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Relationship Between Normalized Difference Vegetation Index (NDVI) and Rice Growth Phases in Danda Jaya Swamp Irrigation Area Regency Barito Kuala

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RELATIONSHIP BETWEEN NORMALIZED DIFFERENCE VEGETATION INDEX (NDVI) AND RICE GROWTH PHASES IN DANDA JAYA SWAMP IRRIGATION AREA REGENCY BARITO KUALA

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Abstract. One of the factors that influence the success of rice productivity is rice growth, from land preparation to harvesting. With remote sensing technology, the phase of rice growth can be known more quickly. The purpose of this study was to analyze the NDVI value as a representation of vegetation density characteristics and analyze cluster data grouping based on the results of the identification of the rice growth phase using Sentinel-2 Imagery in the 2019 planting season cycle in Danda Jaya Swamp Irrigation Area. The method used in this study is a quantitative descriptive method with the interpretation of Sentinel-2 Image. Image data were collected in the form of time series in 2019 and downloaded via the Google Earth Engine (GEE) platform. Rice productivity was calculated using NDVI to identify plant vegetation density. Then calculate the statistical zone using a GIS application to get the average NDVI value per rice field plot. NDVI values were analyzed using the K-means Cluster method for class determination. These results support the hypothesis that the time series NDVI value in the sentinel-2 image with a high spatial resolution (10 m) computed from the Google Earth Engine produces a strong correlation with the rice growth phase. The next research development is to analyze the estimation model of rice productivity on Sentinel-2 Image by utilizing the relationship between rice productivity and NDVI.

Keywords: NDVI, Rice Productivity, K-Means, Danda Jaya

1. Introduction

The Danda Jaya Swamp Irrigation Area was developed in 1969 by the Department of Ministry of Public Works, located in Rantau Badauh District, Barito Kuala Regency, South Kalimantan Province. The potential of 2,400 ha of land for tidal swamp farming allows farmers to innovate technology that is suitable for the location to produce high-quality products that meet market demand and are produced efficiently [1]. Therefore, to increase productivity, farmers need access to the right technology tools [2]. One method of monitoring rice or other seasonal crops is monitoring through remote sensing satellite data, which has high temporal resolution and adequate spatial resolution (1-10 m). The use of remote sensing imagery can explain more detailed information for monitoring paddy fields where each land has a different growth phase. One of the remote sensing satellite data that has an adequate spatial and temporal resolution is Sentinel-2 Image [3]. Sentinel-2 is a remote sensing satellite with passive sensors made in Europe. Sentinel-2 is multispectral and has 13 channels (bands), four channels spatial resolution of 10 m, six channels spatial resolution of 20 m, and three channels with a spatial resolution of 60 m [4]. Analysis of the growth phase of rice plants was carried out after the paddy fields were successfully classified for their growth age using the vegetation index algorithm. Image multispectral that shows the aspect of vegetation density so that it can be used to perform plant growth phase analysis. The algorithm used in this study is the Normalized Difference Vegetation Index (NDVI). NDVI is the greenness index of vegetation which is determined from the photosynthetic activity of vegetation. Kurniawan (2020) had previously conducted research on planting phase analysis using the NDVI algorithm on Sentinel-2 Image. However, the data processing process in this study requires high data processing device capabilities and requires large data storage space, so it takes longer to process the data [4]. This study will use a cloud, namely Google Earth Engine (GEE) [5]. Cloud-based computing is a combination of the use of computer technology with internet-based development. GEE allows users to create and run custom algorithms and fast computations that enable easy global scale analysis. Google has archived many datasets and integrated them into cloud computing for open source, one of which is the medium-resolution satellite image Sentinel-2 Image [4]. This study intends to relate the NDVI value to the rice growth phase of DIR Danda Jaya, Barito Kuala Regency. This analysis aims to analyze the NDVI value as a representation of vegetation density characteristics and analyze cluster data grouping based on the results of the identification of the rice growth phase using Sentinel-2 Imagery in the 2019 planting season cycle.

2. Materials and Methods

2.1. Study Area

The research location is in the Danda Jaya Swamp Irrigation Area, Rantau Badauh District, South Kalimantan Province. Danda Jaya is geographically located between 3°4'50''S - 3°8'10''S and 114°41'50''E - 114°38'10''E. The study area location can be seen in Figure 1. The topography of the area ranges between -3 and 4 m [6]. Based on the analysis of hydro-topographic maps, the Danda Besar area consists of three hydro-topographic classes, namely the areas of class B and C are relatively the same, namely 820,78 ha and 815,17 ha, while class A is only 800,20 ha. The actual conditions in the field are mostly used for agricultural crops (rice), and a small portion is used for annual crops, especially in the yard [7]. Scheme of the Danda Besar Unit water management network, which has primary canals, secondary canals, and 54 Tertiary canals, which are divided into 27 Left Tertiary canals and 27 Right Tertiary canals as well as a tidal pool that is a no more extended function [8]. Tropical monsoon is the type of climate in Barito Kuala; climatological conditions throughout the year are hot and humid with a dry season of about 2-3 months with rainfall depth of less than 100 mm/month. The wet season around 5-6 months, has a rainfall depth of more than 200 mm/month [9]. From the analysis result of

precipitation data for Mandastana rain station from 2000-2020, the result of the regression analysis model of rainfall from 2000-2020 shows an increasing tendency pattern of 18,944 mm/year.
There was a shift in the dry season in period II. 8 months of the rainy season in the period I start from October to May, nine months in period II start from October to June, and the dry season from July to September. Analysis of annual average rainfall in the rainy season in periods I and II decreased by -2,663 mm/year and -11,542 mm/year, respectively. In the dry season, the value of annual average rainfall increased in the period I by 4,886 mm/year and period II by 3,083 mm/year [10]. The dry season in Indonesia occurs as an effect of the southeast winds pushing dry Australian continental air masses toward the archipelago, while the wet season occurs when the monsoon winds blow from a northwest direction [11]. The climate of South Kalimantan, especially in Barito Kuala, is strongly influenced by the monsoon. The Monsoon type of rain pattern is U-shaped. The pattern thus has a wet season around October to March; this pattern was also strongly influenced by the movement of winds from the northwest towards the southeast starting in October and ending in March. The dry season starts from April to September as an effect of the wind from the southeast to the northwest, which is from April to September. In addition, this pattern is also strongly influenced by extremely wet situations (La-Nina) and extremely dry situations [12]. The monthly average temperature in South Kalimantan is 26,22°C; the minimum temperature mainly occurs in January and December. The maximum temperature occurs in May [13].

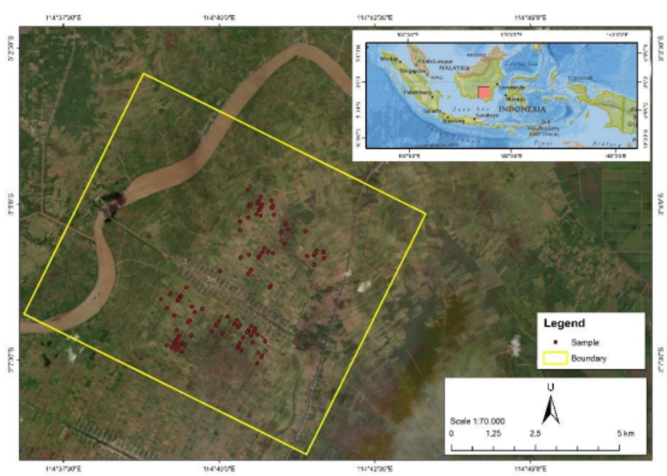

Figure 1. Map of Study Area

2.2. Rice Cultivation Practices

Rice fields in Danda Jaya have two cropping seasons. Crops during the wet season (November to March) are called the main season or are locally known as *Musim Hujan*. The rice planted is superior rice varieties such as *Inbrida* (*Inpari 42 & Inpara 02*) and *Hibrida* (*Mapan 05, Suppadi, and Sembada*) with a planting period of 3 months. Crops planted during the dry season (April to September) are called the offseason or are locally known as *Musim Kemarau*. The rice is planted in local rice varieties such as *Siang Mayang* and *Karang Dukuh*, with a planting period of 5-6 months. Based on the cropping pattern Danda Jaya has three cropping patterns; the 1-time local rice cropping pattern carried out by farmers encounters a shortage of water or a deficit in the middle of the first month of July. Planting patterns using superior rice can be done up to 2 times a year, but the recommended planting period is the beginning of the first planting period, November-February, and the second planting period, March-June. However, in the third scenario, namely two local rice plantings, water shortages were encountered for several planting periods. Increasing the cropping index can be done if the planting period and the type of rice used can be adjusted, namely superior rice with a shorter planting period [14].

2.3. Satellite Imagery Datasets

The search for sentinel imagery was only carried out in 2019 (January to December) due to the difficulty in finding satellite imagery with less than 50% cloud cover at the research location and research focused on the dry season. Table 1 presents the characteristics of the Sentinel-2 data used in this study.

Table 1. Product of the Satellite Data Used In This Study

Satellite	Product ID	Date	Optic Sensor
Sentinel-2	S2B_MSIL2A_20190220T022729_N0211_R046_T49MHS	February 20	MSI
Sentinel-2	S2B_MSIL2A_20190322T022549_N0211_R046_T49MHS	March 22	MSI
Sentinel-2	S2A_MSIL2A_20190506T022551_N0212_R046_T49MHS	May 6	MSI
Sentinel-2	S2A_MSIL2A_20190605T022551_N0212_R046_T49MHS	June 5	MSI
Sentinel-2	S2A_MSIL2A_20190705T022551_N0212_R046_T49MHS	July 5	MSI
Sentinel-2	S2A_MSIL2A_20190725T022551_N0213_R046_T49MHS	July 25	MSI
Sentinel-2	S2A_MSIL2A_20190814T022551_N0213_R046_T49MHS	August 14	MSI
Sentinel-2	S2A_MSIL2A_20190913T022551_N0213_R046_T49MHS	September 13	MSI
Sentinel-2	S2A_MSIL2A_20191023T022741_N0213_R046_T50MKB	October 23	MSI

The image data collected is in the form of time series in 2019 and downloaded via the Google Earth Engine (GEE) platform. The image used has been geometrically corrected and radiometrically corrected. Band 4 (Red) and band 8 (NIR) from Sentinel-2 multispectral image (MSI) data were used to calculate NDVI. The spatial resolution of the images was 10 m.

2.4. Methodology

Figure 2 presents a flowchart of the methodology for this study. Each step is described in the following sections.

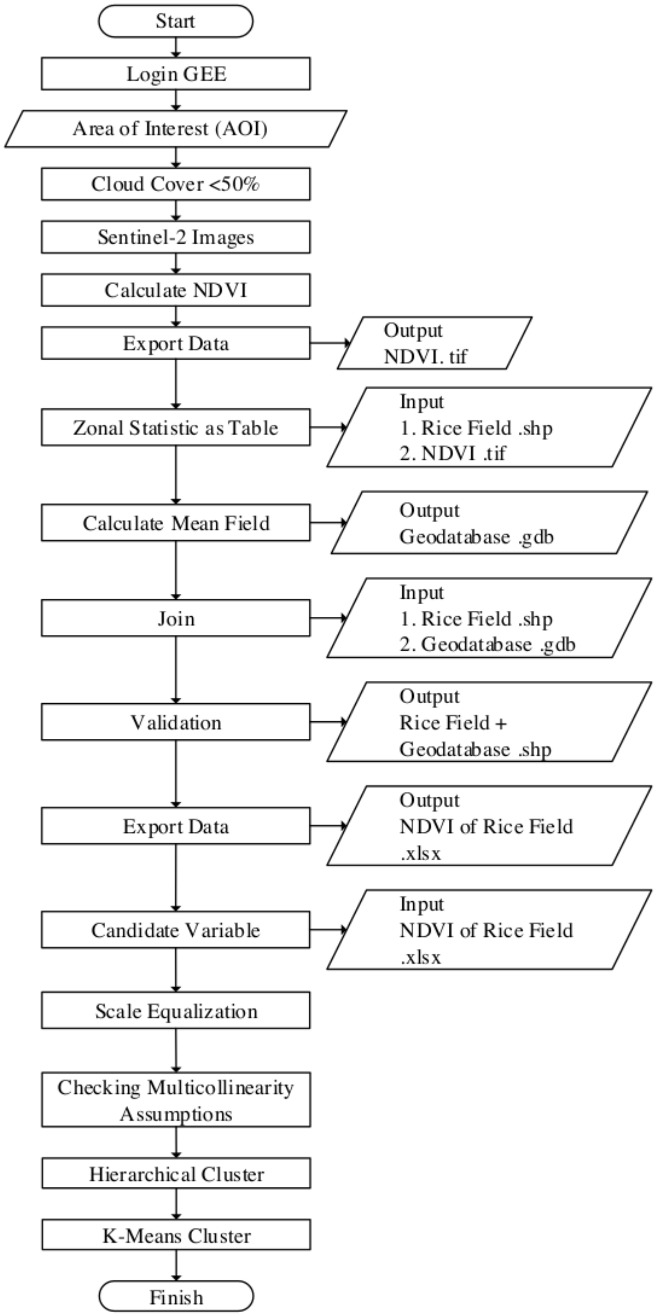

Figure 2. Research Flow Chart

Based on the flow chart presented in Figure 2, if the user does not have a GEE account, the user can register on the website (https://signup.earthe-ngine.google.com/) and can use the account e-mail which has existed. It usually takes 1-2 days to get the notification e-mail agreement. Then the next step is to enter location data with the format shape file. On the Code Editor menu, open Assets → New → Table Upload → Shape Files, and select the format (.shp; .shx; .dbf; .prj; and .zip). When the upload is complete, the user can see the uploaded file on the Asset tab. The next step is inserting script code on the Scripts tab; the first is location data, the second is cloud cover, the third is a collection of Sentinel-2 imagery based on date and <50% cloud cover, and the fourth is calculating normalized index values such as NDVI. Calculated the NDVI in the red (band 4) and near-infrared (band 8) as measured by Sentinel-2 as follows.

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

The next step is the Zonal Statistic As Table analysis; the input data includes rice field polygon data and NDVI data. Then the value of each NDVI pixel that is in the polygon area of the rice field plots will be averaged to get an average NDVI value that is in the polygon area so as to produce information in the type geodatabase. The next step is the rice field polygon data, as well as the information in the type geodatabase, which will be combined using analysis join. Then on to the analysis join, the two will be validated to match the data with each other. The polygon data of the paddy field area, which contains the file geodatabase then it will be exported to Microsoft Excel for cluster analysis. The next step is to prepare candidate variables, which consist of information columns for paddy field polygon data and rows for the date of collection of NDVI data. Then the next step is to do scale equalization with the method z-score. Then the next step is checking multicollinearity assumptions, where variables have a strong correlation with each other, then proceed with hierarchical cluster analysis, which assumes that each existing data is a cluster at the beginning of the process. If the number of data is n, and the number of clusters is k, then the magnitude of n = k. Then the distance between clusters is calculated using the Euclidean distance based on the average distance between objects. Furthermore, from the results of the distance calculation, the minimum distance is selected and combined so that the value is n = n -1. When two clusters are merged, the distance between the two clusters that are joined to the other cluster is updated. Cluster merging will continue and will stop if it satisfies the condition for the sum of k = 1. At the end of the hierarchical clustering stage, a dendrogram is obtained, which shows the order in which each member is grouped in the cluster. The next step is K-means cluster analysis. The first step is to determine how many k-clusters you want to form from the hierarchical cluster results. Then calculate the distance of each input data to each centroid using the distance formula (Euclidean Distance) until the closest distance from each data to the centroid is found. The next step is to classify each data based on its proximity to the centroid (smallest distance). Then update the centroid value. Score centroid newly obtained from the cluster average. Sample training using the slovin formula with a confidence level of 5% [16]. Then calculate the cluster with k-means [17].

3. Results

3.1. Cloud Cover Analysis

Based on climate observations, the percentage of clouds is influenced by the Asian Monsoon Wind pattern. These winds carry a lot of water vapor which results in greater potential for cloud formation. The clouds that form block the radiation or solar heat that should be released into the atmosphere. The temperature from solar radiation that is absorbed by the earth and reflected into the atmosphere is prevented from being released because there is still a lot of cloud cover. Finally, the sun's heat returns to the earth so that the earth's temperature rises [7].

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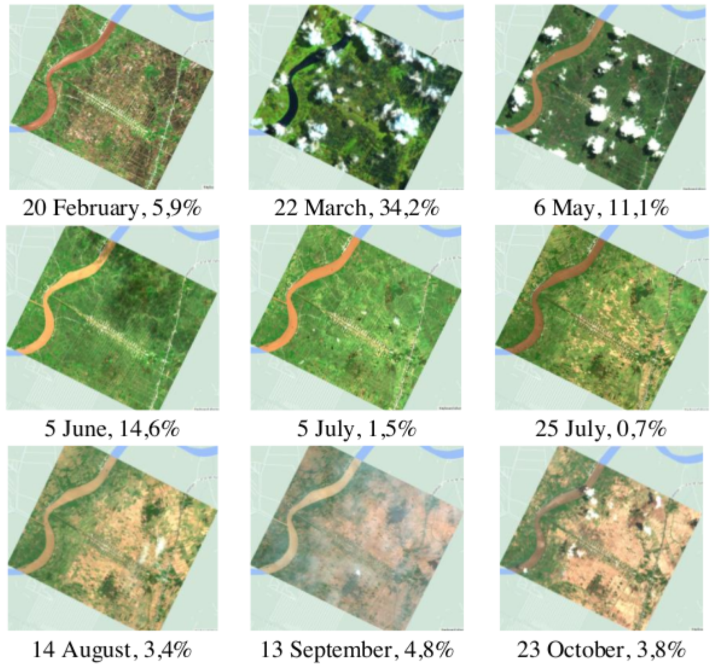

Figure 3. Sentinel-2 Image Collection

Image search results on Google Earth Engine (

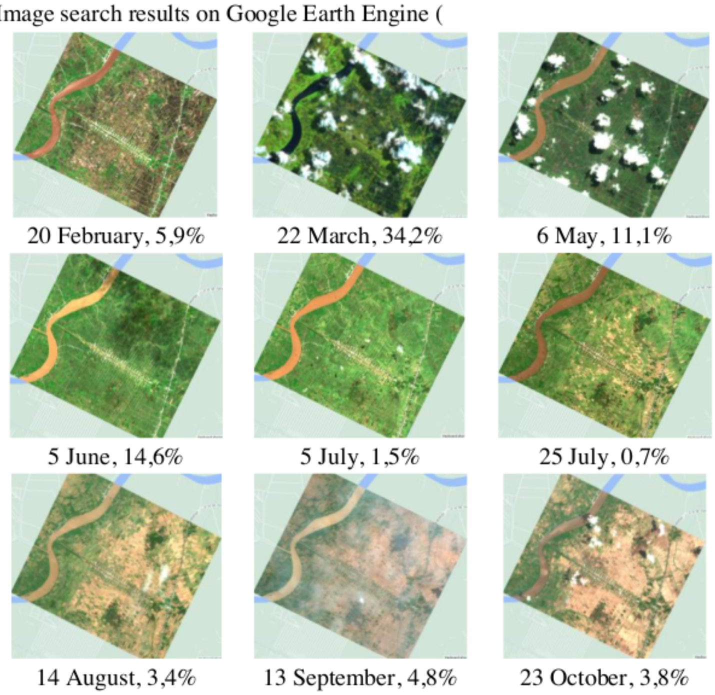

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Figure 3) show that nine images of Sentinel-2 were selected for analysis from a total of 61 images between February - October 2019. Images with >50% cloud cover were not used for analysis because the near-infrared sensor will only absorb the color of the cover—lands such as plant vegetation, soil, and water. Therefore, thick clouds in paddy fields are considered to interfere with the reflectance value of land cover so that it can affect the NDVI value. The highest cloud cover occurred on March 22 at 34,2%; this is influenced by the Southwest Monsoon, which blows from October to April. This wind pattern is wet and produces a lot of rain. The lowest cloud cover occurred on July 25 at 0,7%; this is influenced by the East Monsoon, which blows from April to October. This wind pattern is dry because it brings a period of dry air; the impact occurs in the dry season.

3.2. NDVI Analysis

NDVI is an index that describes the level of greenery of plants. The value of the greenness of the plant ranges from -1 to +1. The relationship between NDVI and rice plants lies in the change in the color of the rice leaves in each growth phase. The color of the leaves will continue to be greener, in line with the growth of leaves that grow tall and large. The green color of the leaves will be absorbed more by near-infrared sensors and red light.

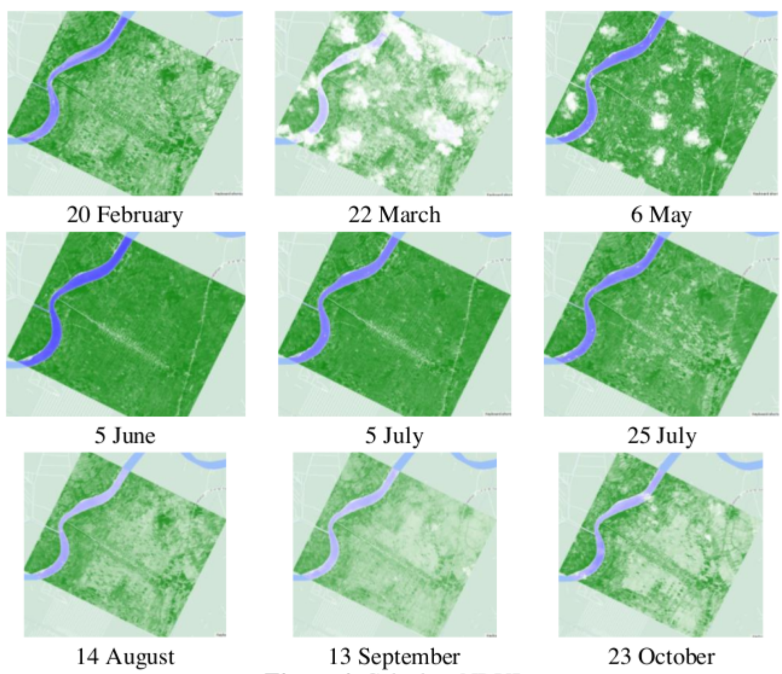

Figure 4. Calculate NDVI

Figure 4 presents the highest greenery level of rice plants that occurs on June 5; rice leaves grow tall and wide and receive full sun or degrees of heat in June or the term called photoperiodic sensors so that near-infrared sensors absorb more rice leaves. While the lowest greenery level of rice plants occurred on February 20, rice was still in the seedling/nursery phase, so the infrared sensor absorbed very few rice leaves and absorbed more soil and water.

3.3. Cluster Analysis

The number of paddy fields that are not covered by clouds is 135 plots, then using sample training with a confidence level of 5%, so that the paddy fields used for the sample are 100 plots. Cluster analysis aims to group data based on similarity. Cluster analysis using SPSS. The analysis procedure is to prepare candidate variables or the average value of the NDVI time series in quantitative form. Then determine the type of cluster analysis with hierarchical (hierarchical cluster) and non-hierarchical (k-means). Hierarchical cluster analysis aims to present all possible clusters optimally, while the k-means cluster analysis presents cluster results for a predetermined k value. Based on hierarchical cluster analysis, the optimal number for grouping is four clusters or k = 4. Next, the k-means cluster is performed to calculate the number of variables in each cluster. The results of the k-means analysis are shown in Table 2.

Table 2. K-means Final Cluster Analysis

Date	Planting Age (days)	Cluster			
		1	2	3	4
February 20	-53	0,28	0,32	0,31	0,33
March 21	-24	0,21	0,25	0,22	0,40
April 14	0	0,33	0,47	0,38	0,56
May 6	22	0,37	0,71	0,56	0,74
June 5	52	0,75	0,79	0,79	0,78
July 5	82	0,75	0,76	0,77	0,72
July 25	102	0,64	0,61	0,70	0,40
August 14	122	0,42	0,32	0,49	0,34
September 13	152	0,29	0,28	0,27	0,29
October 23	192	0,24	0,26	0,26	0,25

Based on the analysis, the maximum cluster occurred on June 5 in cluster 3, which was 0,75, and the minimum final cluster occurred on March 21 in cluster 1, which was 0,21. The cluster value in April is calculated using forecasts because, during discussions with Balai Penyuluh Pertanian (BPP), local rice varieties are planted during the dry season between Aprils – September. The amount of data used as a sample is 100 data, and each data has a lot of similarity data.

1. Cluster 1

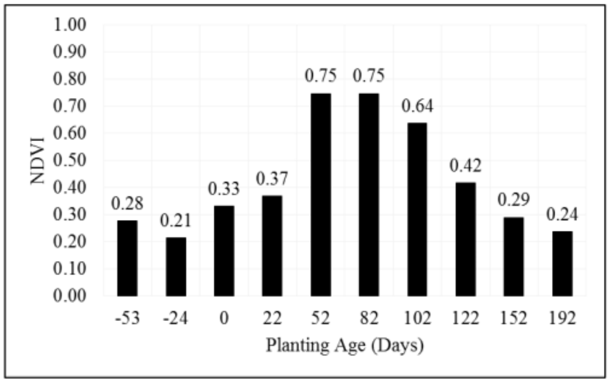

Figure 5. Analysis of Cluster 1

Based on the graph, the NDVI value for planting age (–53) – (-24) days decreased because the land was still in the preparation stage. The plowed land is left until the soil is saturated with water; at the planting age of -24 – 0 days, the harrowing stage is carried out to destroy and muddy the soil. The NDVI value for planting age 0-22 days, there was an insignificant increase due to rice in the seedling/nursery phase until rice entered the vegetative state at 52 days of planting. Entering the generative phase of the planting age of 82 days, the NDVI value did not change but entered the reproductive phase until the planting age of 102 days; the value decreased because rice was in the flowering phase. At the planting age of 122 days, the NDVI value decreased significantly because it was already in the ripening phase until, at the planting age of 152-192 days, the rice was ready to be harvested.

2. Cluster 2

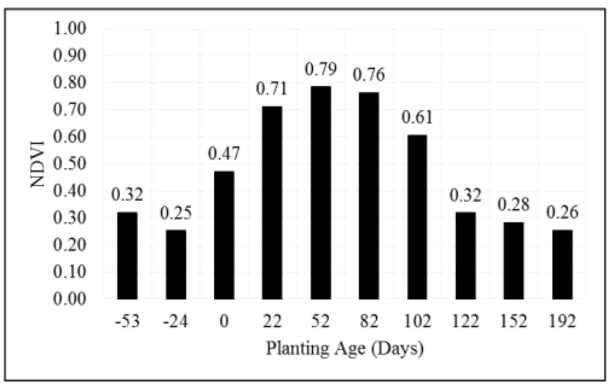

Figure 6. Analysis of Cluster 2

Based on the graph, the NDVI value for planting age (–53) – (-24) days decreased because the land was still in the preparation stage. The NDVI value of planting age -24 – 0 days there was a significant increase; this means that rice began to be sown at the planting age of -15 days until the rice entered vegetative at the planting age of 52 days. Entering the generative phase of the planting age of 82 days, the NDVI value did not change but entered the reproductive phase until the planting age of 102 days; the value decreased because rice was in the flowering phase. At the planting age of 122 days, the NDVI value experienced a significant decrease which caused the rice to be ready for harvest.

3. Cluster 3

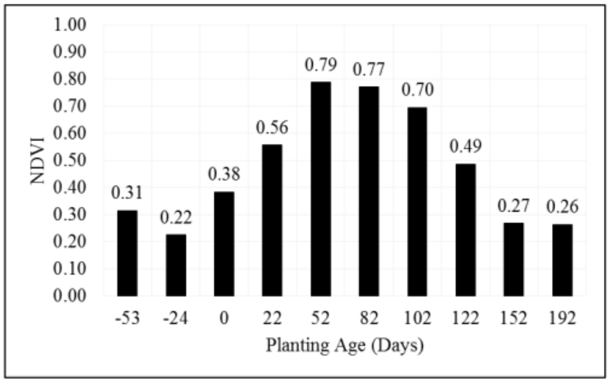

Figure 7. Analysis of Cluster 3

Based on the graph, the NDVI value for planting age (–53) – (-24) days decreased because the land was still in the preparation stage. The plowed land is left until the soil is saturated with water; at the planting age of -24 – 0 days, the harrowing stage is carried out to destroy and muddy the soil. The NDVI value of planting age 0-22 days increased in the phase of rice stalks growing large and tall until rice entered vegetative at 52 days of planting. The NDVI value at the planting age of 82-102 days did not decrease significantly but entered the reproductive phase until at the age of 122 days; the NDVI value decreased; this phase of rice was in the flowering phase. The NDVI value at the planting age of 152-192 days experienced a significant decrease which caused the rice to be ready for harvest; this means that the flowering phase of rice occurred at the planting age of 134 days.

4. Cluster 4

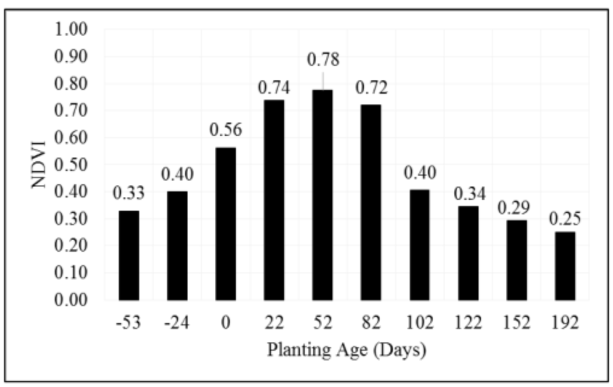

Figure 8. Analysis of Cluster 4

Based on the graph, the NDVI value of planting age (–53) – (-24) days, there was a difference in the increase from grades 1 – 3; rice had been sown first until the rice entered vegetative at the planting age of 52 days. Entering the generative phase of the planting age of 82 days, the NDVI value did not change but entered the reproductive phase until the planting age of 102 days; the value decreased because rice was in the flowering phase. At the planting age of 122 days, the NDVI value decreased because it was already in the ripening phase until, at the planting age of 152-192 days, the rice was ready to be harvested.

Table 3. Comparison of Cropping Calendars from Clusters

Rice Cluster	Planting Age (Days)									
	-53	-24	0	22	52	82	102	122	152	192

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1	LP	V1	V2	R	M	H
2	LP	V1	V2	R	H	
3	LP	V1	V2	M	H	
4	V1	V2	M	H		

Description:
LP = Land Preparation, V1 = Vegetative- 1, V2 = Vegetative-2, R = Reproductive, M = Maturity, H = Harvest

From the crop calendar data, the cluster 1 planting calendar is the normal planting age for rice plants in the study area and is in accordance with discussions with them. In contrast to the cluster 1 planting calendar, in the cluster 2 calendar, the vegetative phase 1 is shorter, and the vegetative phase 2 is longer. It is suspected that the application of excess fertilizer makes the plants grow tall and large so that the harvest period is faster. The cluster 3 planting calendar has similarities with the cluster 1 planting calendar, but there is a difference where the vegetative phase 2 is longer. In the planting calendar, cluster 4 is a different cluster from the others. The vegetative phase 1 is longer, and it is suspected that land preparation will be carried out in January.

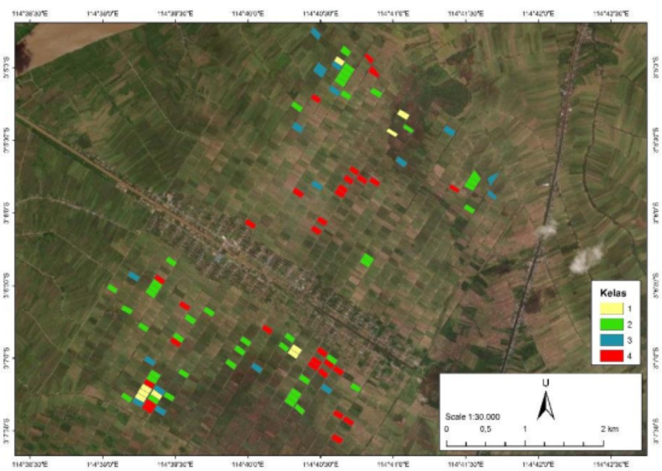

Figure 9. Cluster Map

Figure 9 shows the distribution of the cluster map. The results of the k-means analysis show that cluster 1 has 9 data, cluster 2 has 43 data, cluster 3 has 18 data, and cluster 4 has 30 data. Cluster 1-4 is the rice growth phase for local rice varieties. The various growth phases are influenced by several factors, namely the duration of plowing of paddy fields, fertilizer application, and the preparation of planting plans by farmers.

3.4. *Rice* Productivity Estimation Model

The formation of an equation model for rice estimation is carried out using rice field plots that have productivity data. The data used is data with the highest NDVI value on June 5 or 52 days after planting. Rice productivity was obtained through a field survey of rice field owners or cultivators from 100 plots of land with an average area of 1 hectare. The value obtained from this equation has been converted to tons/ha. The average productivity of each class can be seen in Table 4 below.

Table 4. NDVI Relationship with Productivity

Cluster	NDVI	Productivity (ton/ha)
Cluster 1	0,75	2,77
Cluster 2	0,79	2,95
Cluster 3	0,79	2,94

Cluster	NDVI	Productivity (ton/ha)
Cluster 4	0,78	2,87

Based on the classification results in Table 4, the highest productivity is in class 2 of 2,95 tons/ha with an NDVI value of 0,79, while the lowest is in class 1 of 2,77 tons/ha with an NDVI value of 0,75. To get the regression value, the linear equation model used is linear, which can be seen in Figure 10 as follows.

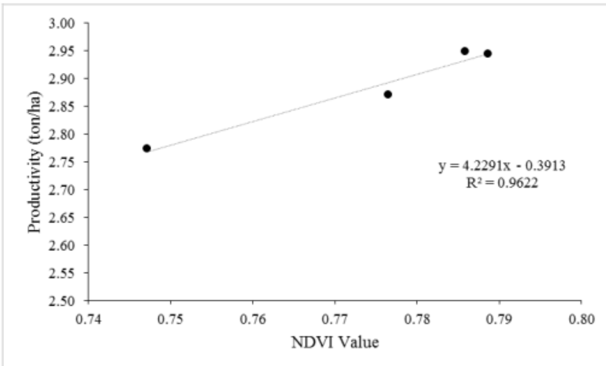

Figure 10. NDVI Coefficient of Determination and Productivity

Based on the classification results in Figure 10, the NDVI value of each class has a significant influence on productivity which has a coefficient of determination (R2) of 0,962 and has an equation model, namely productivity = 4,2291 (NDVI) – 0,3913 with standard error of 0,019, which means that the estimated productivity value can shift up to 0,019 tons/ha. The deviation of this value is small, so the rice productivity estimation model has good precision. According to the results in the field, the average productivity of rice is 3 tons/ha, so this method is close to the results in the field.

4. Conclusions

The use of NDVI on the productivity of rice plants using the main data source, namely Sentinel-2 imagery level 2A from February-October according to the planting phase, has a fairly strong relationship. The sample used was 100 data samples which were then analyzed into four clusters. The productivity of rice plants has four clusters, namely cluster 1 produces 2,77 tons/ha of rice, cluster 2 produces 2,95 tons/ha of rice, cluster 3 produces 2,94 tons/ha of rice, and cluster 4 produces 2,87 tons of rice. /Ha. the NDVI value of each class has a significant effect on productivity which has a coefficient of determination (R2) of 0,962 and has an equation model, namely productivity = 4,2291 (NDVI) – 0,3913 with a standard error of 0,019, which means that the estimated productivity value can shift up to 0,019 tons/ha. The deviation of this value is small, so the rice productivity estimation model has good precision. According to the results in the field, the average productivity of rice is 3 tons/ha, so this method is close to the results in the field.

5. Acknowledgment

The authors thank the data providers, namely the European Space Agency and Google Earth Engine, and the authors thank the Badan Penyuluh Pertanian (BPP) of Rantau Badauh District for taking the time to discuss the development of rice plants in the village of Danda Jaya.

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