Remote sensing based habitat mapping of Vankalai coral reef, Sri Lanka

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Abstract: Coral reefs are an important coastal eco-system in Sri Lanka. Current study was conducted on Vankalai area regarding to develop new method of remote sensing technique to mapping and monitoring the particular coral reef eco-system. Downloaded Landsat 8 satellite images were processed under the three headings which are preprocessing, processing and post processing. Image preprocessing is used to eliminate errors in satellite images. Depending upon the source of error, inadequacy revision and imperfection expulsion are separated into two types such as radiometric correction and geometric correction. In radiometric correction the foremost requirement is to conversion of DN values to spectral radiance values. And the next step is conversion of radiance values to Top of Atmospheric (TOA) reflectance which could be identify as a unit less ratio measurement. Normalized difference water index was used to enhance water features and suppress the land area. Different types of bottom substrates were identified using Depth invariant index (DII) for study area and which are classified according to the bottom substrate using unsupervised classification. Five types of different spectral classes were identified using developed method which are coral reef, rough bottom, vegetation cover, sandy bottom and deep muddy area. These spectral classes are related to elevation of benthic habitat. Ultimately map was generated with regarding to the bottom substrate for particular study area using Landsat 8 image. It is an extensive reef area but lack of details yet. This study is the first attempt to use Landsat 8 for coral reef mapping in Sri Lanka.

Keywords: Coral reef, Depth invariant index, Landsat, Vankalai.

Introduction

Coral reefs are important and very sensitive ecosystem. It is a very fragile environment. Coral reefs are rich in diversity and concern as rain forest of ocean. These areas provide shelter for numerous animals and plants. Hence it act as feeding and nursery ground for numerous reef and reef associated organisms. This area is important to protect coast against wave action and as a result create ideal conditions for another coastal ecosystem. Coral reefs are affecting the country's economy and there has lot of benefits for human being.

Including Sri Lanka and in other tropical countries coral reefs are in severe stress due to effect of man-made threatens and natural causes. In Sri Lanka the major causes of reef degradation are coral mining, destructive fishing practices and unplanned tourism & pollution from land based source.

As an island, Sri Lanka enriched with the fringing reefs, bar reefs and barrier reefs around the coast of Sri Lanka. True coral reefs are found which are mostly found as fringing reefs. They are found Island around the Jaffna peninsula in the North, from Trincomalee to Kalmunai on the East coast, from Tangalle in the South to Akurala in the South western and in the North western area found from Mannar Island southward to Kalpitiya peninsula and Bar reef. There are small coral banks at Kandakuliya and Thalawila on the west coast of Kalpitiya peninsula. In the western coast of Sri Lanka, at three locations barrier type reefs have been identified which are Vankalai, Arippu, Silavathurai and Bar reef. In addition to that corals have also colonized in two under water ridges called, the Great & Little Basses of the South Eastern coast of island (Rajasuriya et al., 1997, Rajasurya and White 1994). In western coast, this barrier type reef is a well-developed eco system (Rajasuriya et al., 1997, Rajasurya and White 1994). But significant factor is no any recent studies have done around this western coast barrier reef of Vankalai, Arippu and Silavathurai area. Hence Vankalai area was selected for the studies in this research study.

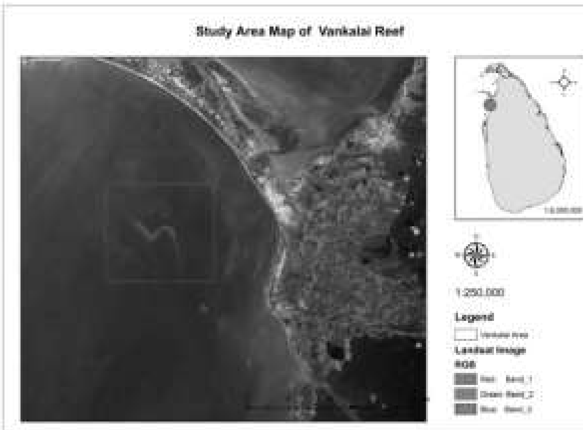

Figure 1. Study area map of Vankalai reef.

Figure 1 illustrates the study area of Vankalai reef. The use and application of this remote sensing technology to study underwater habitats is significantly beneficial. It helps and effects to monitor and protect the environment, resource manage, protect from natural disaster and for the sustainable development of resources and environment. Landsat 8 is a recently launched satellite system under the Landsat Earth Observation program and it contains significant characteristics to provide high quality image. Hence Landsat 8 satellite imageries were used for the studies of this area.

Remote sensing relies on the electromagnetic energy. Incident electromagnetic wave travel twice through the atmosphere as from Sun to the Earth surface and Earth surface to sensor and reflected radiation is representing the information about the surface characteristic of the objects. During this journey, the energy affected to the different interactions. Hence sensor received data is not in accurate to provide the exact real surface reflectance values of the object. Hence before the use of satellite image should have to follow the pre-processing step under the radiometric correction.

Normalized difference water index is used to enhance the open water features and suppress the land area. Also severity of light attenuation is removed using NDWI. Also this is important for the habitat classification. Depth invariant index was used establish the relationship between spectral signatures of similar benthic features at different water depths.

Image classification techniques include two major categories which are supervised and unsupervised classification. Grouping or clustering of pixels with common characteristics is simply known as unsupervised classification. Supervised classification is based on idea of user and it can be applied as individual pixel level or image objects using ground data. Remote sensing satellite techniques are used to study such area under the several factors.

Methodology

Figure 2 illustrates the flow diagram of methodology. The digital image processing was done under the three headings such as Preprocessing, processing and post processing.

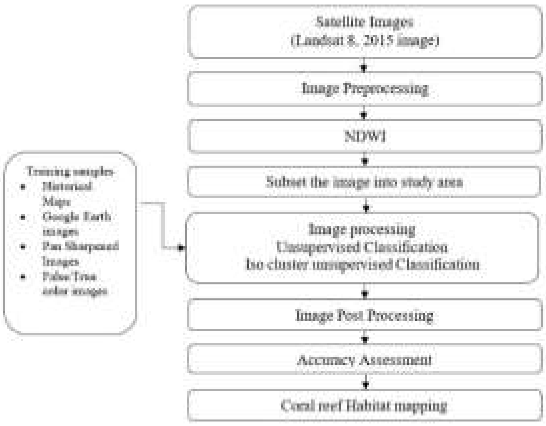

Figure 2. Methodology flow

Image pre processing

Image preprocessing is the most essential requirement to eliminate errors in satellite images. The conventional term for pixel values is Digital Number (DN). It is ordinarily used to portray pixel values that have not yet been aligned into calibrated units. Raw remotely detected image information contains defects or insufficiencies and correction is required proceeding to image processing. Depending upon the source of error, inadequacy revision and imperfection expulsion are separated into two types such as radiometric correction and geometric correction (Minakshi, 1996).

In radiometric correction the foremost requirement is to conversion of DN values to spectral radiance values. Computation of at-sensor spectral radiance is the key advance in changing over image data from different sensors and stages into a regular radiometric scale. Radiometric adjustment of the multi spectral scanner (MSS), thematic mapper (TM), enhanced thematic mapper plus (ETM+) sensors includes rescaling the digital numbers (Q) transmitted from the satellite to calibration (Qcal), which has the equivalent radiometric scaling for all scenes handled on the ground for a particular period. During radiometric calibration, pixel values (Q) from raw, natural satellite image information are changed over to units of absolute spectral radiance using 32-bit floating-point calculations.

$$L\lambda = ((LMAX\lambda - LMIN\lambda)/ (Qcalmax - Qcalmin)) \times (Qcal - Qcalmin) + LMIN\lambda$$

Where;

$L\lambda$ = Spectral radiance at the sensor's aperture [W/ (m2 sr μm)]

Qcal = Quantized calibrated pixel value [DN]

Qcalmin = Minimum quantized calibrated pixel value corresponding to $LMIN\lambda$ [DN]

Qcalmax = Maximum quantized calibrated pixel value corresponding to $LMAX\lambda$ [DN]

$LMIN\lambda$ = Spectral at-sensor radiance that is scaled to Qcalmin [W/ (m2 sr μm)]

$LMAX\lambda$= Spectral at-sensor radiance that is scaled to Qcalmax [W/ (m2sr μm)]

And the next step is conversion of radiance values to Top of Atmospheric (TOA) reflectance which could be identify as a unit less ratio measurement. When comparing images from different sensors, there are several favorable circumstances for utilizing TOA reflectance rather than at-sensor spectral radiance such as it removes the cosine impact of various sun zenith angle because of the time difference between information acquisitions, TOA reflectance makes up for various estimations of the exo atmospheric sun oriented irradiance emerging from spectral band differences, TOA reflectance rectifies for the variety in the Earth-Sun distance between various image dates and etc. These varieties can be noteworthy topographically and temporally. The TOA reflectance of the Earth is calculated as follows:

$\rho\lambda = (\pi \times L\lambda \times d2)/ (ESUN\lambda \times \cos \theta s)$

Where

$\rho\lambda$ = Planetary TOA reflectance [unitless]

Π = Mathematical constant equal to ~3.14159 [unitless]

$L\lambda$ = Spectral radiance at the sensor's aperture [W/(m2 sr µm)]

d = Earth–Sun distance [astronomical units]

$ESUN\lambda$= Mean exoatmospheric solar irradiance [W/(m2 µm)]

θs = Solar zenith angle [degrees] (Chander et al., 2009)

Normalized difference water index (NDWI)

Normalized difference water index is designed to maximize reflectance of water by using green wavelength, minimize to low reflectance of near infrared (NIR) by water features and take advantage of high reflectance of NIR by vegetation and soil features. Hence enhance water features and suppress the land area.

NDWI = (Green-NIR)/(Green+NIR)

Depth invariant index (DII)

Sea bottom classifications are depending on the radiance value of the object but which are not represent the actual value due to the effect of attenuation of electromagnetic energy in the water column.

Depth invariant index is used to establish the relationship between spectral signatures of similar benthic features at different water depths. These spectral signatures are modified from water column effect by this index.

Unsupervised image classification

Grouping or clustering of pixels with common characteristics is simply known as unsupervised classification. It is a most basic technique because clustering does not require training data. First, select the region of interest (ROI) area via grouping the pixels turn in to clusters using their properties. To create clusters, analysts could be use image clustering algorithms. After picking particular algorithms select the number of groups or classes which want to generate.

Accuracy assessment

Quantitatively clarification of the accuracy requires for image classification in order to understand the reliability of the classified result. It provides certification for the classified image while describing its reliability and accuracy. Therefore systematic accuracy determination is most essential in image classification approaches (Minakshi, 1996). For the purpose of accuracy determination, we require ground truth samples and then GCPs were obtained by using the Google earth and the historical maps. Random distribution points were collected and evaluated to obtain the accuracy for each image. We used the assessment between the producer and user and the Kappa coefficient to determine the accuracy (Jiang, Strittholt, Frost, & Slosser, 2004) .

Results

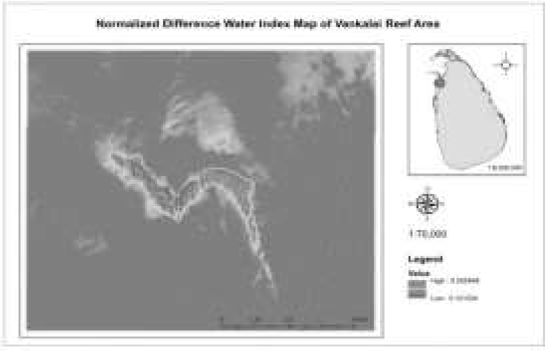

Figure 3. Normalize difference water index of Vankalai reef area.

Figure 3 illustrates the normalized difference water index of Vanakali reef area. After pre processing, NDWI is applied to enhance the water features while suppressing the land area and it represents the relationship between spectral signatures of similar benthic features at different water depths. Comparatively coral reef area represent the high resolution value.

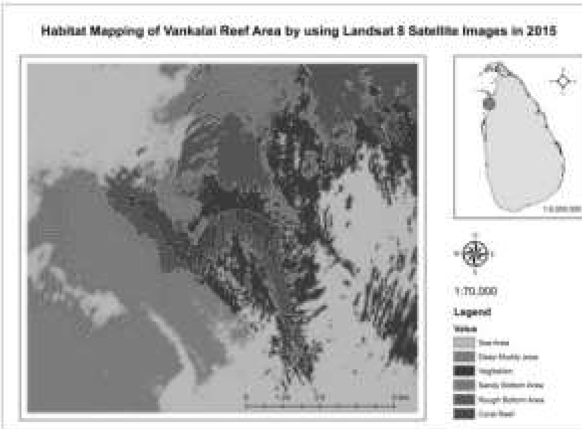

Figure 4. Habitat mapping of Vankalai reef area by using Landsat 8 satellite images in 2015.

Figure 4 illustrates the habitat mapping of Vankalai reef area by using Landsat 8 satellite image. Unsupervised classification is applied to habitat mapping and it's represent five spectral classes in this area which are coral reef area, shallow rough bottom area, sandy bottom area, vegetation and deep muddy area.

Discussion

Habitat mapping was done base on the index variation and these spectral classes are related to the elevation of benthic habitat. Five classes were identified which are coral reef, rough bottom, sandy bottom, vegetation and deep muddy area. Most important thing is such kind of extensive and well-developed reef area is found only around this area in Sri Lanka (Rajasuriya 1988, 1993, 1991). Unfortunately concern about the current status of the coral reefs, reefs are greater threaten than even before (Rajasuriya., 2013). Encountered dynamites fishing activities and use of prohibited mesh gill nets (lyla, surukku nets) for fisheries on coral reef had been caused the coral reef destruction. Unfortunately, no authorities were present to stop them from carrying out their routine dynamiting on extensive shallow coral bank in the area. Hence there were large patches of destroyed coral because of this prohibited fishing operation.

Landsat 8 is a courser resolution satellite system. It means it has medium resolution satellite image and it use for a rough habitat mapping and also roughly estimate the relevant area without having a high resolution satellite image data. Normally high resolution satellite data are used for habitat mapping. But through this study have proven that medium resolution data can used for such approximate habitat classification.

Lack of field data and bathymetry was major limitation of the study. Supervised classification of habitats and accuracy assessment was failed without ground source data. Also this study is cannot identify the exact area due to the low resolution and area is restricted to the small area. The other thing is study area belongs to the sea area. It often results to the changes with current, waves and wind effects. These factors affect as limitation of this study and as further development of this study have to carry these parts to overcome these issues.

Conclussion

Study area of Vankalai reef area is a well-developed and extensive reef in Sri Lanka. Landsat 8 multispectral satellite image data was used to develop the study area map. Developed method was used to identify the spectral characteristics of benthic habitat of the study area. Ultimately map was generated for the coral reffs around the Vankalai area.

Acknowledgement

We would like to acknowledge every person who helped us in different ways during the research work.

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