MAPPING SEAGRASS BED IN THUY TRIEU LAGOON (VIETNAM) BY USING LANDSAT 8 IMAGE

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ABSTRACT: Seagrass play critical roles on the coastal zone ecosystem which are direct food for endangered species including dugong, turtles and other marine organisms. The seagrass bed can protect the sea floor from coastal erosion, absorb nutrients from coastal run-off and stabilize sediment, act as biofilter and provide a habitat for marine animals. Mapping seagrass bed is an importance task for management, conservation and protection seagrass ecosystem. Seagrass beds in Thuy Trieu lagoon was considered as high species biodiversity and forming the huge stands in Vietnam. However, under impacts of socioeconomic development, this area faces to disturbance and reduction of seagrass bed cover area in the recent years. Mapping seagrass bed in this area therefore is coming necessary for environmental management. Remote sensing approached for mapping in this situation being the best choice. It provides the whole map at the same time, overcome the time difference error from traditional mapping by ground survey. In the present study, Landsat 8 OLI image, a free of charge image resource was used to demonstrate mapping the seagrass bed. The selected image is in dry season in 2014. The water column correction is using depth invariance index (DII) and bottom reflectance index (BRI) technique and extracting the seagrass bed is using maximum likelihood classification method. The results were validated by ground trust data with the overall accuracy of 87.32% and 84.51% corresponding. The DII method mapping result presents better than BRI method in area where bathymetry is shallow and flat. The results promise ability of mapping seagrass beds in lagoon area by Landsat 8 OLI using DII method without requirement of bathymetry data.

INTRODUCTION

Seagrasses are flowering plant live under seawater. Like terrestrial grass, seagrasses have root and rhizomes, and they were reproduced via flowers, fruits and seeds. Normally seagrasses grow in shallow water along the coast, estuaries, bay and lagoon (Dai 2011; Fortes 1990; Short et al. 2001). Seagrasses are direct food for dugong and green turtles and seagrass beds sever as nursery area for many marine species (Dai 2011; Dai et al. 1999; Heck and Thoman 1984; Jr. et al. 2003). Seagrass roots and rhizomes could stabilize sediments and prevent erosion and Seagrass leaves absorb nutrients from coastal run-off, act as biofilter and provide a habitat for marine animals (Cabaço et al. 2008; Spalding et al. 2014). Seagrasses therefore play a very important role on marine ecosystem and mapping seagrass beds is necessary to management, conservation and protection seagrass ecosystem.

Traditional methods for mapping seagrass beds are going directly to fields to collect seagrasses information. Those methods have advantaged of accuracy and detail on species level. But those revealed the limited time consuming and manpower cost (Komatsu et al. 2003a; Komatsu et al. 2003b; Mumby et al. 1999). To overcome the limitation, remote sensing technique have proved the advantage in observing the Earth's surface. It supports wide coverage for study area with multi-temporal and it is reduced a lot manpower cost (Green et al. 1996; Komatsu et al. 2003a; Mumby et al. 1999). In this study focus on remote sensing technique for mapping seagrass beds.

In earlier 2013, The Landsat 8 Operational Land Imager (OLI) and/or Thermal Infrared Sensor (TIRS) satellite was launched. And the data were available for download with free of charge in May 2013 (http://landsat.usgs.gov). Landsat 8 OLI image have 8 multispectral bands with pixel size of 30m and data repeated in 16 days. This is a good satellite data source for mapping. In this study is focused on using Landsat 8 OLI for mapping seagrass beds.

There are some remote sensing technique to map seagrass bed, such as using Principal Component Analysis (Ferguson and Korfmacher 1997; Pasqualini et al. 2005), using Normalized Difference Vegetation Index on SPOT image (Barillé et al. 2010), using leaf area index with addition in-situ optical data of Water leaving radiance and attenuation coefficient (Yang et al. 2011). And the most popular know of water correction methods are depth invariant index (DII) proposed by Lyzenga and Bottom reflectance Index (BRI), an improvement of DII by Sagawa (Lyzenga 1978, 1981; Mumby et al. 1998; Mumby and Edwards 2002; Sagawa et al. 2010; Tassan 1996). The objective of this study to verify the DII and BRI methods by using Landsat 8 OLI image on shallow water lagoon in the south of Khanh hoa province of Vietnam.

STUDY AREA

Thuy Trieu lagoon (Fig. 1) is located on upper part of Cam Ranh Bay in the south of Khanh Hoa province of Vietnam. Thuy Trieu lagoon was recorded as high density of seagrass with large meadows and species diversity of 8 species of *Enhalus acoroides, Halophila beccarii, Halophila ovalis, Halophila minor, Thalassia hemprichii, Halodule pinifolia, Halodule uninervis, Ruppia maritime (Hoa 2009; Hoa et al. 2013; Nguyen Huu Dai 2002).* The popular species are *Enhalus acoroides* and *Halophila ovalis*. *Enhalus acoroides*. *Halophila ovalis* are mostly found in the top of Lagoon while *Enhalus acoroides* distribute along the east coast of the lagoon.

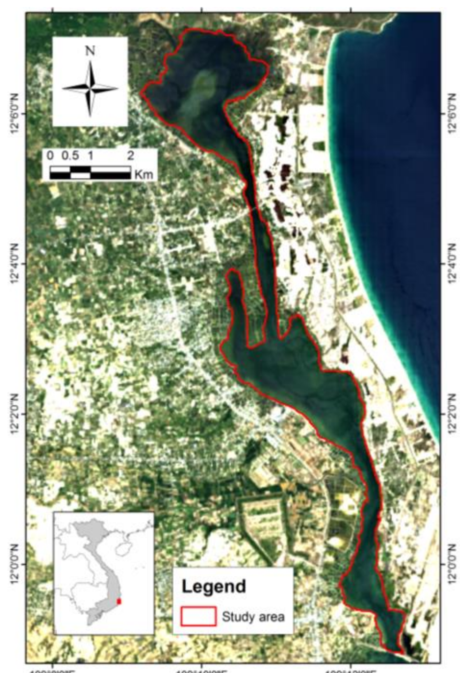

Figure 1: Study area – Thuy Trieu lagoon

In the recent years, under impacts of socioeconomic development, this area faces to disturbance and reduction of seagrass bed cover area. From 1997 to 2002, seagrass beds reduced 30% from 500ha to 350ha (Nguyen Huu Dai 2002; Pham et al. 2006). In 2009, seagrass beds area were recorded about 547ha (Hoa 2009), a big increase on seagrasses cover area. But in 2012, a big reduction of seagrass areas in this lagoon (Hoa et al. 2013). It is mean the seagrass beds in this lagoon is very vulnerable. It is necessary for monitoring and managing to avoid seagrass ecosystem destruction.

DATA AND METHODOLOGY

Satellite data:

Landsat 8 OLI image on May 31st 2014 path 123, row 52 was downloaded from USGS EarthExplorer (https://earthexplorer.usgs.gov).

In-situ data:

The seagrass canopies were observed by using a small boat and by walking around the lagoon with digital camera, GPS and writing paper. 102 points were recorded as seagrass subtraction, 100 points of sand and 80 points of muddy-sand.

Bathymetry map:

Bathymetry data points were measured by using single beam echo sounder Lawrance VP 1000. More than 4000 depth points collected in April of 2013.

Bathymetry map was generated by using Arcmap 10 to interpolate from bathymetry data points using natural neighbor method.

Sun glint removal:

Sun glint on remote sensing image for coastal area are affected to under water habitats mapping and needed to remove its affected (Hedley et al. 2005; Hochberg et al. 2003; Kay et al. 2009). Method of sun glint removal developed by Hochberg *et al*. (2003) and modified by Hedley *et al*. (2005) was used in this study. Three visible bands of 2, 3 and 4 of Landsat 8 OLI image were applied by following equation:

$$R_i' = R_i - b_i(R_{NIR} - Min_{NIR}) \qquad (1)$$

Where: R_i' is sun-glint corrected pixel brightness in band i; R_i is pixel value in band i; b_i is slope of band i to Near Infrared (NIR) band; R_{NIR} is pixel value in NIR band; Min_{NIR} : Min of pixels of no sun glint area in NIR band

Water column correction

Light intensity in the water decreases exponentially with increasing depth. Spectra of sand substrate at 2m depth is very different to at 20m. And spectra of sand at 20m is may similar to spectra of seagrass at 3m depth. Obviously, this problem influences to map habitat. This study introduces two methods called Depth invariant index (DII) (Lyzenga 1981) and Bottom reflectance index (BRI) (Sagawa et al. 2010) to remove the effect of water column. Both method are based on bottom reflectance equation:

$$L_i = L_{si} + a_i r_i \exp(-K_i g Z) \quad (2)$$

Where L_i is radiance at band i, L_{si} is radiance over deep water, a_i is the solar irradianceat band i, r_i is the bottom surface reflectance at band i, K is the attenuation coefficient of water, g is geometric factor, Z is water depth.

Depth invariant index uses two bands to reduce water depth parameter in eq. 3 and expresses as:

$$DII_{ij} = Ln(L_i - L_{si}) - \frac{k_i}{k_j} Ln(L_j - L_{si}) \quad (3)$$

Where: L, k are same as Eq. 2 of band i and j.

k_i/k_j was indicated by calculate slope of band i and band j in natural logarithm scale.

Bottom reflectance index (BRI) was calculate as:

$$BRI_i = \frac{(L_i - L_{si})}{\exp(-K_i g Z)} \quad (4)$$

Where L, K, g, and Z are same as Eq. 2. $K_i g$ was determined by Eq. 2 with Bathymetry data and radiance of band i of sand points.

We can see, $BRI_i = a_i r_i$ in Eq. 2 where r_i is bottom reflectance of band i that why this index called Bottom reflectance index.

RESULTS AND DISCUSSIONS

Sun glint removal result

The Landsat image after applied atmospheric correction, subset and mask land cover in study area in Fig. 2a. There are many sun glints in Fig. 2a. After remove glints, all glints have been remove in Fig. 2b, and some pattern of substrates are appearance clearly.

Seagrass mapping results

The in-situ data dived into two parts, 50 sand points used to indicate parameters for DII method and BRI. 50 seagrass points and 40 muddy-sand points were used to classification. The rest of 50 sand points, 52 seagrass points and 40 muddy-sand point were used to validation.

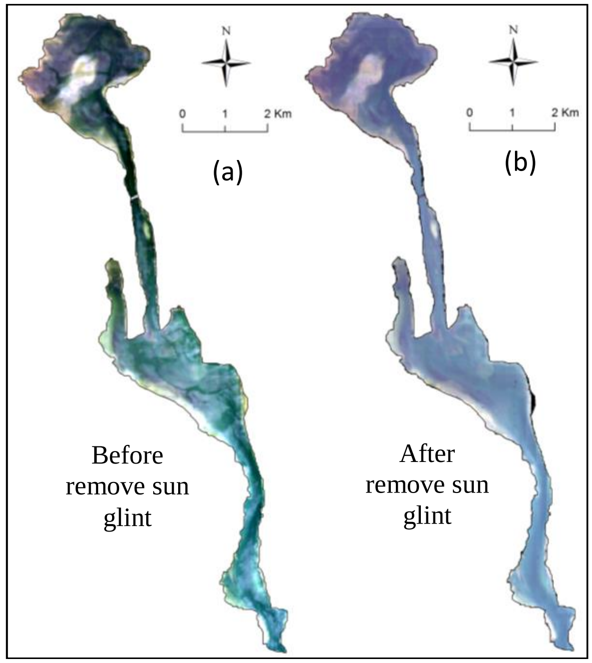

Figure 2: (a). Atmospheric correction result; (b). Sun glint removal result.

The attenuation coefficient ratio of band 1/2, 1/3 and 2/3 for DII:

$k_1/k_2 = 0.79$
$k_1/k_3 = 0.43$
$k_2/k_3 = 0.58$

The DII_{12}, DII_{13} and DII_{23} were classified by using maximum likelihood classification method in to 3 classes, sand, seagrass and muddy-sand. The result shows in Fig. 3. Seagrass beds area is 499ha.

The attenuation coefficient of band 1, 2 and 3 for BRI method are:

$K_1g = 0.0890$
$K_2g = 0.1367$
$K_3g = 0.2744$

The BRI_1, BRI_2, BRI_3 were also classified by using maximum likelihood classification method in to 3 classes, sand, seagrass and muddy-sand with the same training dataset for DII. The result shows in Fig. 4 and seagrass beds area was estimated to 607ha.

The result from DII method (Fig. 3) is nearly similar to result from BRI (Fig. 4). Most of seagrass beds distributed in the top of Lagoon. In lower part the BRI was classified more seagrass than DII result.

Although seagrass areas in both method DII and BRI are very high of 499ha and 607 ha, but according to Hoa at al. 2013 density, biomass and cover level of seagrass beds are very low. The seagrass degradation mainly was caused by eutrophication with nutrient discharges from aquaculture, overfishing and dredging.

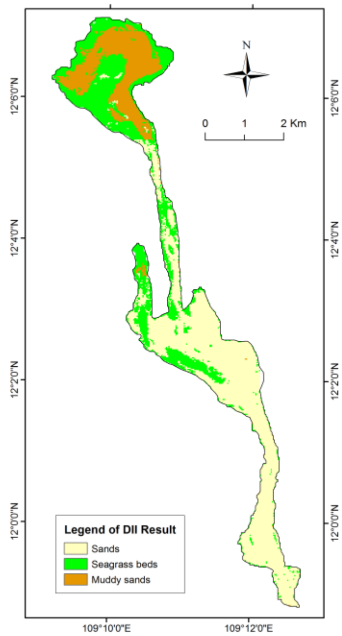

Figure 3: Seagrass beds generated by DII method

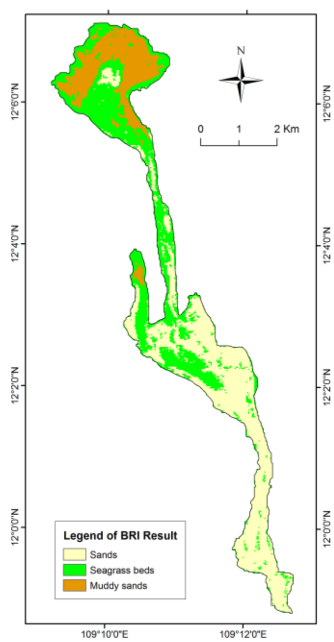

Figure 4: Seagrass beds generated by BRI method

The water depth in this lagoon is very low. Maximum water depth is 6m. On the top of lagoon, maximum depth is just about 3m. And is increasing to lower part. The variation of water depth is not very high with the pixel size of 30m. So with the same radiance value of a pixel, if water depth Z is similar, BRI in Eq. 5 should produce same value. This mean, if the bathymetry is flat, the BRI will be similar to the origin image data. In this case, although BRI method produce more seagrass bed area but the overall accuracy and kappa coefficient are lower than DII method. In this case, DII method gave a better result than BRI method.

<u>Validation results</u>

Table 1: Accuracy assessment of DII and BRI results.

	DII Method	BRI Method
Overall accuracy	87.32%	84.51%
Kappa coefficient	0.81	0.77
Producer accuracy	88.33%	85.67%
User accuracy	87.84%	90.96

CONCLUSION

Landsat 8 OLI is very good resource for mapping seagrass in Thuy Trieu lagoon. With temporal resolution of 16 days, it can be use for monitoring program continuously in time.

In lagoon area, water condition normally is calm, it may got sun glint in image and this affect to the mapping result. From the sun glint remove result in Fig. 2b. The image should apply remove glint before water correction and classification. There many method, in this study suggest sun glint removal developed by Hochberg et al. (2003) and modified by Hedley et al. (2005).

DII method have overall accuracy 87.32% and kappa coefficient 0.81 and BRI method have a little lower overall accuracy of 84.51% and kappa coefficient of 0.77 (Table 1). With higher accuracy, DII method was suggested to use for mapping seagrass beds in this lagoon. Other advantage of DII method is no need bathymetry data.

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