The Relation between Rice Productivity in Ingin Jaya Subdistrict and NDVI (Normalized Difference Vegetation Index) from Surface Reflectance data of LANDSAT 8

Ardiansyah1, Nizamuddin2 and S Amalia2
1 Electrical and Computer Engineering Department, Faculty of Engineering, Syiah Kuala University, Darussalam, Banda Aceh, 23111, Indonesia
2 Informatics Department, Faculty of Mathematics and Life Sciences, Syiah Kuala University, Darussalam, Banda Aceh, 23111, Indonesia

E-mail: ardiansyah@unsyiah.ac.id

Abstract. Rice has an important role as the staple food for most of Indonesian people. Therefore, to ensure the sufficiency of rice stocks, it is necessary to estimate crop production from existing rice fields before they are harvested. This research was conducted to find the relationship between Normalized Difference Vegetation Index (NDVI) and rice productivity of rice fields in Ingin Jaya Subdistrict, Aceh Besar District, Aceh Province. The NDVI was calculated from the surface reflectance data of Landsat 8. The results showed that the NDVI in the study area ranged from 0.4 to 0.84. These results were higher than the NDVI calculated from the Landsat 8 L1 data, which ranged from 0.26 to 0.49. The productivity of rice fields were calculated for 21 locations of sample plot. Based on the calculations, the lowest productivity was 2.047 kg/m², and the highest was 10.462 kg/m². The relation between NDVI and the productivity was tested using the Pearson correlation, but the results showed that there was no significant relation between the NDVI and the rice field productivity in Ingin Jaya Subdistrict.

1. Introduction
Rice is a crop that plays a very important role in meeting the food needs of the majority of Indonesian people. Therefore, the estimated amount of rice production is very important for predicting the adequacy of rice supplies at the regional and national levels. The estimation of rice production is conducted by several agencies, including the Logistics Agency (BULOG), the Central Statistics Agency (BPS) and the Ministry of Agriculture. The method used by each agency is different, so the results obtained are different [1]. Although the methods used are different, most of these estimates include the productivity of rice plants in the calculation. One of the common methods in calculating rice productivity is to use the Crop Cutting Experiment (CCE) [2]. CCE is a statistical survey method that estimates yields of crop production based on yields in several small plots of land [3]. This estimation method cannot be carried out before harvest [1].

Current technological developments have made it possible to monitor the condition and development of plants using remote sensing satellite data. One way is to use imagery from satellites that have been processed into a vegetation index [4]. One vegetation index that is widely used is the Normalized Difference Vegetation Index (NDVI). The relationship between NDVI values and productivity has been shown in several studies [1] [4] [5].
Landsat images data that are normally used for producing NDVI is available for free download at different product levels according to the processing. The lowest level is Level 1 (L1), which is Landsat image data that has undergone the geometric and radiometric correction process [6]. To use this product, the Digital Number of the L1 data is usually converted into the Top of Atmosphere Reflectance to minimize the effects of the atmosphere. Nevertheless, the effect of aerosols on Visible and Near Infra-Red spectral is still difficult to repair. Surface Reflectance, which is a Level 2 data, has been proven to provide better NDVI results [7].

This paper presents the results of research which aimed at investigating the relationship between NDVI values and rice productivity in the subdistrict of Ingin Jaya, Aceh Besar. This subdistrict is one of the top 10 rice producers in Aceh Besar District with a planting area of 2814 hectares and a production of 15632 tons in 2016. NDVI values were calculated from Surface Reflectance Landsat 8 data. The results of these calculations were also compared with NDVI calculated using L1 data.

2. Research Method

2.1 Data
Features and phenomena on the earth surface can be represented using two geospatial data models, namely vector and raster. Vector data model is based on points (point) and coordinate values (x, y) to construct spatial objects. Raster model represents geographic objects as grid cell structures called pixels (picture elements) [8]. This study used both types of data. The vector data included administrative boundary and land use of Aceh Besar District, while the raster data are Landsat 8 surface reflectance imagery acquired on July 31, 2016. This study also used non-spatial data, which is the rice productivity data collected from the crop cutting experiment.

2.2 NDVI calculation
The level of greenness of a plant can be differentiated by utilizing the unique properties of plants which reflect and absorb electromagnetic waves differently than other objects. This method is the basis for distinguishing vegetation objects from objects other than vegetation. Normalized Difference Vegetation Index (NDVI) is an index that describes the level of greenness of a plant. Vegetation index is a mathematical combination between the red band and the NIR band which has long been used as an indicator of the presence and condition of vegetation [9]. NDVI is calculated from the ratio of Near Infra-Red band (NIR) and Red (R) band as described by Eq. (1).

\[
NDVI = \frac{NIR - R}{NIR + R}
\]  
(1)

The range of NDVI values is between -1.0 and +1.0. Values greater than 0.1 usually indicate an increase in the degree of greenness and intensity of the vegetation. Values between 0 and 0.1 are generally characteristic of rocks and vacant land, while values less than 0 may indicate ice clouds, water vapor clouds and snow. Many factors affect NDVI values such as photosynthesis activity in plants, the amount of plant cover, biomass, moisture of plants and soil, and stressed plants (unhealthy).

The NDVI of subdistrict Ingin Jaya was calculated from Landsat 8 Surface Reflectance data according to Equation (1). The data were cropped to the subdistrict boundary before being used in the calculation. The calculation was carried out by using Raster Calculator tool in ArcGIS.

2.3 Crop Cutting Experiment
Crop cutting is an objective method to estimate crop yield from plots of rice plant which is selected using appropriate sampling methodologies. This method involves the actual harvesting of crops from a small area within the farmer’s plot [2]. The size of a plot is 2.5 m x 2.5 m. The total weight of harvested rice from each plot was measured and recorded [10]. This study recorded the yield from 21
plots. The coordinates of each plot were recorded and then used for obtaining the NDVI value of the plot. The NDVI and productivity of each plot were then used for calculating the Pearson correlation value.

2.4 Pearson correlation calculation

Simple correlation is a statistical technique for determining the type and measuring the strength of the relationship between 2 variables with quantitative results. The type relationship between two variables can be positive linear or negative linear correlation, while the strength of the variable relationship is categorized into strong, weak, or no relation. The simple correlation coefficient (r) between two variables, x and y, can be calculated by using the Pearson Product Moment formula, which is shown as equation (2).

\[
    r = \frac{n \sum xy - (\sum x)(\sum y)}{\sqrt{n \sum x^2 - (\sum x)^2}(n \sum y^2 - (\sum y)^2)}
\]

Two variables are said to be associated if the behaviour of one variable influences the other variable. If it has no effect, the two variables are called independent [11].

This study used the Pearson Product Moment formula to measure strength of relationship between the NDVI values and the productivity of sample plots from several rice fields. A statistical test was conducted to determine whether or not the relationship is statistically significant. The null hypothesis (H₀) of the test was that there was no relationship between the NDVI values and the productivity.

3. Result and Discussion

The NDVI of Ingin Jaya subdistrict is shown in Figure 1. The figure shows NDVI obtained from the calculation which used Landsat 8 surface reflectance data. The NDVI was overlaid with village boundaries and location of plots for crop cutting experiment. The NDVI values range from -0.74 to 0.97. The maximum value is higher than the maximum value of NDVI resulting from a calculation which use the digital number directly from a Level 1 Landsat product.

The white points in the map shown in Figure 1 represent the location of plots for crop cutting experiment. The NDVI values at the location of each points were recorded on a table such as shown as Table 1. In the table, NDVI (L1) column contains NDVI values at the calculated from the Landsat Level 1 Data, while NDVI (SR) column contains NDVI values based on Landsat surface reflectance data. It can be seen that NDVI calculated from surface reflectance has higher values.

The productivity (in Kg/m²) at each plot location was obtained from crop cutting experiment on the rice field at the time of harvest. The correlations between productivity of a the plot (ubinan) and NDVI values were calculated using Pearson correlation. The results are shown in Figure 2. The calculation shows that there is no significant correlation between the NDVI values and rice productivity. The results show that no matter which NDVI used, the result is still no significant correlation. This is contrary to the result obtained by [1] and [4]. This may be due to inaccuracy of the results from the crop cutting experiments. Other researches on the same topic are necessary to confirm this result.
Figure 1. Map of NDVI values (using Surface Reflectance) with points representing location of plots for Crop Cutting Experiment in Ingin Jaya subdistrict.
Table 1. Coordinates, NDVI values, and productivity at sample plot location.

| No | Latitude    | Longitude    | NDVI (L1) | NDVI (SR) | Productivity (Kg/m²) |
|----|-------------|--------------|-----------|-----------|----------------------|
| 1  | 5.515099    | 95.365905    | 0.42      | 0.71      | 4.972                |
| 2  | 5.515465    | 95.365383    | 0.29      | 0.53      | 6.75                 |
| 3  | 5.517279    | 95.365541    | 0.32      | 0.58      | 4.05                 |
| 4  | 5.517140    | 95.365829    | 0.49      | 0.84      | 2.587                |
| 5  | 5.517995    | 95.368738    | 0.45      | 0.81      | 6.75                 |
| 6  | 5.519766    | 95.368502    | 0.44      | 0.81      | 8.167                |
| 7  | 5.514358    | 95.360442    | 0.46      | 0.78      | 2.047                |
| 8  | 5.514303    | 95.360588    | 0.46      | 0.77      | 3.442                |
| 9  | 5.493678    | 95.355218    | 0.44      | 0.80      | 4.725                |
| 10 | 5.493817    | 95.355350    | 0.40      | 0.72      | 2.284                |
| 11 | 5.513151    | 95.354761    | 0.49      | 0.82      | 2.925                |
| 12 | 5.513144    | 95.355004    | 0.48      | 0.79      | 4.331                |
| 13 | 5.505001    | 95.359867    | 0.48      | 0.82      | 2.925                |
| 14 | 5.502831    | 95.361904    | 0.46      | 0.81      | 3.375                |
| 15 | 5.497580    | 95.359867    | 0.40      | 0.76      | 5.4                  |
| 16 | 5.497693    | 95.361904    | 0.43      | 0.80      | 4.59                 |
| 17 | 5.514467    | 95.352459    | 0.16      | 0.20      | 10.327               |
| 18 | 5.514726    | 95.352280    | 0.26      | 0.40      | 4.86                 |
| 19 | 5.522906    | 95.350635    | 0.11      | 0.12      | 4.05                 |
| 20 | 5.523044    | 95.350910    | 0.28      | 0.41      | 3.654                |
| 21 | 5.520108    | 95.352693    | 0.24      | 0.32      | 6.142                |
| 22 | 5.519662    | 95.354937    | 0.34      | 0.59      | 4.62                 |
| 23 | 5.516631    | 95.355910    | 0.31      | 0.50      | 10.462               |
| 24 | 5.516042    | 95.354633    | 0.45      | 0.75      | 7.087                |
Figure 2. Results of Pearson Correlations calculations between the rice field productivity of harvest plots and their corresponding NDVI values calculated using (a) SR data and (b) L1 data of Landsat 8.

4. Conclusion
The results showed that the NDVI in the study area ranged from 0.4 to 0.84. These results were higher than the NDVI calculated from the Landsat 8 L1 data, which ranged from 0.26 to 0.49. The productivity of rice fields were calculated for 21 locations of sample plot. Based on the calculations, the lowest productivity was 2.047 kg/m², and the highest was 10.462 kg/m². The relation between NDVI and the productivity was tested using the Pearson correlation, but the results showed that there was no significant relation between the NDVI and the rice field productivity in Ingin Jaya Subdistrict.

Acknowledgments
Authors would like to acknowledge ESRI Indonesia that provided ESRI Grand License for Syiah Kuala University including (ArcGIS Server, ArcGIS Desktop, ArcGIS Pro and Geodatabase Spatial Engine). This research is also partially funded by Hibah Laboratorium Terpadu Unsyiah.

References
[1] Wahyunto, Widagdo and Heryanto B 2006 Pendugaan Produktivitas Tanaman Padi Sawah melalui Analisis Citra Satelit Informatika Pertanian 15 853-869
[2] Rotairo L, Durante A C, Lapitan P and Rao L N 2019 Use of Remote Sensing to Estimate Paddy Area and Production (Manila: ADB)
[3] Kabir M S, Paul D N R, Hossain M I and Rahman N M F 2016 Bangladesh Rice J. 20 1 11-16
[4] Parwati E, Prasasti I, Arief H, Harsanugraha W K, Harini S, Effendy I, Suhartini T and Nugroho G 1999 Model Estimasi Produksi Tanaman Padi Berdasarkan Indeks Vegetasi Majalah LAPAN 11
[5] Thiruvengadachari S and Skathivadivel R 1997 Satellite Remote Sensing for Assessment of Irrigation System Performance: A Case Study in India (Sri Lanka: International Irrigation Management Institute)
[6] Anonymous 2019 Landsat 8 Data Users Handbook (United States: USGS)
[7] Vermote E, Justice C, Claverie M and Franch B 2016 Preliminary Analysis Of The Performance Of The Landsat 8/Oli Land Surface Reflectance Product Remote Sensing of Environment 185 46-56
[8] Puntodewo, A, Dewi S, dan Tarigan J. 2003. Sistem Informasi Geografis Untuk Pengolahan Sumber Daya Alam. Bogor : Center for International Forestry Research
[9] Lillesand, T.R. 1997. Penginderaan Jauh Intepretasi Citra. Terjemahan.Yogyakarta: Universitas Gajah Mada Press
[10] Yuniarto A E, Prasetyo Y, and Haniah 2015. Analisis Tingkat Produktivitas Padi Berdasarkan Metode Ndvi (Normalized Difference Vegetation Index) Dan Lswi (Land Surface Water Index) Menggunakan Citra Landsat Tahun 2007 dan 2009 (Studi Kasus: Kabupaten Karanganyar, Jawa Tengah) Jurnal Geodesi UNDIP 4 3 26-34
[11] Mattjik, A. A. 2000. Perancangan Percobaan dengan Aplikasi SAS dan Minitab. Jilid I. (Bogor: IPB Press)