Spatial distribution of rice productivity utilizes sentinel-2A and NDVI algorithm in Nagrak Sub-district, Sukabumi Regency

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Abstract. Rice is a commodity of rice-producing food crops that plays a vital role in the Indonesian economy. For anticipating increased food needs, accurate information about the amount of harvest becomes very important. Information on the number of harvests, one of which can be known by estimating rice productivity. Rice productivity estimation can be monitored by remote sensing. This study used a remote sensing approach by employing satellite imagery from Sentinel-2A sensors to generate vegetation index. This study used NDVI (Normalized Difference Vegetation Index) to determine rice plants' age and estimate rice productivity. This study analyzes rice productivity and the spatial distribution of rice crop productivity in the Nagrak Sub-district, Sukabumi Regency. The results of this study are Sentinel 2-A and algorithm could provide rice productivity estimation and know the range of the largest rice productivity is greater than 6 ton per hectare, which is widely spread at an altitude of 500-1000 meter above sea level and a slope of 8 to 15 percent, and a distance of 0 - 150 meters from the river.

1. Introduction

Rice is a producing food crop commodity that plays an important role in Indonesia's economic life. As many as 90% of Indonesia's population consumes rice as their daily staple food [1]. The high demand for rice in Indonesia has caused Indonesia to import rice. Rice imports have increased from 2017 to 2018, where imports from Vietnam amounted to 16,599.9 tons to 767,180.9 tons, and imports from Thailand amounted to 108,944.8 tons to 795,600.1 tons [2]. In anticipating the increasing need for food, accurate information regarding the number of harvests is very important. One of the numbers of harvests can be found by estimating rice productivity [3].

Rice productivity estimation can be monitored by remote sensing [4]. Remote sensing techniques are more effective than conventional ground-based monitoring and mapping rice on a regional scale, especially in mountainous and hilly districts [5]. Many rice research uses remote sensing data such as Modis, LANDSAT 8 and Sentinel-2A with some NDVI, LSWI and EVI [6-8]. The three images show that sentinel-2A has a higher spatial resolution and a shorter temporal resolution than Modis and Landsat 8 [9]. Research conducted by Zhang et al. (2017) [10] using sentinel-2A and NDVI shows that the NDVI algorithm can effectively reflect vegetation status. For this reason, this research uses the Sentinel-2A and the NDVI algorithm.

This research will be conducted in Nagrak Sub-district, Sukabumi. Nagrak sub-district is one of the sub-districts in Sukabumi regency, a significant contributor to rice production [11]. In 2018, Nagrak
District had rice production of 21,026 tons with a harvest area of 3,504 hectares. At the same time, productivity is 6.0 tons per hectare [12]. The rice productivity in Nagrak sub-district cannot be separated from the physical condition of the area. This is because the physical conditions of the area can support rice growth [13]. Therefore, the study aims to estimate rice productivity and determine the spatial distribution of rice productivity based on the physical condition in Nagrak district, Sukabumi regency.

2. Methodology

2.1 Description of the study area
Nagrak sub-district is located in Sukabumi Regency, West Java Province. Astronomically, Nagrak District is located at 6° 47' 13" - 6° 53' 20" S and 106° 46' 40" - 106° 55' 40" E (figure 1). The study area has an altitude of 343.34 - 1882.38 meters above sea level and a slope of 0 - > 45%. Climatically, the study area has an annual precipitation of 1,500-2,500 mm and average daily temperature of 18 – 30 °C. Besides, Nagrak sub-district is often fed by rivers. Nagrak sub-district is fed by rivers with a total length of 260,748.20 meters.

Figure 1. Study area.

2.2 Data collection
This study uses spatial data and non-spatial data. The spatial data used are Sentinel-2A imagery (downloaded from https://scihub.copernicus.eu/) image recording dated July 18th, 2020 and August 7th, 2020, Nagrak District administrative map and BIG river flow map, land use map from BPN Sukabumi, Map of elevation and slope from DEM processing (DEM downloadable from http://tides.big.go.id/DEMNAS/). Meanwhile, non-spatial data is in rice productivity data from a field survey on August 16th, 2020.

2.3 Image processing
Sentinel-2A level 2A image data that has been downloaded are geometrically and radiometrically corrected images in the form of the BoA reflected value [14]. According to the study area, the satellite image is cut to continue processing the NDVI algorithm in the QGIS software. The NDVI formula used is like the following formula (1).

\[
NDVI = \frac{NIR - Red}{NIR + Red}
\]
NIR and Red are the values reflected by the NIR and Red bands. Then the image is overlaid with a land-use map using ArcGIS 10.1 software. The result is a Sentinel-2 image with the NDVI value in the study area in the form of rice fields.

### 2.4 Correlation NDVI value and rice productivity

The age of rice can be determined by using the NDVI algorithm. Then, it is used to estimate rice productivity [15]. And obtained a map of the age of rice in the study area. Furthermore, the NDVI value and rice productivity data that have been collected will be regression tested to obtain a regression model. Then that model is used to determine the rice productivity estimation in Nagrak District, Sukabumi. The NDVI value used is in the optimum vegetative phase of rice when the rice reaches 8-13 weeks after planting [16]. Table 1 is the NDVI classification table for identifying the age of rice.

**Table 1. The range of NDVI value for the ages of rice plant**

| NDVI Values | Vegetation Density       | Ages of Rice Plant (Weeks After Planting) |
|-------------|--------------------------|------------------------------------------|
| > 0.17      | Non Vegetation/water     | < 3                                      |
| 0.17 – 0.31 | Very Low                 | 3 - < 4                                  |
| 0.31 – 0.45 | Low                      | 4 - 6                                    |
| 0.45 – 0.52 | Medium                   | 6 - 8                                    |
| 0.52 – 0.88 | High                     | 8 - 13                                   |
| 0.45 – 0.52 | Medium                   | 13 - 16                                  |
| 0.31 – 0.45 | Low                      | > 16                                     |

After the optimum vegetative, the NDVI values will decrease according to the grain maturity level.

### 2.5 Spatial distribution of rice productivity

The rice productivity estimation model is used to create rice productivity maps. The NDVI values and models are processed using the raster calculator in ArcGIS 10.1. The result is raster with a value in productivity value, which is then reclassified into three rice productivity classes. The rice productivity map that has been made is overlaid with a map of physical conditions, namely maps of elevation, slope and distance from the river. So that it showed in the area of each productivity class.

### 3. Results and discussions

#### 3.1. Vegetation index and rice phenology

**3.1.1. Vegetation index.** Sentinel-2A image processing using the NDVI method produces values ranging from -1 to +1. Rice productivity estimates can be made from one month before harvest [16]. Nagrak sub-district harvests in February and August. Thus, the NDVI value in July can be used to estimate rice productivity. Because in February, the image is covered by the cloud. Based on figure 2(a), the NDVI value of rice plants in Nagrak sub-district has a high value, and in August, the NDVI value has decreased in the northern part, as shown in figure 2(b).

**3.1.2. Rice phenology.** On July 18th, 2020, the rice phenology of the Nagrak sub-district was dominated by ages 8-13 after weeks of planting. This indicates that rice is in the highest greenness phase, as shown on figure 3(a). Furthermore, there is some field in the eastern part that has been harvested. Meanwhile, on August 7th, 2020, rice phenology looked diverse. In the northern part of the research area, rice has been harvested compared to the southern part, as shown in figure 3(b).
3.2. Correlation between NDVI and rice productivity

The regression processing can be informed of the model and the coefficient of determination (R2) of the simple linear regression model, which can be seen in figure 4. The regression model has an R2 value of 0.9164 or 91.64%. The strength of the relationship between the NDVI value and rice productivity can be categorized as very strong [17]. The regression model can be used as a model for rice productivity estimation. It can be written like the following model (2).

![Figure 2. NDVI values of rice field in Nagrak sub-district, Sukabumi regency.](image)

![Figure 3. Rice phenology (weeks after planting) in Nagrak sub-district, Sukabumi regency.](image)

![Figure 4. Correlation of NDVI and rice productivity in Nagrak sub-district, Sukabumi regency.](image)

3.3. Validation of rice productivity

The existing equations for estimating rice productivity were tested for validation using the Root Mean Square Error (RMSE) method. Root Mean Square Error (RMSE) is used to determine how much error occurs in the calculation results of the model compared to the actual value. The value of rice productivity estimation is compared with the value of rice productivity that has been collected in the field. Table 2 shows that the RMSE value of both productivity data is 0.218 ton/ha.

| No | Rice Productivity Estimation (ton/ha) | Rice Productivity (ton/ha) | No | Rice Productivity Estimation (ton/ha) | Rice Productivity (ton/ha) |
|----|-------------------------------------|----------------------------|----|-------------------------------------|----------------------------|
| 1  | 6.256                               | 6.07                       | 9  | 6.119                               | 6.30                       |
| 2  | 5.942                               | 6.00                       | 10 | 5.170                               | 4.90                       |
| 3  | 6.259                               | 6.37                       | 11 | 6.139                               | 6.15                       |
| 4  | 6.111                               | 6.00                       | 12 | 5.329                               | 4.80                       |
| 5  | 6.356                               | 6.54                       | 13 | 6.186                               | 6.28                       |
| 6  | 5.218                               | 5.12                       | 14 | 5.465                               | 5.03                       |
Based on the processing of the NDVI value and the regression equation (formula 2), a map of rice productivity in Nagrak District is produced (figure 5). According to table 3, the area of rice fields to be harvested during the second harvest is 1075.551 ha. There are 3 classes of rice productivity in Nagrak sub-district. Rice productivity was dominated by class > 6.0 ton/ha with an area of 598.175 ha or 55.616%. This class is widely distributed in the northern part of the study area, with the largest area being in Cihanyawar village and Nagrak Utara village (figure 5).

**Table 3. Rice productivity area.**

| Rice Productivity (ton/ha) | Area (ha) | Percentage (%) |
|---------------------------|-----------|----------------|
| < 5.5                     | 166.744   | 15.503         |
| 5.5 – 6.0                 | 310.632   | 28.881         |
| > 6.0                     | 598.175   | 55.616         |
| Total                     | 1075.551  | 100.00         |

The spatial distribution of rice productivity can be seen based on the physical conditions of the area. It can be known by overlaid rice productivity maps and physical condition maps. This result shows rice productivity in each physical condition area is dominated by class > 6.0 ton/ha that spread at 100 – 500 masl, slopes of 8 - 15% and distance 0 - 150 masl from the river. Meanwhile, rice productivity that least
in each physical condition area is class 5.5 – 6.0 ton/ha. This class spread at 100 – 500 masl, slope > 45% and distance from the river of 450 - 600 m. This study's results are following the results of research conducted by Yang et al. (2014) [18], which states that agricultural productivity is low on steep slopes. Besides, the results of his research also mention agricultural productivity at high altitudes is also low. However, this study did not show this because many rice fields were at a higher altitude (500-1000 masl). Besides, lowland rice plants are plants that need water. The need for rice water can be fulfilled by irrigation water, rainwater, reservoirs or rivers. The distance from the river near the rice fields in the study area has a good impact on rice productivity.

4. Conclusion
The research shows that sentinel-2A and NDVI algorithm processing could estimate rice phenology and provide rice productivity estimation in Nagrak Sub-district, Sukabumi Regency. Then, The NDVI value correlates positively with rice productivity. Moreover, the RMSE value of rice productivity estimation and rice productivity is 0.218 ton/ha. On the other hand, rice productivity is dominated by a class of >6.0 ton/ha with an area of 1075.551 ha. This class is widely distributed in the northern part of the study area 598.175 ha, with the largest area being in the villages of Cihanyawar and Nagrak Utara. Furthermore, this class is widely spread at an altitude of 500 - 1000 meter above sea level and a slope of 8 to 15 percent, and a distance of 0 - 150 meters from the river.

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References
[1] Donggulo C V, Lapanjant I M and Made U 2017 Agroland: Jurnal Ilmu-ilmu Pertanian 24 2735
[2] Badan Pusat Statistik 2020 Impor beras menurut negara asal utama 2000-2018 (Available from: https://www.bps.go.id/)
[3] Mosleh M K, Hassan Q K and Chowdhury E H 2015 Sensors (Basel) 15 769–91
[4] Sari D K, Isumullah I H, Sulasi W N and Harto AB 2010 J. Iternas Rekayasa 14
[5] Yang H, Pan B, Wu W and Tai J 2018 ITC j. 69 226–36
[6] Yudo Prasetyo et al. 2018 IOP Conf. Ser.: Earth Environ. Sci. 165 012002
[7] Ramadhiyanti P M, Supriatna, Manessa D M and Risty Y 2019 KnE eng. 355–362
[8] Sahararini A F, Supriatna and Wibowo A 2010 IOP Conf Ser Earth Environ Sci. 481 012056
[9] Kefauver S C, Segarra J, Buchaillot M L and Araus J L 2020 Agronomy 10 641
[10] Zhang T, Su J, Liu C and Chen W 2017 Proceedings of the 23rd international conference on Automation & computing, university of Huddersfield
[11] Badan Pusat Statistik Kab. Sukabumi 2020 Kabupaten Sukabumi dalam Angka 2020 (Available from: https://sukabumikab.bps.go.id)
[12] Badan Pusat Statistik Kab. Sukabumi 2018 Kecamatan Nagrak dalam Angka 2018 (Available from: https://sukabumikab.bps.go.id/)
[13] Yudarwati R 2010 BSc Projects (Bogor: Bogor Universitas Agriculture)
[14] User Handbook. Sentinel-2 User Handbook. Esa.int. (Available from: https://sentinel.esa.int/)
[15] Supriatna, Wibowo A, Shidiq I P A and Rokhmatus 2020 Int j GEOMATE. 19 49–53
[16] Pradipta D 2012 Analisis Data Time Series NDVI-SPOT Vegetation untuk Tanaman Padi (Studi Kasus: Kabupaten Karawang) BSc Projects (Bogor: Bogor Universitas Agriculture)
[17] Guilford J P and Fruxhter B 1977 Fundamental Statistics in Psychology and Education, 6th edition (New York: McGraw Hill)
[18] Yang X, Li Y, Cai H, Xiao L, Xu X and Liu L 2014 Sustainability 7 96-110