USE OF FORMOSAT-2 SATELLITE IMAGERY TO CLASSIFY OIL PALM IN INDONESIA

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ABSTRACT: Indonesia produces the majority the world's palm oil, accounting for approximately 44%. Since 2006 Indonesia is the biggest crude palm oil (CPO) exporter in the world (Sukamto, 2008). Oil palm is a valuable sector to support Indonesian economics but it also causes environmental impacts. Sustainable oil palm development (SOPD) is a key important to improve quality of oil palm development. Remote sensing technology then can be utilized to support SOPD. This study has tried to classify growing stages of oil palms using high spatial resolution FORMOSAT-2 satellite image. FOMOSAT-2 data has 4 multispectral bands (8 m) and 1 panchromatic band (2m). Because oil palms in plantation has triangular planting pattern where a space between oil palm trees is about 9 meter, the 2 m panchromatic band can be used to recognize this planting pattern by texture calculation. Texture extraction using image matching by correlation and supervised image classification using maximum likelihood classifier have been used in this study. In detail, image classification attempted to use only multispectral data and the combination of multispectral data plus texture information. Both results then were compared. The study area was Cimulang oil palm plantation in West Java province, Indonesia. The result shows that the overall accuracy (OA) of 66.4% is achieved from the image classification that used only multipectral bands. The OA of 76.8% is achieved from the image classification that used multi spectral plus texture information. By adding texture information to multispectral bands in classification, the OA is improving 10.4%.

1. BACKGROUND

Indonesia produces the majority the world's palm oil, accounting for approximately 44% and since 2006 Indonesia is the biggest crude palm oil (CPO) exporter in the world (Sukamto, 2008). There have been environmental impacts such as deforestation and social impacts (Colchester et al., 2006). Hence the need for sustainable oil palms development (SOPD) that deals with economic development whilst also caring for environment. Sophisticated and reliable technologies such as Geographic Information Systems (GIS) and remote sensing (RS) can be utilized to support implementation of SOPD.

GIS and RS have been used to study oil palm. Lukman *et al.* (1996) successfully used satellites imaging data from Landsat Thematic Mapper and SPOT to identify oil palm growing areas and to map differences in palm age at early stages of growth. Wahid *et al.* (2005) used multispectral Landsat 7 ETM (Enhanced Thematic Mapper) images and GIS to develop a rapid procedure of producing the 1:50 000 scale oil palm land use in Malaysia. The oil palm land use was discriminated by supervised classifications using Nearest Neighbour (NNB). The composite of TM bands 4, 5 and 3 gave the best discrimination of oil palm from other land cover types. Although there are previous GIS and RS studies about oil palm, but none of them used FORMOSAT-2 data or specifically used texture information.

Texture in daily life refers to something that can be touched and it felt rough, silky, and bumpy. In image, texture can be defined through its digital number (DN). A moving window (kernel) then is used to probe all of DN entire the image to characterize the textural features numerically by the algorithms. The incorporation of spatial variation (image texture) in image classification procedures is an increasingly important aspect of high spatial resolutions remotely sensed data analysis. Overall improvement in classification accuracy indicates that the addition of image texture improves image classification (Jensen, 2005).

In this study with 2 m spatial resolution of FORMOSAT-2 panchromatic image, triangular oil palm pattern can be well recognized through our eyes and has potential to be extracted by texture analysis algorithm. Therefore, this study has tried to utilize RS technology especially utilization of texture information in image classification to support SOPD. Furthermore, this study has following objectives: (1) To classify growing stages of oil palms using only multispectral bands and combination multispectral bands plus texture information of FORMOSAT-2 data, (2) To test the accuracy of both classification results, and (3) To support sustainable palm development by providing more often updated oil palm land use map.

2. STUDY AREA AND DATA COLLECTION

2.1 Study Area

The study area was Cimulang oil palm plantation in Bogor District, West Java Province, Indonesia. Cimulang plantation has total area 1,004.33 hectare. There were 38 planting blocks where 2 blocks (5.53 %) have been planted oil palm in 2002, 13 blocks (31.08 %) planted in 2003, 13 blocks (36.75 %) planted in 2004, and 10 blocks (26.64 %) planted in 2005.

2.2 Data Collection

2.2.1 FORMOSAT-2 Satellite Data

Image data that used in this study was captured by FORMOSAT-2 satellite on April 1, 2009. FORMOSAT-2 is a Taiwanese high resolution satellite launched on May 21, 2004. Its imagery has spatial resolution of 8 m in four spectral bands (0.45–0.52µm (Blue), 0.52–0.60µm (Green), 0.63–0.69µm (Red), and 0.76–0.90µm (Near-infrared)) and 2 m in one panchromatic band (0.45–0.90µm) with a scene coverage 24 km x 24 km. For purpose this study the scene was cropped to the study area. Level 2A preprocessing product of FORMOSAT-2 was used, it has radiometric corrections identical to Level 1A with geometric corrections to frame the image in a given map projection (default projection is UTM WGS 84).

2.2.2 Ground Truth

Ground truth is important in the initial supervised classification of an image. In this study ground truth data was collected a combination of field survey, high resolution image, and thematic map. Field survey was done on 10-11 August, 2009. High resolution DigitalGlobe's satellite image was captured from Google Earth has date 2007 and 2009. The thematic map was sourced from year planting map of oil palms. This map was made by the authorities PTPN VIII in 2008. This map describes when and where oil palms were planted based on planting blocks. Finally, by combining those data the ground truth map formed as shown in Figure 1.

3. METHODS

3.1 Multispectral image classification

The objective of image classification is to assign all of pixels in the image to particular classes or themes (water, forest, barren land, etc.) and to generate a thematic map (Weng, 2010). The basic strategy in supervised classification is to sample areas of known cover types to determine representative spectral values of each cover type (Verbyla, 1995). These sample areas namely training fields. In this study, base on ground truth data the training fields have been established. The training fields were delineated on area of oil palms that planted in 2002, planted in 2003, planted 2004 planted 2005, immature oil palms mixed with grass, grass, and non-vegetation cover types. After every training field of each land cover types was determined, then the image was classified using Maximum Likelihood classifier. It was chosen because this classifier is simple and still one of the most widely used in many studies. After supervised maximum likelihood classification was done then classified-image created, it still needs some procedures to be done to achieve final image classification result. These processes were regrouping classes and smoothing zone edges.

3.2 Image Classification with Texture Information

This part describes how image classification was conducted with utilizing not only multispectral bands of FORMOSAT-2 data but also added it with texture information. Texture information was derived from panchromatic band of FORMOSAT-2 data. Panchromatic band has 2 m spatial resolution. With this spatial resolution, planting pattern of oil palms can be recognized visually by our eyes on screen computer.

Remember, oil palms in plantation have unique planting pattern (triangular) where the space (distance) between trees is about 9 meter apart (Figure 2). Therefore we could see oil palms in the plantation through panchromatic image through their unique texture. Different ages of oil palms and different direction of planting patterns in different planting blocks also can be differentiated by their textures. These textures have potentially to be extracted automatically by texture analysis algorithm in computer. Since texture information was generated then it was added to multispectral bands to enrich the spectral signature information for image classification. Figure 3 shows some textures of oil palm planting patterns in different direction in panchromatic band of FORMOSAT-2 data.

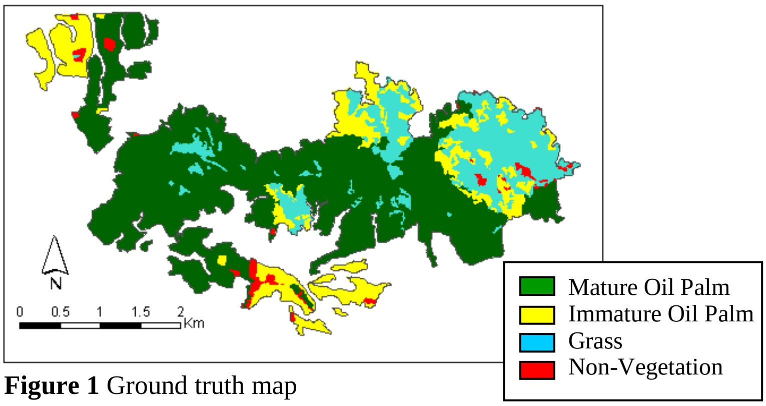

Figure 1 Ground truth map

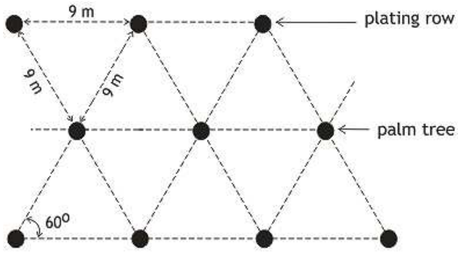

Figure 2 Configuration of triangular planting pattern of oil palms

Supervised classification method that employed here was also using maximum likelihood classifier. Training fields that have been used for this classification also the same with that were used to classify multispectral bands, both the total number of training fields and their locations. The only different here was texture information layers that added to multispectral bands so the spectral signatures of each cover types were different with spectral signatures that were used to classify only multispectral bands. Before texture analysis was run, the panchromatic band of FORMOSAT-2 was filtered by high-pass filter. A high pass filter retains the high frequency information within an image while reducing the low frequency information.

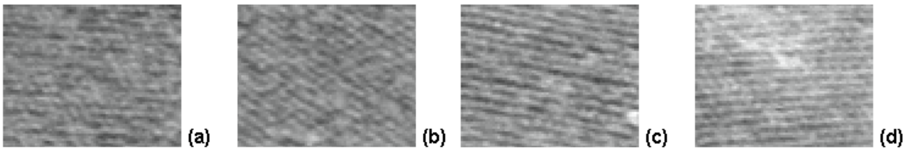

Figure 3 Cropped FORMOSAT-2 panchromatic images which depict texture of (a) oil palms 2002, (b) oil palms 2003, (c) oil palms 2004, and (d) oil palms 2005.

After panchromatic image was filtered, then the image matching by correlation method was applied. This method was chosen because oil palm planting pattern that has periodic texture can be recognized easily in panchromatic FORMOSAT-2 image by our eyes, and it has potential to be extracted by image matching by correlation. The GLCM (grey level co-occurrence matrix) with its statistical measure methods such as Homogeneity, Contrast, Dissimilarity, Entropy, Second Moment, and Correlation that known as simple texture descriptor (Coburn and Roberts, 2004) have been tried to extract oil palm planting pattern, but the results were not too clear to express the oil palm planting texture.

Applying image matching by correlation it needs reference image and test image. In formula, the correlation between reference image $w(x, y)$ of size $J \times K$ within the test image $f(x, y)$ of size $M \times N$ where it assumed that $J \leq M$ written as follows (Gonzales and Woods, 2002).

$$\gamma(x, y) = \frac{\sum_s \sum_t [f(s,t) - \overline{f}(s,t)]\ [w(x+s, y+t) - \overline{w}]}{\left\{ \sum_s \sum_t [f(s,t) - \overline{f}(s,t)]^2 \sum_s \sum_t [w(x+s, y+t) - \overline{w}]^2 \right\}^{\frac{1}{2}}} \qquad (1)$$

where $x = 0,1,2,\ldots, M-1$, $y = 0,1,2,\ldots, N-1$, $\overline{w}$ is the average value pixels in w (computed only once), $\overline{f}$ is the average value of f in the region coincident with the current location of w, the summation are taken over the coordinates common to both f and w. The correlation coefficient $\gamma(x, y)$ is scaled -1 to 1, independent of scale changes in the amplitude of f and w.

3.3 Accuracy assessment

In according to know how accurate the classification was, accuracy assessment through error matrix established. From this matrix the Overall Accuracy, User Accuracy, Producer Accuracy and Kappa (KHAT) value were calculated.

4. RESULTS AND DISCUSSION

4.1 Results of Multispectral Images Classification

Supervised classification was performed with all 4 multispectral bands of FORMOSAT-2 data. At the beginning the classification used 44 training fields which represented 7 land cover types, they were: oil palms planted in 2002, oil palms 2003, oil palms 2004, oil palms 2005, grass, immature oil palm mixed with grass, and non-vegetation. Using these training fields, the multispectral image was classified. These classes were then grouped to those 7 land cover types. Although it already grouped to 7 classes, some classes were still not well separated, mainly among different planting ages of oil palms. This is because the spectral signatures and separability of these cover type classes are relatively close each other. Hence in the final classified image, those 7 classes were then grouped into 4 classes. The classes of oil palm that were planted in 2002, 2003, and 2004 were grouped into a new class namely Mature oil palms (MA), the oil palms 2005 class were grouped to Immature oil palms (IM), the immature oil palms class mixed with class grass and the class of grass were grouped to Grass (GR), then the non-vegetation class still remained the same name Non-vegetation class (NV). The result of final classified image is depicted through Figure 4-a. From statistic calculation of final classification result, it inform that the 35.23% of area is covered by mature oil palm, 41.94% is covered by young oil palm, 18.01% is covered by grass, and 4.82% is covered by non-vegetation.

When looking at Figure 4-a, grass (blue color) is spreading in some places with the largest one concentrated in the north east of the plantation. By checking the year planting map of oil palm there is exactly no land cover type for grass or in other words the plantation is divisible only for oil palm cover types not for others. But in fact the grasses are there. It is because rodents' attacks have occurred. In these areas grass is dominant, the oil palm trees still can be seen but the density is quite low and they were mixed with grass. The red color indicates the non-vegetation class, which is concentrated in eastern part of plantation where there is barren soil, in southern part are the houses of PTPN VIII employees and in other parts are access roads (rocky roads). The yellow strips among the green color are the misclassified, actually these are access roads.

Table 1 Error matrix of final classification map of multispectral FORMOSAT-2 bands.

	Ground Truth					**User Accuracy**
Predicted Cover Type	**MA**	**IM**	**GR**	**NV**	**Row Totals**	**(%)**
MA	18913	31712	5727	367	56719	**33.3**
IM	4633	62651	466	130	67880	**92.3**
GR	3461	2578	22729	247	29015	**78.3**
NV	1398	2556	969	2769	7692	**36.0**
Column totals	28405	99497	29891	3513	161306	
Producer Accuracy (%)	**66.6**	**63.0**	**76.0**	**78.8**		
Overall Accuracy (%)	**66.4**		**KHAT**	**0.48**		

MA = Mature oil palm, IM = Immature oil palm, GR = Grass, NV = Non vegetation

According to the accuracy test, error matrix was created. This error matrix is shown in Table 1. From this table, the lowest user accuracy is achieved by mature oil palm (33.3 %) while the highest user accuracy is achieved by immature oil palm (92.3%). The lowest producer accuracy 63% is achieved by immature oil palm while the highest producer accuracy is achieved by non-vegetation (78.8%). Meanwhile an overall accuracy of 66.4 % and a kappa value (KHAT) of 0.48 were achieved.

4.2 Results of Multispectral and Texture Information Images Classification

In according to get texture information from the image, texture extraction using image matching by correlation method was applied to panchromatic FORMOSAT-2 image. Before it was applied, the panchromatic image was already filtered by high pass filter. Using 5 reference images (each reference image has size 17 x 17 pixels), where each reference image represented one texture of oil palm planting pattern on image, then the 5 texture layers information were generated. Those five texture information layers are the best texture layers that have been resulted. Actually the process has been tried many times. While attempting to get texture information if the result texture information from a reference image was not good then the reference image was changed (shifted or moved) to new locations then the process rerun again until texture result is good enough. Good here means the output texture information has more bright color and it should be concentrated not dispersed.

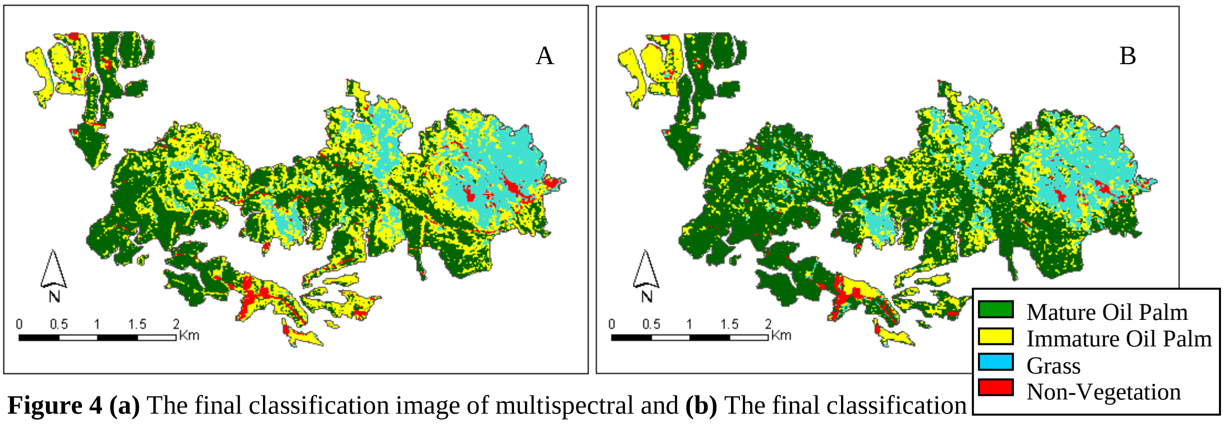

Figure 4 (a) The final classification image of multispectral and **(b)** The final classification image of multispectral bands plus texture information of FORMOSAT-2 data.

It was easier while attempting to get good texture information results from mature oil palms areas than from immature oil palms areas or even from young oil palms areas that mixed with grass (the area that has been attacked by rodents). The 5 texture information layers that resulted from the process then were stacked together with 4 multispectral images. In this process 2 meter spatial resolution of each texture layer then was resized to 8 m spatial resolution. Now a new bundle image with 8 m spatial resolution that has 9 layers inside was ready to classify.

Using the same 44 area of interests (the area that have been used to classify multispectral bands), new spectral signatures have been created then supervised classification was applied to a new bundle image. The image classification result then was created like what it was done to get final classification image which derived from only multispectral bands of FORMOSAT-2 data. The final classification image that derived from multispectral bands plus texture information is shown in Figure 4-b. This final classified image also has 4 land cover type classes, they are: mature oil palm, immature oil palm, grass, and non-vegetation. From the calculation of its statistics data, 22.38% area is covered by mature oil palm, 56.73% area covered by immature oil palm, 18.08% area covered by grass, and 2.81% area covered by non-vegetation.

Table 2 Error matrix of final classification image of multispectral FORMOSAT-2 data plus texture information

Predicted Cover Type	Ground Truth					User Accuracy
	MA	**IM**	**GR**	**NV**	**Row Totals**	**(%)**
MA	16708	15317	3887	233	36145	**46.2**
IM	8416	81077	1942	379	91814	**88.3**
GR	2631	2507	23735	310	29183	**81.3**
NV	631	952	302	2589	4474	**57.9**
Column totals	28386	99853	29866	3511	161616	
Producer Accuracy (%)	**58.9**	**81.2**	**79.5**	**73.7**		
Overall Accuracy (%)	**76.8**		**KHAT**	**0.60**		

MA = Mature oil palm, IM = Immature oil palm, GR = Grass, NV = Non vegetation

In according to test the result image, accuracy assessment was done through error matrix that shown in Table 2. This matrix shows that the overall accuracy of 76.8% and the kappa value (KHAT) of 0.60 are achieved. The lowest user accuracy of 46.2% is achieved by mature oil palm cover type (MA) while the highest user accuracy of 88.3% is achieved by immature oil palm (IM). The lowest producer accuracy of 58.9% is achieved by mature oil palm (MA) while the highest producer accuracy of 81.2% is achieved by immature oil palm (IM).

4.3 Comparison

The purpose this section as it title name is trying to compare between the final classification image that derived from only multispectral bands with final classification image that derived from multispectral bands plus the texture information. From Table 1 and Table 2 we can see that accuracy of image classification result that used multispectral bands plus texture information (overall accuracy and kappa value are 76.8% and 0.60 respectively) is better than it only used multispectral bands (overall accuracy and kappa value are 66.4% and 0.48 respectively). The overall accuracy different is 10.4 % better and the kappa value different is 0.12 better.

Texture information has given a good effect to improve the user accuracy of mature oil palms class (MA) as it written in both error matrix tables from 33.3% to 46.2%. Visually it can been through Figure 4-b, in this picture the mature oil palm that represented by green color looks more smoother (blocky) compare to the Figure 4-a. Misclassification because of noises that effected by too many access roads in this area were reduced by texture information. But for immature oil palm (IM) cover type by adding the texture information to multispectral bands the user accuracy is decreasing from 92.3% to 88.3%. In the picture it can be seen clearly especially in south part of the study area, yellow color that representing the immature oil palm looks a little bit more noise in the Figure 4-b compare to Figure 4-a. To get good texture information in this area is not as easy as in mature oil palm area. Uniquely happened in the grass class (GR), the grass class that originally consists of grass and sparsely young oil palm mixed with grass has better user accuracy, it’s increasing from 78.3% to 81.3% by adding texture information to multispectral bands but actually the case is to get good texture information was not easy on this area because no strong regular pattern can be recognized in this area.

5. CONCLUSION

Oil palm is important for Indonesia. Sustainable oil palm development (SOPD) is a key important to meet economic purposes and to reduce environmental impacts. In according to utilize remote sensing to support SOPD, this study has successfully used high spatial resolution FORMOSAT-2 satellite image (8 m for 4 multispectral bands and 2 m for 1 panchromatic band) to classify growing stages of oil palms at Cimulang plantation, West Java, Indonesia. Image classification using maximum likelihood classifier has done by utilizing multispectral bands and the combination multispectral bands plus texture information.

Oil palms has common triangular planting pattern where the space between trees is separated 9 m apart. This planting pattern has slightly different in direction (orientation) depends on slope and aspect of the terrain where the oil palms are planted its above. This pattern can be seen visually in 2 m spatial resolution of panchromatic FORMOSAT-2 image. According on these conditions, automatic oil palm pattern recognition (texture extraction) using image matching by correlation method was applied to panchromatic FORMOSAT-2 image. This method has successfully extracted texture information from different oil palm planting pattern at Cimulang plantation. In this study the overall accuracy of image classification result that derived only from multispectral bands is 66.37% and the kappa value is 0.48. Whereas the overall accuracy of 76.8% and kappa value 0.66 are achieved in the final image classification result of multispectral bands plus texture information layers. Comparing both classification results, by adding texture information to multispectral bands, the overall accuracy and kappa value increase 10.4 % and 0.12 respectively.

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