Spatial distribution of phenology stage on paddy field in Karawang Regency

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Abstract. Irrigated paddy fields in Indonesia generally harvested twice a year. Variations in rice production due to climate change are observable through changes in plant phenology using remote sensing imagery. The research aim is to study the spatial distribution of phenology stage on the paddy field using Remote Sensing Data in Karawang Regency. To answer the aim of research used image data processing with Sentinel 1 and Sentinel 2. The Karawang Regency had two growing seasons, first is Marc-June, and the second growing season is June-November. The research concluded that the spatial distribution of harvesting stages dominant in June, validated with image data on 22 June 2017, was the first growing season in Karawang Regency. The second image on 13 November 2017, with the spatial distribution of generative and harvesting stages, are dominant around Karawang Regency, the harvesting stage dominant with 31% area those validated that November 2017 is second growing seasons in a paddy field in Karawang Regency.

1. Introduction

The food security program is part of Indonesia's efforts to provide adequate food for its citizens [1]. In carrying out the program, a study related to food provision needs to carried out. Rice, which is the basic food needs of the Indonesian people, is very dependent on climate. Changing climatic conditions will have an impact on the changes in rice production from national rice barns in Indonesia. Paddy in Indonesia generally is harvested twice a year (80-90 growing days) in well-irrigated areas, and in non-irrigated areas is harvested once a year (100-130 growing days) [2]. The need for sufficient water to grow makes the paddy vulnerable to drought and flood [3]. In Indonesia, paddy usually planted at the beginning of the rainy season in October - December then to be harvested in February [4]. Java Island is a significant paddy field in Indonesia because of rice production is still dominant nationally [5,6]. West Java with irrigation system from Jatiluhur Dam known as Citarum Irrigation Region considered as the national rice barn with rice fields stretching along the north coast of West Java, starting from Bekasi Regency to Cirebon Regency. When there is a disturbance with the harvest in West Java, the national rice stock will also be disturbed [7,8].

To understand the growth of rice plants, and to be able to predict their harvest, research on plant phenology is needed. Changes in the plant on the phenology of paddy considered to be an indicator of plant responses to climate change. The plant phenology is observable by temporal remote sensing images. The detection phenology of paddy could be done using remote sensing [9,10,11,12,13,14,15]. Spatial information shows that the actual conditions on the paddy filed can obtain from remote sensing data that has high spectral and temporal resolutions such as LANDSAT 8 data and MODIS [16], and also Sentinel-1A [13,14,15]. By implementing the Vegetation Index (NDVI) value and the temporal analysis by Zheng [17] can determine the phenology on the stage in the age of paddy fields.

Karawang Regency considered one of the national rice barns of Indonesia because of the paddy field dominance in the area. Karawang Regency also part of areas irrigated by the Citarum Irrigation Region and generally could harvest rice twice a year. The research aim is to study the spatial distribution of phenology stage on the paddy field using Remote Sensing Data in Karawang Regency.

2. Material and method

This research is focusing on the analysis of the spatial distribution of the phenology stage in the paddy field. Karawang Regency - West Java was chosen as a study area because of its the highest rice producer on Java island.

2.1. Study Area

Java island is the highest producer of rice, especially Karawang, Subang dan Indramayu. The Karawang Regency had a paddy field of more than 80% from total areas. BPS of Karawang Regency in 2018 records the area of paddy fields is > 95,330.50 hectares from the total area of Karawang Regency is 116,332.56 hectares. The paddy field observed in this study planted within a cycle of three main periods, which are planting period, growing period, and harvesting period.

2.2. Image processing

This study used NDVI as a tool to differentiate different types of crops. NDVI has widely used in many applications, and one of them is for identifying plant characteristics in the ground. NDVI calculated with the following (formula 1):

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

where ρred and ρNIR are reflectance value of red and near-infrared bands.

3. Result and discussion.

3.1. Irrigation Region and Growing Season in Karawang Regency

The distributions of the Irrigation Region in Northern Part of West Java Province with two system irrigation regions, first Citarum Irrigation Region and second Cimanuk-Cisangggarung Irrigation Region. Karawang Regency part of the Citarum Irrigation Region (Figure 1). Paddy in Indonesia generally is harvested twice a year in well-irrigated areas, moreover Karawang Regency, as part of the Citarum Irrigation Region, also harvested twice a year. Karawang Regency has an irrigation pattern that starts from southern Karawang near Jatiluhur Dam and ends at the northern parts of Karawang. Rice crops in Southern Karawang Regency receive water ahead of the middle and northern parts of Karawang Regency.

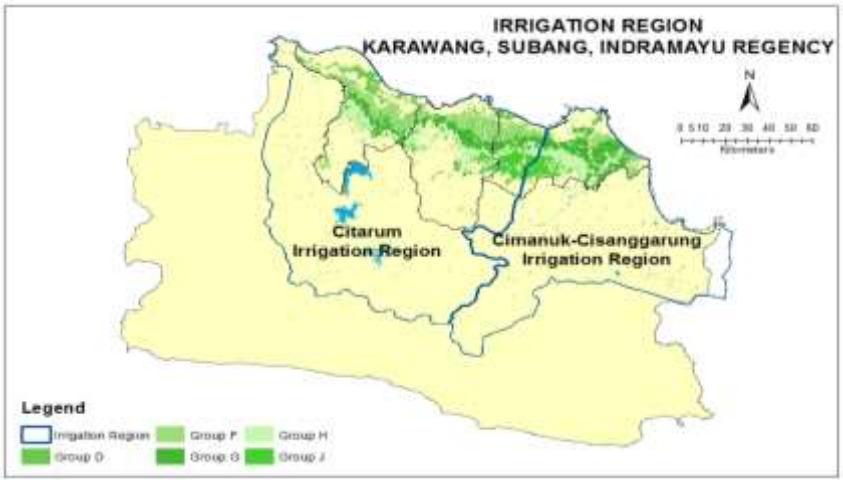
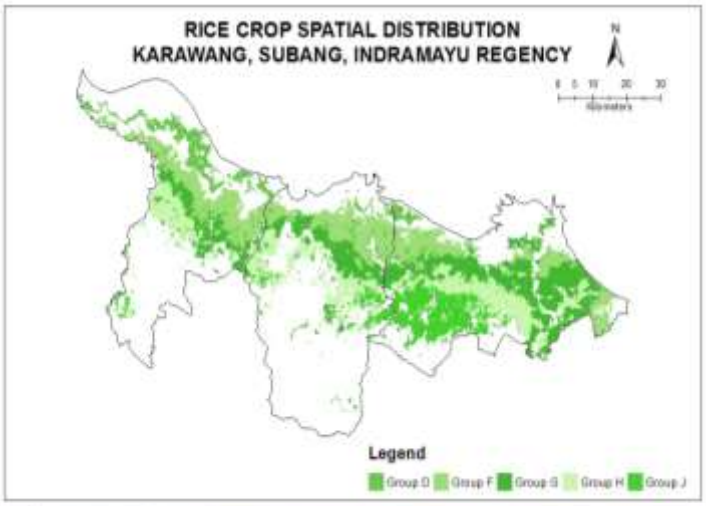


Figure 1. Irrigation Region Karawang, Subang, and Indramayu Regency
Source: Semedi [4]

The rice crop spatial distributions on Karawang, Subang, and Indramayu Regency, have twice harvested or growing seasons (Figure 2). First growing seasons, between December-March, January-March/April, and January-May, and March-June. The second growing season, between April-July, May-August, and August-November. The Karawang Regency, as dominance group D, tended to have a growing season between August-November as second growing seasons. On the other hand, the first growing seasons between March-June. The paddy phenology stages during the study from 2008 until 2010 based on the MODIS satellite [9].



Group	Growing Season (GS) Days					
	2008 GS 1	2008 GS 2	2009 GS 1	2009 GS 2	2010 GS 1	2010 GS 2
D	16 Feb – 9 Jun	12 Aug – 16 Nov	4 Feb – 12 Jun	15 Aug – 28 Nov	8 Mar – 15 Jun	2 Aug – 6 Dec
F	1 Jan – 8 May	9 Jun – 13 Sep	19 Jan – 25 Apr	12 Jun – 2 Oct	8 Jan – 14 May	15 Jun – 22 Nov
G	(2007) – 22 Apr	24 May – 12 Aug	16 Dec 08 – 24 Mar	11 May – 15 Aug	6 Jan – 28 Apr	15 Jun – 3 Sep
H	(2007) – 21 Mar	22 Apr – 27 Jul	16 Nov 08 – 8 Mar	25 Apr – 30 Jul	21 Dec 09 – 12 Apr	14 May – 2 Aug
J	(2007) – 5 Mar	6 Apr – 11 Jul	2 Dec 08 – 9 Mar	9 Apr – 28 Jun	6 Jan – 27 Mar	28 Apr – 17 Jul

Figure 2. Temporal Growing Season in Karawang, Subang and Indramayu Regency
Source: Semedi [9]

Previous Research on Indramayu Regency by BPPT [18] explains the Phenology of paddy from Image Data Processing using Sentinel-1 between February-May as the first growing season (Table 1). Paddy phenology in Subang Regency is at land preparation stages in February. Vegetative stages are March, generative stages in May, and harvesting stages also May. Moreover, the second growing seasons start in June in Subang Regency. Based on Semedi [9], the Subang Regency dominance group is Group F, had the first growing season is February-May, and the second growing season is June-September/October.

Table 1. The NDVI and Phenology in June 2017 on Subang Regency

No.	Acquisition Date	Rice Phenology
1	7 February 2016	Land Preparation
2	19 February 2016	Land Preparation
3	02 March 2016	Early Vegetative
4	14 March 2016	Vegetative
5	26 March 2016	Late Vegetative
6	25 May 2016	Generative and Harvesting
7	30 June 2016	Land Preparation
8	24 July 2016	Vegetative

Source: Agency for the Assessment and Application of Technology Indonesia (BPPT), 2016

The Karawang Regency had first growing seasons between March-June and the second growing season between August-November. On the other hand, Subang Regency had the first growing seasons between March-June second growing seasons is June-September/October. That growing season in Subang Regency is faster than Karawang Regency.

3.2. Spatial Distribution of Phenology Stages on Paddy in Karawang Regency

Based on the irrigation system irrigation region and Growing Season stages in Karawang Regency during 2008-2010, those are two growing seasons in Karawang Regency. First, growing seasons between March-June and the second growing seasons was August-November. The study used two Sentinel Data; it was Sentinel-1A and Sentinel-2A.

The result, based on data processing from backscatter classification of 22 June and 13 November 2017 using Sentinel-1 SAR images, there were five classes of paddy phenology, which are land preparation, early vegetative, vegetative, generative, and harvesting. Spatial distribution of phenology stages in Karawang Regency using Sentinel-1A saw in Figure 2 and Figure 3. Furthermore, Figure 2 saw phenology stages on 22 June 2017, the spatial distribution of generative and harvesting stages are dominant around Karawang Regency. The harvesting stages is 57.1%. This spatial distribution of harvesting stages dominant validated that on 22 June 2017 is the first growing season in Karawang Regency. The second image (Figure 3) saw phenology stages on 13 November 2017, the spatial distribution of harvesting stages was dominant around Karawang Regency. The harvesting stage with 31.9% area from total area Karawang Regency validated that 13 November 2017 is the second growing season in a paddy field in Karawang Regency.

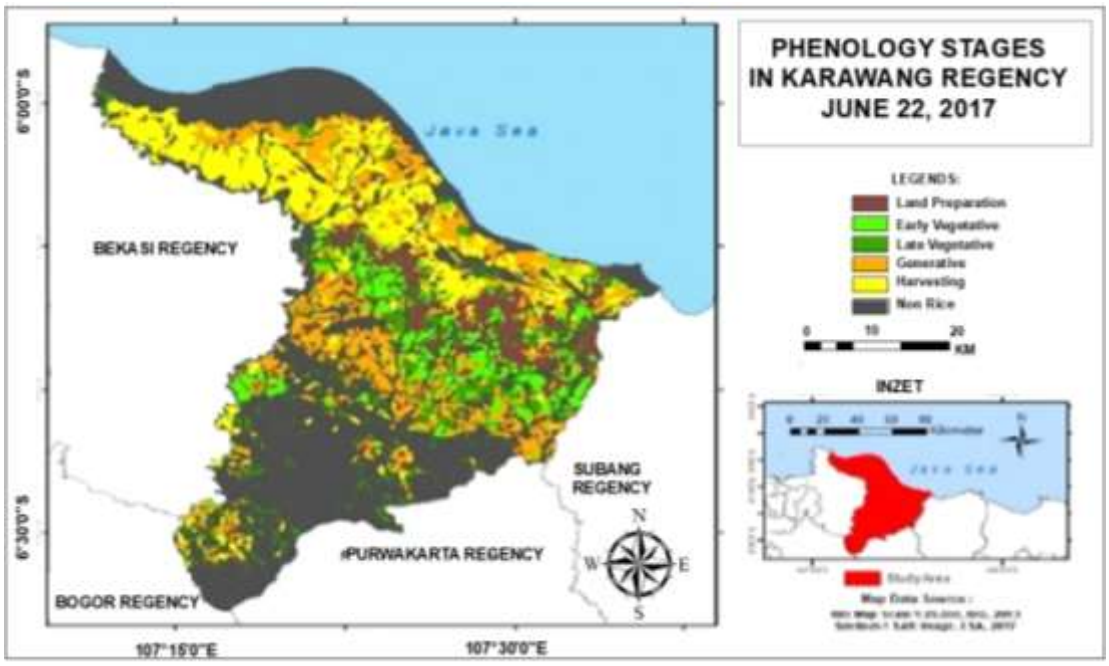


Figure 3. Phenology Stages on Paddy in Karawang Regency on 22 June 2017

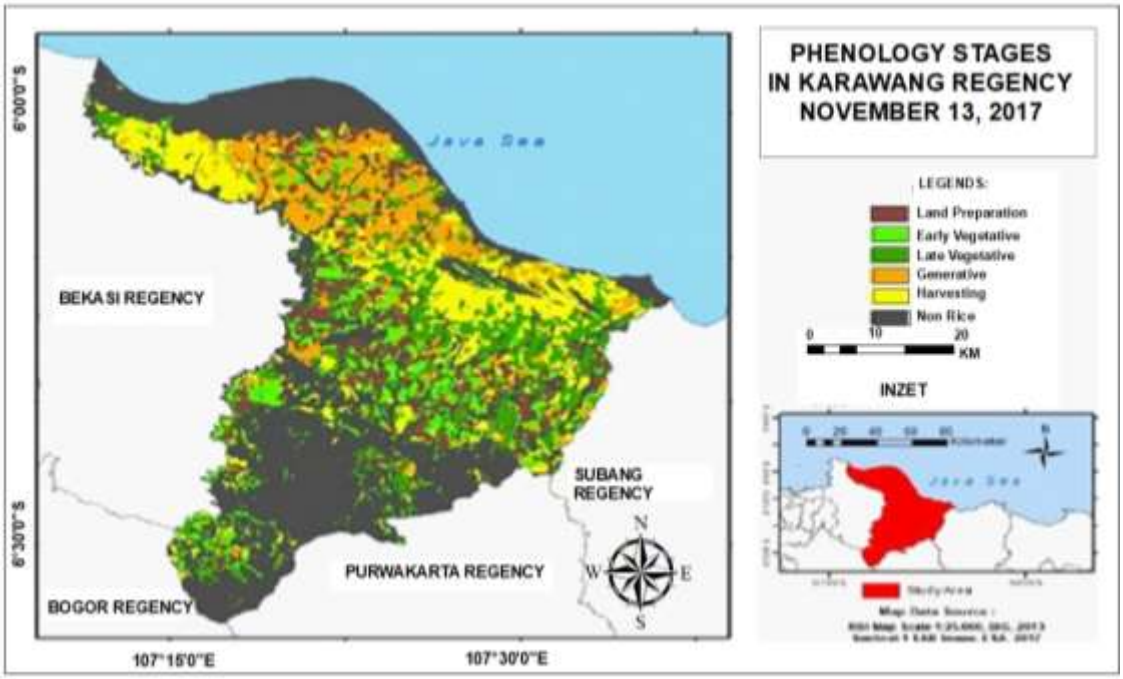


Figure 4. Phenology Stages on Paddy in Karawang Regency on 13 November 2017

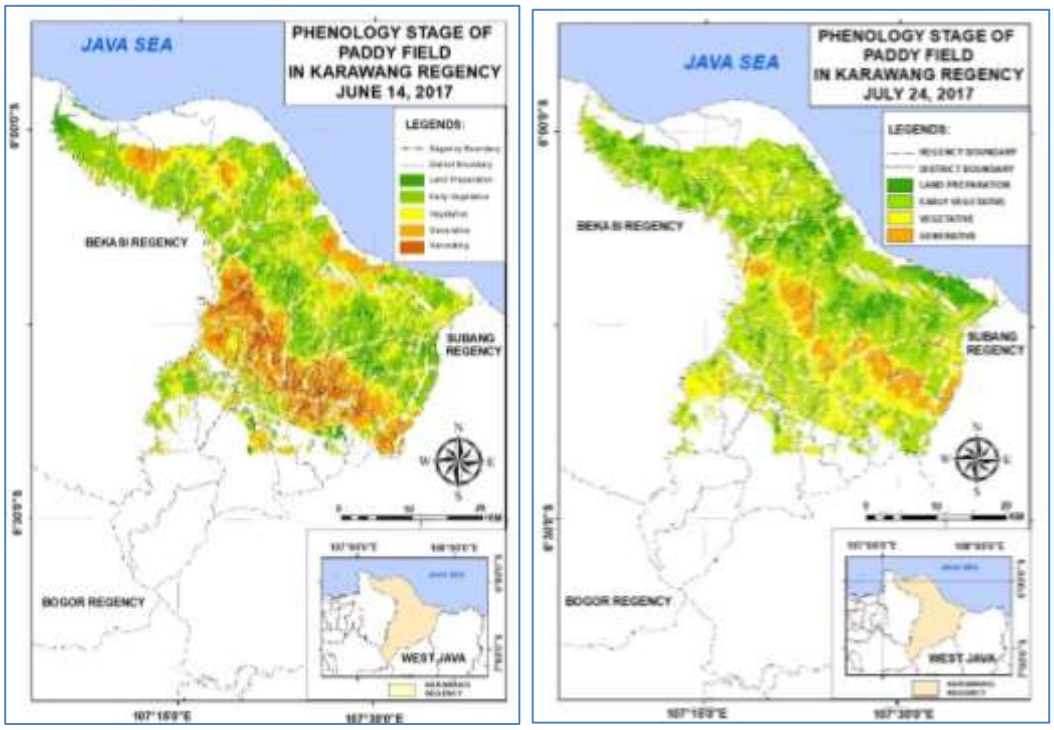
The vegetative stage (early and vegetative stages) in Karawang Regency is 20.8% of the total area, and the harvesting stage is 57.1% in Karawang Regency based on data 22 June 2017. Phenology stages on 13 November 2017 had the vegetative stage with 26.4% and harvesting stage with 31.9% of the area (Table 2).

Table 2. The Backscatter and Phenology Stages on Paddy in June 2017 and November

Backscatter (dB)	Phenology Stages	Area (Ha) June	Percentage (%)	Area (Ha) June	Percentage (%)
-13.62-12,8	Land Preparation	13,227.0	12.8	19,114.0	18.6
-19,4-17.61	Early vegetative	14,165.0	13.8	10,127.0	9.9
-17.61-15.6	Vegetative	7,236.0	7.0	16,955.0	16.5
-15.6-13.3	Generative	9,563.0	9.3	23,657.0	23.1
-13.3-11.0	Harvesting	58,774.0	57.1	32,691.0	31.9
	Total Area	102,965.0	100.0	102,544.0	100.0

Source: Data Processing

The spatial distribution of phenology stages in Karawang Regency saw in figure 4, the result using Sentinel-2A and NDVI algorithm. Figure 5(a) shows phenology stages on 14 June 2017, and Figure 5(b) shows phenology stages on 24 July 2017. Figure 5(a) shows the spatial distribution of vegetative stages are dominant around Karawang Regency with 66.7%. This spatial distribution of vegetative stages dominant validated that on 14 June 2017 is the first growing season in Karawang Regency. The second image (Figure 5(b)) shows phenology stages on 24 July 2017, the spatial distribution of vegetative stages is dominant around Karawang Regency. The vegetative stage with 77.1% area from total area Karawang Regency validated that 24 July 2017 is still in first growing seasons in a paddy field in Karawang Regency.



(a) (b)

Figure 5. The phenology stage on paddy (a) 14 June 2017 and (b) 24 July 2017 in Karawang Regency

The vegetative stage area in Karawang Regency on 14 June was 66.7% of the total area, and harvesting stages is 6.4%. Paddy phenology on 24 July 2017 had the vegetative stage with 77.1%, and the harvesting stage is 0% of the total area in the Karawang Regency (Table 3).

Table 3. The Area of NDVI and Phenology Stages in June and July 2017

NDVI	Phenology Stages	Area (Ha) June	Percentage (%)	Area (Ha) July	Percentage (%)
0.096-0.036	Land Preparation	6,114.98	5.6	15,973.56	14.6
0.036-0.240	Early vegetative	44,560.09	40.8	59,507.50	54.4
0.240-0.450	Vegetative	28,376.57	26.0	24,785.00	22.7
0.450-0.630	Generative	23,335.85	21.3	9,077.92	8.3
0.450-0.630	Harvesting	6,950.78	6.4	0.00	0.0
	Total Area	109,338.27	100.0	109,338.27	100.0

Source: Data Processing

4. Conclusion

The Karawang Regency had two growing seasons regarding to phenology stages. The first is Marc-June, and the second growing season is June-November. The research concluded that the spatial distribution of harvesting stages dominant in June, validated with image data on 22 June 2017, is the first growing season in Karawang Regency. The second image 13 November 2017, with the spatial distribution of generative and harvesting stages are dominant around Karawang Regency, the harvesting stage dominant with 31% area those validated that November 2017 is second growing seasons in the paddy field in Karawang Regency.

5. References

[1] Food Security Board 2015 *Food and Nutrition Strategies Policy 2015-2019* (Jakarta: Ministry of the Agriculture Republic of Indonesia)

[2] Indonesian Agency for Agricultural Research and Development 2009 *Rice seeds are the result of research by Balai Besar Penelitian Tanaman Padi* (Jakarta: *Ministry of the Agriculture Republic of Indonesia*)

[3] UNCTAD 2009 Info comm: Market Information in The Commodities Area. *United Nations Conference on Trade and Development* http://r0.unctad.org/infocomm/anglais/rice/crop.htm

[4] Directorate General of Food Crops 2009 *Sentra Produksi Padi Rawan Banjir* Ministry of the Agriculture Republic of Indonesia

[5] Malian A H, Sudi M and Mewa, A 2004 Faktor-faktor yang mempengaruhi Produksi, Konsumsi dan Harga Beras serta Inflasi Bahan Makanan *Jurnal Agro Ekonomi* **22** (2) pp 119–146 doi:https://doi.org/10.21082/jae.v22n2.2004.119-146

[6] Bashir A and Yuliana S 2018 Identifying factors influencing rice production and consumption in Indonesia. Jurnal Ekonomi Pembangunan *Kajian Masalah Ekonomi dan Pembangunan* **19** (2) doi:https://doi.org/10.23917/jep.v19i2.5939

[7] Nuraisah G, Andriani R and Kusumo B 2019 Impact Of Climate Change On Paddy Farming In Wanguk Village Anjatan Subdistrict Indramayu District *J. Pemikir. Masy. Ilm. Berwawasan Agribisnis* **5** (1) pp 60–71

[8] Mamenun, M and Wati T 2019 Analisis Karakteristik Kekeringan Lahan Padi Sawah di Wilayah Utara Provinsi Jawa Barat *J. Tanah dan Iklim* **43** pp 43–57

[9] Semedi J M 2012 Rice Crop Spatial Distribution and Production Estimation using Modis EVI (Case Study of Karawang, Subang, and Indramayu Regency) *Master Thesis* (Bogor: IPB)

[10] Nelson A, Setiyono T, Rala A B, Quicho E D, Raviz J V, …. And Thongbai P 2014 Towards an operational SAR-based rice monitoring system in Asia: Example from 13 demonstration sites across Asia in the RIICE project *Remote Sensing* **6** (11) pp 10773-10812

[11] Dong J, Xiao X, Kou W, Qin Y, Zhang G, Li L, Jin C, Zhou Y, Wang J, Biradar C and Liu J 2015 Tracking the dynamics of paddy rice planting area in 1986-201 through time series Landsat images and phenology-based algorithms *Remote Sensing of Environment* **160** (1) pp 99-113

[12] Chaparro D, Piles M, Vall-llossera M., Camps A, Konings A G and Entekhabi D 2018 L-band vegetation optical depth seasonal metrics for crop yield assessment *Remote Sensing of*

Environment **212** pp 249-259
[13] Rokhmatuloh, Supriatna, Pin T G, Hernina R, Ardhianto R, Shidiq I P A and Wibowo A 2019 Paddy Field Mapping Using UAV Multi-Spectral Imagery *International Journal of Geomate* **17** (61) pp 241-247
[14] Supriatna, Rokhmatuloh, Shidiq I P A, Pratama G P, Gandharum L and Wibowo A 2019) Spatio-Temporal Analysis of Rice Field Phenology Using Sentinel-1 Image In Karawang Regency, West Java, Indonesia *International Journal of Geomate* **17**(62) pp 101-106
[15] Afdhalia F, Supriatna S, Shidiq I P A, Manessa M D M, Ristya Y 2019 Detection of Rice Varieties Based on Spectral Value Data Using UAV Based-image *Proceeding of SPIE* **LIS100** 1137222-1
[16] 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 *IOP Conference Series: Earth and Environmental Science* **54** (1)
[17] Zheng H, Cheng T, Yao X, Deng X, Tian Y, Cao W and Zhu Y 2016 Detection of rice phenology through time series analysis of ground-based spectral index data *Field Crops Research* **198** pp 131-139
[18] Agency for the Assessment and Application of Technology Indonesia (BPPT) 2016 Prosedur Pengolahan Citra SAR Sentinel-1 Untuk Identifikasi Fase Tumbuh Padi *Modul Pelatihan* BPPT

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