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Rice Productivity Estimation Using Remote Sensing Method

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ABSTRACT

The calculation of crop productivity has now been facilitated by technological development using remote sensing technology or data generated by satellites. Determining the value of productivity using images will shorten the time and does not require much effort. A remote sensing model that connects satellite image reflectance data with rice plant parameters will be handy for monitoring biomass growth and predicting crop yields more quickly and efficiently. This study aimed to determine the regression equation to estimate the productivity of regional rice in Harau District, Lima Puluh Kota Regency. This study consisted of several stages: data collection, data processing, and calculation of rice productivity, NDVI regression analysis with rice productivity, and Nash-Sutcliffe Efficiency (NSE) test against the obtained equations. The regression equation obtained from the results of data analysis to estimate rice productivity in Harau District, Lima Puluh Kota Regency is y = - 82152x4 + 208465x3 - 197654x2 + 82986x - 13014, with an NSE value of 0.64 which is categorized as 'sufficient'.

1. INTRODUCTION

Estimating rice growth and productivity is necessary, considering that rice is the staple food crop for most Indonesian people. Plant growth needs to be determined for scheduling fertilization, pesticide application, weed control, and harvesting. Decisions can be made more quickly and precisely if the plant development phase can be predicted earlier. Estimating rice production before harvesting is essential to evaluate the adequacy of food supplies and become a consideration in deciding whether it is necessary to import if there is a deficit or export if there is a surplus of rice/rice supplies.

In Indonesia, the estimation of rice production has been carried out by several agencies: 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). The approach taken by each agency is different. The

Central Bureau of Statistics calculates the value of rice productivity using agricultural surveys and randomly selected tiles. The tile method used is to take 10 sample points randomly in the field, and the value of the tiles taken has a size of 2.5 m x 2.5 m by cutting, threshing, and weighing (BPS, 2021). Meanwhile, the Ministry of Agriculture uses agriculture officers called Mantri Tani and Field Agricultural Extension Officers as well as data on rice fields from BPS by considering the area of land and the number of seeds distributed by farmers (Yuniarto *et al.*, 2015).

The calculation of crop productivity has now been made easier by remote sensing technology or satellite data (Yuniarto *et al.*, 2015). Everyone can access the data without going through a long process. Analysis of the level of rice production can be done by considering the greenness of the plant based on the image results. The greenish value that will be produced is between –1 to +1. The greater the value, the more lush or green the plant will be (Yuniarto *et al.*, 2015).

Determining the value of productivity using images will shorten the time and does not require much effort. The resulting productivity value is based on tiles from image processing (using software) and available image data. This method is more accurate when compared to manual data collection because some currently available data use random sampling, and primarily to facilitate data collection, it is only done to certain farmer groups in the area.

Determining rice productivity is currently conducted using modern technology with effective and accurate methods. The results of the review of articles by Wójtowicz *et al.* (2016) describe with advances in satellite, airborne and ground based remote sensing, reflectance data are increasing being used in agriculture. A remote sensing model that connects satellite image reflectance data with rice plant parameters will be beneficial for effective and efficient monitoring biomass growth as well as predicting crop yields.

The use of remote sensing technology is currently common because it is proven that the results are effective and accurate. The NDVI (Normalized Difference Vegetation Index) method is very suitable for determining the rice planting period, which can be used to analyze the level of rice production. The research by Berd *et al.* (2022) in the Talang District, Solok Regency, West Sumatra Province showed that the validation test of actual production data and the use of the NDVI algorithm resulted in an NSE (Nash-Sutcliffe Efficiency) value of 0.868 categorized as good. The results of Prasetyo *et al.* (2018) research show that the NDVI and LSWI algorithms are the best combination of linear regression in estimating the level of rice productivity with a coefficient of determination of 0.639. The results of Son *et al.* (2014) research also prove that there is a significant correlation between the estimated rice yields obtained from the EVI and NDVI-based models. This study aims to determine the regression equation to estimate the productivity of regional rice in Harau District, Lima Puluh Kota Regency based on the NDVI value using regression equation resulted from the rice productivity data.

2. MATERIALS AND METHODS

2.1. Time and Place

This research is conducted in Harau District, Lima Puluh Kota Regency. Based on the Decree of the Governor of West Sumatra Number 521.305.2013, Lima Puluh Kota Regency is one of the production centers for the food crop sub-sector for rice commodities. Harau District is the largest area in Lima Puluh Kota Regency. The area of rice fields in Harau District is 3,992 Ha with a total area of 416.80 km2 and consists of 11 Nagari (sub-districts). Lima Puluh Kota Regency is geographically located between 0° 25'28.71” North Latitude to 0°22'14.52” South Latitude, and between 100°15'44.10” -

100°50'47.80” East Longitude. The climate type of Lima Puluh Kota Regency is B2 according to the classification of Schmidt and Ferguson with an average rainfall of around 3 000 - 3 353 mm per year. This research was conducted from October to November 2021 in Harau District and analyzed at the Laboratory of Agricultural Land and Water Resources Engineering, Department of Agricultural Engineering and Biosystem, Andalas University.

2.2. Tools and Materials

The tools used in the study are a laptop with ArcGIS software installed, GPS (Global Positioning System), Smartphone with Open Camera application and data storage (external hard drive), ArcMap 10.4.1, MS. Excel and MS. Words. While the materials needed for this research are:

1. MODIS image data in the form of MOD13A1 v006 with a spatial resolution of 500 m downloaded from The US Geological Survey (USGS). MOD13A1 V6 is an accumulation of MOD09A1 with an acquisition period of 8 days after being Mod13 to 16 days, has 7 bands with 13 layers, after being made MOD13 there are only 4 bands (RED, NIR, Blue, MIR) with 12 layers including NDVI, EVI and VI in this study used only the NDVI layer. MODIS data used for 1 full year (2021) with a temporal resolution of 16 days MODIS, to see the planting period and the growing phase of rice that occurred.
2. Data on Regional Spatial Plans (RTRW) for Lima Puluh Kota Regency downloaded from the website of Geospatial Information Agency (BIG). Spatial data provided by BIG online is in Vector format (point, line, polygon) with tabular attributes in it, Raster data is not used.
3. The Lima Puluh Kota District image is downloaded from the SASPlanet software.
4. Data on the rice fields distribution in West Sumatra is downloaded from the website of the Geospatial Information Agency (BIG), that is spatial data in shp format with tabular attributes.

2.3. Research procedure

This research consists of several stages, i.e., data collection, data processing, calculations of rice productivity, analysis of NDVI regression with rice productivity, and NSE test against the obtained equation.

2.3.1. Data collection

The data used for this study consisted of MODIS image data, Lima Puluh Kota Regency Spatial Plan (RTRW) data, West Sumatra BIG rice fields data, and Lima Puluh Kota Regency image data. MODIS image data used is MOD13A1 v006 obtained by downloading MODIS satellite imagery on *https://earthexplorer.usgs.gov/*. In order to download the data, a USGS account and an Earthdata account are required. Registration can be done at *https://earthexplorer.usgs.gov/* and *https://urs.earthdata.nasa.gov/*. Registration can be done at web.erthexplorer.usgs.gov and web.urs.earthdata.nasa.gov. West Sumatra is located in 4 scenes and is adjusted to the research location. The Lima Puluh Kota Regency is in the h28v09 scene. MODIS image data available on USGS website has two options, i.e., data based on time trends or only the latest data recorded by the satellite. Both data were taken and used in the time trend to create the final phase and coverage to view production data.

Lima Puluh Kota RTRW data and West Sumatra BIG rice field data were obtained from the Geospatial Information Agency (BIG) website in .shp format. Data clipping for research locations was conducted in ArcMap 10.4.1 software.

2.3.2 Data processing

The collected data were then processed using ArcGis 10.4.1 software to get the NDVI value for each frame and work planning maps in the field. The stages of the process were summarized as the following (Yanti *et al.*, 2021):

1. Exporting data for NDVI, Red band, and NIR band that have been added to the software
2. Correcting geometric score of NDVI image based on a correction factor. This correction aims to adjust the position or coordinates of the MOD13A1 v006 image based on its position on the earth's surface. The initial image values ranging from (-2,000) to 10,000 whereas NDVI value has range (-1) to (+1) so NDVI range to be processed is (-0.2) to (+1). The range is obtained by performing calculations using Equation 1.

$$NDVI = \frac{\rho_{nir} - \rho_{red}}{\rho_{nir} + \rho_{red}} \qquad (1)$$

   where ρ_{nir} is the NIR (near infrared) channel surface reflectance, and ρ_{red} is the red channel surface reflectance.
3. Adapting projection between layers with NDVI image. The NDVI image has a sinusoidal projection, so when the layer's projection is adjusted to the earth projection, the image will appear skewed. The shape of the NDVI can be adjusted to the layers'coordinates using projections and transformations and project raster. The result is that the image projection matches the layers. The coordinate system used is WGS 1984.
4. Cutting the raster according to research location (Harau District). It is based on districts administrative boundaries of Lima Puluh Kota Regency (from the RTRW data of Lima Puluh Kota Regency). Cutting is carried out using extract by mask tool. This tool helps cropping the image as desired. What is obtained after this process is raster data for the Harau location.
5. Inputting satellite image data for the Lima Puluh Kota Regency to simplify analysis on the research location based on the earth's shape.
6. Shaping grid in accordance with MODIS image's grid using sampling and generate tessellation tool. This grid helps to show geographic coordinate locations based on latitude and longitude. A grid is an imaginary line in the form of horizontal and vertical lines.
7. Displaying the NDVI value of each grid using raster to point
8. Inputting NDVI values into the grid using add field
9. Overlaying rice field data with NDVI value. Overlay merges two or more data in order to obtain graphic data for mapping. The overlay process uses intersect tool.
10. The final process before conducting a field survey is to determine the location based on cell size, with the size of rice fields between 45% to 100% of the area of each grid. The maximum size of a grid is 25 hectares. To produce a percentage, a Modis (500x500)m overlay of the rice field spatial data is carried out, then a percent calculation is carried out on the outside of the intersect between the two data.

2.3.3. Field Survey

The field survey was conducted using the interview method with farmers. Field data taken included the paddy growth phases, i.e., Day After Planting (DAP), the weight of seeds used, the weight of yields obtained, planting area (AT), and varieties used. The survey was conducted on 45% - 100% of the paddy fields area per grid. A sample size of less than 45% is not used due to significant errors resulting from the grid size being more extensive than the rice field area. The determination of the survey location was based on the NDVI value generated through data processing. The planting area determined using GPS coordinates is put into the ArcGis software to find its accurate location on the earth's surface. The data obtained is then analyzed using the NDVI value generated by the MODIS image.

2.3.4. Rice Productivity Calculation

Land production was obtained by direct measurements in the field. The land area was determined from land tracking results, which then processed using ArcGIS software. The observational rice productivity (PP, ton/ha) was calculated from rice production (Q, ton) and rice plantation area (L, ha) using Equation (2).

$$PP = Q/L \tag{2}$$

2.4. Data Analysis

After obtaining NDVI data and land productivity at the sample points of the observation location, then we proceeded with analyzing the relationship. The equation obtained was the one that will be used to estimate productivity. The equation for estimating productivity was determined using a polynomial equation of the order of two, three, or four, according to the smallest error value. The obtained equation was tested for model reliability using the Nash-Sutcliffe Efficiency (NSE) test using equation (3) with evaluation criteria presented in Table 1.

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

where OBS is observational or field productivity value (ton/ha), SIM is simulation or analysis productivity value (ton/ha), and $\overline{OBS}$ is the average observational productivity value (ton/ha).

Table 1. Assessment criteria for NSE (*Nash-Sutcliffe Efficiency*) value

NSE Value	Assessment criteria
0.75 < NSE 1.00	Very good
0.65 < NSE 0.75	Good
0.50 < NSE 0.65	Sufficient
NSE 0.50	Insufficient

Source: Yunarni *et al.* (2019)

3. RESULTS AND DISCUSSION

3.1. Image of Sampling Location

The sampling location is based on the work map that has been made with the provision that the area is on the grid ≥ 45% (Figure 1). Based on Ekaputra *et al.* (2020), sampling data with MODIS is more than 50% of the pixel area, so samples with less than 50% are not used. It aims to reduce the significant error due to the MODIS image resolution of

500 x 500 m or equivalent to 25 Ha for an area of 1 whole grid. Yanti *et al.* (2021) also did the same thing, limiting the data collection area to only those containing rice fields from 50%-100% on MODIS pixels.

In Figure 1 it can be seen that there are a total of 863 grids for Harau Regency, for cells with 75% rice fields there are 45 grids; 50% of 109 grids; and 45% as many as 125 grids. In this case, % is to describe the percentage of cells occupied by rice fields. For example, cell sizes > 75% means that 75% of the area in that cell is paddy field. Of the 863 grids available, there are 45 grids of which 75% of the area in the cell is rice fields. There are 125 productivity data obtained based on data collection in the field and 37 grids representing productivity data in Harau District in general.

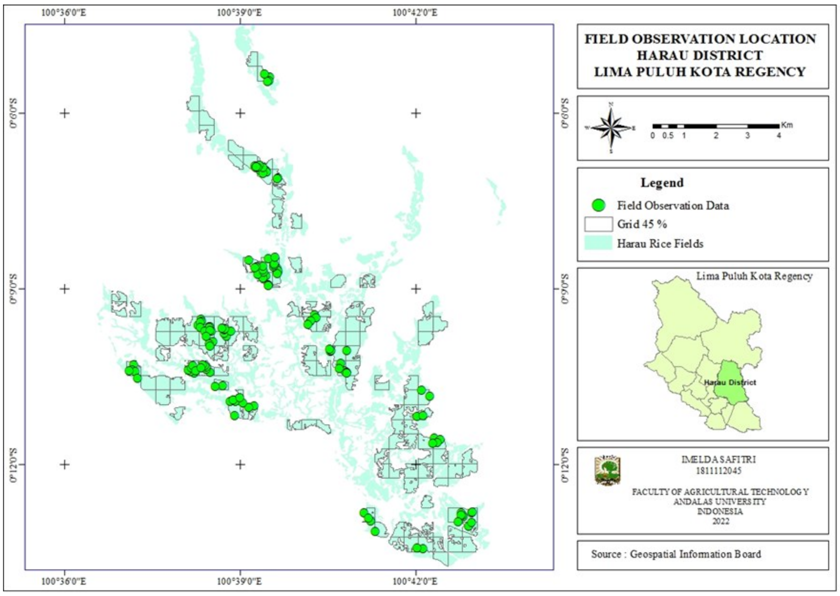

Figure 1. Map of the observation location

3.2. Relationship of NDVI Algorithm Value and Rice Crops

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). The results of the analysis of the health of oil palm plants conducted by Yuniasih *et al.* (2022) based on the NDVI value are in accordance with the results of the leaf sampling unit (LSU) analysis which analyzes the level of nutrient content in the leaves.

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 represent period). This process eliminates clouds from the composite (except in areas that are cloudy for all 14 days (Lillesand *et al.*, 2015).

The greenness index of plants is expressed by the value of the NDVI algorithm, based on satellite image data analysis using ArcGIS software. The rise and fall of the NDVI value indicate the growing period of an area based on the plant growth phase. According to Hafizh *et al.* (2013), the NDVI value will explain the relationship between NDVI and the rice growth phase. The greenness index value of plants in Harau District, Lima Puluh Kota Regency can be seen in Figure 2. The image data used to determine the planting period in Harau District is from January 1, 2021, to February 2, 2022. Therefore, 26 MODIS image data were analyzed to see the planting period in the area.

In Figure 2, there are maximum, minimum, quartile 3, quartile 2, and quartile 1 values, which show the rise and fall of the NDVI value. Data analysis was carried out based on these values to obtain the NDVI value. The use of these values will assist in the analysis of the NDVI values that dominate or represent the plant growth phase on one MODIS image output date.

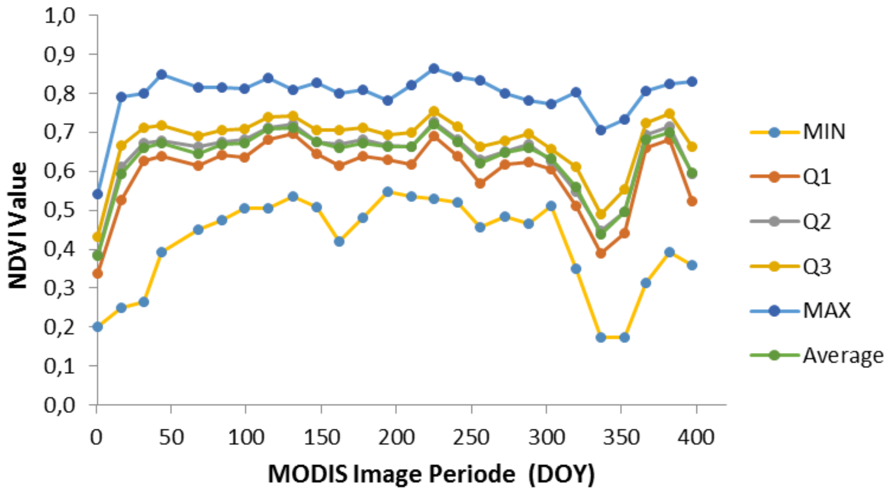

Figure 2. NDVI value of Harau District, Lima Puluh Kota Regency for the period of January 1, 2021 – February 2, 2022

Based on the 26 MODIS image data, analysis was carried out to obtain NDVI value one planting period. The results of field data collection showed that one time planting period in Harau District was ± 120 days according to the rice variety used by farmer. The varieties of rice generally grown in Harau District, Lima Puluh Kota Regency can be seen in Table 2, with a planting period ranging from of 4 months or the equivalent to 120 days.

Based on MODIS image data in Harau District Lima Puluh Kota Regency, there are two planting periods according to Figure 2 by looking at the rise and fall of the NDVI value. MODIS image data from June 26, 2021 to November 17, 2021 (120 days) were used to determine the growth phase range using one period of rice planting. The use of data until November 17, 2021, is based on the planting phase. After harvesting, in Harau District, there will be a 1-month-period of vacant land to prepare for further planting in the form of reprocessing the soil and preparing seeds for planting rice. An illustration of the NDVI value for one planting period is presented in Figure 3.

Figure 3 shows plant growth based on the processed MODIS image value. The highest NDVI value was at the 6th week of the plant and decreased until the 10th week. The rise and fall of the NDVI values are related to the plant growth phases. The phases are water, vegetative 1, vegetative 2, generative 1, generative 2, and fallow (Hafizh *et al.*, 2013). According to Budiman *et al.* (2021), the minimum value of NDVI indicates that the land does not have vegetation or surface water around the rice plants and is typical for rice plants with the age less than three weeks or 21 days. Figure 3 shows that the NDVI values spread from 0,35 to 0,8 at every growth phase. The NDVI value is the average image data used to determine the planting period in Harau Regency, which is from January 1, 2021 to February 2, 2022.

Table 2. Varieties of rice plants in Harau District of Lima Puluh Kota Regency

No.	Rice Varieties	Plant Age
1.	Ciredek	more than 4 months
2.	Kuriak	more than 4 months
3.	Bujang Marantau	4 months
4.	Banang Pulau	3.5 months
5.	Padi Putiah	3 months
6.	Junjuang	3.5 months
7.	Pandan Wangi	100 days
8.	Kuniang Kuriak	more than 4 months
9.	Dharmasraya	100 days
10.	Ale-Ale	3 months
11.	Padi Rahmat	3.5 months
12.	Padi A1	100 days
13.	Kuning Ome	90 days
14.	Putih Malabar	4 months
15.	Putih Bukittinggi	3.5 months
16.	Bakwan	3 months 10 days
17.	IIR-66	100 days
18.	IR-42	4 months
19.	Siliah	4 months
20.	1000 Gantang	4 months
21.	Sokan	4 months
22.	Sungkam	4 months

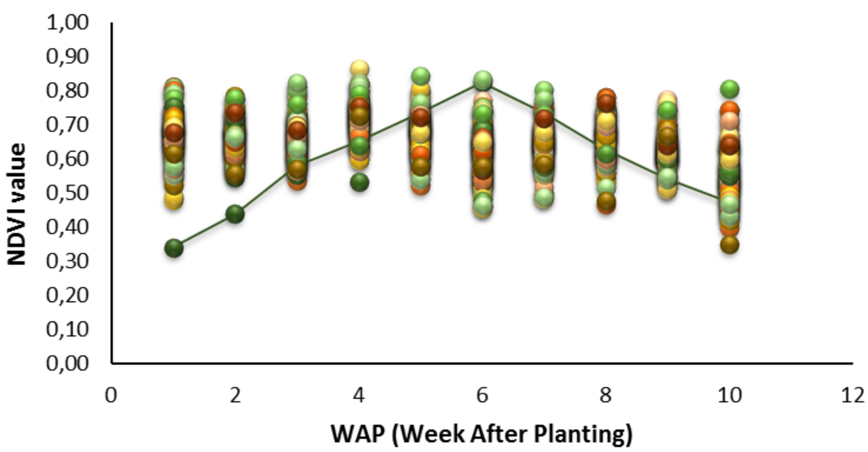

Figure 3. Rice plant's NDVI value in Harau District, Lima Puluh Kota Regency

In comparison, the maximum NDVI value describes the high greenery of plant where the plant is in the vegetative phase 2 and entering the grain maturation phase. The vegetative phase is the second phase marked by an increase in the NDVI value due to increased vegetation development. The NDVI value will decrease due to the reduced level of greenery when the plant enters the generative phase until harvest. The relationship between plant's age (Day After Planting / DAP) and NDVI value in Harau District, Lima Puluh Kota Regency is presented in Figure 4.

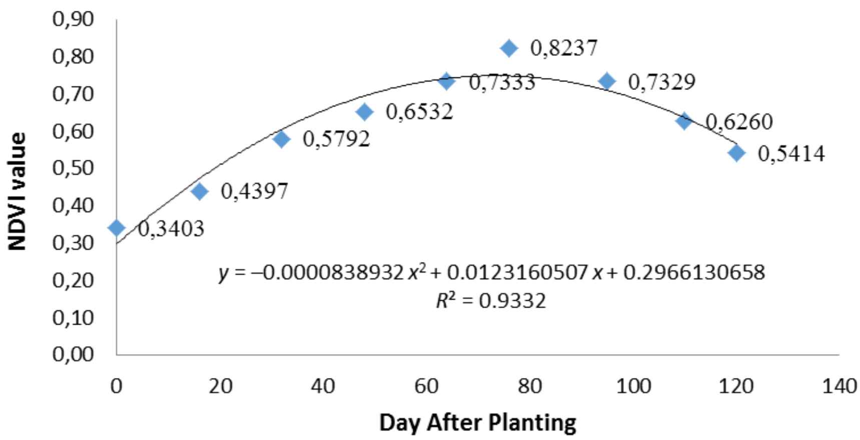

Figure 4. The correlation between NDVI value and rice plant's age in Harau District, Lima Puluh Kota Regency

In utilizing MODIS imagery, the NDVI value of each grid is known. On the other hand, in the planting phase determination, the plant's age must be calculated using the obtained equation. Result research Ajith *et al.*, (2017), shows that the best form of relationship between NDVI and rice age uses a quadratic equation. Estimation of rice growth phase in Harau District based on NDVI value is presented in Equation (4):

$$y = -0.00000838932\, x^2 + 0.0123160607\, x + 0.2966130658 \quad (4)$$

The range of rice plant growth phases in the Harau District is determined with image data from July 26, 2021, to November 1, 2021, and using the polynomial equation obtained. The relationship between the NDVI value and the growth phase of rice plants can be seen in Table 3.

Table 3. The NDVI values of rice plant's growth phases in Harau District, Lima Puluh Kota Regency

Phase	NDVI	DAP	WAP
Water	< 0.4722	< 21	< 3
Vegetative 1	0.4722-0.6945	21 - 45	3 - 6
Vegetative 2	0.6945-0.7412	45 - 65	6 - 9
Generative 1	0.7412-0.6363	65 - 95	9 - 14
Generative 2	0.6363-0.5665	95 - 120	14 - 17
Fallow	0.5665-0.4799	>120	> 17

In Table 3, it can be seen, that there are 5 phases for one planting period. The NDVI value for the aqueous phase is < 0.4722 and for final plant/fallow phase, the NDVI value ranges from 0.5665 to 0.4799. The range of NDVI values obtained differs from the NDVI values in (Hafizh *et al.*, 2013). These differences are caused by several factors, including different locations, plant varieties used, the year of data collection due to changes in land or vegetation around the rice fields, the influence of clouds, and the type of MODIS imagery. Hafizh *et al.* (2013) used MODIS MOD02HKM image type (level 1 Calibrated Radiance), and in this study MODIS image MOD13A1v006 was used.

In general, the data pattern in Hafizh *et al.* (2013) is relatively the same as the data pattern in this research. There is an increase in NDVI values up to the vegetative phase 2 and a decrease in NDVI values in the generative phase 1. There is a change in the NDVI value related to chlorophyll levels of the plants. The decrease in NDVI value in generative phase 1 is related to plant's development. In this phase, plant's photosynthesis products will be mostly used for plant fertilization until the plant becomes ready for harvest, which is marked by wilting leaves and the presence of rice grains.

3.3. Estimation of Rice Crop Productivity

The data used in the analysis in the Harau District are rice plants in generative phase 1 and generative 2. Productivity analysis of MODIS image data uses data in generative phase 2, approaching the harvest period. By observation, rice plants in Harau District have a lifespan of 100-120 days, depending on the rice variety used. Pradipta (2012) also estimates that rice production uses the NDVI value when the rice is ready to harvest (reaching 80–90 days or 8–13 weeks after planting). 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. Data collection was carried out from December 2021 to early January 2022. A backward calculation or normalization of field data was carried out to adjust the plant's age, corresponding to the generative phase 2.

Data from research in the field contained 125 productivity data, but not all data could be used. Only plants in generative phase 1 and generative 2 could be used because this period was a period of high plant growth. The period is marked by an increasing NDVI value in generative phase 1 and decreasing value in generative phase 2. There are 12 data used to see the relationship between NDVI and observed rice productivity. The data are presented in Table 4.

Table 4. Observational rice productivity data of Harau District, Lima Puluh Kota Regency

No.	Grid ID	Plant Age (DAP)	NDVI	Observational Rice Productivity (ton/ha)
1	I-38	33	0.5422	3.34
2	J-38	22	0.5733	3.99
3	S-40	55	0.5875	4.67
4	R-41	20	0.6071	3.63
5	N-28	13	0.6211	2.65
6	K-44	24	0.6250	3.99
7	K-39	22	0.6411	3.23
8	P-38	14	0.6816	3.57
9	Z-51	11	0.7148	4.02
10	W-53	42	0.7166	5.62
11	M-27	14	0.7306	2.43
12	Y-46	17	0.7373	1.48
Average				**3.55**

Based on Table 4, the average productivity of rice in the Harau District, Lima Puluh Kota Regency is 3.55 tons/ha. Regression between NDVI and observational rice productivity is a base in choosing equation for estimating the productivity. The equation is presented in Figure 5.

In Figure 5, it can be seen that the highest determinant coefficient (r^2) is an equation of order 4, which is 0.6639, meaning that the model's accuracy is > 0.5, categorized as 'good'. Determination of the equation is also taking into account the smallest error value of the estimated productivity data. The estimated rice productivity data is presented in Table 5.

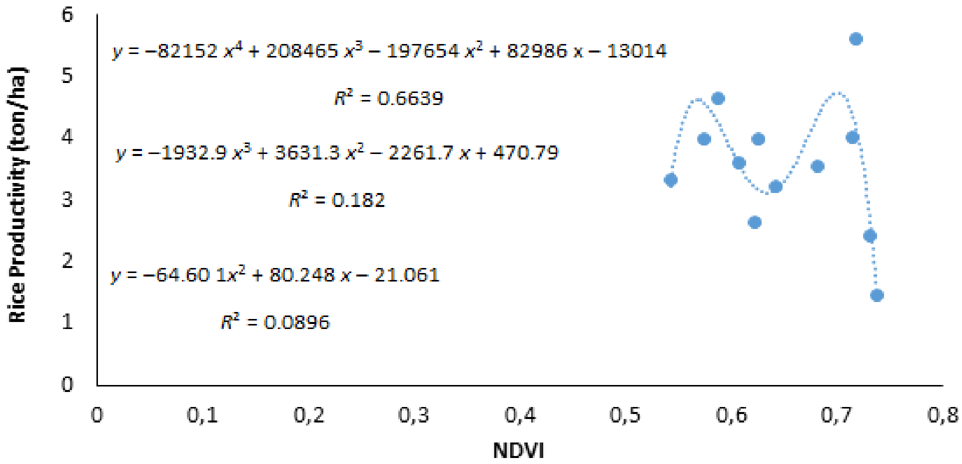

Figure 5. Relationship between NDVI value with observational and estimation rice plant productivity of Harau District, Lima Puluh Kota Regency

Table 5. Estimated rice productivity data of Harau District, Lima Puluh Kota Regency

Sample Points	Grid ID	NDVI	Observational Rice Productivity (tons/ ha)	Estimated Rice Productivity		
				Eq. Order 2	Eq. Order 3	Eq. Order 4
1	I-38	0.542	3.34	3.46	3.89	3.13
2	J-38	0.573	3.99	3.71	3.44	4.50
3	S-40	0.588	4.67	3.79	3.44	4.15
4	R-41	0.607	3.63	3.85	3.57	3.46
5	N-28	0.621	2.65	3.86	3.72	3.09
6	K-44	0.625	3.99	3.86	3.77	3.03
7	K-39	0.641	3.23	3.84	3.95	3.00
8	P-38	0.682	3.57	3.63	4.10	4.16
9	Z-51	0.715	4.02	3.30	3.49	4.18
10	W-53	0.717	5.62	3.28	3.43	4.07
11	M-27	0.731	2.43	3.10	2.84	2.58
12	Y-46	0.737	1.48	3.00	2.48	1.36
		Error		24.55 %	23.17 %	12.10 %

Based on Table 5, the polynomial equation used to estimate rice productivity in Harau District, Lima Puluh Kota Regency is a polynomial equation of power 4 because it has the smallest error value than polynomial equations to powers of 2 and 3 by 12.10%. The regression equation used to estimate rice productivity in Harau District, Lima Puluh Kota Regency is $y = -82152\ x^4 + 208465\ x^3 - 197654\ x^2 + 82986\ x - 13014$.

Where y is the productivity value and *x* is the NDVI value on October 16, 2021, according to the sample location. The correlation between observational productivity and estimated productivity based on a polynomial equation of order 4 is presented in Figure 6.

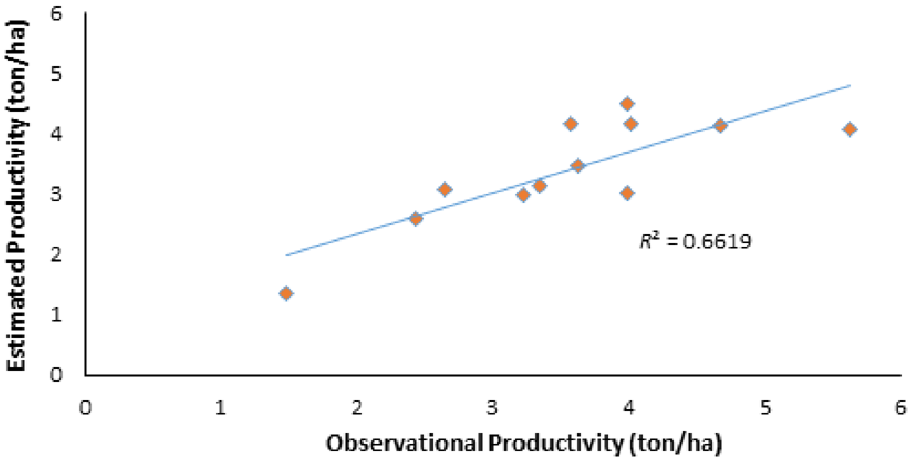

Figure 6. Relationship between observation productivity and estimation using a polynomial equation of order 4 in Harau District, Lima Puluh Kota Regency

From the analysis that has been done, the coefficient of determination (R^2) is 0.6619 with a correlation coefficient (*r*) of 0.8136. The correlation between the X variable (observation productivity) and Y (estimated productivity) is in the strong category, because the r value is between 0.50 – 0.75. The value of the correlation coefficient (r) obtained is positive, meaning that the variables X and Y have a unidirectional relationship.

A comparison of observed rice productivity with estimation (models) is presented in Table 6. There is a difference between the observed and the estimated productivity values because the measured NDVI is an average value in an area of at least 1 hectare (or an average value of 1 grid area). In other words, the measured NDVI value is the average productivity. Sahararini *et al.* (2020) also concludes that the estimation of rice productivity based on the NDVI value from image processing shows that each village has a varying NDVI value. Thus the rice productivity obtained also varies according to the NDVI value. Based on the model reliability test results, the Nash-Sutcliffe Efficiency (NSE) value of 0.64 is obtained, which is categorized as 'sufficient. Saputri *et al.* (2018), also uses NSE to validate the SWAT model to predict the hydrological conditions of the Way Sekampung Hulu watershed.

To increase the NSE value, when observing the plant phase in the field, it is necessary to multiply the sample points in one stretch of rice fields, so that the NDVI value used to predict the growing phase is more representative of real conditions. Verification of the resulting model can be carried out for several planting periods, so that questionable observation productivity data (considered as outliers) can be removed from the observed sample points, so that errors can be minimized and NSE will be higher. The weaknesses of the assumptions used in the model predicting the productivity of rice plants in Harau District are: 1) The data used to see cropping patterns is only one year of MODIS (DOY) image observation, and 2). Verification of the rice plant phase in the field is only carried out for one planting period.

Table 6. Observed and estimated productivity data of Rice Plants in Harau District, Lima Puluh Kota Regency

Sample Point	Grid ID	NDVI	Observational Productivity (ton/ha)	Estimated Productivity (ton/ha)
1	I-38	0.542	3.34	3.13
2	J-38	0.573	3.99	4.50
3	S-40	0.588	4.67	4.15
4	R-41	0.607	3.63	3.46
5	N-28	0.621	2.65	3.09
6	K-44	0.625	3.99	3.03
7	K-39	0.641	3.23	3.00
8	P-38	0.682	3.57	4.16
9	Z-51	0.715	4.02	4.18
10	W-53	0.717	5.62	4.07
11	M-27	0.731	2.43	2.58
12	Y-46	0.737	1.48	1.36
Nash-Sutcliffe Efficiency (NSE)			0.64	

4. CONCLUSION

Based on the research, the equation for estimating rice productivity in Harau District, Lima Puluh Kota Regency is $y = -82152\ x^4 + 208465\ x^3 - 197654\ x^2 + 82986\ x - 13014$, with an NSE value of 0.64, which is categorized as ‘sufficient’.

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