Using NDVI algorithm in Sentinel-2A imagery for rice productivity estimation (Case study: Compreng sub-district, Subang Regency, West Java)

F Khoirunnisa, Supriatna and A Wibowo
Department of Geography, Faculty of Mathematics and Natural Sciences (FMIPA), Universitas Indonesia, Depok 16424
Corresponding author’s email: ysupri@sci.ui.ac.id

Abstract. Rice is the major staple food for nearly half of Indonesia’s population and has a considerable contribution to the global agricultural economy. As a rice granary with the highest rice productivity in Subang Regency, Compreng Sub-district plays an important role in food security. In 2017 Compreng Sub-district had 5,263 ha of rice harvested area with the productivity of 5.7 tons/ha. Therefore, it is urgently necessary to update information about the area and distribution of rice fields to estimate its productivity accurately. This study aims to explain the correlation between the Normalised Difference Vegetation Index (NDVI) values and rice productivity and then to estimate the rice productivity in Compreng Sub-district, Subang Regency in 2017. The methods used were Sentinel-2A imagery with NDVI equation. The results indicated that a Linear R Correlation best described the correlation between the NDVI value and rice productivity and an R2 value of 0.88 was obtained. The estimated calculation of Compreng Sub-district productivity in 2017 is an average of 5.65 ton/ha and the results of data accuracy using Root Mean Square Error between rice productivity estimation with the data from Department of Agriculture in Compreng Sub-district is 0.63.

Keywords: Rice productivity, NDVI, Sentinel-2A imagery

1. Introduction
As one of the world’s staple food for its three billion people consumer, rice stands as one of the most important crops in Asia and Indonesia. The ricefield itself covers around 70% of the world area equipped for irrigation is in Asia [1]. Up to now, more than 50% of Indonesian rice production comes from rice fields in West Java, thus the volatility in the rice productivity in West Java can affect nationwide rice availability and create dominos effect on other sectors [2]. Compreng Sub-district is one of the main rice producers in Subang Regency that in 2017 had 5,263 ha of rice harvested area with the productivity of 5.7 tons/ha. Therefore, it is necessary to keep the information updated about the area and distribution of rice fields to estimate its productivity accurately and to maintain nation’s especially Compreng Sub-district food needs [3]. For decades, the extensive use of satellite remote sensing has been recognized as advantageous to detect any land cover or use change [4].

The extensive used of Sentinel-2A satellite imagery is expected to monitor the rice growth and productivity in this study [3, 5]. The recently launched high spatial and temporal resolutions (10–20 m; 5–10 days revisit interval) Sentinel satellites with first generation of operational satellite
EO missions for both optical multi-spectral and radar C-band detection of global continental scale (Sentinel-1 and Sentinel-2) were used in this study [6]. The Sentinel-2A sensor from the European Space Agency (ESA) which could provide additional data to monitor vegetation density was added to the bands of red edge [7]. Analysis of satellite imagery carried out in the observation of rice fields is by observing vegetation density [8]. Parameters the vegetation density can be done by analyzing NDVI method. The NDVI method is a vegetation index method that describes the vegetation density with a mathematical combination between the red band and the NIR band (Near-Infrared Radiation) as an indicator of the presence and condition of vegetation in satellite imagery [9].

Due to red edge band’s sensitivity towards the chlorophyll content, the red edge band remote sensing image is preferred in this study to estimate the vegetation density at a large-scale area in a non-destructive manner [10]. Sentinel-2A imagery at a spatial resolution of 10 m was used to know the NDVI values in Compreng Sub-district, Subang Regency, West Java. The Sentinel-2A imagery provides better spatial resolution than NOAA and Landsat imagery. The accuracy test of the estimation results of rice productivity from processing Sentinel-2A imagery with NDVI, it is necessary to examine the rice productivity data released from the Department of Agriculture. Therefore the results of both will be compared using Root Mean Square Error (RMSE). If the results of standard error calculation between 0.0–1.0, it can be said the results are small, so the NDVI method in Sentinel-2A imagery can be relied upon in estimating rice productivity. Thus, the aim of this study: (1) to explain the correlation between the NDVI values and rice productivity (2) to estimate the rice productivity in Compreng Sub-district, Subang Regency in 2017.

2. Location, data and method

2.1. Background and study area
The studied area is located in Compreng Sub-district, Subang Regency, West Java, Indonesia, at 6°41’10” S latitude and 107°33’10” E longitude (figure 1). Serving as the central of rice production in West Java, 4,814 ha rice fields in Subang Regency could produce 2–3 harvesting time annually. The UPT (local social organisation focusing on farming) manages the irrigation and rice plantings [11]. Vast coverage of rice plantings makes it manageable to be monitored by remote sensing technology.

2.2. Sample collection of rice grain
For deciding the rice grain sampling sites, several considerations must be taken such as broad and identifiable planting area from Sentinel-2A imagery and various rice phenology of the observed area.. Thus, based on the stated considerations, 30 samples were obtained during this study. At each sampling location, rice growth is calculated in the period of January to December 2017. At each sample point, collected productivity data refers to a field survey that measured in ton/ha.

2.3. Sentinel-2A imagery
Set up with a new high-resolution 13-bands (visible light to infrared short-wave) multispectral imager (MSI), ESA Sentinel-2A was launched on the 23th of June 2015 [12]. The satellite, which was planned to last for seven years, has a spatial resolution of 10 meters (for visible and near-infrared bands), 20 m and 60 m (for near infrared and short-wave infrared bands) [13]. The red channel (665 nm) and the near infrared channel (842 nm) included in a 10-m spatial resolution. The used imageries in this study were from 13 scenes with different dates during 2017. Geometrically corrected (Level-1C) multispectral image data from Sentinel-2A was used in this study [14].

2.4. Data analysis
The images were pre-processed, rice spectral information was collected from the Sentinel-2A imagery and statistical analysis were conducted during this step. Pre-processing the Sentinel-2A imagery data consisted of downloading the data from ESA website, selecting the cloud-free imageries and
transforming the geographic coordinates. Sentinel-2A imagery was cropped according to the rice fields landuse of the study area. Afterward, the NDVI value was then calculated from the Sentinel-2A imagery rice spectral information. NDVI is a mathematical combination between the red band and the NIR band that produces values between -1 to +1, according to the following expression:

$$NDVI = \frac{NIR - Red}{NIR + Red}$$

The NDVI values will be classified based on the table 1. At the beginning of rice planting the value of the vegetation index will be in the range of < 0.170 even contrary (due to the domination of water appearance) and the index value will be increased as followed by ages of the rice plant, then reach at a maximum when rice is around 8–13 weeks after planting. Furthermore, the value of the vegetation index will decrease according to the grain maturity level until nearing the harvest.

The relationship between the NDVI values and rice productivity was then determined from 30 different sample locations. The linear R correlation could explain the correlation between NDVI values and rice productivity from the previous studies [15]. The NDVI values was used when rice is ready to be harvested (reaching 60–90 days or 8–13 weeks after planting). Thus, a high NDVI value corresponds to high chlorophyll content. As the most important part of the rice plant, chlorophyll is in charge of photosynthetic activity that will produce carbohydrates supporting the growth of the rice [16].

![Figure 1. Location of the study area.](image)
3. Results and discussion

Figure 2 shows the distribution of rice phenology across the Compreng area where water bodies dominated the northern part of the study area. The age of rice plants is in the range of < 20 days, while on the other hand, the southern part of the study area has been dominated by rice leaves between 30–60 days-old. The availability of water has clearly shown its important influence on rice growth. In the study area there was an irrigation channel originating from the Jatiluhur Reservoir and flowed from the north and then split into two main streams that flowed to west and east. This might correlate to the NDVI value distribution across the region.

| NDVI values | Vegetation density | Ages of rice plant (week) | Ages of rice plant (days) |
|-------------|--------------------|---------------------------|--------------------------|
| < 0.170     | Non-vegetation/water| < 3                       | < 20                     |
| 0.170–0.310 | Very Low           | 3 – < 4                   | 20–30                    |
| 0.310–0.450 | Low                | 4–6                       | 30–40                    |
| 0.450–0.520 | Medium             | 6–8                       | 40–60                    |
| 0.520–0.884 | High               | 8–13                      | 60–90                    |
| 0.450–0.520 | Medium             | 13–16                     | 90–110                   |
| 0.310–0.450 | Low                | > 16                      | > 110                    |

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

Figure 2. Rice phenology in Compreng sub-district.
Based on the results of data processing NDVI values and the age of rice plant value of $R^2 = 0.85$ (figure 3), according to Guilford showed that the correlation was very strong [17]. Likewise, the NDVI value and productivity of rice plants which showed a strong correlation with a value of $R^2 = 0.88$ means that the increase in NDVI value would be followed by an increase in the value of productivity of rice plants (figure 4). If the strong correlation between NDVI values and productivity has been obtained, it could be used to estimate the rice productivity of each village.

Based on the estimated results, Jatimulya Village has the maximum productivity with a total of 8.4 ton/ha while Compreng Village has the lowest productivity with a total of 4.3 ton/ha. Based on the results from The Department of Agriculture in Compreng Sub-district, it is known that the maximum productivity is in Jatimulya Village with a total of 9.7 ton/ha while the minimum productivity results are in Mekarjaya Village with a total of 4.2 ton/ha. We used a standard error namely RMSE for testing the data accuracy between rice productivity estimation and the data from the Department of Agriculture in Compreng Sub-district. The results of the RMSE across the regions is 0.63 (table 2). The result of standard error calculation is considerably small (in the range of 0.0–1.0) which implies that the NDVI method in Sentinel-2A imagery could be relied upon in estimating the rice productivity.

| Villages     | Estimation rice productivity (ton/ha) | Rice productivity from the department of agriculture (ton/ha) |
|--------------|---------------------------------------|-------------------------------------------------------------|
| Mekarjaya    | 4.9                                   | 4.2                                                         |
| Jatireja     | 5.6                                   | 5.1                                                         |
| Sukatani     | 4.3                                   | 4.8                                                         |
| Kalensari    | 4.7                                   | 4.9                                                         |
| Compreng     | 4.3                                   | 4.4                                                         |
| Kiarasari    | 7.7                                   | 7.7                                                         |
| Jatimulya    | 8.4                                   | 9.7                                                         |
| Sukadana     | 5.3                                   | 4.8                                                         |
| Average      | 5.65                                  | 5.70                                                        |
|              | RMSE                                  | 0.63                                                        |

Figure 3. Correlation between NDVI value and the lifespan of rice plant

Figure 4. Correlation between NDVI value and rice productivity
Figure 5. Estimation of rice productivity in Compreng sub-district, Subang Regency 2017.

Figure 5 shows the various estimation of rice productivity in Compreng Sub-district. The southern and southwest part of the study area has high rice productivity, which is above 7 ton/ha. There is a brighter colour gradation while getting to the north, which indicates that the productivity is decreasing around less than 7 ton/ha. Kiarasari Village and Jatimulya Village were in the southern and southwest in Compreng Sub-district, these villages have high productivity compared to other villages which are above 7 ton/ha, it can be caused by several factors, from the type of soil, rice varieties used, drains that flow, how to plant, and many more. The more northward rice productivity is decreasing showed in figure 5 that Jatireja Village and Sukadana Village have rice productivity around 5–7 ton/ha. Rice productivity decreases along with the north with rice productivity below 5 ton/ha that located in Compreng, Kalensari, Mekarjaya, and Sukatani Villages.

4. Conclusion
Based on the results of this study, it found that Sentinel-2A imagery used to estimate the rice productivity with NDVI equation. The increasing of NDVI value would correspond to an increase in the value of productivity of rice plants. The results indicated that a linear R correlation best explained the correlation between the NDVI value and the rice productivity with R² values of 0.88. The estimated calculation of Compreng Sub-district productivity in 2017 is an average of 5.65 ton/ha and the results of data accuracy using RMSE between the rice productivity estimation with the data from The Department of Agriculture in Compreng Sub-district is 0.63. The cause of the deviation is due to the calculation of rice productivity estimation which was based on the NDVI value. Thus the rice productivity obtained would also vary according to the NDVI value in each individual village.
Acknowledgments
The authors feel highly grateful for the advisors’ continuous support, strong encouragement, endless supervision and useful inputs throughout the research. The author also be thankful to the Department of Geography, Faculty of Mathematics and Natural Sciences, Universitas Indonesia to facilitate this research.

References
[1] FAO 2011 The State of the World’s Land and Water Resources for Food and Agriculture available at http://www.fao.org/3/a-i1688e.pdf pp 38-9
[2] Panuju D R, Mizuno K, and Trisasongko B H 2013 Journal of the Saudi Society of Agriculture Sciences 12 27-37
[3] Shao Y, Fan X, Liu H, Xiao J, Ross S, Brisco B, Brown R and Staples G 2001 Remote Sens. Environ. 76 310-25
[4] Treitz P M, Howard P J and Gong P 1992 Photogramm. Eng. Remote Sens. 58 439-48
[5] Ghosh S M, Saraf S, Behera M D and Biradar C 2017 Proc. National Academy of Sciences 87 769-79
[6] Delegido J, Verrelst J, Alonso L, and Moreno J 2011 Sensors 11 7063-81
[7] Li C, Zhul X, Wei Y, Cao1 S, Guo1 X, Yu1 X, and Chang C 2018 Scientific Reports 8 37-56
[8] Noureldin N A, Aboelghar M A, Saudy H S, and Ali A M 2013 Egypt. J. Remote Sens. Space Sci. 16 125-31
[9] Lillesand T, Kiefer R and Chipman J 2015 Remote Sensing and Image Interpretation 7th Edition (New York: John Willey and Sons) pp. 61-2
[10] Xie G X, Yang R J, and Lu Y 2014 Journal of Guangxi Teachers Education University: Natural Science Edition 2 88-96
[11] Badan Pusat Statistik Kabupaten Subang 2017 Kecamatan Compreng Dalam Angka 2017 available at https://subangkab.bps.go.id/publication/download.html?nrbfvefe=yz1I2xQwNTK3ZmM0NWZlMGU3MjIjYTli&xzmna=HR0cHM6Ly9zdWJhbmdrYWluYnBzLndvLm1kL3B1YmxpY2F0aW9uaW1TM2cvMDkvMjAvYzIzJQwNTk3ZmM0NWZlMGU3MjIjYTliLzIyYHRhbibj1jb21wcmVzYi1kYWxbS1hbmdrYS0yMDE3Lmh0bWw%3D%3D&twoadfnoarfeauf=MyAyMC0wMj0xOSAxMToxMToxMToxMToxMA%3D%3D pp 48-9
[12] Huck A 2015 Sentinel-2 MSI Introduction ESA available at https://sentinel.esa.int/
[13] Drusch M et al. 2012 Remote Sens. Environ. 120 25-36
[14] Gascon F et al. 2017 Remote Sens. 9 6-13
[15] Hogrefe K R, Pati V P, Ruthrauff D R, Meixell B W, Buddle M E, Hupp J W and Ward D H 2017 Remote Sens. 9 1234
[16] Nuarsa I W, Nishio F and Hongo C 2011 J. Agric. Sci. 3 2-9
[17] Guilford J P and Fruchter B 1977 Fundamental Statistic in Psychology and Education 6th edition (New York: McGraw Hill) pp 345-55