DETERMINATION OF FOREST AND NON-FOREST IN SERAM ISLAND MALUKU PROVINCE USING MULTI-YEAR LANDSAT DATA

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Abstract. Seram Island is one of the islands in Maluku Province. Forest in Seram Island still exists because there is Manusela National Park, but they should be monitored. The forest and non-forest information is usually obtained through the classification process from single remote sensing data, but in certain places in Indonesia it is difficult enough to get single Landsat data with cloud free, so annual mosaic was used. The aim of this research was to analyze the stratification zone, their indices and thresholds to get spatial information of annual forest area in Seram Island using multi-year Landsat Data. The method consists of four stages: 1) analyzing the base probability result for determination of stratification zone 2) determining the annual forest probability by applying indices from stage-I, 3) determining the spatial information of forest and non-forest annual phase-I by searching the lowest boundary of forest probability, and 4) determining the spatial information of forest and non-forest annual phase-II using the method of permutation of three data and multi-year forest rules. The results of this study indicated that Seram Island could be coumpond into one stratification zone with three indices. The index equations were B2+B3-2B for index-1, B3+B4 for index-2, and -B3+B4 for index-3. The threshold of index 1, 2, and 3 ranged between -60 and 0, 61 and 104, and 45 and 105, respectively. The lowest boundary of forest probability in Seram Island since 2006 to 2012 have a range between 46% and 60%. The last result was the annual forest spatial information phase II where the missing data on the forest spatial information phase I decreased. The information is very important to analyze forest area change, especially in Seram Island.

Keywords: *Landsat data, missing data, index equation, forest probability*

1 INTRODUCTION

The definiton of forest in juridical concept is formulated in Article 1 of point (1) of the Act of Republic of Indonesia Number 41 of 1999 on forestry. According to this law, forest is a unified ecosystem in the form of land contains bioresources dominated by trees in a natural environment which one and other cannot be sparated. Besides, forest definition can also be related to area, tree height, and canopy percentage.

Forest definition according to the Ministry of Forestry of Indonesia provides limitation for minimum canopy, tree height, and area as follows 30%, 5 meters, and 0.25 hectare, respectively (FAO, 1998). That definition is in accordance with what the United Nation Convention on Climate Change (UNFCCC) defines because countries participating in the UNFCCC can choose how they want to define a forest from within those ranges. UNFCCC defines a forest as an area of land 0.05–1 hectare in size, of which more than 10–30% is covered by tree canopy. Trees must also have the potential to reach a minimum height of 2-5 metres (Gilbert, 2009).

There are two ways to get spatial information about forest and non-forest, that are visual and digital ways. The

visual way uses method of digitation on the screen. This method need more the time and depend on capability of intepreter in delineating boundary line between forest and non-forest. The digital way most often done is supervised classification that depend on training sample. Danoedoro (2012) explained that digital image classification is the process of a grouping of pixels into certain classes. This is consistent with the assumption used in the multispectral classification that any object can be distinguished from the other based on their spectral value.

The supervised classification includes a set of algorithm based on entering sample of objects by interpreter. The consideration in classification is classifcation system and sample criteria.

Forests can be visually identified through interpretation key. Kartika et al. (2013) said that characteristics of forest on the remote sensing data can be known by keys interpretation such as color, hue, form, texture, location, and pattern.

In Indonesia and the Malaysian archipelago were obscured by clouds, the forest losses of the region appear to have been relatively large, including the expansion of oil palm plantations over the 1990–2000 period before a sharp drop in losses in the early 2000s (Hansen *et al.*, 2009 in Kim *et al.*, 2014). Indonesia as a tropical country which is often covered by clouds. This cloud cover condition becomes the problem when remote sensing data is used to get spatial information of land cover. To solve this problem, there is a method from *Indonesia's National Carbon Accounting System* (INCAS) program which can be used as reference. INCAS is a national program that had purposed to provide a land calculation system that reliable, comprehensive, and credible (Wardoyo, 2009; LAPAN, 2014). In INCAS program, annual land cover information for example forest and non-forest spatial information become one of their input (IAFCP, 2012). Therefore, this method can be applied to obtain forest and non-forest spatial information in Indonesia, but with adjustments.

According to Furby and Wallace (2011) and Symeonakis *et al.* (2012), multi-year classification has many advantages, such as it can increase the consistency and accuracy of the classification result of forest and non-forest, and able to estimate land cover of forest and non-forest for filling the missing pixels due to cloud cover. Theoriticaly, forest is not grow instantly, but it need long time to form the forest.

This study is a continuation of previous research by Kartika *et al.* (2014). This study applied the index equation which derived from Landsat data 2008 to Landsat data years 2006 until 2012.

According Kartika *et al.* (2014), Seram Island could be divided into two stratification zones, and each zone had the same indices but the diferent thresholds. It was interesting to reanalyse whether those thresholds could be changed so Seram Island could be grouped into one stratification zone. This is one of aims this study.

The objectives of this study are to determine the stratification zone and the best threshold so that the Seram Island can be grouped into one stratification zone, and to get spatial information of annual forest and non-forest since 2009 to 2012 by minimizing the missing pixel caused by cloud cover.

2 MATERIALS AND METHODOLOGY

2.1 Location and Data

Seram Island is one of the islands in Maluku Province. In this island there is found Manusela National Park that is ecologycally divided into seven types of vegetation, started from the coast to the top of mountain. The forest types consist of mangrove, swamp, and rain forests (Wikipedia, 2008). Location of Seram Island is shown in Figure 2-1.

Figure 2-1: the location Seram Island in Maluku Province

Remote sensing data that be used in this research were annual mosaic of Landsat-5 and Landsat-7 data since 2006 until 2012. The images to be used in the annual forest monitoring are selected. The selected images must be aligned geographically to each other and to other map data. Cloud and shadow, and the other image noise that obscure the ground cover are then masked from the images. The individual images are then mosaiced into larger units (Kustiyo *et al.*, 2015).

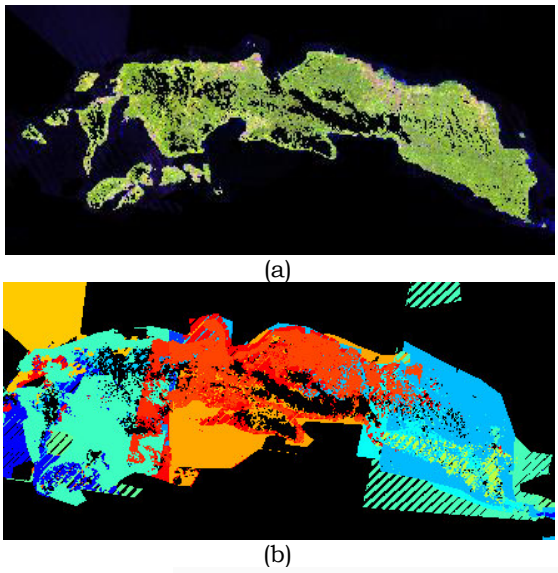


Figure 2-2: (a) Mosaic of Landsat Data and (b) Landsat data used where the colors shown about path/row and date of the data

Figure 2-2 (a) shows an example of the mosaic Landsat data with the composit RGB-542 and (b) shows paths/ rows and dates of Landsat data that were used where the different color shows different path/row and date. Each path/row in the mosaic data composed of two to five images.

The other data were Seram Island stratification zone and their indices.

2.2 Methods

The research stages were as follows:

Stage I: Analyzing the Stratification Zone.

In previous research, Seram Island was divided into two stratification zones with three indices. Both of zones have same index with different threshold. Analysis steps are as follows:

a. Recheck the training sampel.
b. Analyses on the separateness of forest and non-forest based on indices resulted by *Canonical Variates Analysis (CVA)* method (Tofallis, 1999; Campbell and Atchley, 1981). CVA method for Landsat data processing carried out also by Furby et al. (2008), and Furby et al. (2010),
c. Applying those indices to Landsat data in 2008 to obtain the base forest probability.
d. Reanalyses the boundary of stratification zones to determine threshold for forest and non-forest.

Stage II: Calculating annual forest probability

Applying indices obtained in Stage I for the other years (2006, 2007, 2010, 2011, and 2012).

Stage III: Determining spatial information of forest and non-forest phase I is an annual image that has value 0,1,and 2 that show missing data, forest, and non-forest, respectively.

a. Comparing the Landsat data and forest probability image
b. Determining a lowest probability values for forest pixel
c. Creating an algorithm in which a value of 0, 1, and, 2 respectively show the missing data, forest and non-forest

Stage IV: Determining spatial information of forest and non-forest phase II is an annual image with the value of 0,1, and 2 that show missing data, forest, and non-

forest, respectively and has minimal missing data.

Making rules to determine of forest, non-forest, or missing pixel based on permutation and multi-year classification of forest and non-forest as shown in Figure 2-3. The permutation used in this research was the permutation with repetition. The algorithm of total amount of the order possible shown by equation (2-1).

$$n^r \quad (2\text{-}1)$$

where n is the number of objects and r is the object that will be chosen (Fisher, 1971).

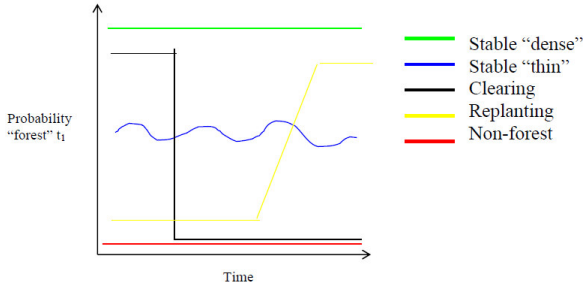


Figure 2-3: Forest and non-forest multi-year classification rule (Source: Furby and Jerremy (2011)

3 RESULTS AND DISCUSSION

The result of previous study (Kartika *et al.*, 2014), Seram island area could be divided into two stratification zones with the same indices, where the index equations are B2+B3-2B for index-1, B3+B4 for index-2, and -B3+B4 for index-3.

If the chosen samples were reinterpreted, then the result of CVA method could produce good distribution of forest and non-forest because they had been sparated well, as shown in Figure 3-1.

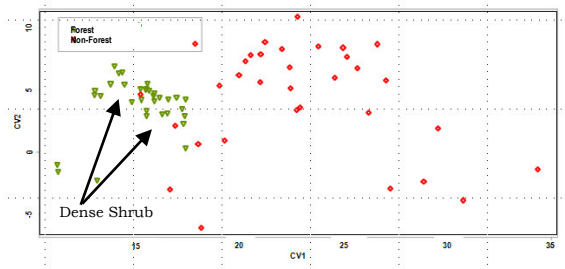


Figure 3-1: Result of CVA method gave forest and non-forest good distribution

The red color shows non-forest area and there are two samples were inside forest area. They are dense shrubs near the forest areas. Consequently, the thresholds have to be reanalyzed, whether the same threshold will produce good result for Seram Island. The result indicated that by expanding the threshold, the two zones could be jointed, thus the Seram Island could be grouped into one stratification.

Figure 3-2 shows the annual threshold value for the forest, non-forest, and uncertain classes. They can be used to determine threshold interval and the result are interval forest threshold for index 1 between -60 and 0, index 2 between 61 and 104, and index 3 between 45 and 105.

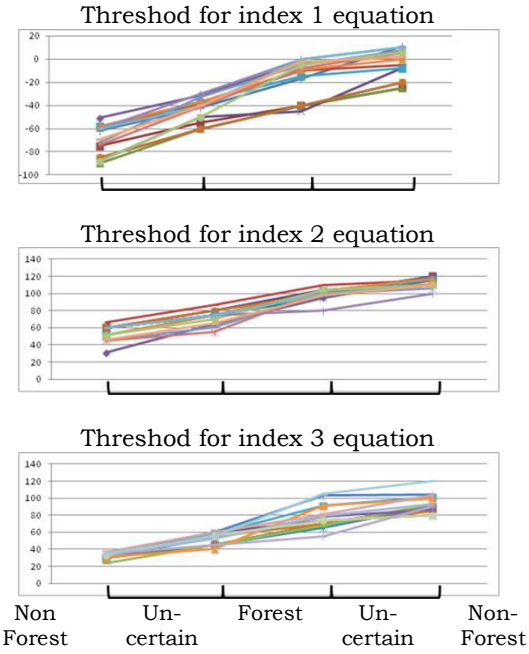


Figure 3-2: The thresholds for forest, uncertain, and non-forest

Process in the stage two was based on the above indices and thresholds to determine forest probability. Forest probability has value 100%, non-forest probability has value 0%, and uncertain probalities has values more than 0 % but less than 100 %. Example of forest probability image was shown in Figure 3-3.

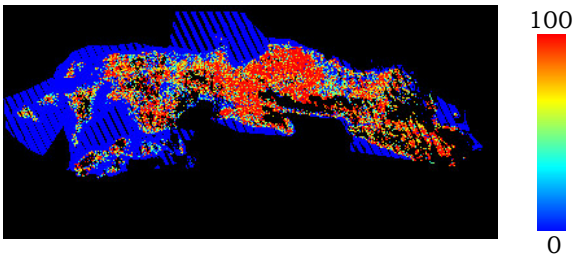


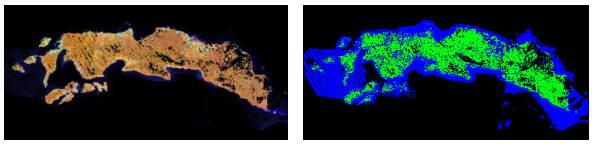
Figure 3-3: Forest probability image for Seram Island in 2008

The stage three was to classify forest and non-forest by comparing the color composite RGB-453 for Landsat-5 and Landsat-7 data with forest probability image to produce the class of forest and non-forest, in Phase I. For this purpose, it has to be known the characteristics of object - forest in remote sensing data - where these characteristics could be known from image interpretation keys: color, hue, form, texture, location, and pattern. The results indicate that the lowest probability of forest in Seram Island in 2006 until 2012 years ranged between 46% dan 60%. The detailed results are presented in Table 3-1.

Table 3-1: The lowest boundary of probabilities for forest area in Seram Island in 2006-2012

Year	The lowest value of forest probability
2006	50
2007	50
2008	60
2009	46
2010	55
2011	50
2012	55

The example of classification result from stage I is shown in Figure 3-4. The green color was forest, the blue color was non-forest, and the black color was missing pixels. Missing pixels in the island were caused by clouds or cloud shadows covering those areas.



Landsat of 2009 year | Forest and non-forest spatial information of 2009 year

Forest | Non-forest | Missing data

Figure 3-4: Landsat image (left) and forest and non-forest spatial information (right) in 2009

The stage four or classification Phase II was aimed to reduce missing pixels. For this purpose, we used data of three successive times. Determination of forest and non-forest in Table 3-2 was based on the rule shown in Figure 2-3. Value 1 is forest, value 2 is non-forest, and value 0 is missing pixel.

For example. the time series data of 2006, 2007, and 2008 were used to determine forest spatial information in 2006. The order in 2007, 2008, and 2009 was used to determine forest spatial information in 2007, and so forth. Look at the Table 3-2, if n=2006 then the order years were 2006, 2007, 2008.

Table 3-2 in the red box shows the rule to determine the final condition of forest in 2006 when the permutation order was 0, 2, 2, which means that in 2006 there was missing pixel, in 2007 and 2008 there were non-forests. Based on the rule of multi-year classification as shown in Table 3-2, the final condition in n=2006 was non-forest or the value is 2.

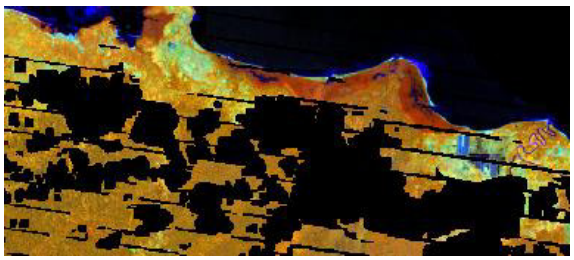
However, for the three last years final forest condition of 2010, 2011, and 2012 determined by it's own year. Thus the forest spatial information of n=2010 was derived using the same algorithm with previous years, while forest spatial information of n+1=2011 and n+2=2012 were derived by final condition at year n+1 and n+2 of the multi-year classification rule in Table 3-2.

Table 3-2: the permutation order and final forest condition based on multi-year classification rule

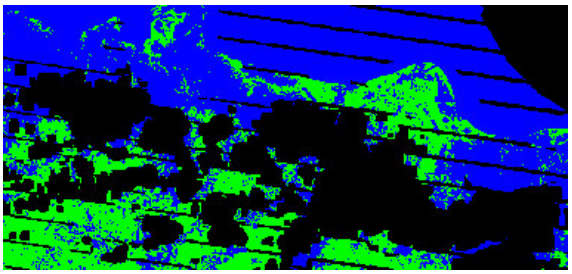
Condition	The order of Permutation			Final condition		
Year	n	n+1	n+2	n	n+1	n+2
Multi-year Classification Rule	0	0	0	0	0	0
	0	0	1	1	1	1
	0	0	2	2	2	2
	0	1	0	1	1	1
	0	1	1	1	1	1
	0	1	2	1	1	2
	0	2	0	2	2	2
	0	2	1	2	2	1
	0	2	2	2	2	2
	1	0	0	1	1	1
	1	0	1	1	1	1
	1	0	2	1	1	2
	1	1	0	1	1	1
	1	1	1	1	1	1
	1	1	2	1	1	2
	1	2	0	1	2	2
	1	2	1	1	1	1
	1	2	2	1	2	2
	2	0	0	2	2	2
	2	0	1	2	2	1
	2	0	2	2	2	2
	2	1	0	2	1	1
	2	1	1	2	1	1
	2	1	2	2	1	1
	2	2	0	2	2	2
	2	2	1	2	2	1
	2	2	2	2	2	2

The detailed classification results are shown in Figure 3-5. Figure 3-5(a) is the mosaic of Landsat Data 2010, Figure 3-5(b) is the result of classification Phase I with all missing data caused by cloud cover and cloud shadows, and Figure 3-5(c) is the result of classification where the missing pixels had been filled as the forest or non-forest according to multi-year classification rule in Table 3-2. From the results, it has proved that multi-year classification could provide solution for missing pixels caused by cloud cover and cloud shadows.

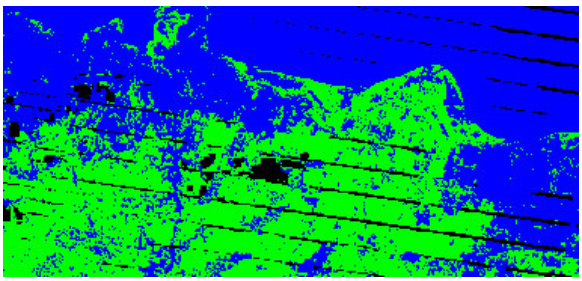
The final result is very important for forest monitoring, since the increasing forest loss of Indonesian primary forests has significant implications for climate change mitigation and biodiversity conservation efforts as found by Margono *et al.* (2014).



(a) Landsat data of 2010



(b) The result of Classification Phase I of 2010



(c) The result of Classification Phase II of 2010

:Forest :Non-forest :Missing data

Figure 3-5: The detailed comparison between results of classification phase I and phase II in Landsat data of 2010

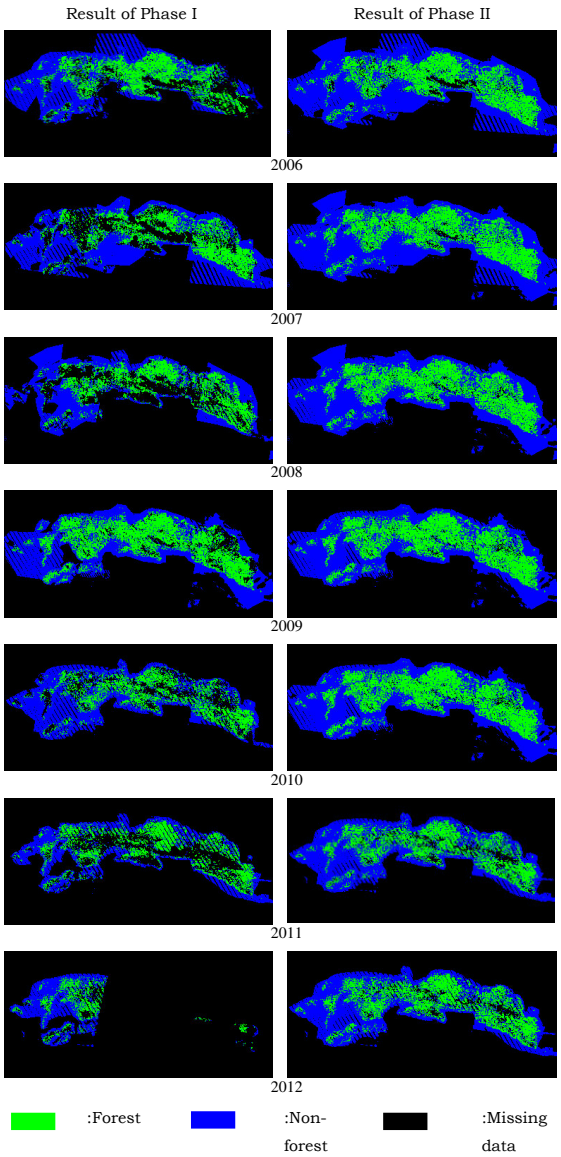


Figure 3-6: Comparison between results of classification phase I and phase II.

Figure 3-6 indicates comparison between results of classification phase I and phase II in the years 2006 until 2012. They show that the missing pixels at the spatial information result of phase II had filled by information as a forest or a non-forest. Therefore if the classification result of phase I compared with the phase II, the missing pixels on the result of phase II was decreased.

4 CONCLUSION

Seram Island could be compound into one stratification zone using three indices. The index equations were B2+B3-2B for index-1, B3+B4 for index-2, and -B3+B4 for index-3. The threshold range of indices 1, 2, and 3 were between -60 and 0, 61 and 104, and 45 and 105, respectively.

The classification method using multi-year data could overcome the missing pixels caused by cloud cover and cloud shadow so that all missing pixels could be classified into forest or non-forest.

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