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Spatial modelling for rice production analysis in Central Java province Indonesia

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Abstract. Rice is one of staple food in Central Java province because rice is the main carbohydrate and calorie source for society in general. From year to year rice production in various regions in Indonesia shows a significant increase. Central Java is one of the provinces in Indonesia which has the agricultural sector as its main sector. However, in the last five years, the average rice production in Central Java showed a stagnant decline in value. This study was aimed to model the spatial effects on rice productivity in the cities in Central Java along with the factors that influence it. The method used is spatial modeling approach. The results of the analysis show that spatial lag X (SLX) model has the smallest AIC value, estimation result shows that rice production and harvest area have significant effect on rice productivity in Central Java.

1. Introduction

Indonesia is an agricultural country with agricultural sector as the most frequently encountered work. One of the most common cultivation crops in agricultural sector is rice plant. Agricultural sector is also one of the main components in government programs and strategies to alleviate poverty [1]. According to [2], in Indonesia, rice is a very important commodity because rice is a staple food and source of calories for the majority of the population, and the situation of rice may indirectly affect other consumption products. Rice is a staple food in Indonesia because rice is a major source of carbohydrates and calories for the society in general. According to [3], one of the goals of agricultural development is to create food security and to improve the welfare of farmers so that the government has an obligation to always strive for its availability through various steps.

Central Java Province, with Semarang city as the capital, is geographically located between East Java and West Java Provinces with an area of 3.25 million hectares or around 25.04 percent of the total area of Java (1.70 percent of Indonesia's area). Central Java Province plays an important role in regional and national economy as a food granary. Rice production in this area has a surplus and has the potential to support regional food security. The province has a total of 35 cities which are rice producers. In 2015, the largest rice producers were in Cilacap and Grobogan Regencies with the harvested areas of 138,864 and 126,935 hectares respectively.

According to the Central Statistics Agency (BPS), Central Java is nationally the third largest rice producer after West Java and East Java, with the production reaching 10.34 million tons of dry milled rice in 2013. However, the average production of rice in the last five years has stagnated. According to [4], the main problem that occurs in lowland rice farming is low productivity, which is considered to be caused by the lack of application of recommended cultivation technologies such as the use of seeds and fertilizers, environmental factors, and the socio-economic and institutional conditions of the

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farmers. In addition, the decline in rice production occurred in the last few years is supposed to be caused by the degradation of rice fields, while the rice intensification program has relatively not improved [5].

Spatial data analysis is an analysis related to the influence of location. Based on the first law about geography proposed by Tobler in [6], it states that all things are interconnected with one another, but something closer has more influence than the distant one. Spatial effect often occurs between one region and another one. In spatial data, an observation in a location frequently depends on the observation in other adjacent locations. Spatial regression is the development of classical regression analysis. This development is based on the spatial effect on the data. Spatial data cannot be applied to ordinary regression analysis because it will lead to inaccurate conclusions. In addition, the error assumption of mutually independent and homogeneity assumption is not met.

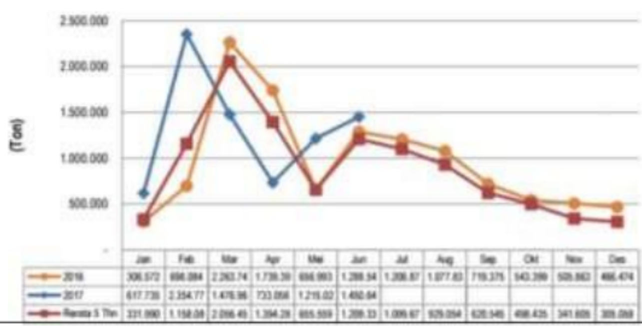

Figure 1. Rice production pattern of 2012-2017
Source: Statistics Bureau of Central Java province in 2017

Spatial regression studies had been conducted, including the research of [7] which examined the pure participation rates in Central Java Province using spatial regression. In addition, [8] examined the factors that influenced children for not going to school. The result is that the population and the number of children attending school are very influential in the number of children who did not attend school.

The studies on rice productivity had also been conducted, including the research of [9] and [10] examined the productivity of rice. In 2014, [11] also examined the productivity of rice plants in Pesawaran Regency. The results show that farmers' income has a significant effect on the productivity of rice farmers. In the research in Brazil, [12] examined the risk of diseases using spatial regression analysis. The other spatial modelling studies conducted by Karim and Wasono [13] used spatial data panel modelling to model the rice production in the Central Java Province of Indonesia. The importance of this research, the policy implications that can be made rice production in Central Java has significant spatial dependencies, which shows that the regions governments must be strengthened from a broader perspective by making targeted regional autonomy policies.

2. Methods

The data used in this study was the observation data to the Central Bureau of Statistics in Central Java for the period of 2015. The observation units in this study were the Regencies and Cities in Central Java Province, and the data used were rice productivity and the factors influencing it. The operational definition of the variables used in this study referred to [13], as follows:

Table 1. Operational definition of the variables

Variable	Indicators	Analysis Units	Data Source

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Table 1. Operational definition of the variables

Variable	Indicators	Analysis Units	Data Source
Productivity (Y)	Rice production per unit area of land used in farming rice	quintals per hectare	The BPS of the Regencies/ Cities of Central Java Province
Rice Production (X1)	Total output or the rice harvest from the land of the farmers during the planting season in the form of Harvested Dry Grain (GKP)	kg	The BPS of the Regencies/ Cities of Central Java Province
Harvested area (X2)	The area of rice plants harvested after the rice plants were sufficiently mature	ha	The BPS of the Regencies/ Cities of Central Java Province

The following is the data structure to be processed can be seen in table 2.

Table 2. Data structure

Regions	Y	X1	X2
1	y1	x11	x21
2	y2	x12	x22
⋮	⋮	⋮	⋮
35	y35	x135	x235

The analysis used in this study consisted of mapping based on the distribution of employment. According to [14], the spatial weighting matrix (**W**) can be obtained from the intersection between regions and the distance from neighbourhood or the distance between one region and another. The regression models used included Spatial Lag X model (SLX), Spatial Autoregressive Model (SAR), and Spatial Error Model (SEM). This study used a queen-type spatial weighting matrix because it did not only focus on the side intersection but also considered the intersection of the locations between the regencies and cities. According to the definitions of Wuryandari et al. [15], the queen weighting is a weighting with the area of observation determined based on the intersecting sides and angles which are also taken into account. The Queen Contiguity method defines that $\mathbf{W}_{ij}$ = 1 if the location intersects sides or angles with other locations, whereas $\mathbf{W}_{ij}$ = 0 if it does not intersect [15].
Furthermore, spatial autocorrelation analysis was conducted to determine the inter-district and city relation based on labor absorption. Furthermore, the modelling of rice productivity and the factors that influence it used the best spatial regression model.

1. Spatial Lag Independent (SLX)
   $y = \alpha_0 + \alpha_1 X_1 + \alpha_2 X_2 + \theta_1 W X_1 + \theta_2 W X_2 + s_i$ (1)
2. Spatial Autoregressive Model (SAR)
   $$y = \rho W y + \alpha_0 + \alpha_1 X_1 + \alpha_2 X_2 + s_i \quad (2)$$
3. Spatial Error Model (SEM)
   $$y = \alpha_0 + \alpha_1 X_1 + \alpha_2 X_2 + u_i$$
   $$u = \gamma W y + s_i \quad (3)$$

The followings are the stages of the analysis for each method in accordance with the formulation of research problems:

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a. Mapping the rice production value of each District and City in Central Java as the initial study to determine the spatial weight matrix;
b. Modelling the spatial lag X, spatial autoregressive and spatial error model (SEM) using the method of maximum likelihood;
c. Evaluating the spatial model formed by testing the error assumption so that the system of assumption regression equation was obtained. The error assumptions in the spatial model included normal distributed errors, the error with a constant variance and free error.

3. Results and discussions

The first step in this study was mapping based on the distribution of rice productivity. The distribution of rice productivity in the Regencies and Cities in Central Java Province along with the influencing factors is as follows:

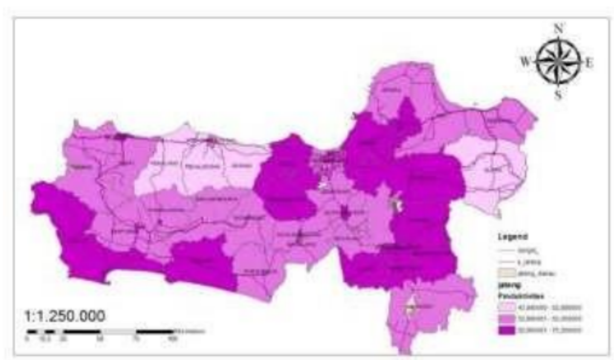

Figure 2. Distribution patterns of rice productivity in Central Java province

Figure 2 shows the distribution of rice productivity in the regencies / cities in Central Java province in 2015. Based on figure 2, it can be seen that the darker the colour of the location, the higher the productivity of rice. It illustrates that the cities with high rice productivity in the range from 6,206,0001 to 7,526,0000 quintals per hectare were found in Tegal City, Magelang City, Cilacap Regency, Kebumen Regency, Temanggung Regency, Kendal Regency, Demak Regency, Kudus Regency, Grobogan Regency, Sragen Regency , Surakarta City, Karangayar Regency, Sukoharjo Regency, and Klaten Regency. The cities with medium rice productivity in the range from 5,289,0001 to 6,206,0000 quintals per hectare were found in Brebes Regency, Tegal Regency, Banyumas Regency, Purbalingga Regency, Banjarnegara Regency, Wonosobo Regency, Purworejo Regency, Magelang Regency, Boyolali Regency, Semarang Regency, Semarang City, Wonogiri Regency, Jepara Regency, Pati Regency, and Rembang Regency. The regencies/ cities with low rice productivity in the range from 4,309,0000 to 5,289,0000 quintals per hectare were found in Pemalang Regency, Pekalongan Regency, Batang Regency, and Blora Regency.

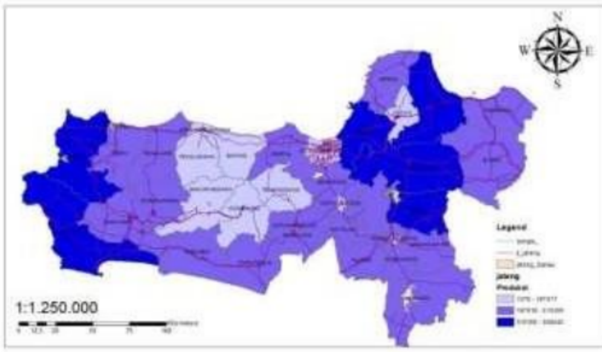

Figure 3. distribution patterns of rice production in Central Java province

Figure 3 shows the distribution of rice production in the cities in Central Java province in 2015. Based on figure 3, it can be seen that the darker the colour of the location, the higher the rice production. It depicts that the regencies with high rice production in the range from 516,356 to 888,642 quintals per hectare were located in Cilacap Regency, Brebes Regency, Demak Regency, Pati Regency, Grobogan Regency, and Sragen Regency. The regencies/ cities with medium rice production were located in the range from 197,618 to 516,355 quintals per hectare were located in Tegal Regency, Banyumas Regency, Purbalingga Regency, Pemalang Regency, Kebumen Regency, Purworejo Regency, Magelang Regency, Kendal Regency, Semarang Regency, Boyolali Regency, Klaten Regency, Karangayar Regency, Sukoharjo Regency, Wonogiri Regency, Rembang Regency, Blora Regency, and Jepara Regency. The regencies/ cities with low rice production were located in the range from 1,378 to 19,7617 quintals per hectare were found in Tegal City, Pekalongan City, Pekalongan Regency, Banjarnegara Regency, Batang Regency, Wonosobo Regency, Batang Regency, Temanggung Regency, Semarang City, Salatiga City, Magelang City, Kudus Regency, and Surakarta City.

Figure 4. Distribution pattern of rice harvested area in Central Java province

Figure 4 shows the distribution of rice harvested area in the cities in Central Java province in 2015. Based on Figure 4, it can be seen that the darker the colour of the location, the higher the rice harvest area. It shows that the regencies/ cities with high harvested areas in the range from 75,204 to 138,864 quintals per hectare were located in Brebes Regency, Cilacap Regency, Pemalang Regency, Kebumen Regency, Demak Regency, Grobogan Regency, Sragen Regency, Pati Regency, and Blora Regency. The regencies/ cities with medium harvested areas located in the range from 29,928 to 75,203 quintals per hectare were found in Tegal Regency, Purbalingga Regency, Banyumas Regency, Pekalongan Regency, Batang Regency, Kendal Regency, Purworejo Regency, Magelang Regency, Semarang Regency, Boyolali Regency, Regency Klaten, Karanganyar Regency, Wonogiri Regency, and Sukoharjo Regency. The regencies/cities with low harvested areas in the range from 206 to 29,927 quintals per hectare were located in Tegal City, Banjarnegara Regency, Wonosobo Regency, Temanggung Regency, Semarang City, Salatiga City, Kudus Regency, and Surakarta City.

The next step in this study was to test the spatial dependency. Spatial dependency test was conducted to see whether the observations in a location affect the observations in other adjacent locations [16]. The hypotheses used were:

H_0: $I_i = 0$ (it has no inter-location dependency)
H_1: $I_i \neq 0$ (it has inter-location dependency)

Table 3. Global Moran's test results

Variable	Morans'I value	P-value	Conclusion
Y	0.078	0.180	Accept H0
X1	0.152	0.066 *	Reject H0
X2	0.148	0.071 *	Reject H0

Note: * significant at $\alpha = 10\%$

Based on the Morans'I test results, it can be seen that the variable X1 is rice production and the variable X2 is rice harvested area having the spatial dependency with $\alpha = 10\%$. Then, in the variable Y which is the rice productivity, there is no spatial dependency because the p-value value is <10%. Therefore, it can be concluded that there is a spatial dependency or regional relationship in the observation data in the production variable and rice harvested area.

The modelling of rice productivity and the factors that influence it were determined after finding the best spatial regression model. The determination of the best model was seen from the value of *AIC* (*Akaike's Information Criterion*) on each model. The value of AIC has advantages over choosing the best model using R^2. It can explain the suitability of the model with existing data (in-sample forecasting) and the value that occurs in the out of sample forecasting [17]

Table 4 shows the results of the parameter estimation in each model. The model estimations of SLX, SAR and SEM resulted in the parameters that affect the rice productivity in Central Java Province with a significance level of 5%. It can be seen that all parameters in each SLX, SAR and SEM model show a significant value at $\alpha = 5\%$. However, the SLX estimation model has the smallest AIC value of 177.387. Based on the SLX model, it means that the rice production and rice harvested area provided a positive and significant sign to rice productivity in Central Java. Thus, the weighting matrix **W** in each independent variable did not play an important role in the modelling. This provides an interpretation that there is not enough evidence of the existence of spillover effects on rice production and rice harvested area variables in Central Java. It means that the rice production and harvested area in an area do not significantly influence the rice productivity in the adjacent areas.

The final step in this study is to evaluate the classical assumptions to find out the classic assumptions of residuals whether all classical assumptions are met or not. Some classic assumptions that must be fulfilled are residuals with normal distribution, no multicollinearity, no heteroscedasticity, and autocorrelation. The results of model evaluations are given at table 5.

Table 4. Parameter estimation test results

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	SLX (P-Value)	SAR (P-Value)	SEM (P-Value)
Constant	0.605 (0.000 *)	0.570 (0.000 *)	0.618 (0.000 *)
X1	0.001 (0.000 *)	0.001 (0.000 *)	0.001 (0.000 *)
X2	0.009 (0.000 *)	0.009 (0.000 *)	0.009 (0.000 *)
W * X1	0.002 (0.862)		
W * X2	0.005 (0.998)		
Rho		0.349 (0.167)	
Lambda			0.267 (0.271)
AIC	177,387	178,592	178.808

Note: * significant at $\alpha = 5\%$

Table 5. Evaluation of model assumption

Classic Assumption Test	Criteria	SLX
Normality	p-value > α	M
Autocorrelation	p-value > α	M*
Heteroscesdacity	p-value > α	M
Multicollinearity	VIF < 10	M

Note: M = meeting the econometrics criteria
TM = not meeting the econometrics criteria
*the autocorrelation test used global Moran's test

Table 5 is an evaluation of classic assumption results. The Kolmogorov-Smirnov test of SLX result p-value of 0.1475 that indicates the data is normally distributed. Moran's results show p-value of 0.5059 which means that no autocorrelation occurs. Then, the Breusch-Pagan test obtained p-value of 0.066 and the VIF value for each variable has the value lower than 10. It means that SLX has met the criteria of classic regression assumption.

4. Conclusion

From the overall model, the SLX estimation model has the smallest AIC value of 177.387 so that the SLX model is the best model compared to the other models. Based on the SLX model, it means that the rice production and rice harvested area provide a positive and significant sign of the rice productivity in Central Java. Thus, the weighting matrix **W** in each independent variable does not play an important role in the modelling. This provides an interpretation that there is not enough evidence of the existence of spillover effects on rice production and rice harvested area variables in Central Java. It means that the rice production and harvested area in an area do not significantly influence the rice productivity in the adjacent areas.

Acknowledgments

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