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Analysis of Rice Availability in Indonesia Using Multi-Dimensional Scaling

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Abstract

One major problem faced in increasing rice production is that Indonesia still relies on Java Island to be the main rice producer. Until today, about 55 percent of rice production comes from Java Island, while the rest is produced in other islands. The large size of Indonesia with its diverse natural resources has caused a production discrepancy among the regions. This disparity often causes rice insufficiency in some areas and significant rice-price differences. Therefore, a rice production mapping is required so that the potential areas for rice production can be developed while the areas with limited production can be given special attention.

One of the methods that can be used for mapping is the multidimensional scaling. Using this method, we can transform or interpret a response based on data similarity or preference into the distance represented in a multidimensional space. Based on all the rice attributes, Sumatra, Maluku, and Papua islands are similar, while Bali Island is similar to Nusa Tenggara and Sulawesi islands. Java Island is different from the other islands, while Borneo Island tends to be similar to Maluku Island, although it is located in a different quadrant from the other islands.

1. Introduction

The efforts to meet the demand of national food through self-sufficiency have not shown optimum results until now. The situation is reflected in the availability level of several domestic food commodities that still depends on imports. However, through the program of national food security enhancement in 2012, the production of strategic carbohydrate source commodities has increased by 2.74 percent for rice and by 7.38 percent for corns, while for soybeans the production has decreased by 8.24 percent.

The main problem in increasing rice production is that Indonesia keeps relying on Java Island to be the major rice producer. About 55 percent of rice production comes from Java Island, while the rest is produced in Sumatra (23 percent), Sulawesi (11 percent), Borneo (5 percent), and other islands (5 percent). With such a pattern of production distribution, Java maintains its role as the buffer of national rice (paddy) production. The extensive size of Indonesia and its various natural resources has caused a production disparity among the regions. Some regions have the excellent potential for the development of agriculture, especially rice production. Meanwhile, several other regions are unable to develop their agricultural sector due to natural resource constraint. This production gap has caused a frequent problem in which the rice demand of some regions is not fulfilled and the price of rice varies significantly. In order to fulfill the rice demand of the whole country, therefore, a mapping of rice production areas is created so that the regions with potential rice production can be developed and those with insufficient rice production can get special attention. To overcome the periodic rice-production disparity, a well-planned rice management is required so that there is no rice shortage at certain periods. The method that can be used for mapping is the multidimensional scaling (MDS). MDS is a tool used to determine the interdependence relationship among variables. Using MDS, a transformation or interpretation of response data can be performed based on the similarity or preference into a distance represented in a multidimensional space.

2. Multidimensional Scaling

MDS can determine the interdependence relationship among variables. MDS can help to determine (1) the important dimensions that are used to evaluate an object, (2) how many dimensions are considered in certain situations, (3) the relative importance of each dimension, and (4) the perceptions of relationship among objects. MDS is also known as perceptual mapping or spatial mapping (relative perceptual mapping), a procedure that can help researchers to determine the actual relative image of a set of objects. MDS is useful for transforming a response based on the similarity or preference into a distance represented in a multidimensional space. If object A and object B are similar compared to other pairs of objects, MDS will place A and B at a distance closer than the object distance of other pairs in a multidimensional space (Lee, 2001; Joseph, *et al*., 1995 and Everitt, 2005). In addition, other studies using MDS were conducted by Lee (2001) who has utilized MDS to establish a cognitive model, Ilham (2004) who conducted a study to determine the economic condition of Indonesia in relation to agricultural production, such as the factors that influence land conversion and its economic impact as well as the factors that affect production, consumption, and prices of rice (Malian, 2004). MDS can also be used to represent the proximities (closeness) between objects in the form of stimulus coordinate map. To establish the map, first, the proximity value of each island towards the overall attributes should be identified. The Euclidean distance is a distance value that can describe the proximity relationship of each island towards a particular attribute. The closer the Euclidean distance between two islands is, the more similar the two islands towards a particular attribute are. The naming of dimensions in the perception map can utilize the semantic differential analysis. Before performing a semantic differential analysis, a semantic differential graph should be first identified. After that, the naming of dimensions is conducted to determine the attributes of the x-axis and the attributes of the y-axis. Attributes are divided based on five evaluation criteria; therefore, the naming of dimensions will result in a lot of combinations and average scores. Since there is no specific guideline, the naming of dimensions on each axis in this analysis is a relative evaluation based on the researcher's point of view, information analysis, as well as other relevant bases. The approach in this study uses the values resulted from an observation towards the positions of islands and the semantic differential scales. These semantic differential scales are useful to identify the position of each island based on evaluative criteria.

A stress value is defined as a measurement used to determine an MDS model or to reflect suitability in MDS. A stress value indicates whether the model is good or not. The smaller the stress value is, the better the model is. The benchmark of stress value is taken from Kruskal's stress formula that follows the Malholtra criteria. The formula can be seen in Table 1. According to Steyvers (2000), the following formula can be used to determine the stress value:

$$S = \sqrt{\frac{\sum_{ij}\left(d_{ij} - {d_{ij}}^{*}\right)^2}{\sum_{ij} {d_{ij}}^2}}$$

where d_{ij} is the distance between points i and j calculated from the stimulus coordinates in the stimulus space of each dimension, while ${d_{ij}}^*$ represents trasformation disparities.

Table 1 Stress Value and the Established Conditions

stress (percent)	Condition
20	Bad
10	Moderate
5	Good
2,5	very good
0	Perfect

3. Method

This study uses secondary data retrieved from BPS (Statistics Center Agency) and Ministry of Agriculture. The research steps are as follows:

a. identifying factors that affect rice availability
b. scoring the data, i.e. transforming the data into ordinal forms
c. identifying the average score of each island
d. identifying the Euclidean distance of the islands based on the average score
e. conducting a multidimensional-scaling analysis for the obtained Euclidean distance
f. conducting a semantic differential analysis by drawing a semantic differential graph
g. determining the x-axis and y-axis based on the semantic differential analysis
h. interpreting the perception map obtained from the MDS analysis
i. conducting a leverage analysis
j. identifying the leverage analysis image of the average score
k. interpreting the analysis results and drawing conclusions

4. Results and Discussion

In this study, the factors that affect rice production (Y) are crop extent (X_1), precipitation (X_2), humidity (X_3), temperature (X_4), irradiation duration (X_5), average rice price (X_6) and total number of labors (X_7). The data include all provinces in Indonesia. In the MDS analysis, the examined attributes will be grouped into economic and ecological aspects. For the economic aspect, the rice data comprise such attributes as rice production (Y), crop extent (X_1), average rice price (X_6) and total number of labors (X_7). Meanwhile, the ecological aspect consists of such attributes as rice production (Y), precipitation (X_2), humidity (X_3), temperature (X_4) and irradiation duration (X_5). Prior to the analysis for mapping the attributes in economic and ecological aspects, the attribute data that have different units are scored in order to obtain data in ordinal forms by configuring class intervals.

In order to find the similarity between the islands and the attributes in terms of economic and ecological aspects, the Euclidean distance of each island should be calculated. The results show that the closer the distance between two islands is, the more similar the two islands are to the related attributes. To clarify these results, a

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mapping will be conducted by determining the stimulus coordinates in terms of economic and ecological aspects followed by generating the perception map.

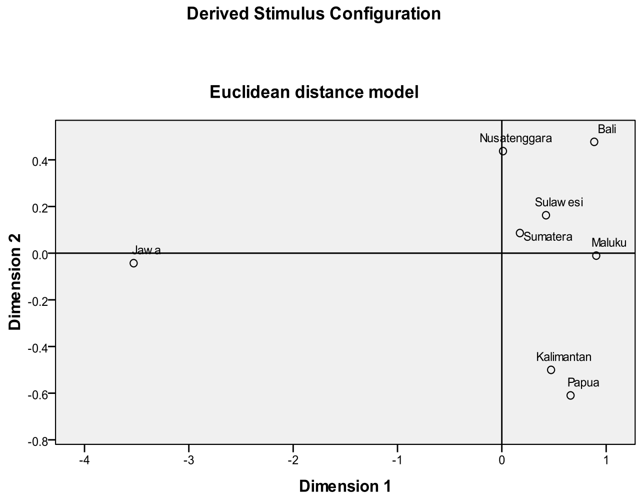

Figure 1. Rice Perception Map from Economic Aspect

Figure 1 shows that from the distance of islands on the map, the economic aspect of rice attributes for Nusa Tenggara, Bali, Sulawesi, Sumatra, and the Maluku islands is similar to each other, while that for Borneo island is similar to the one for Papua. However, Java Island is less similar to the other islands because of its distant position from those islands. The obtained stress value from the economic aspect as high as 0.06008 indicates that the MDS analysis has been well performed.

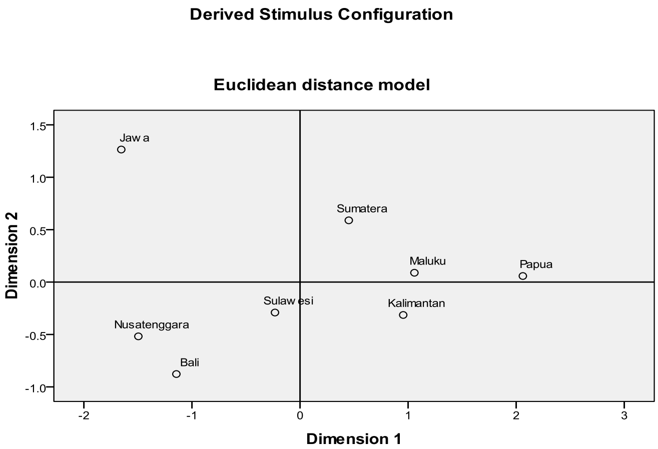

Figure 2. Rice Perception Map from Ecological Aspect

Figure 2 shows that from the distance of islands on the map, the ecological aspect of rice attributes for Sumatra, Maluku and Papua islands is similar to each other, while the one for Nusa Tenggara Island is similar to that for Bali and Sulawesi islands. However, because Java Island lies on a different quadrant from the other islands, it has a less similarity compared to those islands. This situation also occurs to Borneo Island as it is less similar to the other islands. The stress value of 0.01020 indicates that the MDS analysis has been well conducted.

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Next, a comprehensive analysis is conducted towards all the rice attributes in terms of economic and ecological aspects for all the islands in Indonesia. Using the same steps, the average score of all attributes and the Euclidean distance are obtained. The Euclidean distance is then used to determine the coordinate points of each island shown in Table 2 and further illustrated in the perception map of overall attributes for all the islands in Indonesia as shown in Figure 3.

Table 2 Overall Stimulus Coordinates of Rice

Stimulus	Dimension	
	1	2
Sumatera	0,3632	0,4737
Java	-1,9869	1,3999
Bali	-0,8141	-1,0935
Nusa Tenggara	-1,2397	-0,7807
Borneo	0,9599	-0,0887
Sulawesi	-0,1623	-0,3611
Maluku	0,9049	0,0558
Papua	1,8523	3947

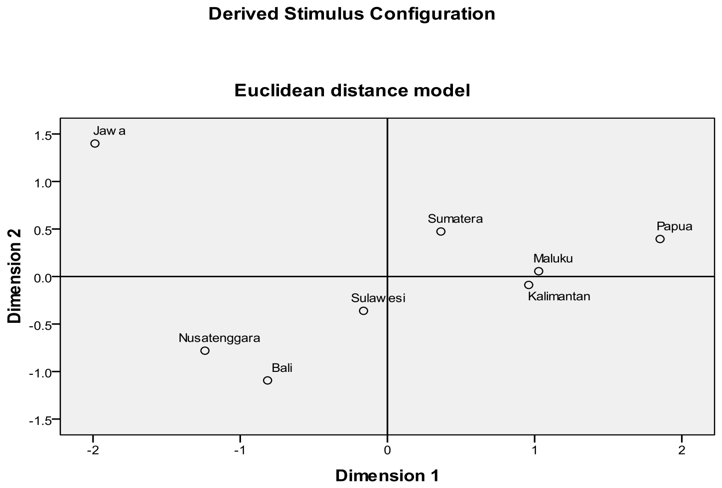

Figure 3. Perception Map of Overall Rice Attributes

From Figure 3, considering the overall attributes, it can be seen that Sumatra, Maluku and Papua islands have a similarity to each other, while Bali Island is similar to Nusa Tenggara and Sulawesi islands. Java, however, is quite different from the other islands, and Borneo Island, although located in a different quadrant from the other islands, tends to be similar to Maluku Island. The obtained stress value is 0.02734, which means that, according to Table 1, this analysis is very well performed. To explain Figure 3 more vividly, a naming of dimensions is required for the attributes in this analysis. Therefore, a semantic differential analysis is conducted by first drawing a semantic differential graph as shown in Figure 4.

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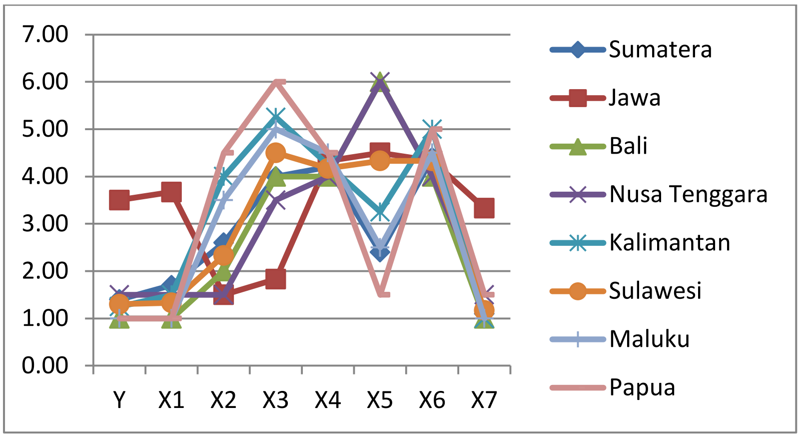

Figure 4. Semantic Differential Graph of the Eight Rice Attributes for the Islands in Indonesia

Figure 4 shows that, in general, there is no definite segment on each island because each of the attributes indicates a varied segment; consequently, a further analysis is required to classify the attributes according to the segments available. Therefore, Figure 4 is divided into five evaluation criteria, namely the evaluation I *(Y*, X_1, X_7), evaluation II (X_2), evaluation III (X_3), evaluation IV (X_4, X_6), and evaluation V (X_5). The five evaluations are then described in five semantic differential graphs. Evaluation I is depicted in Figure 5 below.

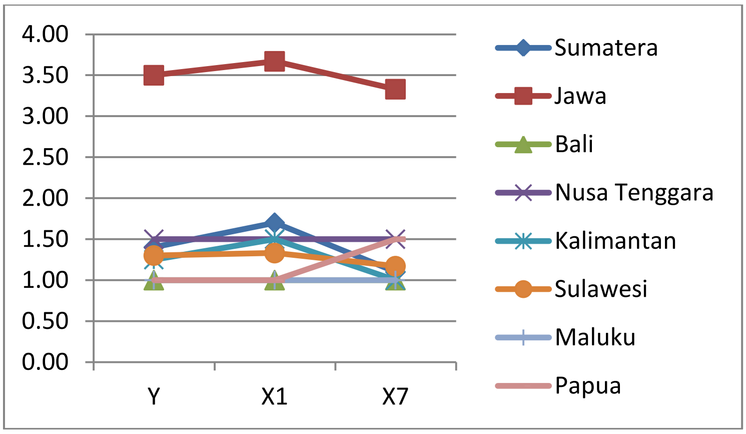

Figure 5. Semantic Differential Graph of Rice Production, Crop Extent, and Total Number of Labors Attributes

Figure 5 indicates that the rice production, crop extent, and total number of labors attributes are divided into two segments, which include the segment of Java Island and the segment of Sumatra, Bali, Nusa Tenggara, Borneo, Sulawesi, Maluku and Papua islands. Evaluation II is depicted in the semantic differential graph shown in Figure 6 below. Figure 6 shows that the precipitation attribute is divided into three segments, namely the first segment consisting of the islands of Papua, Borneo, Maluku, the second segment comprising the islands of Sumatra, Sulawesi, Bali, and the third segment including the islands of Java and Nusa Tenggara.

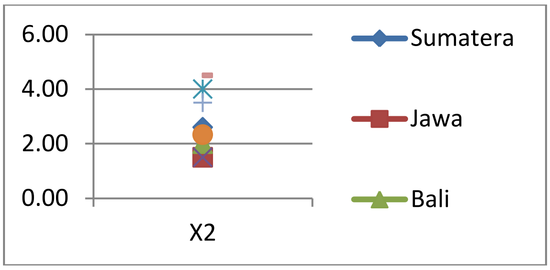

Figure 6. Semantic Differential Graph of Precipitation Attribute

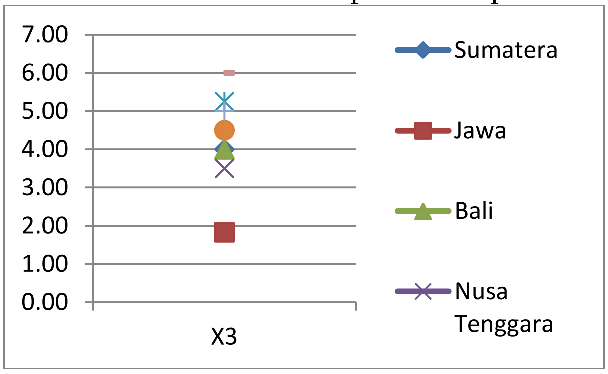

Figure 7. Semantic Differential Graph of Humidity Attribute

Evaluation III for humidity attribute is illustrated in Figure 7. From Figure 7, it can be seen that the humidity attribute is divided into six segments. The first segment includes Papua Island, and the second segment consists of the islands of Borneo and the Maluku. The third segment includes Sulawesi Island, and the fourth segment consists of the islands of Sumatra and Bali. Meanwhile, the fifth segment consists of Nusa Tenggara Island, and the sixth segment includes the island of Java. Evaluation IV for the temperature and average rice price attributes is illustrated in Figure 8 below.

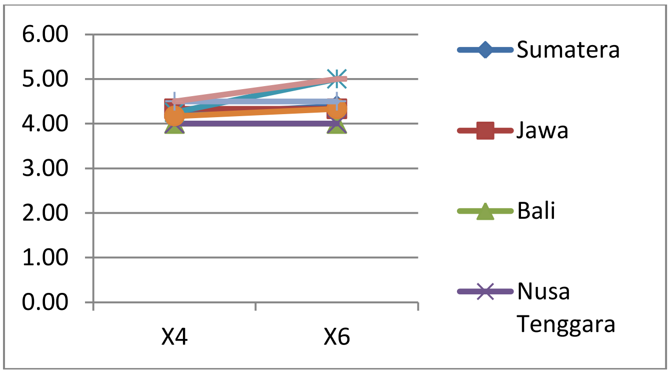

Figure 8. Semantic Differential Graph of
Temperature and Average Rice Price Attributes

From Figure 8, it is clear that the temperature attribute is divided into three segments, i.e. the first segment consisting of the islands of Maluku and Papua, the second segment comprising the islands of Java, Sumatra, Sulawesi, and the third segment including the islands of Nusa Tenggara and Bali. Meanwhile, the average rice price attribute is divided into three segments in which the first segment consists of the islands of Borneo and Papua, the second segment consists of the islands of Java, Sumatra, Sulawesi, Maluku, and the third segment consists of the islands of Nusa Tenggara and Bali. Evaluation V, which is the evaluation of irradiation attribute, is shown in Figure 9. Figure 9 shows that the irradiation attribute is divided into five segments where the first segment consists of the islands of Nusa Tenggara and Bali, the second segment consists of the islands of Java and Sulawesi, the third segment consists of Borneo Island, the fourth segment consists of the islands of Sumatra and the Maluku, and the fifth segment consists of Papua Island.

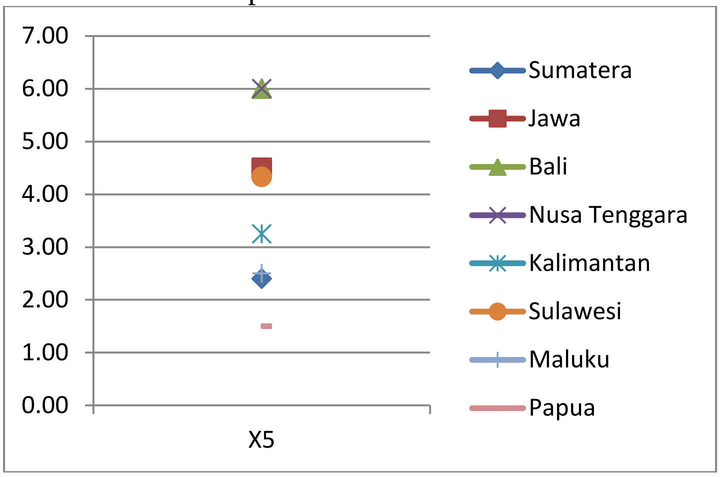

Figure 9. Semantic Differential Graph of Irradiation Attribute

After the semantic differential graphs are made, the next step is naming the dimensions of Figure 3 to determine the attributes of the X axis and the attributes of the Y axis starting from the five evaluations that will provide many combinations of the average score available. The naming of dimensions in this analysis is based on the observations towards the island locations and the semantic differential scales. These scales help to indicate the position of each island based on evaluative criteria.

Based on Figure 3, the farthest distance on the Y axis exists between the islands of Java and Bali. Of the five semantic differential graphs, the farthest distance between the islands of Java and Bali is found in evaluation I; therefore, the temporary conclusion is that the attributes of Evaluation I is the Y axis with the distance between the two islands shown in Table 3.

Table 3 Distances between Java and Bali

evaluation	Java	Bali	distance
I	3,50	1,00	2,50
II	1,50	2,00	-0,50
III	1,83	4,00	-2,17
IV	4.33	4,00	0,33
V	4,50	6,00	-1,50

To determine the X axis, Figure 3 is used. It is found here that the furthest distance exists between the islands of Java and Papua. In addition, the distance between the two islands should be observed for each evaluation. The result is presented in Table 4 below. From Table 4, it can be seen that the furthest distance between the islands of Java and Papua exists in Evaluation III; therefore, the attribute of Evaluation III is tentatively taken as the X axis.

Table 4 Distances between Java and Papua

evaluation	Java	Papua	difference
I	3,50	1,17	2,33
II	1,50	4,50	-3,00
III	1,83	6,00	-4,17
IV	4.33	4,75	-0,42
V	4,50	1,50	3,00

For other evaluations that have not been included in the X or Y axis, the farthest distance of several possibilities is calculated and presented in Table 5. Table 5 shows that the most significant difference in the first possibility for the X axis is Evaluation III, and for the Y axis, it is found in the combination of Evaluation I, II, IV, V. From these results, it can be concluded that the X axis shows the moisture and the Y axis shows the rice production, crop extent, precipitation, temperature, irradiation duration, average rice price, and total number of labors.

From Figure 3, it can be interpreted that the islands of Papua, Maluku, Sumatra, have all good attributes, while the island of Java has the good attributes of rice production, crop extent, precipitation, temperature, irradiation duration, average rice price, total number of labors, but the humidity is worse. The islands of Sulawesi, Bali and Nusa Tenggara have all worse attributes, while the island of Borneo has a good humidity attribute, but its attributes of rice production, crop extent, precipitation, temperature, irradiation duration, average rice price, and total number of labors are less favorable.

Table 5 Possible Coordinates and the Evaluation Values

possibility	coordinate	evaluation	value	difference
I	X	III	1,83	-12
	Y	I,II,IV,V	13,83	
II	X	III,II	3,33	-9
	Y	I,IV,V	12,33	
III	X	III,IV	6,16	-0,67
	Y	I,II,III	6,83	
IV	X	III,V	6,33	-3
	Y	I,II,IV	9,33	
V	X	III,II,IV	7,66	-0,34
	Y	I,V	8,00	
VI	X	III,II,V	7,66	-0,17
	Y	I,IV	7,83	
VII	X	III,IV,V	10,66	5,66
	Y	I,II	5,00	
VIII	X	III,II,IV,V	12,16	8,66
	Y	I	3,50	

5. Conclusions

Based on the results and discussion, the following conclusions are drawn. In terms of economic aspect, the rice attributes that include rice production (Y), crop extent (X_1), average rice price (X_6) and total number of labors (X_7) for the islands of Nusa Tenggara, Bali, Sulawesi, Sumatra, and the Maluku are similar, while those of Borneo Island are similar to those of Papua Island. However, Java Island has fewer similarities compared to the other islands because of its distance from the other islands. From the ecological aspect, the rice attributes of rice production (Y), precipitation (X_2), humidity (X_3), temperature (X_4) and irradiation duration (X_5) for the islands of Sumatra, Maluku and Papua are similar, while the island of Nusa Tenggara has similarities with Sulawesi and Bali islands. However, the island of Java, due to its different quadrant, is less similar to the other islands. It also occurs to the island of Borneo.

Considering all the rice attributes, Sumatra, Maluku and Papua have similarities, while Bali Island is similar to the islands of Nusa Tenggara and Sulawesi. Java Island, however, is quite different from the other islands, while Borneo Island, although located in a different quadrant, tends to be similar to the Maluku. The islands of Papua, Maluku, and Sumatra have all good attributes, while Java Island has good attributes of rice production, crop extent, precipitation, temperature, irradiation duration, average rice price, and total number of labors, but the humidity attribute is worse. Meanwhile, the islands of Sulawesi, Bali and Nusa Tenggara have less favorable attributes, while Borneo Island has good humidity attributes, but the attributes of rice production, crop extent, precipitation, temperature, irradiation duration, average rice price, and total number of labors are worse.

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