

Research Article

Comparison of soil physical properties and soil-vegetation indices to predict rice productivity in Malang Regency of East Java

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Abstract

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Rice has become the leading food commodity in Indonesia, with total production reached ± 54.60 million tons in 2019. However, the production tended to decrease by around 8% from 2018 to 2019, while the rice consumption increased by ± 1.53 tons. This study aims to develop a rice production estimation model using the soil-vegetation index transformation (MSAVI and SAVI) and soil physical properties, which has the advantage of being faster, cheaper, and more accurate than conventional methods. The soil physical properties were taken based on soil mapping units and analyzed with soil physical parameters. The results showed strong relationships between rice productivity - soil physical characteristics and rice productivity - MSAVI and EVI with r values of 0.97, 0.83, and 0.74, respectively. The soil physical properties have a better coefficient of determination and accuracy than soil-vegetation index. The prediction model of rice production by soil physical properties is formulated inward $\gamma = -8.96 + 0.01$ (Top Soil Sand) + 0.01 (Top Soil Silt) + 6.28 (Bulk Density) - 14.07 (Penetration) - 0.13 (Sub Soil Permeability). There is no difference in the productivity value between model and laboratory analysis result. These results indicate that the rice yield prediction model can be used for estimation purposes.

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Introduction

Indonesia is the third-largest producer of rice production in Asia after China and India, with production reached ± 54.60 million tons in 2019 (Central Bureau of Statistics, 2020). In Indonesia, East Java is the highest contributor to rice production for fulfilling the food needs of 39.36 million people (Ministry of Internal Affairs, 2020). Ironically, the high demand for rice is faced with a decline in production, reaching -6.83% (on average from 2015-2019). This decline in production should have been predictable from the beginning to be followed up with preventive steps. Currently, the estimation of rice production measurement is mostly done by looking at soil chemical properties. Remote sensing technology

has also been running using medium to high-resolution images.

Soil physical property is an essential indicator of soil fertility in addition to soil chemical properties. Degradation of soil physical properties has been shown to reduce the production of various kinds of plants (Erizilina et al., 2018). Many factors can cause damage to the physical properties of the soil, such as the use of chemicals (pesticides and fertilizers) and land mismanagement (Saputri et al., 2016). The increased use of chemical fertilizers and pesticides can cause a problem in soil physical properties, leading to a decline in rice production (Indrajati, 2008). The influence of soil physical properties on rice production is significant to investigate to what extent these properties affect production. Previous research by

Ishaq et al. (2017) showed that the decrease in rice production in Java Island amounted to 829.97 thousand tons was due to the decrease in land area and the impact of chemical fertilizer residues that damaged the soil's physical properties. Apart from estimating using soil physical properties, the use of Unmanned Aerial Vehicle has also been used to analyze soil physical properties. Previous research by Mustafa et al. (2020) showed that multispectral image technology from a drone could correlate the healthiness of crops with the soil's physical properties. Besides, rice production can also be predicted by a fast and precise method using remote sensing techniques. Remote sensing can set up information quickly, accurately, and cost-effective for estimating rice production. According to Parsa et al. (2017), remote sensing of the earth's surface includes specific land areas that can monitor the rice plant's physical condition. Therefore, the use of GIS to determine the role of the vegetation index and soil physical properties to yield data information is more easily understood (Susetyo and Setiono, 2013). It is crucial to compare the estimated rice production between the soil physical properties and the soil-vegetation index to obtain the best model. The resulting model is expected to be used to predict

rice productivity quickly, precisely, and accurately. This study aimed to compare the rice productivity prediction method in the Malang Regency by soil physical properties and soil – vegetation indices.

Materials and Methods

Research location

The research was conducted from March to September 2019 in Malang Regency, East Java (Figure 1), specifically into the coordinates $112^{\circ} 17' 10,9''$ - $112^{\circ} 57' 0,0''$ longitude and $7^{\circ} 44' 55,11''$ - $8^{\circ} 26' 35,45''$ latitude (Malang District Government, 2016). Malang Regency is one of the areas that supports the second rice production in East Java. Central Statistics Agency of Malang Regency (2019) indicated that rice production in Malang Regency in 2015, 2016, and 2017 was 286,048 tons, 292,758 tons, and 302,117 tons, respectively, with a harvest area of 63,065 ha, 63,558 ha, and 67,181 ha. The research location is in an area affected by volcanic activity, river sedimentation, and calcareous areas. The nature of the formed soil is then influenced by intensive land management carried out on rice fields.

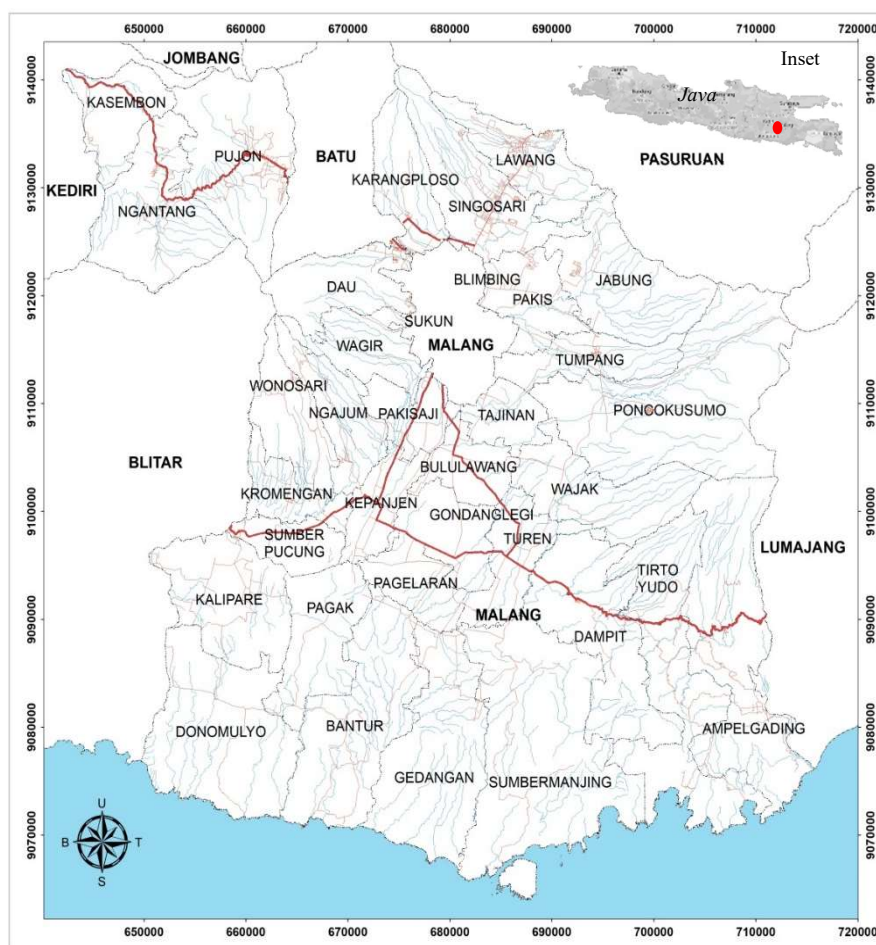


Figure 1. Research location.

Field estimation of rice yield

Field survey activities were conducted to observe rice productivity, collect soil samples, and measure soil penetration resistance. The area frame count method was used to calculate the rice harvest area. The area frame count method formula is described in the following equation 1 (BBPadi, 2017).

$$Y = a + \frac{10.000 \text{ m}^2}{L}$$

where:

- Y = estimate of production (t/ha)
 a = average yield weight (kg)
 L = frame width (m)

Soil sampling

Determining the observation point begins with creating a land unit consisting of a geology map 1:100,000 (Keaton and Degraff, 1996) and DEMNAS 8.25 m (Sutanta and Tiera, 2019). Geological map detailing is done by digitizing it using ArcGIS with the smallest area 0.4 cm². This detailing was carried out considering the slope and relief maps produced from DEMNAS 8.25 m (Rayes, 2007). Determination of the point observation used the physiographic method (Rayes, 2007) based on the land unit and rice fields' existence (topography map 1: 25,000). The point observation is shown in Figure 2.

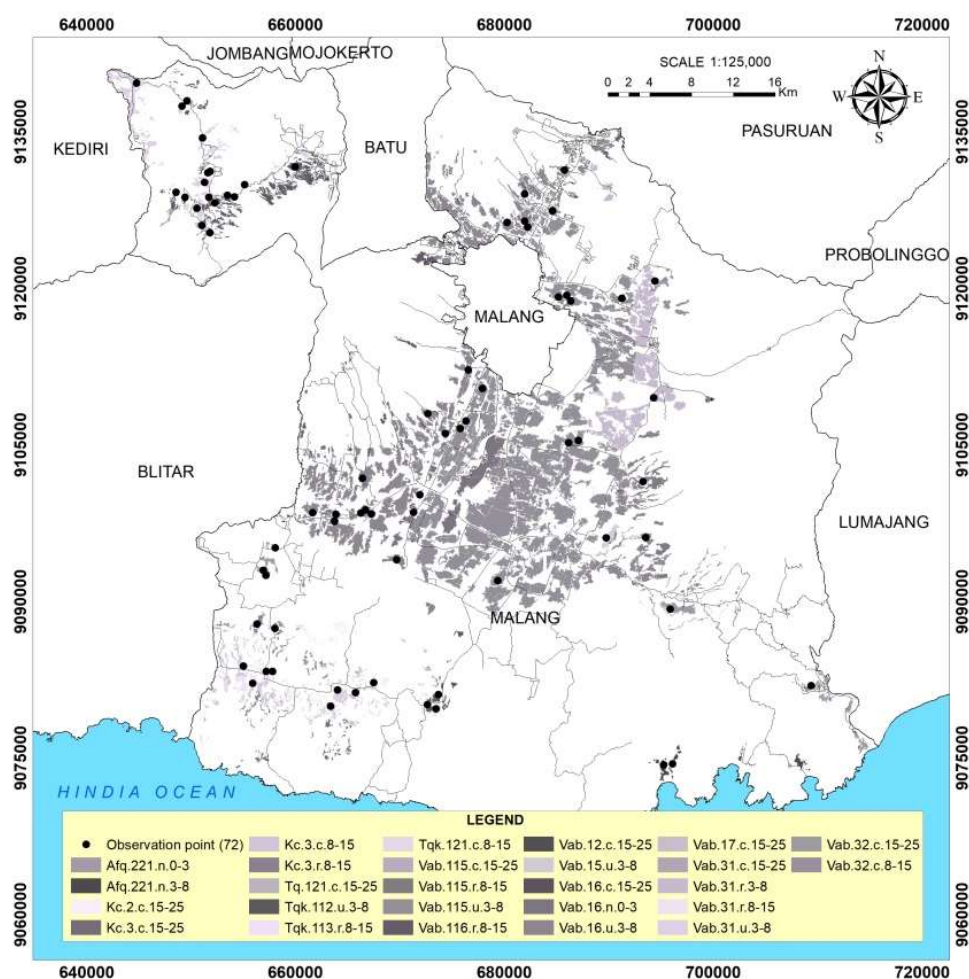


Figure 2. Soil mapping unit.

Observation points that were plotted in 26 land units consisted of 72 observation points for rice productivity identification, 33 observation points for soil physical properties, and 24 observations points for validation. The data retrieved were spread evenly. In areas above the average, soil physical analysis and rice production sampling were repeated.

Soil analysis

Soil samples were analyzed in the laboratory to determine texture (Gee and Bauder, 1986), bulk density (Tan, 2005), particle density (Blake and Hartge, 1986), porosity (Blake and Hartge, 1986), permeability (LPT, 1979), and soil penetration (Armbruster et al., 1990).

Image processing and soil-vegetation index transformation

Landsat 8 is the latest generation of satellite imagery replacing Landsat 7, which has an Onboard Operational Land Imager (OLI) sensor and a Thermal Infrared Sensor (TIRS) with 11 channels with a resolution of 15 m. The pre-processing was divided into radiometric correction and haze-cloud removal to clear up the dust in the image (Widhaningtyas et al., 2020). The next step was to transform satellite images using a soil-index transformation consisting of EVI and MSAVI. The index number was extracted by point analysis from ArcGIS 10.6. Modified Soil Adjusted Vegetation Index (MSAVI) is a modified version of the SAVI, which replaces the constant soil adjustment factor (L) with L adjusting the conditions in the field (Qi et al., 1994). MSAVI algorithm parameters used were the near-infrared band and red band. MSAVI is an index that is more sensitive to vegetation than other indices. MSAVI is a modified version of SAVI, which differentiates between MSAVI and constant soil values and adapts to environmental conditions (Chehbouni et al., 1994). Enhanced Vegetation Index

(EVI) is a vegetation index resulting from improvement from NDVI and is sharper and has a constant L (soil condition) factor. The transformation index formula (MSAVI and EVI) is shown in Table 1. These two indices (MSAVI and EVI) are perfect for use in other crops, especially horticultural commodities (Mutmainna et al., 2017) but have not been widely used specifically for rice commodities. So, as a novelty, this study uses both indices for rice commodities. Estimation of rice productivity can be done through remote sensing and soil physical properties. Estimation through remote sensing is far more efficient in terms of cost, time, and effort. Barus and Wiradisastra (2000) used GIS to collect information about resources because it saves time and expenses incurred and the more stunning final results. Processing using GIS can facilitate the entry and updating of data that can be accessed and corrected quickly and up to date (spatial) and time (temporal) (Marwoto and Danang, 2007). Monitoring rice growth is more manageable because it can increase rice plants' growth that can weigh the stock of rice production in the long term (Said et al., 2015).

Table 1. The formula of vegetation index.

Vegetation Index	Formula	Reference
Enhanced Vegetation Index (EVI)	$2,5 \times \frac{(NIR/red)}{(1 + NIR + 6RED - 7,5 \times BLUE)}$	(Rudiana et al., 2017)
Modified Soil Adjusted Vegetation Index (MSAVI)	$\frac{\sqrt{(2NIR + 1) - (2NIR + 1)^2 - 8(NIR - RED)}}{2}$	(Sripada et al., 2006)

Statistical analysis

Statistical analyses covered normality test, correlation, linear regression (index number), stepwise regression (soil physical parameters), and test of validation by t-paired test using R_{studio} (Putra and Nita, 2020). The correlation regression was carried out on rice productivity calculations in the field with soil physical characteristics and index number (SAVI and MSAVI). The stepwise analysis involves several independent variables. A good regression model should not occur the correlation between independent variables or multicollinearity symptoms. The first step to test stepwise is multicollinearity or near-linear dependence, a statistical phenomenon in which two or more predictor variables in a multiple regression model are highly correlated. Multicollinearity appears when two or more independent variables in the regression model are correlated. A little bit of multicollinearity sometimes will cause a big problem, but it will be a problem to solve moderate or high (Daoud, 2017). A total of 12 variables of soil physical properties were analyzed by multicollinearity test using two criteria, e.g., VIF and tolerance. The hypothesis adopted was tolerance value > 0.10 and VIF value < 10.00. Multicollinearity analysis resulted from four variables that passed into the soil physical criteria. These variables were particle density, topsoil

permeability, subsoil permeability, and resistance of soil penetration. Other parameters were excluded in further tests because they had values that did not fit VIF and tolerance (Andayani et al., 2016). The stepwise regression function was employed to select variables of soil physical properties that affect rice productivity. The stepwise regression test would eliminate the independent variable that does not affect rice productivity (Hanif, 2018). The elimination will show the variables that match the modelling criteria used to estimate rice productivity (Andayani et al., 2016). The stepwise regression result indicated that the variables that passed the multicollinearity test, i.e., soil penetration resistance, particle density, and topsoil permeability, affected rice productivity. The best model selection was based on the results of statistical tests, especially on the results of the correlation and regression between production and the index value or soil physical characteristics.

Rice productivity mapping

The results of the best statistical analysis were used to compile a map of rice productivity using map algebra (Kuria et al., 2011). Map Algebra is a collection of functions for handling continuous spatial data, allowing modelling of different problems and getting new information from the existing data. There is an

established set of map algebra functions in the GIS literature, initially proposed by Dana Tomlin. Tomlin's map algebra has become a standard way of processing coverages, especially for multicriteria analysis (Camara et al., 2005).

Results and Discussion

Rice productivity

Rice productivity in Malang ranged from 4 to 9 t/ha with 6.64 t/ha on average. The highest production that ranged from 8.74 to 8.70 t/ha was in Singosari and Dampit sub-districts. The lowest rice production of 4.85 t/ha was observed in the Sumberpucung. Based on Central Statistics Agency of Malang Regency (2019),

the rice production in Malang ranges from 6 to 7 t/ha. This rice production is above the national average rice production of 5.7 t/ha (Central Bureau of Statistics, 2020).

Soil physical analysis

In general, the soil texture in the research location has a very varied proportion in terms of sand, dust, and clay (Figure 3). The soil bulk density was very high (1.4 g/cm^3), and particle density ranged from 2.1 g/cm^3 to 2.5 g/cm^3 . Based on the bulk and particle density analyses, the porosity value in the study location ranged from 30 to 37%. The high bulk density affected soil penetration, which reached 0.75 to 1.7 MPa. Soil permeability measured on top and subsoil ranged from 0.01 to 0.28 cm/h (Figure 3).

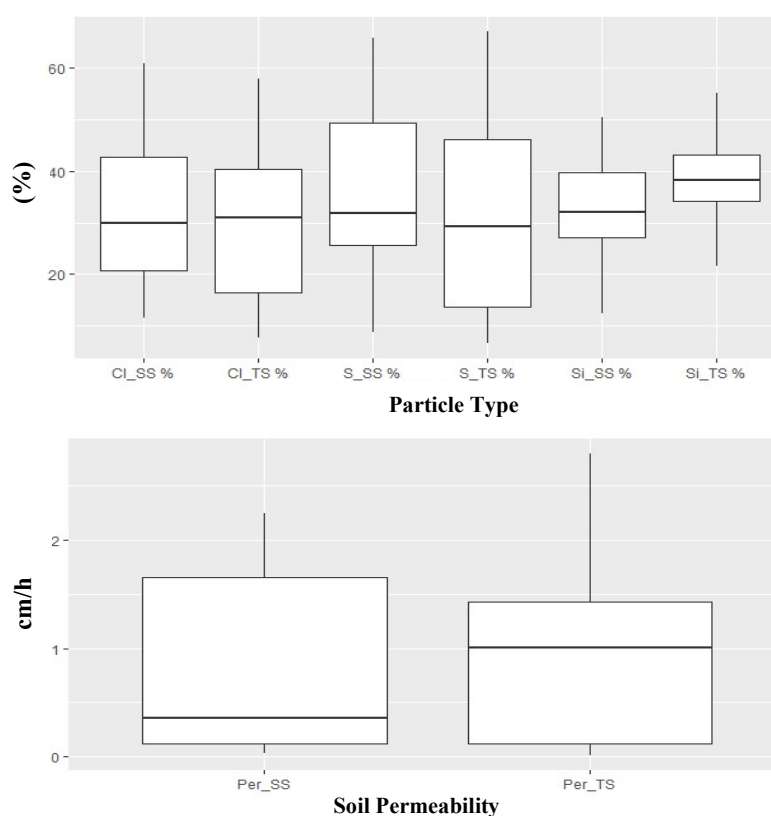


Figure 3. Boxplot analysis soil texture in the research location (Cl: clay, S: sand, Si: silt, TS: topsoil, SS: subsoil) and soil permeability.

The silt was the fraction with the most considerable average amount compared to the sand and clay fractions. The amount of silt (average) in the topsoil layer reached 40% and was higher than that of the subsoil layer, which was only around 35%. The average clay content was about 35% in both the topsoil and subsoil. On the other hand, the sand content ranged from 15 to 45%. Malang regency is formed from young quarter volcanoes covering an area of 44.25% or 148,152.52 ha from the entire Malang Regency area. There is a small part developed from a new limestone

facies Miocene with an area of 90,884.00 ha or 27.15% of the total area of Malang Regency. These geological conditions affect the type of soil that exists. The type of land in Malang regency consists of alluvial, regosol, brown forest, andosol, latosol, median and litosol soils. This type of land is not entirely spread in the sub-districts in Malang but is dominated by andosol, latosol, and mediteran soil types with an area of 43,782.42 ha, 86,260.36 ha and 55,811.30 ha, respectively (Malang District Government, 2016). The bulk density was relatively high, ranging from 1.4

to 1.7 g/cm³. The high bulk density is likely due to the high percentage of sand and clay fractions in the study site. Besides, the silt fraction in the research location has experienced compaction in rice fields. Bernoux et al. (1998) found a correlation of about 50% between texture and bulk density. Dinesh Kumar and Phogat (2009) indicated that soil texture-specific tests would be required to determine the correct organic matter level to achieve a target bulk density to avoid the problem of compaction. The soil bulk density is also strongly influenced by land management. The lowest bulk density value obtained at the soil's surface after mechanical processing of the soil is carried out until the soil compaction process occurs. The section of land under the tractor line will have a much higher bulk density than the rest of the soil (Agus and Hardjowigeno, 2004).

The particle density measurements showed that the soil had particle density value ranging from 2.1 to 2.5 g/cm³ (Figure 7). The high bulk density affected soil porosity which only ranged from value 33 to 35%. Bulk density is very closely related to particle density, and if the particle density of the soil is high, then the

bulk density is also high. This condition is because particle density is directly proportional to the bulk density, but if a soil has a high-water content level, then the bulk density and particle density will decrease. This condition is because particle density is inversely proportional to moisture content. It can be proven if in soil has a high level of water content in absorbing water, then the density of the soil will also be low because the pores in the soil are large so that the soil that has large pores will be easier to put water in the soil aggregate (Hanafiah, 2007). Besides affecting porosity, high bulk density affects soil penetration. At the research location, the penetration value ranged from 0.85 to 0.95 MPa. Bulk density soil is closely related to the ease of penetration of roots into the soil, drainage, and aeration of soil with other soil properties such as total pore space and distribution of pore space. (Haryati, 2014). Soils with high bulk density values ranging from 1.3 to 1.5 g/cm³ have low aeration pores and stability index that cause the soil to become compacted quickly. As a result, the growth of plant roots is hampered because the roots penetration power into the soil becomes reduced (Holiullah et al., 2015).

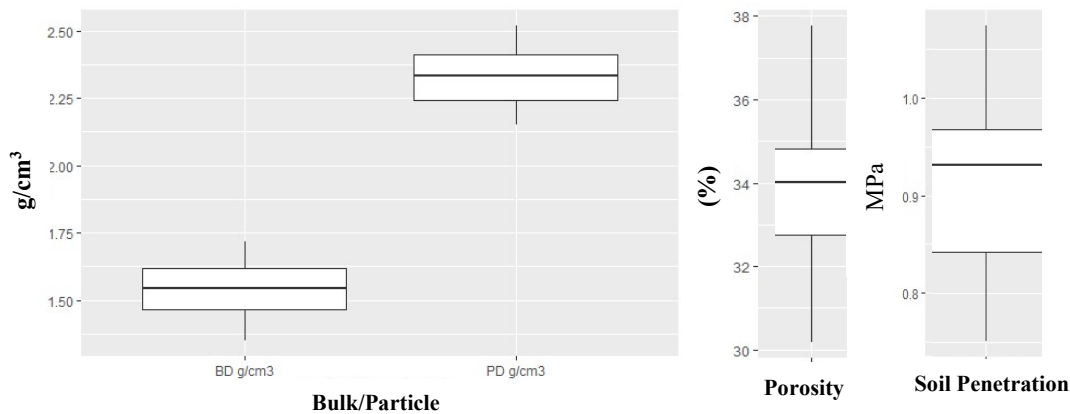


Figure 4. Boxplot analysis bulk density (BD), particle density (PD), soil porosity, and soil penetration in the research location.

Soil-vegetation index number

The satellite image transformation results using MSAVI and SAVI showed a similar trend, where the

higher the production, the greater the index value will be. The EVI number ranges from > 0.2 to approximately 0.35, while the MSAVI ranges from 0.6 to 0.85 (Figure 5).

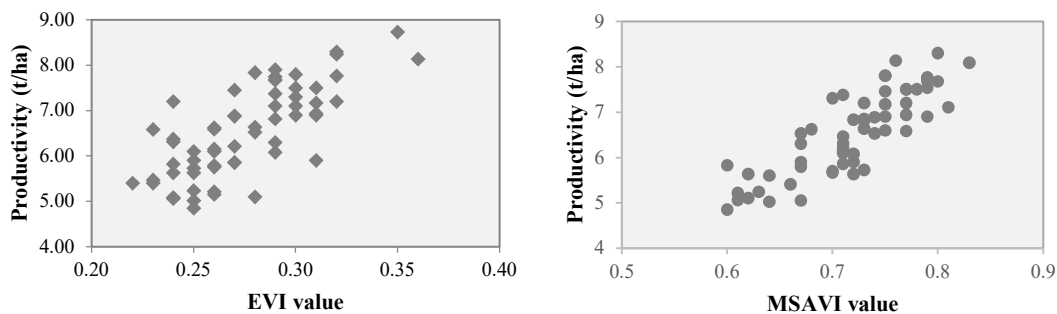


Figure 5. Distribution of MSAVI and EVI number based on rice productivity.

Based on research by Burke and David (2017), the distribution of EVI number and rice productivity is 0.21 to 0.40, and the distribution of MSAVI number is 0.63 to 0.74. Sari and Sukojo (2015) reported the integration of remote sensing technology using Landsat 8 satellite imagery to identify the growing phase and the Autoregressive Integrated Moving Average (ARIMA) to forecast rice productivity. Linear regression analysis between the growing phase of rice plants with the value of vegetation index obtained a coefficient of determination (R^2) for MSAVI algorithm of 0.879. Sudarsono et al. (2016) analyzed the growing phase of rice planting and predicted rice productivity with remote sensing technology in Kendal district with EVI vegetation index method, obtained a coefficient of determination value (R^2) of 0.427496.

Correlation between soil physical properties and rice productivity

Bulk density has a positive correlation with rice production ($r = 0.11$) (Table 2). Likewise, porosity density has a positive correlation with rice production ($r = 0.15$). Rice production and porosity show a negative correlation with a value of $r = -0.02$. A negative correlation also occurs in the penetration aspect of -0.82 . These soil variables influence soil productivity. The ability of rice roots to penetrate the soil is influenced by soil penetration resistance. The ease of movement of the roots in the soil will help the rice obtain water and nutrients. Higher soil penetration will interfere with root movement in search of nutrients and water. This process will inundate the rice fields causing the soil to become massive so that root movement is affected by soil density.

Table 2. Correlation analysis result between rice productivity (t/ha) and soil physical properties.

	SS	TS	Penetration	Porosity	PD	BD
TS	0.85***					
Penetration	0.76***	0.68***				
Porosity	-0.52**	-0.38*	-0.41*			
PD	0.46**	0.50**	0.37*	-0.49**		
BD	0.56***	0.52**	0.44**	-0.80***	0.92***	
Production	-0.53**	-0.44**	-0.82***	-0.02	0.15	0.11

Note: an asterisk (*) can be interpreted that there is a relationship between them and the value higher than the r -table. Bulk Density (BD), Particle Density (PD), soil porosity, and soil penetration, Top Soil (TS), Sub Soil (SS).

The soil density is influenced by particle density (Brady, 1984). Good quality soil has a high particle density value because of the particle density value. The ability of soil to hold water is a significant factor in determining plant growth and rice production, reducing soil density. The low capacity of the soil to hold water causes the groundwater level to drop rapidly. A decrease in groundwater content will usually be followed by an increase in soil penetration to physically inhibit root growth (Wahyunto and Heryanto, 2006). Soils that are most suitable for rice fields have permeability in the relatively low to low range. This process aims to prevent water loss. However, it is still large enough to dry (wash) toxic materials. The soil will not harden and support the root rice movement (Agus and Hardjowigeno, 2004). The correlation value between soil physical properties and rice production is closely related and is following previous research. Soil characteristics aspects that most influence rice productions are weight and soil type.

Correlation between soil-vegetation index and rice productivity

Correlation test results showed a strong positive correlation between MSAVI and rice productivity, with an r -value of 0.83. In comparison, the correlation between EVI and rice productivity has an r -value of 0.74. Based on the correlation analysis, the MSAVI

Index is more closely related to rice production than the EVI Index. This condition is supported by Gong et al. (2013) research if the MSAVI (Modified Soil Advanced Vegetation Index) is an equation that includes the soil calibration factor in the calculation process, so it is developed to obtain the vegetation index value by eliminating the soil factor.

The Enhanced Vegetation Index (EVI) is an extension of determining the vegetation index to observe the limitations of NDVI by optimizing better vegetation signal sensitivity in areas with high biomass (a severe drawback of NDVI), increasing the greenness of plants through the influence of the background. Soil and canopy signals and reduce atmospheric conditions on the vegetation index value from adding information to the blue channel. EVI is more responsive to the determination of variations in canopy structure, including Leaf Area Index (LAI), canopy type, plant physiognomies, and canopy architecture, than NDVI, which generally only responds to the amount of chlorophyll (Huete, 1988). So, the MSAVI index is considered to be more detailed in capturing vegetation signals because it ignores the soil factor and focuses on the vegetation index value.

Stepwise regression between soil physical properties with rice productivity

Rice production is more determined by soil The stepwise regression analysis on soil physical properties

and rice production showed $\gamma = -8.96 + 0.01$ (Top Soil Sand) + 0.01 (Top Soil Silt) + 6.28 (Bulk Density) - 14.07 (Penetration) - 0.13 (Sub Soil Permeability), and R^2 was 0.97. Based on the regression analysis, it was found that the physical properties of the soil, such as topsoil sand, topsoil silt, bulk density, penetration, and subsoil permeability, were closely related to rice productivity. This result is also indicated by the R^2 value of 0.97. conditions (Holilullah et al., 2015). Based on Munawar's research (2011), soil suitable for rice plants should be clay textured to sandy loam, light structure, about 20% micropores. The soil must also have 1-1.5% organic matter, CEC 10-20 me/100 g, available P 5 - 10 ppm, K, which can be exchanged 0.15 - 0.30 me/100 g, and soil pH of 5 - 7.

Regression analysis between index number with rice productivity

The equation formed from linear regression to the MSAVI was $y = 13.134x - 2.9026$ with a coefficient of determination $R^2 = 0.69$ and to the EVI was $y = 24.004x - 0.064$ ($R^2 = 0.56$) (Figure 6). Figure 6 shows that the value of R^2 in the index number EVI parameter with rice production is 0.56, with the resulting formula being $y = 24.004x - 0.0644$. If the variable x (EVI) increases 1 % with a value coefficient of 24.004, then the variable y (rice productivity) will

increase by 0.0644. The value of R^2 in the MSAVI index number parameter with rice productivity is 0.69, with the resulting formula being $y = 13.411x - 3.0841$. If the coefficient of variable x (MSAVI) of 13,411 increases by 1%, then the variable y (rice productivity) increases to 3.0841. The R^2 value in the soil index method with MSAVI has a value of 0.69, which means that the accuracy value reaches 69%. Meanwhile, using the EVI index has a value of R^2 0.56, which means that the accuracy value is 56%. The highest accuracy value uses the Soil Physical Properties method with an accuracy value of 97% because the R^2 value reaches 0.97. This is supported by the research of Shabrina et al. (2020) if the results of determining the phase of rice growth, the results of using the EVI algorithm with Sentinel-2A images which have a spatial resolution of 10 meters, can be used to identify rice growth phases with an R^2 value of 0.592 so that it has an accuracy value of 59.2%. In Useng's research (2015), the results of estimating rice production with the MSAVI plant index have an R^2 value of 0.35, so the accuracy of the index is 35%. In Cahyono's research (2019), the validation of rice plant predictions based on the physical conditions of the soil in Mayang District obtained a value close to the actual result with a value of 0.93 or reaching 93%.

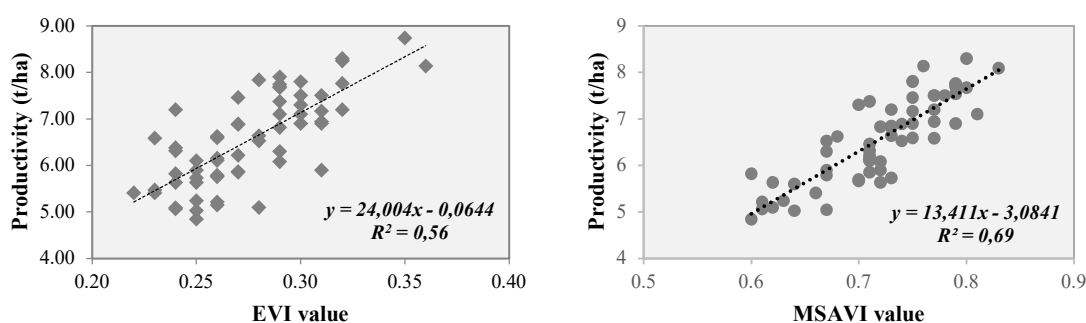


Figure 6. Regression equation from EVI and MSAVI.

Based on the regression analysis between the MSAVI and EVI soil vegetation indexes, the R^2 value of MSAVI was higher than that of the EVI. This result can be concluded if the MSAVI Index is more closely related to rice production. MSAVI can be quite effective in approaching the growth phase of rice plants, closely associated with leaf density estimation. This is because, in the MSAVI vegetation index, the value of the background effect of the soil has been minimized so that the reflectance of the leaf canopy cell structure will be better. Prahasta (2008) states that the soil background disturbance is a disturbance in different variations in the spectral response of the soil, which causes the resulting vegetation index to be inaccurate. On the ground line, there are various soil pixel vectors with different moisture and possibly different colours. In Kang's research (1996), after

analyzing and comparing it with other algorithms such as NDVI, SAVI, and PVI, the MSAVI algorithm can not only be obtained. Increases plant signal but also dramatically minimizes the effect of soil cover.

The best formula to predict rice productivity

The R^2 value on an index soil vegetation can be used, but the choice of the formula is taken from the highest coefficient of determination. The best formula to predict rice productivity is $\gamma = -8.96 + 0.01$ (Top Soil Sand) + 0.01 (Top Soil Silt) + 6.28 (Bulk Density) - 14.07 (Penetration) - 0.13 (Sub Soil Permeability), R^2 was 0.97. The best productivity estimation resulted from soil physical properties. MSAVI and EVI have a lower value R^2 , although equally usable. According to Kravchenko (2003), the level of data variability is important for site-specific management, as soil

properties with high variability are potentially better candidates to be managed on a site-specific basis than the more uniformly distributed soil properties. On the other hand, mapping soil properties with higher variability can be less accurate than soil properties with lower variability. Trends in the variation of soil attributes obtained in this study are consistent with those observed by Bernardi et al. (2014) for several

soil parameters. The condition of the soil's physical properties, such as soil structure, ability to hold water, porosity, infiltration rate, and easy penetration of roots can increase land productivity, and crop yields can increase (Suwardjo, 1981). The productivity estimation map was shown in Figure 7; the green colour indicated high productivity, and the red was otherwise.

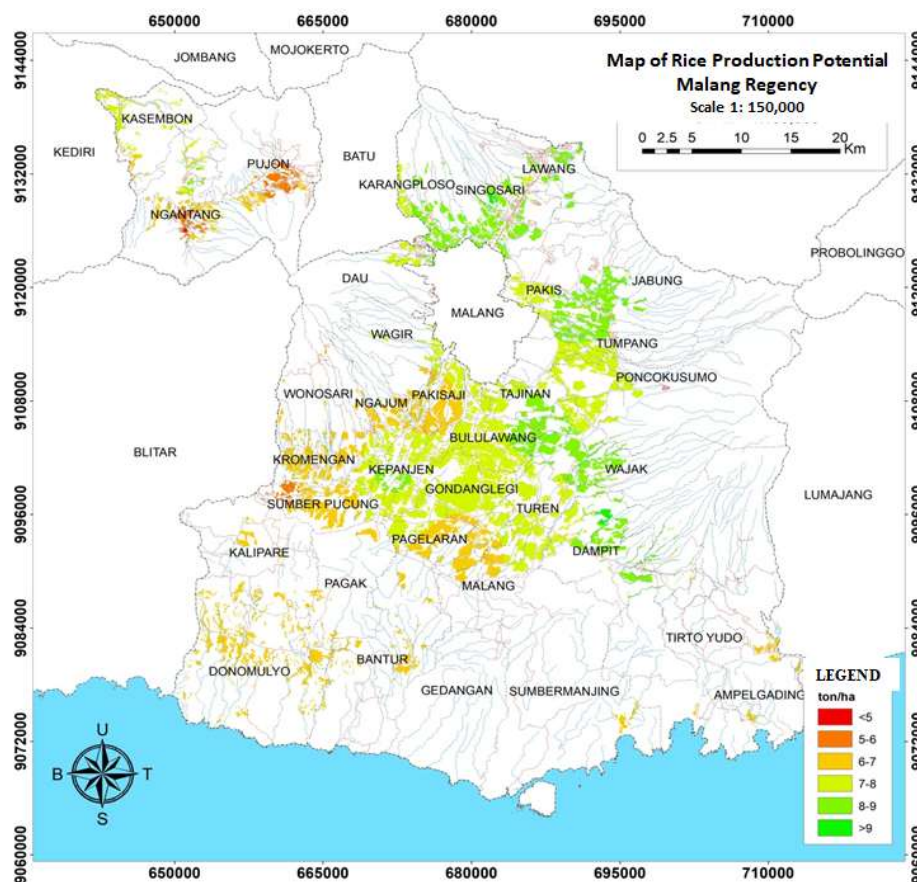


Figure 7. The map of rice productivity estimation.

Accuracy assessment

The accuracy assessment was used to determine whether the resulted equation can predict rice productivity in Malang. The accuracy assessment used the paired t-test to compare the validation point rice productivity results and estimation of rice productivity. The paired t-test was $t = -1.5603$, $df = 23$, $p\text{-value} = 0.1323$. Based on the t-test, there is no difference between the soil physical estimated results and the field's measurement results. Besides, it is reinforced with a p-value of more than 0.05.

Conclusion

Monitoring rice productivity is essential over time to assess how agricultural systems are working. Accuracy of using the physical properties of soil can

be used as an alternative to calculating the level of productivity precisely and accurately. The results of the regression analysis carried out on the method of soil physical properties and soil index to predict rice production were obtained if the process of estimating rice production using the technique of soil physical properties was considered the most accurate with an accuracy value of up to 97% ($R^2 = 0.97$). This result is because soil conditions more directly determine rice production. The method of estimating rice production with a soil index uses the MSAVI and EVI indexes. The MSAVI index is better than EVI, with an accuracy value of 69% between the two indexes. In the MSAVI vegetation index, the weight of the background effect of the soil has been minimized so that the reflectance of the leaf canopy cell structure will be more visible. Image processing should be carried out in more than one rice planting period to determine a more accurate

maximum vegetation index value. In further research using remote sensing technology, the advantages of monitoring methods over conventional methods are also more efficient in terms of time and cost.

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