ESTIMATION OF OIL PALM PLANT PRODUCTIVITY USING SENTINEL-2A IMAGERY AT CIKASUNGKA PLANTATION PTPN VIII, BOGOR, WEST JAVA

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Abstract. Palm oil is one of the commodities that is growing well in Indonesia with a high commercial value which makes the demand for processed palm oil products increase, it is necessary to have data and technology to estimate the productivity of oil palm plantations more efficiently. Remote sensing technology is one of the technologies that can be used to decide problems spatially and accurately, efficiently, and dynamically. One of them is remote sensing using Sentinel-2A imagery. This study aims to analyze the distribution and the accuracy of the NDVI and ARVI algorithms for the estimation of oil palm productivity at the Cikasungka Plantation PTPN VIII. The estimated productivity of oil palm plantations at Cikasungka Plantation varies in each block with estimated productivity of oil palm plantations of 35,061 Kg/Ha/Month using the algorithm NDVI and ARVI algorithm is 35,431 Kg/Ha/Month. Oil palm productivity was regressed by vegetation index and plant age to generate a model. Based on modeling with these two algorithms, the accuracy of the ARVI algorithm model has a lower RMSE value than NDVI, so it can be said that it is better for estimation of oil palm plant productivity at the Cikasungka Plantation.

Keywords: *estimated productivity, oil palm plants, vegetation index algorithm, sentinel-2A imagery*

1 INTRODUCTION

Oil palm (Elaeis Guineensis Jacq) is one of the plants that can produce oil and has an important role to produce raw materials for food and non-food industries (Sastrosayono, 2003). Palm oil plants are palms and come from West Africa, Brazil, South America, and Nigeria (Corley & Tinker, 2003). Palm oil is processed to produce vegetable oil needed by the industrial sector which can be used for cooking oil, industrial oil, or fuel (Darmadi, 2013). With the increasing demand for palm oil processing products, it is necessary to have data on estimates of oil palm productivity that are faster and more accurate. Estimation of oil palm productivity is carried out to provide an overview or estimate of the results of oil palm productivity in the future. The development of information and technology can utilize secondary data derived from remote sensing images that can be useful for monitoring the development of oil palm plantations (Chong et al., 2017).

Remote sensing technology such as satellite imagery can be used for monitoring related to oil palm plantations to save cost, effort, and time through spectral analysis (Sum & S.A.A, 2019). The remote sensing image that can be used in related plantations such as oil palm plantations can take advantage of Sentinel-2A has 13 spectral channels with a spatial resolution of 10-60 meters that can be used to get the vegetation index value (Poortinga et al., 2019). The NDVI algorithm is often touted as the best vegetation index algorithm for processing related vegetation data. NDVI (Normalized Difference Vegetation Index) is an algorithm formed from the mathematical combination of Band Red and Band Near-Infrared Radiation (NIR) (Fadlin et al., 2020). In addition to the NDVI algorithm, there is a vegetation index algorithm which is the development and refinement of the NDVI algorithm that can be used in agriculture, namely ARVI. ARVI (Atmospherically Resistant Vegetation Index) can carry out the correction process for atmospheric effects on the Band Red and use the difference between the Band Blue and the Band Red (Kaufman & Tanre, 1992). The use of these two algorithms is adjusted to local conditions and the images obtained to determine the level of accuracy to determine the vegetation index algorithm which has a higher accuracy level and is precise in estimating the productivity of oil palm plants.

Oil palm yields are influenced by two of the three main factors in making a model for estimating oil palm productivity, namely genetic factors (plant age), environment, and genetic interaction with environmental factors (vegetation index) (Taufik et al., 2021). The plant age variable is very supportive in estimating oil palm productivity (Mansor & Saker, Md., 2015). Estimation of oil palm plant productivity can be analyzed using the vegetation index algorithm NDVI and ARVI as was done by Vidya, Abdi, and Hana (2021) as well as Setyowati and Heru (2015) where this study used Sentinel-2A image. Oil palm plantations in Indonesia play an important role in improving the welfare of the nation and have high commercial value, so the productivity of palm oil in Indonesia needs to be considered.

One of the oil palm plantations located in Bogor Regency, West Java Province is Cikasungka Plantation PTPN VIII, which has a palm oil factory to process palm oil products into crude oil. This study is adapted from several previous studies about the estimation of oil palm plants productivity. Therefore, I am interested in conducting research entitled “Estimation of Oil Palm Plant Productivity Using Sentinel-2A Imagery at Cikasungka Plantation, Bogor, West Java”. High-resolution image data with NDVI and ARVI values were used in this study for modeling the oil palm plants productivity. This study aims to analyze the distribution estimation of oil palm plant productivity and the accuracy of the NDVI and ARVI algorithms for the estimation of oil palm productivity at the Cikasungka Plantation PTPN VIII, Bogor, West Java in 2022 using Sentinel-2A imagery.

2 MATERIALS AND METHODOLOGY

2.1 Location and Data

The research area is located at Cikasungka Planation, Cigudeg District, Bogor Regency, West Java Province, Indonesia at the 6°23′38″-6°32′54″S latitude and 106°29′24″-106°31′51″L latitude. The Cikasungka plantation PTPN VIII has an area of 3.520,16 hectares which is quite spread over several districts and is one of the plantations owned by PT Perkebunan Nusantara VIII.

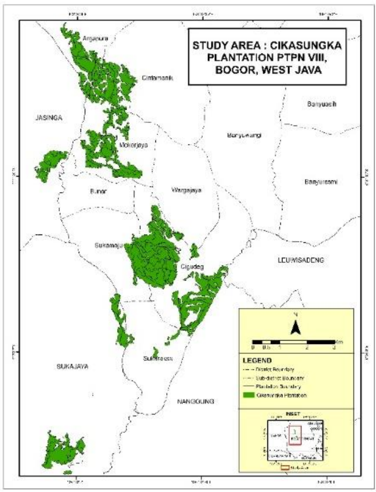

Figure 2-1: Research Study Area

In this study, the focus of the research area used is Afdeling Cikasungka and Afdeling Toge in Cigudeg District. In addition, each block in each division has a fairly uniform planting year for oil palm plantations, namely 2001, 2002, 2003, 2004, and 2009. So that the two divisions can represent other divisions to estimate the productivity of the oil palm plant in the Cikasungka Plantation PTPN VIII. In this research, there are several data and materials used to obtain the estimation results of oil palm productivity using Sentinel-2A imagery in Table 2-1.

Table 2-1: Materials, data used, and the source of data collection.

Materials and Data	Source of Data
Sentinel-2A Imagery 4th January 2022 part of Cigudeg, Bogor, West Java	United States Geological Survey (USGS) https://eros.usgs.gov/sentinel-2
Administrative area Cigudeg, Bogor, West Java	Geospatial Information Agency (BIG)
Palm Oil Plantation Land Use	Cikasungka Plantation PTPN VIII
Age of Oil Palm Plants	Cikasungka Plantation PTPN VIII
Productivity of Oil Palm Plants	Cikasungka Plantation PTPN VIII

2.2 Methods

2.2.1 Sentinel-2A Imagery Data Pre-processing

Sentinel-2 imagery has two constellation satellites, Sentinel-2A launched in 2015 and Sentinel-2B launched in 2017 by the European Space Agency (ESA), which are European optical imaging satellites. Sentinel-2 imagery has medium resolution and a temporal resolution of 10 days for one satellite and 5 days for two satellites. This Sentinel-2 image has 13 high-resolution spectral channels for new perspectives on soil and vegetation on the Earth's surface (European Space Agency, 2017). Sentinel-2A image data downloaded from the United States Geological Survey (USGS) according to the research area on 4th January 2022 has good quality because it is clean from cloud disturbances. The data is then processed in ArcMap 10.8 software to be overlaid with a map of the research area in the form of PTPN VIII Cikasungka Plantation.

2.2.2 NDVI Algorithm

NDVI (Normalized Difference Vegetation Index) is a vegetation index algorithm proposed by Kriegler et al., in 1969 and developed and refined by Rouse et al., in 1973. Utilization of the NDVI (Normalized Difference Vegetation Index) algorithm is a vegetation index from NIR (Band 8) and red (Band 4) spectral transformation that can show vegetation aspects, which include vegetation density, leaf area index (LAI), vegetative growth, and chlorophyll concentration, NDVI values ranging from -1 to +1 and values less than 0 (zero) usually have no ecological significance [14]. The NDVI algorithm formula is as follows:

$$NDVI = \frac{NIR - RED}{NIR + RED} \tag{2-1}$$

Explanation:
NIR = Band Near-Infrared Radiation
RED = Band Red

2.2.3 ARVI Algorithm

ARVI (Atmospherically Resistant Vegetation Index) is a vegetation index algorithm developed by Kaufman and Tanré in 1992. The development of the ARVI algorithm from NDVI is a refinement of the equation that considers the scattering of light from blue spectral in the atmosphere [15]. The vegetation index value of this algorithm ranges from -1 to 1 according to the pixel value based on the greenness of the vegetation (Huete et al., 1997). The ARVI algorithm formula is as follows:

$$ARVI = \frac{NIR - [RED - \gamma(RED - BLUE)}{NIR + [RED - \gamma(RED - BLUE)} \tag{2-2}$$

Explanation:
NIR = Band NIR
RED = Band Red
BLUE = Band Blue
Gamma (γ) = 1

2.2.4 Relationship between plant age and vegetation index value

The calculation of the vegetation index value with NDVI and ARVI algorithm is carried out using ArcMap 10.8. The vegetation index value can be used to determine the density of vegetation in an area. In addition, the vegetation index value with these two algorithms can be used to analyze the level of plant age, one of which is oil palm plants. Research conducted by Taufik et al., (2021) and Setyowati & Heru (2015) showed that vegetation index value can be used as an indirect measurement to analyze the age level of the plant based on the correlation value obtained, where the more mature oil palm plants, the value of the vegetation index tends to increase.

2.2.5 Modeling with multiple linear regression for the estimation productivity

The use of independent variables and dependent variables refers to the reference of Taufik *et al.*, (2021) to build a model for estimating oil palm productivity based on 2 main factors of oil palm production, namely plant age and vegetation index value. The use of two main factors in the development of the model is based on statistical tests, where the independent variables used have varying values and a strong level of correlation. The multiple linear regression equation used is the Ordinary Least Square (OLS) estimation method as an estimation model for oil palm productivity in the study area. The Ordinary Least Square (OLS) formula for estimation of oil palm productivity is a follows:

$$Y = a + b_1X_1 + b_2X_2 + \ldots\ldots \quad (2\text{-}3)$$

Explanation:
Y = Oil Palm Plant Productivity
a = Intercept
b_1, b_2 = Parameter
X_1 = NDVI/ARVI
X_2 = Age Plant

Oil Palm Productivity = a + b1 (NDVI/ARVI) + b2 (plant age)

From the above equation, it will produce an equation that can determine the estimated value of oil palm productivity and produce a correlation coefficient (R) to explain the close relationship between oil palm productivity produced in the field with data processing of NDVI and ARVI values, as well as plant age. The correlation coefficient value has a range of -1≤ r +1, where if the coefficient value is -1 or close to -1 then it can be said that the relationship between variables has an opposite relationship. Meanwhile, for a feasible value of 0 or close to 0, then there is no correlation between variables and if the coefficient value is 1 or close to 1, it can be said that there is a relationship between variables and there is a strong correlation (Sugiyono, 2018).

Table 2-2: Materials, data used, and the source of data collection.

Correlation Coefficient	Relationship Level
0,00-0,199	Very Low
0,20-0,399	Low
0,40-0,599	Moderate
0,60-0,799	Strong
0,80-1,000	Very Strong

2.2.6 Model accuracy test with RMSE

This research was conducted to test the accuracy to compare the productivity results generated from the model with the actual productivity results from the field data results. This study also used the Root Mean Square Error (RMSE) test. From the results of the accuracy test, the smaller the RMSE value, the more accurate the prediction results. The RMSE value ranges from 0 to infinity, but a good accuracy value is if the prediction result is close to 0 (zero). The Root Mean Square Error (RMSE) test formula is as follows:

$$RMSE = \sqrt{\frac{\sum (X - Y)^2}{n}} \quad (2\text{-}4)$$

Explanation:
X = Field Result Value
Y = Predicted Result Value
n = Number of Data

3 RESULTS AND DISCUSSIONS

3.1 Distribution Estimation of Oil Palm Plant Productivity

The Sentinel-2A imagery used in this study was recorded in January 2022 with a resolution of 10 meters. In the Sentinel-2A imagery, two spectral channels are used to determine the NDVI value, namely band 4 (red) and band 8 (NIR). Then, three spectral channels are used to determine the ARVI value, namely band 4 (red), band 8 (NIR), and band 2 (blue). From the result of the calculation based on the vegetation index algorithm formula in the Cikasungka Plantation, the NDVI value is spread from 0,133 to 0,864 and the ARVI value s spread from 0,279 to 0,875. The results of the distribution of the value of the vegetation index can be associated with the age of the plant in the study area to determine the level of relationship between independent variables. Figure 3-1 represents the result of the relationship between vegetation index and plant age in the Cikasungka Plantation.

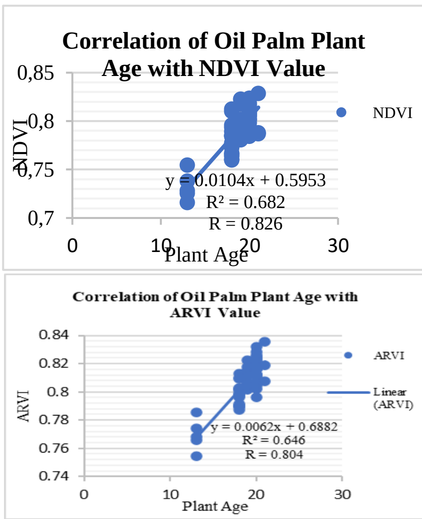

Figure 3-1: Graph of correlation of oil palm plant age with the vegetation index value.

The value of the correlation coefficient is strong and from the results of the multicollinearity test, the value of VIF < 10 indicates that the independent variables used in this study can be continued to make multiple linear regression models. Based on the correlation test, it can be analyzed that the older the age of the oil palm plant, the value of the vegetation index tends to increase. This could be due to the denser palm oil crown as the plant matures.

Estimation of oil palm productivity at the Cikasungka Plantation was built by modeling the results of multiple linear regression with 52 representative samples using disproportionate stratified random sampling based on the age level of each block in the study area. From the results of data processing based on multiple linear regression, it is known that the value of Sig. both independent variables are worth 0,00 to the dependent variable. So, it can be assumed that the results of Sig. 0,00<0,05, where the age of the plant and the value of the vegetation index have a significant effect on the productivity of oil palm plants. Table 3-1 represents the result of equation and correlation coefficient of the oil palm productivity estimation model in Cikasungka Plantation.

Table 3-1: Equation and correlation coefficient of oil palm plant productivity estimation model.

Algorithm	Equation	R^2	R
NDVI	Y = 15.155 (X1) - 119 (X2) – 9.078	0,699	0,836
ARVI	Y = 21.847 (X1) - 106 (X2) – 14.930	0,538	0,733

The results of monthly oil palm productivity estimation using the NDVI algorithm have a range of 228.92-1134.04 Kg/Ha/Month in each plantation block. The distribution estimated of oil palm plant productivity is dominated by the range of 752.09-938.43 Kg/Ha/Month with a land area of 391,19 hectares or 31% of the total area. Figure 3-2 represents the result of the distribution estimated of oil palm plant productivity with the NDVI algorithm in the Cikasungka Plantation.

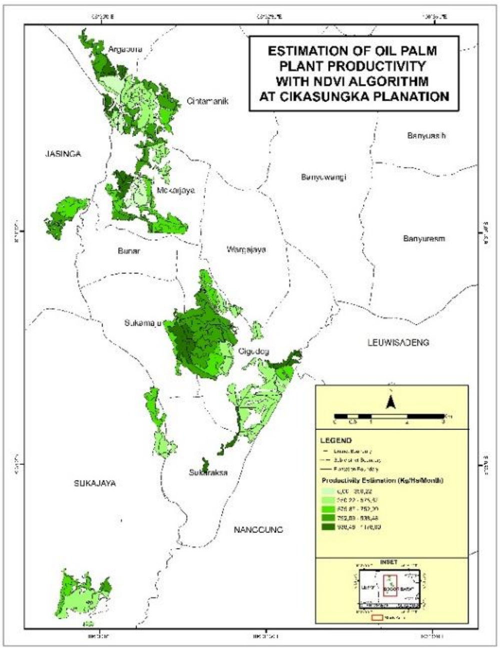

Figure 3-2: Distribution estimation of oil palm plant productivity with ndvi algorithm.

Whereas the results of monthly oil palm plant productivity estimation using the ARVI algorithm have a range of 352,15-1115,82 Kg/Ha/Month in each plantation block. The distribution estimated of oil palm productivity is dominated by the range of 575,67-752,09 Kg/Ha/Month with a land area of 437,17 hectares or 35% of the total area. Figure 3-3 represents the result of the distribution estimated of oil palm plant productivity with the ARVI algorithm in Cikasungka Plantation.

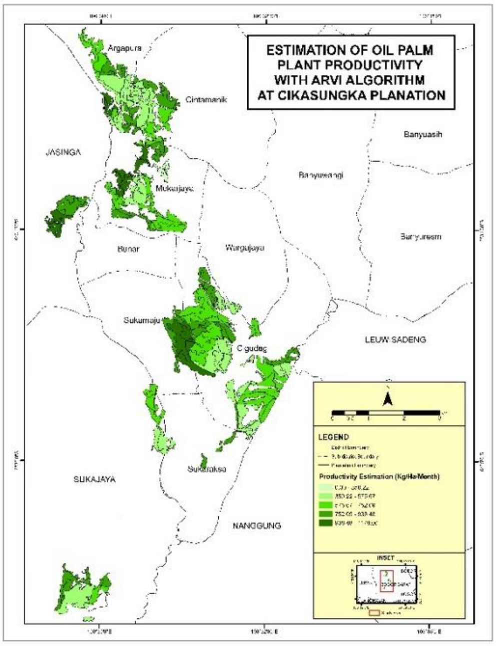

Figure 3-3: Distribution estimation of oil palm plant productivity with arvi algorithm.

3.2 Level Accuracy of Oil Palm Productivity Plant Estimation Model

The results of the estimation of oil palm productivity at Cikasungka Plantation PTPN VIII using Sentinel-2A imagery in January 2022 using the NDVI algorithm of 35,061 Kg/Ha/Month and with the ARVI algorithm 35,431 Kg/Ha/Month. The estimated total production of oil palm plantations is lower than the productivity of oil palm plantations produced in the field, which is 38,471 Kg/Ha/Month. The estimation of the productivity of oil palm plantations at Cikasungka Plantation obtained from the multiple linear regression equation models can be calculated based on the accuracy test based on the comparison of field data using the RMSE test. The result Root Mean Square Error (RMSE) test for the estimated productivity of oil palm plants in January 2022 at Cikasungka Plantation.

- NDVI :

$$RMSE = \sqrt{\frac{(38471 - 35061)^2}{52}} = 473$$

- ARVI :

$$RMSE = \sqrt{\frac{(38471 - 35431)^2}{52}} = 421$$

Based on the results of the calculation of the accuracy of the linear regression equation for estimating oil palm productivity at the Cikasungka Plantation in January 2022, the level of accuracy using the NDVI algorithm is lower than the ARVI algorithm. This is because the RMSE value with the NDVI algorithm is greater than the ARVI algorithm. Based on the results of the accuracy test with the two vegetation index algorithms used, the results of the estimation of oil palm productivity at the Cikasungka Plantation are better when using the ARVI algorithm. The results of the accuracy test can be assumed that the ARVI algorithm can reduce the influence of the atmosphere by using Band Blue and Band Red so that the pure vegetation index value is expected from the vegetation.

4 CONCLUSIONS

The estimated results of monthly oil palm productivity in 2022 at the Cikasungka Plantation have varied values and are spread over each block dominated by oil palms producing an age (14-20 years) with a range of 575,67-752,09 Kg/Ha/Month with the ARVI algorithm and 752,09-938,43 Kg/Ha/Month with the NDVI algorithm. The results of the accuracy test of the monthly oil palm productivity estimation model with the NDVI algorithms have an RMSE value of 473. While the RMSE value with the ARVI algorithm is 421. So, from the two algorithms used, this ARVI model can be said to be better in estimating crop productivity. oil palm in Cikasungka Plantation because it can be more sensitive to atmospheric disturbances and sensitive to vegetation, so it has a pure vegetation index value of oil palm plants. In addition, the results obtained by the ARVI algorithm have a lower RMSE value and the estimation results are close to the results of field data.

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