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COMPARISON OF SEVERAL RED EDGE BAND SENTINEL SATELLITE IMAGERY FOR MANGROVE MAPPING IN LEMBAR BAY LOMBOK INDONESIA

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ABSTRACT

The use of the vegetation index algorithm in determining density is a challenge for researchers to find out the ability of an algorithm to accurately present vegetation information. Each vegetation index produces different accuracy values for the value of the density of mangroves depending on the combination of bands used. This study aimed to evaluate those red edge band sentinel satellite imagery 2B for mangrove mapping using the algorithm of modified SR and NDVI. The research method used is the direct or indirect survey method. The algorithm analysis of the vegetation index used in this study is $NDVI_{red\ edge}$, $NDVI_{red\ and\ red\ edge}$, $MSR_{red\ edge}$, $MSR_{red\ and\ red\ edge}$. Correlation analysis, determinant, and Root Mean Square Error (RMSE) were used to test the accuracy of the analysis results for each of the vegetation index algorithms. Based on the comparison results, the $NDVI_{red\ and\ red\ edge}$ algorithm are the most reliable because they have the lowest RMSE value (0.05) with a high correlation and determinant coefficient values between the vegetation index values with their respective field density values 82 % and 0.90. Thus, the extraction results of the $NDVI_{red\ and\ red\ edge}$ algorithm are the closest to the actual conditions in the field.

Keywords: *Mangrove; NDVI; SR; Vegetation Index*

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A. INTRODUCTION

Research on estimation of mangrove density through remote sensing technology has been carried out such as ALOS (Thapa et al., 2015), Quickbird (Hirata et al., 2014), IKONOS (Proisy et al., 2007), ICESat (Lefsky et al., 2005), Landsat TM and ETM + imagery (Sugianthi, 2007). The research resulted in the estimation of mangrove density with different determination coefficients depending on the spatial resolution of the satellite imagery used. The use of different satellite image resolutions will produce different model accuracy. Estimation of mangrove density through the use of remote sensing data in the coastal area of the Lembar bay has never been done and only through a field study approach with limited samples and location accessibility causes the resulting data has not produced comprehensive information. The use of high-resolution remote sensing data can provide more accurate and extensive spatial information with the right method approach in accordance with the characteristics of the data and the objectives to be achieved. Satellite images with high spatial resolution have the opportunity to map mangrove densities in more detail (Ni-Meister et al., 2010; Heumann, 2011; Winarso and Purwanto, 2014). One of the satellites with high spatial resolution is Sentinel-2 which can carry out terrestrial monitoring and observation in support of services such as forest monitoring, detection of changes in land cover and natural disaster management that have a higher resolution than Landsat 8 so that it can provide better results in mapping spatial mangrove (ESA, 2015).

The number of algorithms in determining mangrove density is a challenge for researchers to determine the extent to which a vegetation index can present vegetation information appropriately. According to Jensen (2012) that there are various analyzes of vegetation index including the NDVI index. NDVI (Normalized Difference Vegetation Index) is one of the most widely used vegetation indexes (Green et al., 2000; Danoedoro, 2012; Wicaksono et al., 2016). The algorithm is made simple enough to have significant weaknesses, namely external factors that are not considered, such as noise due to atmospheric interference and background factors in the form of soil and wavelength sensitivity used in satellite sensors in detecting vegetation. Therefore, a new vegetation index algorithm was developed which is a development or modification of SR (Simple Ratio) called $MSR_{red\ and\ red\ edge}$ (Modified Simple Ratio Red and Red Edge) and modification of NDVI (Normalized Difference Vegetation Index) called $NDVI_{red\ and\ red\ edge}$ which utilizes red, red edges and near-infrared band (Xie Q et al., 2018). Both of these algorithms are modified results that utilize edge red bands that are not possessed by the transformation of other vegetation indices, besides that the wavelength of the red edge bands has a better sensitivity level than other bands in assessing vegetation status both biomass and density (Zhu et al., 2017).

Sentinel 2 satellite imagery has a satellite sensor that has a high sensitivity in detecting vegetation that is not owned by other satellite sensors, namely the red edge band which consists of band 5, 6, 7 and 8a. Red edge bands are known to be more sensitive and have a consistent influence on biophysical parameters such as vegetation density compared to other bands (Zhu et al., 2017). The vegetation index algorithm $NDVI_{red\ \&\ red\ edge}$ and $MSR_{red\ and\ red\ edge}$ (Modified Simple Ratio Red and Red Edge) is the result of a more detailed vegetation index modification that can increase the coefficient of determination (R^2) in estimating the leaf area index (LAI) by 10% compared to only utilizing the red edge band on the vegetation index (Xie Q et al., 2018). Vegetation indexes with red and red edge bands can be a powerful alternative to estimating the leaf area index of plants with a wide range of chlorophyll and can provide valuable information for satellites equipped with red edge bands. The use of $NDVI_{red\ and\ red\ edge}$ vegetation index algorithms and $MSR_{red\ and\ red\ edge}$ are new in detecting the spatial distribution of mangrove density. Therefore, both of these transformations will be used in the hope of producing spatial estimates of mangrove density with the best accuracy. The research objectives was to evaluate those red edge band sentinel satellite imagery 2B using the algorithm of modified SR and NDVI.

B. METHOD

1. Site Map of Research

The location of this research was conducted in the area of mangrove ecosystems in Lembar Bay area (Figure 1). The mangrove ecosystem in Lembar Bay is one of coastal ecosystems located in the coastal area of West

Lombok which is administratively located in Lembar sub-district, West Lombok District, West Nusa Tenggara Province, Indonesia

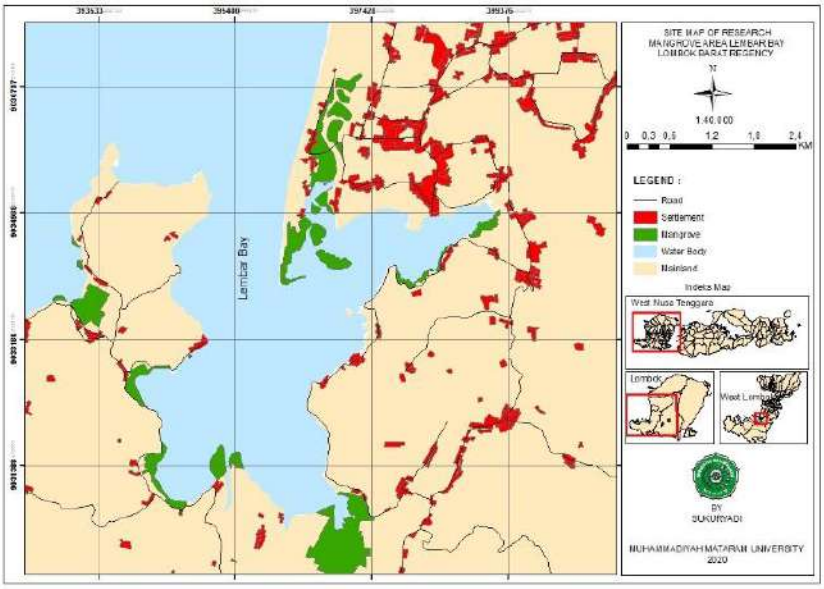


Figure 1. Site map of research

2. Standardization of data

The satellite data used in this study is the sentinel-2B multispectral satellite imagery. Sentinel-2B imagery are obtained for free which can be downloaded directly on the website of ESA Copernicus level 1C (https://scihub.copernicus.eu/dhus/#home). Downloaded Sentinel-2B imagery is level 1C data, which means that the image data has been corrected geometrically and radiometrically. The Sentinel-2B imagery has 13 sensors with different spatial resolutions. The sensors or bands used in this study are the combination of red band (B4; 665 nm), near-infrared (B8; 842 nm) and red edge band consisting of B5 (705 nm), B6 (740 nm), B7 (783) nm) and B8a (865 nm) in the Sentinel 2B satellite imagery.

3. Research procedure

The stages carried out in this study are 1) Image pre-processing; 2) Image processing; 3) Field survey. The three stages are carried out in order to obtain an estimate of mangrove density from Citra Sentinel-2B based on the value of mangrove density in the field.

The details of these stages are as follows: 1) image pre-processing, and 2) image processing. Image pre-processing is the first step in processing satellite images include cropping image and image resampling (Shofiyati, 2010). Image Processing, the corrected Sentinel-2 image is then extracted to obtain the vegetation index value through Spectral transformation. The most common and widely used spectral transformation for mapping and modelling mangroves is the vegetation index. Vegetation index that will be used in this study is a modified vegetation index algorithm as in table 1.

Table 1. Index Vegetation Algorithm Investigated in This Study

Description	Formula	References
Red Edge MSR Index	$MSR_{Red-edge} = \frac{\frac{NIR}{RE} - 1}{\sqrt{\frac{NIR}{RE} + 1}}$	Wu C et al (2008)
Red Edge NDVI	$NDVI_{Red-edge} = \frac{NIR - RE}{NIR + RE}$	Gitelson A (1994)
Red and Red Edge MSR Index	$MSR_{red\&RE} = \frac{NIR/(\alpha * red + (1-\alpha) * RE) - 1}{\sqrt{NIR/(\alpha * red + (1-\alpha) * RE) + 1}}$	Xie Q et al (2018)
Red and Red Edge NDVI	$NDVI_{red\&RE} = \frac{NIR - (\alpha * red + (1-\alpha) * RE)}{NIR + (\alpha * red + (1-\alpha) * RE)}$	Xie Q et al (2018)

NIR refers to near-infrared and RE refers to red-edge consists of band 5, 6, 7 and 8a; α € [0, 1]

4. Retrieval of Field Data

The transect plot method is a sampling method for sample populations of an ecosystem. This method uses a sample plot approach that is on a line drawn across the ecosystem. Quadrant line transects were drawn in which sampling plots were established to record and identify the plant species contained within the plot with size following the method proposed by several literature (KEMENLH 2004; Sofian et al. 2012) and described as follows: (i) Tree, i.e. plants with stem diameter ≥10 cm and height ≥ 1.5 m, in the sample plot of 10 x10 m^2. (ii) Stake, i.e. plants with stem diameter <10 cm and plant height ≥ 1.5 m, in the sample plot of 5 x 5 m^2. (iii) Seedling, i.e. plants with a height of <1.5 m, in the sample plot of 2 x 2 m^2.

5. Data Analysis

a. Mangrove Density Analysis

The equation used to determine the mangrove density value is as follows (Bengen, 2002):

$$Di = \frac{ni}{A} \quad (1)$$

by Di is the density of mangrove species (ind/m^2), ni is the total number of stands of mangrove species, and A is the total area of plots per transects.

b. Linear Regression

The analysis regression coefficient is a coefficient that measures the effect of the independent variable (x) on the dependent variable (y) in the regression analysis model. Regression is a measuring tool that is also used to measure the presence or absence of correlation between variables. The term regression itself means forecast or estimate. The equation used to get the regression line in the scatter diagram data is called the regression equation. Regression analysis in this study was used to determine the effect of vegetation index on the value of mangrove density in the field. The form of the regression equation based on (Dewi et al (2017) can be seen as follows.

$$Y = a + bx \quad (2)$$

$$b = \frac{n(\sum xy) - (\sum x)(\sum y)}{n(\sum x^2) - (\sum x)^2} \quad (3)$$

$$a = \frac{\sum y - b(\sum x)}{n} \quad (4)$$

by y is the dependent variable, x is the independent variable, a is Constanta, b is regression coefficient, and n is the Amount of data

c. Determination Coefficient Test (R^2)

The coefficient of determination in this study was used to determine the best vegetation index for estimation of mangrove density in the Lembar bay area. The coefficient of determination (R^2) essentially measures how far the model's ability to explain the variation of the dependent variable. The coefficient of determination is between 0 – 1, a small R^2 value means that the ability of the independent variables to explain the variation of the dependent variable is very limited. A value close to one means that the independent variables provide almost all the information needed to predict the variation of the dependent variable. According to (Sugiono (2010), the determination of the coefficient can be determined through equation as follows. After the correlation value is determined, then proceed with calculating the coefficient of determination. This coefficient of determination serves to determine the magnitude of the influence of independent variables on the dependent variable. In use, the coefficient of determination is expressed as a percentage (%) with the following formula.

$$KD = r^2 x\ 100\% \qquad (5)$$

by KD is the determination Coefficient, and r is the correlation coefficient

d. Model Accuracy Test

Validation test is a testing process to find out the deviation of the estimated value of mangrove density results from regression models built with data in the field. Model validation uses data from 50 sample plots. The validation test of the built model uses RMSE (Root Mean Square Error). Root Mean Square Error (RMSE) is a method approach used to assess a prediction technique used to measure the accuracy of a model's prediction results. RMSE is the average value of the number of error squares which states the size of the error generated by a prediction model. A low RMSE value indicates that the variation in values produced by a prediction approaches the variation in its observational value. According to Makridakis et.al (1982) one measure of the error in forecasting is the mean square root value or Root Mean Square Error (RMSE). Thus the use of the Root Mean Square Error (RMSE) formula is to find out the value of the error that occurs in the calculation results of the model with its observation value. If the RMSE value is smaller, the smaller the error value that occurs in the use of the model. RMSE calculation can be seen as follows.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(P_i - O_i)^2}{n}} \qquad (6)$$

by Pi is predictive value, Oi is observation value, and n is the number of validation observations

C. RESULTS AND DISCUSSION

Theoretically, the value of NDVI ranges from -1 to +1. Values between -1 to 0 indicate non-vegetation objects (Sudiana, 2008). While values from 0 to 1 indicate the object of vegetation. Getting closer to 1 indicates that the vegetation is denser. However, the mangrove index value, in general, is in the range between +0,1 to +0,7. NDVI values greater than this range are associated as a representation of a better level of vegetation health (Dewanti, 1999; Prahasta, 2008). NDVI is the most commonly used vegetation index algorithm. The principle of this formula is that radiation from visible red is absorbed by the green chlorophyll of the leaf so that it will be reflected low, while radiation from near-infrared light will be strongly reflected by the structure of the spongy mesophyll leaf. This index has a range of values from -1,0 to 1,0 (Arhatin, 2007). Clouds, water and non-vegetation objects have NDVI values less than 0. If the index value is higher it means that the vegetation cover is healthier (Lillesand and Kiefer, 1990). Based on the analysis of vegetation index transformation applied to sentinel 2B satellite imagery shows that the range of vegetation index can be seen in tables 2, 3, 4 and 5.

Table 2. Results of NDVI Vegetation index Algorithm for each Red Edge Band

Band Combination	Min Values	Max Values	Std	R Values	Determination Coefisiens (%)	RMSE
Red Edge(5) and NIR	-0.504	0.695	0.086	0,85	72	0,06
Red Edge(6) and NIR	-0,65	0,667	0,039	0,27	7	0,15
Red Edge(7) and NIR	-0,725	0,631	0,043	0,17	3	0,17
Red Edge(8A) and NIR	-0,741	0,619	0,043	0,08	1	0,18

Table 3. Results of NDVI Modified Vegetation Index Algorithm for each Red Edge Band

Band Combination	Min Values	Max Values	Std	R Values	Determination Coefisiens (%)	RMSE
Red, Red Edge (5) and NIR	-0,351	0,729	0,0992	0,90	82	0,051
Red, Red Edge (6) and NIR	-0,526	0,667	0,0636	0,6	33	0,104
Red, Red Edge (7) and NIR	-0,598	0,644	0,053	0,45	20	0,123
Red, Red Edge (8A) and NIR	-0,615	0,638	0,048	0,36	13	0,134

Tabel 4. Results of SR Vegetation index Algorithm for each Red Edge Band

Band Combination	Min Values	Max Values	Std	R Values	Determination Coefisiens (%)	RMSE
Red Edge(5) and NIR	-0,537	5,178	0,407	0,83	68	0,42
Red Edge(6) and NIR	-0,698	4,599	0,140	0,21	4	0,5
Red Edge(7) and NIR	-0,769	3,997	0,090	0,09	1	0,5
Red Edge(8A) and NIR	-0,784	3,823	0,096	0	0	0,5

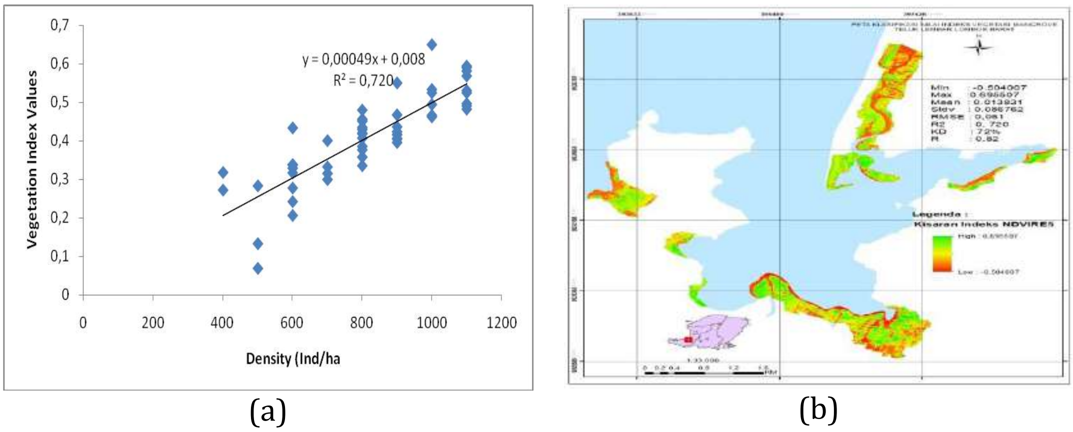
Tabel 5. Results of SR modified Vegetation index Algorithm for each Red Edge Band

Band Combination	Min Values	Max Values	Std	R Values	Determination Coefisiens (%)	RMSE
Red, Red Edge(5) and NIR	-0,342	6,027	0,514	0,87	76	0,5
Red, Red Edge(6) and NIR	-0,563	4,604	0,254	0,53	29	0,5
Red, Red Edge(7) and NIR	-0,643	4,205	0,188	0,41	17	0,48
Red, Red Edge(8A) and NIR	-0,661	4,109	0,174	0,32	10	0,49

The use of a red-edge band in the SR and NDVI vegetation index modification algorithm has been shown to be able to map mangrove biomass better than other vegetation indexes such as NDVI and DVI. This is due to the red edge band known to be more sensitive to biophysical parameters such as vegetation density compared to other bands (Zhu et al., 2017). Algorithm of vegetation index modified is supported by sentinel satellite imagery that has a red edge band. Red edge bands on satellite sensors are not widely owned by various remote sensing satellites. Both vegetation index algorithms utilize a combination of red band (B4; 665 nm), near-infrared (B8; 842 nm) and edge red band (Red Edge) consisting of B5 (705 nm), B6 (740 nm), B7 (783) nm) and B8a (865 nm) in the Sentinel 2B satellite imagery.

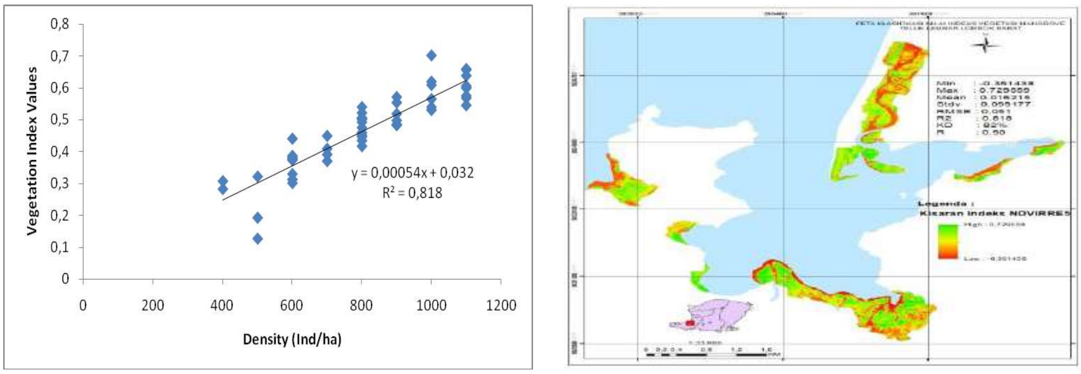
MSRred edge (Modified Simple Ratio Red Edge) algorithm (Wu C et al., 2008), $NDVI_{red\ edge}$ (modified NDVI red edge) (Gitelson A, 1994), $MSR_{red\ \&\ red\ edge}$ (Modified Simple Ratio Red and Red Edge) and $NDVI_{red\ \&\ RE}$ (modified red and red edge NDVI (Xie Q et al., 2018) is a modified SR and NDVI vegetation index algorithm based on a combination of bands. The use of red edge bands on the vegetation index algorithm has the advantage in the combination of red and red edge bands is because the red-edge bands are more sensitive to the biophysical parameters of vegetation than other bands (Zhu et al., 2015; Xie Q et al., 2018).

The use of a red-edge band of Sentinel 2B satellite imagery on each vegetation index algorithm shows that the red edge band (band 5; 705 nm) has the highest accuracy on each algorithm of vegetation index modification. Correlation value and determinant coefficient between the vegetation index value and the density of mangroves in the field on algorithm of modified simple ratio red edge ($MSR_{red\ edge}$) are 0.83 and 68% respectively, algorithm of modified simple ratio red and red edge ($MSR_{red\ and\ red\ edge}$) respectively 0.87 and 76%, algorithm of modified normalized differences vegetation red edge index ($NDVI_{red\ edge}$) are 0.82 and 72% respectively and algorithm of modified normalized differences vegetation index red and red edge ($NDVI_{red\ and\ red\ edge}$) respectively 0.90 and 82% as shown in figures 2, 3, 4, and 5. The combination of the use of red, red edge and infrared bands in one vegetation index algorithm shows a higher coefficient of determination compared to using only a combination of edge red and infrared bands both the modified NDVI and SR algorithm. According to Xie Q et al., (2018) that $MSR_{red\ \&\ red\ edge}$ index algorithm (modified simple ratio red and red edge) and $NDVI_{red\ \&\ red\ edge}$ (normalized differences vegetation index red and red edge) is a more detailed modification algorithm and can increase the coefficient of determination (R^2) in estimates the leaf area index (LAI) of 10% compared to only utilizing the red edge and infrared bands on the vegetation index algorithm. The determinant coefficient values in the algorithm of modified simple ratio and normalized differences vegetation index only combine red edge and infrared bands of 68% and 72% respectively, while the use of red, red edge and infrared band combinations have determinant coefficient values of 76% and 82%. This shows that there is an increase in the value of the determinant coefficient on each modified SR and NDVI algorithms by 12% and 14% for the use of a combination of red, red edge and infrared bands.



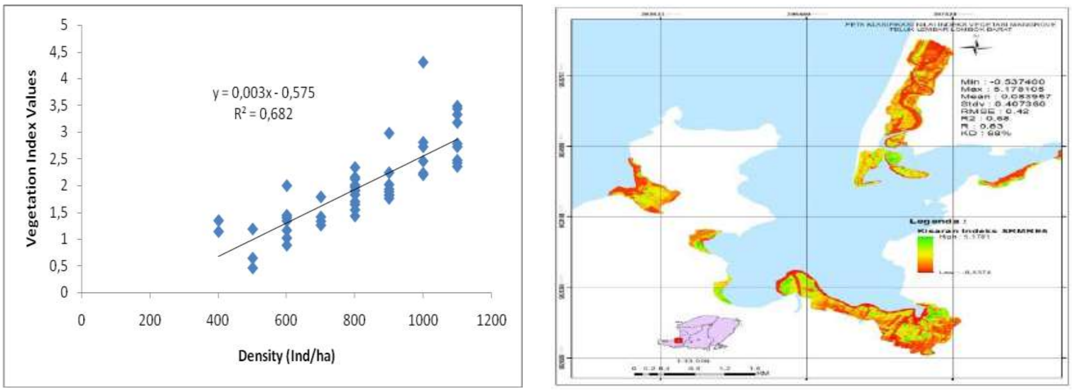
(a) (b)

Figure 2. Relationship between $NDVI_{red\ edge\ (B5)}$ vegetation index values with mangrove density (a) and map of mangrove vegetation index distribution (b)



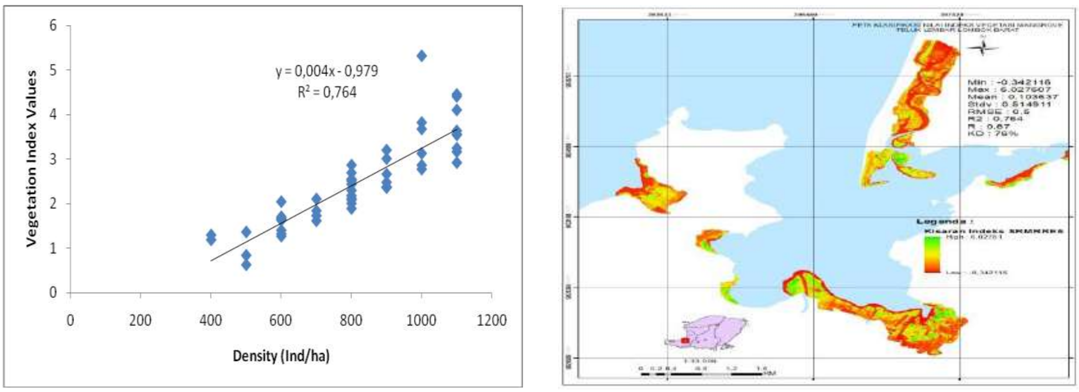
(a) (b)

Figure 3. Relationship between $NDVI_{red\ edge\ and\ red\ edge\ (B5)}$ vegetation index values with mangrove density (a) and map of mangrove vegetation index distribution (b)



(a) (b)

Figure 4. Relationship between $SRM_{red\ edge\ (5)}$ vegetation index values with mangrove density (a) and map of mangrove vegetation index distribution (b)



(a) (b)

Figure 5. Relationship between $SRM_{red\ and\ red\ edge\ (5)}$ vegetation index values with mangrove density (a) and map of mangrove vegetation index distribution (b)

Based on the results of the comparison shows that the algorithm of $NDVI_{red\ and\ red\ edge}$ vegetation index modification has the highest accuracy because it has the lowest RMSE value (0.05) with a correlation value and a high coefficient of determination between the vegetation index value in the image with the respective field density values 0.90 and 82%. Therefore, the extraction of vegetation index results from the modified $NDVI_{red\ and\ edge}$ algorithm that will be used to map the status of mangrove ecosystem areas in the Lembar area West Lombok.

D. CONCLUSION AND SUGGESTION

Based on the results of the comparative analysis shows that the red edge band (B5) has the highest accuracy compared to other red edge bands on each vegetation index algorithm. The results of comparison between the modified vegetation index algorithm used show that the highest accuracy of $NDVI_{red\ and\ red\ edge}$ vegetation index algorithm, because it has the lowest RMSE value (0.05) with a correlation value and a high coefficient of determination between the vegetation index value in the image with field density values, are 82% and 0.90, respectively. Thus, it is necessary to use various vegetation index algorithms on satellite imagery which has a red edge bands with a higher spatial resolution so as to produce a higher accuracy of mangrove ecosystem density

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