Estimation Of Productivity Based On Rice Growth Phenology Using Sentinel-2 Image (Case Study In Karawang And Malang District)

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Abstract. Estimation and monitoring of rice plants using satellite imagery must be to provide information on rice growth and predict the yields efficiently. Utilization of remote sensing using the Sentinel-2 satellite is expected to be able to analyze agriculture at a detailed scale. The research was conducted in Karawang and Malang to compare rice plants' phenology, harvested areas, and productivity. The Enhanced Vegetation Index (EVI) parameter of Sentinel-2 multitemporal 10-day images in 2019-2021 was used to produce regional rice data information. Based on the analysis of maximum EVI values, 7 classes of rice fields were identified, namely 0.40-0.45; 0.45-0.50; 0.50-0.55; 0.55-0.60; 0.60-0.65; 0.65-0.70; and > 0.70. The days (age) after planting, locally termed as Days After Planting (DAP) based on the EVI value in Karawang is 0.91, while Malang is 0.90. The identified harvested area in Karawang Regency in 2019 is 174.95 thousand hectares and in 2020 is 185.80 thousand hectares, the average ratio is 0.94 slightly smaller than the statistics agency BPS data. While in Malang, the the average ratio was 0.87. Based on productivity, production in Karawang in 2019 was 73.87 qwintals/Ha, and in 2020 it was 72.91 qwintals/Ha. The estimated production in Malang Regency 2019 and 2020 was 74.59 qwintals/Ha, and 74.87 qwintals/Ha respectively. This result shows the potential of remote sensing for rice growth monitoring.

Keywords: Sentinel-2; EVI; rice; phenology, productivity.

1 Introduction

Rice is one of the most important grain crops cultivated and it is primary food for almost half of the world's population [1]. Around 969 million tonnes of rice were produced worldwide in 2010 [2]. The Asian continent produces almost 90% of the world's total rice production [3]. Indonesia is ranked 3rd in the world with the highest rice production after China and India, with a production level of 70.8 tons in 2015 [4]. Two of the regions in Indonesia having high rice production are Karawang Regency and Malang Regency. Karawang Regency is the second largest rice producer in Indonesia after In-

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dramayu Regency. Rice productivity in Karawang Regency is 77.67 tons/ha with a production of 1,101,076.56 tons in 2018 [5]. In contrast to Malang Regency, which has a productivity of 71.07 tons/ha with a total rice production of 312,544 tons [6].

It is necessary to estimate and monitor the phenology of a wide range of rice plants in order to provide information on rice growth. Monitoring plant phenology over a large area can estimate net primary production spatially [7]. Monitoring using conventional approaches like surveys requ ires large costs, time, money, and manpower [8]. Remote sensing has been increasingly used as a monitoring tool due to its efficiency. Haw et al. [9] used photo spectral color vision to detect rice ripeness, but only covered a small (limited) area. Pei et al. [10] used an integrated sensor system to monitor rice growing conditions based on the UAV (Unmanned Aerial Vehicle) system. However, field observations are difficult to extrapolate data to a large area [11, 12]. This problem can be overcome by using remote sensing technology combined with field parameterization. Remote sensing imagery is useful in many applications, especially to obtain land cover information at a lower cost and shorter time [13, 14].

Remote sensing techniques for precisely mapping agriculture can be carried out by the use of Sentinel-2. The Sentinel-2 constellation, with its enhanced spatial, spectral, and temporal resolution, was specifically designed to meet the needs of semi-detailed agriculture [15]. Sentinel-2 features a multispectral (MSI) instrument holding an anastigmatic telescope that minimizes thermo-elastic distortion, and an optimized optical design to achieve cutting-edge imaging quality across a 290 km field of view [16]. MSI displays 13 spectral bands with a spatial resolution ranging from 10 m to 60 m (depending on the band) and a current temporal resolution of about 5-10 days (depending on latitude). [16]. The spatial, temporal resolution and free image availability make Sentinel-2 suitable for agricultural monitoring [17].

Several remote sensing approaches using sentinel imagery for agricultural applications have been widely used. Research [18] evaluated several methodologies that automatically delineate cropland boundaries from Sentinel-2 imagery with image segmentation to delineate farmland, orchards, and vineyards. Promising results were achieved by applying Canny edge to Sentinel-2. In [19] the Sentinel 2 imageries were used to design the pre-operational service for rice farming systems, based on the assimilation of EO products and in-situ data into crop modeling solutions. The research of Son et al [20] developed a methodology to create a map of rice plants using S2 data and plant phenological information. The [21], proposed a method to create rice cultivation maps using Random Forest and time-series data S1 and S2.

Most of the analysis of satellite imagery is carried out on the observation of rice fields, namely by observing the density of vegetation [22]. Detection of vegetation density commonly uses a spectral index such as the Enhanced Vegetation Index (EVI). EVI is sensitive to changes in water and vegetation which can help differentiating normal plants or rice plants [23, 24, 25, 26]. EVI also is sensitivity to the greenness of plants due to the influence of soil background and canopy signals and reduces the influence of atmospheric conditions by adding information on the blue channel [27]. The research of [28] used the multitemporal MODIS EVI to determine the growth model of rice plants in Sumatra. Another example is [29] with the use of time series of vegetation indices (EVI, NDWI, and NDBI) derived from Landsat images to develop a method for classifying paddy and non-rice paddy fields in Indramayu. Later, the [30] used the EVI Landsat 8-OLI index to estimate the harvested area and productivity of rice crops in Bekasi Regency.

Based on the background that has been prepared regarding the study of rice phenology using remote sensing, the purpose of this study is (a) Identifying the trend of rice growth from the beginning of planting to harvesting in the period 2019-2021 in Karawang Regency and Malang Regency. (b) Estimation of harvested area and estimation of rice crop productivity using the 2019-2021 remote sensing approach in Karawang Regency and Malang Regency.

2 Methods

2.1 Research Location

The location of this research study is in Karawang Regency, West Java and Malang Regency, East Java (Figure 1). Geographically, Karawang Regency is located between 107°02'-107°40'BT and 5°562'-6°34'LS. Meanwhile, Malang Regency is located 112°17' - 112°57' east longitude and 7°44' - 8°26' south latitude. The area of Karawang Regency is 1,753.27 km^2, most of the land is used for agriculture. Meanwhile, Malang Regency has an area of 3,530.35 km^2. This research was conducted by using Sentinel-2 satellite imagery in a time series 2019-2021.

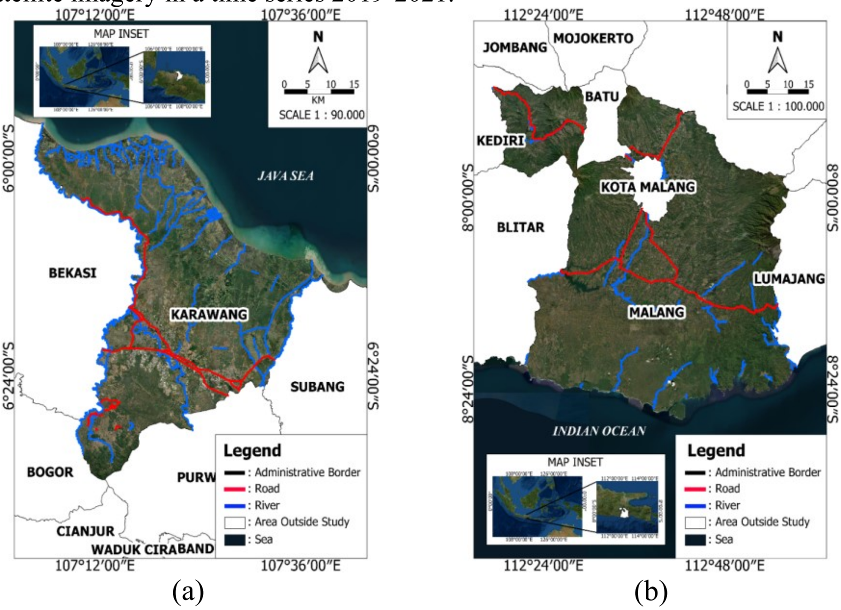


Fig. 1. (a) Image Map of Karawang Regency, West Java and (b) Image Map of Malang Regency, East Java

In this study, Sentinel-2 imagery with a spatial resolution of 10 meters was used to determine the EVI value in Karawang Regency and Malang Regency. Sentinel-2 imagery provides better spatial resolution than MODIS and Landsat images as in previous studies. Therefore, to determine the level of accuracy, a validation was carried out on rice productivity data issued from the local statistical agency “Badan Pusat Statistik (BPS)”. The results were evaluated using the coefficient determination (R^2). If the results show the standard error values between 0.0–1.0 can be said to be small, thus the EVI method on the Sentinel-2A image can be considered reliable in estimating rice productivity [31].

2.2 Trend Analysis of Rice Phenology in Karawang Regency and Malang Regency

The stages of rice phenology management derived from satellite imagery vegetation index and the management and planting data from field were used for validation. The tools used to run the analysis are Google Earth Engine, Qgis, and ArcGis, with additional tools are rulers and cameras to measure height, leaf width, number of tillers and age of rice plants. Besides Sentinel-2 for 2019-2021, the ancillary data collected are Sentinel-2 Image for 2019-2021, administrative boundary vectors, productivity data for 2019-2021, raw land data for rice fields at a scale of 1:10,000 in 2019, field data on rice crop variability in Karawang Regency in 2019 and Malang Regency in year 2021.

Detection of paddy fields is using a combination of EVI, NDBI, and NDWI vegetation indices data as shown in Table 1. Meanwhile, prior to statistical analysis, all blank or missing pixels were interpolated using the Savitzky-Golay method, which is also to reduce time series image noise [32] and to do Smoothing 3x3 [28]. All was performed using Google Earth Engine (GEE).

Table 1. Vegetation Index Algorithm for Rice Plants

No	Vegetation Index	Algorithm	Source
1	EVI (Enhanced Vegetation Index)	$\text{EVI} = 2.5\text{x}\frac{NIR-Red}{(NIR+6xRed-7{,}5xBlue+1)}$	[33]
2	NDWI (Normalized Difference Water Index)	$\text{NDWI} = \frac{Green-SWIR2}{Green+SWIR2}$	[34]
3	NDBI (Normalized Difference Build-up. Index)	$\text{NDBI} = \frac{SWIR1-NIR}{SWIR1+NIR}$	[35]

The value that has been extracted is determined by a threshold to determine paddy fields with IV Max > 0.45; IV Range (IV Min – IV Max) > 0.3; and IV Early Planting (NDWI > 0.226 and EVI < 0.188) and IV Harvest (NDBI > 0), other than this value, it is not a rice crop area [36]. The total area of rice fields was assessed for the overall accuracy and Kappa accuracy using observation data on raw rice fields with a scale of 1:10,000 [37, 38]. Extraction of the vegetation index that has been smoothed, was carried out by applying the density slicing for rice grades based on the Maximum EVI and cut into 5-7 classes from the EVI max range of 0.40-0.45 as class 1 [28]. The maximum

EVI was assumed to occur when the rice is 60 DAP (Days After Planting). Thus, early planting (AT) and harvest time (WP) on Sentinel 10 daily data can be seen in equations (1) and (2) below

$$AT = LM - 60/P \tag{1}$$

$$WP = LM + 60/P \tag{2}$$

Where, AT = Early Planting; WP = Harvest Time, LM = Maximum Place, P = Daily Period (Sentinel Daily Period-2 Basis (10 days))

To be able to distinguish the vegetative and generative phases, two images with different dates (t and t-1) are needed. Rice plant growth phase conditions can be detected from changes in the value of EVI (dEVI). Determination of the rice growth phase according to the following formula (3) [39]:

$$dEVI = EVIt - EVI\ t\text{-}1 \tag{3}$$

Where: dEVI = Values change (+/-); EVIt = EVI; EVIt-1 = EVI previously

Training area of EVI time series plotting based on the same planting date was analyzed by regression to obtain a rice plant growth model. Sampling used purposive random sampling based on the EVI Maximum class. Image sampling is done with a buffer of 30 x 30 meters. The form of the regression equation is a polynomial of order 3 or Spline Qubic [28] with the following equation (4)

$$Y = b0 + b1{*}X + b2{*}X2 + b3{*}X3 \tag{4}$$

Where, X = Rice Crop time/age (HST); Y = maximum EVI growth parameter; b0 = intercept; b1, b2, b3 = coeficient

2.3 Estimation of Harvest Area and Rice Crop Productivity Using Remote Sensing Approach in Karawang Regency and Malang Regency

The rice plant growth profile that has been made is extracted based on the same harvest time polygon to determine the harvested area. The harvested area is divided into 3 periods, namely January-April, May-August, and September-December which are then added up to get the harvest area for 1 year. The harvested area for 1 year will be compared with BPS data using a ratio to find out the comparison.

Estimation of lowland rice productivity is based on the formula (5) resulting from the dissertation [40] which explains the productivity value derived from the Maximum EVI value. Then the results of a simple linear regression in the formula (6) are used to determine the relationship between productivity and Maximum EVI [30]. Random sampling was conducted to obtain the relationship between productivity and Maximum EVI. From this equation, the coefficient of determination (R^2) is obtained which explains the closeness between the productivity of Rice Plants and the maximum EVI value

$$Productivity = \log(EVI\_Max/0{,}103) \times (38{,}46154 \times 1{,}11) \tag{5}$$

$$Productivity\ (qwintals/ha) = b0 + b1\ x\ EVI\_Max \quad (6)$$

Where, EVI_Max = EVI_ Maximum, b0 = constanta; b1 = n parameters; EVI_Max = EVI Maximum.

As a validation step, the model was applied in the research area by estimating the average productivity for 1 year and then compared with BPS data. The results will calculate the ratio and coefficient of variance to determine the comparison and spatial diversity of productivity in the two study areas [41].

3 Results and Discussion

3.1 Rice Phenological Trend Analysis in Karawang Regency and Malang Regency

The extraction results of the threshold data for fields classification from Sentinel 2 images for a period of 2 years (2019-2020) was 89,723.51 Ha for Kerawang Regency, while in Malang Regency it was 32,902.20 Ha (Figure 2). The results of the rice field classification using the threshold method are smaller than the classification of Raw Rice Fields in 2019, namely for Karawang Regency 97,541 Ha and Malang Regency 45,851 Ha [42, 43]. The results of the classification of rice fields were tested with detailed data of Rice Raw Land in 2019 from BPN using the error matrix method, namely Overall Accuracy and Kappa. The results are presented in table 2.

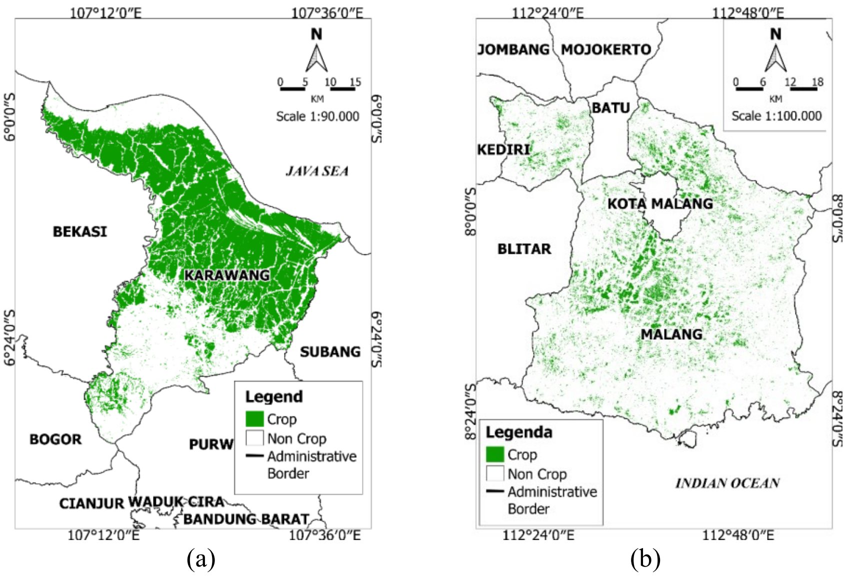


Fig. 2. Classification of Rice Fields based on Image Sentinel 2 years 2019-2020 (a) Rice fields in Karawang Regency and (b) Rice fields in Malang Regency

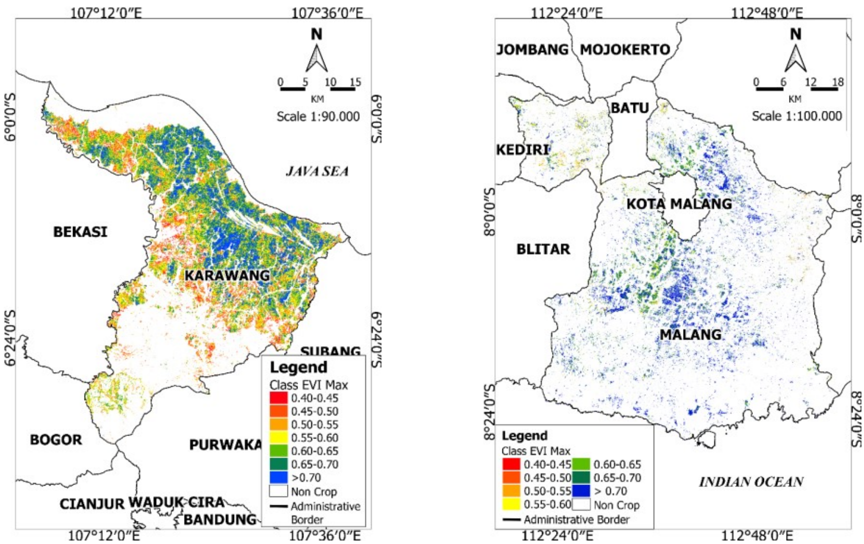
Table 2. Rice Field Accuracy Test in Karawang Regency (Left) and Malang Regency (Right)

Class	Crop	Non Crop
Crop	1967	72
Non Crop	176	2105
Overall Accuracy: 0.94		*Kappa*: 0.87

Class	Crop	Non Crop
Crop	5001	251
Non Crop	461	266
Overall Accuracy: 0.87		*Kappa*: 0.36

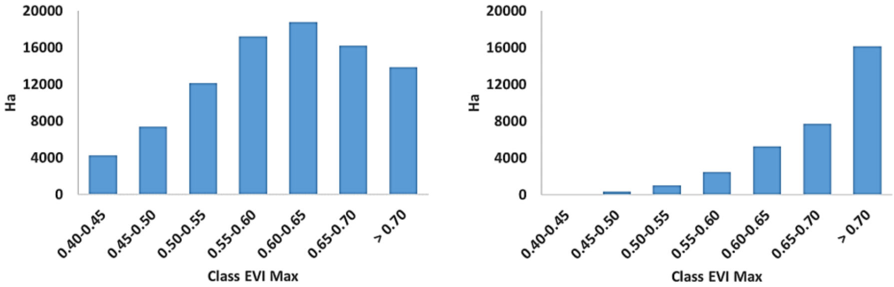
The classification accuracy of the threshold index method has a fairly good accuracy value in Karawang Regency and Malang Regency. Overall accuracy for each region has a value above 0.8, so it can be categorized as good enough and can be used [44]. The Kappa value in Karawang Regency is 0.874 and Malang Regency is 0.363, this indicates that the distribution element of the data sample is less balanced in Malang Regency. However, this classification can be used as a reference to analyze the growth phenology of rice plants.

The results of the spatial distribution show that the spectral value of the Rice Plant object in the study area is different. Rice field area based on Maximum EVI in Karawang Regency is dominantly high in class 0.60-0.65 with an area of 18758.49 Ha and class 0.40-0.45 with the lowest area of 4263.50 Ha. Meanwhile, in Malang Regency, the class > 0.70 was at most 16149.04 Ha and the class 0.40 to 0.45 was at least 58.85 Ha. The percentage of paddy fields based on the Maximum EVI class can be seen in Figure 3 and Figure 4.



(a) (b)

Fig. 3. Rice Field Classification Map based on Maximum EVI (a) Karawang Regency and (b) Malang Regency



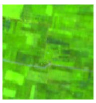
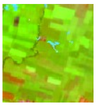
(a) (b)

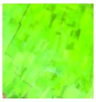
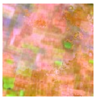
Fig. 4. Rice Field Area according to Class EVI Maximum (a) Karawang Regency and (b) Malang Regency

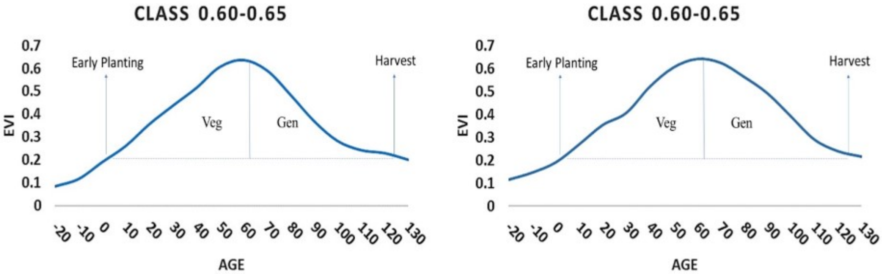
Based on the Maximum EVI class, the rice field class in Karawang Regency is more evenly distributed when compared to the rice field class in Malang Regency. It indicates that in Karawang Regency there are many classes of Rice Plants that can grow, while in Malang Regency only certain classes are dominant. This can occur due to several factors such as rainfall, soil, topography, water requirements, rice crop patterns, and types of rice plants in the area [45].

Visually, the growth phase of the Rice Plant can be seen from the Sentinel-2 RGB bands 11, 8, and 3. The appearance of the rice field will be in the form of an irregular square with certain colors according to its growth stages as can be seen in table 3. If detected through the EVI spectral values, the beginning of planting was < 0.2, fallow with a value of 0.2-0.1 and each vegetative/generative phase was worth > 0.2 (Figure 5). The vegetative phase is characterized by a positive change in the value (dEVI) and the generative phase is characterized by a negative change in the value (dEVI) (Figure 6) [41]. By identifying this, it is easy to detect the beginning of planting and harvesting rice plants.

Table 3. Rice Plant Phase seen from Sentinel 2 RGB Images (11, 8, 3) in Malang areas.

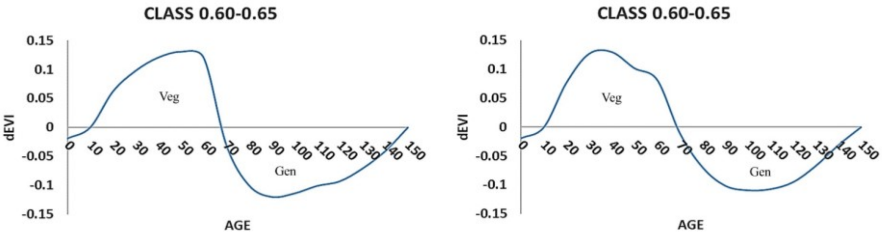
Image	Photo	Phase	Age	Image	Photo	Phase	Age
		Early Planting	0-10			Gen 1	60-90
		Veg 1	10-30			Gen 2	90-110

		Veg 2	30-60			Harvest	110-120



(a) (b)

Fig. 5. Profile of Days After Planting (DAT) of Rice Plants based on Maximum EVI Class 0.60-0.65 (a) Karawang Regency and (b) Malang Regency



(a) (b)

Fig. 6. dEVI of Rice Plants (a) Karawang Regency and (b) Malang Regency Class 0.60-0.65

The results of statistical analysis of the polynomial 3 or spline qubic regression model in each research area were shown. Regression was applied to 7 classes of rice fields in the two research areas. The regression model parameters obtained can be seen in tables 4 and 5.

Table 4. 3rd order polynomial regression test based on rice class in Karawang Regency

EVIMax	0,40-0.45	0,45-0,50	0,50-0,55	0,55-0,60	0,60-0,65	0,65-0,70	> 0,70
b0	2E-07	3E-07	-3E-08	2E-08	-4E-08	-8E-08	2E-07
b1	-9E-05	-0,0001	-7E-05	-9E-05	-9E-05	-9E-05	-0,0001
b2	0,0087	0,011	0,0097	0,0118	0,0126	0,0127	0,017
b3	0,1506	0,1267	0,1563	0,1408	0,1336	0,1408	0,1111
R^2	90,07%	90,72%	90,06%	90,89%	90,25%	91,27%	92,66%

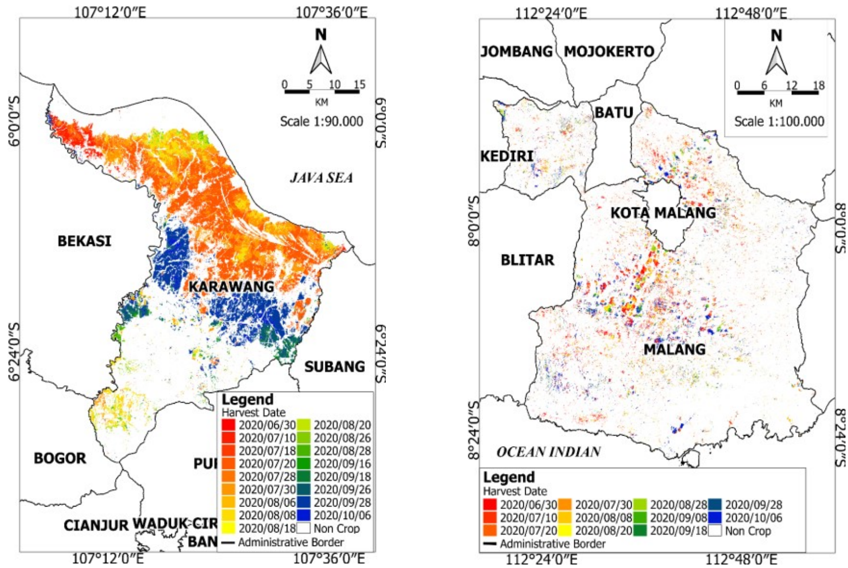
Table 5. 3rd order polynomial regression test based on rice class in Malang Regency

EVIMax	0,40-0.45	0,45-0,50	0,50-0,55	0,55-0,60	0,60-0,65	0,65-0,70	> 0,70
b0	-5E-08	1E-07	8E-08	3E-07	2E-07	3E-07	2E-07
b1	-6E-05	-8E-05	-1E-04	-0,0001	-0,0002	-0,0002	-0,0002
b2	0,0072	0,0089	0,011	0,0139	0,016	0,0178	0,0183
b3	0,1737	0,1544	0,1513	0,1481	0,1202	0,1292	0,1357
R^2	91,02%	87,61%	89,21%	89,25%	90,36%	91,83%	91,44

The regression test of the two research areas throughout the Maximum EVI class resulted in the coefficient of determination (R2) > 0.8 or 80% indicating it was good [46]. Karawang Regency has an average R2 = 0.91 or 91% and for Malang Regency an average R2 = 0.90 or 90.1%. This indicates that the two regions have a significant relationship between the EVI value and the age of the rice plants. Therefore, the phenology of rice growth can be applied in the research area.

3.2 Estimation of Harvest Area and Productivity of Rice Crops Using Remote Sensing Approach in Karawang Regency and Malang Regency.

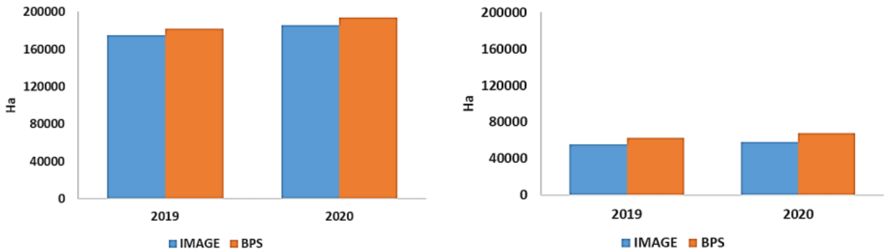
Based on multitemporal analysis of Sentinel-2 satellite imagery, the estimated rice harvested area seen from May-August 2020 images in Karawang Regency is 78,002.79 Ha while for Malang Regency it is 27,964.28 Ha. The spatial distribution of rice crop yield estimates from satellite imagery analysis is presented in Figure 7.



(a) (b)

Fig. 7. Image Harvest Dates May-August 2020 (a) Karawang Regency and (b) Malang Regency

The harvested area yields are accumulated for 1 year so that in general the harvested area data generated from the analysis of Sentinel 2 satellite imagery is relatively smaller than the harvested area data released by BPS in the same period. The total harvested area for lowland rice in Karawang Regency based on Sentinel-2 images in the 2019 period is 174,955 Ha and for 2020 it is 185,806 Ha, while in Malang Regency in 2019 it is 55,318 and in 2020 it is 38,192. The results of the comparison of image data with BPS data can be seen in Figure 8.



(a) (b)

Fig. 8. Comparison Graph of Harvest Area (a) Karawang Regency and (b) Malang Regency

Table 6. Comparison of Harvested Area on Image and BPS data

Area	**2019**			**2020**		
	Image (Ha)	**BPS (Ha)**	**Rasio**	**Image (Ha)**	**BPS (Ha)**	**Rasio**
Kab Karawang	174.955,79	181.737,09	0,96	185.806,99	193.976,07	0,91
Kab Malang	55.318,23	62.773	0,88	58.192,33	67.833	0,86

The difference between the harvested area in the Image and the BPS data can be seen from the ratio value. The average Karawang Regency has a ratio of 0.935 while in Malang Regency it is 0.87. If the ratio value is close to 1, it means that the harvested area of Image Sentinel-2 data with BPS data tends to be the same. If the ratio value is more than 1, it means that the Image harvested area is larger than the BPS data. On the other hand, if the ratio value is less than 1, it means that the harvested area according to BPS data is greater than the harvested area based on Image [41]. Thus, the harvest area based on images in Karawang is better than in Malang areas.

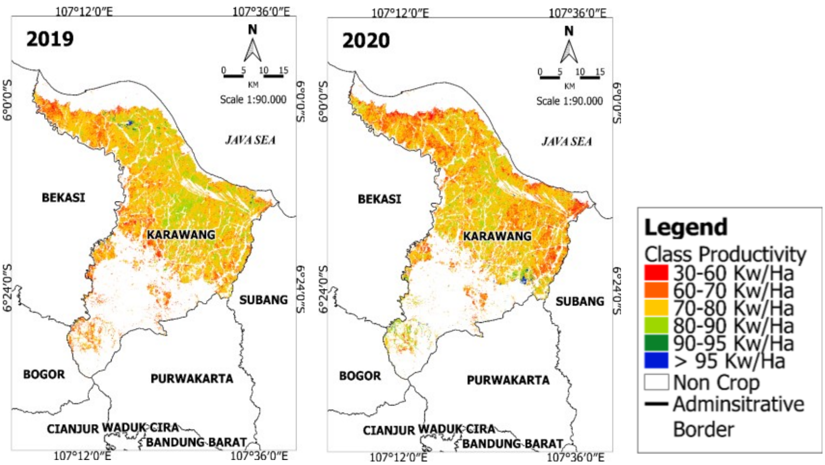


Fig. 9. Rice Crop Productivity in Karawang Regency

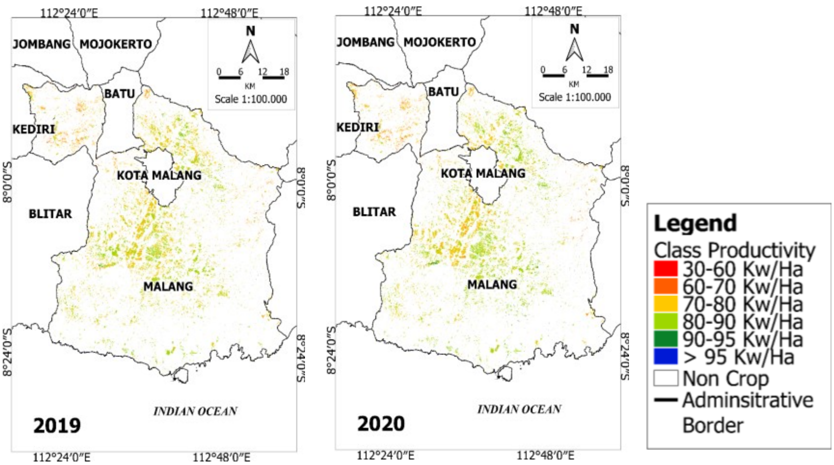


Fig. 10. Rice Crop Productivity in Malang Regency

The average productivity of paddy fields as a result of the analysis of Image Sentinel-2 (Figure 3.9) in Karawang Regency in the 2019 period was 73.87 and in 2020 it was 72.91 Qwintals/Ha, then for Malang Regency, in the 2019 period it was 74,59 Qwintals/Ha and in 2020 as much as 74.87 Qwintals/Ha. When compared with BPS data, in general, the average productivity of lowland rice resulting from Image analysis has a greater value than BPS data. For more clarity, a comparison of the estimated data for lowland rice productivity from Image and BPS analysis is presented in table 7 and table 8.

Table 7. Comparison of 2019 productivity estimates

Area	2019				
	Image (Qwintals/Ha)	BPS (Qwintals/Ha)	Rasio	Std Dev	Coef Varians (%)
Karawang	73,87	60,14	1,23	5,30	4,31
Malang	74,59	70,91	1,05	5,32	5,06

Table 8. Comparison of 2020 productivity estimates

Area	2020				
	Image (Qwintals/Ha)	BPS (Qwintals/Ha)	Rasio	Std Dev	Coef Varians (%)
Karawang	72,91	61,49	1,19	6,12	5,16
Malang	74,87	70,91	1,06	5,37	5,09

Based on tables 7 and 8, the ratio of Image to BPS data in Karawang Regency in 2019 is 1.23 and Malang Regency is 1.05 while in 2020 Karawang Regency has a ratio of 1.19 and Malang Regency 1.06. If the ratio value is close to 1, then the productivity of Image data with BPS data tends to be the same. If the ratio value is more than 1, it means that Image productivity is greater than the BPS data. On the other hand, if the ratio value is less than 1, it means that productivity according to BPS data is greater than Image [41]. This indicates that the productivity results based on Image Sentinel-2 in both Karawang Regency and Malang Regency have greater results than BPS data in 2019-2020.

Furthermore, the results of the coefficient of variance in Karawang Regency in 2019 were 4.73% and Malang Regency 5.06%. Meanwhile, in 2020, Karawang Regency has a coefficient of variance of 5.16% and Malang Regency is 5.09%. If the percentage of the coefficient of variance is small, it means that the distribution of productivity on the Image tends to be homogeneous (same). If the percentage coefficient is high, it means that productivity differences tend to be heterogeneous (various) [41]. Apparently that rice farmings'productivity in 2019 in Karawang Regency are more homogeneous, and for 2020 Malang Regency has a more homogeneous productivity than Karawang Regency.

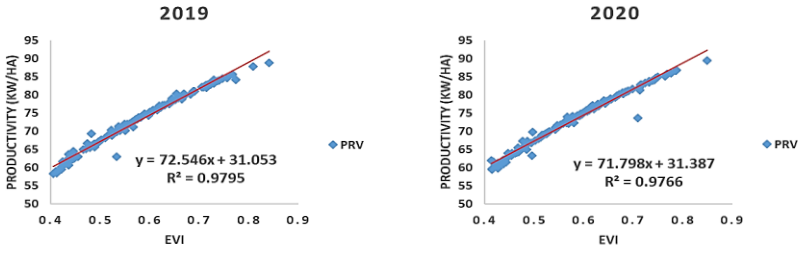


Fig. 11. Relationship of Maximum EVI with Rice Productivity in Karawang Regency

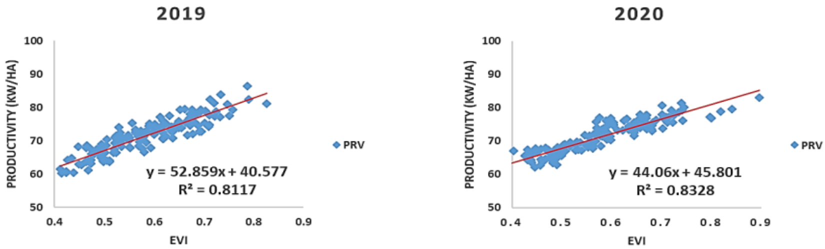


Fig. 12. The Relationship of Maximum EVI with Rice Crop Productivity in Malang Regency

Figures 11 and 12 explain the relationship between the maximum EVI value and rice productivity in different areas, namely Malang Regency and Karawang Regency. Based on the statistical analysis carried out, the regression value for Karawang Regency in 2019 was R2 = 0.98 and in 2020 it was R2 = 0.97. While in Malang Regency in 2019 it was R2 = 0.82 and in 2020 the R2 = 0.83. The two areas indicate that there is a positive relationship between the maximum EVI value and the productivity of rice plants. The correlation between the two variables is also interpreted as a strong relationship. Interpretation with R2 value close to 1 as a strong variable relationship, indicating its high potential for application [46].

4 Conclusions

The results of the identification of the Multitemporal Sentinel-2 Image in 2019-2021 in each research area has a maximum EVI class of rice fields from 0.40 to > 0.70. Karawang Regency has a dominant EVI class of 0.60-0.65 while in Malang Regency the EVI Maximum class is dominant > 0.70. The accuracy of the relationship between age and the EVI value in each rice field class is quite significant or related, namely in Karawang Regency an average of $R^2 = 0.9084$ and Malang Regency with an average of $R^2 = 0.9010$.

Based on Image Sentinel-2, the estimated harvested area in 2019-2020 is smaller than BPS data, while productivity is greater than BPS data. Harvested area is measured by the ratio value, namely in Karawang Regency it has a ratio of 0.93 and Malang Regency has a ratio of 0.86, which is smaller than BPS data. While productivity is measured by the coefficient of variance, Karawang Regency has an average of 4.73% and Malang Regency has an average of 5.07%.

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