FRAGMENTATION OF IRRIGATED AND RAINFED PADDY FIELD IN CIANJUR REGENCY, WEST JAVA

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ABSTRACT

Paddy field is the agriculture land that produces rice and needs to be protected because of the threat of high conversion. In the period 2003-2013, paddy field in West Java Province has decreased by 9098 ha, while all of Indonesia increased by 235 538 ha (2014) because of the new paddy field outside Java. In the period January-September 2022 national production reached 45.43 millian ton. Conversion of paddy field into built up area, especially in Java will affect to fragmentation level of paddy field themsefves. The purpose of this research is to analyze the fragmentation of irrigated and rainfed paddy field in Cianjur Regency. Fragmentation index that used in this research are Class Area (CA), Number of Patch (NumP), Mean Patch Size (MPS), Patch Size Standard Deviation (PSSD), Mean Sharp Index (MSI). The results showed that rainfed paddy field are more fragmented than irrigated paddy field, which is indicated by greater NumP values. Clutering of districts based on irrigated and rainfed paddy fields fragmentation index, each of which produces 3 groups . The high group has an increasingly fragmented tendency that identified by the high value of area (CA) and the number of patchs (NumP), while the other parameters are less able to characterize fragmentation difference. The fragmentation of irrigated and rainfed paddy fields in northern Cianjur Regency is influenced by the land conversion while in central and southern due to sloping topography.

Key words: Cianjur, paddy fields, patch analysis

INTRODUCTION

Paddy field is the agriculture land that produces rice and needs to be protected because of the threat of high conversion. In the period 2003-2013, paddy field in West Java Province has decreased by 9 098 Ha, while all of Indonesia increased by 235 538 Ha (Central Bureau of Statistics of Cianjur Regency, 2014) because of the new paddy field outside Java. In the period January-September 2022, national production of paddy field reached 45.43 million ton (milled dry paddy), it decrease 0.19 % compare with the same periode in 2021 (Central Bureau of Statistic 2022, in Santosa, 2022). Cianjur Regency is *lumbung padi* that has contributed 12,21% (2012) and 13,30% (2014) to the rice demand of West Java Province (Ministry of Agriculture, 2014). The conversion rate of paddy fields in Cianjur Regency in the period 2000-2015 is 1.5% (5 438 Ha) that dominant (67%) change into settlements (Chairunnisa, 2015). This causes farmers' land, especially rice fields to be smaller and fragmented. Therefore, these paddy fields need to be protected (Law 41 of 2009) to support the national food security program.

Land fragmentation can be defined as a situation where a farming household possesses several non-contiguous land plots, often scattered over a wide area (Sunqvist and Andersson 2006). Land fragmentation can be caused by land inheritance (Sunarto, 2009) and land convertion (Munibah et al., 2013). Some of disadvantages of land fragmentation associated with inefficient allocation of recourses (labour and capital) leading to increased costs of production, and with the hindering of agricultural. The recognized advantages are closely related to the demand-side causes of fragmentation (Sunqvist and Andersson, 2007).

In this study, the fragmentation of irrigated and rainfed paddy fields will be analyzed in each district and grouped based on a fragmentation index. The fragmentation index is a widely used empirical tool to assess agricultural fragmentation such as Class Area (CA), Number of Patch (NumP), Mean of Patch Size (MPS), Patch Size Standard Deviation (PSSD) and Mean Shape Index (MSI) (McGarigal and Marks, 1995). Carranza et al., (2014) used the index of percent of forest cover (% Forest), edge density (ED, m/ha), mean patch size (MPS, ha) and patch density (PD, number of patches/ha). This study aims to analyze the fragmentation of irrigated and rainfed paddy field in Cianjur Regency

MATERIALS AND METHOD

Study Area

The study area (Figure 1) is Cianjur Regency, West Java, Indonesia and has coordinate of 6° 21'- 7° 25' S and 106° 42'-107° 25' E. The total areas cover 361.435 ha, comprising 32 districts. Regency Capital is located in Cianjur Distric.

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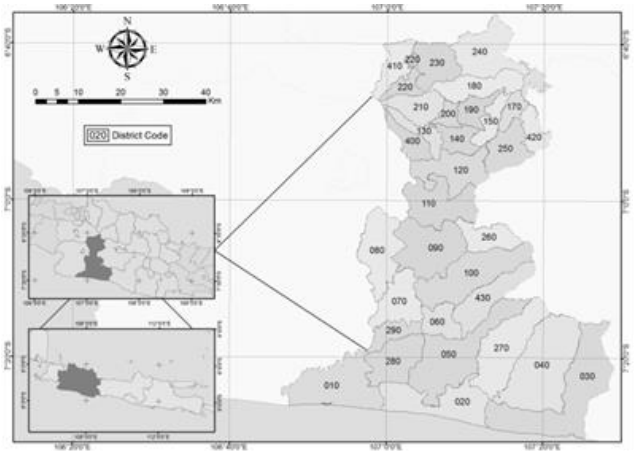


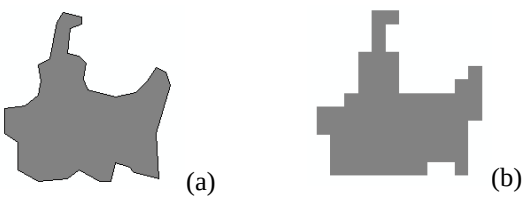
Figure 1. Location of study area

Calculation of Land Fragmentation Index

The main data used in this study were irrigated and rainfed paddy fields which were interpreted visually from high resolution satellite imagery and verified in the field by the Ministry of Agriculture in 2010-2011 (Ministry of Agriculture, 2011). Fragmentation index used in this study were CA (class area), NumP (number of patch), MPS (mean patch size), PSSD (patch size standard deviation) and MSI (mean shape index). MSI could be used for describing human intervention. Dewan and Yamaguchi (2009) in Giraldo (2012) indicated that in agricultural landscape, human intervention is seen as a progression toward geometrization and simplification of the ecosystem structure. The definition of fragmentation index and the illustration of the patch can be seen in Table 1 and Figure 2.

Table 1. Definition of fragmentation index

Patch Fragmentation types		Definition
CA	Class area	Sum of areas of all patches belonging to a given class (hectar)
NumP	Number of patch	Total number of patches for each individual class
MPS	Mean patch size	Average/mean patch size (hectar)
PSSD	Patch size standard deviation	Standard deviation of patch areas (hectar)
MSI	Mean shape index	Shape Complexity.MSI is greater than one, MSI = 1 when all patches are circular (polygons) or square (grids). MSI = sum of each patches perimeter divided by the square root of patch area (hectares) for each class (Class Level)



(a) (b)

Figure 2. Illustration of patch: (a) vector format and (b) raster format

Correlation between Paddy Field Fragmentaion Index

Fragmentation index to indentify paddy field fragments is NumP because many patch of paddy field show increasingly fragmented. To obtain other indices that describe agricultural fragmentation, correlation analysis was carried out with NumP. Furthermore fragmentation indexes are used for clustering fragmented levels. The correlation was calculated based on Formula (1), where *X* is NumP and *Y* is another fragmentation indexes, *r* is correlation coefisient and *n* is number of data.

$$r = \frac{n\sum XY - \left(\sum X\right)\left(\sum Y\right)}{\sqrt{\left(n\sum (X)^2 - (\sum X)^2\right)\left(n\sum (Y)^2 - (\sum Y)^2\right)}}$$

Grouping of Districts based on Fragmentation Index of Paddy Field

Data standardization was carried out prior to dendogram analysis due to the different measurement units of the fragmentation index. Data standarization of data (CA and NumP) is done based on Formula (2), where Z is standarizaion value, *x* is data of fragmentation index, *xrata* is mean of fragmentation index, *s* is standard deviation and n is number of data.

$$Z = \frac{(x - xrata)}{s}$$

Cluster analysis cunducted by using cluster dendogram for grouping districts based on the fragmentation index of paddy field to identify hierarchy of clusters. This method started with calculating distances from each individual to all another using euclidean approach. Groups are then formed by a partitioning process with objects allowed to move in or out of groups at different stages of the analysis (Manly 1988). Cutting of dendogram based on the largest clustering distance (Dillon da Goldstein 1984). Event the dendogram concept is already old but it still relevant to be used for many researches, like (Utari & Hanun, 2021) and (Sampurna et al., 2017). The calculation of Euclidean distance presented by Formula 3, where d_{ij} is euclidean distance, *x* is data of fragmentation index.

$$d_{ij} = \sqrt{\sum_{k=1}^{p}(x_{ik} - x_{jk})^2}$$

RESULT AND DISCUSSION

Relationship between Fragmentation Indexes of Irrigated and Rainfed Paddy Field

Table 2 shows that relationship between the fragmentation index of irrigated and rainfed of paddy field give the deferent result, where R^2 values in the irrigated higher than in the rainfed paddy field. The relationship between the fragmentation index of irrigated paddy field has a pattern where the larger the irrigated paddy field area (CA) is followed by the increasing number of patches (NumP) and patch size standard deviation (PSSD) as indicated by R^2 values of 0,9 and 0,7 respectively. In addition, the patch size standard deviation (PSSD) correlates linearly with the mean patch size (MPS) and the mean shape index (MSI) with R^2 values of 0.8 and 0.6 respectively. So that the larger the irrigation paddy fields (CA) will be followed by icreasing of the number of patches (NumP), the mean patch size (MPS), the patch size variation (PSSD) and the patch shape complexity/Index (MSI).

The fragmentation indexes of rainfed paddy field with significant correlation are the area (CA) with the number of patch (NumP) and the patch size standart deviation (PSSD) with the mean size patch (MSP) indicated by the R^2 value 0.9 and 0.8 respectively. Other fragmentation indexes do not have a significant relationship.

Fragmentation Indexes of Irrigated and Rainfed Paddy Field for whole Cianjur

Table 3 shows that rainfed paddy field in Cianjur Regency are more fragmented than irrigated paddy field that indicated by high number of polygon (NumP) and also high area (CA). The mean patch/polygon size (MPS) of irrigated paddy fields (2.8) is higher than that of rainfed paddy fields (1.5). This phenomenon naturally occurs because irrigated paddy fields are located on a flat topography for effectiveness of irrigation canals flow. The polygon shape of irrigated paddy fields is more rounded than rainfed paddy field, which is indicated by a higher MSI value.

Grouping of Districts based on Fragmentation Index of Irrigated Paddy Fields

The dendogram of the fragmentation index of irrigated paddy fields (Figure 3) resulted in 3 clusters (Figure 5a) that have differences in statistical values (maximum, mean, minimum) as shown in Table 4. In general, the higher the class, the more fragmented land, which is indicated by the high value of the irrigated paddy field area (CA) and the number of patch (NumP), while the mean size of patch (MPS), the standard deviation (PSSD) and the shape index (MSI) are not fragmentation marker.

Table 2. Correlation between fragmentation indexes

	Irrigated paddy field						Rainfed paddy field				
	CA	NumP	MPS	PSSD	MSI		CA	NumP	MPS	PSSD	MSI
CA	1					CA	1				
NumP	0,9	1				NumP	0,8	1			
MPS	0,5	0,3	1			MPS	0,2	-0,2	1		
PSSD	0,7	0,5	0,8	1		PSSD	0,2	-0,1	0,9	1	
MSI	0,4	0,3	0,4	0,6	1	MSI	-0,1	-0,2	0,2	0,1	1

Tabel 3. Fragmentation Indexes of Irrigated and Rainfed Paddy Field for whole Cianjur

Index fragmentation		Irrigated of paddy field	Rainfed of paddy field
CA	(hectars)	29,758.7	36,890.4
NumP	(polygon)	10,543	24,897
MPS	(hectars)	2.8	1.5
PSSD	(hectars)	8.2	4.7
MSI	(no unit)	3.1	1.8

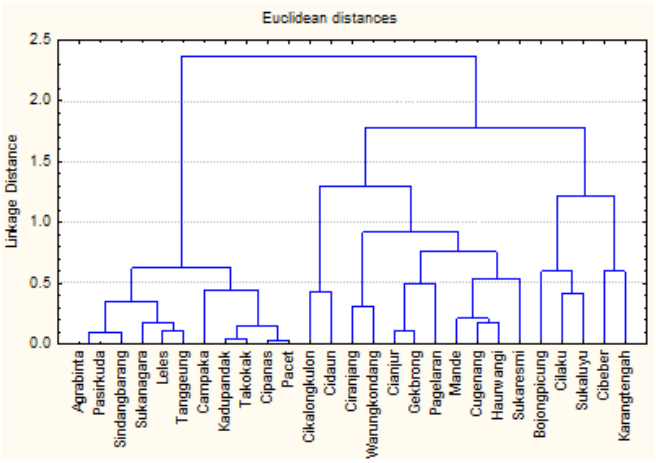


Figure 3. Dendogram of Fragmentation Index of Irrigated Paddy Field

Group 1 is characterized by districts that have the small irrigated paddy field area (CA) and a small number of patch (NumP) and also a very small patch size (MPS) of 2,9 Ha. The complex patch shape shown by the value of MSI > 1 and the small PSSD value indicating that the districts in this group have a small patch size variation as well. The number of districts in this group are 11 districts (34%) with 6 districts in the central, 3 districts in the southern and 2 districts in the northern. The fragmentation of irrigated paddy field in the central and southern parts are affected by the topography, where the paddy fields are on plains (slope < 8%) between the hilly and mountainous structural so that patterned a small and scattered. The districts of this cluster are located away from the road so that it will be safe from the threat of conversion to the built up area. The irrigated paddy field in northern is well established so that farmers are not easy to convert their irrigated paddy field (main livelihood).

Group 2 is characterized by districts that have the irrigated paddy fields (CA), standard deviation (PSSD) and mean patch size (MPS) values higher than cluster 1 and number of patches much higher than cluster 1. This indicates that group 2 is more fragmented compared to cluster 1. The complexity of the patch shape of the irrigated fields in group 1 is almost the same as group 2 indicated by the value of MSI> 1. The number of districts in this group are 11 districts (34%), mostly 9 districts in the northern and 2 districts, respectively in the central and southern. The fragmentation of irrigated paddy field in the central and southern parts are affected by topography because the paddy fields are obtained on the plains between the hilly and mountainous structures (slope <8%) so that patterned a small and scattered. The irrigated paddy fields in northern Cianjur Regency are flat (<8%) and close to urban areas so that several roads through irrigated paddy fields become smaller stretches.

Group 3 is characterized by districts that have the highest value in all parameters of fragmentation index of irrigated paddy fields, namely the area (CA), the number of patch (NumP), the average polygon size (MPS), the standard deviation (PSSD) and the MSI value compared to groups 1 and 2. This shows that group 3 more fragmented than group 1 dan 2. The districts in Cianjur Regency included in this group are 5 districts (16%) and all of them are located in the northern. The fragmentation of irrigated paddy fields in this group are affected by land convertion. Irrigated paddy fields are on flat land (<8%) and wide but are located in urban area and bypass Bogor-Puncak Road so that they have potential to be converted into built up area.

Grouping of Districts based on Fragmentation Index of Rainfed Paddy Fields

The dendogram of the rainfed paddy fields fragmentation index (Figure 4) resulted 3 groups (Figure 5) that have differences in statistical values (maximum, mean, minimum) (Table 3). In general, the higher the group indicates the more fragmented as characterized by the value of irrigated rice field (CA), the number of polygons (NumP), while the mean size of the polygon (MPS), the standard deviation (PSSD) and the polygon form (MSI) are not fragmentation marker.

Group 1 is characterized by districts that have the small rainfed paddy field area (CA) and a small number of patch (NumP) and also a very small patch size (MPS) of 1,6 Ha. The complex patch shape is shown by the value of MSI > 1 and the small PSSD value indicating that the patch size have a small variation as well. The districts in Cianjur Regency included in this group are 19 districts (59%) spread over 11 districts in the northern, 6 districts in the central and 2 districts in the southern. Fragmentation of rainfed paddy fields in this group are affected by topography and land convertion. The rainfed paddy fields in northern, central and southern Cianjur located on the slopes of volcanoes (8-25%) with a terrasering system and also found in dead river channels with following a river pattern. However, especially for the rainfed paddy fields in the northern are located around urban area and bypass Bogor-Puncak Road so that they have potential to be converted into built up area.

Group 2 is characteriszed by districts that have the rainfed paddy field (CA), the number of patch (NumP), the standard deviation (PSSD), the mean patch size (MPS) values higher than group 1. This means that group 2 is more fragmented than group 1. The complexity of the patch shape from the irrigated fields in group 1 is almost the same as group 2 indicated by the value of MSI> 1. The districts in Cianjur Regency included in this group are 2 districts located in central and southern. The fragmentation of rainfed paddy fields in this group are affected by topography. The rainfed paddy fields in central and southern Cianjur found on the slopes of the hilly and mountainous structures (8-25%) with a terrasering system and also found in dead river channeles with following a river pattern.

Group 3 is characteristic by districts that have the rainfed paddy fields (CA) smaller than group 2 but the highest in number of patch (NumP). This means that group 3 more fragmented than group 1 and 2. The districts in Cianjur Regency included in this group are 6 districts spread over 1 district in central and 5 districts in southern. The fragmentation of rainfed paddy fields in this group are affected by topography. The rainfed paddy fields in central and southern Cianjur found on the slopes of the hilly and mountainous structures (8-25%) with a terrasering system and also obtained in the dead river channel with following a river pattern.

Table 4. Cluster of Districts based on Fragmentation Index of Irrigated Paddy Field

District	Statistik value	Fragmentation Idex of Irrigated				
		CA (Ha)	NumP	MPS (Ha)	PSSD	MSI
GROUP 1						
Cipanas, Pacet (**north**),Campaka, Kadupandak, Pasirkuda, Takokak,Tanggeung,Sukanagara (**center**), Agrabinta, Leles, Sindangbarang (**south**)	Maximum	413,8	297	12,0	8,6	5,6
	Mean	200,6	122	2,9	4,5	2,8
	Minimum	2,9	5	0,6	0,6	1,4
GROUP 2						
Cianjur, Cikalongkulon, Ciranjang, Cugenang, Gekbrong, Haurwangi, Mande, Sukaresmi, Warungkondang (**north**), Pagelaran (**center**), Cidaun (**south**)	Maximum	1882,0	789	6,2	21,7	4,3
	Mean	1293,0	488	3,5	10,6	2,7
	Minimum	670,0	328	1,2	3,0	1,6
GROUP 3						
Bojongpicung, Cibeber, Cilaku, Karangtengah, Sukaluyu (**north**)	Maximum	3006,8	901	26,1	52,6	6,4
	Mean	2558,5	716	10,8	26,4	4,2
	Minimum	2330,2	519	3,3	9,3	2,1

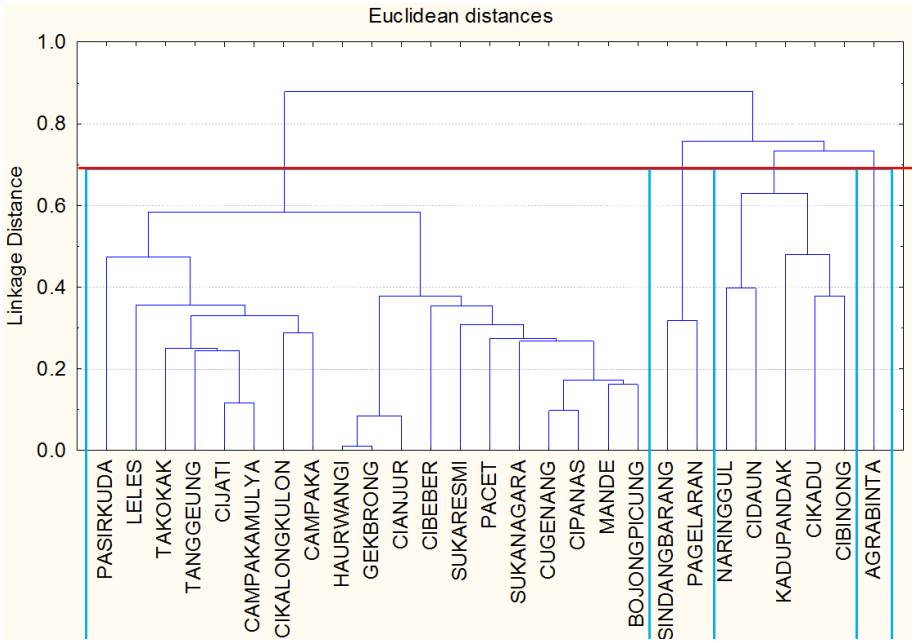


Figure 4. Dendogram of standardized fragmentation index of rainfed paddy field

Table 5. Group of districts based on fragmentation index of rainfed paddy field

District	Statistik value	Fragmentation Idex of rainfed				
		CA	NumP	MPS	PSSD	MSI
GROUP 1						
Bojongpicung, Cianjur, Cibeber, Cikalongkulon, Cipanas, Cugenang, Gekbrong, Haurwangi, Mande, Pacet, Sukaresmi (**north**), Campaka, Campakamulya, Pasirkuda, Takokak, Tanggeung, Sukanegara (**center**), Cijati, Leles (**south**)	Maximum	1799,7	1340	4,3	14,2	2,5
	Mean	758,7	534	1,6	4,3	1,9
	Minimum	11,6	10	0,6	1,2	1,5
GROUP 2						
Pagelaran (**center**), Sindangbarang (**south**)	Maximum	2954,4	1115	2,8	10,2	1,8
	Mean	2833,5	1041	2,7	8,7	1,8
	Minimum	2712,7	967	2,6	7,2	1,8
GROUP 3						
Kadupandak (**center**), Agrabinta, Cibinong, Cidaun, Cikadu, Naringgul (**south**)	Maximum	3459,2	2399	2,3	7,0	1,8
	Mean	2675,3	1882	1,5	4,1	1,7
	Minimum	1969,2	1510	1,1	2,5	1,6

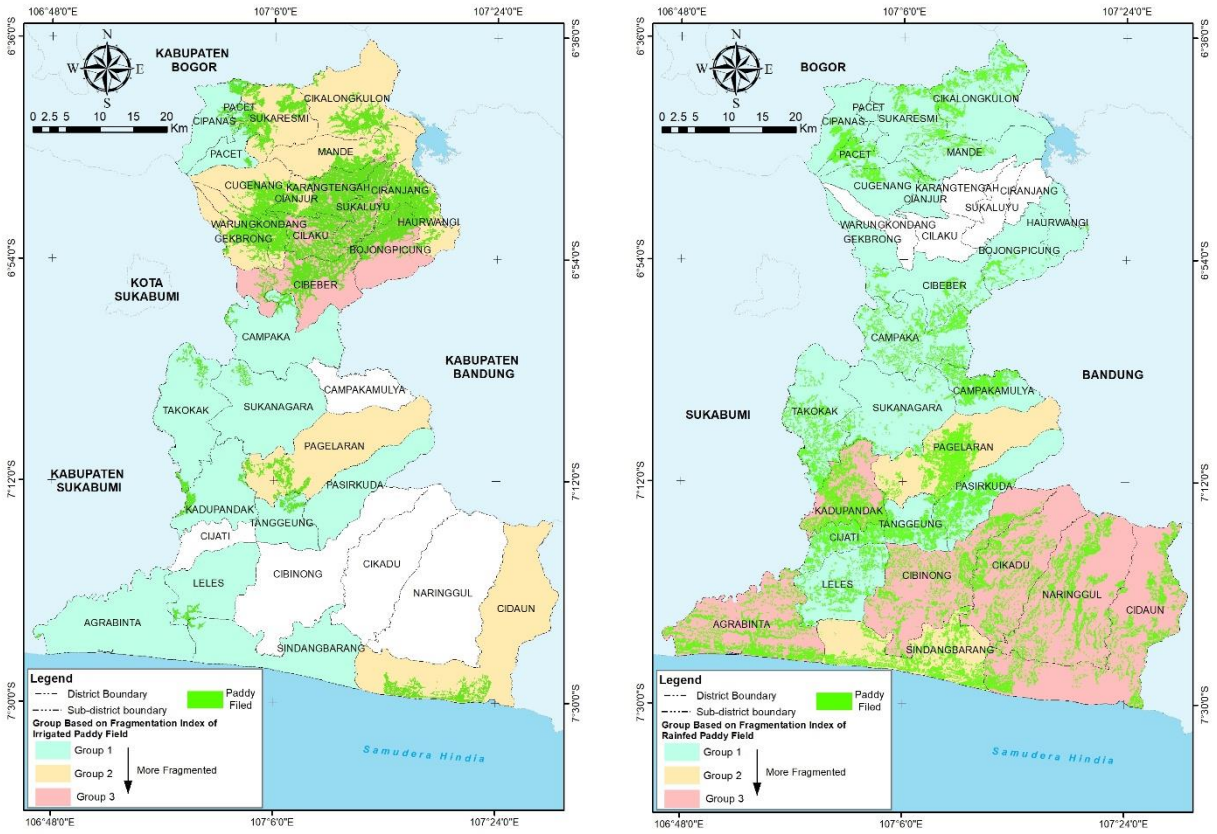


Figure 5 Grouping Districts based on Fragmentation Index of Irrigated Paddy Field (a) and Rainfed Paddy Field (b)

CONCLUSION

The grouping of the districtcs in Cianjur Regency based on the fragmentation indeks of the irrigated and rainfed paddy fields resulted in 3 groups each having different statistical values (maximum, mean, minimum). The higher the class indicates the more fragmented one identified by the value of area (CA) and the number of patchs (NumP), while the other parameters area less able to characterize fragmentation.

Fragmentation of irrigated and rainfed paddy fields in northern part of Cianjur Regency is more due to land conversion factor. The irrigated paddy fields found on the plains with slope (<8%) while the rainfed paddy fields found on the volvanic slope (8-25%) with terrasering system and in the dead river channel with following a river pattern. In addition, they are also found on the urban area traversed by the Bogor-Puncak road so that potential for convertion into built up area

Fragmentation of irrigated and rainfed paddy fields in central and southern Cianjur Regency is influenced by topography factor. The irrigated paddy fields are found on plains (slope< 8%) between the hilly and mountainous structures so the pattern is a small and scattered. The rainfed paddy fields are found on the slopes of the hilly and mountainous structures (8-25%) with terrasering system and also located in the dead river channel with following a river pattern.

ACKNOWLEDGMENTS

This paper is supported by Manistry of Research, Technology and Higher Education in term of collecting data on the field through the research funds.

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