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Visible Band Optimation of Unmanned Aerial Vehicle for Estimating Synthetic NDVI on Rice Vegetation

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Abstract

Serntinel 2A provide Normalized Difference Vegetation Index (NDVI) to be used as an estimate of soil fertility, plant varieties and productivity. The weakness of satellite data is that the data obtained is often inaccurate due to cloud cover, especially in tropical countries with high rainfall such as Indonesia. The use of unmanned aerial vehicle (UAV) as an alternative data have limitation as it captured Red Green Blue (RGB) imagery. The research was conducted from July to September 2020 at Pasir Kaliki Village, District of Rawamerta, Karawang Regency, West Java province. The study has discovered that NDVI showed higher number in result of vegetation index compared to Normalized Green-Red Difference Index (NGRDI) with correlation coefficient is 0.94. The regression model resulted as y=4.78x+0.38 and MAPE value expresses as 26.74%, where the regression model with Pearson's correlation coefficient value is 0.88. A qualitative assessment using statistical data and a spatial assessment using sampled data from the rice vegetation map reveal a high mapping accuracy with the corresponding R^2 *being as high as 0.74; however, the mapped rice vegetation accuracy might influenced by other physical factors such as water reflectant, sunlight and the RGB camera limitation itself. Nonetheless, the highest values of NGRDI only reach 0.2 while NDVI can attain at 0.9 at the peak of vegetative phase of rice growth stage. This means that Green Band have limitation in detecting vegetation index. In relation to the different approaches performed, it is noted that the average trend line on both NDVI and NGRDI shown the similarity tendency in all growth stage.*

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1. Introduction

The use of Unmanned Aerial Vehicle (UAV) can also be used in remote sensing as an alternative data. UAV is a machine capable of flying without a pilot or controlled by the pilot remotely (Chao *et al.* 1995). UAV is well known to produce high resolution images and cheap to be accessed by society. However, the use of UAVs is usually not able to measure NDVI because of the absence of Near Infrared (NIR) wave data. The use of UAV was limited by the RGB values only.

An object within the spatial image can be delineated by its spectral signature, if each object had been independently run through a standard spectrophotometer. Once identified, objects can be classified, and differentiated through their spectral signatures (Bock *et al.* 2010; Grieve and Hammersley 2015).

Spectral signature have possibility to be developed from visible band such as RGB band values and developed to substitute NIR values to calculate NDVI. Therefore, RGB values need to be optimized. Hence it can substitute the NIR values and estimate the NDVI by using false NDVI.

The main objective of the research is to discover alternative band to replace Near Infra-red in attain vegetation index. This study aimed at; (1) examining the correlation between vegetation indexes resulted from satellite Sentinel 2A imagery and visible band (RGB) imagery from UAV, (2) estimating NDVI value by using false NDVI (NGRDI) generated from visible band, and (3) estimating the rice growth phase (days after transplanting) by approaching NDVI and false NDVI values.

2. Materials and Methods

The research was conducted from July to September 2020 at Pasir Kaliki Village, District of Rawamerta, Karawang Regency, West Java province. Detail of the study location is shown in Figure 1. The areas of interest were designed following capability of UAV and Sentinel 2A flight direction (Figure 1). The plot setting was created following the flight path of Sentinel 2A direction. Total of designated plot were 81 sites with areas 100 m^2 (black square on Figure 1), following Sentinel 2A pixel size of 10×10 meters.

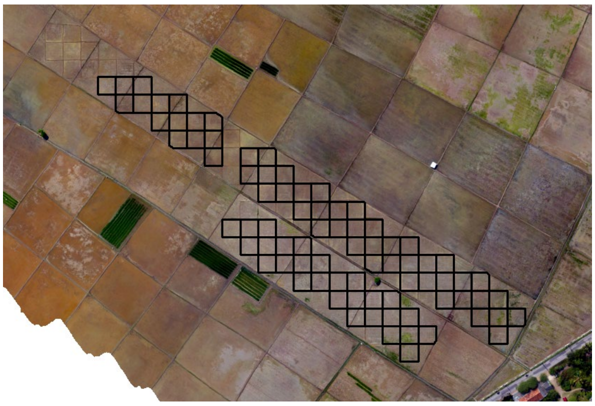

Figure 1. Design of research sampling location and the flight path setting

Data used in this research was obtained from several sources such as Google Earth, ESA (European Space Agency), and field measurements. As it displayed on Table 1.

2.1 Paddy Fields Mapping

The Sentinel 2A used in this study has S2MSI2A sensor with data type has been ortho-rectified and UTM/WGS84 geocoded Bottom-Of-Atmosphere (ESA, 2021). UAV imagery and paddy field control points were repositioned to attain the exact paddy fields was same with Sentinel 2A imagery. Therefore, UAV imagery taken was georeferenced with Sentinel 2A imagery, hence Vegetation Indexes at certain coordinates can be compared accurately. UAV was flight at the certain height measured as 60 meter above the ground with persistent flight time every 11 to 13 am, with interval 10 days following the time and schedule of Sentinel 2A when crossing the research location (Pasir Kaliki village). Therefore both Sentinel 2A and RGB imagery acquired were consistent.

2.2 Spectral Signature Reflectance Analysis

Temporal spatial data from UAV were used to be analyzed by using false NDVI analysis approach to obtain spectral reflectance from rice vegetation. The spectral reflectance analysis results were

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validated by using NDVI value generated from Sentinel 2A imagery. In this study, quantification of the time series Normalized Difference Vegetation Index (NDVI) has been conducted. Normalized Difference Vegetation Index (NDVI) using Sentinel 2A imagery, and the formula becomes as follows;

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

where RED is red reflection and NIR is NIR reflection. The results of the NDVI analysis will be correlated with the age level of the observed paddy fields (Costa et al., 2020).

Normalized Green–Red Difference Index (NGRDI) used to analyze the images from the digital camera in order to get false NDVI value:

NGRDI = (Green DN -Red DN)/(Green DN+Red DN) (2)

where Green DN and Red DN are the digital numbers of the green and red bands, respectively (Lussem et al., 2018).

Table 1. Data acquisition (from July to September 2020)

No	Data	Function	Source
1	Google Earth high resolution image	Paddy fields mapping	earth.google.com
2	ESA (European Space Agency) - Sentinel 2A (scene code: L2A_T48MYU)	Sentinel Satellite Imagery - Paddy fields mapping - NDVI temporal analysis - Cloud avoidance	scihub.copernicus.eu
2	Field Measurements - Location survey	Validate satellite imagery approach	DIPA Research Team
3	Multi Spectral UAV Imagery (flight at 60 m height)	Paddy fields mapping - Cloud avoidance - High resolution imagery	UAV through field observation by DIPA Research Team
4	Farmer Contribution Information/Data - Location - Area	Basic data	DIPA Research Team

3. Results and Discussion

3.1 The Correlation Between Vegetation Indexes Resulted from Sentinel 2A Imagery And Visible Band (RGB) Imagery from UAV

Several vegetation indexes have been developed, with the normalized difference vegetation index (NDVI) been the most studied and commonly used. To generate an NDVI map, a relatively high-cost multispectral sensor is required; but currently, most UAVs are equipped with low-cost RGB cameras. For that reason, other indexes that utilize RGB data have been developed to generate maps similar to NDVI and minimize the data acquisition cost. Comparisons were performed between the data sampled from the ground-truth data by UAV and Sentinel 2A derived data taken for 67 days with interval 10 days between each observation days. Based on the comparison between NDVI generated from Sentinel 2A imagery by utilizing NIR value and NGRDI generated from RGB value of UAV, appeared similar graph movement during the same day of observations. By the correlation coefficient is 0.944625, it can be assumed that NDVI and NGRDI has positive correlation. Much like the NDVI and other indexes, Costa *et al.* (2020) stated that the NGRDI has some limitations as well, with the first being the effects of the weather and sunlight in the measurements. In different weather conditions the index could generate different measurements for the same plant. The second important limitation is that the NGRDI formula is not normalized, and as such could generate values higher than one on non-vegetation areas.

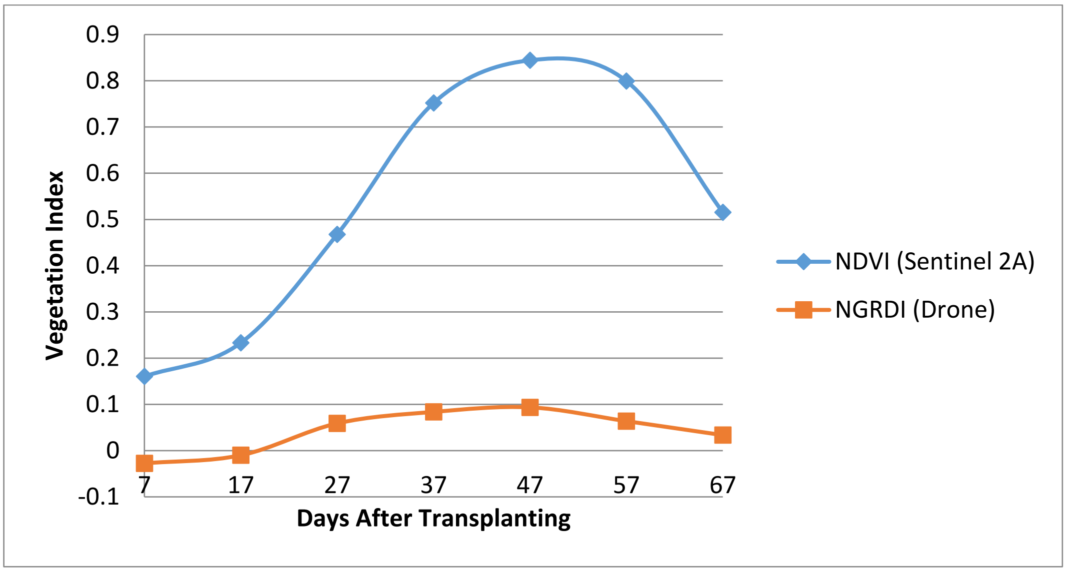

Figure 2. NDVI and NGRDI values comparison based on Vegetation Index on different rice growth stages

During the late period of crop growth, panicles change the canopy structure of crops and affect crop canopy spectral reflectance. As Kawamura *et al.* (2018) studied; it was believed that the vegetation indexes are influenced by saturation effects under moderate to high biomass condition (LAI and chlorophyll contents). The green LAI, defined as the one-sided green leaf area per unit horizontal ground area is directly related to the growth status of crops and largely influences the spectral reflectance. Therefore, it justified the graph on figure 3 are slowly decrease after it passed the peak of generative phase and started to grow panicles.

3.2 Estimate NDVI value by using false NDVI (NGRDI) generated from visible band

The cloudy and rainy weather characteristics of the tropical season greatly reduce the likelihood of obtaining high-quality optical remote sensing images. In addition, the diverse crop-planting system in Indonesia also hinders the comparison of NDVI among different crop stages. To address this problem, this study apply the higher resolution image by using UAV and calculate the NGRDI value measure approach to produce similar vegetation index.

The regression model showed formula as;

$$y = 4.77x + 0.385$$

where x is actual value as independent variable on models. The negative data produced as data taken by UAV and appeared bias probably be affected by physics factor such as water reflectant or soil. Figure 11 show the regression model with Pearson's correlation coefficient value is 0.878, which means the model has strong relation.

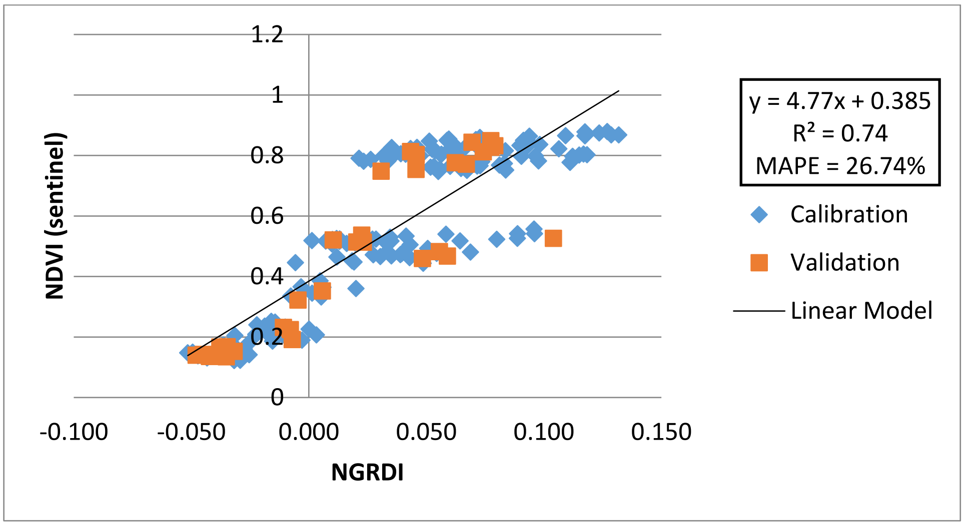

Figure 3. Linear regression model on rice vegetation index study between NDVI and NGRDI (standard error: 0.13348, Pearson's correlation: 0.877885)

The outlier shown on the figure 4 has linearly similar as stated by Song and Park (2020), that seasonal changes revealed different NDVI mean value gradually on vegetation indexes. Filgueiras *et al.* (2019) also provide data derived from Sentinel that showed NDVI of agricultural crops are depend on their phenological cycle, soil water content and canopy closure. Study by Hunt *et al.* (2005) also proved that plant density with varies of chlorophyll content measurements reflected different spectral reflectance. NGRDI also linearly related to biomass levels for alfalfa, corn and soybean that saturated at a maximum value. A qualitative assessment using statistical data and a spatial assessment using sampled data from the rice vegetation map reveal a high mapping accuracy with the corresponding R^2 being as high as 0.7429; however, the mapped rice vegetation accuracy might influenced by other physical factors such as water reflectant, sunlight and the RGB camera limitation itself.

Yu *et al.* (2015) also agreed that spectral indices are not able to represent all spectral variability because they often employ a limiting number of band and regression models based on it are easy to be over-fitted to the limiting observations. The mean absolute percent error (MAPE) value expresses as 26.74%, which means the forecasting model have rather good performance target. It implies that on average, the forecasts distance from the true value is more than a quarter of the true value. Study by Song and Park (2020) about comparison of NDVI and NGRDI by profile analysis, proved that NGRDI were stronger to detect water body reflectant than vegetation indexes. Compared to NDVI that more effective for capturing vegetation reflectant even on aquatic plants. This explained the condition of field observation on this study, that the peak of growth stage was captured only on several sites among other sites on the designated research area.

Based on IRRI (2015) about rice growth stage, the observed data of rice vegetation on figure 12 and 13, can be classified on to; (1) Vegetative phase I; showed on areas captured at 18 and 28 July 2020, or on 7th and 17th days after transplanting; (2) Vegetative phase II, showed on areas captured at 7 August 2020, or on 27th days after transplanting; (3) Generative phase I, showed on areas captured at 17 and 27 August 2020, or on 37th and 47th days after transplanting; (4) Generative phase II, showed on areas captured at 6 September 2020, or on 57th days after transplanting; (5) Harvesting, showed on areas captured at 16 September 2020, or on 67th days after transplanting. Below are figure 5 and 6, illustrates the reflectance of each vegetation indexes on different days after transplanting. Early in the planting season of rice vegetation, there were significant differences noticeably among 7 pictures captured by both UAV and Sentinel 2A observed.

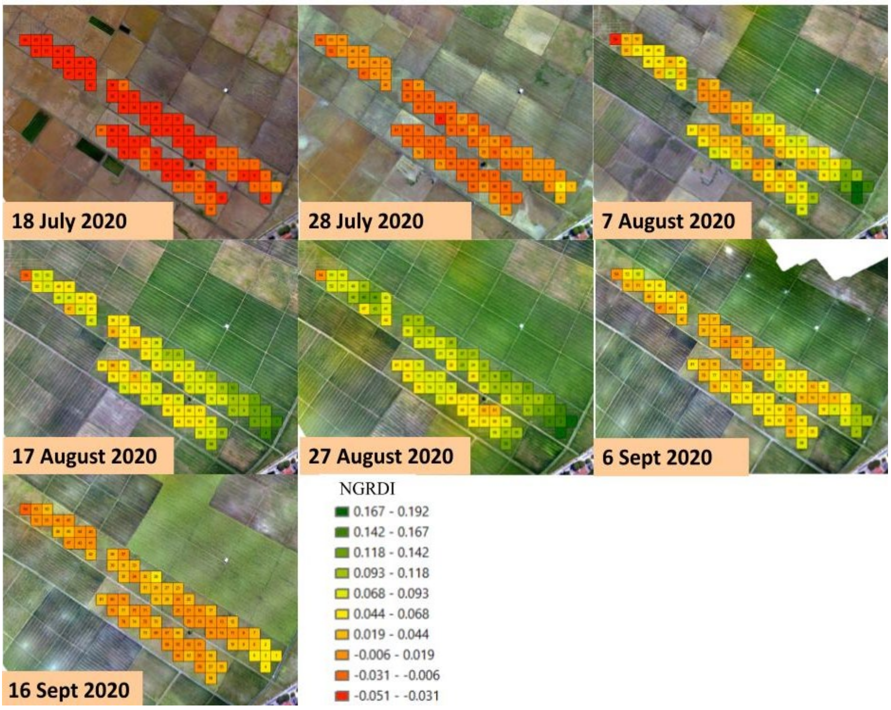

Figure 4. NGRDI on rice vegetation based on growth stage every 10 days

On 18 July 2020, both NDVI and NGRDI recorded the lowest indexes on many areas. This was because the study areas are water body since it was the 7th day of rice transplanting, where the plants

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are smaller compared to water body, which means, the vegetation intensity are low. The more dense the vegetation, the more high the vegetation indexes resulted from both NDVI and NGRDI.

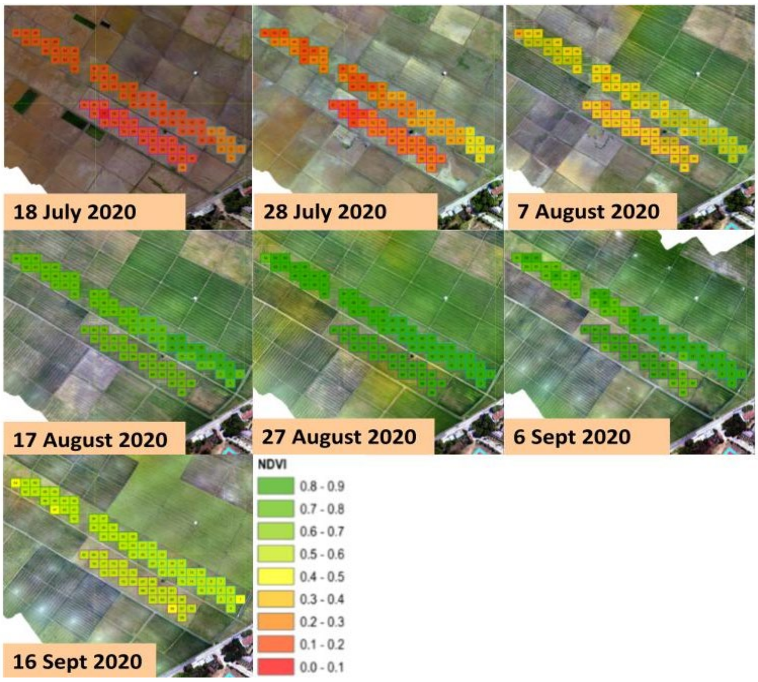

Figure 5. NDVI on rice vegetation based on growth stage every 10 days

The number of NDVI and NGRDI showed the same pattern that decreased on both 16 September 2020 observation dates by UAV and Sentinel 2A. It was 67th days after transplanting, where the rice vegetation has ended it generative phase II and started the harvesting season. Harvesting season has lower scale compared to vegetative and generative phase because the green color leaf has gradually changed in to yellow color. It affected the vegetation indexes value were different between each stage of rice growth. In contrast to the reflectant on 18 July 2020, those recorded on both 27 August 2020 or 47th days after transplanting displayed peaks in many areas. This was because the vegetation intensity had expanded and dense as it related with rice growth stage that started the generative phase I, which resulted in an increase of reflectance in rice vegetation on study areas.

3.3 The Rice Growth Stages (Days after Transplanting) by Predicting NDVI and NGRDI Values

The disparate of vegetation intensity might affected by nutrients, water contents on plants, pest and diseases. The largest range between maximum and minimum number of NDVI was shown on 17th days after transplanting. On the other side, smallest range between maximum and minimum number of NDVI were shown on last stage of rice growth. The last stage at 67 days after transplanting is harvesting. This explained that the leaf color reflected and calculated into vegetation index had similar responses captured by Sentinel 2A.

Similar to the previously described analysis results, the vegetation indexes calculated with NGRDI through RGB reflectant showed a similar trend on rice growth stage classification. The similar number shown on both figure 7 and 8 at the two growth stage was explained by Kawamura *et al.* (2018) on their study, that the vegetation reflectance was influenced by the biomasses and internal leaf structure characteristics. Harvesting season has lower scale compared to vegetative and generative phase because the green color leaf has gradually changed in to yellow color. It affected the vegetation indexes value were different between each stage of rice growth as it also experienced by Jaramaz *et al.* (2013). Therefore, both harvesting phase and young plant at the beginning of vegetative phase on rice growth stages has similar reflectant number because the green color that indicate the chlorophyll content was alike with each other. On the other side, the highest values of NGRDI only reach 0.2 while NDVI can attain at 0.9 at the peak of vegetative phase of rice growth stage. This means that Green Band have limitation in detecting vegetation index.

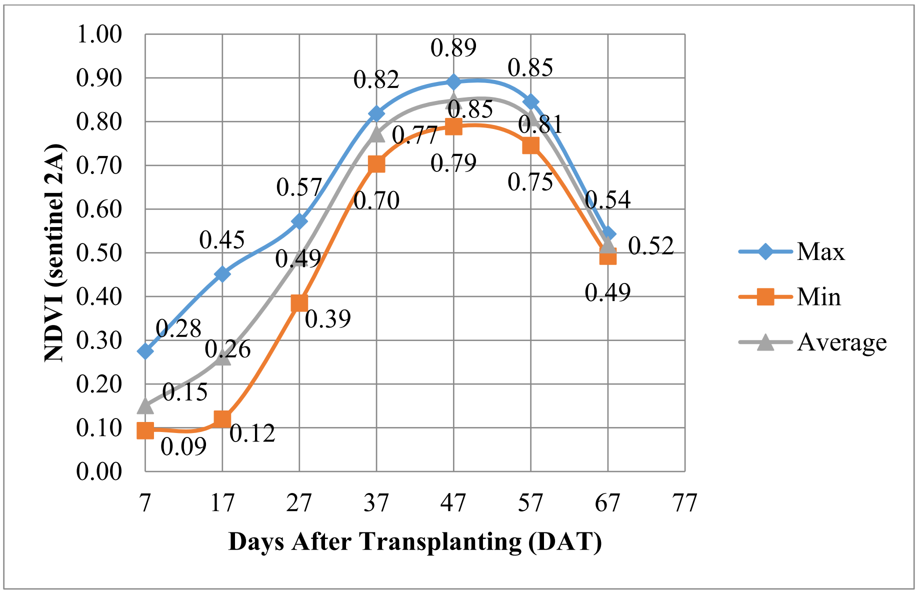

Figure 6. Rice growth stage classification based on NDVI

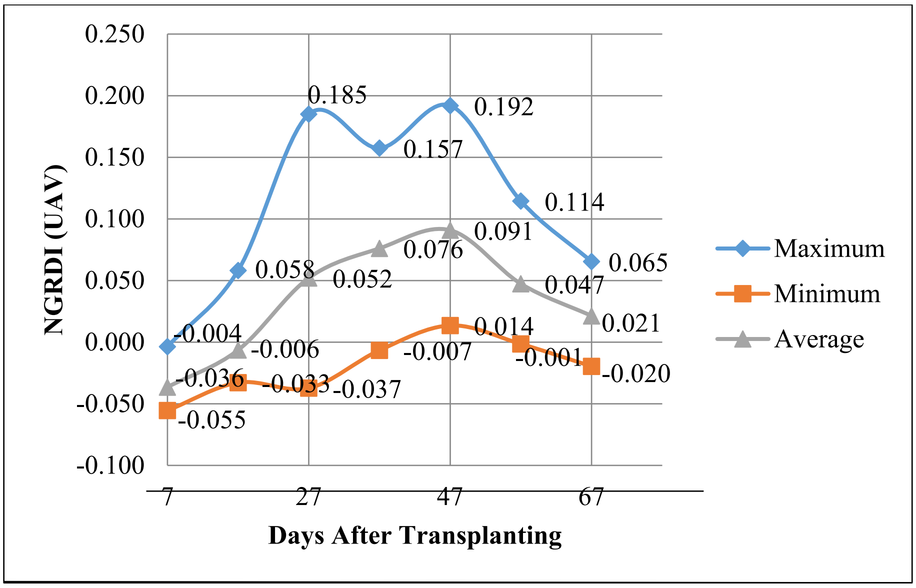

Figure 7. Rice growth stage classification based on NGRDI

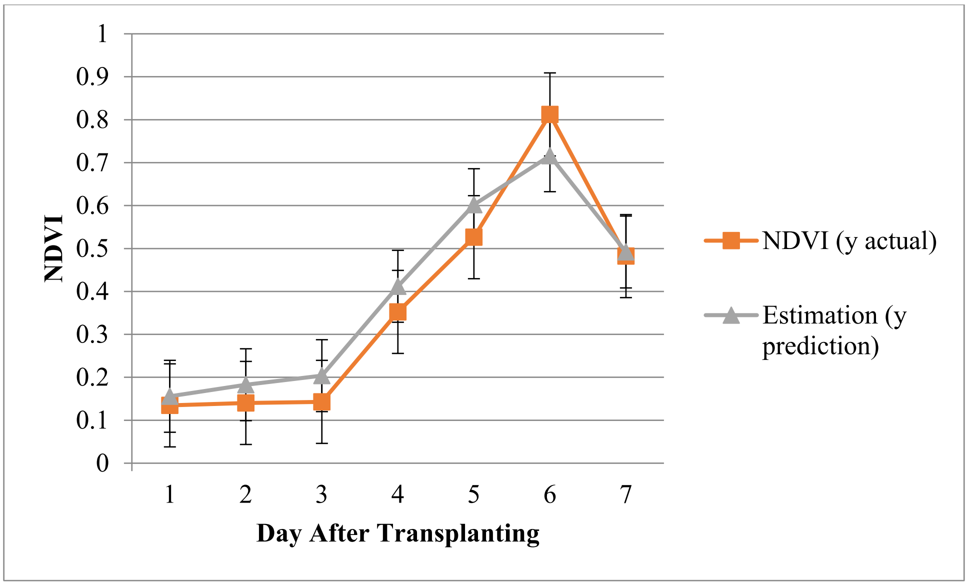

Figure 8. NDVI comparison between actual and estimated value of rice growth based on days after transplanting

Estimated value were calculated by using simple linear regression model. The actual conditions of rice vegetation on the open field were certainly affected by several factors. Contrary, Sentinel 2A was well-programmed with consistent flight directions on the atmosphere with fewer affected factors. However, the average trend line showed similar pattern with NDVI rice growth stage.

4. Conclusion

This study can be concluded that;

1. The proposed approach had MAPE 26.74% when it performed on rice vegetation with R^2 is 74.29 % that indicates a better fit model linear regression between NDVI and NGRDI. The correlation between vegetation indexes resulted from Sentinel 2A imagery and visible band (RGB) imagery from UAV showed positive correlation.
2. Visible band or RGB generated by UAV can be used to estimate NDVI value by using NGRDI formula. Where NIR values are substituted by Green Band values captured from RGB imagery, but with limitation.
3. Rice growth phase classification (based on days after transplanting) performed on this study showed similar pattern between NDVI and NGRDI score indexes. The NDVI and NGRDI were highly correlated and showed the same characteristics according to the rice vegetation surfaces on 67 days observations. On the other hand, the NGRDI had anomaly on classifying rice growth stage on 37^{th} day after transplanting, where it was vegetative phase II and the graph supposed to be raised to the peak. However, the average trend line on both NDVI and NGRDI shown the similarity tendency in all growth stage.

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