Spatial pattern of paddy fields and rice mills in Mande, Karangtengah and Cilaku Districts, Cianjur Regency, West Java, Indonesia

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Abstract. Cianjur Regency is one of granary area in West Java Province which produces an average of 847,741 tons/year and ranks 5-7th at West Java Province during 2010-2015. This rice production should to be supported with rice milling infrastructure to convert paddy to rice. In general, location and number of rice mills are related to location and area of paddy field because they need each other. Objectives are to analysis spatial pattern of paddy fields and rice mills using nearest neighbor distance and relationship between area of paddy fields and number of rice mills using regression. Results show that spatial pattern of paddy fields in Mande, Karangtengah, Cilaku District are clustered, dispersed, clustered, respectively. This difference is due to topography, where land with hilly or mountainous topography, the spatial pattern of paddy fields is clustered on flat land. The spatial pattern of rice mills in Mande, Karangtengah, Cilaku District are clustered, clustered, dispersed, respectively. This rice mill is located along the road, therefore rice mills are clustered on tight road, flat topography and around the paddy fields. The relationship between area of paddy fields and number of rice mills in Mande and Cilaku Districts are strong (r² = 0.62, r² = 0.64), while Cilaku District is sufficient (r² = 0.37).

1. Introduction
Cianjur Regency is one of granary area in West Java Province. On the period of 2010-2015, the Regency has produced of rice of 862,229 ton, 790,824 ton, 868,538 ton, 882,662 ton, 830,545 ton and 851,650 ton rice in turn [1]. The contribution of Cianjur Regency to supply the rice demand for West Java Province on that period in ranking 5, 5, 6, 5, 5, and 7 in turn [1]. The data shows that the Regency had an important position in term of rice production. Unfortunately, the area of paddy fields in the Regency lately tends to decrease due to the land conversion i.e from agricultural to build up area. Paddy field in Cianjur Regency in the year 2000-2015 periods has decreased about 5,438.4 ha, because of converting into built up area and dry land [2]. Meanwhile, land rent of paddy fields were (44.12 – 1,070.44 Rp.-)/m²/year in compare to (208.33 – 35,069.44 Rp.-)/m²/year for settlement [3]. It shows that the land rent of settlement was (5-33) times higher than the paddy field.

The phenomenon described above seems affect to declining of rice mills number in the Regency, because both of them have a function as a suppy and demand. The basic objective of a rice milling system is actually remove the husk and the bran of rice and to produce an edible, white rice that is
sufficiently milled and free of impurities [4]. In this paper, “paddy” means crude rice with husk and bran, and “white rice” means rice for edible and just before cooking. Rice mills are every company that is driven by mechanical power and is intended and used to work paddy into white rice (beras) [5]. Rice milling is one of production infrastructure that has a vital role to support the availability of rice. According to the Survey of harvest and post harvest in 2005-2007, the conversion of dry paddy (Gabah Kering Giling/GKG) for milling into white rice (beras) was 62.74 % [6].

In compare to several ten years ago, paddy fields in Indonesia were still substantial and the rice production was really abundant. Unfortunately at the time, the number of rice mills was limited, so that, there was not enough availability of rice to the demand. To overcome it, eventually, the government issued the Emergency Law No.7 of 1952 concerning the Obligations of Rice Mills and Foodstuff Trade. This regulation was issued actually in considering to 3 conditions at the time, namely the importance of food availability; welcoming the harvest season (panen raya) and the situation’s urgent for setting up the availability of rice. This situation was to face an imbalance between the amount of rice grain and the number of rice mills that threaten the availability of rice.

But now days the phenomenon was different, where the existing of rice mills are difficult to operate or getting rice grain to be milled. These phenomena can be caused among others, by the land conversion of paddy fields happened in the area. According to data of 2012, there were 182,191 rice mill companies in Cianjur Regency, where 94% were small-scale mills, 5% medium-scale and 1% large-scale mills [7]. To compare to other area in Kampar Regency (Riau Province, Sumatra) for instance, the distribution of the small-scale rice mills in that area was concentrated in a wider area of paddy field, they had a high level of production due to a high demand of milling rice [8]. And because of most farmers of the area were subsistence types, so they milled the rice when they want to consumed. In this way, the small-scale of rice mills can be operated along the year [8]. Based on the Paman’s research, there was a relationship between the location of rice fields and the location of rice mills although it is not supported by spatial data. Therefore, this study aims to identify the spatial patterns of rice fields and rice mills and study the relationship between area of paddy fields and the number of rice mills.

2. Material and Method

2.1. Study Area
The study area located in 3 districts adjoined at Cianjur Regency, i.e. Mande (9,837 ha), Karangtengah (4,841 ha) and Cilaku (5,425 ha) (figure 1). Geomorphologically, these three districts have different topography, where Mande District is characterized by a flat plain to mountainous area; District Cilaku by a flat plain to small hilly (hummock), while Karangtengah District is completely a flat plain areas (slope <8%). These geomorphic conditions seem affect the distribution of infrastructure (roads), rice mills, and paddy fields.

2.2. Data collection
Secondary data utilized in this research, viz paddy field map (scale 1:10,000) sourced from Department of Food Crop Agriculture and Horticulture, Cianjur Regency; topographic map of Cianjur Regency (scale 1:25,000) obtained from Geospatial Information Agency; and rice milling industries in 2012 obtained from Central Bureau of Statistics of Cianjur Regency. The available rice milling data was in the form of table data and no spatial data available.

Primary data used in this research was location of rice milling industries collected from field work by census techniques using GPS (Global Positioning System). Atributes of rice milling industries were collected by interviewing to the owner or employee of rice milling industries.
2.3. Spatial pattern based on average nearest neighbor (ANN)

Spatial pattern of paddy fields and rice milling industries were determined by average nearest neighbor (ANN) approach. The Average Nearest Neighbor Distance is the distance between each feature centroid and its nearest neighbor’s centroid location. Spatial pattern can be expressed by Nearest Neighbor Index (NNI) that can be calculated by formula [9] below:

\[
NNI = \frac{D_{nn}}{De}
\]

\[
D_{nn} = \frac{\sum (\min(D_{ij}))}{N}
\]

\[
De = 0.5\sqrt{A/N}
\]

Where:
- \( NNI \) : Nearest Neighbor Index
- \( D_{nn} \) : Mean nearest neighbor distance (observed distance) (m)
- \( De \) : Mean random distance (expected distance) (m)
- \( D_{ij} \) : Nearest neighbor from object i to j (m)
- \( N \) : Number of observed object
- \( A \) : Area of Mande, Karangtengah and Cilaku Districts (m\(^2\)).

Measurement of the nearest neighbor distance is based on euclidean distance (figure 2), namely that is the length of a straight line drawn between two objects [10]. This Euclidean distance was applied to vector data and can be operated very quickly on ArcGIS software. Form of spatial patterns...
can be divided into 3 types, i.e. random (NNI = 1); dispersed (NNI > 1) and clustered (NNI < 1). Ilustration of spatial pattern form are presented in figure 3.

**Figure 2.** Ilustration of euclidean distance.

**Figure 3.** Ilustration of spatial pattern forms, (a) random (b) dispersed and (c) clustered.

2.4. Correlation for analyzing relationship between area of paddy field and number of rice mills

Relationship between area of paddy field and number of rice milling industries was calculated by regression formula. A correlation is a statistical technique that showing whether and how strongly pairs of variables are related [11]. The strength of the relationship between two variables will be expressed by a correlation coefficients that was classified into 6 classes (table 1) [12]. This relationship analysis was done on each districts where every village was used as analysis unit.

\[
r_{xy} = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{n(\sum x^2) - (\sum x)^2} \cdot \sqrt{n(\sum y^2) - (\sum y)^2}}
\]

Where:
- \( r_{xy} \) : Relationship between x and y
- \( x \) : Area of paddy field on each village (ha)
- \( y \) : Number of rice milling industry on each village

**Table 1. Classification of coefficients correlation**

| Correlation coefficients | Strength of the relationship |
|--------------------------|------------------------------|
| 0                        | No correlation               |
| > 0 - 0.25               | Very weak                    |
| > 0.25 - 0.50            | Sufficient                   |
| > 0.50 - 0.75            | Strong                       |
| > 0.75 - 0.99            | Very strong                  |
| 1                        | Perfect correlation           |
3. Results and Discussion

3.1. Spatial pattern of paddy field

Paddy field is a type of land used where rice was planted, both continuously in a year or rotating with other crops [13]. Still, paddy fields have a flat or terraced surface and are bounded by embankments, so there is a pool of water for tillage. The paddy field pattern reflects the spatial arrangement of the paddy field expanse which is much influenced by many factors. Table 2 below shows that the spatial pattern of paddy fields in study area varies, where in Mande and Cilaku Districts tend to be clustered with NNI values <1, whereas in Karangtengah District tend to be dispersed (NNI> 1).

Table 2. Parameters of ANN for determining the spatial pattern of paddy fields

| Parameters                          | Mande   | Karangtengah | Cilaku  |
|-------------------------------------|---------|--------------|---------|
| Area of district (ha)               | 9,837   | 4,841        | 5,425   |
| Area of paddy field (ha)            | 1,469   | 3,047        | 2,320   |
| Number of paddy field centroid      | 962     | 1,093        | 622     |
| Mean nearest neighbor distance (Dnn) (m) | 129     | 121          | 157     |
| Mean random distance (De) (m)       | 217     | 116          | 170     |
| Nearest Neighbor Index (NNI)        | 0.59    | 1.05         | 0.92    |
| Spatial pattern                     | Clustered | Dispersed   | Clustered |

Geomorphologically, general slope of Mande District varies from flat (<8%) in plain area to steep (≥ 25%) in mountainous area, but the area with slopes <8% (land and Cirata lake) is 33.77%. Paddy fields in Mande District spatially have been clustered both on flat areas found in the eastern and south part or clustered in valley area found in the western part (figure 5a). The paddy plots and breeding ponds are situated near the valleys [14].

Meanwhile, around 64.13% of Cilaku District’s topography is a flat area (<8%) and the rest are composed by small hills or hummock that have slopes from gentle (8-15%) to rather steep (15-25%). In this area the clustered pattern of Paddy fields can be found in flat areas in the west and northeast part (figure 5b). The spatial pattern of paddy fields in Mande District is more clustered than in the Cilaku District as indicated by its smaller NNI value.

Karangtengah District is spatially dominated by flat slopes (<8%) reach around 98.51% and remaining a small hills (hummock) with gentle slopes (8-15%). In this area paddy fields spread on flat plain evenly (figure 5c). Paddy production (dry paddy harvest or GKP) in Mande, Karangtengah, and Cilaku District for the last 5 years, were 18,843 tons/year, 47,067 tons/year and 24,704 tons/year respectively [15].

Distribution of paddy fields in Mande, Karangtengah, and Cilaku Districts was more influenced by geomorphologic aspect or topographic conditions than infrastructure (roads) due to better water availability. The type of paddy fields in the Mande, Karangtengah, and Cilaku Districts was dominated by irrigated paddy fields successively covering about 75.18%, 100%, 100% of their area. The dominant distribution paddy field was mainly on flat slopes (<8%), and the value is 33.77% in Mande, 98.51% in Karangtengah, and 64.13% in Cilaku. If regarded from distance from local or village road, the dominant existence of paddy field on the distance of 100-200 m was 87.10%, 86.70% and 95.25% consecutively for Mande, Karangtengah and Cilaku Districts. In general pattern, land on the distance of <100 m from the road has been used for built up area, and land on the distance of > 200 m from the road competing with other land uses, such as mixed gardens, forests etc.
3.2. Spatial pattern of rice mills
Field verification results show that the number of rice milling industries in 2017 has changed in compared to 2012 (table 3.). This is due to the fact that some of the rice milling industries were not found in the field area in 2017, such as the case in the Mande and Karangtengah District. In addition, the number of rice mills in the Cilaku District increased, because there was a new milling industry, or the rice mills inventarisation in 2012 might be incomplete.

| Districts     | 2012 Operational | 2017 Operational | 2017 Not operational | Total |
|---------------|------------------|------------------|----------------------|-------|
| Mande         | 63               | 47               | 7                    | 54    |
| Karangtengah  | 111              | 85               | 10                   | 95    |
| Cilaku        | 105              | 93               | 20                   | 113   |

Table 4 shows that the spatial pattern of rice mills in Mande and Karangtengah Districts is clustered (NNI<1), while that in Cilaku District is dispersed (NNI>1). The spatial pattern of rice mills are predominantly affected by infrastructure (road) because of the ease of accessibility in paddy transportation. Figure 5 shows that rice mills in Mande, Karangtengah and Cilaku Districts spread...
along the road at a distance of <100 m from the road, which is around 87.04%, 88.42%, 91.15%, respectively. Rice mills in Mande District are clustered in the eastern and central part, because the road network of the parts is denser than in the western part with steep slopes (>25%). Rice mills in Karangtengah District cluster in the southeast and northeast part because the road network is more dense. Another phenomenon, it appears that the road is denser in the northern part but is not found the rice mill grouping, because it is rarely paddy field. Rice mill in Cilaku District spreads almost evenly in the region in accordance with the development of the road network and topography.

Table 4. Parameters of ANN for determining the spatial pattern of rice mills

| Parameter                        | Mande  | Karangtengah | Cilaku |
|----------------------------------|--------|--------------|--------|
| Area of district (ha)            | 9,837  | 4,841        | 5,425  |
| Number of rice mills             | 54     | 95           | 113    |
| Observed mean distance (Dnn) (m) | 543    | 327          | 372    |
| Expected mean distance (De) (m)  | 675    | 359          | 343    |
| Nearest Neighbor Index (NNI)     | 0.80   | 0.91         | 1.08   |
| Spatial pattern                  | Clustered | Clustered    | Dispersed |

Figure 5. Distribution of rice mills in (a) Mande; (b) Karangtengah, (c) Cilaku
3.3. Relationship between paddy fields and rice mill

Paddy produced from rice fields must be processed into rice, so that it can be consumed by the community. Rice milling is one of the infrastructures used to convert paddy into rice. Therefore, the more rice production is needed the more rice mills. As mentioned at “Introduction” at 2005-2007 the conversion from dry paddy (Gabah Kering Giling/GKG) for milling to rice is 62.74%. The conversion yields from dry paddy (Gabah Kering Giling/GKG) for milling to rice in Mande, Karangtengah, and Cilaku Districts were 53.61%, 53.13% and 52.90% respectively [15]. The conversion yield in these three districts is lower than the national conversion yield.

Figur 6 shows the flow diagram of conversion from paddy to rice, where the harvested paddy will be threshed and cleaned and then (1) sold in the form of (dry) paddy harvested (Gabah Kering Panen/GKP); (2) dried, cleaned and milled and polished which produces such as rice, husk, bran, broken rice (menir). In general, Indonesian farmers will store some of the harvested paddy for their family’s needs until the next harvest. The threshed paddy is dried, cleaned and stored. The paddy will be milled according to family’s needs. The rest will be sold by farmers in the form of harvested (dry) paddy (Gabah Kering Panen/GKP). This sale and purchase transaction is carried out in fields after harvest.

![Flow diagram of converting from paddy to rice](image)

**Figure 6.** Flow diagram of converting from paddy to rice

Figure 7 shows that the correlation equation is positive, meaning that a large area of paddy field will be supported by a high number of rice mills. This phenomenon is found in Mande, Karangtengah and Cilaku District, but is different in terms of its relationship strength. The relationship between the area of paddy fields with the number of rice mills in Mande and Cilaku District is relatively similar in strength ($r^2 = 0.62$ and $r^2 = 0.64$) and is stronger than in Karangtengah District ($r^2 = 0.37$). Mande and Cilaku Districts have a strong linear relationship between the area of paddy fields and the number of mills, while Karangtengah District has weak linear relationships. In general, the large rice milling industry will buy paddy from outside Cianjur Regency, such as Kerawang, Subang, Sukabumi Regency, because the paddy supply from Cianjur Regency did not reach the specified target.
4. Conclusions
The spatial patterns of paddy fields in Mande, Karangtengah and Cilaku Districts are clustered, dispersed, clustered, respectively. The spatial pattern of paddy fields is influenced by topography where paddy fields are clustered on flat land and valley between hills or mountains. The spatial pattern of rice mills in Mande, Karangtengah and Cilaku Districts, are clustered, clustered, and dispersed, respectively. The spatial pattern of rice mills is more influenced by roads because rice mills are spread along the road (local road/village road). Rice mills are clustered on dense roads. However, the topography and location of paddy fields also affect the spatial pattern of rice mills although not as strong as roads.

The correlation equation is positive, meaning that a large area of paddy field will be supported by a high number of rice mills but is different in terms of its relationship strength. The relationship between the area of paddy fields with the number of rice mills in Mande and Cilaku District is relatively the same strength with $r^2 = 0.62$ and $r^2 = 0.64$ respectively, but stronger than in Karangtengah District ($r^2 = 0.37$).

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