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# The Use of A Geographically Weighted Regression Model to Analyze Predictors of The Rice Supply in Bojonegoro

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**ABSTRACT**

The research goal would be to understand all potential influences on the amount of rice available within every sub-district in the Bojonegoro district. Geographically weighted regression (GWR), a technique used for this study, uses kernels: adaptive bisquare, fixed bisquare, adaptive gaussian, and fixed gaussian. The state office for food security and farming inside the Bojonegoro district provided secondary statistics for the 2018 year that included information on the population, the harvested area, the rice production, and the rice supply. The outcomes from the kernel-fixed gaussian elected model using AIC minimum criteria for the GWR model. The implementation's conclusion is due to the impact of variety in locations. The next research recommendation is a time-series spatial study of the rice problem.



## 1. Introduction

According to law number 18 in the 2012 year related food, food security has the understanding as a condition food met by a state to individuals, which indicated food by providing adequate quantity and quality and healthy, evenly for life productive, and sustainable (Pemerintah, 2012). Food agriculture organization (FAO) said that four aspects are the main pillar in providing food security are food availability affordability, access to food, food price stability, and food utilization (Pratama et al., 2019). Where in the pursuit of food security, food availability to the quantity and the quality of initial capital can be sufficient to ensure affordability, access, price stability, and food utilization (Susanto et al.,

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2020).

According to Food Security and Vulnerability Atlas (FSVA), the Bojonegoro district is on food security better with a score of the food index (IKP) of 81,21. In addition, the district that ranked fourth highest in east java in contributed rice production made the Bojonegoro regency one of the main producers of rice unseeded in the province of east java (Darsan & Dawud, 2021). But, the achievement that has been acquired does not guarantee that every region of the district has the resilience of good food. In fact, from 28 in Bojonegoro district, there are still 9 districts that enter into a group with the condition of food security as well as poor; they were Balen, Baureno, Gondang, Kepohbaru, Malo, Ngasem, Ngraho, Sekar, and Sumberejo (Supardi et al., 2020). This indicates that still needs to be an increase in food security, especially in terms of even distribution of food in the Bojonegoro district.

Rice as a commodity prime food has high consumption, supply needs to be maintained which could give impact on economic conditions. (Cahya et al., 2018). Based on agency data food security and agriculture Bojonegoro district (2022) mentioned the availability of rice in Bojonegoro district from 2017 to 2020 was decreasing. The availability of rice in the Bojonegoro district from 2017 until 2018 decreased by 58.526 tons. Meanwhile, in the year 2018 to 2019, the availability of rice decreased by 43.716 tons. And from 2019 to 2020, the availability of rice in the Bojonegoro district decreased by 55.281 tons. It provides information that the decline in the availability of rice is the most significant happened in 2018.

In realizing food security through the food availability of rice in the Bojonegoro district can be prefixed to know the predictor variables are anything to exert an influence upon the availability of rice. Based on research conducted by Wijoyo et al. (2020) related to the availability of rice in east java multiple linear regression modeling shows that the harvest is a significant positive impact on the availability of rice. Aside from the issue of the harvested area the availability of rice is relatively determined by the increase or decrease in rice production. This is following research by Ilyas et al. (2020) related to the availability of rice in Indonesia by the method of analysis the pathway that produces rice production had a significant impact on the availability of rice in Indonesia. Another factor that can affect the availability of rice is the population. Pujiati et al. (2020) suggested that the increasing number of people can influence food availability. Based on research conducted by Utami et al. (2019) The dynamic panel approach shows that the number of people of influence has a significant impact on the ratio of the availability of rice in east java.

Bojonegoro district is a district with several sub-district enough which is 28 in which every area has the characteristics of different. Hence, equity food rice in the Bojonegoro district is when factors affect the availability of rice in every region sub-district known. To anticipate problems that should be implemented in an analysis is the availability of rice in The Bojonegoro district by taking into consideration the influence of geographical location or by using a geographically weighted regression (GWR) model. This is important for a pattern of relationships in terms that can be observed. Nisa (2022) suggested that the analysis with a spatial approach like GWR is applicable if the data involved in the study detected the effect of spatial. Putu et al. (2020) said that affect spatial can be divided into two of them the correlation across the residual (dependencies) spatial and the diversity between the (heterogeneity spatial) testing a heterogeneity spatial involving Breusch Pagan test.

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Lu et al. (2017) defined GWR as one local technique used to form a model of relations varying in terms. The researchers before many researchers have used of GWR model research conducted by Li et al. (2019) about the urban analysis in China, Tizona et al. (2017) in modeling dengue fever in east Borneo, Cholid et al. (2019) about a case of baby stunting, Yang et al. (2018) about modeling house cost in the Dalian city in the China, Pratiwi et al. (2019) related Life Expectation Score in the central Java, dan Azies (2019) about the death score of the baby in the east Java. This study used modeling GWR that seeks to capture the impact on the availability of rice in the Bojonegoro district and sub-district.

Research is expected to help the government of Bojonegoro district determines policy in the pursuit of security and equity food for every sub-districts in Bojonegoro district. Hence, the researchers attempted to submit the title research "The Use Of A Geographically Weighted Regression Model To Analyze Predictors Of The Rice Supply In Bojonegoro".

## 2. Method

### *2.1. Research Design*

In this study design, applied research is quantitative research involving the Geographically Weighted Regression (GWR) method. The weightings of used consist of four function kernels spatial, namely Adaptive Bisquare, Fixed Bisquare, Adaptive Gaussian, and Fixed Gaussian. In an implementation, the tool used is R-Studio software version 4.1.2 with the criteria for selecting the best model of the Akaike Information Criterion (AIC) minimum.

### *2.2. Population and Sample*

The population research is the availability of rice and the predictor variable in the Bojonegoro district, while data on who would be the sample is the rice supply, harvested area, the rice production, and the population in the Bojonegoro district in 2018. The study locations will be carried out in the local food security and agriculture office in the Bojonegoro regency within four months, where research begins between October and April 2022.

### *2.3. Sampling Technique*

The sampling technique applied is purposive sampling, where data is taken from a database adapted to needs or. research objectives. As in the implementation of a case study in this study, sample data associated with the rice supply and its predictor variables was obtained from the office of food security and agriculture in Bojonegoro district.

### *2.4. Research Subject*

In this study, the data used is secondary data originating from the food and agriculture Bojonegoro district of data and data regarding the rice supply and factors that influence it in every region in Bojonegoro district 2018 year totaling 28 unit observation or in a ratio measurement. The variables contained in this study are presented in Table 1 as follows:

**Table 1**. Definition of Research Variables

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| Variable | Variable Name | Description |
|---|---|---|
| Respon | The Rice Supply (ton) ($Y$) | The number of reserved rice at each sub-district is under the supervision dept of agriculture and food security in the Bojonegoro district. |
| Predictor | The Harvested Area (Ha) ($X_1$) | The number of reserved rice at each sub-district is under the supervision dept of agriculture and food security in the Bojonegoro district. |
| | The Rice Production (ton) ($X_2$) | Agricultural products from commodities rice in each sub-district in the Bojonegoro district. |
| | The Population (head) ($X_3$) | The number of people who settled in every district in the Bojonegoro district. |

This research used the rice supply variable with predictor variables like harvested area, rice production, and population. In addition, this research also involved two variables relating to the geographical variable $u$ are defined as latitude and $v$ as longitude.

### *2.5. Technique of Data Analysis*

The analysis that there are procedures in this research will be used to analyze variable predictor that affects the rice supply in Bojonegoro by considering the influence of spatial uses in the GWR method using R-Studio software. The following step is to analyze the data used in this research:

1. Performing data modeling starts with entering observation data.
2. Undertook the identification of data characteristics on the rice supply and variable predictor influence.
3. Testing for spatial effects which in this paper only tests for spatial heterogeneity using the Breusch Pagan statistical test. If the spatial heterogeneity effect is not found, the global regression model or multiple linear regression model is used in step 4; If the spatial heterogeneity effect is met, the local regression model or GWR model is used in step 6.
4. Do modeling the rice supply with the multiple linear regression (MLR) model with the following procedure:
   a. Detect multicollinearity symptoms.
   b. Perform multiple linear regression model estimation.
   c. Performing parameter significance testing with F test and t test.
   d. Testing the assumptions of normality, heteroscedasticity, and autocorrelation; then if the test passes then proceed to step 7, but if it is not fulfilled then continue to step 5.
5. Do modeling the rice supply with the multiple linear regression (MLR) model based bootstrapping with the following procedure::
   a. Specifying a bootstrap sample of usually 100.
   b. Taking a repeated sample by replacing 100 observations from the sample data set, run the regression model and save the coefficients obtained. In the end, we will have 100 pairs of coefficients or parameters of the regression model.


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c. Creating confidence intervals for each parameter of the regression model.
d. Checking the significance of model parameters is done with parameters that are significant if they are within the confidence interval then continue to step 7.

6. Do modeling the rice supply with the geographically weighted regression (GWR) model the following:
   a. Do a reckoning of the Euclidean distances between the observations.
   b. Do the bandwidth levels by considering the minimum on cross-validation (CV).
   c. Choosing the best function of weight kernels to vote by considering the AIC (Akaike information criterion).
   d. Doing the calculating value and estimation of the GWR model parameters with the kernels' functioning.
   e. Testing the method to see the contrast between MLR and GWR methods.
   f. Testing the partial significance of this fact to parameter model GWR with the best weight functions.
7. Present the output of the regression model and measuring goodness-of-fit measures.
8. Provide an interpretation of the regression model regarding the relationship patterns of the research variables that contribute to food security and agriculture in Bojonegoro Regency.

### *2.6. Flow Chart*

The procedure of the analysis contained in the research is described in the form of a flow chart like Figure 1, following in:

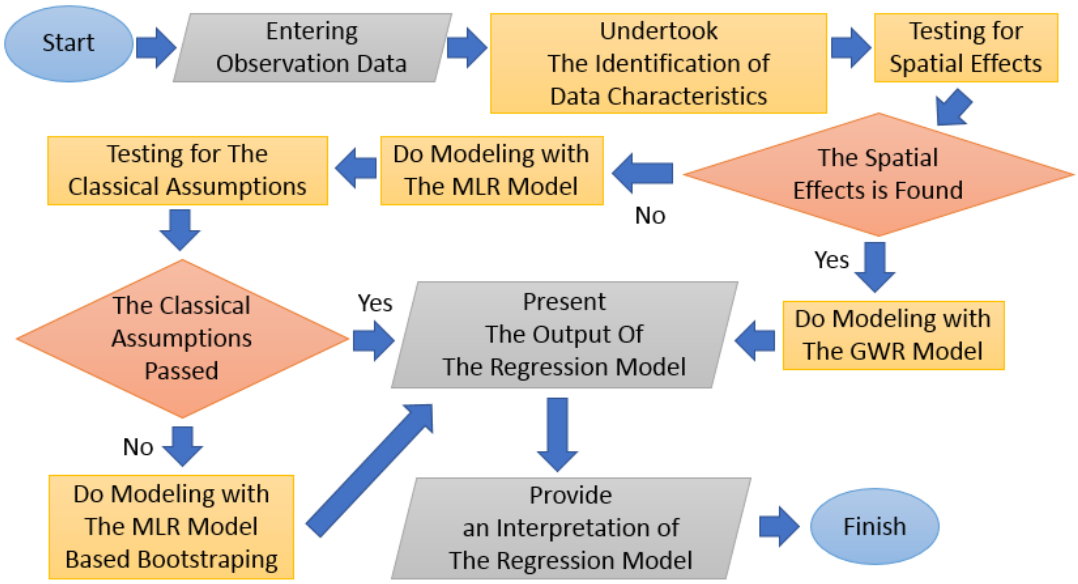


**Figure 1**. Flow Chart for The Procedure of Data Analysis.

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## 3. Results and Discussion

### *3.1. Results*

Before conducting more advanced analysis, statistical descriptive first to see how a general picture of data from each variable would check. The amount of data the observations that have been involved in this study, as many as 28 observations where data those with extensive data harvested area ($X_1$), the rice production ($X_2$), the population ($X_3$), and the rice supply ($Y$) on any sub-districts in the Bojonegoro district in 2018. Table 2 served as a summary of the findings and descriptive statistics of any variable research.

**Table 2**. Descriptive Statistics of The Rice Supply Data in Bojonegoro District

| | Min | Median | Mean | Max | Variance |
|---|---|---|---|---|---|
| $Y$ | 2,223 | 13,744 | 17,249 | 42,029 | 142,439,724 |
| $X_1$ | 687 | 4,244 | 5,328 | 12,981 | 13,588,551 |
| $X_2$ | 0 | 20,799 | 29,663 | 74,326 | 509,141,512 |
| $X_3$ | 11,451 | 45,595 | 46,836 | 85,972 | 483,543,649 |

Table 2 it can be seen information related information on the descriptive statistics variable research of the lowest value (minimum), the middle value (median), the average (mean), the highest (maximum), and the variance. Next, Figure 2 will be given a picture in visual in a map thematic to see the scatter data on the rice supply in the Bojonegoro district, where the area division is classified into five categories.

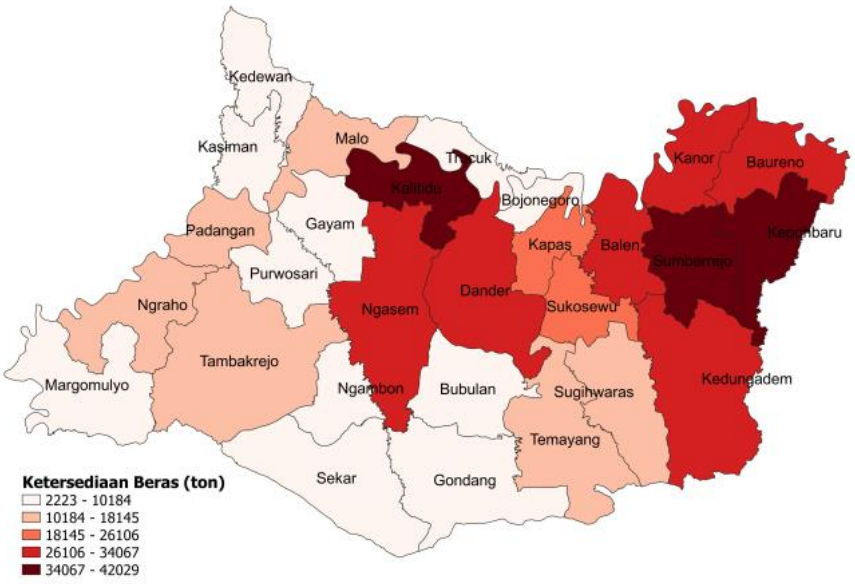


**Figure 2**. The scatter data on the rice supply in the Bojonegoro district

After obtaining the results statistics descriptive of variables, research next represented the result of spatial effect testing was first. The spatial effects which in this paper only tests for spatial heterogeneity using the Breusch Pagan statistical test.

**Table 3**. The results of spatial heterogeneity test

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| Breusch Pagan test | Statistic | p-value |
|---|---|---|
| | 13.655 | 0.0034* |

*The significance for α by 5%.

Based on the results of testing heterogeneity spatial in Table 3, the benchmark for consideration in decision-making was valued p-value ≤ α but failed to receive $H_0$, or it can say that variant in every region is heterogeneous. So, data will be processing rice availability in the Bojonegoro district with the GWR.

Following in Table 4 served the value of an optimum bandwidth, each with its function of the kernel of the results with a method of GWR modeling.

**Table 4**. The optimum bandwidth on each function kernels

| Function Kernels | Value of CV Minimum | Bandwidth |
|---|---|---|
| Fixed Gaussian | 12.4100 | 0.0571 |
| Fixed Bisquare | 13.9995 | 0.2236 |
| Adaptive Gaussian | 22.6543 | 0.2143 |
| Adaptive Bisquare | 23.3796 | 0.8571 |

After obtaining the optimum bandwidth value in each kernel function, the next step that you can do is to determine the weight kernels function best by taking into account the Akaike information criterion (AIC) in each kernel function. Following Table 5 will be presented the AIC value on each kernel function.

**Table 5**. The AIC value in each kernel function

| Model | Kernel Function | AIC |
|---|---|---|
| GWR | Fixed Gaussian | -22.9673 |
| GWR | Fixed Bisquare | 17.3486 |
| GWR | Adaptive Gaussian | 27.0710 |
| GWR | Adaptive Bisquare | 26.9919 |

Based on the results outlined in Table 5, obtained information was that the kernel function has the best function kernels in that it has a value of the AIC minimum.

After obtaining the best kernel function, the tested conformity model was to see if the GWR model is better than a linear regression or global regression model. Table 13 will be displayed the result of testing conformity GWR model.

**Table 6**. The results of the conformity GWR model

| Model | df | SSE | F-statistic | P-value |
|---|---|---|---|---|
| MLR | 3.5894 | 8.9766 | | |
| GWR | 24 | 0.3379 | 26.569 | 0.0048* |

*The significance for α by 5%.

From Table 12 known p-value is 0.0048. A standard significance of 5 % stated that the p-value ≤ *a* with α by 5%, which we can conclude failed to receive H0, meaning there is a significant difference between the global regression and GWR.

From the implementation of the GWR model obtained, the predictor variables significantly influence the availability of rice at each sub-districts, and


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the form of modeling where from test results significance in partial 28 equation produce different models the next one represented into Table 7.

**Table 7**. The GWR model in each sub-district.

| Sub-District | Significant Predictor | GWR model |
|---|---|---|
| Balen | - | $\hat{y} = 0.5608 + 0.7859X_1 + 0.2968X_2 + 0.0191X_3$ |
| Baureno | - | $\hat{y} = 2.9107 + 1.0454X_1 + 0.2102X_2 – 0.2543X_3$ |
| Bojonegoro | $X_2$ | $\hat{y} = 0.7575 – 2.5595X_1 + 0.7220X_2* + 0.0548X_3$ |
| Bubulan | $X_1$ | $\hat{y} = -0.0804 + 2.8918X_1* - 0.0464X_2 + 0.0912X_3$ |
| Dander | - | $\hat{y} = 0.2490 + 1.5345X_1 + 0.1985X_2 + 0.0418X_3$ |
| Gayam | $X_2$ | $\hat{y} = 0.2075 + 0.1723X_1 + 0.6571X_2* - 0.0577X_3$ |
| Gondang | - | $\hat{y} = -0.0067 + 3.1918X_1 + 0.0003X_2 + 0.0061X_3$ |
| Kalitidu | $X_2$ | $\hat{y} = -0.0381 – 0.6358X_1 + 0.7536X_2* + 0.0515X_3$ |
| Kanor | - | $\hat{y} = 2.6753 + 0.8242X_1 + 0.2601X_2 - 0.2319X_3$ |
| Kapas | $X_2$ | $\hat{y} = 0.8217 - 2.5668X_1 + 0.7290X_2* + 0.0548X_3$ |
| Kasiman | $X_3$ | $\hat{y} = -0.4618 + 0.7769X_1 - 0.0557X_2 + 0.4206X_3*$ |
| Kedewan | $X_3$ | $\hat{y} = -2.3899 + 4.4150X_1 - 0.5907X_2 + 0.9667X_3*$ |
| Kedungadem | - | $\hat{y} = -0.0170 + 2.7520X_1 + 0.0719X_2 + 0.0133X_3$ |
| Kepohbaru | - | $\hat{y} = 1.3495 + 0.0955X_1 + 0.4721X_2 - 0.1083X_3$ |
| Malo | $X_2$. $X_3$ | $\hat{y} = -1.3146 – 3.3093X_1 + 0.7642X_2* + 0.7330X_3*$ |
| Margomulyo | - | $\hat{y} = 0.0423 + 1.6472X_1 + 0.1764X_2 + 0.0486X_3$ |
| Ngambon | $X_1$ | $\hat{y} = 0.0250 + 3.0947X_1* + 0.0429X_2 - 0.0128X_3$ |
| Ngasem | $X_2$. $X_3$ | $\hat{y} = 0.3262 + 2.1385X_1 + 0.3735X_2* - 0.1609X_3*$ |
| Ngraho | - | $\hat{y} = 0.2063 – 1.0776X_1 + 0.4314X_2 + 0.1383X_3$ |
| Padangan | - | $\hat{y} = 0.1359 + 1.4341X_1 - 0.0354X_2 + 0.1689X_3$ |
| Purwosari | - | $\hat{y} = -0.1655 + 0.6277X_1 + 0.2697X_2 + 0.2003X_3$ |
| Sekar | - | $\hat{y} = 0.0005 + 3.2364X_1 + 0.0008X_2 - 0.0003X_3$ |
| Sugihwaras | - | $\hat{y} = -0.1164 + 1.6701X_1 + 0.1737X_2 + 0.0893X_3$ |
| Sukosewu | - | $\hat{y} = 0.0963 - 0.0098X_1 + 0.3797X_2 + 0.1156X_3$ |
| Sumberrejo | - | $\hat{y} = 0.4515 + 1.2956X_1 + 0.2641X_2 + 0.0067X_3$ |
| Tambakrejo | $X_1$ | $\hat{y} = 0.0130 + 3.1586X_1* + 0.0082X_2 + 0.0015X_3$ |
| Temayang | - | $\hat{y} = -0.0836 + 1.7568X_1 + 0.1412X_2 + 0.0896X_3$ |
| Trucuk | $X_2$. $X_3$ | $\hat{y} = -0.4169 – 0.5481X_1 + 0.7493X_2* + 0.1305X_3*$ |

*The significance for α by 5%.

Next, based on the results in Table 7, the variables' significant impact on the availability of rice in each sub-districts in district 5 is grouped into a group that has the same criteria that visualization in Figure 3.

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**Figure 3**. Grouping sub-district in Bojonegoro district based on the results of the partial test with the GWR method

### *3.2. Discussion*

Table 2 shows that value variants in each variable observation have great value, meaning that data from each variable is quite varied. In the meantime, in Figure 1 can be seen that distribution points the availability of rice in the Bojonegoro district is very low, by category low, are, high, and very high in the area did not cluster a particular area.

Based on Table 3, the test results involving heterogeneity spatial with the Breusch-Pagan test showed that a variant in every region is heterogeneous. So that could go forward data processing the availability of rice in the Bojonegoro regency with a method of geographically weighted regression (GWR).

As shown in Table 4, the implementation GWR model involving four kernels obtained the value of the bandwidth optimum for each kernel function. The value of the bandwidth optimum was determined by looking at numbers cross-validation (CV) minimum. Next, based on Table 5 obtained information, the model of best criteria is a GWR model involving the function of the fixed gaussian kernel function due to has Akaike information criterion (AIC) minimum. Where the bandwidth obtained with the process of the fixed gaussian kernel is 0,0571 who has the sense that a point included in a radius of 0,0571 has been designated the influence of optimal parameter in developing model at every location.

Table 6 indicates the exam results conformity model intended to see if the GWR model involving the function of the fixed gaussian kernel is better than a linear regression or global regression model. Where obtained test results were the conclusion that there is a significant difference between global regression models and GWR has the sense that the GWR model, by involving the function of the fixed gaussian kernel better if compared with global regression models.

Next, based on the parameters, partial testing in Table 7 obtained 28 different equation models different in the model of the rice supply at every area in the Bojonegoro district. Where from the testing in partially formed five groups by the same criteria just in Figure 2, which provides information that group 1 with variable significant broad crop consisting of three sub-district (Bubulan,

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Ngambon, and Tambakrejo), Group 2 has significant rice production consisting of 4 sub-districts (Gayam, Kalitidu, and Kapas), group 3 has a considerable population comprised of 2 sub-districts (Kasiman and Kedewan), group 4 has significant rice production and a population consisting of 3 sub-districts (Malo, Ngasem, and Trucuk), as well as on every team in which every predictor variable did not influence significantly consisting of 16 sub-districts (Balen, Baureno, Dander, Gondang, Kanor, Kedungadem, Kepohbaru, Margomulyo, Ngraho, Padangan, Purwosari, Sekar, Sugihwaras, Sukosewu, Sumberrejo, and Temayang).

## 4. Conclusions

Based on the minimum Akaike information criterion (AIC) value, the results of the GWR model with fixed gaussian kernel function weighting is a model with a measure for the best model in rice availability in Bojonegoro Regency. From The GWR modeling, the rice supply in each sub-district is influenced by different factors due to the diversity effect.

The suggestion given in this research is to use observation data from the last few years so that it can provide more information about the current rice supply in Bojonegoro Regency. The suggested method is a time series spatial study. Future research can add other predictor variables such as rice consumption, rice import volume, and others.

## Author Contributions

The first and second authors contribute to the creation of scientific articles, as well as managing papers for the publication process. The third author contributes to the processing and analysis of research data. The fourth author contributed to data collection.

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## Declaration of Competing Interest

The authors report that there are no potential conflicts of interest in the preparation of this scientific article.

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