UTILIZATION OF MULTI TEMPORAL SAR DATA FOR FOREST MAPPING MODEL DEVELOPMENT

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Abstract. Utilization of optical satellite data in tropical region was limited to free cloud cover. Therefore, Synthetic Aperture Radar (SAR) becomes an alternative solution for forest mapping in Indonesia due to its capability to penetrate cloud. The objective of this research was to develop a forest mapping model based on multi temporal SAR data. Multi temporal ALOS PALSAR data for 2007 and 2008 were used for forest mapping, and one year mosaic LANDSAT data in 2008 was used as references data to obtain training sample and to verify the final forest classification. PALSAR processing was done using gamma naught conversion and Lee filtering. Samples were made in forest and water area, and the statistical values of the each object were calculated. Some thresholds were determined based on the average and standard deviation, and the best threshold was selected to classify forest and water in 2008. It was assumed that forest could not change in 1-2 years period. The classification of forest, water, and the change were combined to produce final forest in 2008, and then it was visually verified with mosaic LANDSAT in 2008. The result showed that forest, water, and the change could be well classified using threshold method. The forest derived from PALSAR was visually consistent with forest appearance in LANDSAT and forest produced from INCAS. It has better performance than forest derived from INCAS for separating oil palm plantation from the forest.

Keywords: *Forest mapping, multi temporal, ALOS PALSAR, threshold, LANDSAT*

1 INTRODUCTION

Utilization of remote sensing satellite data has been carried out extensively to support various sectors, such as agriculture, forestry, water resources, marine fisheries, and disaster mitigation. Currently, optical satellite sensor is still the most widely used sensor in the world, because it can detect object with high spatial and spectral resolution. By those capabilities, optical satellite data can give the detail information of the objects (i.e. shape and color) which are closely similar to the condition of real objects on the earth's surface. The main problems of optical data are the presence of cloud cover and the dependency on sunlight as a light source. These problems caused a lot of data acquired by optical sensor could not be used due to the high cloud cover.

Synthetic Aperture Radar (SAR) is one of the most promising satellite sensors for monitoring the earth surface at a regional to global scale. SAR has many useful characteristics for supporting various applications, such as cloud-free, day or night observation capability, highly spatial resolution produced by the synthetic aperture technique, and also polarimetric and interferometric information. In particular, cloud-free observation by SAR is a great advantage for monitoring in humid tropical regions such as Indonesia. Regarding to that reason, it is very important to explore the potentiality of SAR capability and utilize the SAR data to support various applications in Indonesian region.

Recently many SAR data in different frequency and spatial resolution can be accessed to support various applications i.e., ALOS-PALSAR, RADARSAT, and SIR-C/X-SAR. ALOS (Advanced Land Observing Satellite) is an advanced generation of Jers-1 and ADEOS which was equipped with more advanced technology. ALOS has three instruments i.e., Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM), the Advanced Visible and Near Infrared Radiometer type-2 (AVNIR-2), and the type L band Phased-Array Synthetic Aperture RADAR

(PALSAR) which is a SAR sensor with spatial resolution 10-100 meter. PALSAR has capability to record data in full polarization (HH, VV, HV, and VH) mode (Jaxa, 2008). Some research related to the PALSAR data utilizations have been published. The studies showed that PALSAR data was potential to be used or identified paddy field in small area with varied landforms (Raimadoya *et al*., 2007), and land use/land cover using multi polarization of PALSAR data (Sambodo *et al*., 2005; Arifin, 2007).

The application of SAR (including PALSAR data) in forestry shows that SAR systems have a good capability in discriminating various types of forest cover i.e., swamp forest, low land forest, and up land forest (Sgrenzaroli, 2004). PALSAR also has been proven to be good data for mapping forest-non forest by combining with a time-series of Landsat-based maps (Lehman *et al*., 2012). However, in general classification results based on SAR data are still poor if only used single-frequency, single-polarization or single overpass data (Ferrazzoli *et al*., 1999). In order to improve the radar classification capability, data either multi-temporal or multi-frequency are required. Multi-temporal data, which may be acquired by airborne or satellite systems, are particularly important to separate forest types.

This research was intended to explore the possibility of PALSAR data as one alternative solution for forest mapping due to its capability to penetrate cloud cover. For obtaining good accuracy of classification, multi temporal PALSAR data in 2007 and 2008 were used to separate between forest and non forest in Riau Province, Sumatera Island of Indonesia. This research was expected to get a forest mapping model based on multi temporal SAR data which is useful for forest mapping activity in Indonesia.

2 MATERIALS AND METHOD

The study area was located in Riau Province, as shown in Figure 1. The land covers was dominated by rain forest and oil palm plantation. Other land covers were water body (such as river), open area and bush. The remote sensing imageries used in this research are PALSAR data single polarization (HV polarization) level 1.5 acquired on 28 June 2007 and 15 August 2008. It was also used one year mosaic LANDSAT data in 2008. The mosaic LANDSAT data was used as references data to obtain training sample and to verify the final forest classification.

The approach of this research is presented in Figure 2. PALSAR data pre-processing was conducted by performing gamma naught (backscatter) conversion and Lee filtering (Lee, 1981). The method of gamma naught conversion (DN to dB conversion process) was shown in Figure 3, and the conversion algorithm used the

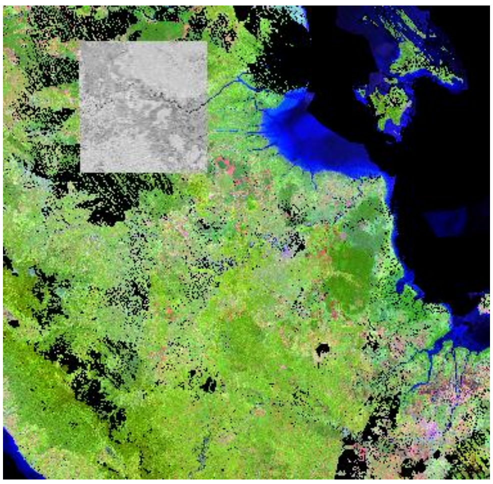


Figure 1. Study area in Riau Province, Sumatera Island, Indonesia

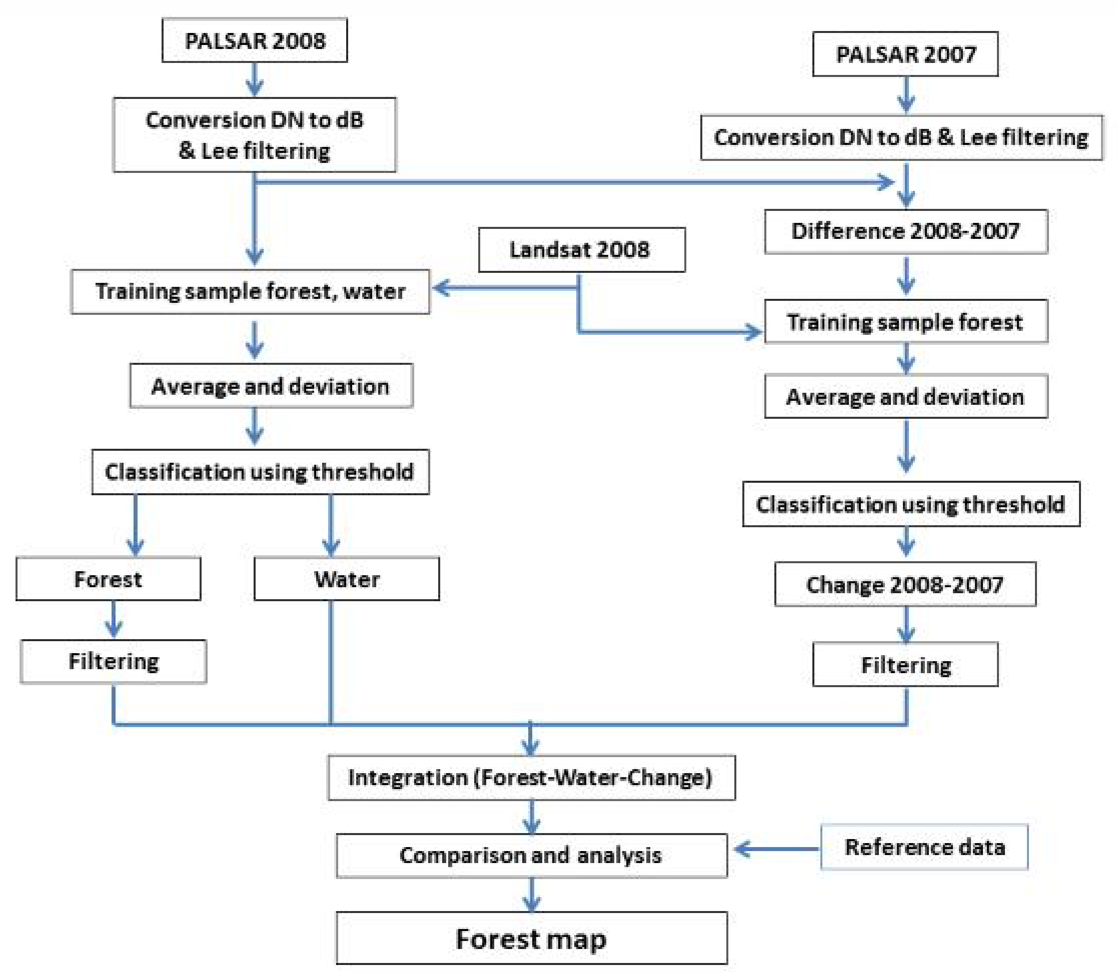


Figure 2. Flowchart of the research procedure

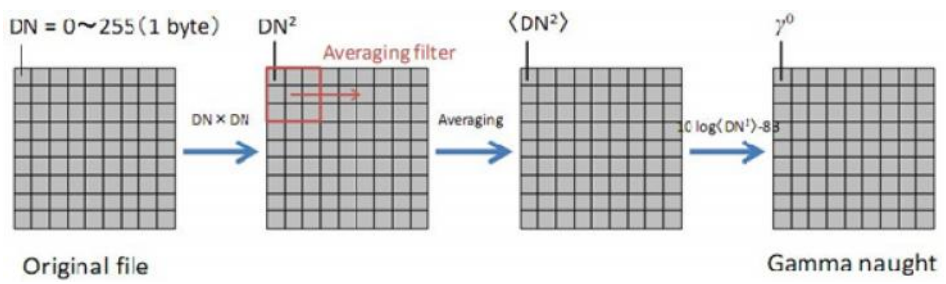


Figure 3. Procedure of DN to dB conversion process

Following equation:

$$\gamma^{\circ}_{(dB)} = 10.\log_{10}\langle DN^2\rangle - CF \quad .... \quad (1)$$

where, γ° is gamma naught in dB unit, DN^2 is average value of window 3x3, and CF is calibration factor for PALSAR data with the value 80 (Shimada *et al*., 2009). Lee filtering was conducted using window 3×3, this filter removes the noise by minimizing either the mean square error or the weighted least square estimation (Qiu *et al*., 2004).

Training samples were plotted in forest and water area by visually referring to mosaic LANDSAT data. Then the statistic values (mean, standard deviation, minimum and maximum) of each object (forest and water) were calculated. Some thresholds were determined based on the average and standard deviation, and then the best threshold was selected to classify forest-non forest and water-non water area in 2008. It was assumed that forest could not change in 1-2 years period; therefore the change in the area occurred between 2007 and 2008 was classified as non-forest.

For the change identification, the difference of gamma naught in 2008 and 2007 was determined by doing the substitution process, and then the differences in forest pixel were statistically calculated to get the statistic values. Some thresholds were determined based on the average and standard deviation, and then the best threshold was selected to classify change and non change in forest area during period 2007-2008. The classification of forest, water (water was classified as non-forest) and the change (based on the previous assumption that change was non-forest) were filtered using median filter and combined to get the final forest classification in 2008 using the following equation:

Final forest = Forest – water (non-forest) – Change (non-forest) ...... (2)

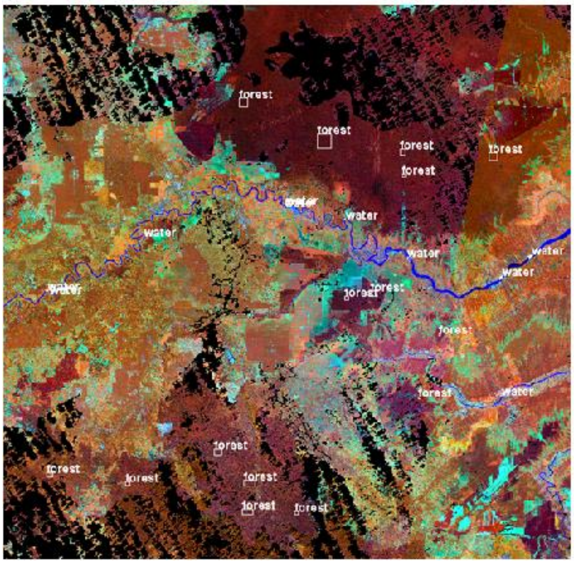
The final forest derived from PALSAR was evaluated using reference data. Here, one year mosaic LANDSAT in 2008 and forest map in 2008 produced by Indonesia national Carbon Accounting System (INCAS) were used to evaluated the final forest map. INCAS is collaboration program between Indonesia and Australia, that produces annually forest cover information in Indonesia based on LANDSAT data to support REDD+ program.

3 RESULT AND DISCUSSION

3.1 Forest and water classification

A total of 25 training samples were made, where 15 samples in forest and 10 samples from water by visually referring to mosaic LANDSAT data. Then the statistic values of forest and water were calculated. Figure 4 shows the location of training sample and the result of statistical values of forest and water area. According to the statistical parameter, the forest backscatter was higher and more homogenous comparing to the water backscatter.

Thresholds were determined based on the mean and deviation of sampling measurement (mean ± A*deviation). Constant A that used for forest was varied from 0.5 to 4, mean and deviation of forest calculated from forest samples were -11.887 and 0.831, respectively as shown in Figure 4. On the other hand, A used for water was varied from 1 to 4 and mean and deviation



Statistic result of forest and water for PALSAR based on sample

No.	Forest	Nilai
1	Minimum	-16.389
2	Maximum	-7.961
3	Mean	-11.887
4	Deviation	0.831

No.	Water	Nilai
1	Minimum	-30.076
2	Maximum	-23.736
3	Mean	-26.922
4	Deviation	1.223

Figure 4. Training samples of forest and water (left), and statistic parameter of backscatter of the samples (right).

calculated from water samples were -26.922 and 1.223, respectively (see Figure 4). If a pixel had the value inside the threshold, it would be classified into forest or water class. But if a pixel had the value outside the threshold, it would be classified as non forest or non water. All thresholds were applied into PALSAR data, and the best threshold for forest and water was selected referring to LANDSAT image visually. Figure 5 and 6 show the result of forest and water classification based on threshold method. It was found that the best threshold for forest was mean ± 2 deviation, and for water was mean ± 3 deviation.

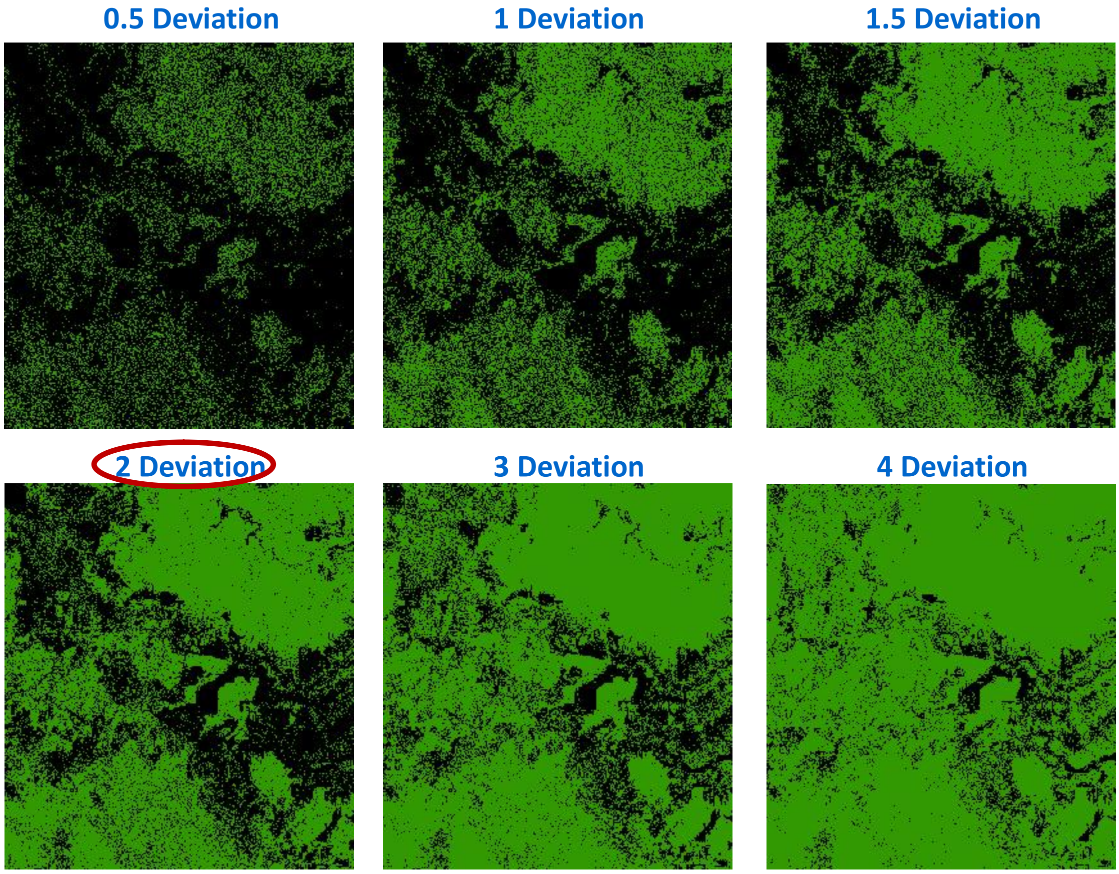


Figure 5. Forest classification using thresholds (Green: forest, Black: non-forest)

3.2 Change detection and classification

The difference of gamma naught in 2008 and 2007 images, and statistic value of gamma naught difference in forest area are shown in Figure 7. White color showed high difference between 2008 and 2007 images; grey color showed small difference between 2008 and 2007 images. The difference of the two images can be caused by some factors, such as: land cover change and radiometric effect (atmospheric or terrain effect). Land cover change leads to high difference of spectral value, but radiometric effect leads to small difference of spectral value. The high difference due to land cover change must be extracted. The training samples were taken in forest area for both images (assumes that small differences in forest area were caused by radiometric effect), and mean and deviation values of gamma naught difference were calculated. Based on those values, some thresholds were determined to identify the change in forest area due to land cover change (Figure 8), and the best result was selected visually referring to the change occurred in multi temporal PALSAR image.

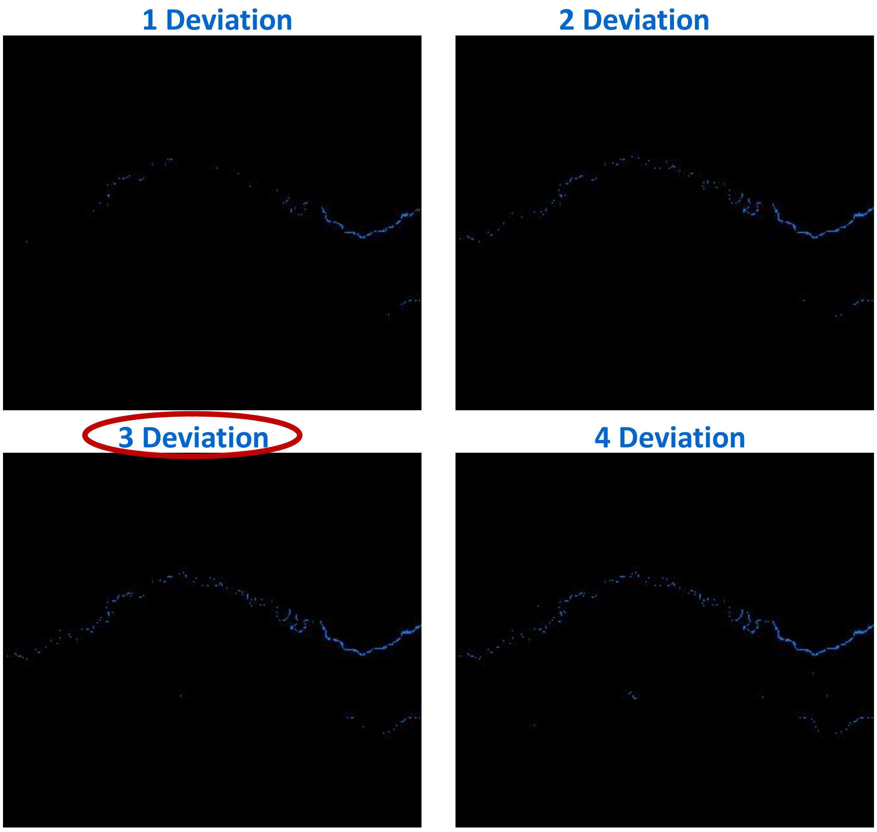
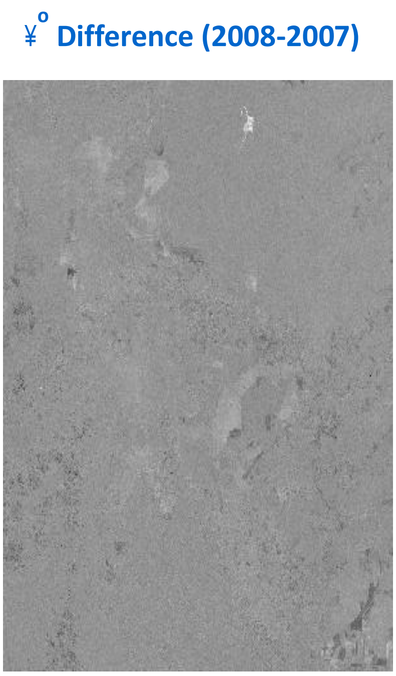


Figure 6. Water classification using thresholds (Blue: water, Black: non-water)



Statistic result of forest for PALSAR based on sample

No.	Nilai Forest	Nilai
1	Minimum	-4.098
2	Maximum	3.539
3	Mean	-0.024
4	Deviation	0.822

Figure 7. Gamma naught difference in 2008 and 2007 (left), and the statistic value in forest area (right)

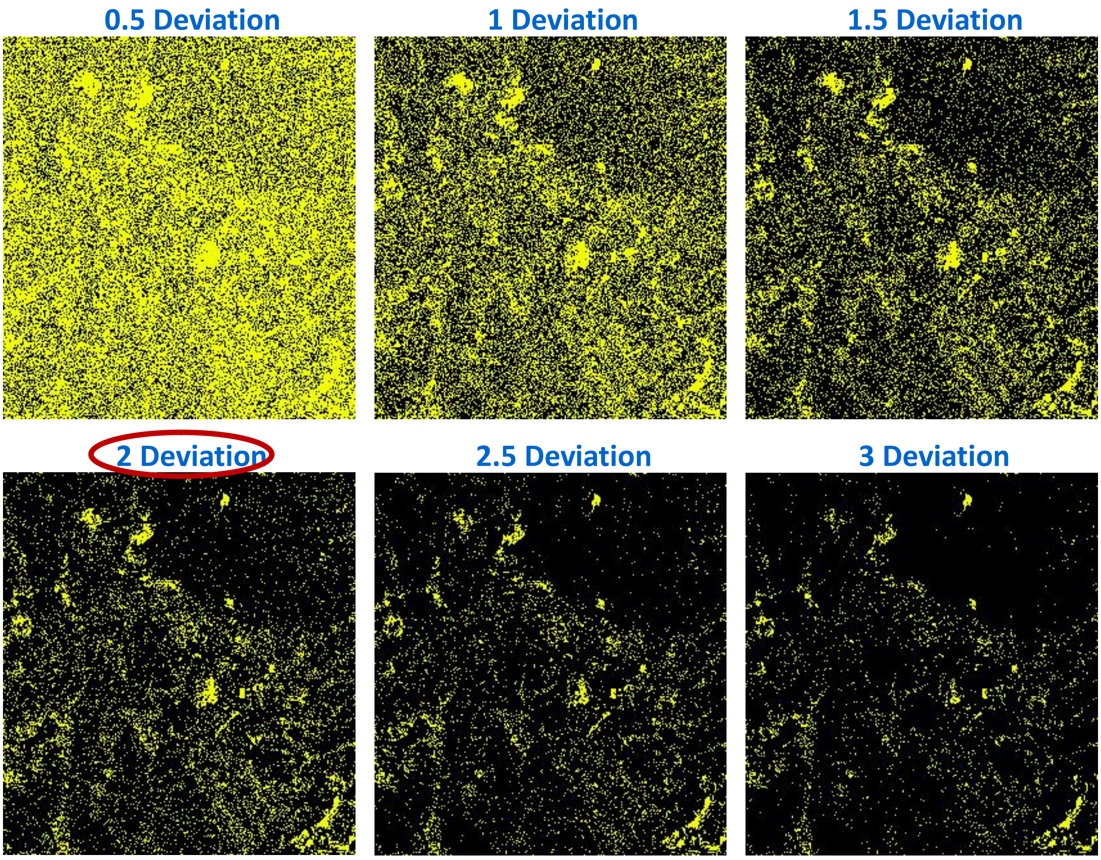


Figure 8. Land cover change classification using thresholds
(Yellow: change, Black: non change)

It was found that the best threshold for change identification is mean ± 2 deviation (see Figure 7 (left)).

3.3 Forest classification and evaluation

After filtering process (majority filter using windows 3×3) to reduce "salt and pepper", all classification results (forest, water and change) were integrated using equation 2 to produce final forest. Figure 9 shows an illustration of result integration method, and the final forest derived from PALSAR in the study area. The final forest in 2008 was consisting of three classes: forest, water, and non forest.

The final forest was also visually compared with one year mosaic LANDSAT and the forest produced from INCAS program as shown in Figure 10. From the comparison in Figure 10, the forest classification from PALSAR data was relatively consistent with forest appearance in LANDSAT image and the forest produced by INCAS program. The further analysis showed that forest derived from PALSAR had better performance than forest produced by INCAS Program. In the forest derived from PALSAR the forest and oil palm plantation can be differentiated (white box in Figure 10) more accurate.

4 CONCLUSION

Multi temporal ALOS PALSAR data was used to classify forest area in Riau Province using statistical values of object backscattering. The results showed that threshold method based on mean and standard deviation of each object backscattering can well classify forest, water and land cover change in forest area. The final forest derived by multi temporal PALSAR was visually consistent with forest appearance in LANDSAT image and forest produced from INCAS program. The further analysis showed that the forest has better performance than the forest produced by

INCAS for separating forest and oil palm plantation. Although, there were still some difficulties to separate forest and other land cover types such as oil palm. The forest classification model based on multi temporal SAR data was supposed to be a good alternative method for forest mapping in tropical region such as Indonesia.

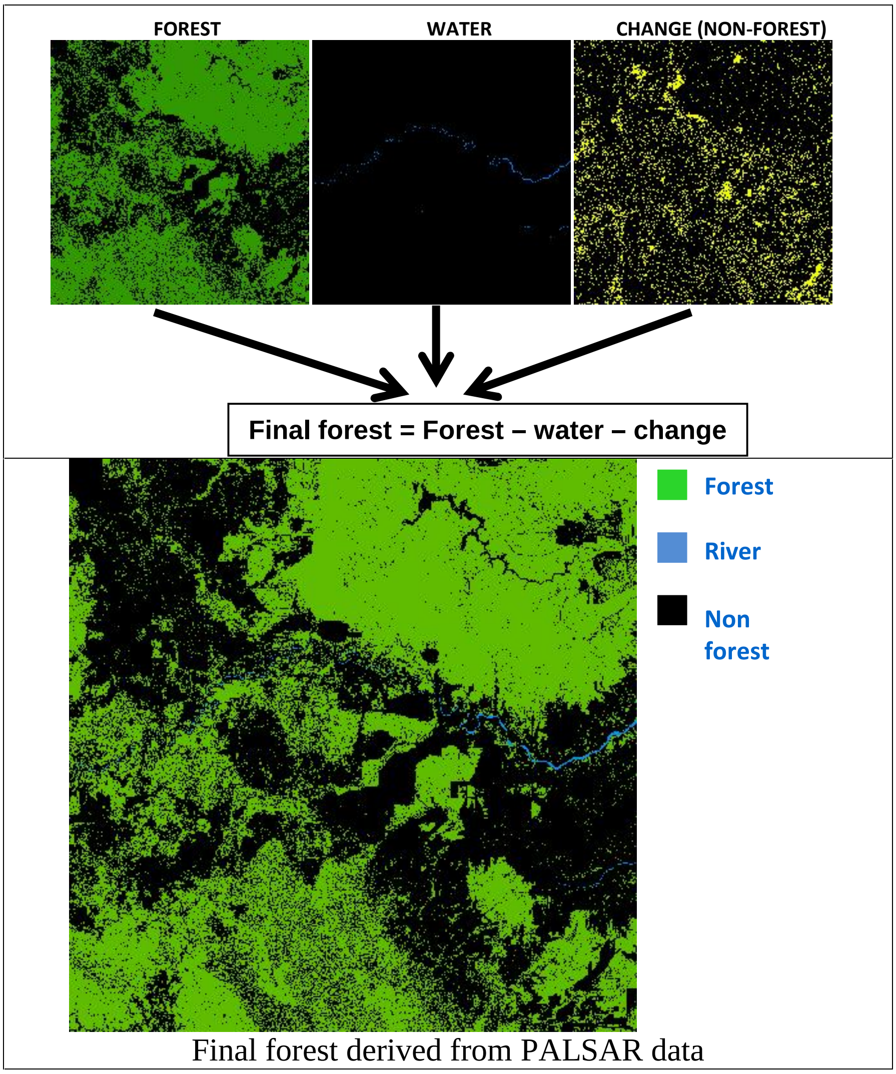
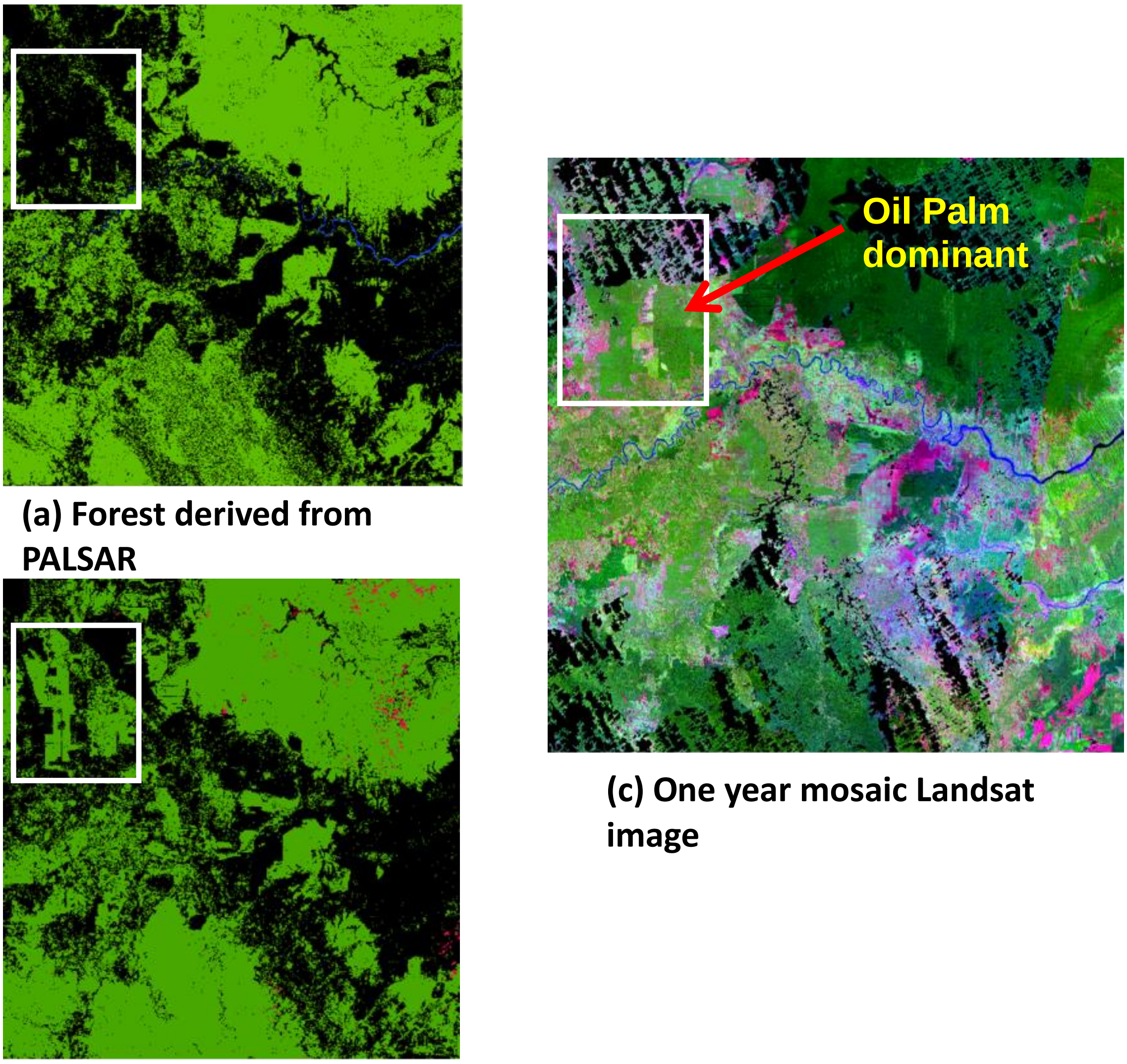


Figure 9. An illustration of integration method (up), and the final forest derived from PALSAR in the study area (bottom)



(a) Forest derived from PALSAR

(b) Forest produce by INCAS

(c) One year mosaic Landsat image

Figure 10. Comparison of forest derived from PALSAR (a), forest produced by INCASS (b) and one year mosaic LANDSAT image (c).

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