MAPPING SEAWEED DISTRIBUTION USING HIGH-RESOLUTION MULTISPECTRAL IMAGERY

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ABSTRACT: Tropical countries like Indonesia have the potential to be producers of seaweed for various commercial uses. The ability to map distribution this commodity is important to support management and development of cultured seaweed. Distribution of seaweed that lives in tens meter depth is mapped using high-resolution imagery. The distribution map is derived based on information of suitable environment to grow such as the depth or bathymetry. This study explores the use of high resolution WorldView-2 image to map seaweed distribution. Field survey was conducted to provide ground information and location of the cultured seaweed in Dolago, Province of Parigi-Moutong, Sulawesi Island. The processes include applying derivative filter to enhance the image and k-means image classification. This research found that unsupervised classification from color composite of near infra red-1, red and coastal blue provide a good result for identifying seaweed habitat in coastal area. Unsupervised classifications using bands NIR 1, red and coastal blue give proof to the ability of seaweed identification from the 2 meter spatial resolution image. Investigation using band ratios using the uniquely available bands (NIR 1, NIR 2, and red edge) in WorldView2 image further enhance the advantage of this image for seaweed distribution mapping.

1. INTRODUCTION

Indonesia is the largest archipelagic country in the world with over 13,600 islands and a coastline that stretches up to 1,000 km. The Indonesian water, covering 3.1 million km2 and is located in the tropical region, have made the country's marine resources rich biodiversity. One of the commodities which are high in economic value and has huge potential to be developed is seaweed. Seaweed farming remains potential for further development due to Indonesia's coastline and tropical location. The most common types of seaweed found in Indonesia are from the family of Gracilaria, Gelidium and Gelidiella, which are the main ingredients in jelly production; another type is Sargassum. There is a big opportunity for seaweed export, considering the high demand especially the Eucheuma type.

Seaweed is also termed as macroalgae; it is cultivated by anchoring a small branch onto a piece of wood or bamboo; it does not possess roots extending below the surface. After about 45 days, it is ready to be harvested. Seaweed grows best on shallow, moderate temperature (25-29°C), and clean water, and may be along side of coral habitat (Zatnika, 2009).

The area of research is Dolago, in the Parigi Moutong Regency, Central Sulawesi Province, Indonesia. Previous study has identified the coastal area of Parigi Moutong as having a huge potential for developing seaweed farming because of its coastal characteristics and the relatively little impact of climate change on this area. Moreover, this research also compares the result of previous research which utilizes 2009 ALOS-AVNIR2 data.

2. DATA AND METHOD

This research utilizes a brand new high-resolution 8-bands multispectral image from WorldView-2 satellite provided through the 8-band challenge organized by Digital Globe. The multispectral image has a 2 m spatial resolution with 8 spectral bands, namely coastal blue (400-450 nm), blue (450-510 nm), green (510-580 nm), yellow (585-625 nm), red (630-690 nm), red-edge (705-745 nm), near infra red-1 (770-895 nm) and near infra red-2 (860-1040 nm). The data sets are processed using ENVI produced by ITT Visual Information Solutions and the free software called Mirone tool (Luis, 2007).

Figure 1 displays the Dolago area with a band combination of 7, 5 and 1 for Red-Green-Blue (RGB) color composite. With this color combination, healthy vegetation is shown in red color, water saturated soil or fish pond and turbid water are shown in grayish black color, and deep water is shown in grey color. Note that near the coastline some black stripes are visible which may indicate the presence of seaweed.

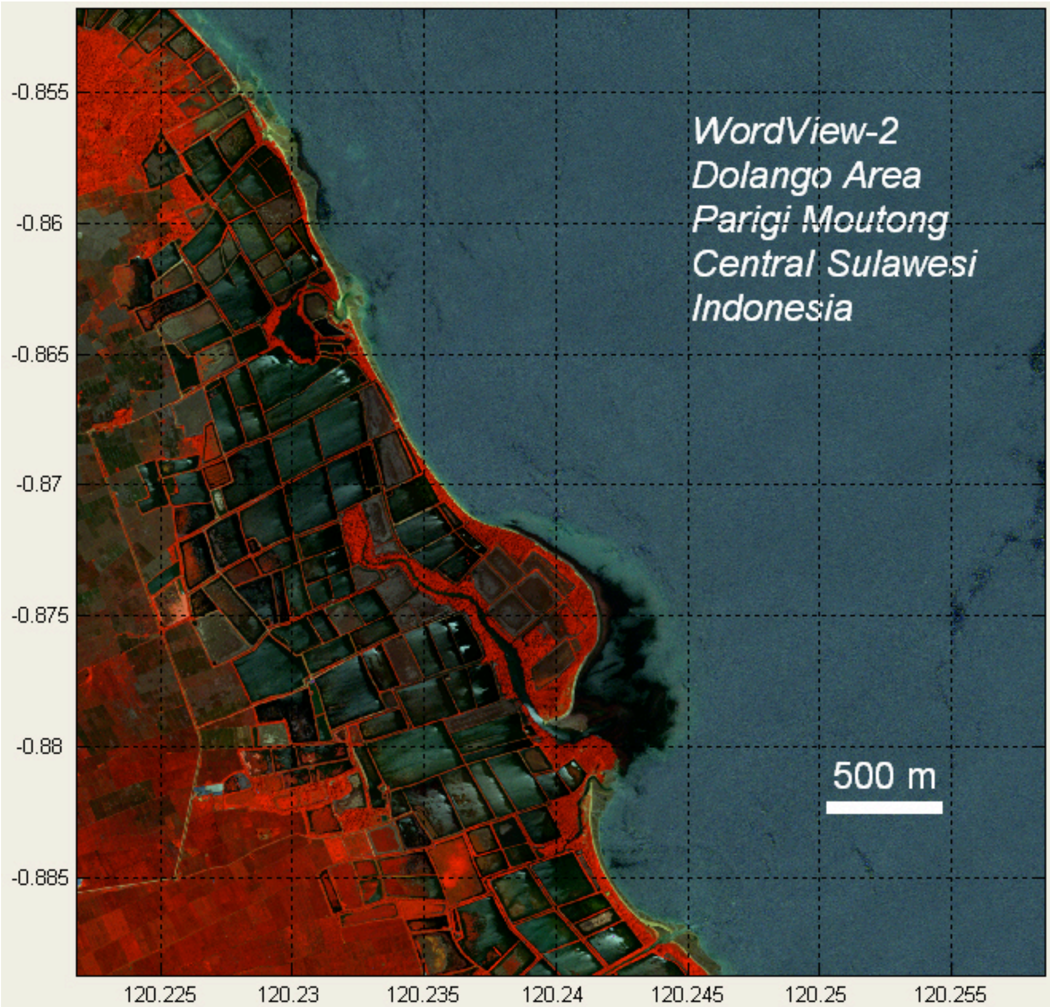
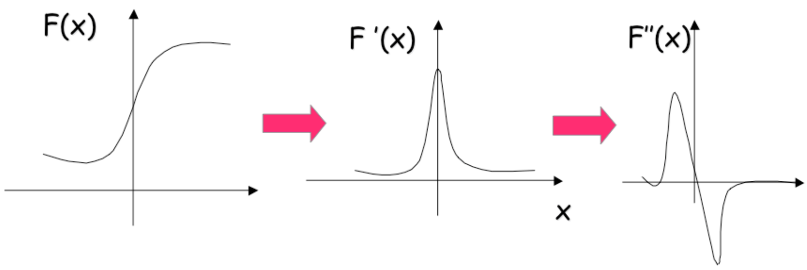


Figure 1. RGB Color Composite of WorldView-2 Image (band: 751).

The first step of investigation is using image enhancement to accentuate the object difference based on color spectral to highlight fine detail, remove blurring from images, and highlight edges. This is done by applying 2nd derivative filter as follows (equation 1):



$$\frac{\partial^2 f}{\partial^2 x} = f(x+1) + f(x-1) - 2f(x)$$

combined with Laplacian Zero Crossings algorithm (equation 2) i.e. by Kimmel and Bruckstein (2003).

$$\begin{aligned} g(x,y) &= f(x,y) - \nabla^2 f \\ &= f(x,y) - [f(x+1,y) + f(x-1,y) + f(x,y+1) + f(x,y-1) - 4f(x,y)] \\ &= 5f(x,y) - f(x+1,y) - f(x-1,y) - f(x,y+1) - f(x,y-1) \end{aligned}$$

After enhancement, image classification was conducted based on k-means classification of unsupervised algorithm. This algorithm uses an iterative approach that minimizes the sum of distances from each object to its cluster centroid, over all clusters. This algorithm moves objects between clusters until the sum cannot decrease further. The result is a set of clusters that are as compact and well separated as possible.

A second investigation using vegetation index is conducted by exploiting the bands uniquely available in WorlView-2 images, namely the NIR 2 and Red-edge bands. Vegetation index such as NDVI is widely used to detect vegetation, where it uses NIR and red bands. For this study, the bands available in WorldView-2, which are Red (630-690 nm), NIR 1 (770-895 nm), NIR 2 (860-1040 nm), Red-edge (705-745 nm) are employed, the band indices formulated are:

$$NDVI_1 = \frac{(NIR_1 - \mathrm{Re}\,d)}{(NIR_1 + \mathrm{Re}\,d)}; NDVI_2 = \frac{(NIR_1 - \mathrm{Re}\,dedge)}{(NIR_1 + \mathrm{Re}\,dedge)}$$

$$NDVI_3 = \frac{(NIR_2 - \mathrm{Re}\,d)}{(NIR_2 + \mathrm{Re}\,d)}; NDVI_4 = \frac{(NIR_2 - \mathrm{Re}\,dedge)}{(NIR_2 + \mathrm{Re}\,dedge)}$$

Field survey was conducted in Dolago in May 2010. While there is a time difference between field survey and image acquisition, through communication with the local government in Dolago, seaweed is still cultivated at the time of image acquisition. During field survey, the information collected are: geo-location, number of days after planting, color or type of seaweed, weight, water temperature, water salinity, water color, and seaweed health condition. Figure 2 illustrate samples of seaweed collected during the survey. A total of 10 points were collected. The field information will be used to get relationship between indices of WorldViwe-2 image and biomass.

Figure 2. Samples of seaweed collected during field survey for biomass measurement.

3. RESULTS

The result of image enhancement using Laplacian difference derivative filter is illustrated in Figure 3. The filter developed is based on equation (2), which applied in a 3 x 3 matrix dimension as follows:

$$\begin{pmatrix} 0 & -1 & 0 \\ -1 & 5 & -1 \\ 0 & -1 & 0 \end{pmatrix}$$

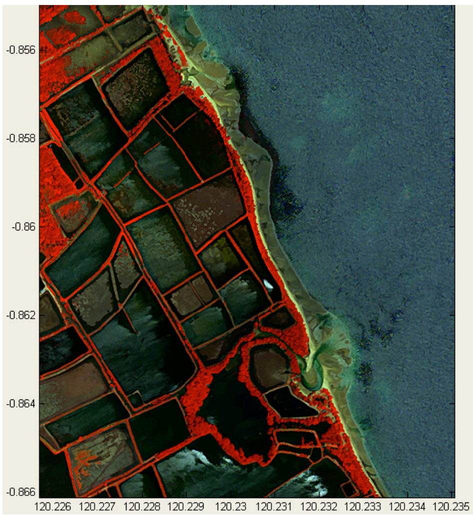
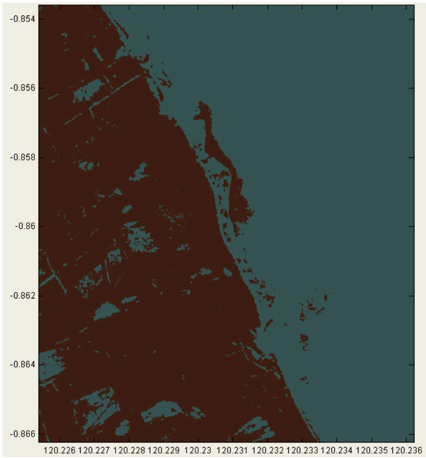
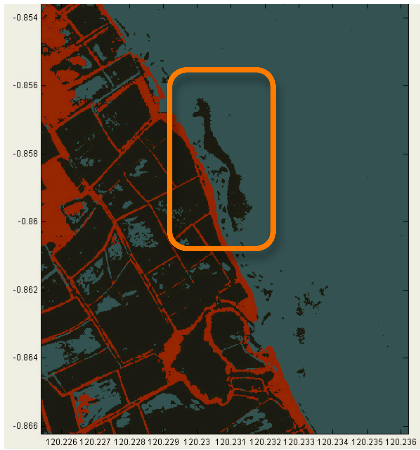


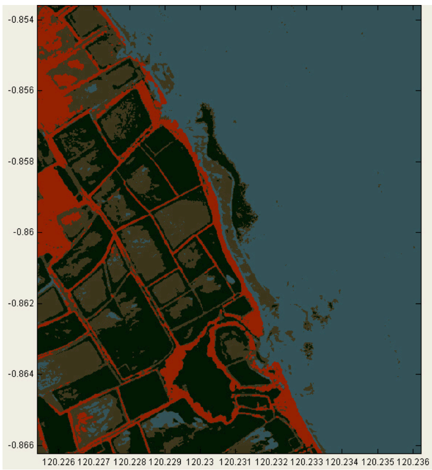
Figure 3. Enhanced image of zoomed area.



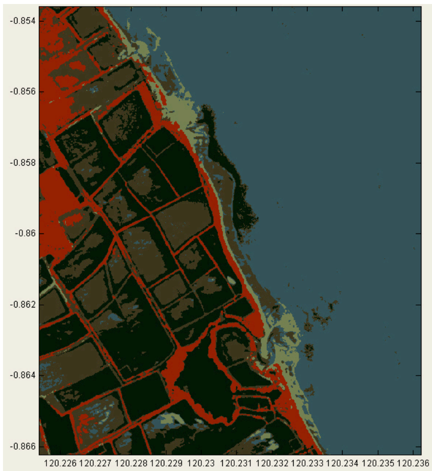
(a) Unsupervised, 2 classes: water and non water



(b) Unsupervised, 3 classes: water, vegetation and unclassified (in the box)

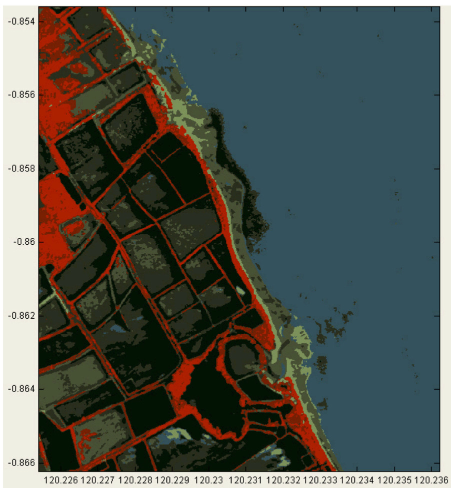


(c) Unsupervised, 4 classes: water, vegetation, sand, and unclassified



(d) Unsupervised, 5 classes: water, vegetation, sand, sediment, and unclassified

(e) Unsupervised, 6 classes: seawater, pond, vegetation, sediment, sand, and unclassified



(f) Unsupervised, 7 classes: seawater, pond, vegetation, sediment, sand, non water and unclassified

Figure 4. Results of unsupervised classification for 2, 3, 4, 5, 6 and 7 classes.

The image classification based on unsupervised k-means algorithm is conducted starting from 2 up to 7 classes to assess the ability of this algorithm to differentiate the various objects. The results are illustrated in Figure 4. Figure 5 shows results of the 4 indices ($NDVI_1$ through $NDVI_4$). Note that each indices produces image that highlight different objects, both on coastal and deep water, as well as inland areas.

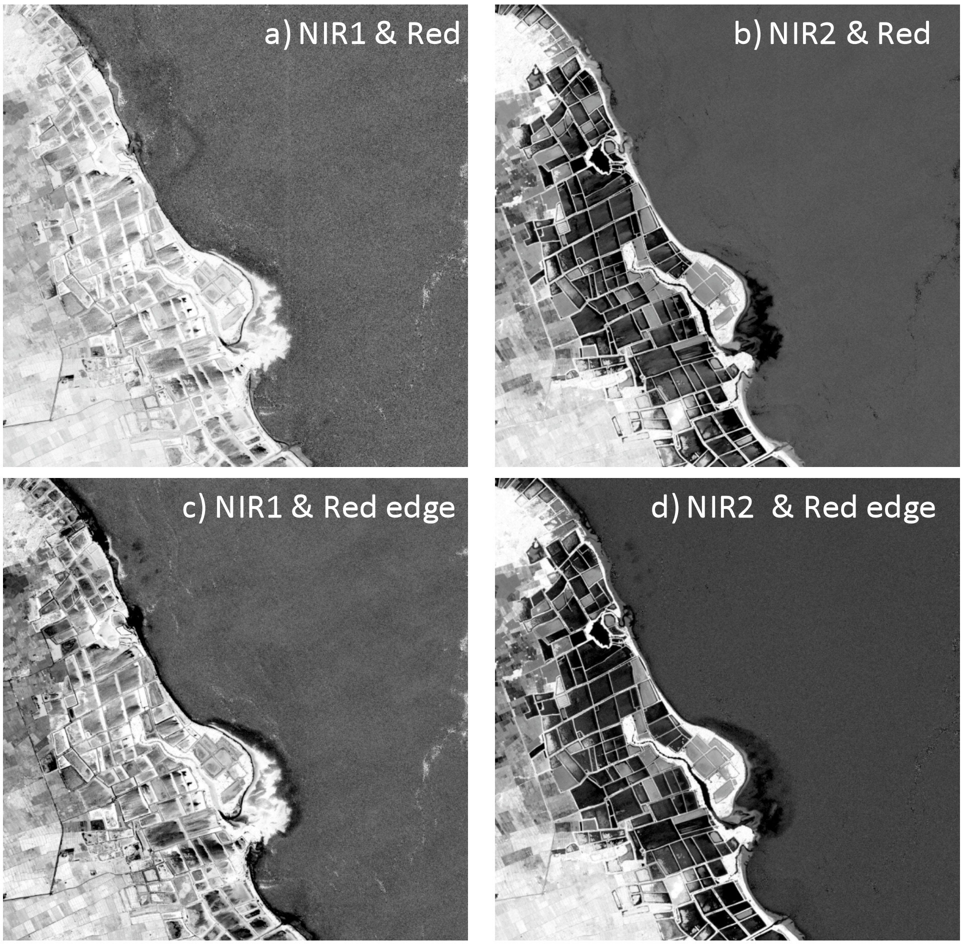


Figure 5. Results of band indices application

4. DISCUSSION AND CONCLUSIONS

Result of processed high-resolution 8-bands multispectral image from WorldView-2 acquired on October 24th 2010 gives clear information of coastal environment for the Dolago study area. Image enhancement is key which leads to shallow water identification. The 2nd derivative filter based on Regularized Laplacian Zero Crossings algorithm is included in sharpening spatial filters that seek to highlight fine detail, remove blurring from images, and highlight edges. Figure 4 illustrates very clear object differentiation of sediment transport in the estuary and also the coastline is clearly shown. Using k-means unsupervised algorithm, the objects are classified and the classes are listed in Figure 4.

In the 3-classes classification, there is an object located on the coastal area, marked by an orange rectangle in Figure 5-b. After narrowing the classification until 7 classes, this object is still clearly identified. It means this object is totally different with the other objects in that coastal area. For that reason, this object is suspected as the habitat of seaweed since the location is still near the coast and on shallow water. Previous study using ALOS-AVNIR data acquired on November 9th 2009 (almost one year difference) found the area to be potential for seaweed farming using supervised classification method based on field information. The result is illustrated in Figure 6.

A relationship between indices produced from the WorldView-2 image and biomass collected from field survey was also investigated. Seaweed biomass for each of the 10 field points was resampled to represent the spatial resolution of WorldView-2 image. Figure 6 shows the 4 indices plotted against biomass for the 10 field points. Straight lines represent linear regression analysis. The equations of regression as well as the R^2 are also shown for each of the indices.

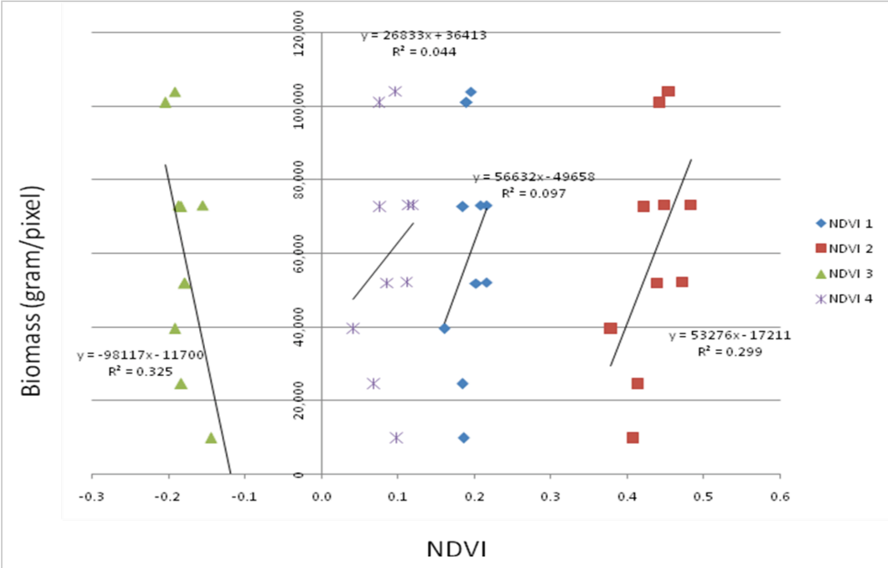


Figure 6. NDVI-biomass relationship for seaweed in Dolago

$NDVI_2$ (using bands NIR_1 and Red-edge) is shown to give the best relationship among the 4 indices with R^2 of 0.299. While $NDVI_3$ gives the worst result with a negative relationship. The overall low value of R^2 is probably due to the different dates of image acquisition and field survey. The period of planting to harvest is only 45 days, so between the field survey in May and image acquisition in October (around 150 days) the growth stage and seaweed coverage are more likely be different. Another reason of the low R^2 value is the small number of biomass collected (only 10 locations).

There are two conclusions that can be made from this study. The high-resolution 8-bands multispectral image from WorldView-2 satellite can be processed using the freely available software to identify seaweed habitat, and therefore useful for maritime and developing countries such as Indonesia. The additional bands available in the WorldView-2 image, namely the NIR and Red-edge bands are proved to be very useful in identifying vegetation on water, such as seaweed.

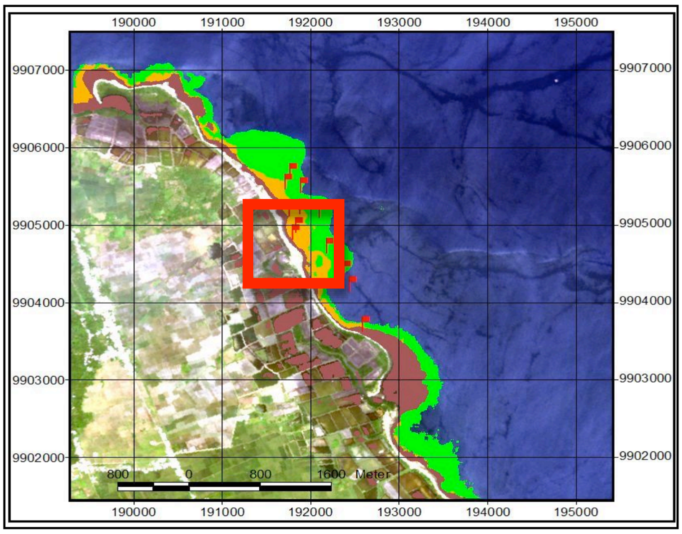


Figure 6. Previous Study based on ALOS-AVNIR2. The potential area is illustrated with green color. Red colored box represents the coverage area of WorldView-2 image.

References

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