

# **Application of Analytical Algorithm to Classify Near Shore Substrate Types and Coral Reef Environment.**

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## **Abstract**

In the present study, an attempt has been made to classify the near shore substrate types as well as coral reef environment using Landsat and IRS sensors. An analytical approach has been applied to extract the bottom reflectance and finally the supervised classification has been applied to delineate different ecologically sensitive classes. The classification made with raw bands is compared with the classified map generated taking bottom reflectance and water leaving radiance image. The results indicated that much of the submerged feature got exposed after applying atmospheric correction and bottom reflectance retrieval algorithms.

In the present study, an attempt has been made to demarcate suitable sites for coral polyp plantation using the classified image and lagoon bathymetry of Minicoy. It has been found that 23 % of the total lagoon area is suitable for coral polyp plantation.

**Key Words:** Water Leaving Radiance, Bottom Reflectance

## **1.1 Introduction**

Remote sensing is found to be a potential tool to demarcate near shore substrate types and coral reefs in the coastal waters and to monitor the optically, spatially, and temporally complex ecosystem. However, it is a real challenge for extracting meaningful information concerning the ecology and vitality of coral reef communities. Traditional marine science has always utilized *in-situ* monitoring to detect community change, but the archival record of satellite-based information contains synoptic information that could also be tapped to examine change in the coral reef ecosystems. One of the keys to this remote sensing problem of coral reef "health" is the development of a methodology that relates the remotely

sensed satellite signal to the optical signal generated by coral reef environments or reef bio-optics. Using a bio-optical approach, it may be feasible to remotely map benthic habitats.

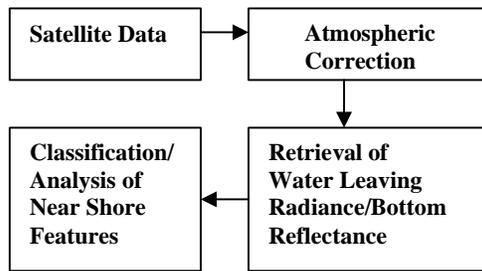
### **1.1 Study Area**

The study area pertains to the Lagoon belonging to Lakshadweep. Minicoy or *Maliku* is the southernmost island in the Union Territory of Lakshadweep. This is an atoll Island like the rest of Islands of Lakshadweep that rests on an underwater platform of about 100 fathoms deep. The islands are formed by the accumulation of coral sand in the form of a sand bar, which eventually gets stabilized with vegetation, and over

the course of time gets compressed into soft sand stone. Coral reefs form unique habitat along the coastal zone area in the benthic family. This ecosystem has an important setting among others ecosystems. However, very little information on maps showing the distribution of various benthic habitats in the coral reef is available. Natural resource managers around the world desperately need maps of coral reefs and adjacent land areas.

## 1.2 Methodology

The brief methodology adopted in the present study is presented in figure 1 below:



**Figure1.** Brief sketch of Methodology

Atmospheric effect has been removed from the IRS-P6 LISS-IV and TM data following atmospheric correction models to retrieve the upwelling water leaving radiance (Gordon et al, 1983). The band averaged solar irradiance; central wavelength for IRS-P6-LISS-IV sensor has been calculated using the equation as given by

$$E_o = [\int \bar{E}_o(\lambda) \phi_i(\lambda) d\lambda] / w_i \quad (1)$$

$$w_i = \int \phi_i(\lambda) d\lambda \quad (2)$$

$$\lambda_i = [\int E_o(\lambda) \phi_i(\lambda) \lambda d\lambda] / [\int E_o(\lambda) \phi_i(\lambda) d\lambda] \quad (3)$$

where,  $E_o(\lambda)$  is extraterrestrial solar irradiance computed from Nickel and Labs (1981),  $\phi$  is the spectral response

function,  $w_i$  is the spectral band width as defined in Wyatt 1978,  $i$  denotes the band number. The computed values of extraterrestrial solar irradiance and the central wavelength ( $\lambda_i$ ) are given in table-1. In the rest of the equations the symbol  $\lambda_i$  is replaced with  $\lambda$  for convenience.

Band No	Wavelength Range (nm)	Central Wavelength (nm)	Extraterrestrial Solar Irradiance ( $mWcm^{-2}nm^{-1}$ )
2	0.52-0.59	0.555	181.450
3	0.62-0.68	0.644	160.217
4	0.76-0.86	0.806	109.975

**Table1:** IRS-P6-LISS-IV Sensor details showing wavelength range, Central Wavelength and Extraterrestrial Solar Irradiance.

The Extraterrestrial solar radiance values and the conversion of satellite digital number to radiance values for Landsat-7-ETM are taken from literature (Chander and Markham,2003, <http://glcf.umiacs.umd.edu>)

## Retrieval of bottom reflectance

The land surveying satellite sensors like Landsat Thematic Mapper (TM) and IRS LISS can be utilised to map the coastal bathymetry. The green band of the sensor is suitable to study the depth profile in the shallow coastal waters. Relative minimum absorption coefficients are associated with phytoplankton, sediments and dissolved yellow substances in the green band region of the electromagnetic spectrum which helps the green light to reach the bottom surface and way back to the satellite sensor after reflection. The received energy from the coastal waters after atmospheric correction can be related to the ocean bottom reflectance. In order to compute water depth using

remotely sensed signals, a relationship between radiance from satellite and the depth of the water must be developed which includes the parameters that have an effect on the sun's energy as it passes through both the air and water paths and reflects from the ocean bottom. The complexity of the variables in this situation suggest that before a relationship can be developed, some simplifying assumptions are necessary. First, the model to be used would neglect scattering in the water. If we are investigating maximum depth penetration in clear water, this is not unreasonable. Secondly, the sensor signal comes only from direct solar radiation. For the wavelengths in the green and red bands, this again is practical since skylight is dominated by blue wavelengths. The third assumption is that the water attenuation coefficient is independent of radiance distribution (Polcyn,1976). In general the radiance (L) at satellite sensor (Figure2) after atmospheric correction can be related to water depth 'Z' through the equation:

$$L = T_1 T_2 E_0 \exp^{-a(\sec \theta + \sec \phi)Z} (R_b/p) (t_1 t_2 / n^2) \quad (4)$$

where

$T_1$  = Transmittance of the atmosphere (Sun to Sea Surface)

$T_2$  = Transmittance of the atmosphere (Sea Surface to Satellite)

$t_1$  = Transmittance of the air-water interface

$t_2$  = Transmittance of the water-air interface

$\theta$  = Angle of refraction

$\phi$  = Angle of incident at the water-air interface

$n$  = refractive index of the water

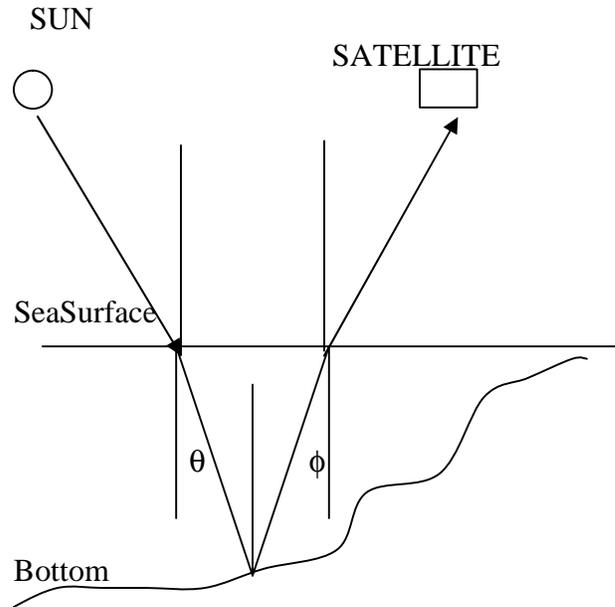
$E_0$  = Extraterrestrial Solar Radiation

$\alpha$  = Attenuation coefficient of water

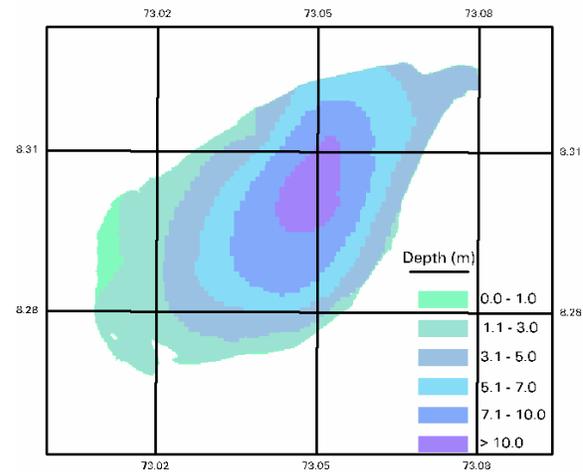
$Z$  = Bottom Depth

$R_b$  = Reflectance of bottom depth.

The water attenuation ' $\alpha$ ' and bottom reflectance ' $R_b$ ' can be measured by using underwater radiometer. The above methodology can be applied to the clear or moderate turbid coastal water. However, if the attenuation coefficient of the water is more, then this method can be avoided.



**Figure 2 :** The figure showing the light path from sun to ocean bottom and finally to satellite.



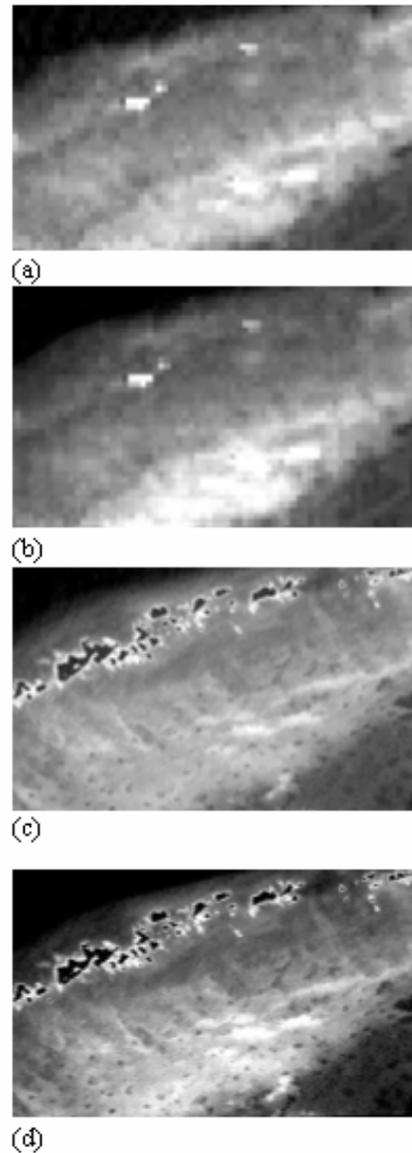
**Figure 3.** Bathymetry map of Minicoy Lagoon

The bottom reflectance  $R_b$  has been derived using equation 4. The input parameters are atmospheric corrected satellite data which provides water leaving radiance, the bathymetry map of study area (Figure 3) showing water depth and the water absorption coefficient. An attempt has been made to interpret the bottom reflectance to classify the bottom substrate types and coral reef environment.

#### 1.4 Results and discussion

The Landsat-7 ETM data (path 146 and row 054) of 04, September, 1999 and IRS-P6 LISS-IV scene (path 202 row 141) of 27, June, 2005 have been processed for analysis. The images were first atmospherically corrected to get water leaving radiance and then processed to get the bottom reflectance. The portion of the raw image of Minicoy Island and bottom reflectance images (Longitude  $73^{\circ} 03' 07.84''$  E and Latitude  $8^{\circ} 19' 08.74''$  N) are presented in figure 4 (a,b,c,d). The figure 4-a and 4-b belong Landsat-7 ETM data. The figure 4-c and 4-d belong to IRS-P6-LISS-IV scene. The bottom features are more demarcated in the bottom reflectance images compared to the raw images. The bottom features are more prominent in IRS-P6 LISS-IV image compared to the Landsat-7 ETM data.

The IRS-P6-LISS-IV raw data has been classified into five major categories e.g coral rubbles/sandy bottom, brain coral dominated area, shallow water coral boulders and sea grass which is presented in and figure 5. The classification is again carried out taking water leaving radiance image and bottom reflectance image together. The classification results are presented in figure 6.

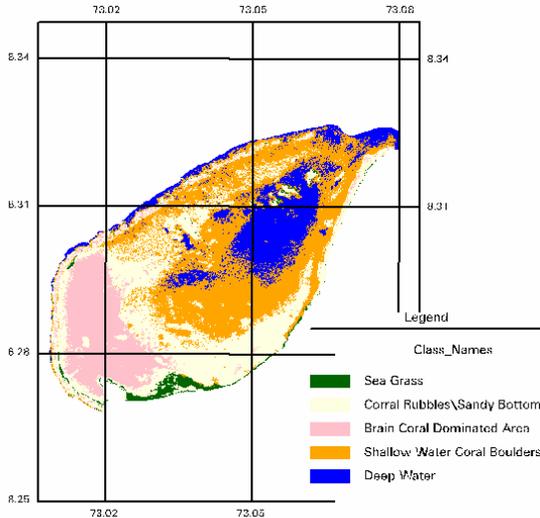


**Figure 4:** (a) Band 2 of ETM, (b) Bottom reflectance image of ETM, (c) Band 2 of LISS-IV and (d) Bottom reflectance of LISS-IV

The two classification indicates that there is an exposure of bottom feature in the classified image combining water leaving radiance and bottom reflectance image. The exposure is noticeable in case of coral rubble/sandy bottom, shallow water coral boulders and sea

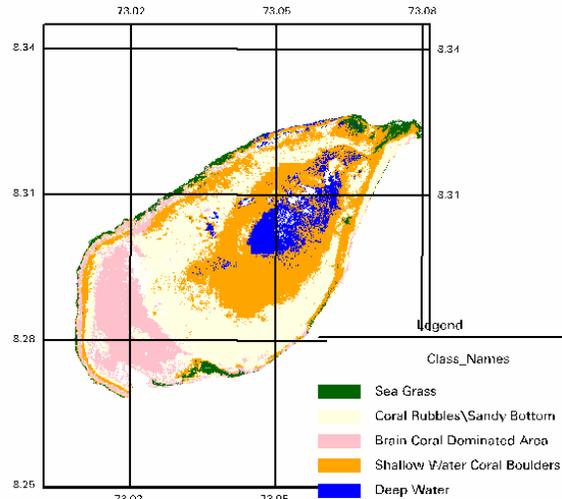
grass. Table 2 presents the area coverage in the two classified images.

An attempt has been made to demarcate the suitable sites for coral polyp



**Figure 5.** Classified Map of IRS-LISS-IV Data (Band2,3,4).

plantation taking bathymetry and the classified map around the lagoon. The coral polyp requires clean warm water with ample supply of oxygen, which it finds primarily in shallow water. If a flow of fresh water carries dissolved substances and dirt into the seawater, the coral stops growing or dies off. Lack of light or the slow deposition of small particles can also cause the death of the polyps. In general the polyps can grow in low turbid water and low productive water (Barnes, 1987). Therefore, in the present study the bathymetry map and the classified map is used to demarcate the suitable site for coral polyp growth. A 100 meters buffer map is created around the coast to demarcate the area of immediate land influence. Reefs are also threatened by tidal emersions. Long periods of exceptionally low tides leave shallow water coral heads exposed, damaging reefs.



**Figure 6.** Classified Map (Water Leaving Radiance and Bottom Reflectance image).

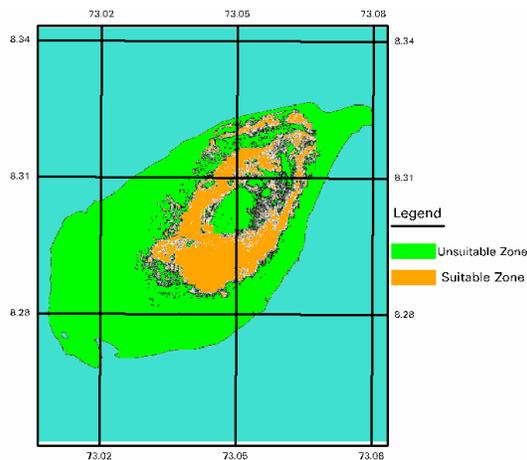
Corals exposed during daylight hours are subjected to the most ultraviolet radiation, which can overheat and dry out the coral’s tissues. Coral may become so physiologically stressed that they begin to expel their symbiotic zooxanthellae, which leads to bleaching, and in many cases, death (Barnes & Hughes, 1999).

Sl. No	Class	Figure 5 (Area in hectares)	Figure 6 (Area in hectares)
1	Sea Grass	66	109
2	Coral rubbles\Sandy Bottom	919	1078
3	Brain coral dominated Area	439	404
4	Shallow water coral boulders	1066	968
5	Deep Water	441	202

**Table 2.** Comparison of area of five classes in two classified images.

In the present analysis, depth beyond 5 meters has been taken as a safe zone for

coral polyp growth. The shallow water coral boulder region is usually away from the coast and the sun light availability is quite sufficient. Therefore, taking into consideration the above factors, suitable zone for coral polyp plantation sites have been demarcated and presented in figure 7. The area suitable for coral polyp plantation is found to be 688 hectares.



**Figure 7.** Suitable zone for coral polyp plantation.

### Conclusion

The atmospheric correction and bottom reflectance algorithm are found to be advantageous for classification of lagoon submerged features.

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