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The Potential of Agricultural Land Drought Using Normalized Difference Drought Index in Ciampel Subdistrict Karawang Regency

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***Abstract*— Karawang Regency, known as the National Rice Reserve, is experiencing drought on farmland. The Regional Disaster Management Agency (BPBD) of Karawang Regency noted that drought in 14 villages spread across three sub-districts in Karawang Regency has developed in 2019, such as Ciampel sub-district. Rice production decreased in 2015-2019 by 19 percent. The purpose of this study is to analyze the drought area of agricultural land using the Normalized Difference Drought Index (NDDI) and analyze the relationship between agricultural land drought and rainfall in Ciampel Sub-District, Karawang Regency in 2015 and 2019. The study used Landsat 8 OLI/TIRS in August-September 2015 and 2019. Agricultural land drought using the NDDI method is the ratio between the Normalized Difference Vegetation Index (NDVI) and the Normalized Difference Wetness Index (NDWI). The results showed a map of the distribution of agricultural land drought in Ciampel Sub-district, Karawang Regency during 2015 and 2019 with three classes of agricultural land drought (dry, rather dry, normal). The total area of agricultural drought in August 2015 was 11,166 hectares and as of September 2019 was 3,119 hectares. While as of September 2015, it was 3,086 hectares, and in 2019 was 3,158 hectares. The drought that hit Ciampel Sub-District in September 2019 hit almost all areas and dry areas in the middle eastern part of the Ciampel Sub-District. The drought, which is included in the classification of dry that hit irrigated rice field, was 20.19 %. Meanwhile, the rainfed rice field was 32.79%, and in dryland was 24.83%.**

***Keywords*— Agricultural land drought; NDVI; NDWI; NDDI; land use.**

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I. INTRODUCTION

Drought is a natural phenomenon that occurs on various timescales, affecting a wide area and part of a hydrological cycle [1]–[7]. Drought is a recurring extreme event that causes great damage to agricultural and community production [8]–[12]. Karawang is one of the national rice barns located in West Java Province. As a rice barn when the dry season struck, Karawang did not escape the drought. The drought resulted in a decrease in rice production. Karawang District Disaster Management Agency noted the drought that hit the rice barn town widened in 2019 and hit 14 villages spread across three subdistricts, one of which was a district of Ciampel, which was quite severe in 2015 and 2019 [13]. Ciampel subdistrict in 2015 produced smaller rice harvest production than 2018 of 20441 tons and 26741 tons [14];[15]. The rice fields affected by drought in Ciampel Subdistrict in 2019 covering an area of 355 hectares of 1131 hectares.

The climate in Indonesia is influenced by the *Indian Ocean Dipole* (IOD) and *El Nino Southern Oscillation* (ENSO) [16]–[18]. IOD is a symptom of the climate that occurs due to the movement of Indian Ocean Sea surface temperatures and the annual phenomenon [19]. IOD consists of positive IOD and negative IOD. Positive IOD occurs when sea surface temperature in the southeastern part of the Indian Ocean decreases or is lower than in the western part of the Indian Ocean, so the wind moves westwards, resulting in a drought in Indonesia, while a negative IOD occurs instead. The impact caused by the 1997 El Nino in Java in the form of the dry season that came earlier (based on February I-III) from the normal period (basis of I-III April) and experienced drought irregularities (the dry season occurred longer than the normal period) especially on the north coast of West Java resulted in a decrease in the area of harvest in Java due to drought during the El Nino period [20]–[22].

The need for water is quite large, i.e., with normal rice crops need a considerable amount of water, about 6-10 mm/day/ha, or with an average rainfall of about 200 mm/month for a minimum of four months or 1500-2000 mm/year [23]. Reduced rainfall during the dry season (May -

October) has the potential to reduce the water supply in rice crop farming areas in Java, especially for rainy rice fields, and result in an increased risk of drought in rice farming, especially in the agricultural areas of generative phase rice crops with symptoms of leaves rolling and finally drying out [19].

Previous research related to drought has been carried out by Rismayatika *et al.* [18]. In Magetan Regency, one of the regencies in East Java Province has a high vulnerability to drought. This research aims to identify dry areas in agricultural land using NDDI and Landsat 8 Imagery, acquiring in August 2017 (Normal Year) and 2019 (El Nino Year). The results of data processing revealed that the dry areas in 2019 are wider than dry areas in 2017 [18]

Putri *et al.* [24] examine the drought with the title Drought Potential of Paddy Fields using *Temperature Vegetation Drought Index* (TVDI) in Kuningan Regency. This study used Landsat 8 OLI/TRIS image variables, rice field use, and rainfall. Landsat imagery was processed into NDVI and LST values, the relationship of the two values was represented into the linear equation value included in the TVDI formula, and the spread of TVDI was extracted using rice fields. The results showed that dry grades dominate TVDI, and there is a relationship between the two variables that are weak, which means the value of TVDI does not have a big effect on rice productivity and the relationship is negative or not unidirectional, which means the higher the TVDI value then, the lower the productivity value [24]. Another research on TVDI was conducted in Upper Progo Watershed to estimated drought distribution based on the number of days without rainfall [25].

Rahman *et al.* [26] used variable NDVI and NDWI to obtain the result of drought of agricultural land using NDDI method. Then compared to the drought map of BNPB No. 02 Year 2012. Based on the validation results obtained NDDI method accuracy rate of 82% and BNPB by 70% [26]. Another research conducted by Du *et al.* [27] showed that NDDI is more sensitive to rainfall in rice fields than other indices and better captures drought and its impact on crops. In forest land, VHI is more sensitive to temperature and has better performance than other vegetation indexes. Therefore, NDDI and VHI are recommended to monitor drought in farmland and forests [27]. This research has the novelty of using Ciampel District as the object of study to analyze the drought of agricultural land based on NDVI and NDWI using the NDDI method with data collection years 2015 and 2019.

II. Material and Method

NDDI is a method of agricultural land drought that combines information about vegetation and water namely from data NDVI and NDWI [28]. NDVI measures the visible and near-infrared reflectance of the vegetation canopy to represent the strength (health or greenness) of vegetation [29]–[32]. NDVI is one of the methods to measure vegetation's greenness by comparing spectral between NIR waves and red waves [33]. In Landsat 8 OLI/TIRS, NIR waves use Band 5 and red waves use Band 4. The vegetation index is a mathematical combination between red bands and NIR bands that have long been used to identify the presence and condition of vegetation [33]. NDVI values have a range between -1 to 1 (positive). Values representing vegetation are in the range of 0.1 to 0.7 if the NDVI value above this value indicates the health level of better vegetation cover. NDWI emphasizes the wetness of vegetation [34], [35].

NDWI uses the reflectance surface*(ρ)* of near-infrared waves and infrared shortwaves, representing changes in water content and mesophiles in the vegetation canopy. NDWI to estimate vegetation moisture conditions. It uses the reflectance surface*(ρ)* of near-infrared waves and infrared shortwaves, which represent changes in water content and mesophiles in the vegetation canopy [36], [37].

Data used in the study is Landsat 8 OLI/TIRS path 122 row 64 acquisition on August 31, 2015, September 11, 2015, July 25, 2019, and September 11, 2019, from USGS, rainfall in 2015-2019, land use data from the National Land Agency. The data is analyzed using descriptive spatial analysis. The analysis is needed to look at the distribution of drought agriculture land with NDDI method using two parameters, namely vegetation greenness (NDVI) and vegetation wetness (NDWI) [34]. The following algorithmic formulas for obtaining NDVI and NDWI values [27] are as follows:

$$\mathrm{NDVI} = \frac{\mathrm{NIR-Red}}{\mathrm{NIR+Red}} \tag{1}$$

$$\mathrm{NDWI} = \frac{\mathrm{NIR-SWIR1}}{\mathrm{NIR+SWIR1}} \tag{2}$$

Where:
NDVI = Normalized Difference Vegetation Index
NDWI = Normalized Difference Water Index
NIR = Near Infra-Red (Band 5)
Red = Red (Band 4)
SWIR1 = Short-wave Infrared (Band 6)

NDDI extracted using the following formula [19]:

$$\mathrm{NDDI} = \frac{\mathrm{NDVI-NDWI}}{\mathrm{NDVI+NDWI}} \tag{3}$$

Based on the results of spatial data processing, the classification of agricultural land drought level based on the digital number value of imagery that has been processed with NDDI algorithm can be seen in Table 1.

TABLE I
DROUGHT CLASSIFICATION WITH NDDI METHOD [19]

NDDI Value	Drought Classification
< 0.5	Normal
0.5 – 1.0	Rather Dry
> 1.0	Dry

III. Result and Discussion

The drought area in Ciampel Subdistrict using the NDDI method is a parameter of the NDVI and NDWI algorithms, obtained spectral or digital number values with a description of the minimum and maximum values. The minimum and maximum value of NDVI as in Table 1, where in August 2015 had the highest maximum value of 0.7734, in August 2015 it reached the maximum vegetation greenness condition.

Fig. 1 NDVI Of Ciampel Subdistrict August 2015, September 2015, July 2019, and September 2019. The NDVI map shows that areas with very low and low NDVI levels are predominantly in the Eastern part of Ciampel sub-district. The low NDVI value in a region indicates a high drought in the Eastern part of Ciampel sub-district.

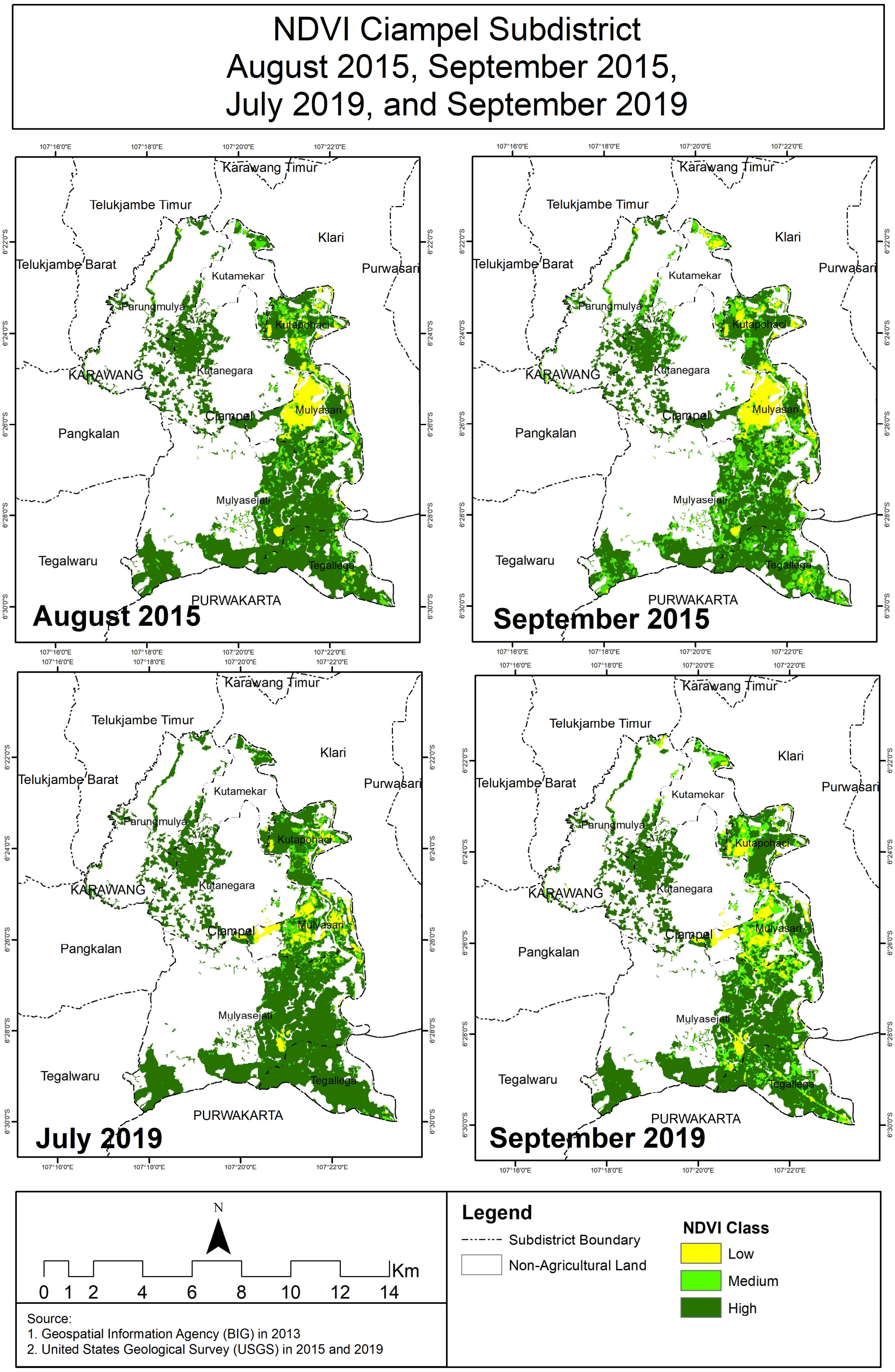

Fig. 1 NDVI Ciampel Sub-District August 2015, September 2015, July 2019, and September 2019

Fig. 2 NDWI of Ciampel Subdistrict in August 2015, September 2015, July 2019, and September 2019. The figure shows that areas with low NDWI levels are predominantly in the eastern part of the Ciampel subdistrict. The value of NDWI in a region indicates the high drought in the Eastern part of Ciampel subdistrict.

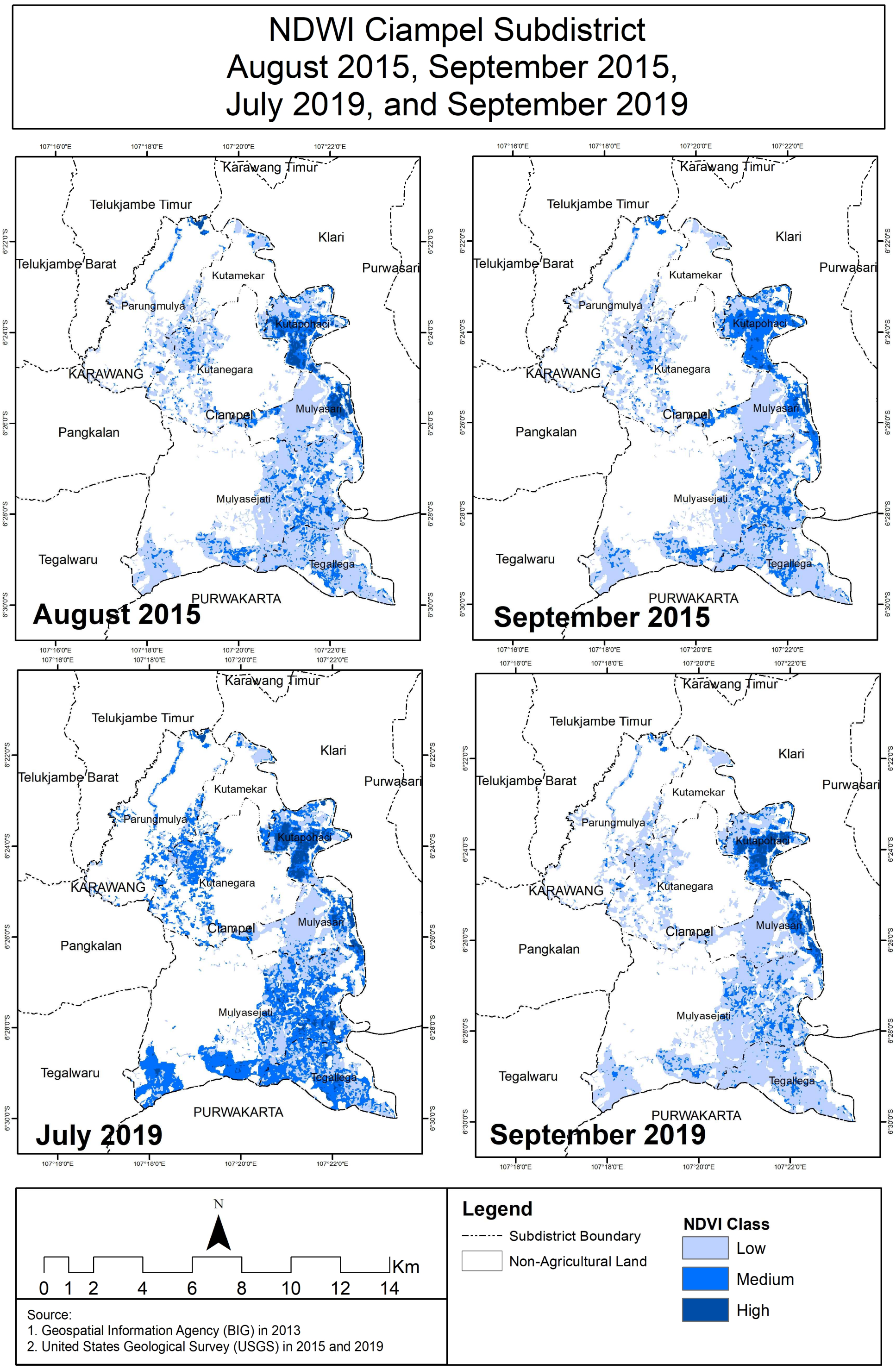

Fig. 2 NDWI Ciampel Sub-District in August 2015, September 2015, July 2019, and September 2019

A. Agricultural Land Drought Area with NDDI Method

The area experiencing drought in Ciampel Subdistrict, Karawang Regency using the NDDI method in August 2015, September 2015, July 2019, September 2019 can be seen in Figure 3. In Figure 3. In August 2015, the drought-stricken agricultural land was large enough. Then, in September 2015, the area of agriculture that had been experiencing drought had turned out to be un dry with normal classification. As of July 2019, drought-stricken agricultural areas are not as large as in September 2019. The dry area was dominated in the eastern part of the Ciampel subdistrict. Meanwhile, the normal area is dominated in the northeastern part of the Ciampel Subdistrict.

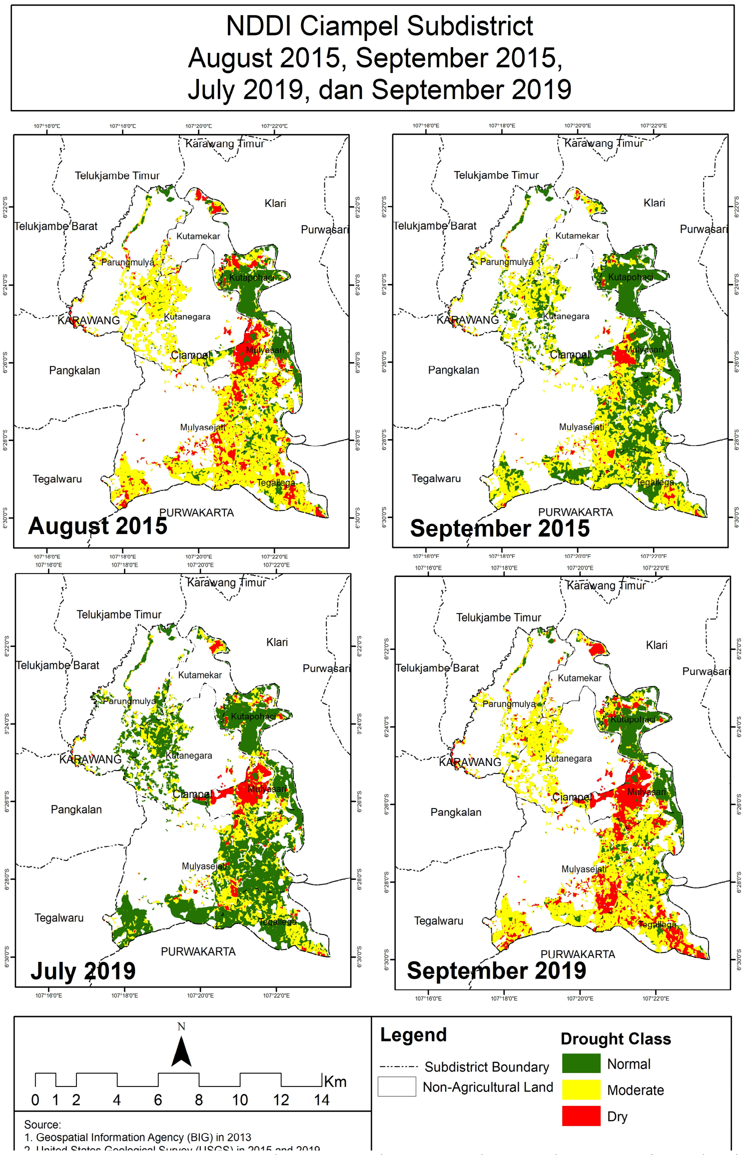

Fig. 3 Dry Areas August 2015, September 2015, July 2019, and September 2019 Ciampel Subdistrict

TABLE II
PERCENTAGE OF AGRICULTURAL LAND DROUGHT AREA CIAMPEL SUBDISTRICT

Time	Drought Classification	Area (km^2)	Percentage (%)
August 2015	Normal	10.0434	23.10
	Rather Dry	25.1173	57.78
	Dry	8.3097	19.12
September 2015	Normal	20.3132	46.73
	Rather Dry	20.3860	46.90
	Dry	2.7709	6.37
July 2019	Normal	25.4041	58.44
	Rather Dry	13.8306	31.82
	Dry	4.2356	9.74
September 2019	Normal	9.4501	21.74
	Rather Dry	23.4782	54.01
	Dry	10.5420	24.25

In Table 2, it can be seen that the change in the area of dry conditions has decreased from 19.12% in August 2015 to 6.37% in September 2015. Then, the area has increased by 9.74% in July 2019 and increased again in September 2019 by 24.25%. The changes in the area of a rather dry condition saw a decrease in the area from 57.78 in August 2015 to 31.82% in July 2019. Then the area increased again in September 2019 by 54.01%. Meanwhile, under normal conditions, changes in the area occurred an increase in area from 23.10% in August 2015 to 58.44% in July 2019. However, in September 2019, the area decreased to 21.74%.

Therefore, when compared between 2015 and 2019, Ciampel District experienced drought (dry and rather dry) in severe conditions in 2019 with a percentage of over 50% of the total area. In September 2015, the dry condition area had an area percentage of 53.27%. Whereas in September 2019, the dry condition area had an area percentage of 78.26%. Meanwhile, in August 2015, the dry condition area had an area percentage of 76.90%. Based on this, the dry area in 2015 was dominated in August with 76.90%. Meanwhile, in 2019, the dry condition was dominated by September 2019 with an area percentage of 78.26%. This is confirmed by rainfall data from the nearest station from Ciampel, that in September 2019, there was no rain, meanwhile, in September 2015, the rainfall was 31 mm.

B. Drought Areas of Agriculture Land Based on Land Use

The use of agricultural land studied is drought on irrigation rice fields, rainfed rice fields, and dry land. The results can be seen in Fig. 4 and Table 3. In a dry land, the dryness class dominated the drought area percentage rather than dry in August 2015. In September 2015, the drought area percentage was dominated by the dry class rather dry and normal. In July 2019, the broad percentage of the drought was dominated by the normal drought class. In September 2019, the broad percentage of the drought was dominated by the rather dry drought class. This indicates that drought affects dry land use. In irrigated rice fields, the percentage of drought area is dominated by the normal drought class from August 2015 to September 2019. This indicates that drought does not affect the use of irrigated rice fields. In rainfed lowland land, the percentage area of drought is dominated by the dryness class rather than dry from August 2015 to September 2019. This indicates that the use of rainfed lowland land can be affected by drought.

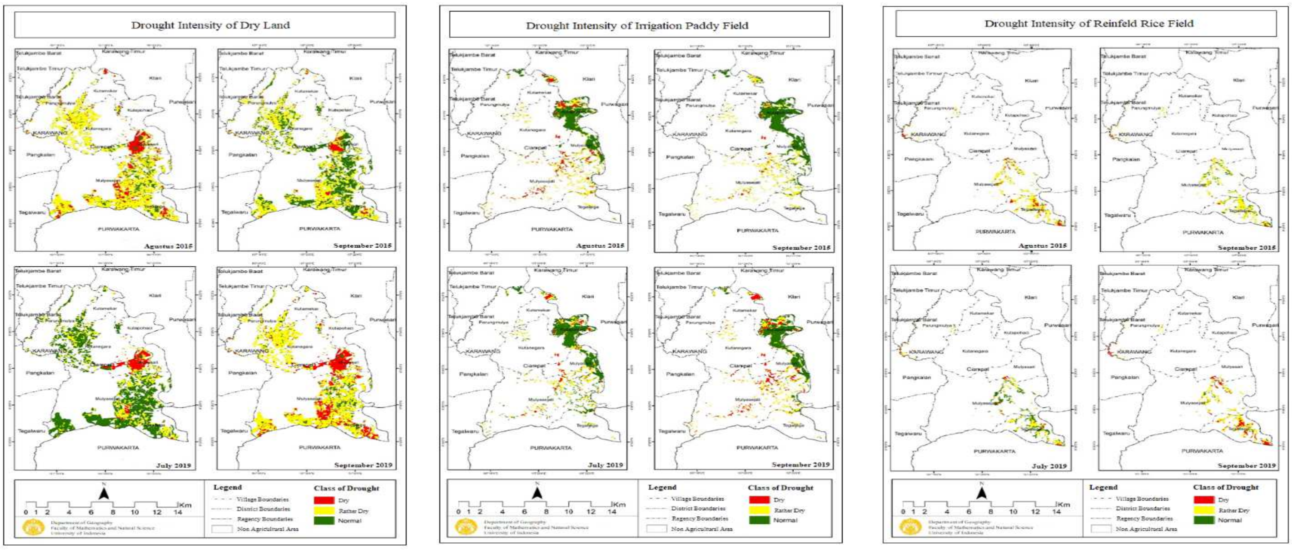

Fig. 4 Dry Areas Based on Land Use in Agricultural Land Drought

TABLE III
AREA OF AGRICULTURAL LAND DROUGHT IN AUGUST 2015 CIAMPEL SUBDISTRICT

Land Use	Class of Drought	Aug 2015	Sep 2015	Jul 2019	Sep 2019
Dry land	Normal	14.64	41.9	59.48	12.11
	Rather Dry	66.92	51.43	31.23	63.06
	Dry	18.44	6.67	9.29	24.83
Irrigation paddy field	Normal	50.48	66.01	60.45	50.72
	Rather Dry	31.07	28.94	28.6	29.1
	Dry	18.45	5.05	10.95	20.19
Rainfed Rice Field	Normal	6.35	24.73	42.24	10
	Rather Dry	66.21	67.05	48.02	57.2
	Dry	27.44	8.22	9.73	32.79

In a dry land, it can be seen that the percentage area of drought that occurred from August 2015 was dominated by the drought class Rather Dry with a value of 66.92%, while in September 2015, the percentage area of the drought was dominated by the Rather Dry drought class 51.43 % and 41.9% Normal. In July 2019, the percentage of the drought was dominated by the Normal drought class of 59.48%, and only a portion of the 'Quiet dry' drought class was 31.23%. However, in September 2019, the percentage of drought area was dominated by the class of dryness with 'Quiet dry' 63.06% and Dry 24.83%. This indicates that in the use of dry land, the area of drought decreased from August 2015 to July 2019 and experienced an increase in the area of drought in September 2019. Meanwhile, in the use of irrigated rice fields in August 2015, the percentage of drought area was dominated by the Normal drought class with a value of 50.48%.

Meanwhile, in September 2015, the drought intensity was also dominated by the Normal drought class 66.01%. In July 2019, the drought area percentage was dominated by the Normal drought class of 60.45%, but the percentage of the drought was Rather Dry 28.6% and 10.95% dry. Meanwhile, in September 2019, the percentage of drought in the Normal drought class decreased by 50.72%, while the percentage of drought in the Rather Dry class was 29.1%, and 20.19% in Dry increased. This indicates that in irrigated rice fields, the percentage area of drought tends to increase in the period August 2015 to September 2019. In rainfed lowland land, the percentage of drought in August 2015 is dominated by the dryness class Rather Dry 66.21% and 27.44% Dry. Meanwhile, in July 2019, the percentage of drought in the Normal drought class of 42.24% in rainfed lowland land use increased. In September 2019, the percentage of drought in rainfed lowland land use was dominated again by the drought class Rather Dry 57.2% and Dry 32.79%

IV. CONCLUSION

The result of this research, it can be concluded that the area of drought in August 2015 to September 2019 was dominated by the dry rather than dry drought class on dry land, while the use of irrigated rice fields from August 2015 to September 2019 was dominated by normal drought class, the use of rainfed lowland land from August 2015 to September 2019 was dominated by rather a dry drought class. This indicates that the use of dry land and rainfed rice fields experiences drought which is classified in the drought class of rather dry. Meanwhile, irrigated rice fields tend not to experience drought because the normal drought class dominates it.

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