Effectiveness of Vegetation Index Transformation for Land Use Identifying and Mapping in the Area of Oil palm Plantation based on SPOT-6 Imagery (Case Study: PT.Tunggal Perkasa Plantations, Air Molek, Indragiri Hulu)

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Abstract. The reflection of land surface, atmosphere and vegetation conditions affect the reflectance value of the object is recorded on remote sensing image so that it can affect the outcome of information extraction from remote sensing imagery one multispectral classification. This study aims to assess the ability of the transformation of generic vegetation index (Wide Dynamic Range Vegetation Index), the vegetation index transformation that is capable reducing the influence of the atmosphere (Atmospherically Resistant Vegetation Index), and the transformation of vegetation index that is capable of reducing the influence of the background soil (Second Modified Soil Adjusted Vegetation Index) for the identification and mapping of land use in the oil palm plantation area based on SPOT-6 archived on June 13, 2013 from LAPAN. The study area selected oil palm plantations PT. Tunggal Perkasa Plantations, Air Molek, Indragiri Hulu, Riau Province. The method is using the transformation of the vegetation index ARVI, MSAVI2, and WDRVI. Sample selection method used was stratified random sampling. The test method used mapping accuracy of the confusion matrix. The results showed that the best transformation of the vegetation index for the identification and mapping of land use in the plantation area is ARVI transformation with a total of accuracy is 96%. Accuracy of mapping land use settlements 100%, replanting 82.35%, 81.25% young oil palm, old oil palm 99.46%, 100% bush, body of water 100%, and 100% bare-soil.

Keywords: Vegetation Index Transformation, Multispectral Classification, Land Use, Oil Palm Plant, SPOT-6 Imagery

1. Introduction

Central data and Agriculture Information System [2] states that Perkebunan Besar Swasta (PBS) dominate the large of Oil palm area, followed by Perkebunan Rakyat (PR) and Perkebunan Besar
Negara (PBN). The total large of Oil palm area in 2011 is approximately 8.91 million hectare with the large of PBS area of 4.65 million hectare (52.22%), PR 3.62 million hectare (40.64%) and PBN 0.64 million hectare (7.15%). Indragiri Hulu district is a region in province of Riau which has Oil palm as its main commodity [4] with number one contribution of total oil palm production in Indonesia [9]. The spread of Oil palm plantation in Indonesia started from Sumatra East Coast and Aceh [7] and continued to most land in Indonesia [15].

Oil palm (Elaeis guineensis jac) is plant from Nigeria and Brazil which has specific characteristics [5]. Composed in Fresh Stem Fruit [1] these plants planted in specific pattern and space therefore the image is easily detected by satellite imagery. Activity of plantation management needs a detail mapping for a large area which impacts to a big budget while high resolution image can only cover narrow area. Remote sensing method, one of them is maximum likelihood multispectral classification, is considered as adequate to classify object accurately in large area. Unfortunately, remote sensing system has weakness to atmosphere impact. Weather condition, climate, rain, cloud, fog, soil background and the side effect of Oil palm industry activity such as smoke, could affect image condition therefore correction to overcome some disruptions is needed. The use of varies transformation of vegetation index like generic, atmosphere effect control, and soil background effect control based on SPOT-6 image is considered to be able to fix obtained spectral value. This study aims to assess the ability of generic vegetation index transformation (Wide Dynamic Range Vegetation Index), the vegetation index transformation which is capable of reducing the influence of the atmosphere (Atmospherically Resistant Vegetation Index), and the transformation of vegetation index that is capable of reducing the influence of the background soil (Second Modified Soil Adjusted Vegetation Index) for the land use identification and mapping in oil palm plantation area based on SPOT-6 archived on June 13, 2013 from LAPAN.

2. Research Area
This research covers part of Indragiri Hulu district, province of Riau at Oil palm plantation of PT. Tunggal Perkasa Plantation as seen in Picture 1.

![Picture 1. Research Location](source: Basic Research Material, 2015)
3. Materials and Methods

3.1. Data
This research used multispectral SPOT-6 Imagery with 6 meters spacial resolution archived on June 13, 2013 from LAPAN. Other used data is Indonesia Topographical Map Scale 1 : 50.000 Page 0915-41 Simpang Kelayang, Indonesia Topographical Map Scale 1 : 50.000 Page 0915-42 Air Molek, Indonesia Topographical Map Scale 1 : 50.000 Page 0915-43 Ukui Satu, Indonesia Topographical Map Scale 1 : 50.000 Page 0915-44 Pangkalan Kapau and Plantation Block Map which are used to extract area boundaries and basic informations.

3.2. Methods

3.2.1 ToA radiometric correction
Technology and Remote Sensing Data Center [13] in Agencies and National Space Flight release that radiometric correction information for satellite imagery SPOT-6 can be done with radiometric correction Top Of Atmosphere (TOA). TOA correction erase obscurity therefore produced imagery data is more focus and visually clear. TOA correction needs zenithal angle input (\(\cos \theta\)) (90- elevation angle), elevation angle, incidence angle, canal gain (\(G_i\)), canal bias (\(B_i\)), canal solar irradiance (solar ESUNi), which are in metadata file attaching in each scene of satellite recording result and earth-sun space (\(d^2\)) which can be calculated from those parameters. All input is entered in formula applying in each canal (DNi) with the formula below:

\[
Reflectance (\text{Top Of Atmosfer}) = \frac{\pi (\frac{DNi}{Gi} + B_i) d^2}{ESUN_i \cos \theta}
\]  

3.2.2 Transformation of Vegetation Index
Transformation of vegetation index used in this research is Transformation of Generic Vegetation Index and Transformation of Vegetation Index which Press the Atmosphere Effect with formula as below [6] with additional combination Hatfield et.al [8] in Susetyo [16] :

a. Generic Transformation of Vegetation Index
WDRVI (Wide Dynamic Range Vegetation Index)
WDRVI is transformation of vegetation index using deviation value of close infrared by adding constants formula as below

\[
WDRVI = \frac{(0.1 \text{Near Infra Red} - \text{Red})}{(0.1 \text{Near Infra Red} + \text{Red})}
\]  

b. Transformation of Vegetation Index Pressing Soil Background Effect
MSAVI2 (Second Modified Soil Adjusted Vegetation Index)
MSAVI is a transformation of vegetation index developed to minimize soil reflection effect as in SAVI and MSAVI formula with formula as below:

\[
MSAVI_2 = \frac{2(NIR)+1 - \sqrt{(2(NIR)+1)^2 - (8(NIR - Red))}}{2}
\]  

c. Transformation of Vegetation Index Pressing Atmosphere Effect
ARVI (Atmospherically Resistant Vegetation Index) is transformation of vegetation index developed to decrease sensitivity of atmosphere effect by applying normalization to blue radiance, red radiance and infrared close to formula below: Gamma values 1

\[
ARVI = \frac{(\text{Near Infra Red} - \text{rb})}{(\text{Near Infra Red} + \text{rb})}
\]

\[
rb = \text{Red} - \text{Gamma(\text{Red} - \text{Blue})}
\]
3.2.3 **Oil palm Identification**
This identification is used to help multispectral classification which will be done if there was similar appearance but factually different. For example the appearance of Oil palm and non-Oil palm which has similarity. This interpretation is done by help from same imagery data or other imagery data processed with certain composite therefore the land cover is seen. This process is done by showing the image parallel. Oil palm plantation has different pattern and texture from other objects surround the area. In comparison with other objects surround, Oil palm plantation has lined cluster pattern therefore it has regular and neat pattern that make multispectral classification easier.

3.2.4 **Multispectral Classification**
Classification method used is supervised classification with maximum likelihood algorithm which algorithm homogen object statistically shows normal distribution of histogram (Bayesian) [6]. Number of samples as training area help differentiate objects. Training area creation can be done with ROI (Region of Interest) with ENVI 5.1 software. Therefore 7 classes of land covers are found, which are residential use, replanting, young oil palm, old oil palm, grass, body of water and bare soil.

3.2.5 **Majority Filter**
After multispectral classification process, there will be anomali pixels in certain class. For example in Oil palm classification class, there are some pixels of body water thus the classification is not as expected, therefore Majority Filter operation is needed to make classification result more compact. Multispectral classification process and majority filter is chosen since both are general classification methods and suitable for wide are coverage. There are also some weaknesses if there were different land covers but had the same spectral numbers, they went to the same class, while in majority filter, if there were an object like a long and narrow garden path, it was generalized with other classes.

3.2.6 **Confusion Matrix**
Field accuracy test method used is by confusion matrix. This method uses independent data collection therefore it is logically acceptable. This accuracy test involve land cover result classification test.

4. **Result, Analysis, and Discussion**

4.1 **Identification of Oil Palm**
Oil palm identification process is done by appearance observation on image to choose ROI or region of interest as Oil palm identification key based on multispectral classification step. To ease Oil palm identification process, interpretation keys are used where old Oil palm has dark green color (in composite 321 true color) or dark red color(in composite 432 false color) while young Oil palm has light green color (in composite 321 true color) or light red color (in composite 432 false color). The appearance distinguish can be seen in Picture 2.
PT. Tunggal Perkasa Plantation is plantation owned by privat company with inti plantation and plasma plantation management (cooperation with local community). Before now, this Oil palm plantation was rubber plantation so there are some rubber trees owned by local people in the borderline of company Oil palm plantation. Beside that, this plantation is also share borderline with protected forest used as arboretum land as seen in Picture 3.

**Picture 2.** Visual Comparison Imagery SPOT-6 (a) in composite condition 321 True Color and composite condition 432 False Color  
(Source: Imagery Processing Result SPOT-6, 2015)

**Picture 3.** Plant Appearance (a) Antigonon leptopus (b) Turnera subulata (yellow) (c) Turnera subulata (white) (d) Arachis pintoi  
(Source: Field Survey Documentation, 2015)
Field condition shows that the main plants are oil palms but to keep soil ecology function and environment as well as to keep soil humidity for oil palm media so some other plants are planted in same field such as mucuna beans, ferns *Nephrolepis biserrata*, flower like *Turnera subulata*, *Euphorbia heterophylla*, *Cassia tora*, and *Antigonon leptopus*, and also natural fertilization in ilfunction inter-row with prunned palm frond, empty stem and etc as in Picture 4. The plants appearance will possibly disturb land use classification since it located near Oil palm and probably has same color.

![Picture 4. Plant Appearance](image)

Oil palm has regular and neat pattern because of good plantation management. Plantation operational standard requires specific plant space therefore it results in specific pattern such as plantation blocks. Oil palm location or site has close connection with block shape where each block is separated with plantation road. Different from other plantation plants, by looking at the plantation road, it could be guaranteed as Oil palm plantation. The pattern of local community Oil palm will be different in appearance because of the lack of plantation management system. Old Oil palm texture is rougher than young Oil palm texture. This is because old Oil palm has tight canopy where young Oil palm has thin canopy, especially for a very young Oil palm. ROI selection for Oil palm identification determine how land cover classification produced. Selection of pixels of samples which are more homogenous and overspread will result in better classification then heterogenous pixels. Heterogenous pixels will result in worse classification because of mixing pixels in training area which do not represent field appearance. Oil palm identification and other land cover are easier with compisite image 432 than composite image 321.

4.2. Multispectral Classification and Majority/Minority Filter
Classification used is multispectral supervised classification with maximum likelihood method and continued with final majority/minority filter classification which generalizetiny objects in bigger class. This method is the most common method in classifying activity. This classification method could classify object based on object spectral value with pixels. Image composite used in this multispectral classification is composite 432 as seen in Picture 2. Which shows red color for vegetation and cyan color for buiding. Land use determination is based on SNI 7645-1:2014 [11] for small scale mapping and middle scale mapping. Multispectral classification process is done with visual interpretation help which has done for Oil palm identification and land cover before. Purwadhi and partners [11] said
A location for Oil palm is suitable in some land covers like field, bushes, bare soil, conversion production forest and settlement of other function areal status; as well as the Oil palm plantation itself both mix plantation or not. This is appropriate with land use determination in research area where after the appearance identification both Oil palm and other land covers are gained seven land covers class in research area, which are body water, settlements, bush, bare-soil, replanting, old Oil palm and young Oil palm. Each transformation of vegetation index has different spectral value range for every object recorded. Table 1. Shows comparison spectral value range formed in image which in general the value can devide into two main object, which are Oil palm vegetation and non-vegetation. Oil palm object of vegetation is devided into two, which are young Oil palm and old Oil palm.

| Object/ Index Transformation of Vegetation | MSAVI2 | ARVI | WDRVI |
|-------------------------------------------|--------|------|-------|
| Non Vegetation                            | -0.013 s/d -0.884 | -0.045 s/d 0.425 | -0.833 s/d -0.625 |
| Young Oil palm                            | 0.881 s/d -0.594 | 0.596 s/d 0.689 | -0.148 s/d -0.016 |
| Old Oil palm                              | -0.884 s/d -0.669 | 0.425 s/d 0.596 | -0.625 s/d -0.148 |

PT. Tunggal Perkasa Plantation as research object area has clear borderline with homogenous plants which is Oil palm therefore the classification process is easier. Oil palm differentiate only by age because the appearance of Oil palm is difficult to see even with 6 metres resolution imagery. Old Oil palm is assumed as productive plant and young Oil palm is assumed as non-productive plant. Oil palm differentiation especially young Oil palm is not enough with only by visual interpretation and spectral value because young productive plant has same spectral with young non-productive plant. Filter majority process result in Picture 5. shows same objects classification therefore the result is better and closer to the real appearance then only applying multispectral classification. While in Picture 5. shows classification result and majority filter in transformation of vegetation index. The closest classification result from the real appearance is formed by ARVI transformation.

**Table 1.** Range of Spectral Value in Vegetation Object and Non Vegetation
(Source: SPOT-6 Imagery Process Result with Some Transformation of Index, 2015)

**Picture 5.** Visual Comparison of Multispectral Classification Result in SPOT-6 Imagery (a) Before Majority Filter, and (b) After Majority Filter
(Source: SPOT-6 Imagery Processing Result, 2015)
4.3. Mapping Accuracy Test with Confusion Matrix

The accuracy of multispectral classification result is counted with confusion matrix table. This accuracy test table compares appearance of classification result object with the real object in field. Based on classification and that majority filter then image result from ARVI transformation is the closest to real image then other transformation, therefore the land cover wide is attain, they are old Oil palm for 10.111.77 hectare, young Oil palm for 2.132.32 hectare, bare-soil for 125.65 hectare, replanting for 420.84 hectare, settlements for 66.98 hectare, bush for 25.23 hectare, manmade-lake for 5.58 hectare and smog for 136.92 hectare. Accuracy test result in Table 2. shows general result for old Oil palm or productive plant classification with felicitous result with accuracy to 99.46%.

**Picture 6.** Visual Comparison of Multispectral Classification Result and Majority Filter in SPOT-6 Imagery (a) With ARVI Transformation of Vegetation Index, (b) With MSAVI2 Transformation of Vegetation Index, and (c) With WDRVI Transformation of Vegetation Index

(Source: SPOT-6 Imagery Processing Result, 2015)
Table 2. Table of Land Cover Multispectral Classification Accuracy Test
(Source: Calculation Result of Interpretation Accuracy, 2015)

| FIELD          | Settlements | Replanting | Young Oil palm | Old Oil palm | Bush | Body Water | Bare Soil | Total | User Accuracy | Error Commission |
|----------------|-------------|------------|----------------|--------------|------|------------|-----------|-------|---------------|------------------|
| Replanting     | 64          | 0          | 0              | 0            | 0    | 0          | 0         | 64    | 100.00        | 0.00              |
| Product Accuracy | 90.14      | 100.0      | 100.0          | 96.86        | 100  | 100        | 100.0     | 327   | Overall Accuracy: 0.960 |
| Error Omission | 9.86        | 0.00       | 0.00           | 3.14         | 0.0  | 0         | 0.0       | 0.00  | Kappa: 0.935 |

The accuracy is affected by sampling selection and numbers of selected sampling. For example in replanting classification with accuracy 82.35% where from 34 samples, there are 6 samples of settlements. This is because those 6 samples have almost similar rooftop color with replanting land. A block of settlements in plantation around the hill made them do not look different with replanting land. Then in old Oil palm classification with 99.46% accuracy, where from 186 samples, there is 1 sample goes to settlements.

Moreover in young Oil palm classification with 81.25% accuracy with total 32 samples, there are 6 samples of old Oil palm or productive plant. This is because new-old Oil palm looks like young Oil palm. In fact, visual appearance and spectral from young Oil palm could mean some more appearance like old Oil palm but youngOil palm (for example TM 5, then young Oil palm (for example TM 1-3) or land cover plants like beans and nephrolepis.

Land covers like settlements, bare-soil, bush, and body water have high accuracy to 100%. This means no single classification mistake or it can also means sample selection for classification accuracy test is felicitous even with random. Interpretation of the object is easier because the appearance is clearer and has specific interpretation key. Picture 7, Picture 8, and Picture 9 show visual appearance of an object in image which possibly have different field information therefore the interpretation result and classification as well as filtering could make accuracy mistakes.
Picture 7. Visual appearance result of settlements (a) Multispectral classification spektral in SPOT-6 imagery with composite 432 with (b) real appearance of water of body in field (c) real appearance of Oil palm industrial complex in field, dan (d) staff settlements complex with living facilities (Source: Field Survey Result of Multispectral Classification Check [14])

Picture 8. Old Oil palm Visual Appearance (a) Marihat Variety in SPOT-6 Imagery Composite 432, (b) Socfind Variety in SPOT-6 Imagery Composite 432, (c) Real Appearance of Marihat Variety in land, (d) Real Appearance of Socfind Variety in land (Source: Field Survey Result of Multispectral Classification [14])
Accuracy test result of multispectral classification with real condition and overall accuracy have approximately 96% while classification accuracy for each land cover has different accuracy. Kappa index shows in 0.935. This means in this multispectral classification process, the writer could avoid interpretation mistake of 93.5% therefore the probability of mistake is only about 6.5%. According to [6] agronomy researchers use accuracy limit as much as 90% for plant classes that also could be said that overall land cover classification results have high accuracy.

5. Conclusion
Research result shows SPOT-6 imagery is capable to identify and map land use in Oil palm plantation with high accuracy as high as 96% with best multispectral classification from ARVI transformation. Mapping accuracy in land use for settlements is 100%, replanting is 82.35%, young Oil palm is 81.25%, old Oil palm is 99.46%, bush is 100%, body water is 100% and bare-soil is 100% therefore land wide for old Oil palm is 10.111,77 hectare, young alm oil is 2.132,32 hectare, bare-soil is 125,65 hectare, replanting 420,84 hectare, settlements 66,98 hectare, bush 25,23 hectare and body water 5,58 hectare.

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