CORRELATION MODEL OF OIL PALM AGE BASED ON OPTICAL AND RADAR SENSORS

Moch Iqbal Fauzan, Anggita Pratiwi Sutrisno, Soni Darmawan*, Rika Hernawati

Institut Teknologi Nasional Bandung (ITENAS),
Jl. P.H.H Mustofa No. 23, Bandung 40124, Indonesia,
Corresponding Author : soni_darmawan@itenas.ac.id

KEY WORDS: Oil Palm, Age, NDVI, Sentinel, Google Earth Engine

ABSTRACT: Indonesia is the largest producer of palm oil that is 80% of palm oil is used for edible products and 20% is used for the oleochemical industry. Oil palm is one of the plantation commodities that provides the highest income, however nowadays the oil palm production has decreased because of older, pet and diseases. One way to increase the productivity of oil palm it can do by continuous monitoring through the age of the oil palm. Monitoring the age of oil palms can be done by applying remote sensing technology using optical and radar sensors. The objective on this study is to investigate Correlation between Oil Palm Age with NDVI on Landsat 8 and backscattering on Sentinel-1A satellite imagery. Study case in the Asahan area, North Sumatra Province, Indonesia. Processing data in this study using the Cloud Computing Google Earth Engine platform. The data that is used as a parameter in the extraction process for Landsat-8 images uses the NDVI vegetation index value, while the Sentinel-1 SAR data uses C-Band with 2 VV and VH polarizations which produce backscatter values. The result was found correlation model of Landsat-8 image is $y = -0.0002x^2 + 0.0052x + 0.7685$ with $R^2 = 0.85$. In sentinel image the correlation model generated for each polarization is $y = -0.0039x^2 + 0.1193x - 7.9247$ with $R^2 = 0.85$ on VV polarization and $y = -0.0036x^2 + 0.1242x - 15.344$ with $R^2 = 0.81$ on VH polarization. From these results, both have different model values with different R^2 values. On this case NDVI and sentinel-1 on VV polarization is the best result and the most correlated.

1. INTRODUCTION

Indonesia is one of the countries in Asia that is the largest producer of palm oil, it is supported because palm oil is a crop that is able to produce production in the form of bunches of fresh fruit and crude palm oil (CPO) and actively produce oil (Cheng et al., 2016) to be distributed for the needs of the community and is a factor that increases the country's economy that will be very useful in the future (Kementrian Pertanian, 2020)(Soni. Darmawan et al., 2021). 80% of palm oil is used for edible products and 20% is used for the oleochemical industry. In increasing palm oil production, a way is done by monitoring through age parameters (Soni. Darmawan et al., 2016). This parameter is a significant parameter in palm oil monitoring (Soni. Darmawan et al., 2018). The age of palm oil is able to provide information related to the feasibility of palm oil for harvesting and rejuvenation (Mariyah et al., 2018).

The palm oil assessment was conducted in a case study of Asahan Regency, North Sumatra Province, Indonesia by utilizing remote sensing technology on google earth engine platforms and using Landsat-8 and Sentinel-1A satellite imagery. The use of the platform is used for the process of extracting data from the NDVI value for Landsat-8 satellite imagery and the backscatter value with VV and VH polarization on Sentinel-1A for each palm age block. So that later the extraction of data is processed using regression methods to find out whether there is a relationship or correlation of the variety used, namely between the age variable with the value of NDVI and the polarization of VV, VH. The extraction of such data will produce a correlation model based on the age of palm oil from the value of NDVI and polarization of VV, VH. The objective on this study is to investigate Correlation between Oil Palm Age with NDVI on Landsat 8 and backscattering on Sentinel-1A satellite imagery.

2. MATERIALS AND METHODS

2.1 Study Area

The case study used for this study was Asahan County. The selection of this case study is because in the Asahan region there are oil palm plantations located in Hessa Plantation, Simpang Empat, Asahan Regency, with 2.98 ° east longitude and 99.67 ° north latitude as shown in Figure 1. This regency itself is located in the province of North Sumatra and is located in the capital of Kisaran, Indonesia. The area of Asahan regency is 3,732.97 km².

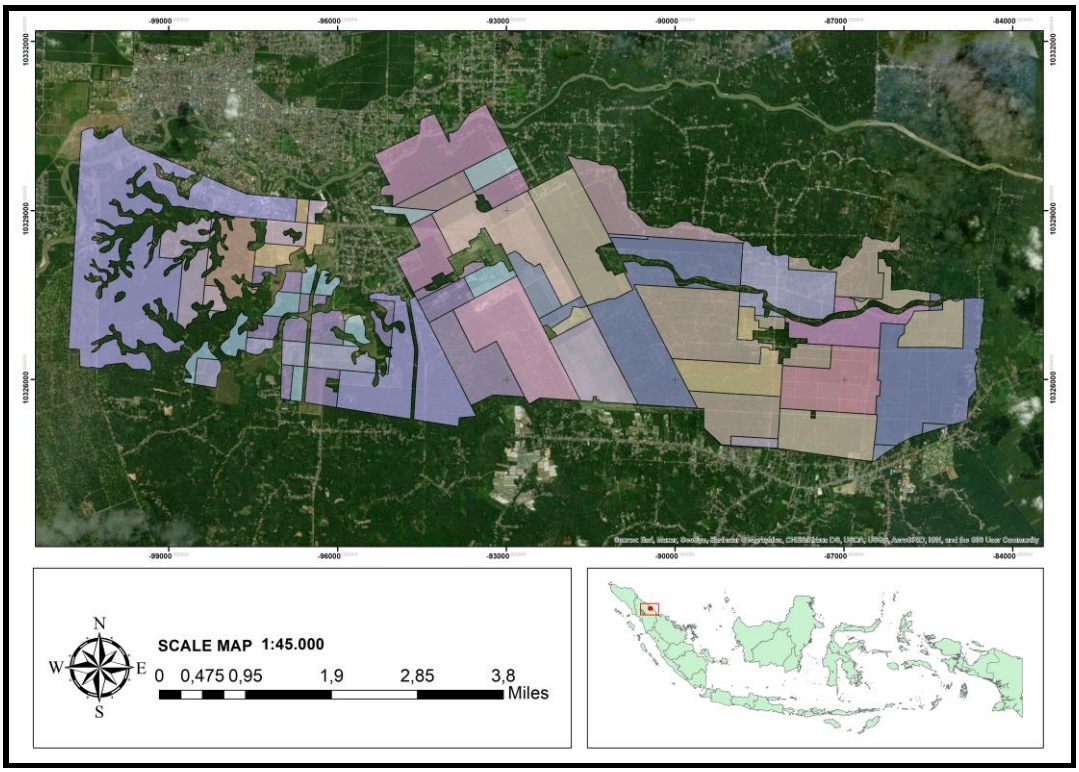

Figure 1. Case Study of Asahan, North Sumatra Province, Indonesia

2.2 Methodology

The methodologies used already include data collection, image processing, data extraction, and model creation. In Figure 2 is a scheme to create a corelation model based on the age of oil palm.

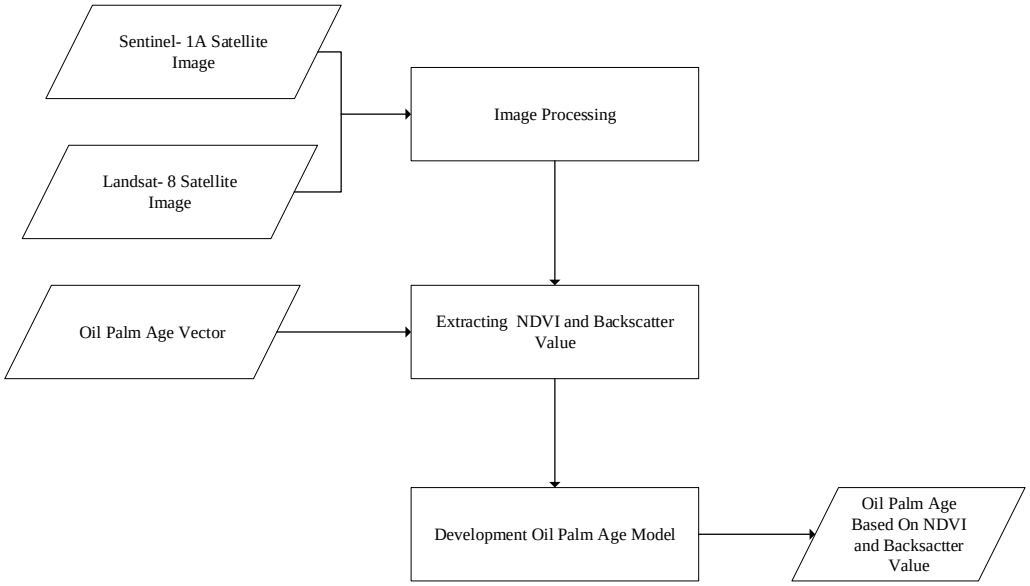

Figure 2. Methodology Of Corelation Model Based On Age Oil Palm

2.2.1 Data Collection

At this stage the data collected is Landsat-8 satellite imagery, Sentinel-1A satellite imagery, and palm age vector data (Figure 2) which will be used in the data extraction process. Sentinel-1A equipped Synthetic Aperture Radar (SAR) has the ability to capture images using spectral C-band under any circumstances, both at night and also when the weather is as bad as the abundance of clouds (ESA Copernicus, 2021). Sentinel-1A on Google Earth Engine is sentinel-1 data with level 1 Ground Range (GRD) and spatial resolution of 10 meters. Ground Range data has been projected to range on the surface using earth's ellipsoid model (ESA, 2021).

Landsat-8 is an optical image equipped with 2 sensors, namely OLI (Operational Land Imager) and TIRS (Thermal Infrared Sensor). OLI sensor is a sensor that has a spatial resolution of 30 meters, while TIRS sensor has

spatial resolution as far as 100 meters (Yanuar et al., 2018).

Palm age vector data is used in the data extraction process in each age box (Figure 3) to retrieve the NDVI value on Landsat imagery and the VV polarization value, VH on the Sentinel image.

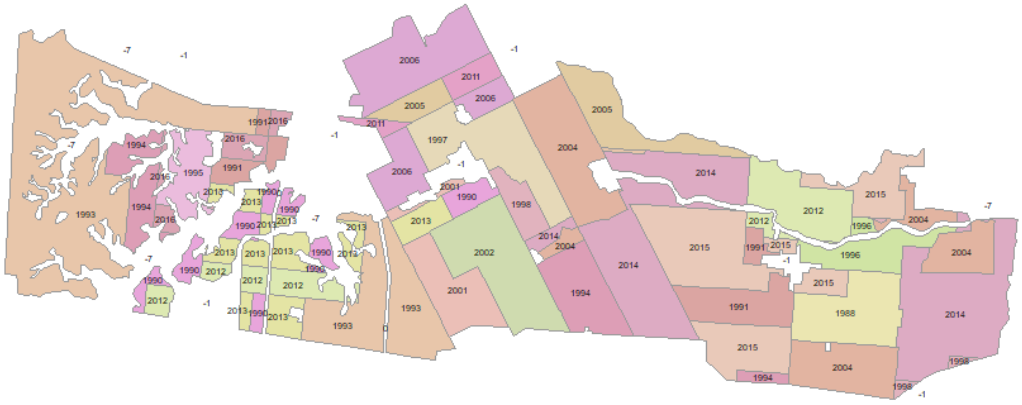

Figure 3. Oil Palm Age of Asahan, North Sumatra Province, Indonesia

2.2.2 Processing Image

Processing images is using Google Earth Engine cloud computing. On the Google Earth engine platform, Landsat imagery has been processed radiometric correction, atmospheric correction, and geometric correction, and sentinel imagery has corrected Radiometric Calibration and Terrain Correction. Furthermore, the Landsat data is carried out by the NDVI process using coding that has been available on Google Earth Engine. Sentinel is then done speckle filtering process in the same way as NDVI by using Speckle Filtering coding that has been available on Google Earth Engine.

(1) The NDVI value is used to look at a plant's greenish index and is a mathematical combination of the red band and the NIR (Near-Infrared Radiation) band (Lillesand & Kiefer, 1997). The NDVI correlation is derived from the ratio between the red band and the near infrared band of the remote sensing image, so that the "greenish" index of vegetation can be determined (Hernawati & Darmawan, 2017). The Normalized Difference Vegetation Index (NDVI) is the most used ratio index for vegetation (Hernawati & Darmawan, 2018). NDVI is calculated on a per-pixel basis of the normalization difference between the red and near infrared bands on the image. The formula of this NDVI is (Prasetyo et al., 2017):

$$NDVI = \frac{NIR - RED}{NIR + RED} \quad (1)$$

With :
NIR = *Band NIR Infrared*
RED = *Band Red*

(2) Polarimetric Synthetic Aperture Radar (PolSAR) is the science of obtaining, processing, and analyzing the polarizing state of electromagnetic fields (Boerner, 2008). The radar system transmits electromagnetic waves, using certain polarizations to achieve the desired scattering. Thus, it can be possible to produce some scattering information that is considered taking into account the properties of electromagnetic waves scattered with respect to incoming waves, which are essentially waves transmitted by radar (López-Martínez & Pottier, 2021). The polarization values of VV and VH are used to analyze the relationship between the back scattering values extracted and the biophysical parameters of the palm oil plant to predict age (S. Darmawan et al., 2020).

(3) Radiometric Calibration is a procedure that converts digital pixel values into radiometrically calibrated SAR backscatters (Filipponi, 2019). Calibration of this scattering value is indispensable for the comparison of radar images obtained with different sensors or with images obtained by the same sensor if the image is obtained in a different mode or by processing on a different processor (Amini & Sri Sumantyo, 2010).

(4) Terrain Correction to eliminate distortions caused by topographic variations so that geometric representations of images will be as close as possible to the circumstances in reality in the field (Filipponi, 2019). Terrain Correction's goal for SAR imaging is to minimize the effect of SAR geometry (foreshortening, layover, and shadow) on radar imagery (Soni. Darmawan et al., 2019; Mohd Najib et al., 2020)

(5) Speckle Noise or often appears in SAR data. This speckle is a common problem with SAR data (Dekker, 1998). This speckle effect is caused by coherent interference of waves reflected from the number of primary scatters (Gebhardt et al., 2012). The speckle filtering process is therefore indispensable, to estimate covariance or matrix coherence by maintaining spatial resolution and spatial detail of data (López-Martínez & Pottier, 2021)

2.2.3 Data Extraction

Data extraction is the process of selecting and retrieving data from one or more sources (Carolita et al., 2019). This data extraction process is done in Google Earth Engine by finding out on each pixel in each data. This data extraction process is carried out in each age box obtained from LAPAN by taking as many as 18 samples in each age box. The value taken in the form of NDVI value and also backscatter value in Sentinel-1 is in the polarization of VV and VH.

2.2.4 Correlation Model Of Oil Palm Age

After retrieving data or extraction of backscatter data from sentinel-1 radar data and NDVI values from Landsat, sample data that has been taken through the data extraction process is created correlation models using regression methods. The existing sample is sorted and arranged according to the age of the palm box. From each age box, the values used as values for the creation of correlation models are the average values of NDVI samples and VV,VH polarizing backscatters.

3. RESULTS

Landsat-8 and Sentinel-1A data are both processed using Google Earth's cloud computing engine. Sentinel-1A data is processed using Lee Filter for speckle filtering process at each polarizing and Landsat-8 data uses NDVI values. In each data used to produce NDVI and Backscatter values on VV polarization, different VH is also affected by the physical properties of palm oil plants. In this study the age range in palm oil was divided into 5, 0-5 years, 5-10 years, 10-15 years, 15-20 years, and 20-25 years.

The correlation model of the age of palm oil using the NDVI value shown in Figure 4, it can be seen that the value of NDVI which is at the age of 5-10 years or young age gets an NDVI value close to 0.79 then when the age increases at 15 years or the age of adolescence the value of NDVI obtained also increases to be at the point of 0.81 but the value again decreases with the age of palm oil, at the age of > 16 years the value of NDVI was reduced to 0.76. This correlation model of palm age produces the quadratic formula $y = -0.0002x^2 + 0.0052x + 0.7685$ with $R^2 = 0.8516$.

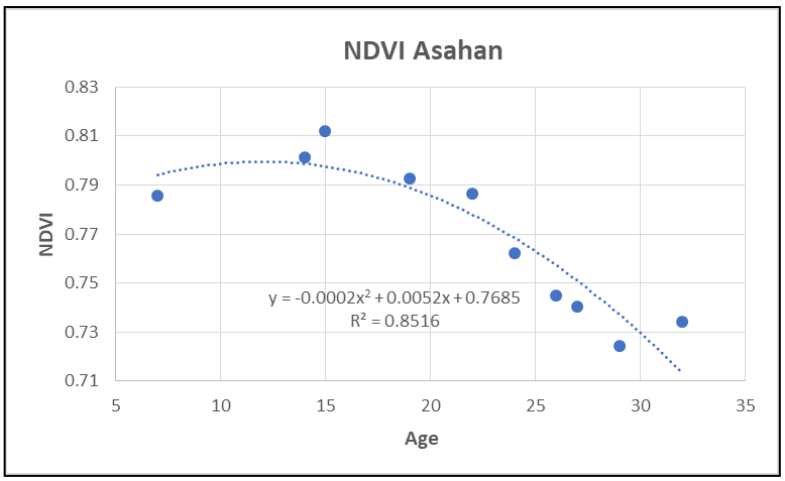

Figure 4 Oil Palm Model Using NDVI

The correlation model of palm age uses Sentinel-1A with VV polarization shown in Figure 5. The resulting backscatter value starts at -7.4 dB at the age of 5-10 years, then the value increases to -7.1 dB at the age of 10-15 years, at a value of -6.9 dB at the age of 15-20 years, then at the age of > 20 years has a value of -7.2 dB. This correlation model of palm age results in quadratic regression $y = -0.0039x^2 + 0.1193x - 7.9247$ with $R^2 = 0.8525$.

As for the palm age model using Sentinel-1A with VH polarization shown in Figure 6. Having a backscatter value starts at -14.7 dB at 5-10 years of age, then becomes -14.2 dB at 10-15 years old, at -14 dB at 15-20 years old, at > 20 years has a value of - 14.4 dB and further decreases. This correlation model of palm age results in quadratic regression $y = -0.0036x^2 + 0.1242x - 15,344$ with $R^2 = 0.8056$.

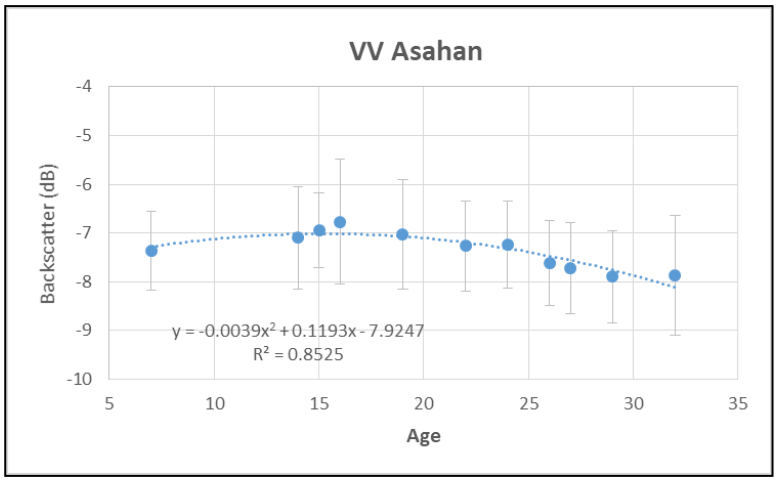

Figure 5 Oil Palm Model Using Polarization VV

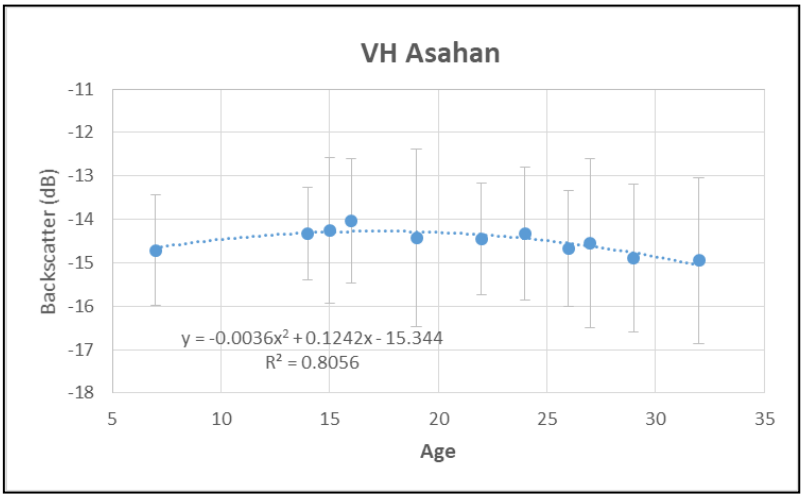

Figure 6 Oil Palm Model Using Polarization VH

Both produce NDVI and backscatter values on VV polarization, vh that vary depending on the age range of palm oil used during the data extraction process, this is due to the age of the palm oil plant itself which is influenced by the physical properties of the plant. In the resulting parabolic graph, it illustrates that the values of NDVI and the polarization of VV, VH undergo an up and down phase in each age range. Where at the age of young palm oil (0-5 years) the value of NDVI and polarization of VV, VH always decreases, then when entering adolescence (6-15 years) the value of NDVI and polarization of VV, VH always increases, and decreases back in old age (> 16 years).

The increase in NDVI value and polarization of VV, VH at a young age (0-5 years) to adolescence (6-15 years) is caused by the title of palm oil plants that are increasingly more and more and more close so that the content of chlorophyll in plants increases every year. In addition, the young age and age of adolescence is a very active age in producing productivity of either fresh fruit bunches or crude palm oil.

The decrease in the value of NDVI and the polarization of VV, VH in old age (> 16 years) is caused by in this age range the activeness of palm oil in production decreases in accordance with its physical properties where the green pigment of the leaves or chlorophyll begins to decrease and the firmness of the header of palm oil begins to decrease with age.

4. CONCLUTIONS

The conclusions of the processing of NDVI and Sentinel-1A show the same thing, that each of these data can predict the age of palm oil. Palm age regression models based on NDVI and backscatter data can be used specifically to analyze the relationship between extracted reverse scattering values and biophysical parameters of palm oil plants to predict, build models, and estimate age parameters. The palm oil regression model based on the NDVI on Landsat-8 and the C band wavelength on the Sentinel-1A satellite can estimate the longevity of the palm by analyzing the vegetation canopy cover to distinguish young and old palm oil plants.

The NDVI and Sentinel data produce quadratic regression models with different R2 values shown in Table 1. R2 is the coefficient of determination where R2 can show how much influence the value of X has on the value of Y, where the value of X in this study is the age of Palm Oil and Y is the value of NDVI and also Backscatter resulting

from the polarization of VV and VH. The result was found correlation model of Landsat-8 image is $y = -0.0002x^2 + 0.0052x + 0.7685$ with $R^2 = 0.85$. In sentinel image the correlation model generated for each polarization is $y = -0.0039x^2 + 0.1193x - 7.9247$ with $R^2 = 0.85$ on VV polarization and $y = -0.0036x^2 + 0.1242x - 15.344$ with $R^2 = 0.81$ on VH polarization. In this case, the palm oil age model is seen from the R^2 value that is more potential to be used and also has a greater value than others is in the polarization of VV using Sentinel-1 data. But it does not rule out the possibility that the palm oil age model produced based on NDVI data can be used to develop the age model of palm oil in Indonesia for the future.

5. REFERENCES

Amini, J., & Sri Sumantyo, J. (2010). Employing a Method on SAR and Optical Images for Forest Biomass Estimation. *Geoscience and Remote Sensing, IEEE Transactions On*, *47*, 4020–4026. https://doi.org/10.1109/TGRS.2009.2034464

Boerner, W. M. (2008). *Basic concepts in radar polarimetry*. 100.

Carolita, I., Yudhatama, D., Dirgahayu, D., Darmawan, S., Hernawati, R., Noviar, H., Kartika, T., Dewi, E. K., Arifin, S., & Silvia. (2019). *INFORMASI SPASIAL TEMATIK KLASIFIKASI TANAMAN SAWIT BERDASARKAN UMUR* (1st ed., Issue 1). Pusat Pemanfaatan Penginderaan Jauh, LAPAN.

Cheng, Y., Yu, L., Cracknell, A. P., & Gong, P. (2016). Oil palm mapping using Landsat and PALSAR: a case study in Malaysia. *International Journal of Remote Sensing*, *37*(22), 5431–5442. https://doi.org/10.1080/01431161.2016.1241448

Darmawan, S., Carolita, I., & Ananta, E. (2020). Identification of Oil Palm Plantation on Multiscatter and Resolution of SAR Data Using Variety of Classifications Algorithm (Case Study: Asahan District, North Sumatera Province). *IOP Conference Series: Earth and Environmental Science*, *500*(1). https://doi.org/10.1088/1755-1315/500/1/012075

Darmawan, Soni., Carolita, I., Hernawati, R., Dirgahayu, D., Agustan., Permadi, D. A., Sari, D. K., Suryadini, W., Wiratmoko, D., & Kunto, Y. (2021). The Potential Scattering Model for Oil Palm Phenology Based on Spaceborne X-, C-, and L-Band Polarimetric SAR Imaging. *Journal of Sensors*, *2021*(6625774), 14. https://doi.org/10.1155/2021/6625774

Darmawan, Soni., Naser, M., Carolita, I., Sari, D. K., & Kania Sari, D. (2018). State of The Art Remote Sensing Technology For Oil Palm Management In Indonesia. *Proceedings Asian Conference on Remote Sensing (ACRS) 2018, Kuala Lumpur, Malaysia*, *1*(1), 830–834.

Darmawan, Soni., Sari, D. K., Takeuchi, W., Wikantika, K., & Hernawati, R. (2019). Development of aboveground mangrove forests' biomass dataset for Southeast Asia based on ALOS-PALSAR 25-m mosaic. *Journal of Applied Remote Sensing*, *13*(04), 1. https://doi.org/10.1117/1.jrs.13.044519

Darmawan, Soni., Takeuchi, W., Haryati, A., Najib, R. A. M. A. M., & Na'Aim, M. (2016). An investigation of age and yield of fresh fruit bunches of oil palm based on ALOS PALSAR 2. *IOP Conference Series: Earth and Environmental Science*, *37*(1). https://doi.org/10.1088/1755-1315/37/1/012037

Dekker, R. J. (1998). Speckle filtering in satellite SAR change detection imagery. *International Journal of Remote Sensing*, *19*(6), 1133–1146. https://doi.org/10.1080/014311698215649

ESA Copernicus. (2021). *Sentinel-1*. 2002-2021.

ESA, S. O. (2021). *Sentinel-1A Acquisition Modes*. 2002-2021.

Filipponi, F. (2019). Sentinel-1 GRD Preprocessing Workflow. *Proceedings*, *18*(1), 11. https://doi.org/10.3390/ecrs-3-06201

Gebhardt, S., Huth, J., Nguyen, L. D., Roth, A., & Kuenzer, C. (2012). A comparison of TerraSAR-X Quadpol backscattering with RapidEye multispectral vegetation indices over rice fields in the Mekong Delta, Vietnam. *International Journal of Remote Sensing*, *33*(24), 7644–7661. https://doi.org/10.1080/01431161.2012.702233

Hernawati, R., & Darmawan, S. (2018). Change detection analysis using NDVI in Bandung, Indonesia. *Proceedings - 39th Asian Conference on Remote Sensing: Remote Sensing Enabling Prosperity, ACRS 2018*, *2*(October 2018), 1203–1210.

Hernawati, R., & Darmawan, S. (2017). Analisis Kerapatan Vegetasi Berbasiskan Data Citra Satelit Landsat Menggunakan Teknik NDVI di Kota Bandung Tahun 1990 dan 2017. *Seminar Nasional Rekayasa Dan Desain Itenas 2018. Peranan Rekayasa Dan Desain Dalam Percepatan Pembangunan Nasional Berkelanjutan, 4 Desember 2018, Kampus Institut Teknologi Nasional - Bandung.*, 33–39.

Kementrian Pertanian. (2020). Statistik perkebunan Indonesia 2018-2020. *Buku Statistik Perkebunan Indonesia*, 1–82.

Lillesand, T. ., & Kiefer, R. . (1997). Penginderaan Jauh dan Interpretasi Citra. Diterjemahkan : Dulbahri, Prapto Suharsono, Hartono, Suharyadi. In *Universitas Gajah Mada, Yogyakarta*.

López-Martínez, C., & Pottier, E. (2021). Basic Principles of SAR Polarimetry. In *Remote Sensing and Digital Image Processing* (Vol. 25, pp. 1–58). Springer Science and Business Media B.V. https://doi.org/10.1007/978-3-030-56504-6_1

Mariyah, M., Syaukat, Y., Hartoyo, S., Fariyanti, A., & Krisnamurthi, B. (2018). Penentuan Umur Optimal

Peremajaan Kelapa Sawit di Kabupaten Paser Kalimantan Timur. *Jurnal Ekonomi Kuantitatif Terapan*, 103. https://doi.org/10.24843/jekt.2018.v11.i01.p08

Mohd Najib, N. E., Kanniah, K. D., Cracknell, A. P., & Yu, L. (2020). Synergy of active and passive remote sensing data for effective mapping of oil palm plantation in Malaysia. *Forests*, *11*(8). https://doi.org/10.3390/F11080858

Prasetyo, N. N., Sasmito, B., Prasetyo, Y., & Kunci, K. (2017). *(Area Studi : Kabupaten Semarang)*. *6*, 21–27.

Yanuar, R. C., Hanintyo, R., & Muzaki, A. A. (2018). PENENTUAN JENIS CITRA SATELIT DALAM INTERPRETASI LUASAN CAHAYA TAMPAK Studi Kasus : Wilayah Pesisir Sanur. *Geomatika*, *23*(2), 75–86.