Spatial analysis of rice phenology using Sentinel-2 and UAV in Parakan Salak, Sukabumi Regency

Rokhmatuloh ¹, Supriatna ², A Wibowo, IPA Shidiq ¹, TG Pin ¹, R Hernina ¹

Department of Geography, Faculty of Mathematics and Natural Sciences, University of Indonesia Depok, 16424, Jawa Barat, Indonesia

Author.rokhmatuloh.ssi@sci.ui.ac.id, iqbalputut@sci.ui.ac.id

Abstract. West Java is the third province with the largest area of paddy field. On the province scale, there are five districts with more than 60,000 hectares of the paddy field area. Sukabumi is fifth largest districts with 6.8% of the area covered with paddy field. Although it is not the greatest number, Sukabumi is the largest producer of paddy with more than 6 ton per hectare, especially in 2011. Rice is the primary food for most of Indonesian. Therefore, monitoring the rice planting regarding the phenology, planting area, and productivity is a critical process. Information from the process is very important to address the national issue of food security. This study aims to generate spatial and temporal information on rice phenology. This study uses the excellence of remote sensing technology to cover a big area of paddy field. Sentinel-2 imageries and photos from Unmanned Aerial Vehicle (UAV) are being applied to generate Normalized Difference Vegetation Index (NDVI). With NDVI, this study determines the growth stage of paddy by discriminating each stage based on the spectral value. The planting phases that have discovered in the area are land preparation, vegetative, generative, and harvesting. Based on the NDVI value, it is known that the vegetative stage ranges from 0.181 to 0.80. The study concludes that result from Sentinel-2 and UAV can be used to show the distribution of paddy based on different growth stage.

1. Introduction

Sukabumi Regency is part of West Java, Indonesia. Sukabumi Regency is one of the rice producers and becomes one of the West Java Rice Barn located in the southern region. Sukabumi Regency recorded in BPS has an area of rice farming and horticultural area of ± 3,816 Ha and produce 64.97 Quintal/Ha rice paddy field [1]. The availability of the rice of West Java will depend heavily on the districts that become the barn.

Spatial information shows that the actual conditions on paddy field can obtain from remote sensing data that has high spectral and temporal resolutions such as LANDSAT 8 data and MODIS, and also Sentinel-1A [2], [3],[4],[5]. By implementing the Vegetation Index (NDVI) value and the temporal analysis by Zheng [6] can determine the phenology on the stage in the age of paddy fields. The Sentinel imageries (Sentinel-2) which have a spatial resolution of 10 meters, can provide spectral information on the earth surface in relatively narrow temporal resolution. Regarding the methods in data collection, remote sensing technology has a significant advantage over the conventional terrestrial survey.
The technology allows rapid data collection for relatively larger mapping area. UAV system presents as an alternative to the more-conventional airborne or satellite remote sensing system [7],[8]. The objectives of this study are to test the capability of UAV-based multispectral system to map rice paddy field; to generate vegetation index from UAV, and to use the value of vegetation index for classifying different types of crop. The study aims to analyze the spatial and temporal of rice phenology and productivity using unmanned vehicles (UAV) and Sentinel-2 in Parakan Salak.

2. Method

The study area is Sukabumi Regency (Figure 1 and Figure 2) located on the western part of Java Island or 11.21% total area of West Java Province. Sukabumi Regency had 47 District, one of the districts is Parakan Salak (Figure 3) laid nearby Salak Mountain.

2.1. Image Processing Sentinel 2

The Sentinel-2 imagery which has a spatial resolution of 10 meters. The NDVI algorithm method used to determine the age of rice plants, which then used to estimate rice productivity. The stage of rice was land preparation, vegetative, generative, and harvesting. In the study used high-resolution imagery and object-based image analysis (OBIA) method to classifying the phenology of the paddy field based on their spectral signature.

The study aims to spatial analysis pattern of rice phenology and estimation of rice productivity using Sentinel-2A imagery in Sukabumi Regency. The NDVI algorithm method used to determine the age of rice plants, which then used to estimate rice productivity. The stage of rice was land preparation (NDVI=0.096-0.036), vegetative (NDVI=0.0 36-0.24), generative (NDVI=0.24-0.45) and harvesting (NDVI=0.45-0.63). This study used NDVI as a tool to differentiate different types of crop. NDVI has widely used in many application, and one of them is for identifying plant characteristics in the ground. NDVI calculated with the following [9] (equation 1).

\[
NDVI = \frac{\rho_{NIR} - \rho_{red}}{\rho_{NIR} + \rho_{red}}
\]  

(1)

Which is \(\rho_{red}\) and \(\rho_{NIR}\) are reflectance value of red and near-infrared bands.

Vegetation index was generated using different bands from the sensor. This study used NDVI as a tool
to differentiate different types of crop. NDVI has widely used in many applications, and one of them is for identifying plant characteristics in the ground [10],[11],[12].

2.2. The Object-Based Identification Analysis
The photo or image of the drone recording is processed and classification to get the area of paddy fields based on the growth phase. In the classification process, there are two methods, which are the Object-based classification and pixel-based (Pixel-based) method. The classification method used in this research is the Object-based Classification method. This method has a characteristic that the smallest unit is not a pixel but a segment, where this segment is a combination of several pixels that have a marked resemblance.

Based on the experiments conducted by Weih [13], the classification results using Object-based techniques provide better accuracy than pixel-based methods. In the classification process, the Pixel-based approach only looks at the parameters of the pixel value, while the object-based plan not only looks at the pixel value but from the spatial aspect. Object-Based Classification is a classification method that can produce similarity of objects based on segmentation of spectral values in imagery by creating a similar polygon by considering spectral and space characteristic. Segmenting algorithms not only relies on one single pixel value, but also on the shape, texture, and continuity of the pixels.

3. Result and Discussion

3.1. Rice Phenology Using Sentinel 2
West Java Province was the biggest paddy field in Indonesia, and Sukabumi Regency as part of West Java Province (Figure 4). The paddy field dominant laid on northern of Java Island.

![Distibuted paddy field in surrounding West Part of Java Island](image)

The spatial distribution of NDVI value in Sukabumi Regency, generated using Sentinel-2A, saws in Figure 5 and Figure 6. Based on Figure 5 saw NDVI in July 2017, and Figure 6 NDVI in August 2017. Figure 5 saw the spatial distribution of NDVI 0.631-0.820 is dominant around Sukabumi Regency with > 40.0% of the total area. Moreover, the spatial distribution of August 2017 dominant with NDVI > 0.50 covered by more than 60% from the whole area.

![The NDVI July 2017 Sukabumi](image) ![The NDVI August 2017 Sukabumi](image)

Based on Table 1, Sukabumi Regency based on data July 2017, paddy phenology had the harvesting stage with 41.4% and Generative phase with 24.56% of the total area. Moreover, based on August 2017, the harvesting state with 49.42% and generative with 30.46% of the whole area. To the
explained potential of estimation product of paddy field, based on productivity 5.0 ton/hectare, Sukabumi Regency has potential 1,000,000.00 quintal/ha on July and 675,000.00 quintals/ha.

Table 1. The NDVI and Phenology of Paddy on July and August 2017 in Sukabumi Regency

| NDVI     | Greenness Leverage | Phenology   | Area (m²) | Percent (%) | Area (m²) | Percent (%) |
|----------|--------------------|-------------|-----------|-------------|-----------|-------------|
| -0.31-0.181 | Very Low          | Land Preparation | 24,344.84 | 7.80        | 0.06      | 0.04        |
| 0.181-0.360 | Low               | Vegetative   | 30,842.28 | 9.88        | 3,246.62  | 6.09        |
| 0.361-0.510 | Moderate          | Late Vegetative | 47,831.69 | 15.32       | 19,026.10 | 14.18       |
| 0.511-0.630 | High              | Generative   | 76,688.22 | 24.56       | 44,266.77 | 30.46       |
| 0.631-0.820 | Very High         | Harvesting   | 132,556.06 | 42.45       | 95,100.17 | 49.24       |
| Total Area |                   |              | 312,263.15 | 100.0       | 321,261.61| 100.0       |

Source: Data Processing

The result from image analysis of phenology vegetative until the harvest of NDVI was indicating 0.181 until >0.80 related data from Sentinel-2 on July and August 2017 in Sukabumi Regency.

3.2. Rice Phenology Using Drone UAV

Figure 7 shows the paddy field collected from a Drone UAV with phenology is the generative stage (planting phase 12-15 weeks/100 days).

![Figure 7. The rice field from UAV](image)

The result from image analysis of phenology vegetative base on NDVI was indicating 0.21 until 0.85 related data from UAV Drone in Parakan Salak District, Sukabumi Regency. Paddy Sarengguy was 45 day have the highest NDVI index with range 0.79-0.84. (Table 2)
Table 2. Range of NDVI values for paddy in Parakan Salak

| Rice Field               | Min  | Max  | Mean | Stdev |
|--------------------------|------|------|------|-------|
| Paddy                    | 0.21 | 0.85 | 0.61 | 0.25  |
| Sarengui Paddy (45 days) | 0.79 | 0.84 | 0.82 | 0.02  |
| Sarengui Paddy (to be harvested) | 0.38 | 0.85 | 0.66 | 0.25  |
| Super Paddy              | 0.31 | 0.83 | 0.64 | 0.19  |

Source: Data Processing and Survey

4. Conclusion
The result from image analysis of phenology vegetative until the harvest of NDVI was indicating 0.181 until >0.80. The study concluded that the harvest area from Sentinel and UAV imagery could provide an estimation of rice field phenology in Parakan Salak, Sukabumi Regency.

5. Acknowledgments
The study funded by the Ministry of Research and Higher Education, under the Penelitian Dasar Unggulan Perguruan Tinggi (PDUPT) or the Basic Primary Research for Higher Education with grant number: 378/UN2.R3.1/HKP.05.00/2018.

6. References
[1] BPS-Agency for Statistic, 2015, Rice Production Report, Annual Report
[2] Supriatna, Rokhamtuloh, IPA Shidiq, GP Pratama, L Gandharum, and A Wibowo. (2019). Spatio-Temporal Analysis of Rice Field Phenology Using Sentinel-1 Image In Karawang Regency, West Java, Indonesia. International Journal of Geomate, 17(62), 101-106
[3] Chaparro D., Piles M., Vall-Ilossera M., Camps A., Konings A.G., and Entekhabi D., L-band vegetation optical depth seasonal metrics for crop yield assessment. Remote Sensing of Environment, Vol. 212, 2018, pp.249-259.
[4] Rokhamtuloh, Supriatna, TG Pin, R Hernina, R Ardhianto, IPA Shisiq, and A Wibowo. (2019). Paddy Field Mapping Using UAV Multi-Spectral Imagery. International Journal of Geomate, 17(61), 241-247
[5] Domiri, D. D. (2017). The method for detecting a biological parameter of rice growth and early planting of paddy crop by using multi-temporal remote sensing data. In IOP Conference Series: Earth and Environmental Science (Vol. 54, No. 1, p. 012002). IOP Publishing.
[6] Zheng, H., Cheng, T., Yao, X., Deng, X., Tian, Y., Cao, W., & Zhu, Y. (2016). Detection of rice phenology through time series analysis of ground-based spectral index data. Field Crops Research, 198, 131-139.
[7] Shidiq I.P.A., Wibowo A., Kusratmoko E., Indratmoko S., Ardhianto R., and Nugroho B.P., Urban forest topographical mapping using UAV LIDAR. In IOP Conference Series: Earth and Environmental Science, Vol. 98, Issue. 1, 2017, pp. 012034.
[8] Rouse Jr, J., Haas, R. H., Schell, J. A. & Deering, D. W. 1974. Monitoring vegetation systems in the Great Plains with ERTS. NASA Special Publication 351: 309.
[9] Mosleh M.K., Hassan Q.K., and Chowdhury E.H., Application of Remote Sensors in Mapping Rice Area and Forecasting Its Production: A Review. Sensors, Vol. 15, 2015, pp.769-791.
[10] Rokhamtuloh, Supriatna, TG Pin, R Hernina, R Ardhianto, IPA Shisiq, and A Wibowo. (2019). Paddy Field Mapping Using UAV Multi-Spectral Imagery. International Journal of Geomate,
[11] Shidiq, I. P. A., Ismail, M. H., Ramli, M. F., & Kamarudin, N. (2017b). Combination of ALOS PALSAR and Landsat 5 imagery for rubber tree mapping. *The Malaysian Forester, 80*(1), 55-72.

[12] Rouse Jr. J., Haas R.H., Schell J.A., and Deering D.W., Monitoring vegetation systems in the Great Plains with ERTS. NASA Special Publication 35, 1974, pp. 309

[13] Weih Jr. R.C., and Riggan Jr. N.D., Object-Based Classification vs. Pixel-Based Classification Comparative Importance of Multi-Resolution Imagery. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 2010, XXXVIII- 4/C7.