Comparison of Optic Landsat-8 and SAR Sentinel-1 in Oil Palm Monitoring, Case Study: Asahan, North Sumatera, Indonesia

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Abstract: World production of palm oil increased spectacularly in the last 20 years, especially in Indonesia and Malaysia. As the largest producer, good management in oil palm plantation is very important, the expansion of plantation also must be well planned, because its existence must not affect the surrounding environment. Therefore the information of oil palm age or condition of their growth is needed. Remote sensing has significant potential to aid oil palm monitoring and detection effort. It also provides a cost-effective method to these purposes and at same time provides side specific assessments of management areas. Synthetic Aperture Radar (SAR) is crucial for this task. The SAR is an active sensor that operates in all weather condition and daylight independent delivering information all year around at the time that is needed. SAR is sensitive to texture, size and orientation of structural objects, moisture content and ground conditions. This study has objectives to compare the methods that have been developed to monitor oil palm by using optic data and SAR data. The data that used are Landsat 8 and Sentinel-1. The study area is Asahan district North Sumatera. The regression analysis by using regression method indicates that oil palm age can be monitored by using NDVI or backscatter of SAR values with growth model. The $R^2$ of model for Landsat 8 is 0.85 and 0.77 for Sentinel 1. Both models can be used for monitoring the condition and age of oil palm.

Key words: oil palm plantation, Sentinel-1, backscatter, growth model

1. Introduction
Oil palm (Elaeis guineensis Jack.) is one of the world’s most important tropical tree crops. It is grown commercially in Southeast Asia, Africa and Central and South America for its palm oil, the world’s second most widely consumed edible oil [1]. World production of palm oil has increased spectacularly in the last 20 years, especially in Indonesia and Malaysia. Indonesia is the largest producer of palm oil (data of oil world).

As the largest producer, monitoring of oil palm condition is very important. This is needed for good management in fertilization plan, irrigation, replanting, yield estimation and other plans. By
using information from monitoring. The expansion of plantation also must be well panned, because its existence must not affect the surrounding environment. Government also can plan the regional development properly and avoid the decreasing of environment quality. Identification, mapping and monitoring are therefore required to impose such ideal working environment.

Age of oil palm is the main parameter in yield estimation. Figure 1 shows the strong correlation between age and oil palm productivity \[6,7\] Therefore the mapping and monitoring of oil palm to estimate of yield is important. It will help Ministry of Agriculture because the data that collected by conventional method doesn’t give pretty information with high accuracy level and not in spatial distribution format.

![Figure 1. The Productivity of oil palm according to it’s age](image)

Remote Sensing has significant potential to aid oil palm monitoring and detection efforts. It also provides a cost-effective method to these purposes and at the same time provides site-specific assessments of management practices and growth performance of the palms. Some aspects of oil palm monitoring have been studied. Within the domain of land cover classification, previous studies show that oil palm can be mapped, for instance, have reported that oil palm plantation in some South East Asian countries can be observed by coarse-scale MODIS [2].

Figure 2 shows the condition of oil palm trees from at very young age up to old age from optic image and form the field. The optic image with RGB of true colour describe the real condition of oil palm trees. At a young age the oil palm tree is still short, with a little leaf midrib and the leaves are still short, whereas at an older age the oil palm trees become taller, with a greater number of midribs and long leaves. As a result of these differences, the appearance of the optic image is different. In optical images, young palm oil looks light green, and the surface of the soil is still visible between oil palm, whereas in old oil palm, oil palm looks greener and increasingly tight.

The changes in the greenness of the oil palm plants seen in the optic image can be investigated using the greenish index. Satellites imaging data of Landsat Thematic Mapper [3,4] and SPOT [5] have been successfully used to identify oil palm growing areas and to map differences in palm age at early stages of growth. Research by LAPAN [8] on oil palm plantation in Lampung Sumatera Indonesia showed that the regression coefficient between Landsat spectral band and oil palm age is 69%. Band 5 of Landsat, IRI (Infra Red index), and MIRI (Middle Infra Red Index) of Landsat give the biggest correlation with oil palm age. Research by LAPAN [9] also showed that the growth of oil palm can be explained by NDVI of SPOT6 with determination coefficient around 87%.

Since many oil palm plantations are located in tropical areas, Synthetic Aperture Radar (SAR) is crucial for this task. The SAR is an active sensor that operates in all weather condition and daylight independent delivering information all year around at the time that is needed. SAR is sensitive to texture, size and orientation of structural objects, moisture content and ground conditions [10]. The differences in characteristics of optic and SAR will give complimentary performance of oil palm trees mapping.
The difference in tree height, number of leaf midribs and length of palm oil leaves gives a different surface texture, thus providing a different scattering value from the SAR image. The study that has been carried out other researchers using PALSAR ALOS shows the pattern of logarithmic curve pattern is the most suitable to describe oil palm growth [15][20].

This study has aims to build and compare the growth model of oil palm by using optic Landsat-8 and SAR Sentinel-1. Sentinel-1 is the first of the Copernicus Programme satellite constellation conducted by the European Space Agency. Sentinel-1 is being realized by an industrial consortium lead by Thales Alenia Space Italy as Prime Contractor, with 3 Astrium Germany being responsible for the C-SAR payload, incorporating the central radar electronics sub-system developed by Astrium UK. This space mission is composed of two satellites, Sentinel-1A, Sentinel 1B, that carry a C-band synthetic aperture radar which provides a collection of data in all-weather, day or night.

The models that can be used for monitoring the condition of oil pam plantation. The model that obtained by SAR Sentinel-1 will become as good options instead Landsat-1 in case there in no Landsat data with minimum coverage of cloud.

2. Method
   2.1. Study Area
   This area of study is located in Asahan District, North Sumatra (Figure 3). The location of plantation area is in 2.98 East Longitude; 99.67 North Latitude and 2.92 East Longitude; 99.75 North Latitude where the type of soil in this area is alluvial, humus glay, regosol and red yellow podzolic. The primary data used for this study is LS-8 dated 16 July 2018 and Sentinel-1 dated April 2018 with polarization HH and HV data obtained from Data and Technology Center of LAPAN, and supporting data is planting calendar obtained from IOPRI (Indonesian Oil Palm Research Institute). that then converted to oil palm age (Figure 4)
2.2. Data Processing

The data processing that run in this study followed Figure 5 for optic data and Figure 6 for SAR data. For optic data, NDVI is calculated from the visible and near-infrared light reflected by vegetation [21], [22]

\[
\text{NDVI} = \frac{\text{NIR} - \text{RED}}{\text{NIR} + \text{RED}}
\]

Identification and classification of land use by using SAR was done by using RGB image with combination HH, HV, HH-HV. Backscattering coefficient data are stored as digital number (DN) in unsigned 16 bit. The DN values can be converted to gamma naught values in decibel unit (dB) using the following equation:

\[
\gamma_0 = 10 \log_{10}(\text{DN}^2) + CF
\]

where, \( CF \) is a calibration factor, and \(<\) is the ensemble averaging -83.0 dB for the CF value. [17]
After obtaining NDVI values for optical data and backscatter values for SAR data, a regression analysis is performed to obtain the oil palm growth equation using both optical data and SAR. The growth model then can be used to monitor of the oil palm in the field.
3. Result and Discussion

3.1. Growth Model by using optic data

Figure 8 (on the left) shows optical LS data with a composite (R, G, B) true color, while the right picture shows the result of the conversion of a digital number (DN) to NDVI value. By investigate the value of NDVI it can be seen that when the age of oil palm is still young, the NDVI value is still low, then increases to around the age of 13-14 years and finally decreases. This pattern can be described as a graph as in Figure 7.

![Figure 6. The RGB of LS-8 and NDVI image](image)

![Figure 7. Oil Palm Growth Model from LS data](image)

The pattern of oil palm growth by using NDVI from LS has equation:

\[ Y = -0.0003X^2 + 0.0068X + 0.4388 \]

where \( X \) is the age of oil palm and \( Y \) is the NDVI.
3.2. Growth Model by using SAR data

The RGB of Sentinel-1 image shows that the oil palm plantation have different colour from dark to the light. The dark is the area of very young oil palm, because the roughness of surface on young oil palm is small, meanwhile the lighter colour means the scatter is very high that come from rough surface area or mature and older oil palm. The pattern of backscatter for HH image and HV image according to its age are described in figure 9.

SAR backscatter analysis at each age level for each polarization was carried out to determine this relationship. The results of the analysis show that the backscatter value of oil palm plant SAR increases from 1 year up to about 13 years. Same as the pattern of NDVI for optic data, the backscatter then decrease after this age up to age around 25 years. By using regression analysis, the formula for oil palm growth by SAR Sentinel-1 area:

\[ Y = -0.0222X^2 + 0.4579X - 17.311 \]  
\[ R^2 = 0.7719 \]

for HV polarization and

\[ Y = -0.0219X^2 + 0.4594X - 9.8191 \]  
\[ R^2 = 0.6834 \]

for HH polarization.

This pattern is different from the pattern obtained using ALOS PALSAR data where equation of oil palm growth models is logartimic [15]. The backscatter of L-band of ALOS PALSAR increases up to the age of around 12 or 13 and then increases slowly, meanwhile the backscatter of Sentinel-1 decreases after the age of 13 years due to the oil palm leaves getting closer and touching each other.
with other oil palm trees so that the surface becomes finer or flat. Sentinel-1 with a short wavelength only penetrate to the leaves so that the value of the backscatter for the dense canopy becomes smaller.

From the results of the regression analysis of both optical and SAR data, it can be seen that the model that can describe oil palm growth is polynomial and the curves are parabola. This shows an increase of vegetation index that reflects the greenness and density of oil palm on optical data and the increase of backscatter values on SAR data which reflects the surface roughness of the oil palm plantation area, until around 12 or 13 years later decreases both NDVI of optical and backscatter of SAR data.

The similarity of the graph pattern can be a complementary optical data if cloud-free optical data is not available, where the spatial resolution of LS data and Sentinel-1 data is almost the same. This growth pattern is a tool to monitor oil palm growth in areas with the same geographic and climate conditions as Asahan North Sumatera.

4. Conclusion
This study found the oil palm growth models by using optic LS data and SAR Sentinel-1. Both models have same patterns of curve: parabola. The growth model can be used for monitoring of oil palm in the area that have similar condition (soil type, climate, etc).

Model that found for optic LS data is:

\[ Y = -0.0003X^2 + 0.0068X + 0.4388, \text{ with } R^2 = 0.85, \]

where X is the age of oil palm and Y is the NDVI

And for Sentinel-1 with polarization HV is:

\[ Y = -0.0222X^2 + 0.4579X - 17.311 \text{ with } R^2 = 0.77 \]

where X is the age of oil palm and Y is the backscatter.

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