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Estimating Corn Productivity Using Sentinel-2 Imagery and Spectrometer

Yeli Oktaviana Liku[1], Daniel Useng[1], Sitti Nur Faridah[1]
[1]Faculty of Agriculture, Hasanuddin University, Makassar, Indonesia

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ABSTRACT

Corn is a staple food for the Indonesian population due to its high carbohydrate content, second only to rice. Estimating corn production before the harvest period is crucial for predicting total production output from a given location. This study aims to develop a production model for corn using Sentinel-2 satellite imagery combined with spectral data from a spectrometer and field measurements. The research involved collecting field data on corn production, downloading Sentinel-2 imagery for the period from December 10, 2022, to February 28, 2023, performing atmospheric correction and image cropping, transforming the data into NDVI and EVI vegetation indices, and analyzing the data using simple linear regression to determine the relationship between the NDVI and EVI indices and corn plant parameters, specifically biomass. The results show a strong correlation between productivity estimates using Sentinel-2 and spectrometer data with field observations. For the Sentinel-2 Vegetation Index, EVI has the highest correlation with productivity at approximately 88%, compared to other vegetation indices at around 80%. For the Spectrometer Vegetation Index, NDVI has the highest correlation at around 83%, while other indices are below 80%. Therefore, Sentinel-2 and spectrometer data can effectively estimate productivity in corn plantations.

Corresponding Author(s):

Daniel Useng
Faculty of Agriculture, Hasanuddin University
Jl. Perintis Kemerdekaan KM.10, 90245, Tamalanrea, Makassar, Sulawesi Selatan, Indonesia
Email: daniel.useng@agri.unhas.ac.id

1. INTRODUCTION

Corn is one of the raw materials in the industrial sector, especially the feed and food sector. As a food source, corn has become a main commodity. Several regions in Indonesia have made corn the main food ingredient. Corn is not only used for human consumption but can also be used as animal feed. Market demand for corn is increasing along with the increase in various types of market opportunities for corn plants. The increase in need for corn must be balanced with an increase in corn production every year (Wulandari & Jaelani, 2019). Estimated corn production (corn stored in warehouses) reaches 18.7 million tons and the need for animal feed is 15 million tons, so it is estimated that there are still national reserves of around 3 million tons which are prioritized for national needs (Rifai et al., 2020).

Estimating the production of corn plants before the harvest period needs to be done to estimate production from a location so that it can be taken into consideration in making decisions regarding the total area of new planting areas for corn plants. One alternative that can be made is to collect productivity data in the field and remote sensing to quickly estimate the production yield of corn plants on land (Irsan et al., 2019).

Remote sensing connects satellite image reflectance data and plant growth parameters and can estimate the production results of a plant. Technological developments support long-distance land monitoring activities with the help of spectral waves reflected by plants and using sentinel satellite imagery and spectrometers with vegetation indices, making it easier to monitor land and carry out land mapping (Wulandari & Jaelani, 2019).

Remote sensing is based on the light spectrum with the main application, the first being the ultraviolet region, moving from 10-380 nm, then the visible spectrum, which consists of the blue wavelength region 450-495 nm, green 495-570 nm, red 620-750 nm, near and mid infrared bands 850-1700 nm (Xie et al., 2008).

The vegetation index is a value of the amount of green vegetation that can be obtained by processing signal data from digital brightness values of various satellite sensor data channels (Irsan et al., 2019). There are several types or vegetation index methods that have different levels of accuracy in determining vegetation density. One of the most widely used indices is the Normalized Difference Vegetation Index (NDVI). NDVI has a sensitive response to green vegetation even for areas with low vegetation cover (Xie et al., 2008). Apart from NDVI, the EVI (Enhanced Vegetation Index), which is a refinement of the NDVI vegetation index, has better sensitivity to images of the greenest (dense and fertile) areas. The EVI can reduce the effects of atmospheric disturbances and can increase biomass sensitivity (Irsan et al., 2019). MSR (Modified Simple Ratio) is a vegetation index as a revision of the RDVI (Renormalized Difference Vegetation Index) in terms of sensitivity to the physical parameters of vegetation through the combination of parameters SR = NIR/Red. The MSR index itself also has a very strong influence on the chlorophyll variable compared to NDVI (Skianis et al., 2007).

The aim of this research is to determine the production of corn plants using sentinel 2 satellite combined with spectral waves from a spectrometer and field measurement data. The benefit of this research is as information in knowing the estimated productivity of corn plants.

2. MATERIALS AND METHODS

2.1. Tools and Materials

The tools used in this research were a laptop, QGis software, Stellarnet spectrometer, SpectraWiz software, cellphone camera, meter and stationery. The materials used in this research are primary data in the form of field survey data and field documentation data. Secondary data are Sentinel-2 image data of Maros Regency and land shp map. The corn used is the feed corn variety Hybrid NK7328 SUMO.

2.2. Field Data Collection

The data collection period is adjusted to the period of Sentinel-2 imagery passing at the research location, which is every 10 days during the growth period of corn plants. Observations were made on 6 plots of corn land. There is 1 observation plot each in each plot of corn land being observed with a plot size of 2 x 2 m. The biomass to be measured is the aboveground biomass in the form of stems and leaves and the belowground biomass in the form of roots. Biomass measurement is carried out by taking samples of 4 corn plants from each plot at the three planting distances then separating the roots, stems, leaves and fruit (if any), then weighing the wet biomass of roots, stems and leaves separately. Then dry each part of the plant to obtain the dry weight of the plant. Next, weigh the dry weight of each plant part, namely roots, stems and leaves using a digital scale.

2.3. Spectrometer data collection

This data was carried out using the StellarNet Inc Spectrometer tool which was connected to the Spectrawiz software on a laptop. Leaf canopy reflectance was measured at the measurement point, namely corn, at 10.00 – 14.00 from the top of the leaf canopy surface at a height of around 30 – 60 cm with a slope angle of 45°. Each measurement was carried out three times.

2.4. Image data preparation

The research location map was created by downloading base map data from Google Earth and then processing the data using ArcGIS software. Sentinel-2 image data was downloaded at https://scihub.copernicus.eu/., in accordance with the time of corn planting in the research location. Sentinel-2 images were downloaded for the time period December 10, 2022 - February 28, 2023. A total of 8 images were downloaded, but only 4 images could be used because the images were covered by clouds. Atmospheric correction is carried out with the aim of reducing errors in image data due to atmospheric factors. The atmospheric correction process was carried out in the Semi-Automatic Classification Plugin which is a plugin of the QGIS software. Image cropping is in accordance with the boundaries of the study area, namely Masale Village, Maros Regency. The image cropping process is done using the clip raster by mask layer tool in QGIS software.

2.5. Vegetation Index Transformation

Vegetation index transformation is used to change pixel values in the image so as to produce new pixel values that indicate vegetation aspects. The vegetation indices NDVI (Normalized Difference Vegetation Index), MSR (Modified Simple Ratio) and EVI (Enhanced Vegetation Index) are determined using QGIS software by inputting image data based on the NDVI, MSR and EVI formulas in Equations 2, 3 and 4 using the Raster Calculator in the software QGIS then creates a visualization map of corn growth based on NDVI, MSR and EVI transformations. The equation used to calculate the NDVI (Normalized Difference Vegetation Index) value is as follows (Diasmara & Sudiana, 2007).

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)} \quad (1)$$

The equation for calculating the EVI (Enhanced Vegetation Index) index value is as follows (Aziz et al., 2018).

$$EVI = \frac{2,5 \times (NIR - Red)}{(NIR + 6 \times Red - 7,5 \times Blue + 1)} \quad (2)$$

The MSR index itself also has a very strong influence on the chlorophyll variable compared to NDVI, with the equation used for the MSR index being as follows (Skianis et al., 2007).

$$MSR = \frac{\left(\frac{NIR}{Red} - 1\right)}{\sqrt{\frac{NIR}{Red}} + 1} \quad (3)$$

Table 1. Classification of NDVI and EVI Indexes

No	Classification	Index Value
1	Land without vegetation	-0,1 to 0,03
2	Very low greenness	0,03 to 0,15
3	Low greenness	0,15 to 0,25
4	Medium greenness	0,25 to 0,35
5	High greenness	0,35 to 1,00

(Setyaputri et al., 2023)

Table 2. Plant Condition MSR Index Value

Plant Condition	Index Value
Chlorophyll is very low	0,1-0,24
Low chlorophyll	0,25-049
High chlorophyll	0,50-0,7
Very high Chlorophyll	0,71-0,8

(Skianis et al., 2007).

2.6. Regression Analysis

The regression analysis used in this study is linear regression. Linear regression analysis was used to see the linear model of NDVI, MSR and EVI on corn plant growth parameters. This stage begins by determining the relationship between the vegetation index value (x) and the growth parameters of corn plants (y), where (y) is the dependent variable and (x) is the independent variable. Furthermore, to see how strong the relationship between the two variables can be seen in the coefficient of determination (R^2). Regression analysis is calculated using the following equation (Rifai et al., 2020)

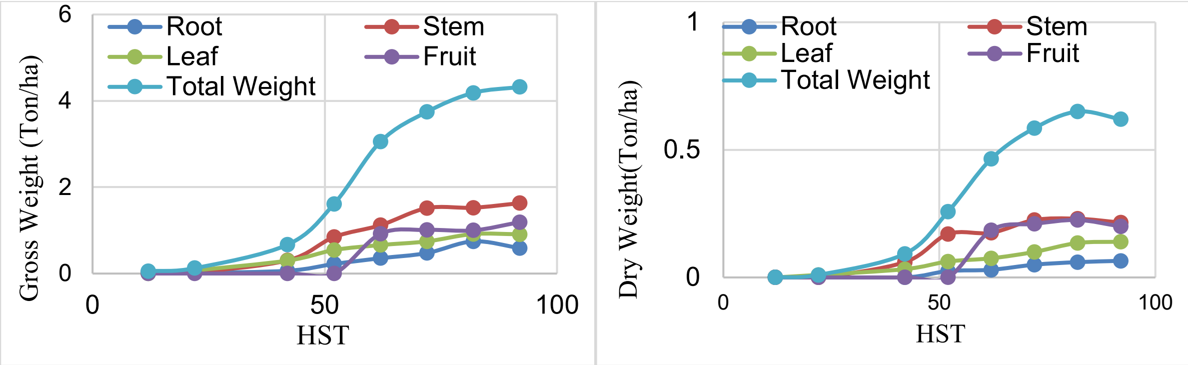
$$y = a + bx \quad (4)$$

Description:
a = Constant
b = Regression coefficient
y = dependent variable
x = independent variable

3. RESULTS AND DISCUSSION

3.1. Wet and Dry Weight of Corn Plants

The increase in wet weight on roots, stems, leaves and fruit greatly increased from 32 HST (Days After Planting) to 72 HST, this was due to optimal growth of corn during the vegetative period. Corn growth will begin to decline at 82 HST when the corn plant enters the fruit ripening period so that the fresh weight of the corn plant begins to decrease. Figure 1 shows the results of measuring the dry weight of corn. Plant dry weight increases with plant age and will remain constant at 82 days after planting. Plant dry weight is influenced by the absorption of nutrients by the plant during growth.



(a) (b)

Figure 1. weight of corn plant (a) Gross Weight, (b) Dry Weight.

3.2. Sentinel Vegetation Index Processing

Table 3. Results of NDVI Spectral Index Values

Image Date	Plant Age (HST)	NDVI Index Spectral Value		
		Minimum	Maximum	Average
10/12/2022	12	0,1396	0,3254	0,2208
20/12/2022	22	0,1458	0,3819	0,2263
14/01/2023	47	0,1	0,326	0,2044
28/02/2023	92	0,1705	0,4025	0,2952

The decrease in plant spectral value at 47 HST (table 3 and figure 2) is caused by the influence of clouds so that the sentinel image is not optimal in capturing color waves in vegetation so that the resulting spectral value decreases. This is in accordance with (Wulandari & Jaelani, 2019) that images obtained through sensor recording are not free from errors caused by the sensor recording mechanism, the movement and geometric shape of the earth and atmospheric conditions at the time of recording. EVI is a development of NDVI to cover the shortcomings of NDVI which is not good at reducing atmospheric influences (Noviantoro Prasetyo et al., 2017).

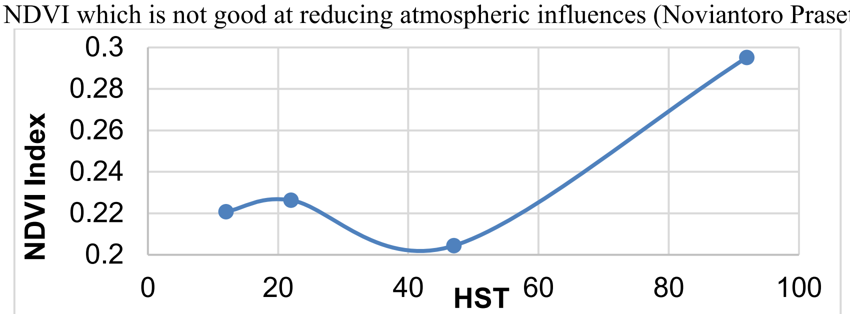


Figure 2. NDVI Sentinel 2 vegetation index

The decrease in index value occurred at 47 days of plant age. This is due to the influence of the atmosphere, namely clouds captured by the sentinel image, so it cannot be corrected properly. Images obtained through sensor recording cannot be free from errors caused by the sensor recording mechanism and atmospheric conditions at the time of recording (Arnanto, 2015).

Table 4. Results of EVI Spectral Index Values

Image Date	Plant Age (HST)	EVI Index Spectral Value		
		Minimum	Maximum	Average
10/12/2022	12	0,2273	0,6141	0,4001
20/12/2022	22	0,2754	0,6582	0,4349
14/01/2023	47	0,2975	0,7798	0,4646
28/02/2023	92	0,3023	0,8047	0,5374

Table 4 shows that the corn plant continues to grow so that the EVI value also increases and has entered the vegetative phase. This was because the corn plants had entered the harvest period. This is in accordance with the statement of (Aziz et al., 2018), who stated that a decrease in the EVI vegetation index value indicates that the corn plant is starting to age and has entered the harvest period.

Significant increase in the EVI index value because the EVI vegetation index is better at correcting atmospheric conditions on the earth's surface in the form of clouds on the earth's surface so that vegetation conditions can be read well by the EVI index. An increase in the index value indicates that the plant continues to grow until the EVI index value also increases (Aziz et al., 2018).

Table 5. Results of MSR Spectral Index Values

Image Date	Plant Age (HST)	MSR Index Spectral Value		
		Minimum	Maximum	Average
10/12/2022	12	0,1662	0,4006	0,253
20/12/2022	22	0,1695	0,5119	0,2625
14/01/2023	47	0,139	0,4026	0,2315
28/02/2023	92	0,1878	0,5321	0,3582

The decrease in the index value, as shown in table 5, was influenced by the low level of chlorophyll captured by the MSR index due to the influence of the atmosphere, namely the large number of clouds on the earth's surface so that the greenness value captured at 47 days was lower than at the previous plant age. This is in accordance with the index criteria of (Skianis et al., 2007), this value includes low chlorophyll levels due to non-optimal image data capture which is influenced by atmospheric conditions.

The relationship between the MSR sentinel 2 vegetation index and plant age shows a decrease in the vegetation index value at plant age 47 days after planting. The decrease in value occurred due to atmospheric conditions on the earth's surface so that the greenness value captured at 47 days was lower than at the previous plant age.

January 14 is the vegetative period of corn plants in the research location plots and has the lowest average spectral value, which can be seen from the color or chlorophyll level which is visible from the average spectral value so that the greenness of the plants can be seen on the three maps. The low level of greenness on January 14 is influenced by atmospheric conditions. This is in accordance with (Arnanto, 2015) that images obtained through sensor recording are not free from errors caused by the sensor recording mechanism, the movement and geometric shape of the earth and atmospheric conditions at the time of recording.

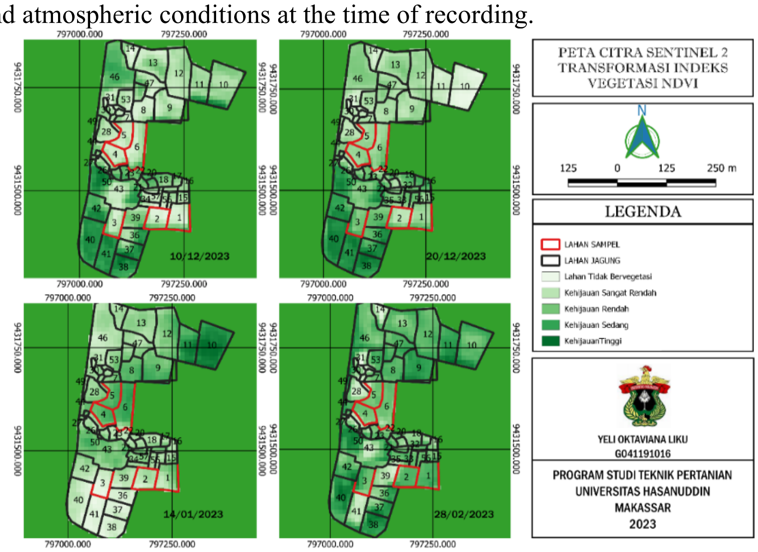


Figure 3. NDVI Vegetation Index Map.

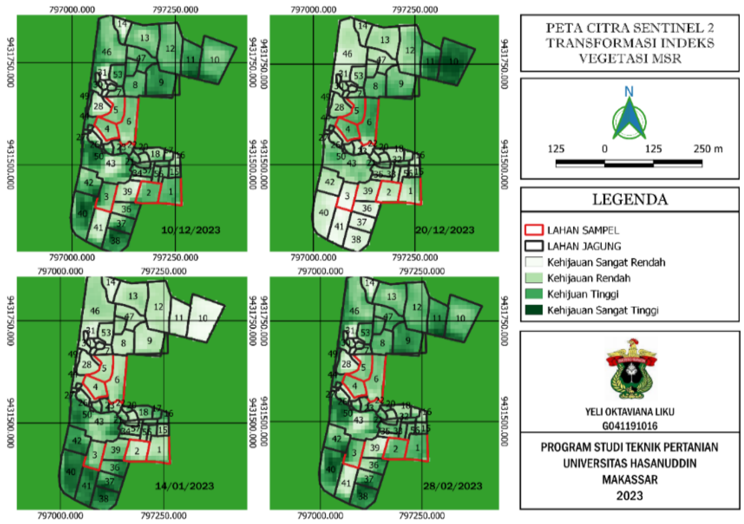


Figure 4. MSR Vegetation Index Map.

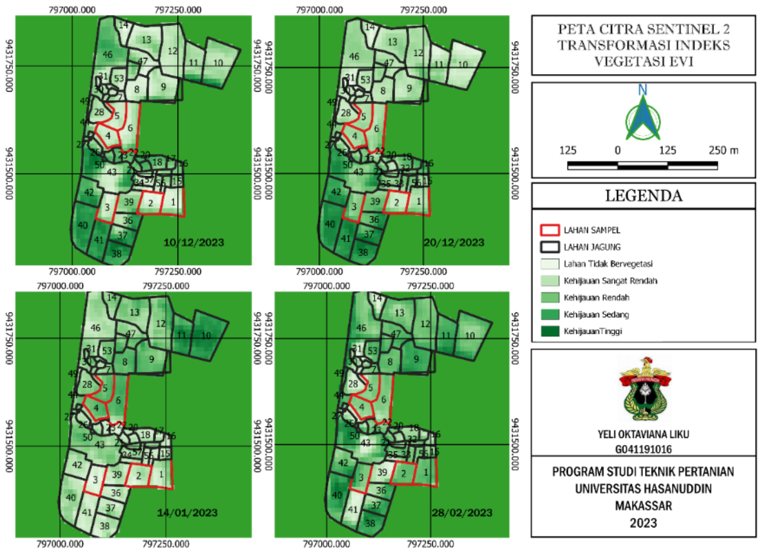


Figure 5. EVI Vegetation Index Map

3.3. Spectrometer Vegetation Index Processing

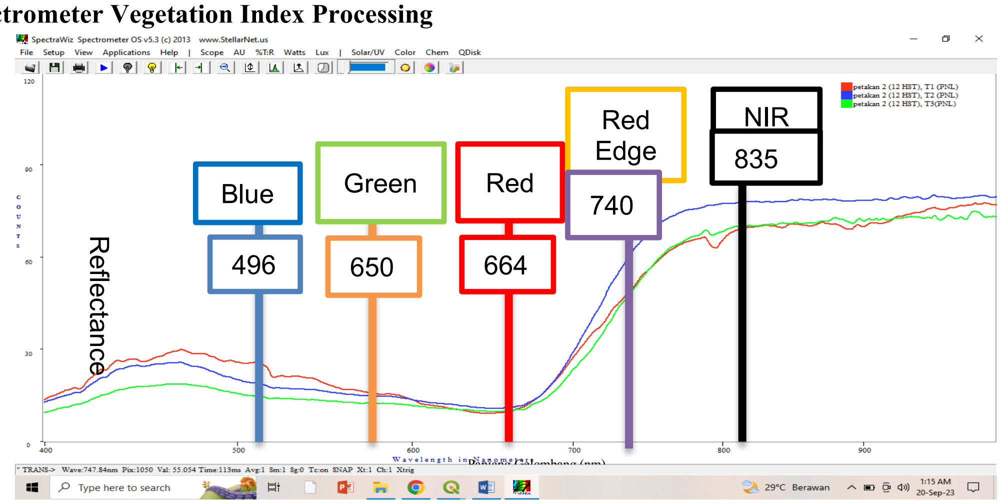


Figure 6. Spectrometer Spectrum Data

The initial processing of spectrum data is to combine each spectrum data from 3 plant spots and then combine them into one single spectrum graph according to the plot and age of the corn plants. The higher blue reflectance compared to green reflectance is caused by other factors that influence data collection, namely when the sensor is less able to capture light due to unfavorable weather conditions. Apart from that, it is also influenced by dust and dirt that sticks to the spectrometer. In practice there are other sources of error, such as environmental influences on the spectrometer and sample, calibration errors, temperature, vibration and contamination (Guardia, 2011).

The relationship between the vegetation index values NDVI, EVI and MSR has increased quite significantly. The index value increases as the age of the corn plant increases. Direct measurements on the surface of the plant cause the spectrometer to properly capture the light waves originating from the plant. The increase in the vegetation index value is influenced by the increase in the greenness value captured by the spectrometer during the growth period of the corn plant.

From the NDVI and MSR vegetation index data using sentinel 2 imagery, there was a decline in the graph on January 14, namely when the plants were at 47 HST. This is because the influence of clouds on the image affects the value of the vegetation index. The NDVI and MSR vegetation index graph using sentinel 2 can be seen in figure 7. Meanwhile, the spectrometer graph using the NDVI and MSR vegetation index continues to experience an increase in the vegetation index value as the age of the plant increases. This is because measurements using a spectrometer are carried out directly on the surface of the plant.

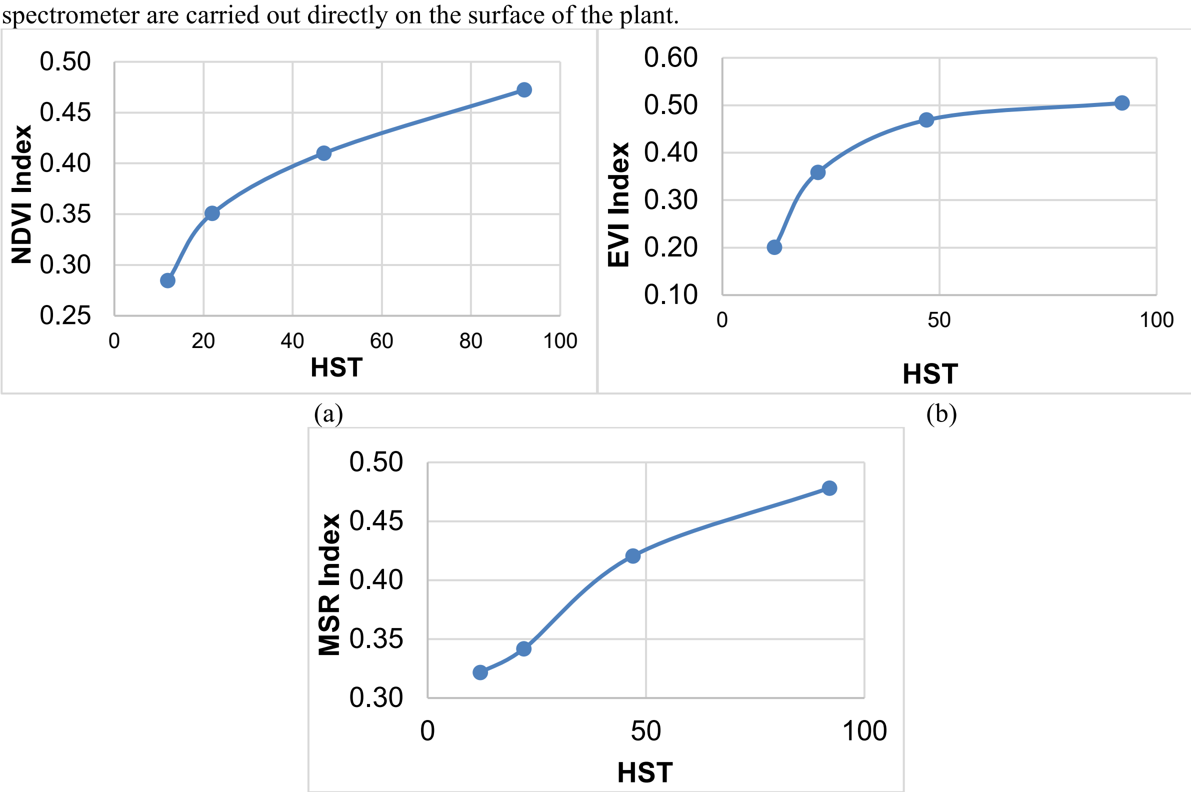


Figure 7. Spectrometer (a) NDVI vegetation index, (b) EVI Vegetation Index, and (c) MSR Vegetation Index

In addition, the EVI vegetation index using sentinel 2 images shows a graph that continues to increase as the age of the plant increases. Likewise, with the EVI vegetation index value obtained from the spectrometer, the resulting graph also continues to experience an increase in the vegetation index value. This is because EVI is a development of NDVI to cover the shortcomings of NDVI which is not good at reducing atmospheric influences (Noviantoro Prasetyo et al., 2017)

3.4. Relationship between Sentinel 2 Vegetation Index and Corn Plant Productivity

From figure 8, it indicates that 75.01% of the influence of sentinel NDVI on corn productivity and the rest there are other factors that influence it. Based on the results of this validation, it can be concluded that the use of NDVI on Sentinel-2 satellite imagery is very good.

The relationship between sentinel MSR and productivity (figure 9) is strong, with 71.84% of the influence of MSR on productivity and the rest being other factors that influence productivity.

Based on the analysis obtained between the EVI sentinel index and actual rice productivity (figure 10), it produces an equation of 11.051 (x) + 0.769 with an R2 of 0.8834, the correlation between EVI sentinel and productivity is strong, where 88.34% of the influence of EVI on productivity.

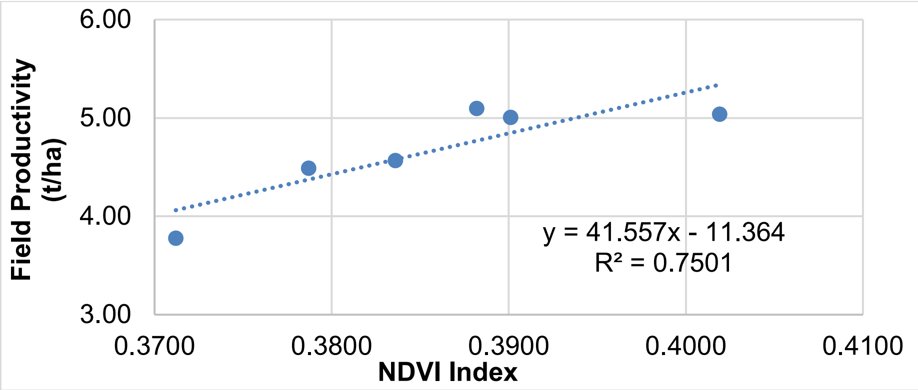


Figure 8. Relationship between NDVI Sentinel Transformation and Corn Field Productivity.

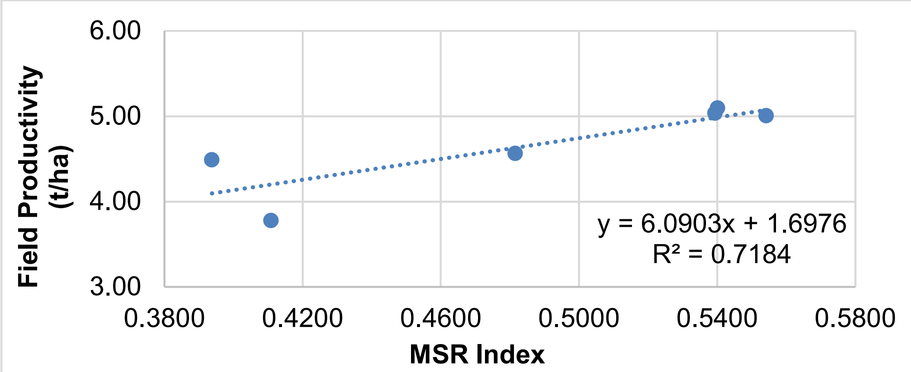


Figure 9. Relationship between MSR Sentinel Transformation and Productivity of Corn Fields.

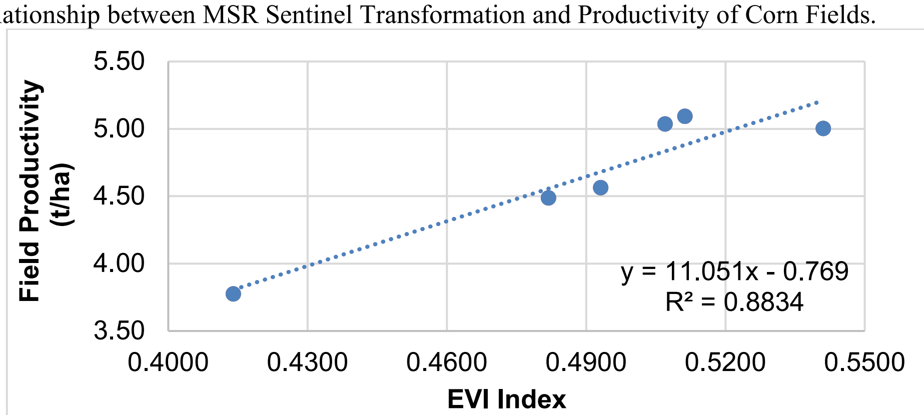


Figure 10. Relationship between EVI Sentinel Transformation and Corn Land Productivity.

3.5. Relationship between Corn Plant Productivity and Spectrometer Vegetation Index

The relationship between corn field productivity and productivity estimates using a spectrometer, the correlation between estimated productivity and field productivity results shows a very strong value where the correlation of the three indices is respectively 0.8369, 0.7726 and 0.763. The correlation according to [8] the resulting correlation value is very strong so that the productivity estimate using a spectrometer is very good. A good coefficient of determination value used for modelling production estimates is a value greater than >0.5 (Aziz et al., 2018).

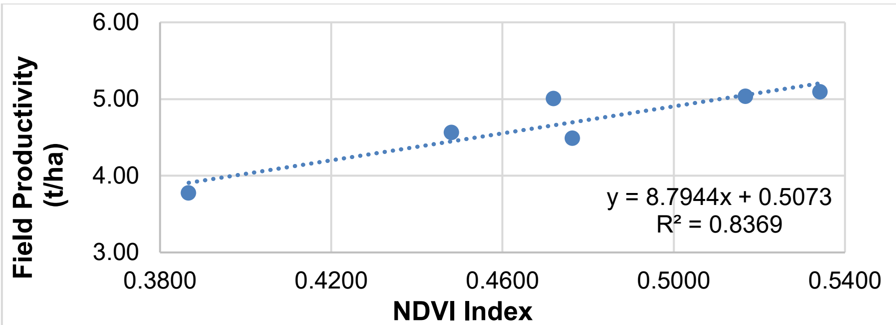


Figure 11. Relationship between NDVI Spectrometer Transformation and Corn Field Productivity.

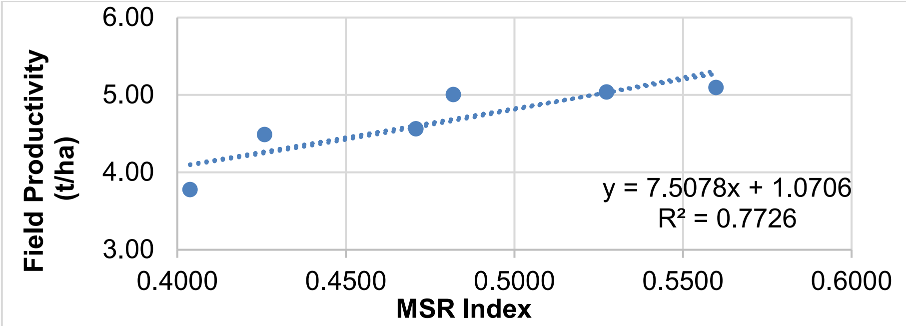


Figure 12. Relationship between MSR Spectrometer Transformation and Corn Field Productivity.

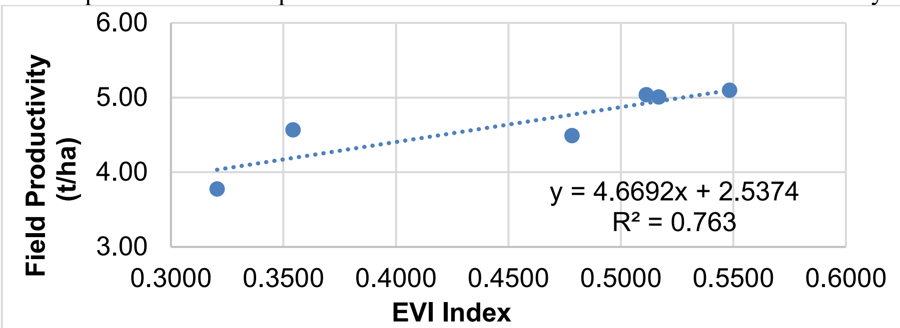
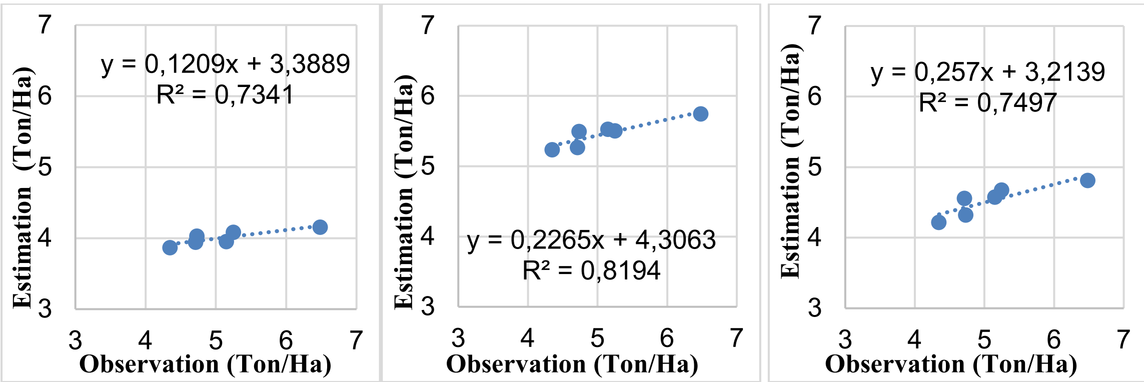


Figure 13. Relationship between EVI Spectrometer Transformation and Corn Field Productivity.

3.6. Validation of Production Estimation Results

The level of accuracy of production estimation results using the NDVI, EVI and MSR vegetation indices are 73.41%, 81.94% and 74.97% (see fig. 24). The level of accuracy of the estimation results using sample plots is strong against actual production results in the field. Estimation of production results using the NDVI and MSR vegetation indices is underestimated due to the index value being lower than the actual production value in the field. This is because the corn plant is in the ripening phase, so the resulting index value is low. Meanwhile, production estimates using the EVI vegetation index experience over and underestimates due to unstable index values.



(a) (b) (c)

Figure 24. Relationship between estimated production results and observations

4. CONCLUSION

Based on the research results, it can be concluded that the correlation value obtained between field productivity and productivity based on the vegetation index values NDVI, MSR and EVI show a very strong relationship. For the Sentinel-2 Vegetation Index, EVI has the highest correlation with productivity, approximately 88%, compared to other vegetation indices which are around 80%. Meanwhile, for the Spectrometer Vegetation Index, NDVI has the highest correlation with a value of around 83%, while the others are less than 80% In another hand, Sentinel 2 and spectrometer are good for identifying corn plant productivity.

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