

Geographically Weighted Regression (GWR) Model of Bandung Regency Food Security during the Covid-19 Pandemic

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ABSTRACT

The Covid-19 pandemic has had an impact on changes in people's economic activities, leading to an increase in the poverty rate. This has an impact on people's ability to obtain safe and sufficient food. The food security status of the city/district does not always guarantee that each individual is food secure because each region has different characteristics. The diversity of each village has the effect of variance in food security results. This study aims to model the influence of the Covid-19 Pandemic and food security indicators in Bandung Regency using Geographically Weighted Regression (GWR). This research was conducted in Bandung Regency in 280 villages. The design used in this research is descriptive quantitative. The data source used was secondary data on food security in Bandung Regency. The results showed that the influence of the percentage of the population infected with Covid-19 on food security was greatest in the southern area of Bandung Regency, and the value of the Local R² coefficient of the influence of indicators in the calculation of the food security composite was highest in Nagreg District.

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1. Introduction

The World Food Programme (WFP) stated that in 2020, coinciding with the Covid-19 Pandemic, there were 768 million people who experienced chronic hunger. The Covid-19 pandemic has had an impact on changes in people's behaviour and economic activities, causing an increase in the poverty rate (BPS, 2021). This occurs due to restrictions on the community's space for movement. In the end, this impact will lead to the community's ability to obtain safe and sufficient food.

The poverty rate, especially in Indonesia, in the worst-case scenario rises by 7.4% or equivalent to 44.5 million people, of which 19.7 million people are newly poor groups caused by the Covid-19 pandemic. Amid the economic decline, the agricultural sector is considered a sector that becomes the foundation of the national economy that can survive. In dealing with the spread of Covid-19, the agricultural sector is a priority need because it is directly related to the fulfilment of human life and is related to national food security (Khairad, 2020).

Based on the Food Security Index 2020, most districts in West Java are highly resilient (priority 6) but are still affected by the largest increase in the number of poor people at 544,000 (World Food Program, 2020). In March 2021, the number of poor people (people with per capita expenditure per month below the poverty line) in West Java increased by around 6.82 thousand people, from 4.19 million in September 2020 to 4.20 million in March 2021. Food security status on a province or city/district scale does not always guarantee that each

individual is food secure. This can be caused by differences in the characteristics of each region within it. The diversity of each village has a variant effect on food security results.

One of the districts in West Java that has an improved Food Security Index in 2020 is Bandung Regency. However, despite its improved food security status, Bandung Regency has the second largest number of people in poverty after Bogor Regency and has the 5th highest extreme poverty rate in West Java (Iqbal, 2021). Since 2015 - 2019, Bandung Regency has had a declining trend in the poverty rate, but in 2020 it has increased again.

From these problems, a geospatial analysis is needed that can identify neighbours that express the relationship between existing components/variables so that it can explain the condition of food security connectivity between villages in Bandung Regency. These results can be useful for policymakers to cooperate between regions to maintain food security which can be seen from the problems of each region that are close to each other. As the concept of geography mentioned by Waldo Tobler in Caraka, (Caraka & Yasin, 2017) namely "Everything is related to everything else, but near things are more related than distant things", meaning that everything has a relationship with everything else, but something close together will have more relationship than something that is far away.

This study aims to do modelling the influence of the percentage of the population infected with Covid-19 and the food security indicator model on the Bandung Regency food security composite in each village using Geographically Weighted Regression (GWR).

2. Methodology

The analysis conducted in this study aims to analyze the model of the influence of the percentage of the population infected with Covid-19 and food security indicators on the composite of food security in Bandung Regency using the GWR (Geographically Weighted Regression) model with ArcGIS tools.

GWR is the development of a classical regression framework that results in the estimation of the regression coefficients of the model that is global to be local. The regression model is said to be good if meets the classical assumptions, namely no autocorrelation, no heteroscedasticity, normally distributed model residuals and no multicollinearity (Mahdy, 2021).

The first step is the classical assumption test including the normality test, multicollinearity test, homoscedasticity test, and Durbin autocorrelation test. Then, the analysis was conducted using GWR with the following steps:

2.1 Weight Matrix

In the GWR model, a weight matrix is required that shows the proximity relationship between locations. The weight function used in this study is a Fixed Exponential Kernel with the following formula:

$$w_j = \exp(-d_{ij}/h) \quad (1)$$

d_{ij} = The Euclidean distance between the i -th location to the j -th location.

h = The optimum bandwidth is fixed or the same at all locations.

The selection of the optimum bandwidth affects the accuracy of the parameter estimation results. One method that can be used is by using Cross Validation which is written as follows:

- CV = $\sum_{(i=1)}^n (y_i - \hat{y}_{\neq 1}(h)) \dots \dots \dots (2)$
 y_i = observation value of the i-th response variable.
 $\hat{y}_{\neq 1}(h)$ = Estimator where the observation at the i-th location is omitted from the estimation process.

The optimum bandwidth selection is obtained from the iteration process that produces the minimum CV value.

2.2 Spatial Dependence and Heterogeneity

Spatial data is data that has the characteristics of spatial dependence and spatial diversity. Spatial dependence is measured to see whether observations in a location affect observations in other adjacent locations. The spatial dependency measurement tool is by using the Moran’s Index with the following formula:

- $Z = (I - E(I)) / \sqrt{\text{var}(I)} \dots \dots \dots (3)$
 Z = statistical value of the Moran’s index test
 I = Moran's index value

3. Results and Discussion

From early March 2020 to October 2021, the trend of Covid-19 infected cases in Indonesia tends to increase. The most significant increase occurred in July 2021, reaching 50,000 cases. This is expected because people began to neglect health protocols. In October 2021, the number of infected cases decreased again, offset by the vaccination program. West Java until February 2022 was confirmed positive for Covid-19 by as many as 887,131 people or 17% of the total in Indonesia.

The number of people exposed to Covid-19 in Bandung Regency is 38,255 and it is the fourth most district-level in West Java exposed to the Covid-19 virus. Currently, all countries are competing to ensure food security to be able to deal with the crisis period due to the Covid-19 pandemic. This situation can lead to limited access to food availability. This is exacerbated by various policies issued to break the spread of Covid-19 in the form of restrictions on population activities. The consequence is a decrease in productivity followed by a decrease in household income and consumption (Tarigan *et al.*, 2020). This situation is in line with Burgui (2020) who stated that the outbreak of a disease that occurs in the world will increase the number of people experiencing hunger and malnutrition.

Figure 1. shows the model of the influence of the Covid-19 infected population on the food security of Bandung Regency using the overlay technique with the distribution of Covid-19 which is depicted with a pink dot. The colour on the map shows that getting redder an area, the area is strongly influenced by the variable percentage of the population infected with Covid-19 in its food security and the more pink dots, the more people infected with Covid-19. In the figure, the colour of each village shows the diversity of the level of influence.

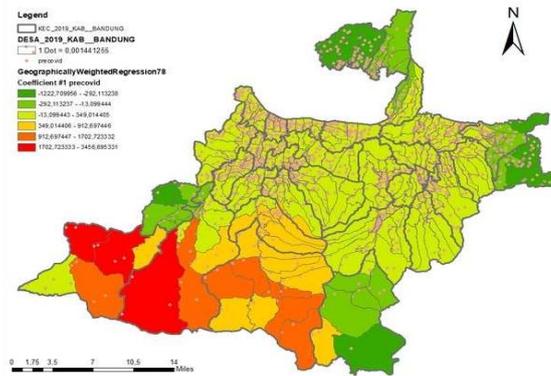


Figure 1. Distribution of GWR Model Estimates of the Influence of the Percentage of Population Infected with Covid-19 on Food Security.

Most of the village areas in Bandung Regency are in the yellow category which is spread in the central part of Bandung Regency with a coefficient value range of -13.099443 - 349.014405. The part of the region with the greatest influence on the percentage of the population infected with Covid-19 on food security is spread in the southern area of Bandung Regency which is spread in villages in Rancabali and Pasirjambu Subdistricts, namely Sugihmukti, Patengan, and Indragiri Villages. In order, the coefficient of the percentage of the population infected with Covid-19 is 3456.695331, 2471.685663, and 2195.490596. In the Bandung Regency food security report, Sugihmukti Village is categorized as a priority 1 village, Indragiri Village as a priority 3 village, and Patengan Village as a priority 5 village.

Table 1. Estimation Results of GWR Parameters the effect of Covid-19 on the Food Security

Variable	Elasticity	GWR Model		
		Min	Avg	Max
Intercept		36.52	64.36	73.41
Covid Percentage (X)	159,87	-1222.70	161.95	3456.60
N				280.00
AICc				1820.00

Meanwhile, villages that have the lowest influence are scattered in parts of the north, west, east, and south areas in Kertasari, Ciwidey, Nagreg, and Cimenyan sub-districts. When associated with the distribution of Covid-19-infected population points, sub-districts with a high influence of Covid-19 variables on food security such as Pasirjambu and Rancabali sub-districts have the same average percentage of Covid-19-infected population as villages that have a low influence of 0.3%. However, Mekarsaluyu village, Cimenyan sub-district does have a high percentage of 0.9%. The distribution of Covid -19 is mostly in the central village of Bandung Regency which has a medium Covid-19 variable coefficient. When viewed from the coefficient of determination.

The covid-19 variable has an R^2 of 0.29, which means that the Covid-19 variable can only explain 29% of village food security in Bandung Regency, and the rest is explained by other variables.

Models of the influence of food security indicators on each village during the Covid-19 Pandemic can be seen in Figure 2. Five indicators of food security become variables. The results of GWR show an AICc value of 1579.3915, a coefficient of determination R^2 of 0.6655 and a standard deviation that varies from < -2.5 to > 2.5 . The coefficient of determination means that the variables can explain 65% while the other 35% is explained by other variables.

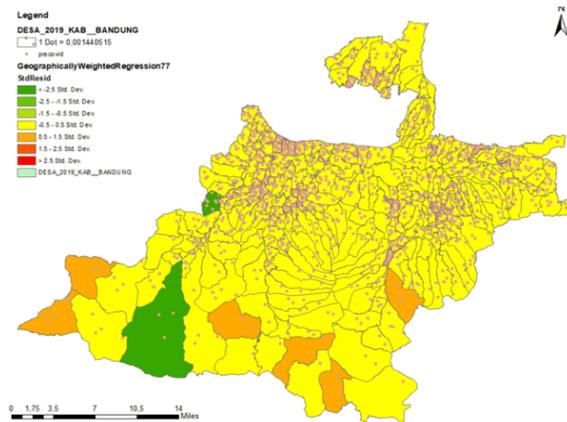


Figure 2. Distribution of Estimated GWR Model of the effect of Food Security Indicators during the Covid-19 Pandemic on the Food Security Composite of Bandung Regency

Standard deviation describes how data values are spread out or as the average deviation distance of data points measured from the mean value of the data. Most villages have a standard deviation range of $-0.5 - 0.5$ which is depicted in yellow. Meanwhile, the green colour in the map has a standard deviation of <2.5 , indicating that the estimated value is lower than the prediction.

Villages that have an estimated value that is much lower than the prediction are Sugihmukti Village, Pasrijambu Subdistrict, which is in priority 1 and Cilame Village, Kutawaringin Subdistrict which is in priority 4. Villages that have an estimated value that is far from the prediction may have other factors that are more influential on their food security or even there must be several factors that must be reduced in knowing the effect of food security indicators on the food security composite during the Covid-19 Pandemic.

Based on the results of the GWR analysis, a model equation was obtained for each village in Bandung Regency. The diversity of each village provides a variant effect on the results of food security as well as poverty (Nugroho *et al.*, 2020). The parameter estimation value of the variable ratio of the standard area of agricultural land to the village area (X_1) ranges from 114.2098809 - 114.2299989, which means that every 1 unit increase in the ratio of agricultural land will add value to the food security composite due to an increase in agricultural land area of 114.2098809 - 114.2299989.

Table 2. Estimation Results of GWR Parameters the effect of Food Security Indicators during the Covid-19 Pandemic on the Food Security Composite

Variable	Elasticity	GWR Model		
		Min	Avg	Max
Intercept	-	66.6539	66.6544	66.6547
(X1)	116.7598	114.2098	114.2176	114.2299
(X2)	75.6887	74.0360	74.0408	74.0477
(X3)	-22.2742	-21.7958	-21.7893	-21.7806
(X4)	-0.5153	-0.5043	-0.5041	-0.5039
(X5)	-13.5135	-13.2211	-13.2192	-13.2176
N				280
AICc				1579

Agricultural land is considered to influence food security because low agricultural land due to land conversion can harm food availability and food security of the population (Prasada

& Rosa, 2018). In line with (Nurpita *et al.*, 2018), which state that the macro impact of land conversion is reduced food availability and results in reduced national food security. In addition, there are other challenges in the agricultural sector, such as the Covid-19 pandemic, which threatens food security with shrinking agricultural land and small farming margins. The highest proportion of workers affected by the Covid-19 pandemic are workers who work in the agricultural sector with a percentage of 29.6% (A'dani *et al.*, 2021). This will certainly disrupt food security.

The parameter estimate of the variable ratio of the number of economic facilities and infrastructure to the number of households (X_2) has a coefficient of 74.03603269 - 74.04773314. The value of the X_2 variable means that an increase of 1 unit in the ratio of the number of economic facilities and infrastructure will add value to the food security composite by increasing the number of food provider facilities by 74.03603269 - 74.04773314.

Variable X_2 is felt from the impact of the spread of Covid-19 which has disrupted food supply and increased food prices in affected areas. The agricultural sector during the pandemic began to be sought after and not a few people behaved panic buying in response to the Covid -19 incident (Hermanto, 2020). This marketing activity is related to food supply facilities that have alternative solutions by distributing agricultural products during a pandemic by utilizing technology.

The parameter estimation value for each variable of the ratio of the number of people with the lowest welfare level to the total village population (X_3) has a negative parameter coefficient from -13.22114838 to -13.2176622. This negative value means that with an increase of 1 unit, the ratio of the number of people with the lowest welfare level in a village will reduce the composite value of food security with the difficulty of community economic access to food.

The diversity of these coefficient values can be influenced by differences in the morphology of a region. According to (Astuti & Musiyam, 2009), there is an associative relationship between poverty levels and geography. Villages with a high poverty rate are generally located in highland areas with dryland farming systems and have a relatively low level of affordability. Meanwhile, villages with a low poverty rate are generally located in lowland areas with a wetland farming system and generally have a relatively high level of affordability Srinita (2018).

In line with research conducted by Sutomo & Shalihati (2015), the factors that influence the level of harmony between poverty and regional development are morphological conditions that tend to be hilly and are located in mountainous areas with steep slopes. This poverty is chronic poverty, unlike the transient poverty caused by the Covid-19 Pandemic. Most people are quite affected, in Bandung Regency, there are approximately 60,000 new poor people who live in urban areas because the spread of Covid-19 in urban areas is faster and higher.

The parameter estimation value of the variable ratio of the number of households without access to clean water to the total village population (X_4), has a negative parameter coefficient from -21.79584547 to -21.78068529. This value indicates that with an increase of 1 unit, the ratio of the number of households without access to clean water will reduce the composite value of food security because it is related to the aspect of food utilization.

Water factors (inadequate drinking water sources, drinking water treatment), and sanitation factors (the use of toilet facilities, open defecation behaviour, disposal of toddler faeces not in latrines) have an impact on aspects of food utilization because they are related to the incidence of stunting, especially in toddlers (Hartati & Zulminiati, 2020). The difference in coefficient values in each region is related to the potential of each region, namely water infiltration. Good water infiltration causes better quality clean water conditions and reduces flood impacts.

Likewise, the parameter estimation value of the variable ratio of population per health worker to population density (X_5) has a negative parameter coefficient from -0.504323641 to -0.503992908, which means that an increase of 1 unit of the ratio of population per health worker to population density will reduce the composite value of food security due to the lack of health workers in a village related to the aspect of food utilization. The partial test results obtained 280 different equations for each village in Bandung Regency.

The difference in the value of the X_5 coefficient is due to the uneven distribution of health workers between regions, especially if the health workers also fell during the Covid-19 Pandemic (Pratitis *et al.*, 2021). The ratio of the total village population per health worker to population density shows the ability of the number of health workers in the village area to serve the community. An adequate number of health workers will improve the food utilization status of the community.

The local R^2 partial test results of the alleged GWR model of the influence of food security indicators are in line with Figure 2. Sugihmukti and Cilame villages are green, which means that the variables do not explain the food security of the village. The local R^2 explains that the greener the region means that the coefficient of determination of these variables is low, while the redder the region, the higher the local R^2 value. Local R^2 partially explains the R^2 value of each village so that it can be seen which areas have variable suitability in food security. In Figure 3, the colours vary from green to red in a calculable manner. The western part of Bandung Regency has a low local R^2 value, while the eastern part has a high local R^2 value. The sub-districts in the reddest colour are Nagreg, Cicalengka, Cikancung, as well as Paseh and Ibum sub-districts with a coefficient of determination of 0.665723 - 0.665919.

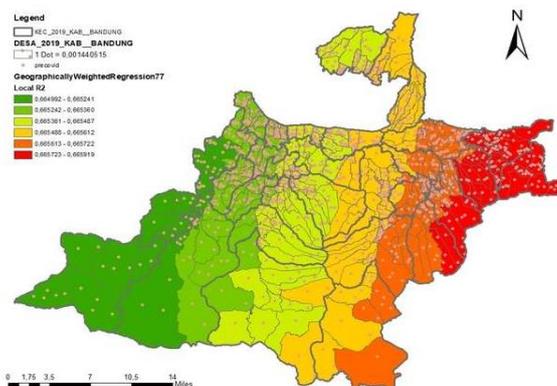


Figure 3. Distribution of Alleged Local GWR Model R^2 Effect of Food Security Indicators during the Covid-19 Pandemic on the Bandung Regency Food Security Composite on the Bandung Regency Food Security Composite

The difference in the influence of indicators on the food security composite, especially during the Covid-19 Pandemic, has different policies/programs and countermeasures which must still have good synergy from all related parties (Candel, 2018). In determining alternative food security policies and countermeasures, various parties are needed, such as economic, social and environmental experts (Zubaedi, 2013).

Areas with high local R^2 values cannot be said to be food secure or food insecure. However, the indicator is very influential in calculating the food security composite of the region. Likewise, a low local R^2 value does not mean that the region is food secure or food insecure. This analysis is needed to evaluate or consider policyholders in conducting development and mitigation programs, especially food security seen from the characteristics of each region.

A region has a different influence on each food security indicator. Therefore, if the region has a high influence on the agricultural land ratio indicator, then development policies and countermeasures are better focused on agriculture. The risk of a decline in the performance of the agricultural sector needs to be mitigated by reorienting agricultural development policies and programs (Khairad, 2020). Likewise, other regions have different influences on each food security indicator. This can make it easier for policymakers to create programs or provide targeted assistance.

4. Conclusion

The variation in the GWR model parameter coefficients indicates the variation in the influence of each independent variable (percentage of the population infected with Covid-19 and food security indicators) for each village so that the response will be different and adjusted to the characteristics of the region so that it is right on target. The influence of the percentage of the population infected with Covid-19 on food security is highest in the southern area of Bandung Regency, and the value of the Local R² coefficient of the influence of food security indicators in the calculation of the food security composite is the highest in Nagreg District. This can be a consideration for policymakers in planning development, especially in food security which is adjusted in chronic or transient conditions.

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