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RICE PRODUCTIVITY ESTIMATION BY SENTINEL-2A IMAGERY IN KARAWANG REGENCY, WEST JAVA, INDONESIA

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ABSTRACT: Karawang Regency is the top rice producer within West Java, Indonesia. Accurate information about the number of harvest areas is essential in rice production in Indonesia, and the population majority eat rice. The Sentinel-2A imagery which has a spatial resolution of 10 meters. The study aims to spatial analysis pattern of rice phenology and estimation of rice productivity using Sentinel-2A imagery in Karawang Regency. The NDVI algorithm method used to determine the age of rice plants, which then used to estimate rice productivity. The Karawang Regency had 30 districts with rice fields. The stage of rice was land preparation (NDVI = 0.096-0.036), early vegetative (NDVI = 0.0 36-0.24), vegetative (NDVI = 0.24-0.45) generative NDVI = 0.45-0.63) and harvesting (NDVI= >0.63). The result from the estimation of harvest area in June and July is 39,364.55 hectares, and the estimation of rice productivity is 275,551.85 tons in Karawang Regency. Finally, the result concluded that the harvest area from Sentinel-2A imagery could provide an estimation of productivity on the paddy field in Karawang Regency.

Keywords: Rice field, Sentinel-2A, Phenology of paddy, Rice Productivity

1. INTRODUCTION

West Java province is the largest rice producer in Indonesia, especially Karawang Regency. Based on the national statistic report, in 2014-2015, rice production has been reduced from 11.085.544 to 10.856.438 tons [1]. From the report, it is possible to acknowledge that efforts to maintain food security in West Java Province are necessary. Karawang Regency is the top rice producer in West Java, Indonesia. Accurate information about the number of harvest areas is essential in rice production in Indonesia. With the population, the majority eat rice.

Rice phenology defined as the changes that occur within the rice from the moment rice is planted in the ground and proceeds to grow during the harvesting stage using Sentinel Imagery [2], [3]. The detection of rice phenology could be done using a remote sensing ([4]; [5]; [6]; [7];[8]; [9]; [10]; [11]). Spatial information shows that the actual conditions on indicators of food security and food vulnerability can obtain from remote sensing data that has high spectral and temporal resolutions such as LANDSAT 8 data and MODIS [12]. The results of the growth detection [12], indicating that the initial planting time of rice crops can know from the value of the Maximum Of Vegetation Index (EVI Max). By implementing the Vegetation Index (NDVI) value and the temporal analysis of Zheng [13] can determine the dates on the stage in the age of rice crops.

The Sentinel-2A imagery has a spatial resolution of 10 meters. The study aims to spatial analysis pattern of rice phenology and estimation of rice productivity using Sentinel-2A imagery in Karawang Regency.

2. METHODS

The Karawang Regency had 30 districts with rice fields. The rice field observed in this study is rice paddies planted in rice fields that grow in a cycle of three main periods, which are planting period, growing period, and harvesting period. Five classes took from these three main periods, according to a literature study on Sentinel-2A using index vegetation values, which are land preparation, early vegetative, late vegetative, generative, and harvesting/ripening. The productivity estimation approach used to answer the aim of the study (Fig. 1).

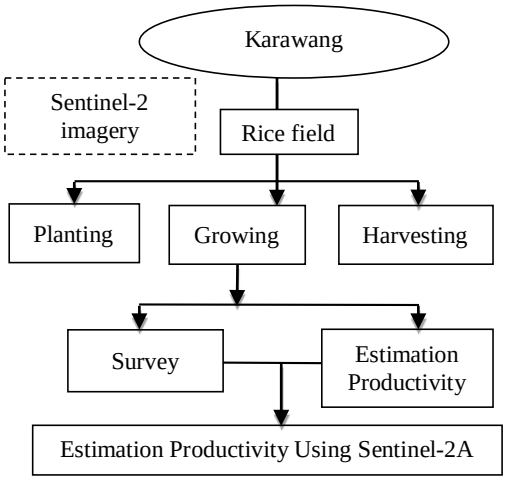

Fig. 1 Conceptual framework of this study

The study aims to spatial analysis pattern of rice phenology and estimation of rice productivity using Sentinel-2A imagery in Karawang Regency. Vegetation index generated using different bands from the sensor used NDVI as a tool to differentiate different types of crops. NDVI calculated with the following formula:

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

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

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), early vegetative (NDVI = 0.0 36-0.24), vegetative (NDVI = 0.24-0.45) generative NDVI = 0.45-0.63) and harvesting (NDVI= >0.63). A field survey conducted in September 2019. Thirty sample points collected during the field survey. A field survey conducted for collecting ground data such as the growing stage or phenology of paddy and productivity for image processing. There are four types of growth stages of land preparation, early vegetative, generative and harvesting, and data productivity from survey-based on NDVI using to estimation productivity Karawang Regency.

3. RESULT AND DISCUSSIONS

The research explained index vegetation firstly based on image processing, second ground through survey productivity, rice phenology estimation based on index vegetation, and finally explained the estimation of productivity in Karawang Regency.

3.1 Index Vegetations

Spatial patterns of the rice paddy using vegetation index show that in June and July, there are different spatial patterns. The spatial distribution of vegetation index in June saw in Fig 2, and spatial distribution of vegetation index in July saw in Fig. 3.

Table 1 Index NDBI and Index Vegetation in June

NDVI	Index Vegetation	Area (ha)
0.096-0.036	No. Vegetation.	6,114.98
0.036-0.240	Very Low	44,560.09
0.240-0.450	Low	28,376.57
0.450-0.630	Medium	23,335.85
0.630-0.850	High	6,950.78
	Total Area	109,338.27

Sources: Data Processing.

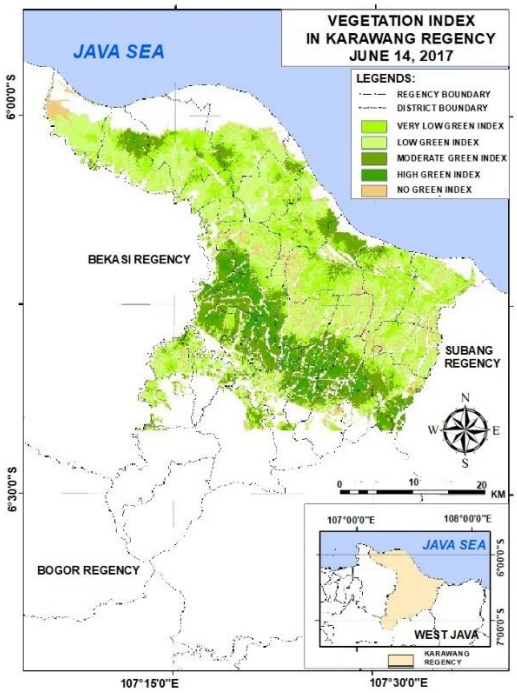

Fig.2 The NDVI in June on Karawang Regency

The high greenish index is in the southern regions of the district of Karawang in June and July. The difference in the relationship pattern occurs based on the area of the high vegetation index. There is a medium and high vegetation index area of 23,335.85 hectares and 6,950.78 hectares in June (Table 1). Table 1 shows that the potential rice harvest area in June is 30,186.63 hectares.

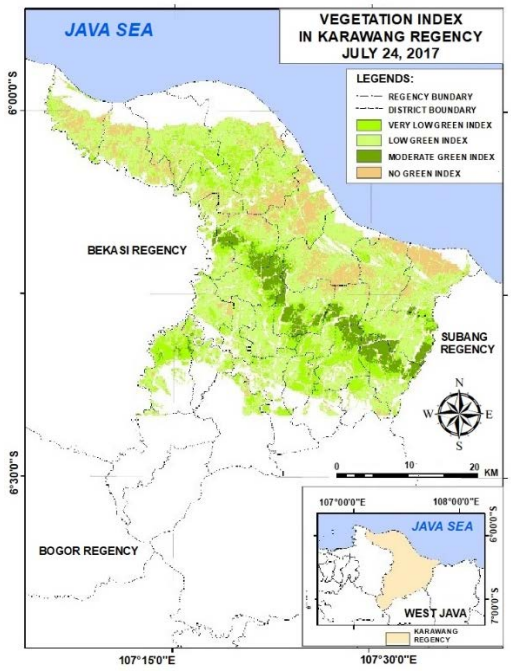

Fig.3 The NDVI in July on Karawang Regency

The high of the vegetation index was not present in July because it was already in the harvest phase.

The NDVI of July has a low vegetation index, with area 9,077.92 hectares. The medium vegetation index area shows the potential of rice harvesting in July (Table 2). High index vegetation value is zero because thus area was after harvesting stages.

Table 2 Index NDBI and Index Vegetation in July

NDVI	Index Vegetation	Area (ha)
0.096-0.036	No. Vegetation.	15,973.98
0.036-0.240	Very Low	59,507.50
0.240-0.450	Low	24,785.00
0.450-0.630	Medium	9,077.92
0.630-0.850	High	0.00
	Total Area	109,338.27

Sources: Data Processing.

3.2 Ground Through Production Data

Based on vegetation index in June and July in Karawang Regency, this research surveying to collect ground through data. The survey collected productivity in Jatisari District.

The production of rice surveying based on index vegetation in Karawang Regency during September 2019. The result is shown in Table 3. The minimum productivity is 7.03 ton/ha on sample number seven with NDVI value was 0.54458. Furthermore, maximum productivity is 7.97 ton/ha on sample number one with the NDVI value was 0.68137. The average of productivity based on NDVI is 7 ton/ha.

Fig.4 Farmers as a respondent in Karawang Regency (after harvesting and land preparation)

3.3 Growing Stage or Phenology

The Growing stage or phenology was starting from land preparation, early vegetative, generative, and harvesting. Rice Spatial patterns of growing stages are associated with the rice field vegetation index.

Fig. 5 shows a growing stage of rice was land preparation and early vegetative. The figure explained water covered on the paddy field when land preparation and paddy already planted on the paddy field during early vegetative. That was related to NDVI value 0.096-0 until 0.24.

Table 3 Index Vegetations (NDVI) and Productivity

No	NDVI	Productivity (ton/ha)
1	0.68137	7.97
2	0.61577	7.68
3	0.58805	7.41
4	0.57102	7.27
5	0.57527	7.30
6	0.56932	7.26
7	0.54458	7.03
8	0.58246	7.36
9	0.59269	7.45
10	0.63500	7.83
11	0.62585	7.75
12	0.61078	7.59
13	0.55851	7.16
15	0.62481	7.76
16	0.59726	7.49
17	0.59393	7.46
18	0.59761	7.06
19	0.60674	7.58
20	0.57817	7.32
21	0.55188	7.10
22	0.60695	7.58
23	0.63185	7.80
24	0.61491	7.63
25	0.64078	7.88
26	0.57808	7.32
27	0.57528	7.30
28	0.59704	7.49
29	0.64720	7.07
30	0.56075	7.18
	Average productivity	7 ton/ha

Sources: Ground truth survey in September 2019

Fig.5 Growing stages of land preparation and early vegetative.

Fig. 6 shows a growing stage generative and harvesting. The figure explained rice already becomes a yellow color when generative and leaf and rice already yellow on the paddy field during late generative or harvesting. That was related to the NDVI value from 0.450 until 0.85.

Fig.6 Growing stages generative and harvesting

Spatial patterns of the growing phase are associated with the rice field vegetation index showing the different patterns between June and July (Fig. 7 and Fig. 8). Based on Fig. 7 those are representing land preparation, early vegetative, vegetative, generative, and harvesting. Based on Fig. 8, those are representing land preparation, early vegetative, vegetative, and generative.

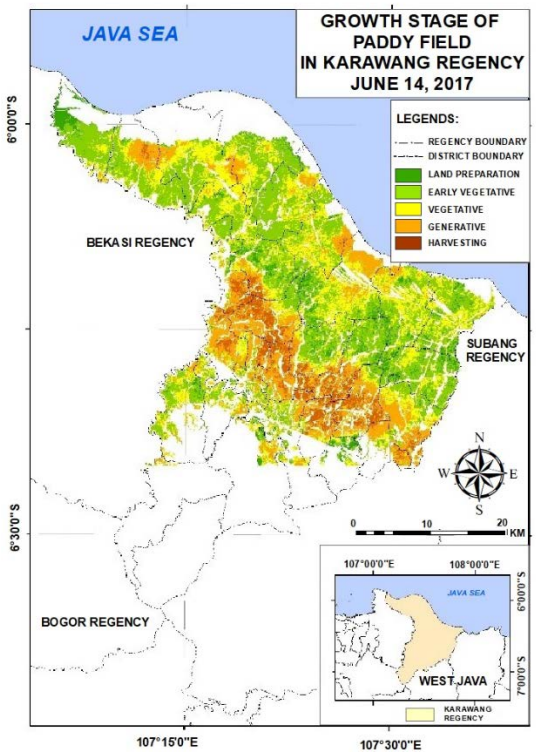

Fig. 7 The phenology or growing stage in June

Based on Table 3, the estimation area will harvest in June was 30,286.63 hectares. That was according to the phenology of rice for more than six weeks. Based on Table 4, the estimation area will harvest in June was 9,077.92 hectares. That was according to the phenology of rice for more than six weeks. The result from the estimation of harvest area in June and July is 39,364.55 hectares,

Table 3 The NDVI and Phenology in June

NDVI	Phenology of Rice (weeks)	Area (ha)
0.096-0.036	Land Preparation	6,114.98
0.036-0.240	Early Vegetative	44,560.09
0.240-0.450	Vegetative	28,376.57
0.450-0.630	Generative	23,335.85
0.630-0.850	Harvesting	6,950.78
	Total Area	109,338.27

Sources: Data Analysis.

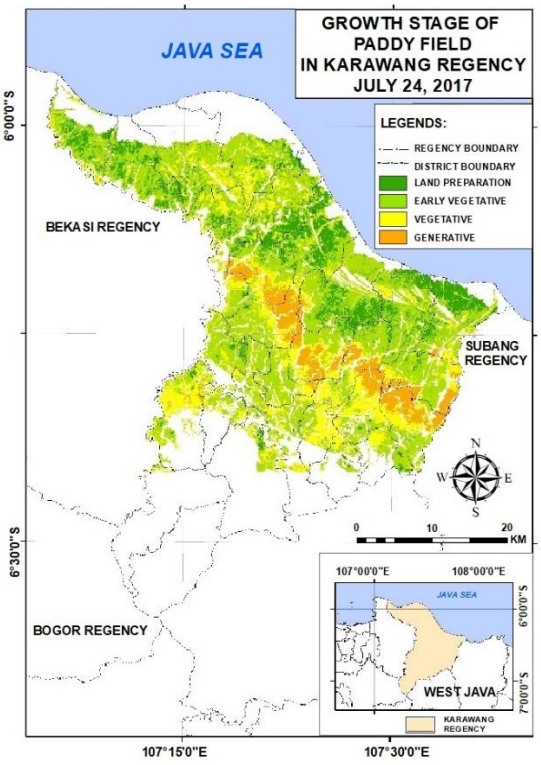

Fig.8 The phenology or growing stage in July

Table 4 The NDVI and Phenology in June

NDVI	Phenology of Rice (weeks)	Area (ha)
0.096-0.036	Land Preparation	15,973.98
0.036-0.240	Early Vegetative	59,507.50
0.240-0.450	Vegetative	24,785.00
0.450-0.630	Generative	9,077.92
	Harvesting	0.00
	Total Area	109,338.27

Sources: Data Analysis.

3.4 Estimation of Productivity

Based on the ground through average productivity was 7 ton/ha in Karawang Regency. The average productivity using estimation productivity in Karawang Regency (Table 5). The harvest area in June was 30,286.63 hectares using average productivity of 7 ton/hectare become production in June reached 212,006.41 tons. Based on growing stages in July, the estimation harvesting area is 9,077.92 hectares using 7 tons/hectare. Thus, result productivity is 63,545.44 tons of rice. The result from the estimation of harvest area in June and July is 39,364.55 hectares with total productivity, which is 275,551.85 tons.

Table 5 The Estimation Productivity

Growing Stage	June	July
Generative	23,335.85	9,077.92
Harvesting	6,950.78	0
Area (ha)	30,286.63	9,077.92
Production (ton/ha)	212,006.41	63,545.44

Sources: Data Analysis.

4. CONCLUSION

The result from the estimation of harvest area in June and July is 39,364.55 hectares, and the estimation of rice productivity is 275,551.85 tons in Karawang Regency. Finally, the result concluded that the harvest area from Sentinel-2A imagery could provide an estimation of productivity on the paddy field in Karawang Regency.

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