Factors Affecting the Resilience Index Food in Papua Province and West Papua Province Using a Spatial Model Approach

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ABSTRAK

Indeks Ketahanan Pangan adalah ukuran dari indikator-indikator untuk menghasilkan nilai komposit yang mencerminkan status ketahanan pangan di suatu wilayah. Ketahanan pangan berperan penting dalam pembangunan berkelanjutan, mencakup ketersediaan pangan, pelestarian lingkungan, dan keseimbangan ekonomi, juga sebagai dasar pertumbuhan ekonomi, pencegah kemiskinan, dan ketidaksetaraan. Di Indonesia, dengan perkiraan pertumbuhan penduduk mencapai 430 juta jiwa pada tahun 2050, tantangan dalam memenuhi kebutuhan pangan semakin besar. Komitmen Indonesia terhadap Sustainable Development Goals (SDGs) mencakup upaya mengakhiri kelaparan dan mempromosikan pertanian berkelanjutan. Penelitian ini bertujuan untuk menerapkan analisis regresi spasial pada Provinsi Papua dan Papua Barat untuk menentukan model terbaik dan faktor-faktor signifikan yang mempengaruhi Indeks Ketahanan Pangan di wilayah tersebut guna mengidentifikasi tantangan yang dihadapi wilayah tersebut dalam memperhitungkan ketersediaan pangan masyarakatnya sekaligus membantu dalam menyusun upaya untuk mengatasinya. Digunakan lima variabel prediktor dengan asumsi memiliki pengaruh yang signifikan terhadap Indeks Ketahanan Pangan, penelitian ini mengkaji persamaan regresi spasial dengan pendekatan wilayah SAR, SEM, dan SARMA. Diperoleh hasil yang menunjukkan bahwa model SEM terpilih dengan nilai *p-value* 0.0082581 yang tepat untuk mengidentifikasi ketergantungan efek spasial terhadap Indeks Ketahanan Pangan di Provinsi Papua dan Provinsi Papua Barat. Angka Harapan Hidup Saat Lahir (AHH), Prevalensi Balita Stunting (PBS), Persentase Penduduk Miskin (PPM), Tingkat Pengangguran Terbuka (TPT), dan Rata-Rata Lama Sekolah (RLS) adalah faktor signifikan yang memengaruhi Indeks Ketahanan Pangan di Provinsi Papua dan Provinsi Papua Barat secara spasial.

Kata kunci: Indeks Ketahanan Pangan; Regresi Spasial; Provinsi Papua, Provinsi Papua Barat, Lagrange Multiplier (Error)

ABSTRACT

The Food Security Index is a measure of indicators to produce a composite value that reflects the status of food security in a region. Food security plays an important role in sustainable development, including food availability, environmental preservation and economic balance, as well as being the basis for economic growth, preventing poverty and inequality. In Indonesia, with an estimated population growth of 430 million people in 2050, the challenge of meeting food needs is increasing. Indonesia's commitment to the Sustainable Development Goals (SDGs) includes efforts to end hunger and promote sustainable agriculture. This research aims to apply spatial regression analysis to the Provinces of Papua and West Papua to determine the best model and significant factors that influence the Food Security Index in the region in order to identify the challenges faced by the region in calculating the food availability of its people as well as assist in developing efforts to overcome them. Five predictor variables were used with the assumption that they have a significant influence on the Food Security Index. This research examines the spatial regression equation using the SAR, SEM and SARMA regional approaches. The results obtained showed that the selected SEM model with a p-value of 0.0082581 was appropriate for identifying the dependence of spatial effects on Food Security Index in Papua Province and West Papua Province. Life Expectancy at Birth,

Prevalence of Stunting Toddlers, Percentage of Poor Population, Open Unemployment Rate, and Average Length of Life are significant factors that influence the Food Security Index in Papua Province and West Papua spatially.
Keywords: *Food Security Index; Spatial Regression; Papua Province, West Papua Province, Lagrange Multiplier (Error)*

INTRODUCTION

Development and food security have strong ties and influence each other in the context of sustainable development. Development that neglects one's own ability to meet the basic needs of its people will lead to high dependence on other countries, which will ultimately eliminate state sovereignty [1] . In the context of sustainable development, food security is not enough just to maintain aspects of food availability, but also to harmonize efforts to preserve the environment and achieve long-term economic balance, building a solid foundation for progress and the welfare of society in the future. Food security is one of many important issues in the development of a country with the agricultural sector as the main food provider, especially for developing countries, because it plays an important role as one of the main development targets as well as the main tool in economic development [2] .

Food security not only acts as a basis for sustainable economic growth with sufficient energy availability and productivity, but also as a preventive measure for poverty and inequality, considering that equitable access to food plays an important role in improving the welfare of the entire community. The historical experience of Indonesia's development confirms that the issue of food security is related to economic stability, especially in the face of inflation, rising costs of living, and national political stability [3] . The importance of food security for national development shows that it is not only necessary to have adequate food availability, but also to pay attention to aspects of safety, quality and fair distribution for society.

The prediction of Indonesia's population growth, which is expected to double with an increase of around 1.5% per year to around 430 million people in 2050, will have a major impact on meeting food needs. As the population increases, demand for food will also continue to increase, because population size has a direct effect on food availability [4] . There is a need for integrated efforts involving the agricultural sector, population policy, and natural resource management to respond to the need for increased food production, diversification of food resources, and the establishment of equitable food distribution policies to maintain food security in line with sustainable population and economic growth.

In the 2030 agenda for Sustainable Development, Indonesia is committed to realizing the targets of "ending hunger, achieving food security, improving nutrition, and promoting sustainable agriculture" [5] . Food Security Index plays an important role in assessing the success of developing food stability in a region, assessing the region's ability to fulfill government responsibilities, and functions as an instrument for determining regional interests and program interventions [6] .

According to the Global Food Security Index , Indonesia's Food Security Index in 2022 is at the level of 60.2, or an increase of 1.7% compared to 2021 which is in 69th place out of 113 countries and below the global average of 62.2. Bali province's Food Security Index is 85.19, the highest value in 2022, while there are two provinces (5.88%), namely Papua and West Papua, which are included in provinces with low Food Security Index, at 37.80 and 45.92 respectively. In general, there appears to be a tendency for provinces with Food Security Index in the very resistant category

to be close to provinces with Food Security Index in the very resistant category as well, and this also happens for provinces with Food Security Index in the lower category. Based on this distribution, there are indications that the Food Security Index between neighboring provinces influence each other spatially, so that the condition of the Food Security Index in a province can be related to the condition of the Food Security Index in its surrounding/neighboring provinces.

From the description above, spatial regression analysis will be used in this research to determine the factors that significantly influence the Food Security Index in Papua Province and West Papua Province by considering the influence of location, analyzed by testing spatial effects using spatial dependencies. Spatial dependency explains that the locations of research objects are related or related to each other [7] . In modeling spatial dependencies, several types of models emerge, such as the Spatial Autoregressive Model (SAR) which indicates a relationship between response values at various locations, Spatial Error Model (SEM) which indicates a relationship between error values at various locations, and Spatial Autoregressive Moving Average (SARMA) which indicates the relationship between response values and error values at various locations.

Research related to Food Security Index was previously carried out by Ayu Safitri, Baharuddin, Agusrawati, Bahriddin Abapihi, Ruslan Gusti Ngurah Adhi Wibawa (2022) regarding Modeling of Factors that Influence Food Security Index in Southeast Sulawesi which can be analyzed using the best spatial dependency modeling, namely the Spatial Error Model (SEM) and shows that the variables that influence the Food Security Index include the Percentage of Malnourished and Stunting Toddlers, the Life Expectancy Rate variable, the Human Development Index variable, the GRDP Rate variable, the Rice Production variable, and the Population Number variable [8] . Other research related to Food Security Index was also conducted by Irma Yani Safitri, Muhammad Arif Tiro, and Ruliana (2022) regarding Spatial Regression Analysis to See Factors that Influence Food Security at the Regency Level in South Sulawesi Province, obtaining the best spatial dependency model, Spatial Error Model (SEM) and shows that the variables that influence the Food Security Index include Per Capita Normative Consumption Ratio to Clean Availability, Percentage of Population Living Below the Poverty Line, Percentage of Households with the Proportion of Expenditure on Food More Than 65% of Total Expenditure, Percentage of Households without Access to Electricity, Percentage of Households without Access to Clean Water, Ratio of the Number of Population per Health Personnel to Population Density Level, Percentage of Toddlers with Height Below Standard (*stunting*), Life Expectancy, Average Length Of School For Women Over 15 Years [9].

This research aims to utilize spatial regression analysis to identify the best regression model and determine the variables that have a significant influence on the Food Security Index in Papua Province and West Papua Province.

METHOD

Data

This research will use data sourced from the National Food Agency, the Indonesian Ministry of Health, the Papua Province Statistics Center and the West Papua Province Central Statistics Agency which consists of 41 Regencies/Cities. The variables used include the Food Security Index (Y), Life Expectancy at Birth (X_1), Percentage of Stunting Toddlers (X_2), Percentage of Poor

Population (X_3), Open Unemployment Rate (X_4), and Average Years of Schooling (X_5) according to Regency/City in Papua and West Papua Provinces in 2022 .

Data Processing Procedures

The following are the stages that will be carried out in this research:

1. Conduct descriptive analysis on Food Security Index in Papua Province and West Papua Province in 2022
2. Using correlation analysis of the data, to identify any predictor variables that are related to the response variable.

$$r_{xy} = \frac{n\Sigma_{i=1}^{n} x_i y_i - (\Sigma_{i=1}^{n} x_i)(\Sigma_{i=1}^{n} y_i)}{\sqrt{[n\Sigma_{i=1}^{n} x_i^2 - (\Sigma_{i=1}^{n} x_i)^2][n\Sigma_{i=1}^{n} y_i^2 - (\Sigma_{i=1}^{n} y_i)^2]}} \quad (1)$$

3. Multiple linear regression analysis of Food Security Index in Papua Province and West Papua Province involving 41 Regencies/Cities and 5 predictor variables.

$$\boldsymbol{Y} = \begin{pmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_n \end{pmatrix}, \boldsymbol{X} = \begin{pmatrix} 1 & X_{11} & X_{12} & \cdots & X_{1n} \\ 1 & X_{21} & X_{22} & \cdots & X_{2n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 1 & X_{m1} & X_{m2} & \cdots & X_{mn} \end{pmatrix}, \boldsymbol{\beta} = \begin{pmatrix} \beta_1 \\ \beta_2 \\ \vdots \\ \beta_n \end{pmatrix}, dan\ \boldsymbol{\varepsilon} = \begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_n \end{pmatrix} \quad (2)$$

If written in equation form it is as follows:

$$\boldsymbol{Y} = \boldsymbol{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon} \quad (3)$$

4. Durbin-Watson test statistic, if autocorrelation occurs then it is indicated that there is a spatial effect on the residual value.

$$D = \frac{\sum_{t=2}^{n}(e_t - e_{t-1})^2}{\sum_{t=1}^{n} e_t^2} \quad (4)$$

5. Determine the spatial weighting matrix using the Queen Continguity weighting matrix
6. Test the effect of spatial dependence with the Moran's I dependency test to evaluate the level of spatial autocorrelation and produce a Moran's scatterplot to visualize the distribution between locations. If there is spatial autocorrelation, the Lagrange Multiplier (LM) test is continued.

$$Z = \frac{I - E(I)}{\sqrt{\mathrm{Var}(I)}} \approx N(0,1) \quad (5)$$

7. Determine the spatial model using the Lagrange Multiplier (LM) test

$$LM_{lag} = \frac{(\varepsilon^T W y)^2}{s^2 (WX\beta)^T M (WX\beta) + Ts^2)} \quad (6)$$

$$LM_{error} = \frac{(\varepsilon^T W \varepsilon / S^2)^2}{T} \quad (7)$$

8. Determining the right Spatial Regression model. The general form of the spatial regression model is as follows:

$$y = \rho W_y + X\beta + u \quad (8)$$

$$u = \lambda w_u + \varepsilon \sim \varepsilon \sim N(0, \sigma^2 I) \quad (9)$$

9. Interpret the model and formulate conclusions.

RESULTS AND DISCUSSION

The Food Security Index in Papua Province and West Papua Province can be described visually as follows:

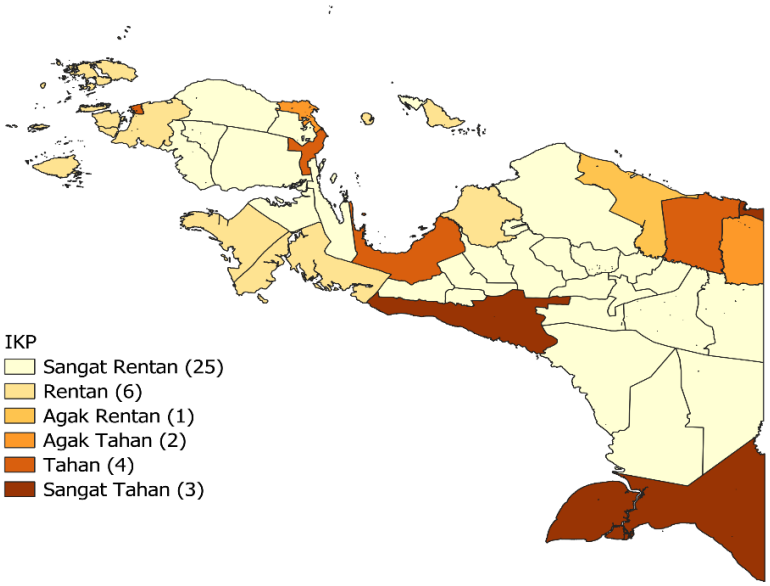

Figure 1. Map of Food Security Index Distribution for Papua Province and West Papua Province

Figure 1 shows the geographical description of Food Security Index in Papua Province and West Papua Province, divided into 6 interval groups. Each interval represents a certain range of values with categories as shown on the map. Apart from that, the colors on the map indicate the Food Security Index level , increasing color intensity on the map indicates a higher Food Security Index value. The highest Food Security Index achievement with a value of 80.55 is in Mimika Regency, while the lowest Food Security Index achievement with a value of 15.66 is in Nduga Regency. Most of the Food Security Index for Regency/City areas are in the very vulnerable category with a total of 25 Regency areas, while Regency/City areas in the very resistant category only cover 2 Regency and 1 City.

Multiple Linear Regression Analysis

The initial step that must be applied to the data before carrying out regression analysis is to carry out correlation analysis first to identify predictor variables that are significant to the response variable. The following correlation results were obtained:

Table 1. Pearson Correlation

Variables	Value	p-value
X_1	0.5596469	0.0001422
X_2	-0.6201429	0.000103
X_3	-0.8339579	1.283e-11
X_4	0.6031419	2.996e-05
X_5	0.826388	2.848e-11

Based on Table 1, the results show that all predictor variables have a linear relationship with Food Security Index because they have a p-value > α(5%), so that all predictor variables are significant and can be used in regression analysis to find their influence on Food Security Index.

Multiple linear regression analysis is carried out with the aim of understanding the relationship pattern of the response variable and a number of predictor variables by evaluating how each predictor variable contributes to changes in the response variable. The following are the results of multiple linear regression estimates:

Table 2. Regression Parameter Estimation

	Estimate	t-value	p-value
Intercept	-41.3413	-0.997	0.325463
X_1	1.5278	2,543	0.015584
X_2	-0.3012	-1,766	0.086181
X_3	-0.9698	-3,926	0.000387
X_4	-1.4181	-1,578	0.123576
X_5	2.9068	2,615	0.013060

In Table 2, the results obtained at a significance level (α) of 0.5 (5%), there are 3 variables that influence the Food Security Index in Papua Province and West Papua Province. The significant variables consist of the Life Expectancy at Birth (X_1), Percentage of Poor Population (X_3), Years of Schooling (X5), because they have a p-value < α(5%). The regression model obtained is formed as follows:

$$\hat{Y} = -25.7868 + 1.3374_{X_1} - 0.3540_{X_2} - 0.9953_{X_3} - 1.2248_{X_4} + 2.7898_{X_5} \quad (10)$$

Next, simultaneous tests and partial tests were carried out on the regression parameters. Simultaneous test results were obtained with a p-value of 3.545e-12 < α(0.05), which means there is enough evidence to say that there must be at least one predictor variable that significantly influences the response variable in the model. Meanwhile, with the partial test it was found that the partial test showed that the Life Expectancy at Birth (X_1), Percentage of Poor Population (X_3), Years of Schooling (X_5) significantly influenced the Food Security Index, because they had a p-value < α (0.05).

Classical Assumption Testing

If the parameter testing is significant and the residual assumptions are met, then the regression model can be said to be good. These assumptions include the following:

1. Normality test

The normality test aims to check that the residuals from a normal distribution have been fulfilled using the Shapiro-Wilk test. It was found that the results of the normality test using the Shapiro-Wilk test, obtained a p-value of 0.3467 > α(0.05), which means that the data is relatively the same as the average, so the residuals are normally distributed.

2. Heteroscedasticity Test

Heteroscedasticity detection was carried out using the Breusch-Pagan test . It was found that from the results of the heteroscedasticity test using the Breusch-Pagan test, the p-value was obtained 0.639 > α(0.05) , which means that the error variance is homoscedasticity.

3. Multicollinearity Test

The multicollinearity test was carried out to determine whether there was a significant relationship between the predictor variables in the regression model. Regression analysis can be carried out if there are no cases of multicollinearity. The existence of multicollinearity can be determined by checking the Variance Inflation Factor (VIF) value.

Table 3. VIF value

Variable	VIF
X_1	1.386125
X_2	1.691362
X_3	2.648298
X_4	2.667831
X_5	4.868858

It was found that the VIF value of all predictor variables was <10, which means that in the regression model there were no symptoms of multicollinearity.

4. Autocorrelation Test

The autocorrelation test is used to evaluate the independence of one residual from another. This test uses the Durbin-Watson test. The results of the autocorrelation test using the Durbin-Watson test show a p-value of 0.01374 < α(0.05), which means there is autocorrelation between the residuals which indicates a spatial effect on the response variable.

Spatial Weighting Matrix

There are indications that there is a spatial effect on the response variable, therefore it is necessary to carry out a Moran's I test with the first step being to determine the spatial weighting matrix. This spatial weighting matrix is a positive symmetric matrix with size $n \times n$, where n is the number of locations observed, and this matrix describes the proximity or relationship between these regions. Information about proximity between regions can be obtained from two relationship conditions, namely neighborhood and distance. The Queen Continguity Matrix will be used in this research, namely a weighting matrix that takes into account the sides and angles that intersect each other between the observation areas. The spatial weighting matrix is described as follows:

$$W = \begin{bmatrix} W_{11} & W_{12} & \cdots & W_{1n} \\ W_{21} & W_{22} & \cdots & W_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ w_{n1} & w_{n2} & \cdots & w_{nn} \end{bmatrix} \quad (11)$$

The W matrix functions to show the proximity between various observation locations. The elements in the matrix, called W ij, where i represents the row and j represents the column in the matrix, indicate whether two regions are adjacent or not. In this context, the element W ij has the value 1 if region i is close to the observation location j. On the other hand, if region i is not close to the observation location j , then the value of W ij is 0. The standardization of the matrix results used in the model is as follows:

$$W_{ij(std)} = \frac{W_{ij}}{\Sigma_{i=1}^{n} W_{ij}} \quad (12)$$

Where:

$W_{ij(std)}$ = Standardized weighting matrix elements
W_{ij} = Elements of the weighting matrix

Testing Aspects of Spatial Data

Spatial dependency means that the value of a variable in one region is related to the value in the surrounding region. Moran's I statistic is used to detect this pattern. The Moran Index test results obtained with the Queen Contiguity weighting matrix produced a p-value of 0.01097379 < α(0.05), which means there is spatial dependency between regions. Next, the Lagrange Multiplier (LM) test was carried out to determine the correct model. The following are the test results:

Table 4. Lagrange Multiplier Test

	Value	p-value
Lagrange Multiplier (Lag)	1.902430	0.01661
Lagrange Multiplier (Error)	5.736823	0.16781
Lagrange Multiplier SARMA	5.800666	0.05500

The LM test results show that only the Lagrange Multiplier (Error) has a p-value of 0.0166 < α(0.05), which means that there is a spatial dependency of error on the response . Therefore, the appropriate model for Food Security Index in Papua Province and West Papua Province is the Spatial Error Model (SEM).

***Spatial Error* (SEM)**

In the Lagrange Multiplier test results, it was found that there was spatial autocorrelation in the response variable errors. This confirms that analysis using the Spatial Error Model (SEM) is the right step. Parameter estimation in this model was carried out using the Wald test . The following SEM model was obtained:

Table 5. SEM Model Testing Estimation Results

	Estimate	Standard Error	z-value	p-value

λ	0.50832	0.1472	3.4532	0.0082581
Intercept	-80.92208	37.62819	-2.1506	0.031510
X_1	2.22200	0.56445	3.9366	8.266e-05
X_2	-0.37523	0.13926	-2.6944	0.007052
X_3	-0.98015	0.22075	-4.4401	8.991e-06
X_4	-1.34116	0.65885	-2.0356	0.041791
X_5	2.23025	0.97869	2.2788	0.022678

Based on Table 4, the SEM model is produced as follows:

$$\hat{y}_i = 0.50832 \sum_{j=1,i\neq j}^{41} w_{ij}y_j - 80.92208 + 2.22200_{X_1} - 0.37523_{X_2} - 0.98015_{X_3} - 1.34116_{X_4} + 2.23025_{X_5} \quad (13)$$

Model Interpretation

The results obtained were that the Life Expectancy at Birth (X_1), Percentage of Stunting Toddlers (X_2), Percentage of Poor Population (X_3), Open Unemployment Rate (X_4), and Average Years of Schooling (X_5) significantly influenced the Regency/City Food Security Index in Papua and West Papua Provinces. Furthermore, the lambda coefficient (λ) obtained has a p-value of 0.0082581 < α (0.05), which means that the lambda value is significant, indicating that there is an error influence in a Regency/City in Papua and West Papua Provinces which will increase the Food Security Index by 3.4532, which significantly influences the Food Security Index of surrounding districts/cities.

It is known that the Regencies/Cities are correlated with each other as indicated by the lambda coefficient (λ) value of 0.50832, which means the spatial interaction between 41 regencies/cities in Papua and West Papua Provinces which have a regional intersection of 0.50832. If the Life Expectancy at Birth (X_1) variable increases by 1 year, then the Food Security Index will also increase by 2.22200%. If the Percentage of Stunting Toddlers (X_2) variable increases by 1%, the Food Security Index will decrease by 0.37523%. If the Percentage of Poor Population (X_3) variable increases by 1%, then the Food Security Index will decrease by 0.98015%. If the Open Unemployment Rate (X_4) variable increases by 1%, then the Food Security Index will decrease by 1.34116%. If the Average Years of Schooling (X_5) variable increases by 1 year, then the Food Security Index will also increase by 2.23025%. The variables that influence the Food Security Index contribute *an R-Square* of 0.84982 which can be interpreted that the Life Expectancy at Birth (X_1), Percentage of Stunting Toddlers (X_2), Percentage of Poor Population (X_3), Open Unemployment Rate (X_4), and Average Years of Schooling (X_5) variables are able to explain the Food Security Index variable in Papua and West Papua Provinces in 2022 by 84.98% while the other 16.17% is explained by other variables not included in the model.

CONCLUSION

It was concluded that based on the best spatial regression analysis, namely the Spatial Error Model (SEM) with Lagrange Multiplier (LM) testing, the Life Expectancy at Birth (X_1) variable and the Average Years of Schooling (X_5) variable had a positive effect on the Food Security Index in Papua Province and West Papua Province. Meanwhile, Percentage of Stunting Toddlers (X_2) variable, Percentage of Poor Population (X_3) variable, Open Unemployment Rate (X_4) variable have a negative effect on the Food Security Index in Papua and Papua Provinces. These factors have a significant real influence at the significance level of 0.05 (5%).

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