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Estimation of Rice Productivity Using the Normalized Difference Vegetation Index (NDVI) Algorithm (Case Study of Gunung Talang District, Solok Regency)

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Abstract

Rice productivity is closely related to rice harvested area and cropping intensity. Remote sensing technology using MODIS MOD13A1 v006 image produces Normalized Difference Vegetation Index (NDVI) values that can be interpreted in analyzing the value of rice productivity. Gunung Talang District has a rice field area of 3,369 m², which is one of the central rice areas in West Sumatra Province. This study aimed to determine the regression equation to estimate rice productivity in Gunung Talang District, Solok Regency using the NDVI algorithm. The NDVI data used to generate the regression equation was taken in the generative phase. From the results of data analysis, the regression equation for estimating rice productivity in Talang District, Solok Regency is $y = 250.33x^4 - 1493.3x^3 + 2293.6x^2 - 1353.9x + 281.13$*, where x is the NDVI value and y is the productivity value (ton* ha^{-1}*). The test results of the model's validity are expressed in the value of NSE (Nash-Sutcliffe Efficiency) is 0.66, which is categorized as adequate.*

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1. Introduction

Solok Regency is one of the main rice areas in West Sumatra Province, according to the Decree of the Governor of West Sumatra Province number 521.305.2013. Solok Regency's topography varies from highlands to relative lowlands, so it has good water conditions and hydrology. There are many water sources, such as surface water, groundwater, and springs. It is very supportive of improving agriculture. The agricultural sector is a major economic sector because of the region's geographical location. Solok is famous for its superior and quality rice production. Solok rice is in great demand by the people of West Sumatra because it has a better flavor than rice from other regions (Mahmud & Mardianto, 2020).

The increasing level of rice consumption along with population growth becomes a challenge to increase rice production. One of the efforts made is to increase land productivity. Land productivity is the yield of rice obtained per unit area of land. Land productivity is closely related to rice harvested area and cropping intensity. Solok Regency is also an area with a vast expanse of rice fields, so this area can be used as a reference for determining the productivity of paddy fields. Rice production can be determined conventionally with the tile method; some are already using technology remote sensing.

Rice production in Indonesia can be estimated by several agencies, including the Logistics Affairs Agency (BULOG), the Central Statistics Agency (BPS), and the Director-General of Food Crops and Horticulture Production Development, Ministry of Agriculture (Wahyunto et al., 2006). Each agency has a different approach, so the information provided differs. According to BPS (2021), West Sumatra rice productivity data from 2014 to 2018 are 5.01 ton ha^{-1}, 5.03 ton ha^{-1}, 5.09 ton ha^{-1}, 5.25 ton ha^{-1}, and 4.74 ton ha^{-1}. Meanwhile, rice productivity data obtained from the Ministry of Agriculture (2021), with a range of 2014 – 2018 included 5.06 ton ha^{-1}, 5.06 ton ha^{-1}, 5.11 ton ha^{-1}, 5.27 ton ha^{-1}, and 5.19 ton ha^{-1}. The two data results have almost the same data trend, from 2014-2017 productivity tends to increase, and in 2018 there is a decline, but in 2018 there are data differences that are too significant, this makes it difficult for data users to make decisions.

BPS estimates rice production using field data collected from Mantri Tani (agriculturist) based on the results of randomly selected tiles (Wahyunto et al., 2006). Meanwhile, the Ministry of Agriculture estimates rice production by considering several parameters, namely the area of planting, the number of seeds planted, the calculation of productivity from the Mantri Tani, Field Agricultural Extension Officer, and BPS (Wahyunto et al., 2006). Along with technology that continues to develop, accurate and precise information is necessary to increase land productivity. One method of estimating the productivity of rice fields can be done using remote sensing. This method can help provide the required data in a short time and with minimal resources.

Remote sensing is used to monitor paddy fields to obtain data information that can be processed. In predicting the productivity of paddy fields, the vegetation index can be used through the Normalized Difference Vegetation Index (NDVI) value which was analyzed from the Moderate Resolution Imaging Spectroradiometer (MODIS13 A1V006) image. Then, survey the area of rice fields that the MODIS image has monitored so that it can be estimated rice production to be harvested in an area.

The results research of Yanti et al. (2022), monitoring rice productivity in Harau District, Lima Puluh Kota Regency with MODIS showed the value of the validity of the equation model linking NDVI with rice productivity of 0.64 which was categorized as sufficient with polynomial trend line. The results research of Prasetyo et al. (2018), namely a model for estimating rice productivity with NDVI and LSWI parameters, show that the NDVI and LSWI values affect the value of rice productivity by 63.9% while the remaining 36.1% is caused by other factors.

The results of research by Suhardi et al. (2017), the relationship between the vegetation index and rice productivity (tons/ha) is weak in SR, NDVI, SAVI, MSAVI, IPVI, and strong in RDVI. Suhadi analyzed the relationship between the vegetation index and rice productivity (tons/ha) using a linear trend line, usually a linear trend indicating something that goes up or down at a constant rate.

The use of the NDVI value in predicting the productivity of rice plants has been done previously by (Wahyunto et al., 2006). This study analyzes the production of rice plants using satellite imagery which can determine the estimated age of the rice plant so that the harvest time and area can also be calculated. Then the NDVI value obtained is directly proportional to the productivity value. Budiman, Ekaputra, and Berd (2021) studied the distribution of lowland rice productivity using satellite image data. The NDVI value becomes a reference in the estimation of productivity which is correlated with the data obtained from the tile survey.

This research was conducted to analyze the vegetation index on the rice fields in Gunung Talang District, Solok Regency, using MODIS 13A1v006 image data through the Normalized Difference Vegetation Index (NDVI) method. NDVI is used to quantify vegetation greenness and is useful in understanding vegetation density and assessing changes in plant health (U.S. Geological Survey, 2022). This method is the difference or subtraction between the reflectance of the near-infrared channel and visible channels' reflectance and is normalized by the sum of the two reflectance values. The value of the transformed vegetation index can be used to determine rice productivity. Therefore, this process can be used to determine the value of vegetation on the monitored paddy fields to predict the land's productivity.

The equation to be chosen in estimating rice productivity needs to be studied in advance by the appropriate data trend line. This study aims to determine the regression equation to estimate rice productivity in Gunung Talang District, Solok Regency using the NDVI (Normalized Difference Vegetation Index) algorithm.

2. Materials and Methods

2.1 Research Location

This research was conducted in Gunung Talang District, Solok Regency, West Sumatera. The area of rice fields in Gunung Talang District is 3,369 m^2 with 2 (two) rice planting seasons in one year. Gunung Talang District is located at coordinates 00.52'33 – 01.04'40 South Latitude and 100.31'34 – 100.41'58 East Longitude, with an area of ± 38.500 ha and is located at an altitude between 500 – 1000 meters above sea level.

2.2 Research Instruments and Materials

This research uses the following equipments:

1. A set of laptops equipped with ArcMap 10.5 software for map making, Microsoft Excel for processing data in the form of numbers, Microsoft Word for writing analysis results from processed data, and Universal Downloader program for obtaining supporting data according to coordinates.
2. GPS and open camera applications to determine the position when conducting field surveys.
3. Smartphone to document activities in the field.

The materials used in this research are as follows:

1. Data from MODIS (MOD13A1 version 006) West Sumatra with horizontal 28 and vertical 09 with a resolution of 500 m x 500 m obtained from The US Geological Survey (USGS) as data to determine the NDVI value. The use of MODIS is because the coverage area is wide, so the data can be considered representative for one sub-district of the research area. MODIS image data were taken from July 28, 2021 – January 1, 2022.
2. Solok Regency administration map was obtained from (tanahair.indonesia.go.id, accessed on January 2022)
3. Mount Talang satellite image was obtained from the Universal Downloader application.
4. The rice field map of West Sumatera was obtained from (www.big.go.id, accessed on January 2022).
5. The RTRW of Solok Regency was obtained from (www.big.go.id, accessed on January 2022).

2.3 Research procedure

In this study, the interpretation of MODIS13A1 image version 006 updated every 16 days using a Geographic Information System (GIS). After processing the MODIS image data, a field survey was conducted. The survey was carried out by direct measurements and interview the farmers who own the rice fields. The survey location is based on the cell size determined during MODIS image processing in the research area. The percent value of the cell size will determine the number of sample points to be surveyed.

2.3.1 Data collection

The data needed in the research are primary and secondary data. The primary data is rice field productivity obtained from direct observations in the distribution area according to the determined sample points. Secondary data is MODIS13A1 v006 image obtained from The US Geological Survey (USGS), Solok Regency spatial plan data, and satellite image data of the research location.

2.3.2 Data processing

MODIS13A1 image data version 6 has previously been downloaded from the USGS website. MODIS image data is processed from July 12, 2021, to January 1, 2022. Then, the geometry correction and image cropping according to the boundaries of the research area were performed. Next, the NDVI was extracted to get the Vegetation Index value. The research area that has been cut will be overlaid with the West Sumatra Rice Field Distribution Map from the Geospatial Information Agency (Yanti et al., 2021).

1. Geometry correction

Geometry correction, better known as Georeferencing, provides specific spatial references to objects in the form of raster or images that do not yet have a coordinate system reference. This process is based on comparing the coordinates of the raster map source and the destination point or control point. In the geometry correction process, we will correlate the coordinates of an object (x,y) in the image with the coordinates (X, Y) on the earth's surface. This correction will transform the coordinates of the points in the image that still contain geometric errors into the correct image (Ekaputra et al., 2020).

2. MODIS image cropping

This process is an activity to make it easier to analyze the image. The MODIS image is cropped using ArcGis 10.5, adapted to the research area. The research area boundaries are identified by entering the administrative map of Solok Regency into ArcGIS 10.5.

3. Determination of NDVI value

The process to get the NDVI value is done after creating a grid on the map. The grid is made manually with mirror tools to limit pixels to an area of 25 ha. After that, enter the NDVI value on each grid that has been created. The NDVI value is extracted according to a predetermined limit, namely -2000 to 10000. Get the range value by performing calculations using the formula in equation 1.

$$NDVI = (\rho\ nir - \rho\ red)/(\rho\ nir + \rho\ red) \quad (1)$$

Where NDVI: Normalized Difference Vegetation Index, ρNIR: NIR channel surface reflectance; and ρred: the surface reflectance of the red channel.

4. Data overlay process

This process is an activity to combine MODIS images with the Badan Informasi Geospatial Rice Field Map of West Sumatra through the intersect process. This process also determines the area of paddy fields and the cell size representing each grid. The percentage of cell size that will be studied in the lot is in the range of 45% - 100%. Then, enter the image of Mount Talang as information on the earth's surface at the research location.

2.3.3 Rice Productivity Calculation

Observed rice productivity data is identified after the production data, and the land planted area is obtained. Direct measurements determine land production in the field. Land area is obtained from the results of land tracking, which is then processed using ArcGIS software. Calculation of observational rice productivity using equation (2).

PP= P/L (2)

Where: PP: rice productivity (ton ha^{-1}), P: production (ton), L: land area (ha)

2.4 Data Analysis

The equation used in estimating rice productivity is obtained from the analysis of the relationship between the NDVI value and rice productivity at the sample point of the observation location. The equation that will be used to estimate rice productivity is a polynomial equation. The determination of the second, third, or fourth order is based on the level of conformity of the observation data with the highest estimate or the smallest error value.

The equation obtained needs to be tested for model reliability with the analysis of the Nash-Sutcliffe Efficiency (NSE) test using equation (3) with assessment criteria such as Table 1.

$$NSE = 1 - \frac{\sum_{i=1}^{n} (OBSi - SIMi)^2}{\sum_{i=1}^{n} (OBSi - \overline{OBS})^2} \quad (3)$$

Where OBS: observed/field productivity value (ton ha^{-1}), SIM: simulation/analytical productivity value (ton ha^{-1}), $\overline{OBS}$: average observation productivity value (ton ha^{-1})

Table 1. NSE Value Assessment Criteria (*Nash-Sutcliffe Efficiency*)

NSE Value	Assessment criteria
0.75 < NSE ≤ 1.00	Very good
0.65 < NSE ≤ 0.75	Good
0.50 < NSE ≤ 0.65	Adequate
NSE ≤ 0.50	Inadequate

Source: Yunarni et al. (2019)

3. Results and Discussion

3.1 Sampling Location

Based on the type of use, the area of paddy fields in Gunung Talang District is 3,369 m^2, while for non-rice lots, it is 23,249 m^2 (BPS, 2020). In Figure 1, 99 grids can be observed in the field, shown in blue on the work map. In contrast, the green color indicates a sample of the area of rice fields that have been tracked using a GPS device. The amount of data that has been observed for productivity based on the work map is 34 grids with 112 data details. The data obtained are representative of each paddy field studied.

Determination of pixel size as a representative of the grid under study is very influential on data collection in the field. Data collection in Gunung Talang District uses a pixel size of 45%, MODIS images with a resolution of 500 m x 500 m which can capture more images in one grid. Rice field samples with a pixel size of < 45% are not used, to reduce the risk of large errors when collecting data in the field.

3.2 The Relationship between the Value of the NDVI Algorithm and the Growth Phase of Rice Plants in Gunung Talang District

The relationship between the NDVI value and the growth phase of the rice plant can be established by analyzing the NDVI value obtained from the MODIS image. The MOD13A1 v006 MODIS image was taken from July 12, 2021 - January 1, 2022, using The US Geological Survey (USGS). The obtained data is processed using the ArcGIS application. The value of the Vegetation Index is calculated using the NDVI formula. The value of the Vegetation Index is limited by the administrative boundary of

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Gunung Talang District, Solok Regency. However, in the NDVI value and the growth phase correlation analysis, the grid is limited to 45%, according to the work map shown in Figure 1.

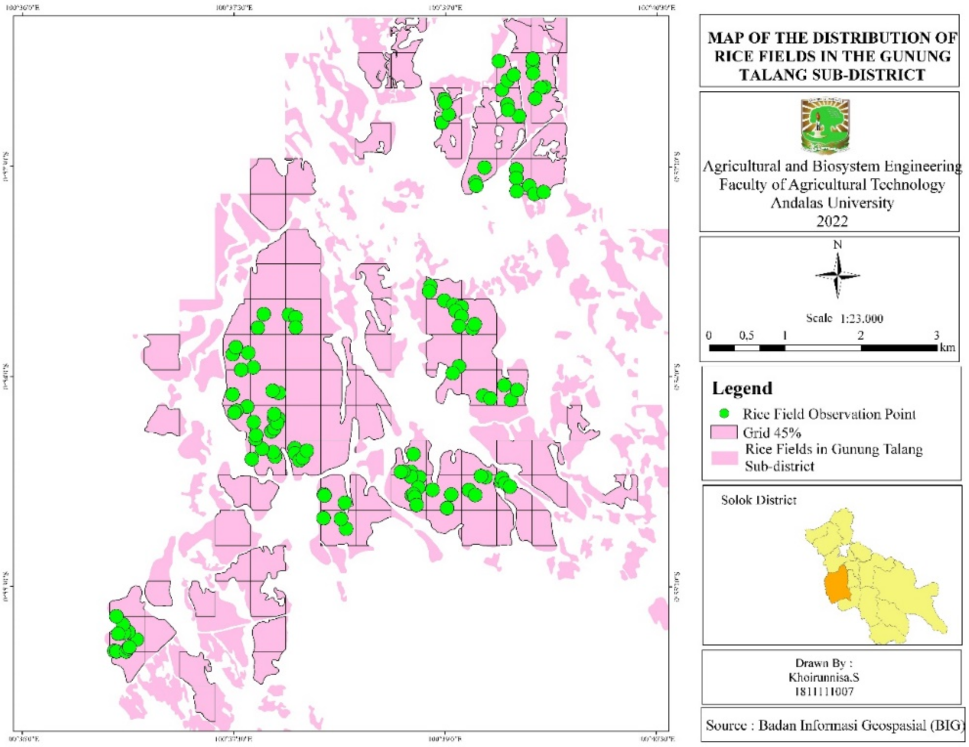

Figure 1. Research Location

Gunung Talang District has a rough and hilly topography and good water conditions. Rice cultivation in the area is dominated by cultivation with a terraced system. In addition to rice, the land is also planted with several horticultural crops such as vegetables. So this can affect the MODIS image in capturing objects. Therefore, the pixel size used in this study is 45%, so more rice fields can be sampled. The NDVI value that has been processed is displayed in graphical form, which can be seen in Figure 2.

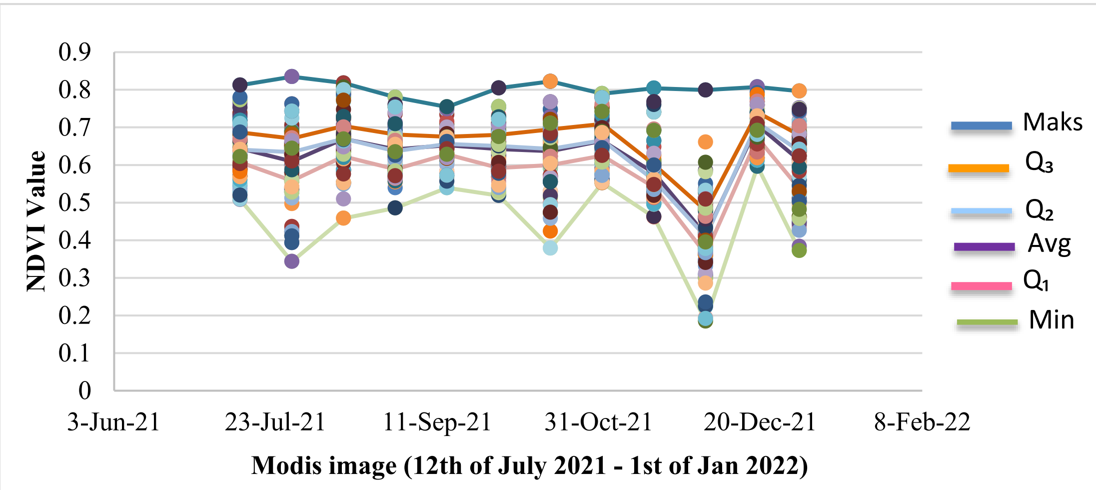

Figure 2. NDVI Value July 12, 2021 to January 1, 2022

The graph was based on the Minimum, Quartile 1 (Q1), Quartile 2 (Q2), Average (Avg), Quartile 3 (Q3), and Maximum NDVI values from July 12, 2021 – January 1, 2022. The x value represents the date the NDVI value is obtained, while the y value is the NDVI value based on the Minimum, Quartile 1 (Q1), Quartile 2 (Q2), Average (Avg), Quartile 3 (Q3), and Maximum values. These values are used to make it easier to analyze the planting period of rice plants. The graph showing the relationship between the growth phase of rice plants and the NDVI value based on the MODIS image acquisition date can be seen in Figure 3.

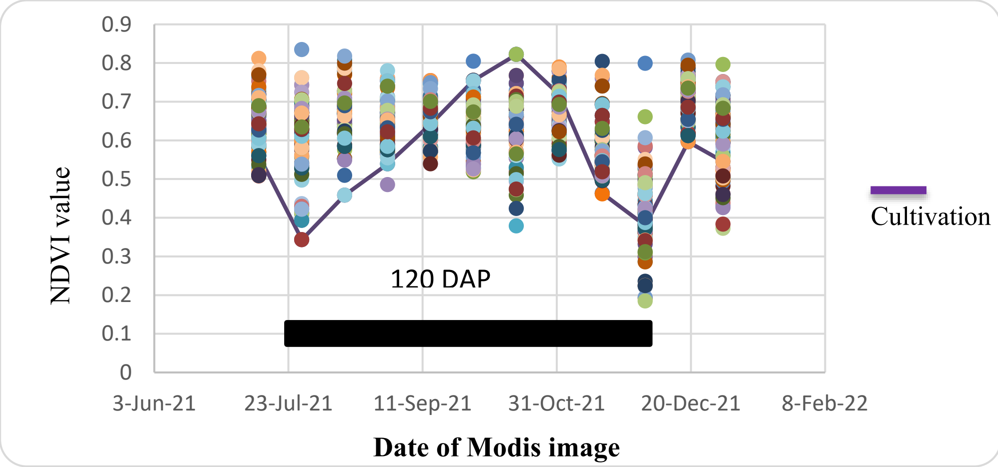

Figure 3. NDVI for Rice Fields in Gunung Talang District

The graph in Figure 3 is a one-time condition of rice planting in Gunung Talang District. The graph form of one planting period is a parabola. In Figure 4, there is a graph showing the NDVI value as a reference for analyzing the relationship between the growth phase of rice plants and NDVI conditions in Sawah, Gunung Talang District. The types of rice varieties used by farmers in Sawah, Gunung Talang District, are also very influential in determining the growth phase of rice plants. It is because the harvest age of rice is different for each variety. Based on the results of observations, the rice varieties found in Gunung Talang District and their harvest ages can be seen in Table 2.

Table 2. Rice Varieties and Harvest Age in Gunung Talang District

No.	Varieties	Harvest Age
1	Sokan Hitam	± 105 days
2	Sokan	± 105 days
3	Bujang Marantau	± 110 days
4	Banang Pulai	± 115 days
5	Kuriak Kusuik	± 115 days
6	Ir 42	± 115 days
7	Anak Daro	±120 days
8	Suntiang Anak Daro	± 120 days
9	Sokan Junjuang	± 120 days
10	Sitongkang Panuah	± 120 days
11	Irna Sumamerah	± 120 days
12	Ciredek	± 120 days
13	Sagantang Panuah	± 120 days
14	Anak Daro Tinggi	± 120 days
15	Junjuang	± 120 days

The harvest age of rice plants in Table 2 ranges from ± 105 – 120 days. It also shows a period of rice growing. The graph shown in Figure 5 shows that the curve that forms the parabola is from July 28 – December 3, 2021. The shape of the graph of the growth phase of the rice plant can be seen more clearly in Figure 4.

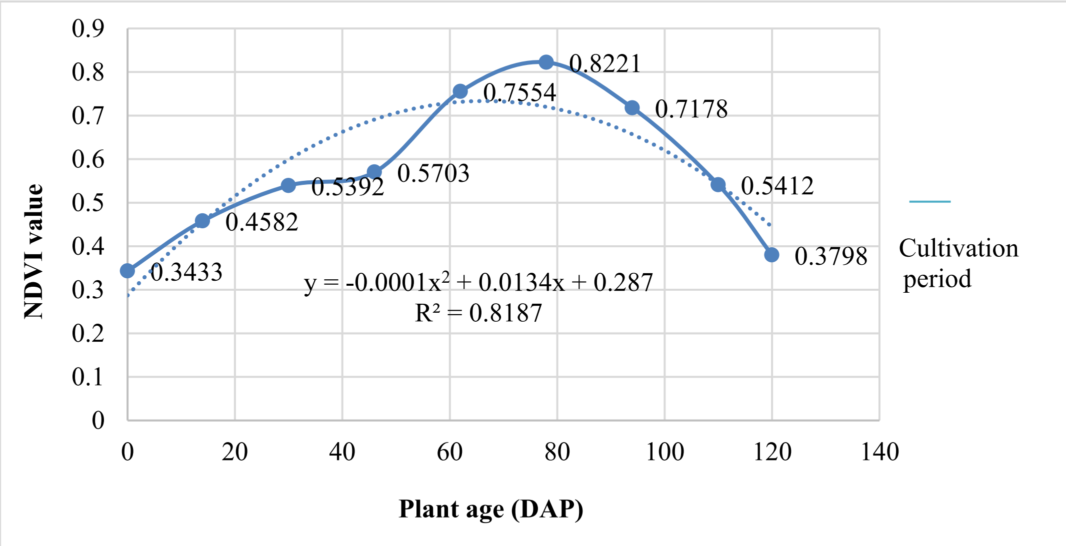

Figure 4. Relationship between DAP and NDVI

In Figure 4 it can be seen that the NDVI value is at 0.343 to 0.8221. The NDVI value in the rice fields of Gunung Talang District shows that at the time of observation, all of the land was vegetated. The NDVI value ranges from -1 to +1. As has been explained that the (-) value indicates the condition of the rice plant in a watery and fallow condition, while the (+) value indicates the vegetation object (Budiman et al., 2021). The NDVI values for vegetation range from a low of 0.05 to a high of 0.66+. Clouds, snow, and bright non vegetated surfaces have NDVI values of less than zero. The NDVI selected for each pixel is the greatest value on any day during the 14-day period (the highest NDVI value is assumed to represen period). This process eliminates clouds from the composite, except in areas that are cloudy for all 14 days (Lillesand et al., 2015).

Rice plants will experience a peak in the early generative phase (10-13 WAP) and when the rice plant is in a state of grain filling until the harvest period, it will decrease. The results research of Yanti et al. (2022), show that NDVI value increased during the vegetative phase and decreased when it entered the generative phase until harvest. The graph in Figure 4 continued to decline after experiencing a peak period, namely at the age of 95 days to a fallow period of 120 days.

Based on Figure 4, the value of x, which represents the plant growth phase (Day After Planting, DAP), and y, which represents the NDVI value, it can be seen that the resulting regression equation is: $y = (-0.0001)x^2 + 0.0134x + 0.287$, with a determinant coefficient of 0.8187. It means that the value of plant age (DAP) has a strong relationship with the NDVI value. The regression equation obtained is used to determine the range of NDVI values.

The NDVI model is based on the dates of the obtained MODIS image for one planting period: July 28 – December 19, 2021. The growing phase of the rice plant is divided into six parts: watery, vegetative 1, vegetative 2, generative 1, generative 2, and fallow (Hafizh S, Cahyono, and Wibowo, 2013). The table showing the relationship between the NDVI value and the growth phase of the rice plant can be seen in Table 5.

Table 5. Correlation of NDVI Value to Rice Plant Growth

Growing Phase	NDVI value	Greenness Level	Plant Age	
			Day After Planting	Week After Planting
Water	≤ 0.4552	Water/Open Land	<21	<3
Vegetative 1	0.4552-0.6910	Low	21 - 45	3-6
Vegetative 2	0.6910-0.7314	High	45 - 65	6-9
Generative 1	0.7314-0.6570	High	65 - 95	9-14
Generative 2	0.6570-0.5423	Low	95-110	14-16
Fallow	0.3261-0.4443	Open Land	>110	>16

The correlation analysis of the NDVI value and the growth of rice plants (Table 5) resulted in a minimum range of 0.3261 and a maximum of 0.7314. Hafizh S et al. (2013), in analyzing rice growth using multispectral images in Indramayu, West Java, showed different NDVI range values. The minimum value range in the water phase is 0.137, and the maximum value remains in the same, generative phase 1. It is because generative phase 1 shows a peak period with a high greenish index.

The difference in the NDVI value is due to the difference in the MODIS image used. Hafizh S et al. (2013) retrieved NDVI value data using MODIS MOD02HKM images, while in this study, MODIS MOD13A1 v006 images were used. According to Triscowati and Wijayanto (2020), MODIS is a satellite image that does not penetrate clouds, so it experiences a lot of cloud cover, especially in mountainous and cloudy areas. MODIS has many bands that can be a source of vegetation information.

Different types of rice varieties can affect the analysis of the NDVI value range. Gunung Talang District is dominated by varieties with a harvest age of 110 -120 DAP. However, the range of NDVI values contained in Table 5 shows the appropriate growth phase of the rice plant as a whole because it displays the NDVI value, which increases when entering the generative phase 1 and continues to decrease after grain filling until the harvest period.

3.3 Estimation of Ricefield Productivity

Land sample data was obtained based on observations using GPS. Land sample data was taken based on a grid of 45%, as shown in Figure 3. Employing the ArcGIS application, the land sample was digitized to calculate the sample land area using the Calculate Geometry tool. In addition to these data, the rice production data for each sample land were also obtained. A comparison of the rice fields' sample area with the rice yield on the land was conducted to get the productivity value (ton ha^{-1}),

The number of productivity data observed in the field is 34-pixel data grids. Productivity data analyzed with NDVI values are in generative stages 1 and 2. I.e 65-110 HST. It is intended that productivity values with NDVI values are not too biased or distorted. Liyantono et al., (2019), also stated that the best period to estimate paddy productivity is 63 DAP (Days After Planting) that NDVI reaches its maximum state. Based on the observed growth phase of the rice plant, there are 19 grids that meet the productivity data.

The average NDVI value associated with productivity data is in the generative period 1 and 2. The NDVI value was obtained on the date of the MODIS image acquisition on November 17, 2021. This can be seen in the analysis of the previous phase **(Figure 3)**. The number of productivity data analyzed with NDVI values is 33 data. Data normalization is carried out to produce a good database. Productivity data that has formed a good relationship structure amounted to 12 data. The productivity data that has been normalized can be seen in Table 6.

Table 6. Normalization of Productivity Data in Gunung Talang District

No.	GRID_ID	NDVI value (November 17, 2021)	Productivity (ton ha^{-1})	Observation plant age (DAP)
1	F4	0.4954	7.10	± 103
2	I7	0.5217	4.90	± 75
3	G10	0.5345	5.09	± 90
4	H2	0.5461	4.47	± 105
5	I2	0.5472	4.42	± 105
6	F7	0.5509	5.70	± 90
7	F9	0.5625	5.35	± 120*
8	A8	0.5955	3.75	± 120*
9	E4	0.6155	4.69	± 120*
10	B8	0.6481	4.20	± 120*
11	D6	0.6642	5.28	± 120*
12	A6	0.8040	3.72	± 114*

Note: *measurement of production at harvest

The value of rice productivity is obtained from the measurement of production at harvest (direct measurement) and the results of interviews with farmers who own/cultivate the land, so the data used is data on real field conditions. While the NDVI value used is the NDVI value before the harvest, namely the NDVI which was released on November 17, 2021, when rice was in generative phases 1 and 2. So the resulting regression equation is an equation for estimating rice productivity before harvest.

Based on Table 6, a regression equation is formed between the productivity and the NDVI value. The x value represents the NDVI value, and the y value represents the productivity value (tonnes/ha). The equation formed is used to predict the value of lowland rice productivity based on the NDVI value later. The NDVI value is a reflection of land conditions which are influenced by factors such as soil fertility, water availability, and plant health. Hence, the polynomial equation becomes one equation supporting predicting productivity. The multiple regression equation formed has an order of 2 to 4, as shown in Figure 5.

In Figure 5, it can be seen that the regression equations of order 3 and order 4 have a determinant coefficient (r^2) of 0.6612 or the same correlation coefficient (r) of 0.813, meaning that the correlation between the NDVI value and rice productivity is categorized as high. Based on the value of the correlation coefficient (r) according to Hadi (1979); Arikunto (2010), the value of r which is between 0.8 to 1.0 is interpreted as having a high correlation.

Effective light reflectance will give a strong contribution to the relationship between the vegetation index value and the weight of harvested dry grain. At the research location, the relationship between the NDVI value (generative phase) and productivity (harvest dry grain) is in the strong category, meaning that the light reflectance at the research location is stable and the effect of cloud cover during image coverage by satellite is not significant. Determination of the Equation that will be used for the estimation of rice productivity is also seen from the error value of the estimated productivity data, which is the smallest error value. The estimated rice productivity data is presented in Table 7.

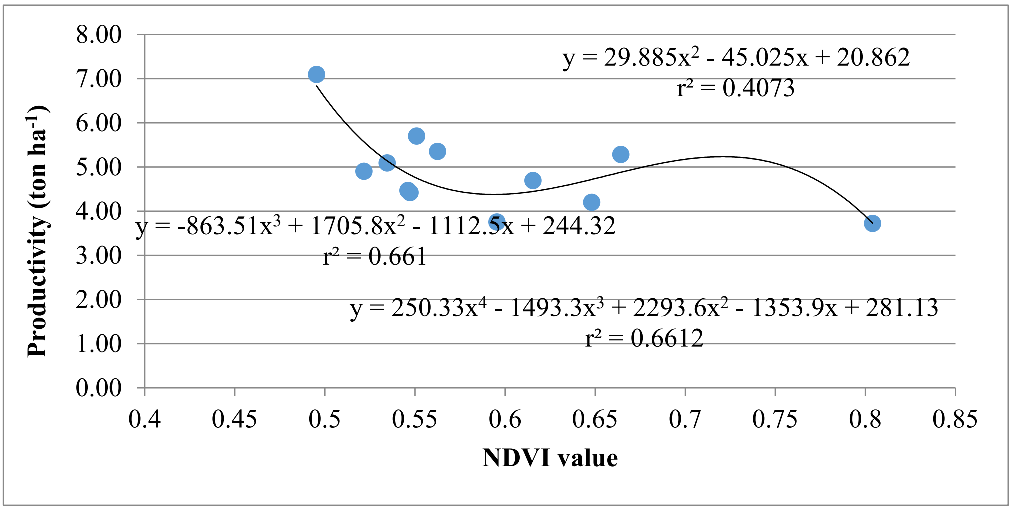

Figure 5. Relationship of NDVI Value with Productivity (ton ha^{-1})

Table 7. Productivity Estimation Data Based on the Regression Equation

X (NDVI value, November 17, 2021)	Observed productivity (ton ha^{-1})	Estimated productivity (ton ha^{-1})		
		Order 2	Order 3	Order 4
0.4954	7.10	5.89	6.84	6.83
0.5217	4.90	5.51	5.59	5.56
0.5345	5.09	5.33	5.16	5.13
0.5461	4.47	5.19	4.86	4.84
0.5472	4.42	5.17	4.84	4.81
0.5509	5.70	5.13	4.77	4.74
0.5625	5.35	4.99	4.58	4.56
0.5955	3.75	4.65	4.38	4.37
0.6155	4.69	4.47	4.45	4.44
0.6481	4.20	4.23	4.73	4.71
0.6642	5.28	4.14	4.91	4.87
0.8040	3.72	3.98	3.74	3.72
	Error	11.81%	9.20%	9.04%

Based on Table 7, the resulting error values are different. The smallest error value is found in the fourth-order multiple regression equation of 9.04%. It means that this equation can be used to analyze the estimated value of rice productivity in Gunung Talang District. namely $y = 250.33x^4-1493x^3+2293.6x^2-1353.9x+281.13$. The selected order 4 equation. which will be used to estimate rice productivity in Gunang Talang District. needs to be tested for the model's validity by finding the Nash-Sutcliffe Efficiency (NSE) value using equation (3). The NSE value obtained is based on the productivity value obtained from observations with estimates. which can be seen in Table 8.

Table 8. Observed and Estimated Productivity

Sample	NDVI	Observed Productivity (ton ha^{-1})	Estimated Productivity (ton ha^{-1})
1	0.4954	7.10	6.83
2	0.5217	4.90	5.56
3	0.5345	5.09	5.13
4	0.5461	4.47	4.84
5	0.5472	4.42	4.81
6	0.5509	5.70	4.74
7	0.5625	5.35	4.56
8	0.5955	3.75	4.37
9	0.6155	4.69	4.44
10	0.6481	4.20	4.71
11	0.6642	5.28	4.87
12	0.8040	3.72	3.72
Average		4.890	4.881
NSE		0.66	

The NSE value shown in Table 8 of 0.66. which is in the range > 0.65 to 0.75. is interpreted in the good category (Yunarni et al. 2019). The 4th order multiple regression equation that has been made is sufficient to be used in predicting the value of rice productivity in Gunung Talang District. Solok Regency.

4. Conclusion

Based on the research that has been done, it is found that the regression equation used to predict rice productivity in Gunung Talang District; Solok Regency; is $y = 250.33x^4 - 1493.3x^3 + 2293.6x^2 - 1353.9x + 281.13$, with a determinant coefficient (R^2) of 0.6612. Which means the correlation of NDVI value (x) with rice productivity (y) is categorized as strong. Based on the model validity test. the equation has a *Nash-Sutcliffe Efficiency* (NSE 0.66) value labeled good as an equation model.

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