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IMPLEMENTATION OF GEOGRAPHICALLY WEIGHTED LOGISTIC REGRESSION ON POPULATION GROWTH RATE IN MAJALENGKA

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ABSTRAK

This study investigates the factors that influence the population growth rate in Majalengka Regency using Geographical Weighted Logistic Regression (GWLR) approach. The data used includes the number of births (X1), the number of fertile age couples participating in family planning (X2), and the number of couples of childbearing age (X3) in each sub-district. Descriptive analysis showed significant variation in the variables used across Kecamatans. The simultaneous logistic regression test showed a significant effect of the three predictor variables on the overall population growth rate. However, the partial logistic regression test results showed that not all predictor variables had a significant influence individually in each Kecamatan. The logistic regression model proved to be feasible and suitable for making predictions based on observed data. The spatial heterogeneity test shows that there is heterogeneous variation in the population growth rate in each subdistrict. The best kernel weighting was selected using the Fixed Gaussian kernel function based on the lower AIC value. The results of GWLR modeling showed different effects of predictor variables on population growth rate in each subdistrict. Model evaluation shows that GWLR provides important information regarding the influence of predictor variables on population growth rate in Majalengka Regency. This study provides in-depth and contextual insights into the factors that influence population growth at the local level, which can be the basis for decision-making in regional planning and development.

Kata Kunci : *GWLR, Population Growth Rate, Population.*

A. INTRODUCTION

In the era of globalization and rapid technological development, population growth is a critical aspect that requires in-depth understanding. Uncontrolled population growth can have a significant impact on the economic, social and environmental development of a region (Aswanto, 2020). Amidst the dynamics of global change, understanding spatial variations in population growth rates is an urgent need, especially for regions such as Majalengka.

Majalengka, as one of the regions in Indonesia, faces unique challenges and opportunities related to its population growth. Achieving sustainable development requires a deep understanding of the factors that influence population growth, both overall and at the local level (Sholikhah et al., 2022). In this context, Geographically Weighted Logistic Regression (GWLR) emerges as a statistical approach that can provide insight into the spatial variation in these factors (Sianipar et al., 2022).

Population growth rate is a measure that describes the change in population of an area over a period of time (Sianipar et al., 2022). It is usually calculated as the percentage change in population from one time period to the next (Wulandari & dkk, 2019). Population growth rate greatly influences the population dynamics of a region and can have a significant impact on economic development, environmental sustainability, and social and welfare policies (Halim, 2020).

GWLR is a spatial analysis method that accounts for local variation in the impact of predictor variables on response variables (Dur et al., 2023). In other words, GWLR allows the identification of differences in population growth patterns across different regions in Majalengka. Through this approach, we can better understand how factors such as education level, employment, infrastructure, and other environmental aspects contribute to population growth in each part of the region (Maulidina & Oktora, 2020).

This study aims to apply Geographically Weighted Logistic Regression in analyzing the population growth rate in Majalengka. By conducting a more in-depth spatial analysis, it is expected that we can identify unique patterns and critical factors that affect population growth at the local level (Faruk et al., 2020). The results of this research are expected to make a real contribution in supporting evidence-based decision making and formulating more effective and sustainable development policies.

This research is structured in several stages, starting from data collection, GWLR analysis, to the interpretation of the results and their implications in the context of development policy in Majalengka. The application of GWLR is expected to provide a better understanding of population growth dynamics at the local level (Mahmudah et al., 2023), open the door for more targeted solutions, and help achieve sustainable development goals in Majalengka.

B. METHODS

This study uses secondary data obtained from the publication in figures of Majalengka district for each sub-district at the Central Statistics Agency (BPS) in 2022 (BPS, 2023). The response variable used is categorical in 26 sub-districts in Majalengka. Data processing was carried out using SPSS 25, Autocad and GWR4 software. Information about the dependent and independent variables used is as follows:

Table 1. Research Variables

Variable	Description	Scale
Y	Population Growth Rate 0 = PGR < 1 1 = PGR > 1	Nominal
X_1	Total birth rate	Ratio
X_2	Number of fertile age couples participating in family planning	Ratio
X_3	Total number of couples of childbearing age	Ratio
Koordinat Kartesius	Spatial effects of logitude and latitude coordinates	Ratio

Source: Primary Data, 2024

The following are the steps to conduct Geograpichally Weighted logistic Regression (GWLR) analysis on the population growth rate in each district in Majalengka:

(1) Make a descriptive analysis to obtain an initial description of all variables. In this case, summary statistics will be presented in the form of minimum, mean, maximum, and variance values for each variable.
(2) Determining the parameters of the logistic regression model
(3) Obtain multiple linear regression models using the OLS method obtained by estimating the equation using GWR software.
(4) Performing Geographically Weighted Logistic Regression (GWLR) spatial modeling on sub-district growth rates in Majalengka with the following steps:
    a. Determine the spatial effect (geographical location) on the longitude and latitude of each sub-district
    b. Calculating the euclidean distance between sub-districts in each observation
    c. Calculation of the weight matrix on the Euclidian distance of the location (ui, vi) d) calculation of the optimum bandwidth using the Cross Validation application
    d. Choosing the best kernel function using the Akaike Information Criterion (AIC) value
    e. Calculating the parameters of the Geographical Weighted Logistic Regression (GWLR) model
    f. Testing Geographical Weighted Logistic Regression (GWLR) on the best kernel weighting function
    g. Perform Model fit test
    h. Conduct significance testing and model interpretation in each sub-district
    i. Predicting the growth rate in each sub-district of Majalengka.

C. RESULTS AND DICUSSION

The results of the Geographical Weighted Logistic Regression (GWLR) modeling stage on the growth rate in each sub-district in Majalengka have several stages as follows:

1. Descriptive Analysis

Descriptive analysis is carried out in order to obtain initial information related to all variables used (Sanusi & Arkas, 2023). The descriptive analysis performed is presented in the form of summary statistics containing the minimum, mean, maximum, and variance values of each variable used (Table 2).

Table 2. Descriptive Analysis Test Results

Variable	Min	Max	Mean	Std. Deviation
X_1	11	37	22,23	6,725
X_2	356	5021	1273,62	861,160
X_3	3267	18544	10530	3288,88

Source: Data processed by SPSS 25, 2024

Based on table 2 above, it explains that most of the values of the number of births in variable X1 in Majalenhka district are 22.23 people with the lowest value of 11 people in Sindang District, and the highest value of 37 people in Jatiwangi District and the average distance of these values is 6.725. The next data information explains the number of fertile age couples participating in family planning (X2) in Majalengka district with an average of 1273.62 couples and the lowest value of 356 couples in Sindang sub-district, then the highest value of 5021 in Panyingkiran sub-district and the distance between the number of fertile age couples participating in family planning with an average value of 861.16 couples. Furthermore, the last variable in the number of fertile age couples is 10530 with the lowest value of 3267 in the Sindang sub-district and the highest of 18544 in the Jatiwangi sub-district with a distance between the average value and the number of these numbers amounting to 3288.8.

2. Logistic Regression Test Results

The results of logistic regression testing with a simultaneous test to determine the effect of the variable (Hutama & Kristiadi, 2019), variable number of birth rates (X1), the number of couples of childbearing age participating in family planning (X2) and the number of couples of childbearing age (X3) on the population growth rate with spatial effects in each District in Majalengka with the following hypothesis:

H_0 : $\beta_0 = \beta_0 = \beta_0 = \beta_0 = 0$ (observed predictor variables have no effect simultaneously)

H_1 : $\beta_j \neq 0$, j = 1,2,3,....,k (there is at least one predictor variable that is observed to simultaneously affect the response variable)

Simultaneous testing in logistic regression with the resulting decision is to reject H0, which means that with an alpha of 5%, it proves that there is a significant effect on all predictor variables observed on the response variable. The following are the results of simultaneous testing:

Table 3. Simultaneous Test Results Logistic Regression Model

	Chi-square	Df	Sig.
Step	8,360	3	0,043
Block	8,360	3	0,043
Model	8,360	3	0,043

Source: Data processed by GWR4, 2024

Based on table 3, it explains that the Chi-square value of the Logistic Regression model is 8.360 with a significance value of 0.04. The significance value is less than the 5% alpha value. Based on this test, it can be concluded that rejecting H0 means that with an alpha of 5% the variable number of birth rates (X1), the number of fertile age couples participating in family planning (X2) and the number of fertile age couples (X3) simultaneously has a significant effect on the population growth rate in Majalengka Regency.

3. Partial Logistic Regression Test Results

Partial testing is done to determine the partial relationship between the observed predictor variables and the response variable (Sari, 2021). Predictor variables (variable number of birth rates (X1), the number of fertile age couples participating in family planning (X2) and the number of fertile age couples (X3)) affect the

response variable (population growth rate) can be seen if you reject H0 if the significance value is less than alpha 5%. with the following hypothesis:
H_0 : $\beta_j = 0$, j = 1,2,3,....,k
H_1 : $\beta_j \neq 0$, j = 1,2,3,....,k

The following are the results of partial testing on the logistic regression model in table 4 explaining that the significance value of the variable number of births is 0.24, the number of fertile age couples participating in family planning is 0.4 and the number of fertile couples is 0.15. The value is more than alpha 5% which can be concluded that accepting H0 which means that with alpha % the variable number of births, the number of couples of childbearing age participating in family planning, and the number of couples of childbearing age cannot be statistically proven to have a partial effect on the development of population growth rates. table 4 also explains the results of the binary logistic regression estimation model parameters as follows:

$$\hat{g} = 4{,}21 + 0{,}008\, X_1 + 0{,}003\, X_2 - 0{,}004\, X_3$$

In equation 1, it can be interpreted that if there is an increase of one soul in the number of births, the population growth rate will increase by 0.008 provided that other variable factors are constant. If the variable number of couples of childbearing age participating in family planning increases by one pair of people, the population growth rate will increase by 0.003 under the condition that other variables are constant. If there is an increase of one pair of people in the number of fertile age couples, there is a decrease in the population growth rate by 0.004 under the condition that other variables are constant. When the values of the variables of the number of births, the number of fertile age couples participating in family planning and the number of fertile age couples are constant, the prediction error value of population growth rate modeling is 4.21.

Table 4. Partial Test Results of Logistic Regression Model

	B	Wald	Sig.
Total birth rate	0,008	1,297	0,238
Number of fertile age couples participating in family planning	0,003	1,135	0,414
Total number of couples of childbearing age	-0,004	1,887	0,157
Constant	4,21	6,662	0,000

Source: Data processed by GWR4, 2024

4. Model Suitability Test Results

This stage is carried out to test whether the model obtained based on partial and serial testing is suitable for prediction or not (Hendayanti & Nurhidayati, 2020) and is explained in table 5. The following is the hypothesis used:
H_0 : The model formed is feasible
H_1 : The model formed is not feasible

Table 5. Model Fit Test Results

Chi-Square	Df	Sig.
3,542	3	0,936

Source: Data processed by GWR4, 2024

5. Spatial Heterogenety Test Results

This test to determine whether the economic growth rate has a spatial effect or not (Pratiwi et al., 2019) can be seen in table 6. The hypothesis in testing spatial heterogeneity with bresuch pagan test statistics is

$H_0: \sigma_1^2 = \sigma_2^2 = \sigma_3^2 = \cdots \sigma_n^2$ (Variety in each District is Homogeneous)

$H_1: paling\ sedikit\ ada\ satu\ \ \sigma_1^2 \neq \sigma$ (Variety in each District is Heterogeneous)

Table 6. Spatial Heterogeneity Test Results

	Nilai	Signifikansi
Breusch Pagan Test	11,1145	0,00491

Source: Data processed by GWR4, 2024

Table 6 explains the Breusch Pagan test of 11.12 with a significance value of 0.00491. This value is smaller than 5% alpha, it can be concluded that the decision taken is to reject H0 which indicates that there is a spatial effect or there is a variation in each sub-district in Majalengka district on the population growth rate is heterogeneous. This indicates that Geographical Weighted Logistic Regression (GWLR) modeling can be done.

6. Selection of The Best Kernel

Optimum bandwidth value by using 2 kernel functions, namely adaptive gaussian and fixed gaussian (Solekha & Qudratullah, 2022). Here is the optimum bandwidth value in table 7:

Table 7. Kernel Function Value

Weighting Function	CV Value Min.	Bandwith	AIC Value
Adaptive Gaussian	7,268	18	34,06
Fixed Gaussian	7,168	0,204	33,89

Source: Data processed by GWR4, 2024

The Bandwidth value of the Adaptive Gaussian kernel function is 7.268 and fixed gaussian is 7.168, so it can be selected that the weight used is fixed gaussian. This result can also be supported by the AIC value of the GWLR model fixed gaussian kernel function is smaller than the Adaptive Gaussian kernel, so the best GWLR model criterion is the fixed gaussian kernel function.

7. GWLR Modeling

The following are the results of the GWLR modeling equation with the Fixed Gaussian kernel function (Nisa, 2022) at one of the Bantarujeg Majalengka sub-district observation locations:

$$\hat{g} = 3{,}650 + 0{,}009\ X_1 + 0{,}002\ X_2 - 0{,}005\ X_3$$

Equation 2 shows that an increase in the number of births (X1) by one person will increase the population growth rate in Bantarujeg District by 0.009, provided that other variables are constant. Then the factor of the number of fertile age couples participating in family planning (X2) will increase by one pair, the population growth rate in Bantarujeg Subdistrict will increase by 0.02, provided that other variables are constant. Furthermore, the factor of the number of couples of childbearing age (X3) will decrease by one pair, the population growth rate in Bantarujeg Subdistrict will increase by 0.005, provided that other variables are constant. When the population growth rate in Bantarujeg Subdistrict is 3.650 when not influenced by the number of births (X1), the number of fertile age couples participating in family planning (X2) and the number of fertile age couples (X3).

8. Partial Parameter Significance Testing

The model suitability test is used to see whether the GWLR model is suitable or not or whether there are other modeling elements such as logistic models (Ikhsanudin & Pasaribu, 2023). The following is the GWLR model suitability hypothesis:

H0 : There is a similarity between the global model and the GWLR model

H1 : There is a difference between the global model and the GWLR model

This result shows that there is a difference between the global model (logistic regression) and the GWLR model. This is evidenced by rejecting H0 when the ratio value of deviance and DOF for the GWLR model is smaller than the global model.

Table 9. GWLR Model Fit Test Results

Source	Deviance	DOF
Global Model	24,6	22
GWLR Model	27,5	20,8
Difference	0,53	5,7

Source: Data processed by GWR4, 2024

9. Model Evaluation

Testing the parameters of the GWLR model on the Fixed Gaussian kernel function is necessary in order to obtain information related to the influence of predictor variables (Damayanti Sihombing et al., 2023) on the response variable in Majalengka District. GWLR modeling produces different coefficient values in each sub-district in Majalengka related to population growth rate. From the tcount test value on each predictor variable observed in each sub-district. The tcount value of Lemahsugih sub-district is 1.522 with a significant value of 0.492. This result proves that H0 is accepted because the t-count value has a value greater than t(0.05,24) of 2.064, which means that there is no significant effect of the variables observed in the Lemahsugih sub-district on the population growth rate. The following are variables that have a significant effect on the population growth rate in each sub-district in Majalengka Regency which are grouped into 3 groups.

Table 10. GWLR Partial Test Results in Each Subdistrict

Group	Variable	Subdistrict
1	X1	Lemahsugih, Cikijing, Argapura, Maja, Majalengka, Sukahaji, Rajagaluh, Jatiwangi, Jatitujuh, Ligung, Sumberjaya
2	X2	Cingambul, Talaga, Cigasong, Leuwimunding, Dawuan, Kasokandel

3	None	Bantarujeg, Malausma, Banjaran, Sindang, Sindangwangi, Palasah, Panyingkiran, Kadipaten, Kertajati

Source: Data processed, 2024

Based on table 10, it can be visualized in the form of a sub-district grouping map in Majalengka district based on the influence of the observed predictor variables on the population growth rate variable using GWLR modeling on the Fixed Gaussian kernel function.

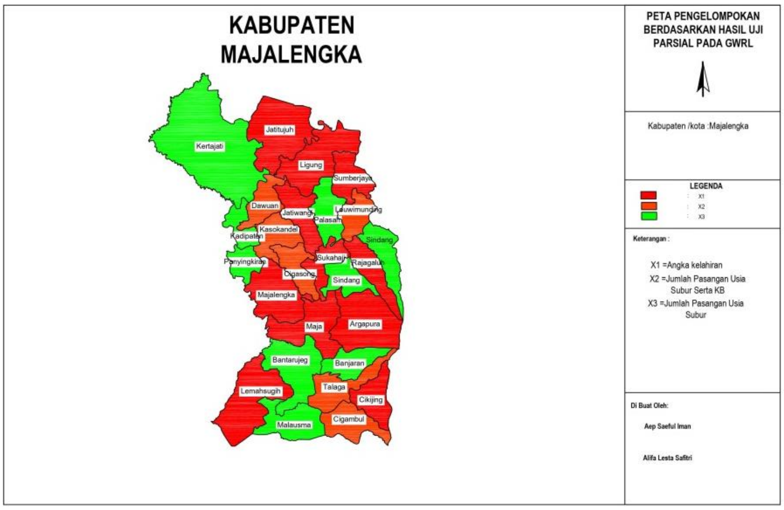

Figure 1. Grouping Based on Partial Test Results in GWLR
Source: Map delineated from autocad, 2024.

Figure 1 is the result of partial testing on observed predictor variables that are significant in each sub-district. There are 11 sub-districts including Lemahsugih, Cikijing, Argapura, Maja, Majalengka, Sukahaji, Rajagaluh, Jatiwangi, Jatitujuh, Ligung, and Sumberjaya which have a significant influence on the number of births (X1) on the population growth rate. There are 6 sub-districts including Cingambul, Talaga, Cigasong, Leuwimunding, Dawuan, and Kasokandel that have a significant influence on the variable number of fertile age couples participating in family planning (X2) on the population growth rate. There are 9 sub-districts that are not proven to have a significant influence on the variable number of birth rates (X1), the number of fertile age couples participating in family planning (X2) and the number of couples of childbearing age (X3) on the population growth rate in Majalengka district. Stage Ten Prediction of Population Growth Rate in Majalengka Regency. The prediction of GWLR modeling on the Fixed Gaussian kernel function on the growth rate in Majalengka Regency in each sub-district is shown in Figure 3. Figure 3 shows the results of the prediction of population growth rate in Majalengka Regency with a low category at LPP < 1 there are 6 sub-districts such as Bantarujeg, Banjaran, Maja, Majalengka, Dawuan, and Jatitujuh. Population growth rate in the high category with LPP> 1 in 20 sub-districts in Majalengka Regency such as Lemahsugih, Malausma, Cikijing, Cingambul, Talaga, Argapura, Cigasong, Sukahaji, Sindang, Rajagaluh, Sindangwangi, Leuwimunding, Palasah, Jatiwangi, Kasokandel, Panyingkiran, Kadipaten, Kertajati, Ligung, and Sumberjaya.

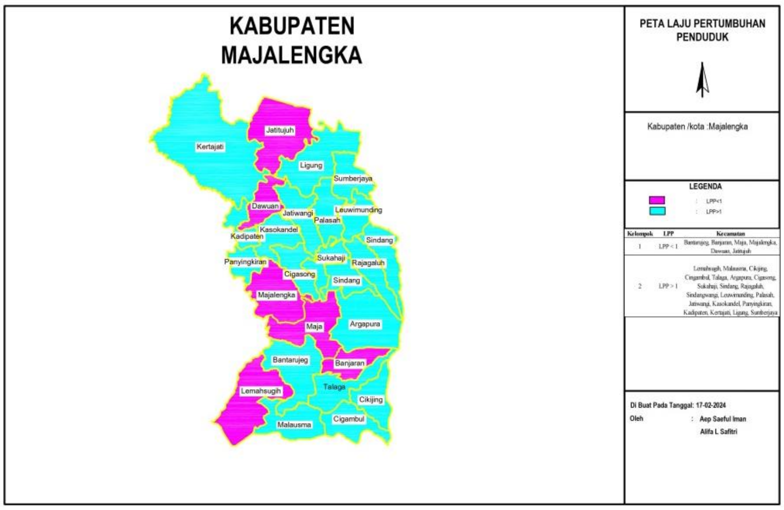

Figure 2. Predictions of GWLR Modeling
Source: Map delineated from autocad, 2024

The model suitability test is used to see whether the GWLR model is suitable or not or whether there are other

D. CONCLUSSION

From the results of Geographical Weighted Logistic Regression (GWLR) modeling on the population growth rate in Majalengka Regency, it can be concluded that the variables used in the modeling, namely the number of births (X1), the number of couples of childbearing age participating in family planning (X2), and the number of couples of childbearing age (X3), have significant variations in value in each sub-district in Majalengka. There is a simultaneous significant influence between the three predictor variables on the population growth rate in Majalengka Regency. Although simultaneously significant, partially not all predictor variables have a significant influence on the population growth rate in each sub-district. The logistic regression model used proved to be feasible and suitable for making predictions based on observational data. There is a spatial effect or heterogeneous variation in the population growth rate in each sub-district in Majalengka Regency. The Fixed Gaussian kernel function was chosen as the best model for GWLR modeling, with a lower AIC value compared to Adaptive Gaussian. The GWLR modeling equation shows the different influence of predictor variables on the population growth rate in each sub-district. There is a difference between the global model (Logistic regression) and the GWLR model, indicating that GWLR is more suitable for testing in a spatial context. GWLR modeling provides important information regarding the influence of predictor variables on population growth rate in each sub-district in Majalengka Regency, with some sub-districts showing significant influence from predictor variables.

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