EVALUATION OF MANGROVE DAMAGE LEVEL BASED ON LANDSAT 8 IMAGE

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Abstract. Monitoring of mangrove damage in Java requires special attention because the mangrove vegetation has been under pressure from various other land uses which are considered more productive. This paper applied quick-mangrove-damage-detection technique using Landsat 8. The purpose of this study is to develop mangrove damage identification algorithm using Landsat 8. The findings from field survey in Segara Anakan-Cilacap show that major mangrove logging generates the growth of minor mangrove, specifically *Derris* and *Acanthus* type; the minor mangrove cover area is categorized as high density based on NDVI value. The index use does not meet the actual condition in the field. This study proposes a new index as mangrove quality indicator. The new proposed mangrove index is derived from 2 bands that could differentiate mangrove vegetation where different digital number of two bands is higher from mangrove forest than non-mangrove forest. That phenomenon is caused the low of SWIR spectral on mangrove forest due to absorption by wet soil below the mangrove forest where flooded in high tide. The new mangrove index is formulated as (NIR – SWIR / NIR x SWIR) x 10000. The new mangrove index has good correlation with density of major mangrove in the field, and also good correlation with mangrove degradation map. Mangrove index has been functioning properly and can be applied in Segara Anakan, Cilacap and potentially can be applied in other locations.

Keywords: *Mangrove, new index, mangrove degradation, remote sensing*

1 INTRODUCTION

Mangrove forest is a forest ecosystem on the seashore influenced by the tide so that their habitat is always flooded by saline water. One of the large mangrove forest areas is located in Segara Anakan, Cilacap. The condition of mangrove forests especially in the area of Segara Anakan, Cilacap has been degraded due to pressure from other land uses that are considered more productive. Hence, the monitoring and evaluation related to the degradation and destruction level of mangrove forest in Segara Anakan, Cilacap are urgently needed.

Multispectral remote sensing have successfully classified mangroves as mangrove vegetation has a distinctive character to the electromagnetic waves. Remote sensing data have been widely used for operational activities such as the activities of the National Forest Inventory established by Directorate General of Forest Inventory and Land Use, Ministry of Forestry in 1985 and was amended in 1992 (FAO, 2003). Mangrove mapping using remote sensing data has also been conducted by Bakosurtanal in 2009 (Saputro, *et. al.*, 2009). Furthermore, NDVI index vegetation has been used to distinguish mangrove density. However, NDVI is more likely associated with canopy density than the stand density. Mangrove density based on NDVI has been used to assess mangrove damage where the low index value are categorized as damaged (Department of Forestry, 2006 in Hidayat *et al.*, 2011). The study of the correlation between NDVI and mangroves density have been conducted by Faizal and Amran (2005). The correlation between NDVI and mangrove trees would be good when the mangrove is in good condition and is dominated by major mangrove.

Vegetation index is very general;it is not specifically design for mangrove vegetation, moreover when dealing with major mangrove and minor mangrove. Thus, this index does not describe the actual condition in the field, for example, grass may has higher NDVI value than forest with less canopy density. It is found that the major mangrove logging generate the growth of minor mangrove, especially the *Derris* and *Acanthus* type. Ecologically, minor mangrove dominance can be regarded as an indicator of mangrove damages (Ardli 2010) and this minor mangrove cover has a high vegetation value and is categorized as dense mangrove class. (Hadiwijaya, *et. al.*, 2013). This study proposes the new mangrove damage index which describes the major mangrove density only and it is not affected by minor mangrove. This new mangrove index is expected to be an alternative indicator of mangrove quality in the damaged area where the density based on NDVI is no longer accurate.

2 MATERIALS AND METHODS

2.1 Research sites

This study took place in mangrove areas in Segara Anakan, Cilacap, Central Java. Segara Anakan is a unique ecosystem, an intertidal area consisting of lagoon and sludge that is sheltered from the ocean by NusakambanganIsland. This area has high sedimentation rate because of the input of fresh water from various rivers. Intertidal area is a potential area for mangrove's growth and development with high potential for fish farming. Segara Anakanis not a conservation area but it isorganized under a special unit which is incorporated into the Department of Fisheries and Marine Resource Management and under the supervision and the working area of the Central Management of Mangrove Forest Region I, the Ministry of Forestry. However, Segara Anakan is still in the working area of the Ministry of Justice and Human Rights for Nusakambangan Prisons.

There are 24,000 hectares of Mangrove ecosystem in Segara Anakan with 14,100 Ha ofintertidal marsh forest (Sunaryo, 1982, in White, *et. al.*, 1989). However, Ecology team (1987) reports that there are only 21,750 Ha of mangrove habitat while the remaining 12,610 Ha is the area which is still influenced by the tide and dominated by mangrove vegetation (White, *et. al.*, 1989).

2.2 Data

The data used in this study consists of remote sensing data and field survey data. The remote sensing data used in this study are Landsat 8 LDCM data taken on May 30, 2013 path/row 121/65. Spectral of Landsat8 data is similar to the spectral of Landsat TM and ETM+ that are commonly used for identification of mangrove. The data level used in this study is Level 1T i.e.,Standart Terrain Correction where the data have already been through systematic radiometric and geometric correction to improve accuracy with the use of the accurate DEM topographic maps (USGS, 2013).

The data field used in this study is field survey results which were conducted twice, on May 2013 and November 2013. The first survey was conducted on 27 and 31 May 2013, with 6 sampling stations to calculate the tree density. The second survey was conducted on November 19 to 24, 2013 and measuring the tree density in 6 stations. There are 12 data to be analyzed in term of density validation and mangrove index. The field survey also measured other parameters but other parameters were not used in this paper. The calculation of the tree numbers was conducted in 30x30 meters plot, then this plot was divided into nine subplots with 10x10 meters, and this measurements were done in several subplots with different subplot numbers were measured in each plot, between 1-5 subplots. The data from several subplots were assumed to represent the plot in 30x30 meters area.

2.3 Method

Mangrove can be visually recognized by Landsat 8 on 564 RGB color composites, so that the index is derived from two channels that distinguish mangrove vegetation, i.e., channels 6 and 5, in which the value differences between the two channels are high on mangrove vegetation object and low on non-mangrovevegetation. This is because, in the SWIR wavelength, the reflectance values will be lower in wetter soil due to tidal inundation where the mangrove vegetation grows. The reflectance differences were seen on channel 5, with lower value for mangrove vegetation. Meanwhile, the reflectance on channel 4 which is related to chlorophyll was not much different.

Where the mangrove areas have lower scores than the non-vegetated areas of mangrove, while reflectance in channel 4 associated with the chlorophyll content of leaves is not much different. This is due to the tidal effects on intertidal areas that make the distinctivecharacters of soil types that affect the reflectance of vegetation community's spectral (Brasco, et al, 1998). The mangrove damage index is formulated as follows:

$$IM = (NIR - SWIR / NIR \times SWIR) \times 10000 \qquad (2\text{-}1)$$

Where IM is the proposed mangrove index, NIR is the near infrared light channel i.e., channel 5 on LDCM sensors and SWIR is short infrared channel i.e., channel 6 on the LDCM sensors. The 10,000 value is a multiplier factor in order to achieve the index value of -1 (minus one) to 1 (one), and the 10,000 value is used because the LDCM level IT data are stored in 16 bit format (0-65535). For applications with other data, the multiplier factor could be different, for example, 8bits format (0-255) for Landsat 7.

Other algorithms such as Normalized Difference Vegetation Index (NDVI) and NDWI (Normalized Difference wetness Index) were used as the comparison of the proposed mangrove index. The comparisons were conducted because mangrove vegetation is closely related to the greenness level and the land wetness level. To identify the canopy density of mangrove vegetation, NDVI (Green *et al.*, 2000, in Waas, 2010) was used. Meanwhile, the land wetness level as identifiedby using NDWI (Gao 1996). The algorithms for NDVI and NDWI are as follows:

$$NDVI = (NIR - RED)/(NIR + RED) \qquad (2\text{-}2)$$

$$NDWI = NIR - SWIR/NIR + SWIR \qquad (2\text{-}3)$$

Where NDVI is vegetation index, NDWI is the land wetness index, NIR is the near infrared light channels i.e., channel 5, RED is the red channel i.e., channel 4 and SWIR is short infrared channel i.e., channel 6 on sensor LDCM3.

3 RESULTS AND DISCUSSION

The proposed Mangrove index (MI)is based on the unique appearance of mangrove in color composites 654 (RGB) scanned by Landsat 8 LDCM or composites 453 (RGB) by Landsat 7 (ETM+) and Landsat 5TM (see figure 3-1). Mangrove appearance should be in dark red such as in area 1 (see circle in Figure 3-1). The dark red is caused by the tidal effects on intertidal areas that create distinctive character of soil typesand affects the vegetation community reflectance (Brasco, *et al.*, 1998). However, mangrove area of Segara Anakan appeared with a slightly different color which is shown in area 2, the dark red changed to green-yellow and the third area is in reddish yellow. Based on image interpretation key, the green color from channel 6 which is sensitive to soil, mix with red color from channel 5 which is dominated by green color. This condition indicates that there is not much vegetation in this area, unlike the three other areas where the vegetation is dominant. Preliminary studies also show that area 3 has high value of vegetation index (NDVI).

The unusual appearances occurred in area 2 and 3, then this phenomenon was investigated directly in the field. The field survey result shows that area 1 is major mangrove area with high density. Area 2 is unflooded or intermittently flooded with less major mangrove and dominant minor mangrove (not from Derris and Acanthus types). Terrestrial vegetation such as hibiscus tree was found in some other areas, this indicates that the area is unflooded by high tide in the long term. Meanwhile, area 3 is dominated by minor mangrove from *Derris* and *Acanthus* types with high density. It is expected that this area has a high NDVI values even though there is no major mangrove at all.

From these facts, it can be estimated that the mangrove area of Segara Anakan is damaged and during thesurvey,several piles of mangrove trees, ships shipping mangrove, fishermen cuttingdown trees and some logs were seen. The level of damage can be identified from the conditions on the field, one of which is the presence of minor mangrove *Derris. Derris trifoliate* LOUR is mangrove associates that normally live as vines and in a zone that gets an ample supply of fresh water (Ardli, 2010). Distribution of *D. trifoliata* in Segara Anakan is clumped (aggregate) especially in areas that are moderately or severelydamaged, thus the distribution of *D. trifoliata* can be used as a mangrove damage biomonitoring agent, because their specific existence and distribution (Ardli, 2010).

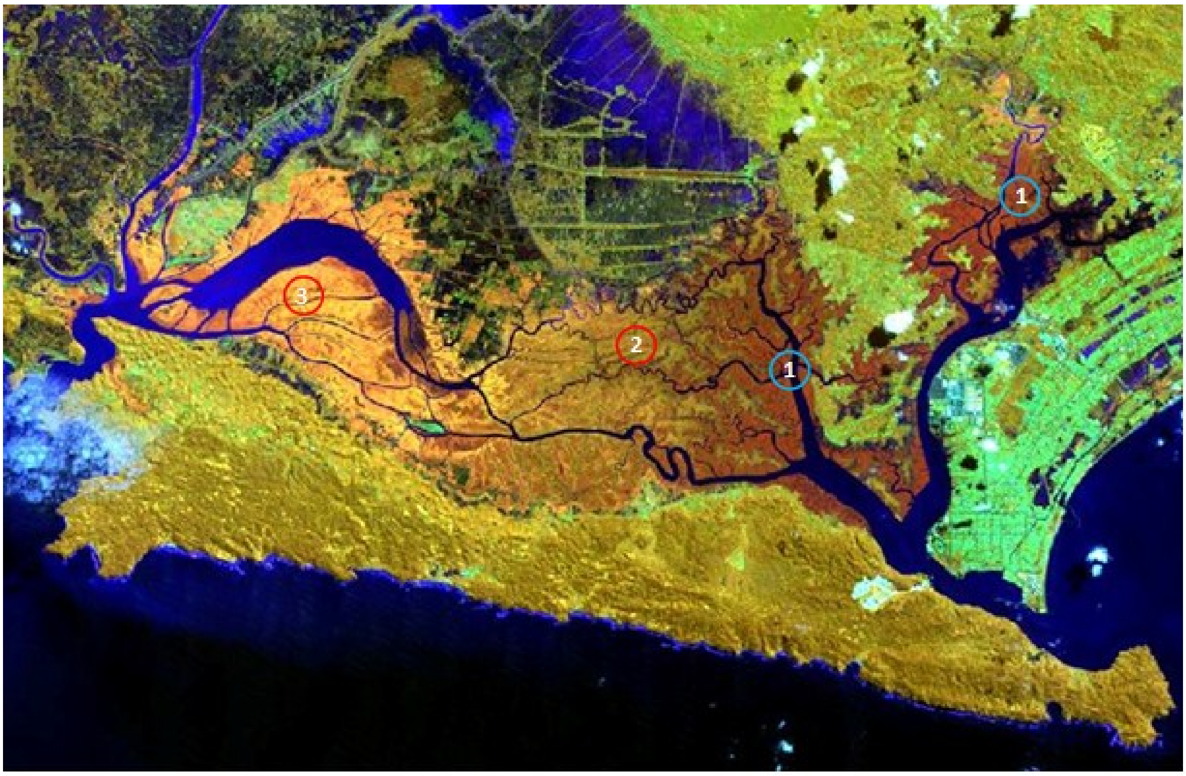


Figure 3-1: Typical appearance of mangrove vegetation in the composite 564 (RGB) Landsat 8 Data

Apart from the distribution of biomonitoring vegetation, the condition of mangrove forest is influenced by tides. Tidal swamp as habitat of mangrove vegetation isvery affected by the rising of sea level; too much of it then the area will be flooded and the mangroves will be drown, too little of it then the productivity will go down and will probably be replaced by other swamp vegetation or community of Cyanobacteria (Lovelock, *et al.*, 2012). Ecologically tides will affect mangrove ecosystems, physically it also affects remote sensing as typical wet soil conditions will absorb electromagnetic waves at short infrared spectrum (SWIR). Over 10,000 years ago mangrove in some situations cannot survive the rate of sea level rise of more than 1.4 mm/year (Ellison, 1993 in Lovestock, 2012), but the rising of sea levels become a barrier in mangrove reduction and community change in swamp areas of brackish water will vary, influenced by the interaction of several factors, including the geomorphology, the high of tidal range, the rate of accretion, land subsidence (Ellison, 1993, Cahoon *et al.*, 1999, *in* Lovestock, 2010), the rate of tree growth and species composition (Cahoon, *et al.*, 1999, Cahoon *et al.*, 2003 and Krauss *et al.*, 2003 in Lovestock, 2012).

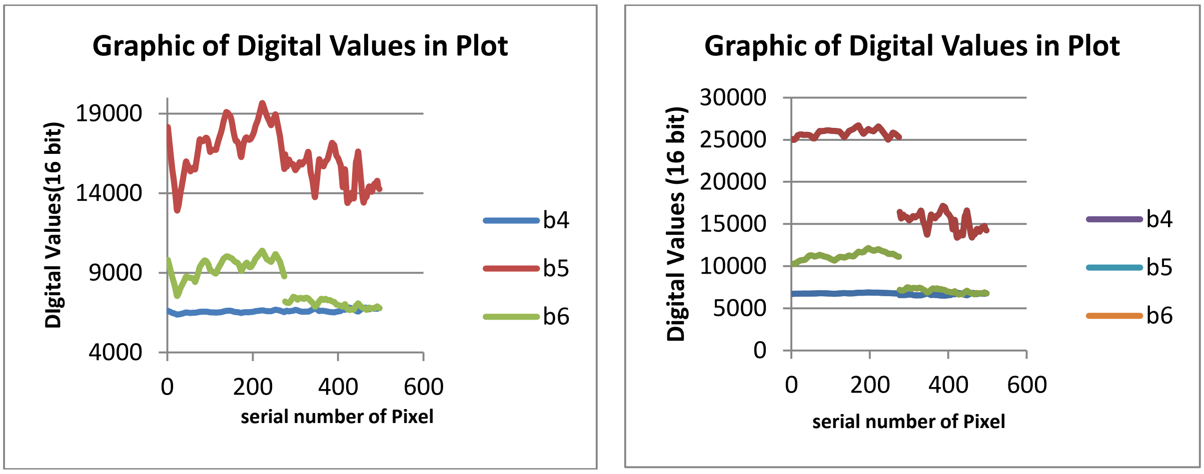


Figure 3-2: Graph of Digital Value in Non-Mangrove Vegetation and Mangrove Vegetation Objects (Left: The Value of X 1-274 Non-Mangrove Vegetation 275-497 Mangrove Vegetation) and in Objects Dominated by Derris vegetation and Major Mangrove Vegetation (Right: The Value of X 1-274 Derris Domination 275-497Major Mangrove Domination)

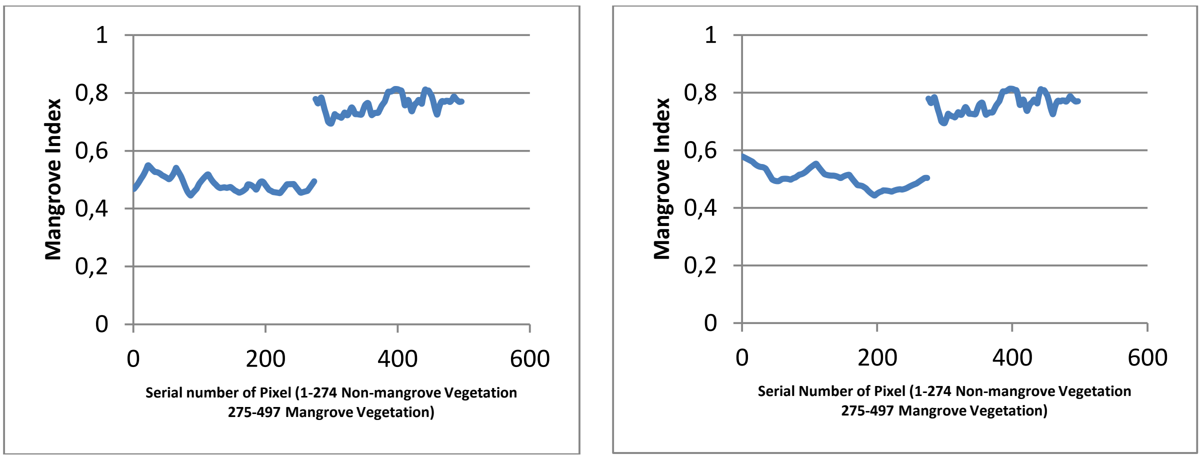


Figure 3-3: Graph of Mangrove Index at Objects of Major Mangrove, Non-mangrove Vegetation and Derris Dominated Vegetation

Mangrove index is based on the visual appearance of mangrove that differs from mainland vegetation as well as significant appearance differences in the of mangrove areas which are actually different from the conditions in the field. It is also triggered by the results of NDVI analysis which produces a high index value, but the density conditionof major mangrove is low and is dominated by minor mangrove.

Digital values analysis of an image with the object of mangrove and non-mangrove is carried, the digital values plot results are presented in Figure 3-2 left. From the left Figure 3-2 it can be seen that the digital value of band 6 mangrove object appears to be lower than the non-mangrove one, although it also happens on band 5, but the decrease in band 6 seemsto be more visible than that in band 5. This indicator is used as the basis for calculation of new indexes. The same thing happens on a comparison of the digital value on the object of vegetation dominated by Derris with digital values on vegetation dominated by major mangrove (see right Figure 3-2.). Derris spectral character in band 5 and 6 differs from the spectral character of major mangrove, but is similar to spectral character of non-mangrove vegetation. It can be said that there has been a change in the spectral character of major mangrove vegetation towards non-mangrove spectral. The difference is used as an indicator in the proposed draft of the new mangrove index.

The changing of major mangrove character towards non-mangrove is used as a parameter in calculating the index mangrove. The difference in the digital value of band 5 and 6 becomes the differentiating factor, division with band 5 and 6 multiplication is used to reinforce the index difference and reduce errors due to differences in the digital value that also occurs on non-mangrove vegetation. But because the digital value on mangrove vegetation is always low on band 6 and slightly low on band 5, this multiplication makes the index value higher because it is divided by lower number. With new mangrove index equation calculation, high indexvalue on object which is dominated by major mangrove vegetation and low index valueon non-mangrove vegetation objects and Derris domainated vegetation are obtained as shown in Figure 3-3.

Figure 3-4. presents the image of the mangrove index calculation, it can be seen that the west region with the dominance of minor mangrove has a lower value, while in the east one has a higher index value. These results are consistent with the results of the field survey that is conducted twice. In the west region, there are rather high index values due to the existence of major mangroves, although the density is not high. The results of field measurement at one station in the western region shows the density result of 0.3 trees/m2, in contrast with the density in the eastern that ranges between 1-2.5 tree/m2.

In Figure 3-5, mangrove index is classified into four classes; high, medium, low and very low. These classes are based on the conditions on the field with the index range value for high class is mangrove index is classified into four classes; high, medium, low and very low. Classes are based on the conditions on the field with the index range value for high class is ≥0,75,medium is 0.6 to 0.74,low is 0.5 to 0.59, and very low is index value that is less than 0.49.

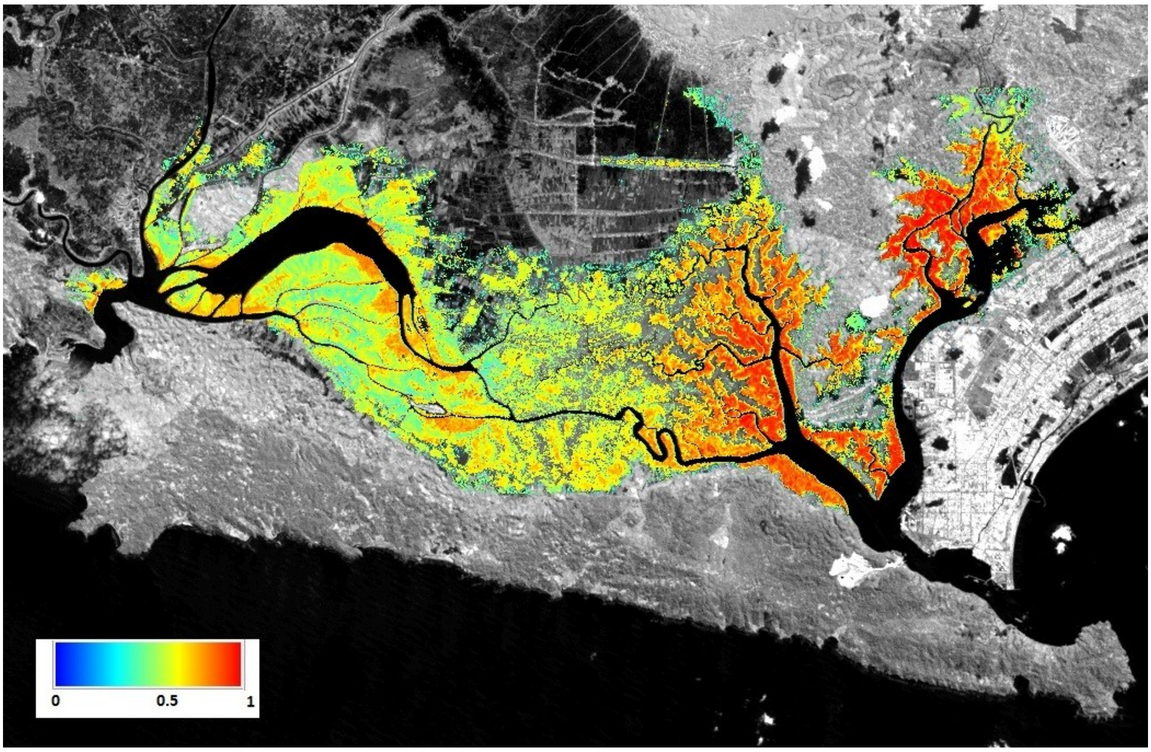


Figure 3-4: Mangrove Index Image of Mangrove area in Segara Anakan

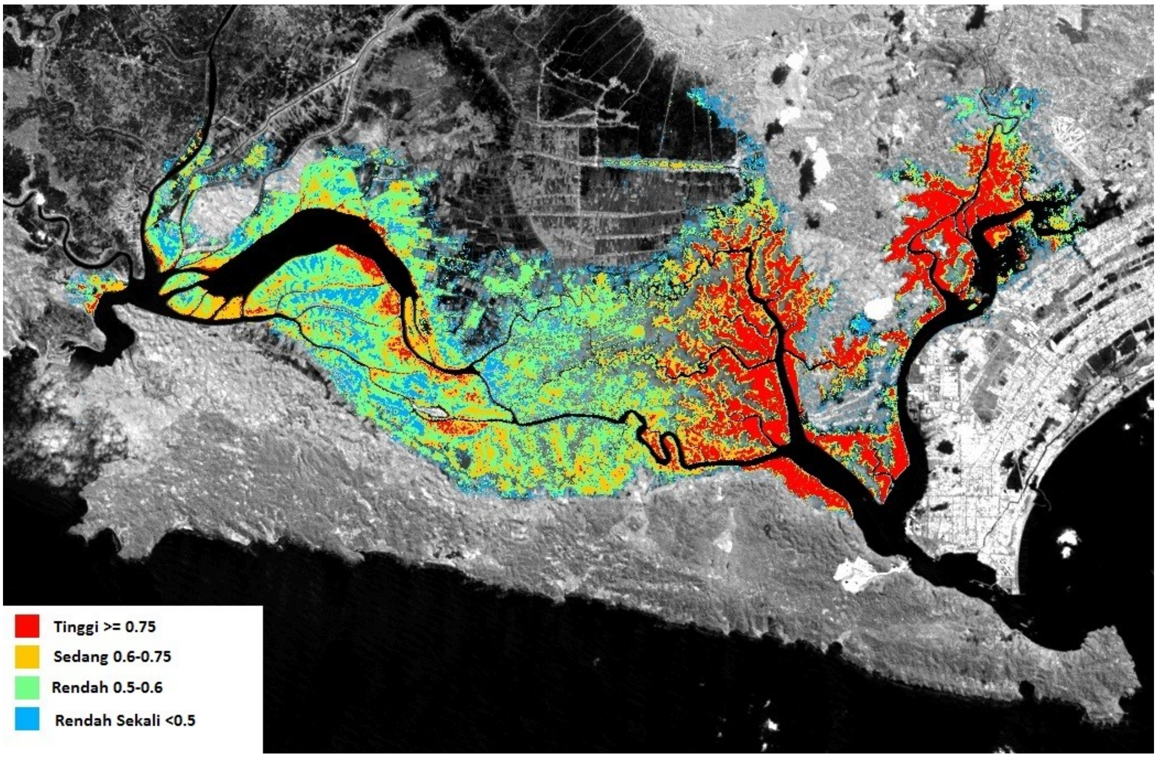


Figure 3=5: Image of Mangrove Index Classification Results in Four Different Classes

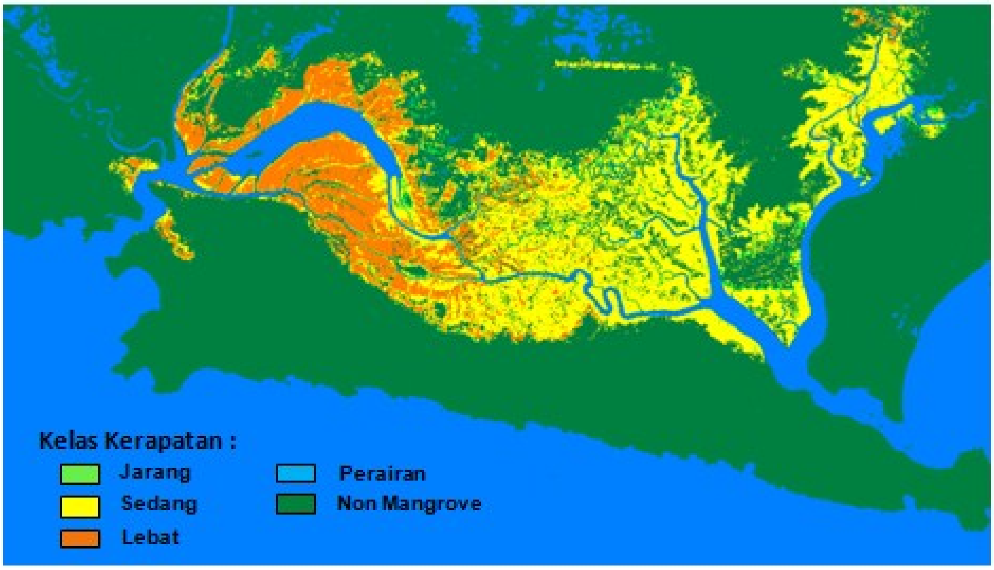
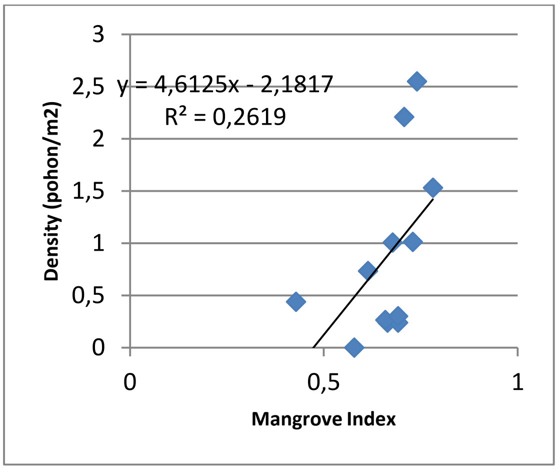


Figure 3-6: Density Image based on NDVI of Segara Anakan (Source: Purwanto, et al. 2014)

The classification is more likely to be determined by differences in the distribution of four classes that is more obvious and on relatively same portion. Almost all of the classes can be seen from the class in the image. Therefore, it appears that they are proportional withequal distribution. But it also occurs in the class division by class density based on NDVI i.e. dense canopy density of 0,43 ≤ NDVI ≤ 1,00 medium canopy density of0,33 ≤ NDVI ≤ 0,42 sparse canopy density -1.00 ≤ NDVI ≤ 0, 32 (Department of Forestry, 2006 in Hidayat *et al.*, 2011).

Distribution of mangroves index value in Figures 3-4 and 3-5 is in stark contrast with the density classification results based on NDVI (Purwanto, *et al.*, 2014) which is presented in Figure 3-6, where the western region is classified into mangrove areas with very dense vegetation density, while the eastern region is classified into medium and sparse vegetation categories. This is certainly not in accordance with the conditions in the field where the density of the eastern region ranges between 1-2.5 tree/m2 and the western region less than 1 tree/m2. This is because the coverageof minor mangrove of Derris and Acanthus in the western region is dense, and has a high NDVI value. Although NDVI has a high correlation with the tree density as stated by Faizal and Amran (2005). This indicates that NDVI is good for estimating the density in areas with good mangrove condition, where the entire region is in the form of major mangrove, so that NDVI values originated from major mangrove canopy. If the region begins to deteriorate and is dominated by minor mangrove, then this will change as the NDVI value of minor mangrove becomes higher, as the high value of NDVI on grass than NDVI value on forest. Therefore, the use of new mangrove index will be able to mitigate these effects and can be an indicator of damage to mangrove ecosystems.

This new mangrove index indicates two things: the existence of a major mangrove vegetation and wetness of the substrate where mangroves live, so it could be expected to be associated with major mangrove density and is associated with the degree of damage or quality of mangrove ecosystems. Mangrove ecosystem will be in good condition when the tidal condition is ideal for their growth. To determine the correlation, connection of this mangrove index with tree density and with damage level map is searched.



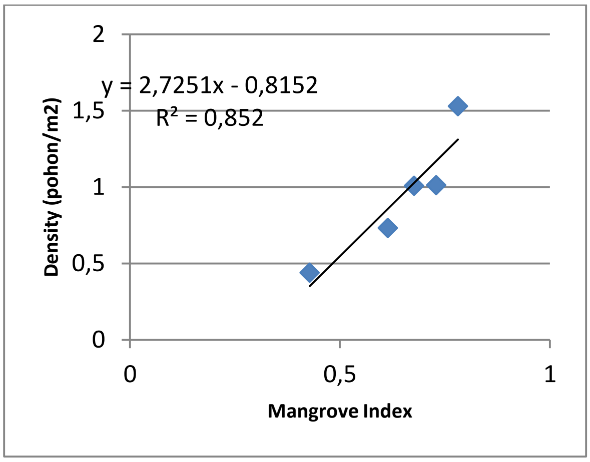


Figure 3-7: Correlation graphic between Mangrove Index and Tree density

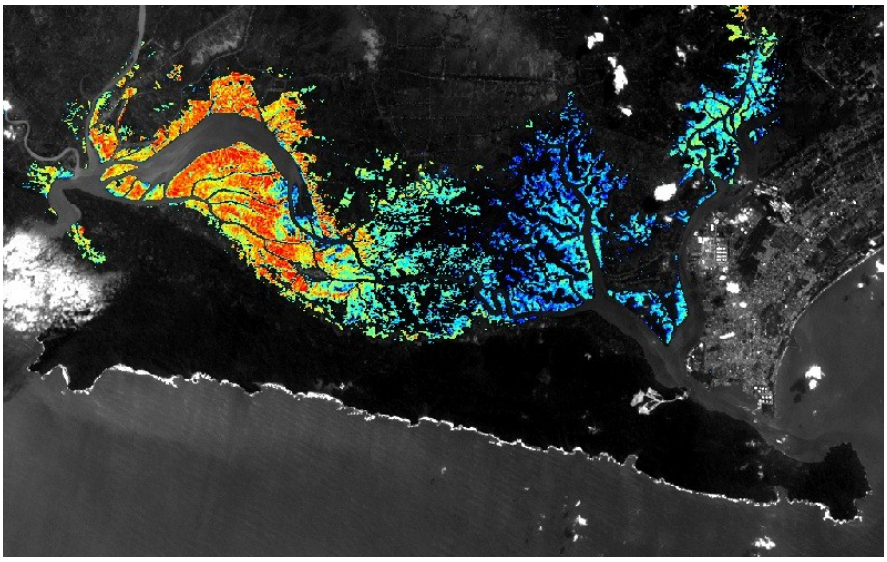


Figure 3-8: The Wetness Index Imagein SegaraAnakan Mangrove Area

Corelation between mangrove index with tree density is presented in Figure 3-7. In the left image, the amount of data is 12, resulting in a rather bad correlation with R^2= 0,26. Then the data reduced on the data that has the potential of reducing the first correlation level is value with high density, because there is the possibility of a decrease in the index because the canopy cover is equal to the high increase in the number of trees because the space for the leaf remains the same. Then the other data is inconsistent. Finally a correlation with R^2= 0.85 is obtained, this is a good correlation. With the results of this correlation, it cannotbe said that the relationship between the density of trees with the mangrove index is very close, because from 12 data, only 5 data have a good correlation. The elimination of 7 data is not meant to cover up the fact that the correlation is still not good, but as part of the analysis of "what" and "why".

Initial analysis shows that 5 data that have good correlation arelocated in the eastern part where the mangrove forests is still in pretty good conditions and just lined with minor mangroves. It can be indicated that the index value is correlated with tree density only in good mangrove areas. In areas with damaged mangroves, the correlation is not good. Further investigation and research is still needed to find the causes of the low correlation value and or improve mangrove index equation. At least this mangrove index could be a canopy density value replacement from NDVI, which at Segara Anakanis not in accordance with the conditions in field.

To calculate the wetness level of a land Wetness Index or wetness level where the more dense the vegetation of an area, the higher the land wetness level in said area is used (Crist, 1984 in Haikal, 2014). Figure 3-8. Displaysthe image of calculation result of wetness level in Segara Anakan, Cilacap.

In Figure 3-8 it is clear that areas which have high level of wetness dominated the western area where from NDVI calculations results in Figure 3-6 these areas also have a high canopy density. While in the eastern area of the location study it can be seen that the wetness level is relatively lower than in the western area and the canopy density is low. This is very supportive of the study conducted by Haikal (2014). But the image of the vegetation and land wetness index calculation cannot be used to describe the condition of mangrove destruction in Segara Anakan, Cilacap because the area has a high vegetation and wetness index dominated by secondary mangrove vegetation that used as an indication of mangrove destruction in the area.

Comparison of the mangrove destruction distribution (Ardli, 2010) with the classification of mangrove index is presented in Figure 3-9. The level of mangrove destruction is obtained from field measurements in the form of a data structure and mangrove vegetation composition, species (diversity), environmental factors such as air temperature, water temperature, soil temperature, light intensity, soil pH, soil salinity, total N and P, content of sand, clay, dust, water and organic matter, then spatial analysis using Surfer 8.0 and ArcView 3.2 softwares are carried (Ardli, 2010). Visual observation results looks quite seems to be in accordancewith the mangrove damage level, the western region is classified into damaged area with low and very low index mangrove. While the middle of the area is categorized as damaged, and in some places thereare areas with medium and high mangroves index value. The eastern part is categorized as damaged with low and very low mangrove index and in the area that is categorized as non mangrove by mangrove non-mangrove classification fromremote sensing data. The east is categorized as medium damaged mangrove and dominated with high mangrove index. There is little difference in the eastern part of north area, which is categorized into damaged mangrove, but in the mangrove index,the medium and low mangrove area was not as vast as damaged mangrove area.

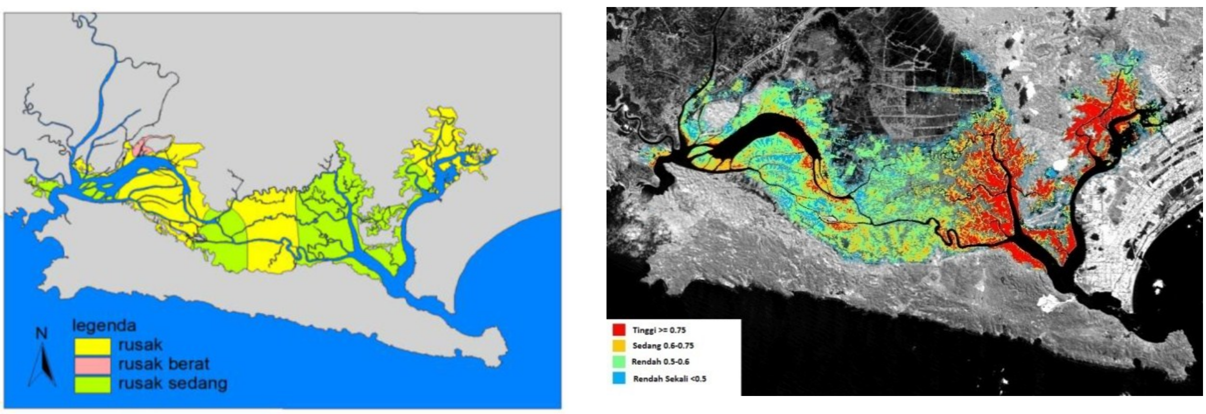


Figure 3-9: Damage Level Distribution Comparison (source: Ardli 2010) with Mangrove Index Classification

4 CONCLUSION AND SUGGESTION

From the analysis and discussion it can be concluded that index mangrove is a prospective new index to be developed and used in the future as replacement for the NDVI vegetation index values based level of density on degraded mangrove forest. In addition, mangrove index can also describe mangrove destruction more optimally than the vegetation index and wetness index. Mangrove index shows higher values ongood conditioned mangrove forest dominated with major mangrove compared to non-mangrove forest vegetation and mangrove vegetation dominated by secondary mangrove (Derris and Acanthus). The spatial distribution of vegetation index values is in accordance with the conditions of damage in the field and inversely proportional to the density distribution of NDVI.

Mangrove index values should be developed using more field data and done in other areas so that deficiencies can be addressed and can be used in general throughout Indonesia. Then further analysis is needed of the low correlation between mangrove index value with tree density in areas dominated by minor mangrove.

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