makers in implementing conservation initiatives. One of the basic requirements for planning coastal protection act it is important to understand coastal process of erosion, deposition and transport of sediment which arise as a result of natural as well as anthropogenic process (Rajawat, et al, 2005). The mangroves on the Piram Island are damaged due to discharge of oil, chemicals and other pollutants from the ship breaking yard at Alang.

This study aims to monitor changes in mangrove vegetation, in Piram Island using multi-temporal Indian Remote Sensing satellite data in GIS environment. The physico-chemical properties of soil at various sites in the Piram Island were also studied. Previous studies showed that mangrove forests has been significantly denuded owing to cutting down trees for firewood, charcoal making, construction materials, construction of salt pan and Aquaculture (Bhavsar et al, 2013).

1.3 Role of Remote Sensing and Geo-informatics

Remote sensing technique due to its synoptic, multi-temporal, coverage and multi-spectral ability in whole range from optical to microwave regions can effectively act as tool par excellence providing advance and reliable information on mangrove extent and status of its growth along the coastal areas. The reflectance pattern of vegetation in visible & NIR spectral region give information on condition of vegetation cover. The various satellite-derived indices such as Normalized Difference Vegetation Index (NDVI) and Ratio of NIR & Red wavelengths can also be effectively used to monitor the vegetation status and condition of mangrove ecosystem. NDVI is based on difference between maximum absorption of radiation in red due to chlorophyll and maximum reflection of radiation in NIR due to leaf cellular structure. The combination of red and Infrared (IR) bands along with vegetation indices help in distinguishing between mangroves, swamps and other vegetation in the wetland zones.

Mangrove mapping of 13-coastal districts with 35-coastal blocks/talukas in Gujarat, have been carried out by BISAG and GEC using Indian Remote Sensing Satellite (IRS) LISS-III digital data of the 2006-07 period. The mangroves have been classified into two density classes namely, dense mangroves and spares mangroves and maps have been prepared at 1:10,000 scale and these are compiled in the form of Mangrove Atlas of Gujarat State. The comparison of mangrove area estimates carried out by BISAG and Forest Survey of India (FSI) indicates a net increase in the area under mangrove cover (Patel et al., 2014).

2. OBJECTIVES

The major objectives of study on mapping and monitoring mangroves in the Piram Island in the Gulf of Khambhat region of Gujarat State (India) are as follows:

- Delineation of Mangrove Density using Indian Remote Sensing (IRS LISS III, IV data of 2007, 2010, 2013).
- Monitoring Changes in Mangrove Status based on Multi temporal Remote Sensing Satellite Data.
- Physico-chemical Analysis of Soil samples of Piram Island

3. STUDY AREA

Gulf of Khambhat which is in the northern part of the Arabian Sea has a width of 80 km at mouth and funnels down to 25 km over the longitudinal reach of 140 km. Seabed in most part of the Gulf remains in quasi steady state and it moves as sand bars with tides. Bhavnagar Port is located on the western part of the Gulf (Sanil Kumar V. et al, 2010). Piram Island is located at 21° 35' North and 72°34 East, at a distance of 7.2 nautical miles south of Ghogha and 4 nautical miles from the nearest part of the mainland (Dist. Bhavnagar, Gujarat, India) (Figure-1).

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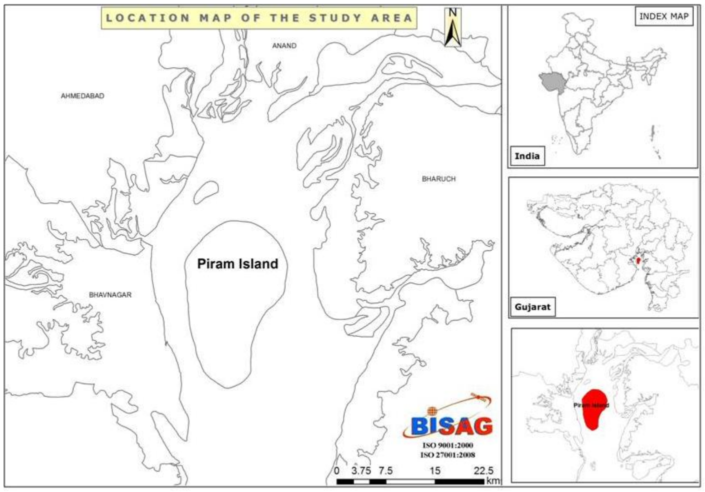

Figure-1: Location map of the Study Area

4. MATERIALS AND METHOD

4.1 Satellite Data Used

In this study Indian Remote Sensing Satellite (IRS) LISS III and LISS IV digital data of three different time periods was used. The multi-year data LISS-III data of 2007, 2010, and 2013 was analysed for mapping mangrove vegetation and monitoring changes in Mangrove cove in he Piram Issland. The location of Piram Island in the Gulf of Khambhat is shown on the IRS LISS-III digital data in Figure-2. The details of Satellite data used is given in Table-1.

Figure- 2: Location map of Piram Isdland in Gulf of Khambhat marked on IRS LISS-III image

Table-1: Details of Indian Remote Sensing Satellite Data used

No	Satellite	Sensor	Path/Row	Date of Pass
1	IRS-1D	LISS-IV	201/104	12-Mar-2007
2	IRS-P6	LISS-III	93/57	7-Jan-2010
3	IRS P6	LISS-III	93/57	3-Jan-2013

4.2 Ground Truth Data Collection

Ground truth / field verification is an important component in this project and an important source of information for verification and accuracy estimation / validation of thematic details mapped from satellite imagery. Initially a reconnaissance survey was carried out to identify mangrove growing areas. Based on this information, base maps were prepared for detailed ground truth data collection. The details of field survey and areas of mangrove along with density observed and associated vegetation are given in Figure-3.

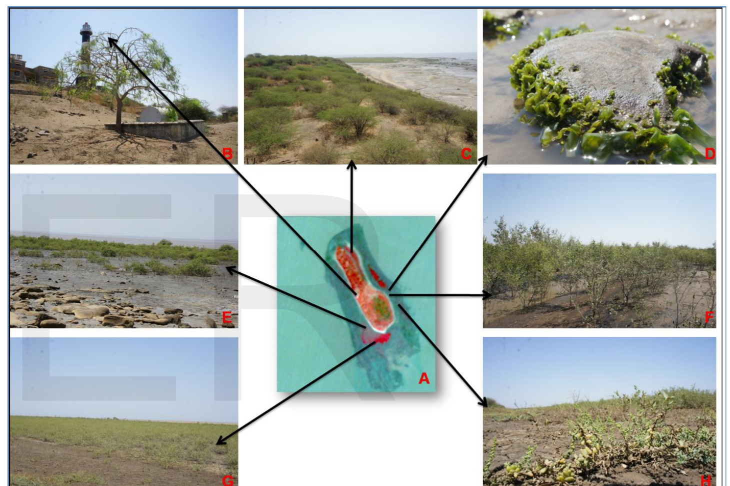

Figure-3: A) Piram Island LISS III Image,2013 B) Light house C) Prosopis dense patch D) Ulva Sp. E) Sparse mangrove F) Sparse patch at opposite site G) Dense Mangrove patch H) Mangrove associates

4.3 Soil sampling and analysis

The soil samples were collected randomly from the study site for physico-chemical analysis. Triplicate soil samples were collected at different depths at 0-10, 10-20, 20-30 cm. The soil samples were allowed to dry at room temperature. The finally grinded soil samples were then passed through sieve of particle size 2 mm. The pH of the soil suspension (1:2) was estimated using pH meter. The conductivity meter was used to determine the electrical conductivity of the soil suspension (1:5).The bulk density was determined using w/v method.

4.4 Satellite Data Analysis

The IRS LISS-III and LISS-IV digital data covering study area was analyzed and it broadly consists of following steps:

i) multi-date data preparation and geo-referencing, ii) Administrative boundary superimposing, iii) Generation of spatial information in GIS environment at the desired scale, iv) superimposing GPS locations of mangrove sites collected during GT

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data collection on the registered LISS-III digital data, v) identification & delineation of mangrove into different density classes, vi) generation of thematic maps showing extent of mangrove areas and v) area estimation under mangroves and change detection in the mangrove vegetation and density classes.
The methodology flow chart of satellite data analysis and Mangrove mapping procedure is given in Figure-4.

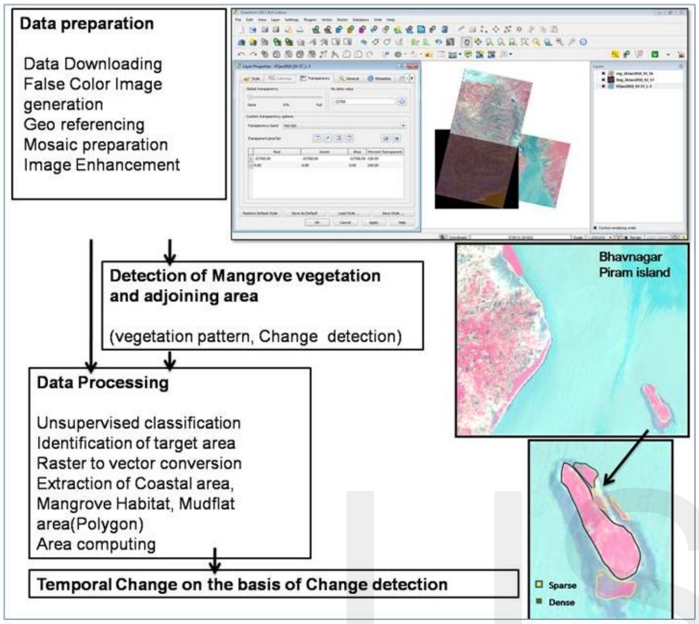

Figure-4: Methodology flow chart of IRS LISS-III data analysis and mangrove mapping

4.4.1 Mangrove mapping Procedure

The multi-date satellite LISS-III digital data have been interpreted visually for mapping mangrove cover in the Piram Island. The mangroves have been classified into two classes namely dense mangrove and sparse mangrove based on the intensity of pink tone observed on LISS-III images. On IRS LISS-III False Colour Composites (FCC) mangroves occur in bright red colour if it is in continuous patch. When mangroves are scattered or degraded then instead of bright red colour, a light brick red colour may be seen.

5. Results and Discussion

5.1 Delineation of Mangrove and Classification

The mangrove mapping was carried out using IRS LISS-III images of 2007, 2010, and 2013. The Quantum GIS software was used for mangrove delineation and computation of area.
The Ground Truth information about mangrove density was superimposed on the IRS LISS-III data before mapping of mangrove classes. The Google images and Wikimedia were also used for reference purpose. There were only two mangrove species were recorded from the study site. This area is directly exposed to the ocean with rocky sandy-muddy substrate. Avecinnia marina and Prosopis chilensis are the dominant species. The mangrove delineation was carried out using Quantum GIS (Q-GIS) software. The vector features were transformed to raster features using polygon formation and polygons were attached with polygon IDs and assigned labels such as mangrove-dense, sparse, degraded, mudflat, etc. The two mangrove density classes identified on IRS LISS-III data along the Piram Island coast are shown in Figure-5.

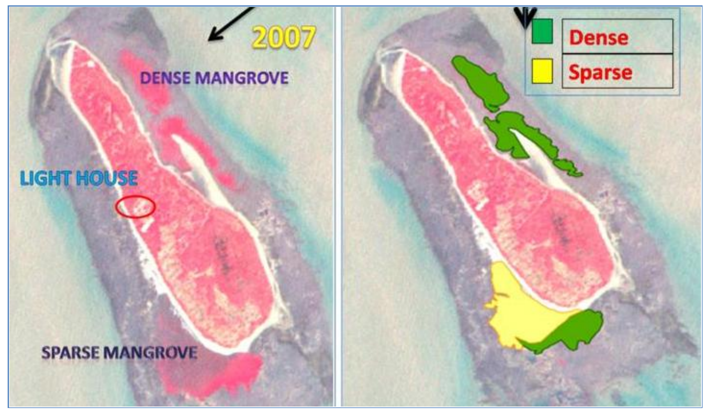

Figure-5: Mapping of Mangrove Density on IRS LISS-III data covering Piram Island

5.2 Temporal Change analysis of mangrove Vegetation

IRS LISS-III digital data of 2007, 2010, and 2013 was used analysed for mapping and monitoring changes in mangrove vegetation in the Piral Island. The mangrove density classes of dense and sparse mangrove were mapped along the coastal areas of Piram Island using Q-GIS open source software. The detailed Ground Truth information along with GPS measurements were superimposed on the LISS-III images for accurate identification of Mangrove as well as its density classes. The IRS LISS-III and LISS-IV data covering Piram Island of 2007, 2010 and 2013 along with mangrove density mapping is given in Figure-6.

5.3 Mangrove Area Estimation and its comparison

The area estimates of mangrove mapping based on IRS LISS-III data analysis of 2007, 2010 and 2013 are given in Table-2.

Table-2: Temporal Change of Mangrove vegetation on Piram Island and its comparison

Sr No	Date of Pass	Satellite	Path/Row	Mangrove Area (Sq km)	
				DOD (GoI)	Present Study
1	12-Jan-1987	Landsat TM	148/45	0.74	--
2	13-Feb-1999	IRS-1D LISS-III	92/57	0.57	--
3	12-Mar-2007	IRS-P6 LISS-IV	201/104	--	0.326
4	7-Jan-2010	IRS-P6 LISS-III	93/57	--	0.273
5	3-Jan-2013	IRS-P6 LISS-III	93/57	--	0.236

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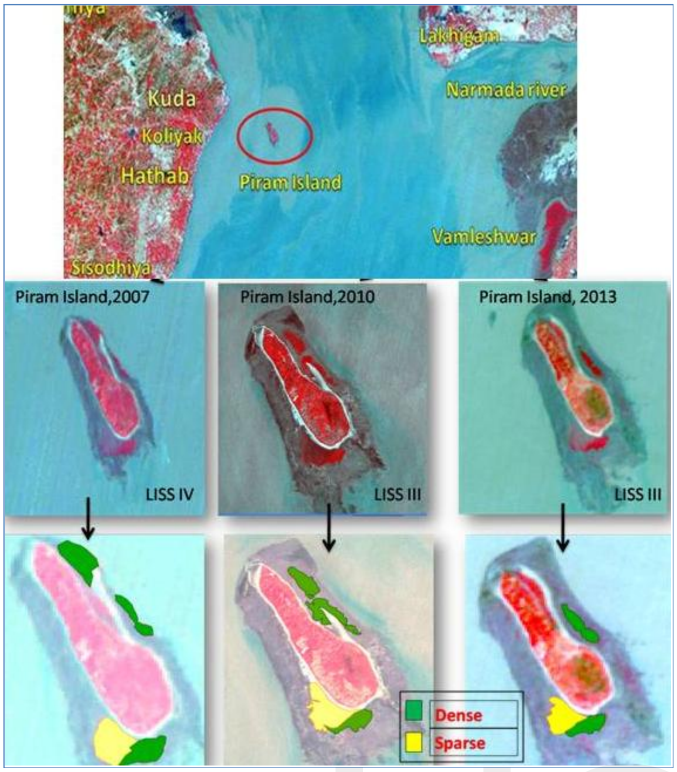

Figure-6: Mapping Temporal Changes of Mangrove on IRS LISS-III data covering Piram Island

The IRS LISS-III Images clearly indicate the decrease of the mangrove area over the period of 7 years from 2007 to 2013. Mangrove exhibited a marginal decline in the area from 0.326 to 0.236 sq km during this period. The Department of Ocean development, Government of India, also mapped the mangrove area on the Piram Island during the period of 12 years from 1987 to 1999 using the Satellite data and their results also indicate the decrease in the area from 0.74 to 0.57 sq km (Table- 2). The comparative results of both the studies are plotted in the graph given in Figure-7.

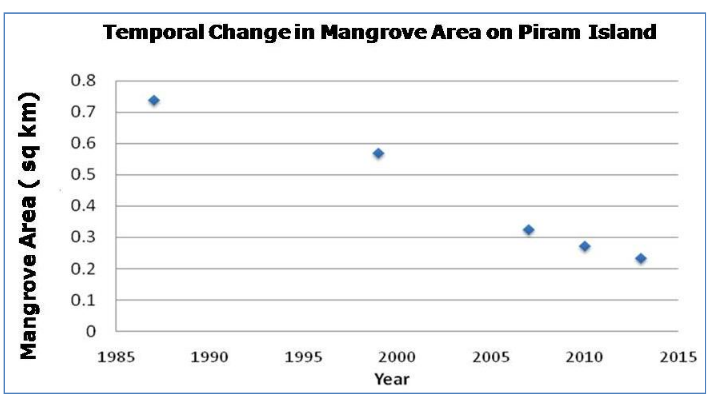

Figure-7: Mangrove Area estimation covering Piram Island

The temporal changes study result revel that mangrove area are consequences decreasing (Table-2 & Figure-7). It can be observed in table and figure that mangrove areas are subsequently decreasing on the Piram Island due to various developmental activities. The risk of oil spill is present at the Island because of Ship breaking yard at Alang. As the tidal current velocity is high at the Gulf of Khambhat, the movement of oil slicks towards mangrove areas especially during high tides is significant and a matter of concern for its impact on mangrove vegetation.

5.4 Analysis of Soil Parameters

The results of soil analysis indicate the soil texture of Piram Island is sandy. The statistical analysis shows that the soil samples collected from this area are alkaline in nature. The Electrical Conductivity range is 13.4 to 22.8 mΩ (18.1±0.227). The hydrogen ion concentration ranges between 8.0 to 8.95 (8.6±0.023). The % Organic Carbon and Soil Organic Carbon content varies between 3.0 to 3.95 (3.6±0.018) and 33.57 to 82.68 mg c ha-1 (52.7±1.22). Anoxic conditions and prevalence of high pH values may be partially responsible for high concentrations of organic carbon.

A non significant ($p < 0.001$) negative correlation were obtained between pH, EC and SOC (r^2 = -0.313, -0.400 and -0.318). However, highly significant ($p < 0.001$) positive correlations were observed between BD and SOC (r^2 = 0.995), BD and %OC (r2 =0.519), %OC and SOC (r^2 = 0.573). A highly significant positive ($p < 0.001$) correlations were obtained between Depth and %OC (r^2 = 0.516) (Figure-8).this phenomenon indicate that %OC increases with the depth. Long periods of tidal flooding and low decomposition rates result in sustained anoxic conditions (below 10 cm depth) and high content of organic matter, which may explain the higher values in organic matter content at 30 cm depth (Ceron- Breton et al, 2011) .

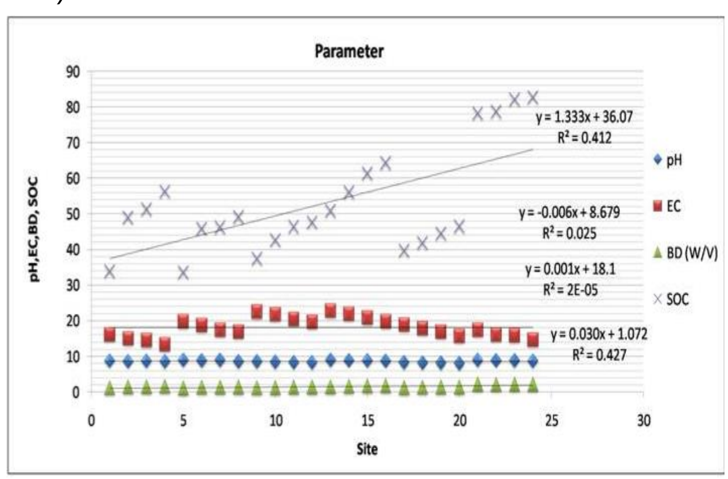

Figure-8: Linear regression analysis of all the soil parameters of the Piram Island

The Soil Organic Carbon rapidly increases with depth which indicates that a small fraction of carbon that is being introduced into the soil remains there. This pattern is typical of Swam forests where organic matter and nutrients accumulate

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in soil layer. We can conclude that the accumulation of organic matter and carbon storage are determined by the rate of decay and the production rate of organic matter. The soil has high carbon content rather than any other terrestrial ecosystem owing to the site is flooded all the time and the combination of anaerobic conditions increases the productivity of the system.

6. CONCLUSIONS

In the present study, Indian remote Sensing Satellite (IRS-P6) LISS-III and LISS-IV digital data covering Piram Island for the period of 2007, 2010 and 2013 have ben analysed for mapping mangroves. The LISS-III and LISS-IV data have been interpreted visually and the mangroves have been classified into two density classes namely, dense mangroves and spares mangroves based on the intensity of pink tone observed on the Satelllite data. Field Survey was carried out for mangrove density identification with the help of GPS measurements at various places in the Piram Island. During field visit soil samples were also collected for physical chemical analysis. Remote Sensing data was analyzed using ENVI Software and the mangrove density classes were delineated using the Quantum GIS software. The physico-chemical properties of soil of various sites in the Piram Island were also studied.

The results of this study on change monitoring of mangroves in the Piram Island indicate that:

- Mangrove area has been consecutively declining from 0.74 to 0.23 sq km in the Piram Island during the period from 2007 to 2013.
- Change detection study was carried out for monitoring mangrove status in Piram Island and results were compared with the mangrove estimates carried out by the Department of Ocean Development (DOD), Government of India.
- DOD carried out the mangrove mapping using the satellite data of 1987 and 1999 covering Piram Island and the results indicated that the mangrove area has decreased from 0.74 to 0.57 sq km.
- The results of present study on change monitoring revels that mangrove area is consecutively declining from 0.74 to 0.23 sq km in the Piram Island.
- Soil samples were also collected and analyzed for parameters like pH (8.6), Electrical Conductivity (8.6 mΩ), Bulk Density (1.5 w/v), %Organic Carbon (3.6%) and Soil Organic Carbon.
- The organic carbon and soil organic carbon is greater at 30 cm depth. The correlation between parameters is also studied in detail.
- The mangrove area has very high potential to sequester the carbon which can be increased further in future by conserving or protecting the mangrove areas in the Piram Island.
- This study gives clear idea to land managers in implementing conservation initiatives for mangroves as well as protection of Piram Island.

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