

Determinants of Rural Poverty in Indonesia: A Provincial Spline Regression Analysis

Sri Undai Nurbayani^{1*}, Abd Rahman Razak², Aditya Idris³, Andi Muhammad Arnan Rahman⁴, Betania Kartika Muflih⁵

^{1,2,4}Faculty of Economics and Business, Hasanuddin University, Indonesia

³Economic Development and Planning, Hasanuddin University, Indonesia

⁵International Islamic University Malaysia, Malaysia

(Article history) Received: 2025-10-19, Revised: 2025-12-20, Accepted: 2025-12-28

DOI: 10.24252/ecc.v7i1.13382

Abstract

This study analyzes the determinants of rural poverty in Indonesia using a nonparametric Spline regression approach. The analysis utilizes cross-sectoral secondary data from 37 provinces in Indonesia for the year 2024, with rural poverty as the dependent variable and five independent variables: village fund allocation, agricultural sector growth, land-use conversion, migration, and unemployment. Testing of data quality and model assumptions confirms that the Spline model effectively captures the nonlinear relationship between variables. The results show that village fund allocation and higher agricultural sector growth significantly reduce rural poverty. These results indicate the importance of implementing fiscal decentralization and agrarian revitalization policies in Indonesia. Conversely, land-use conversion and unemployment tend to exacerbate poverty levels, while migration shows a mitigating effect under certain conditions. These findings confirm the multidimensional and regionally heterogeneous nature of rural poverty in Indonesia. This study provides empirical evidence that policy interventions focused on sustainable land management, job creation, and efficient utilization of village funds can substantially improve rural community welfare and economic resilience.

Keywords: Rural Poverty; Indonesian Countries; Spline Regression

1. Introduction

Poverty remains a critical and persistent concern across nations (Todaro & Smith, 2012). It continues to pose a complex challenge that is difficult to eradicate due to the low living standards that perpetuate its existence (Widiyanto et al., 2021). In several contexts, poverty is assessed not only through income levels but also by considering multidimensional factors such as educational attainment (Ivani & Auwalin, 2024). Although rural poverty in Indonesia has exhibited a gradual decline between 2015 and 2024, it consistently remains higher than that in urban areas (BPS, 2025). This persistent disparity indicates that rural populations continue to face deeper structural constraints, including limited access to infrastructure, healthcare, education, and productive employment opportunities. Such conditions reflect fundamental weaknesses in rural economic systems that require targeted and context-sensitive policy interventions (Fattah et al., 2025). Therefore, understanding the dynamics of poverty escalation in rural settings becomes essential for formulating more effective and inclusive development strategies.

Over the past decade, Indonesia has implemented extensive rural development initiatives, leading to notable progress in village conditions. A considerable number of villages previously classified as underdeveloped have transitioned into developing or advanced status (Diah, 2020), particularly following the implementation of the Village Law, which accelerated decentralization and local development efforts (Herdiana, 2022). However, this progress has not fully translated into the eradication of rural poverty. Empirical evidence shows that poverty pockets persist even in villages that are classified as developing or advanced (F. Rahman et al., 2020). This phenomenon highlights the unfinished agenda of rural development and suggests that improvements in village status do not automatically guarantee welfare gains for all rural households. Poverty continues to exert multidimensional impacts on village-level socioeconomic structures and governance dynamics (Alfons et al., 2024).

To address rural poverty, the government introduced the Village Fund Program as a key fiscal policy instrument aimed at stimulating rural economic activity, accelerating development, and improving welfare outcomes. The program is expected to empower local communities and strengthen rural economic foundations (Hartojo et al., 2022). Nevertheless, empirical findings on its effectiveness remain inconclusive. Some studies find that village fund transfers do not have a statistically significant impact on poverty reduction (Yusuf & Khoirunurrofik, 2022), while others argue that higher allocations are necessary to achieve equitable and meaningful poverty reduction (Arham & Payu, 2020). These mixed findings suggest that the impact of village funds may not be linear and could depend on scale, local capacity, and contextual factors.

In parallel, rural economic development has accelerated land-use transformation, particularly the conversion of agricultural land into residential, industrial, or infrastructure uses. While this process aligns with structural transformation theory where agriculture gradually gives way to industry and services it also poses risks for rural livelihoods. Agricultural land conversion can reduce farm-based income opportunities, increase unemployment, and exacerbate poverty among displaced farmers (Brady & Prior, 2020). Land-use conversion in rural areas has a dual effect on poverty levels: while the transformation of land into productive development zones can stimulate economic and alleviate poverty, the degradation or conversion of fertile agricultural land into unproductive areas may instead intensify it. Importantly, land-use change exhibits a dual effect: productive conversion may stimulate economic growth, whereas excessive or poorly managed conversion can intensify poverty and inequality (Wu et al., 2025). This duality suggests that the poverty impact of land-use conversion may vary across regions and levels of conversion intensity.

Migration further complicates rural poverty dynamics. Persistent poverty often encourages rural residents to migrate to urban areas in search of better economic opportunities (Pratomo, 2018). Migration can function as a survival and livelihood diversification strategy, enabling remittance flows that support rural households (Pradana et al., 2022). However, rural-to-urban migration may generate adverse outcomes such as urban overcrowding, unemployment, regional inequality, and the proliferation of slum settlements. Despite these drawbacks, migration can contribute to the reduction of rural poverty by enabling remittances and expanding livelihood alternatives for those who remain in the villages (Meilvidir & Siman, 2023). Supporting this view, migration effectively decreases poverty rates in rural areas, it concurrently leads to a rise in urban poverty, as the influx of migrants increases the proportion of economically vulnerable populations in cities (Resaski & Marta, 2024). These mixed outcomes indicate that migration's effect on rural poverty is unlikely to be uniform or linear.

Despite extensive research on rural poverty in Indonesia, important gaps remain. Existing studies largely rely on linear regression or static panel models that assume constant marginal effects across regions and poverty levels (Fattah et al., 2025; Rahman Razak et al., 2023). Such approaches are unable to capture nonlinear relationships, identify critical thresholds, or account for heterogeneous policy responsiveness across Indonesia's diverse provincial contexts. Consequently, the literature has not sufficiently explained when, at what levels, and under which conditions key determinants such as village funds, agricultural performance, land-use conversion, migration, and unemployment exert stronger or weaker effects on rural poverty.

Motivated by these gaps, this study seeks to address a fundamental empirical problem: the inability of existing research to identify nonlinear poverty dynamics and threshold effects in rural Indonesia. Understanding these nonlinearities is crucial, as policy interventions may only become effective after certain socioeconomic conditions are met. Without identifying such thresholds, policies risk being inefficient, mistargeted, or producing diminishing returns. Accordingly, this study poses the following research questions. (1) Do village funds, agricultural performance, land-use conversion, migration, and unemployment exhibit nonlinear effects on rural poverty in Indonesia? (2) Are there critical threshold levels at which these determinants significantly alter their impact on rural poverty across provinces? These research questions are innovative because they move beyond average effects and explicitly investigate regime-specific poverty responses, which have been largely overlooked in previous studies.

The main objective of this research is to analyze the determinants influencing rural poverty in Indonesia by applying a spline regression approach. This method allows for the identification of nonlinear relationships and the estimation of explicit threshold points in key socioeconomic indicators. Through this approach, the study captures variations across different provinces and identifies conditions under which policy interventions may yield stronger or weaker effects. This provides a more comprehensive understanding of the structural factors that perpetuate poverty in rural areas and offers deeper empirical insights for policymakers.

The novelty of this study is articulated through several key dimensions. First, this study applies a spline regression approach to rural poverty analysis, allowing for the identification of nonlinear relationships and explicit threshold points that cannot be captured by conventional linear models. Second, it represents the first provincial-level application of spline regression in Indonesia to simultaneously examine multiple poverty determinants, including village funds, agriculture, land-use conversion, migration, and unemployment. Third, the study provides empirical evidence on regime-dependent policy effectiveness, demonstrating that the impact of interventions varies across poverty levels and regional contexts. Fourth, by incorporating spatial heterogeneity across provinces, this research offers a more nuanced understanding of rural poverty dynamics in a geographically diverse developing country; and Five, this study can reveal specific determinants that are not visible on a national scale, so that the very large differences in socio-economic characteristics between provinces in Indonesia can be analyzed in depth.

This study contributes to the literature in several ways. First, academically, it advances poverty analysis by integrating flexible econometric modeling with development theory, enriching empirical discussions on nonlinear and threshold-driven poverty dynamics. Second, it provides methodological contributions by demonstrating the applicability of spline regression in regional development and poverty studies. Third, from a policy perspective, the findings offer actionable insights by identifying conditions under which specific interventions become effective, enabling more targeted and efficient poverty alleviation strategies. Finally, this research lays the

foundation for future studies on nonlinear development processes and encourages policymakers to adopt adaptive, evidence-based approaches to rural development.

In conclusion, understanding the determinants of rural poverty through a spline modeling framework not only enriches the academic discourse on poverty analysis but also produces actionable insights for rural development policy. By identifying nonlinear patterns and critical thresholds, the findings contribute to the design of more targeted, equitable, and sustainable poverty alleviation programs in rural Indonesia. Ultimately, this study underscores the importance of integrating flexible statistical modeling with policy-oriented research to support Indonesia's long-term vision for inclusive and resilient rural development.

2. Literature Review

2.1. Village Funds and Rural Poverty

Persistent poverty in rural areas remains a fundamental challenge, as reflected in consistently higher poverty rates compared to urban regions despite observed improvements from 2015 to 2023 (Siregar et al., 2024 ; Rahman, 2017). Poverty is conceived not merely as income deprivation but as a multidimensional deficit involving limited access to education, services, and productive opportunities (Ivani & Auwalin, 2024). This perspective aligns with global development agendas, where the reduction of poverty particularly rural poverty is a primary objective (Beltran-Peña et al., 2020), enforced by the UN's Sustainable Development Goals emphasizing poverty eradication, food security, and improved nutrition (Vos & Cattaneo, 2021).

Within Indonesia, the persistence of rural poverty is further exacerbated by structural constraints, including unequal resource distribution, limited employment diversification, and vulnerability to economic shocks. These conditions necessitate empirical research capable of capturing the complex interplay between agricultural performance, socioeconomic dynamics, and poverty outcomes across rural regions.

H1: Village funds have a significant negative influence on rural poverty by supporting local development and basic service provision.

2.2. Agricultural Sector and Rural Poverty

Rural development in Indonesia is grounded in the broader theoretical understanding that national economic progress must be evaluated not only through aggregate macroeconomic performance (Wardani & Rifa'i, 2025), but also through the ability to foster inclusive growth across all regions, particularly rural areas (Fitrianti et al., 2022). The agricultural sector constitutes one of the most critical pillars of Indonesia's economic system, contributing substantially to GDP, export revenues, and employment (Afriyanti et al., 2023). Recognized as the backbone of Indonesia's economic structure, agriculture and food security remain central to national priorities, serving as the foundation for sustaining human development (Bukhtiarova et al., 2019).

Beyond its measurable economic contribution, agriculture plays a strategic role as a supplier of essential raw materials and food products, supporting industrial activities and sustaining broader economic stability (Hassoun & Abdelmadjid, 2019). In many developing

economies, agriculture remains the primary livelihood source for rural populations, especially among the poor who rely directly or indirectly on the sector (Inomjonova, 2024). Unlike the mature economies of high-income countries, the agricultural sector in developing nations plays a pivotal role in stimulating economic expansion and fostering long-term development (Razak et al., 2023). Given this context, agricultural performance is influenced by regional comparative advantages, natural resource endowments, and local agricultural potential (Pratama et al., 2023).

Indonesia's agricultural sector is thus central to national and regional development strategies, serving as a major source of employment and a driver of economic resilience in rural communities (Khairiyakh et al., 2015 ; Drean & Bawono, 2021). Strengthening its performance is viewed as essential for increasing productivity, reducing rural inequality, and supporting sustainable rural transformation (Mehraban & Ickowitz, 2021). However, despite its potential, agricultural growth in many rural areas continues to stagnate (Kurnianto, 2024), raising concerns regarding its ability to reduce poverty and unemployment.

H2: Agricultural sector growth has a significant negative effect on rural poverty in Indonesia.

2.3. Land Use Conversion and Rural Poverty

Land use conversion from agricultural land to non-agricultural purposes reflects broader patterns of structural change in rural economies. Rapid land conversion can diminish agricultural productivity, threaten food security, and reduce the livelihood base for rural communities (Alrakhman et al., 2022). While conversion may signal modernization and economic diversification, excessive or poorly regulated conversion contributes to declining agricultural output and may exacerbate rural poverty (Wu et al., 2025). The literature reviewing rural development in Indonesia suggests that changes in land availability, agricultural capacity, and environmental management can significantly shape rural welfare dynamics. However, empirical analyses examining the nonlinear effects of land conversion on poverty remain limited, particularly at fine geographic scales.

H3: Land use conversion significantly affects rural poverty by altering agricultural productivity and rural livelihood structures.

2.4. Migration and Rural Poverty

Migration constitutes a crucial dimension of rural economic transformation. Outmigration from rural to urban areas driven by limited employment opportunities, low agricultural productivity, and demographic pressures creates both push and pull effects on rural welfare. Migration alters the age structure of rural communities, often leaving behind aging populations with fewer productive workers (Rammohan & Tohari, 2023). This dynamic constrains agricultural output, weakens local labor markets, and can intensify poverty when remittances are insufficient or when migration leads to labor shortages. Given these patterns, migration represents an important variable for understanding the drivers of rural poverty, as it is associated with both potential economic gains and structural vulnerabilities across rural regions in Indonesia.

H4: Migration has a significant influence on rural poverty through its effects on labor availability and income redistribution.

2.5. Open Unemployment and Rural Poverty

Unemployment represents a major structural issue affecting rural welfare. Indicators such as labor force participation, availability of productive workers, and employment quality serve as crucial markers of rural economic stability. Despite the relatively lower open unemployment rate in rural areas compared to urban ones, rural employment is dominated by informal, unstable, and low-productivity jobs (Amin & Rotinsulu, 2023). Rural unemployment often triggers outward migration, particularly among young workers seeking better opportunities in urban centers (Lyu et al., 2019; van Twuijver et al., 2020). This process is further stimulated by industrial concentration in metropolitan regions, attracting both male and female workers (Güney Celbiş, 2023).

As a consequence, rural communities face demographic imbalances and reduced labor productivity, conditions that hinder economic vitality and impede development (Steiner et al., 2023). At the national scale, unemployment is influenced by Indonesia's rapidly growing population and continuous inflow of new labor force entrants (Rokhim, 2023). Since unemployment often reinforces poverty through reduced income stability and limited livelihood options, understanding its relationship with rural poverty becomes essential.

H5: Open unemployment has a significant positive effect on rural poverty due to reduced income opportunities and labor underutilization.

While previous studies have examined agriculture, unemployment, migration, and poverty, much of the existing work relies on conventional linear regression or descriptive methods. These approaches assume stable relationships across regions and fail to capture complex or nonlinear interactions among key variables (e.g., threshold effects, regional heterogeneity). Research focusing on Indonesia predominantly uses national or provincial aggregates, leaving limited insight into how determinants of rural poverty vary across different poverty intensities or geographic contexts. Moreover, only a few studies apply flexible nonparametric techniques such as spline regression to identify critical turning points or nonlinear dynamics. This methodological gap calls for more advanced modeling to better understand the multifaceted factors shaping rural poverty in Indonesia. The reviewed literature underscores the importance of agriculture, labor markets, land management, and migration in shaping rural poverty outcomes. Yet, despite continuous development initiatives, rural poverty persists, signaling the need for more nuanced analytical approaches that can accommodate nonlinearities and spatial variation among rural indicators. By integrating village funds, agricultural growth, unemployment, migration, and land use conversion within a spline-based analytical framework, the present study aims to provide a more comprehensive and empirically grounded understanding of rural poverty determinants in Indonesia.

3. Methods

3.1 Data description

This study employs one dependent variable, namely the rural poverty in Indonesia, and five independent variables. The data used are cross-sectional secondary data obtained from each province in Indonesia for the year 2024, covering 37 provinces as the units of analysis. The Special Capital Region of Jakarta (DKI Jakarta) is excluded from the sample, as it is assumed to have no rural areas. Data sources include the Statistics Indonesia (BPS), both national and

provincial offices, as well as the Ministry of Villages, Development of Disadvantaged Regions, and Transmigration, and the Ministry of Agrarian Affairs and Spatial Planning/National Land Agency (BPN). The variables used in this study are presented in Table 1 below.

Tabel 1. Used Variables

Variabel Used	Variable Symbol	Variable Description	Data Source
Dependent Variable	POV	Total of rural poverty (Thousand Persons)	BPS (https://www.bps.go.id)
	DN	Amount of Village Funds Disbursed (Million Rupiah)	Ministry of Villages (https://www.kemendes.go.id/)
	SPT	Agricultural sector growth rate (Percent)	BPS (https://www.bps.go.id)
Independent Variable	AL	Land-use conversion (Hectares)	Ministry of Agrarian Affairs (https://www.atrbpn.go.id)
	MG	Number of migrants (Persons)	BPS (https://www.bps.go.id)
	PNG	Open unemployment rate (Percent)	BPS (https://www.bps.go.id)

3.2 Methods

This study employs nonparametric spline regression as the core modeling technique to capture potential nonlinear relationships between rural poverty and its predictors. Nonparametric regression is appropriate when the functional form of the relationship between the response variable and the explanatory variables is unknown or difficult to specify a priori (Perperoglou et al., 2019) can be expressed as follows:

$$y_i = f(t_i) + \varepsilon_i, i = 1, 2, I, n \quad (1)$$

Where, y_i denotes the dependent variable (rural poverty rate) x_i is represents the predictor variable(s), $f(x_i)$ is an unknown smooth regression function to be estimated regression curve function and ε_i is the random error term assumed to have zero mean and constant variance.

This study applies a truncated power basis spline, which is a form of piecewise polynomial spline regression. Specifically, a cubic spline (degree $q=3$) is used due to its flexibility and smoothness properties, which are widely recommended in applied empirical research. The spline estimator is capable of estimating parameters independently, allowing it to produce models that fit the data structure effectively, even for dynamic datasets (Naser et al., 2022). The truncated power basis allows the regression function to change slope at predefined knot locations while remaining continuous and smooth.

For a dataset $(x_{1i}, x_{2i}, \dots, x_{pi}, y_i)$, where $(x_{1i}, x_{2i}, \dots, x_{pi})$ are predictor variables and y_i the response variable, the spline equation can be formulated as follows:

$$y_i = \beta_{01} + \beta_{11}x_{1i} + \dots + \beta_{q1}x_{1i}^q + a_{11}(x_{1i} - k_{11})_+^q \dots a_{m1}(x_{1i} - k_{m1})_+^q + \beta_{02} + \beta_{12}x_{2i} + \dots + \beta_{q2}x_{2i}^q + a_{12}(x_{2i} - k_{12})_+^q \dots a_{m2}(x_{2i} - k_{m2})_+^q + \beta_{0p} + \beta_{p1}x_{pi} + \dots + \beta_{qp}x_{pi}^q + a_{1p}(x_{pi} - k_{1p})_+^q \dots a_{mp}(x_{pi} - k_{mp})_+^q + \varepsilon_i \quad (2)$$

where:

- q is the polynomial degree (set to 3)
- k_{mp} denotes the m -th knot point for predictor p
- $(x - k)_+^q = (x - k)^q$ if $x > k$, and 0 otherwise
- β and a are regression coefficients to be estimated
- M_p is the number of knots for predictor p
- ε_i is the error term.

In the spline approach, knot points are used to define the model's structure. The selection of optimal knot points is crucial in spline regression, as data behavior often changes within specific intervals (Idris & Rahman Razak, 2025). The selection of knot points is a critical component of spline regression because it determines where changes in the functional relationship are allowed to occur. In this study, knot selection is conducted using the Generalized Cross-Validation (GCV) criterion (Brugnano et al., 2024), which is formulated as follows:

$$GCV(k_1, k_2, \dots, k_j) = \frac{MSE(k_1, k_2, \dots, k_j)}{(n^{-1} \text{Trace}[I - A(k_1, k_2, \dots, k_j)])^2} \quad (3)$$

Where

1, 2, ..., j : The first knot point up to the j-th knot point

I : Identity matrix

N : Number of observations

$\hat{y} : A(k_1, k_2, \dots, k_j) y$

$A(k_1, k_2, \dots, k_j) : X(X'X)^{-1}X'$

$MSE(k_1, k_2, \dots, k_j) : n^{-1} \sum_{i=1}^n (y_i - \hat{y}_i)^2; \min \{GCV(k_1, k_2, \dots, k_j)\}$

The knot search strategy follows a restricted grid search, where candidate knots are placed at empirical quantiles of each predictor. To mitigate overfitting given the relatively small sample size ($n = 37$), the maximum number of knots is limited to three knots per predictor, producing four spline segments. The final knot configuration is selected based on the minimum GCV value.

The research procedures are as follows (1) Analyze the descriptive statistics of each variable to understand the characteristics of the research units. (2) Develop a model for rural poverty using the selected predictor variables. (3) Determine the optimal knot points by identifying the smallest GCV value obtained. (4) Construct a spline regression model for rural poverty using the optimal knots. (5) Conduct parameter significance testing for the established spline model. (6) Calculate the coefficient of determination (R^2) to evaluate model performance. (7) Interpret the results based on the analysis and the developed spline model, complemented by spatial visualization in the form of regional maps.

All analyses were conducted using R version 4.3.2 with the packages splines. Full code for estimation and diagnostics is available upon request, in line with reproducibility standards



required by the journal.

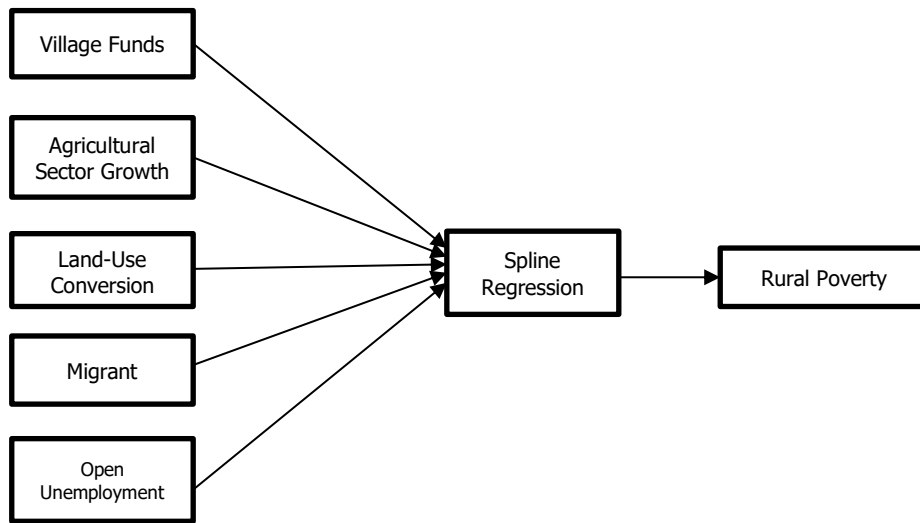


Figure 1. Research Framework

4. Results

Based on the descriptive statistical results presented in Table 2, it can be observed that the distribution of the variables varies considerably, indicating diverse regional characteristics across Indonesia's rural areas. The mean values show general trends in total rural poverty, village fund disbursement, agricultural growth, land-use change, migration, and unemployment. The relatively high variance and standard deviation for several variables suggest the presence of substantial disparities among provinces, particularly in aspects related to land use and rural economic dynamics. This variation implies that socioeconomic and geographical factors play a significant role in influencing rural development outcomes.

The skewness and kurtosis values further illustrate the asymmetry and distributional patterns of the data. Positive skewness in variables such as total of rural poverty, number of migrants, and unemployment rate indicates that most provinces have relatively lower values, with a few regions exhibiting considerably higher levels. Conversely, the negative skewness found in variables like agricultural growth and land-use conversion reflects the opposite pattern, where most regions have higher performance with a few outliers showing lower values. The kurtosis values, which are close to or slightly below three, suggest that the data are generally mesokurtic, implying a moderate concentration of values around the mean and no extreme tail behavior.

The descriptive findings indicate that the characteristics of rural poverty and its associated determinants differ significantly among provinces in Indonesia. The variations in village fund distribution, agricultural performance, and migration dynamics highlight the heterogeneity of rural economies, emphasizing the importance of region-specific policies and interventions. These preliminary results also provide a strong foundation for the subsequent modeling phase using the spline approach, which will capture the nonlinear relationships among these variables more effectively.

Table 2. Descriptive statistic

Statistics	POV	DN	SPT	AL	MG	PNG
Mean	346.51	9160.65	3,20	4.997,24	4.875,00	14,03
Variance	221789.6917	148293,9155	2,187250102	510925,3085	148373,4746	56,13596206
Std.Dev	470.9455294	385,0894903	1,478935462	714,7903948	385,1927759	7,492393614
Skewness	2.958414104	-0,08958258	-0,68405277	-1,12878046	0,759988857	1,445833203
Kurtosis	9.495212058	-0,62405824	0,413127424	2,956726281	0,441328192	2,087849715
Minimum	22.82	8.374,00	-1.05	2.502,50	4.234,00	5,28
Maximum	2304.70	9.841,67	5,44	6.173,67	5.815,67	36,31

The first step in analyzing the determinants of rural poverty in Indonesia using the spline approach is the selection of the most optimal knot points. The determination of these optimal knots is based on identifying the lowest Generalized Cross Validation (GCV) value obtained from each possible knot configuration. Table 3 presents the GCV values corresponding to each knot point considered in the model.

Table 3. GCV Values Produced by Each Knot Point

Knot Point	GCV Values
Knot Point 1	144226.6
Knot Point 2	95749.9
Knot Point 3	88559.7

Table 3 shows that the smallest GCV value is obtained at the third knot point, with a value of 88559.7. Therefore, the modeling of rural poverty in Indonesia is conducted using the three-knot spline model, as presented in the following equation.

$$\begin{aligned} \widehat{POV} = & 64.5540507 - 18.324357DN_1 - 58.07172(DN_2 + 6239.51) - 67.12531(DN_3 + 8603.714) \\ & - 89.229943(DN_4 + 9206.184) - 53.21595SPT_1 - 76.472837(SPT_2 + 1.0669) \\ & - 12.864408(SPT_3 + 4.5123) - 93.201652(SPT_4 + 4.6448) + 14.278674AL_1 \\ & + 12.693(AL_2 + 2590.041) + 17.39146(AL_3 + 4298.857) + 15.74826(AL_4 + 5460.735) \\ & - 11.58376MG_1 - 42.44964(MG_2 + 1898993) - 30.93327(MG_3 + 4984.857) \\ & - 14.31972(MG_4 + 5103.544) + 21.6498PNG_1 + 21.6956(PNG_2 + 11.8546) \\ & + 21.74144(PNG_3 + 31.1185) + 21.78725(PNG_4 + 31.85949) \end{aligned}$$

Subsequently, parameter testing was carried out using two types of tests, namely the simultaneous parameter test and the individual parameter test. The results of the simultaneous estimation test are presented in Table 4.

Table 4. Simultaneous Parameter Testing

Source of Variation	df	SS	MS	F	P-value
Regression	20	3282414	164120.7		
Error	17	4655600	273858.8	3.691013	0.036951
Total	37	7938014			

The statistical test produced a p-value of 0.036951. When compared to the significance level of $\alpha = 0.05$, the decision is to reject H_0 . This result indicates that at least one variable has a significant influence on the established model. The rejection of H_0 suggests the

necessity of conducting individual parameter tests to identify which variables significantly affect the model. The results of the individual parameter tests are presented in Table 5. After determining the significance of each variable, the next step is to calculate the coefficient of determination (R^2) to assess how well the model explains the variation in rural poverty across the Indonesian provinces included in this study.

Table 5. Individual Test Results

Variables	Parameter	Estimator	P-Value	Sig $\alpha = 0.05$
Constant	β_0	64.5540507	0.00547535	Significant
	β_1	-18.324357	0.0171757	Significant
	β_2	- 58.07172	0.0004382	Significant
DN	β_3	-67.12531	0.0494234	Significant
	β_4	- 89.22994	0.0336451	Significant
SPT	β_5	-53.215925	0.0042088	Significant
	β_6	-67.472837	0.0032843	Significant
	β_7	-12.864408	0.0057469	Significant
	β_8	-93.201652	0.0091161	Significant
AL	β_9	14.278674	0.0561853	Not Significant
	β_{10}	12.69300	0.0211076	Significant
	β_{11}	17.39146	0.0415761	Significant
	β_{12}	15.74826	0.0959799	Not Significant
MG	β_{13}	-11.58376	0.0005204	Significant
	β_{14}	-42.44964	0.0646789	Not Significant
	β_{15}	-30.93327	0.0269174	Significant
	β_{16}	-14.31972	0.0550141	Not Significant
PNG	β_{17}	21.649819	0.0272859	Significant
	β_{18}	21.695629	0.0263659	Significant
	β_{19}	21.741441	0.0854464	Not Significant
	β_{20}	21.787250	0.0045264	Significant

$$R^2 = \frac{SS_{\text{Regresi}}}{SS_{\text{Total}}} \times 100\% = \frac{3282414}{7938014} \times 100\% = 41.35\%$$

Based on this calculation, the R^2 value is 41.35%, indicating that the variables used in the model are able to explain 41.35% of the variation in rural poverty across Indonesia's provinces. The remaining variation is explained by other factors not included in this study.

After testing the model using the Spline approach and confirming that all residual assumptions were satisfied, the results indicate that five variables significantly influence rural poverty in Indonesia. These variables include village fund allocation, agricultural sector growth, land-use conversion, migration, and unemployment. The model interpretation is carried out to provide a detailed understanding of how each variable affects rural poverty across the Indonesian provinces.

Assuming that agricultural sector growth (SPT), land-use conversion (AL), migration (MG), and unemployment (PNG) remain constant, the regression model describing the relationship between village funds (DN) and rural poverty in Indonesia can be expressed as follows.

$$\widehat{POV} = -18.324357DN_1 - 58.07172(DN_2 + 6239.51) - 67.12531 (DN_3 + 8603.714) - 89.229943 (DN_4 + 9206.184)$$

$$\widehat{POV} = \begin{cases} -18.324357; DN_1 < 6239.51 \\ -76.42607; 6239.51 \leq DN_2 < 8603.74 \\ -143.555144; 8603.74 \leq DN_3 < 9206.184 \\ -232.781383; DN_4 > 9206.184 \end{cases}$$

Based on the regression model above, it is identified that four regional clusters are formed among the Indonesian provinces according to the village fund (DN) variable, which influences rural poverty in Indonesia. These clusters correspond to the spline segments generated in the model and are illustrated in Figure 2 below.

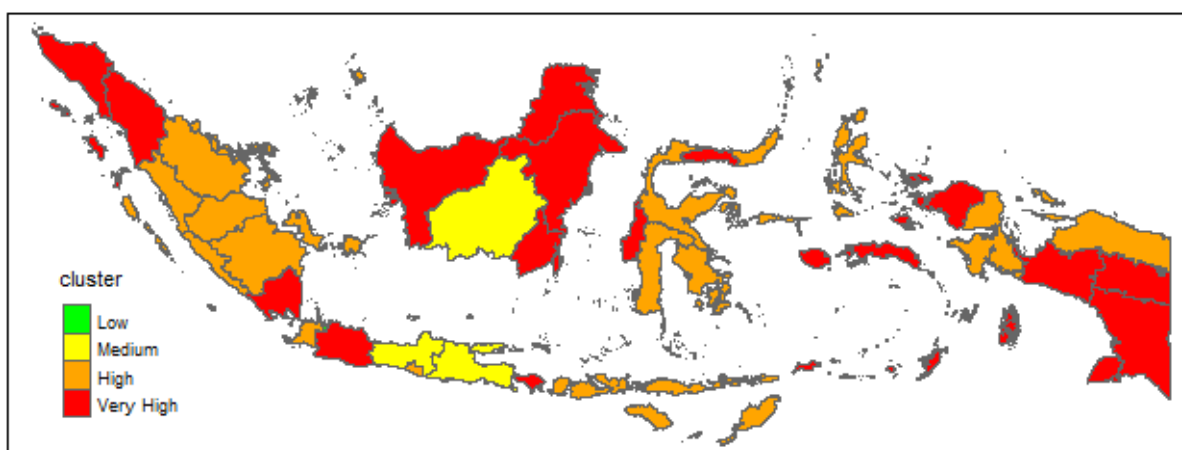


Figure 2. Clustering of Provinces in Indonesia based on Spline Segments Formed for the Village Fund Variable

If a province has a village fund value of less than 6239.51 million rupiahs, the rural poverty in Indonesia tends to decrease by 18.32 Thousand peoples. For provinces with village fund values ranging between 6239.51 and 8603.74 million rupiahs, rural poverty tends to decline by 76.43 thousand peoples. Furthermore, when a province's village fund ranges between 8603.74 and 9206.18 million rupiahs, the rural poverty is expected to decrease by 143.56 thousand peoples. Lastly, if a province's village fund exceeds 9206.18 million rupiahs, rural poverty in Indonesia tends to decline by 232.78 thousand peoples.

Assuming village funds (DN), land-use conversion (AL), migration (MG), and unemployment (PNG) are held constant, the regression model describing the relationship between agricultural sector growth (SPT) and rural poverty in Indonesia is as follows.

$$\widehat{POV} = -53.21595SPT_1 - 76.472837 (SPT_2 + 1.0669) - 12.864408 (SPT_3 + 4.5123) - 93.201652 (SPT_4 + 4.6448)$$

$$\widehat{POV} = \begin{cases} -53.21595; SPT_1 < 1.0669 \\ -129.688787; 1.0669 \leq SPT_2 < 4.5123 \\ -142.553195; 4.5123 \leq SPT_3 < 4.6448 \\ -235.754847; SPT_4 > 4.6448 \end{cases}$$

Based on the regression equation above, four regional clusters are identified among Indonesian provinces according to the agricultural sector growth (SPT) variable, which influences rural poverty. These clusters correspond to the spline segments produced by the model and are depicted in Figure 3 below.

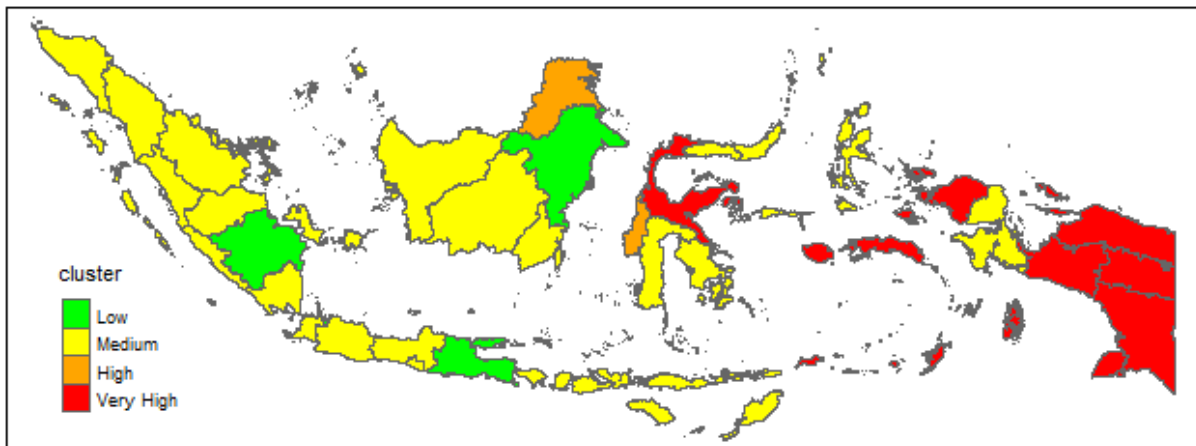


Figure 3. Clustering of Provinces in Indonesia based on Spline Segments Formed for the Agricultural Sector Growth Variable

If a province has an agricultural sector growth rate of less than 1.0669 percent, the rural poverty in Indonesia tends to decrease by 53.22 Thousand peoples. For provinces with agricultural growth rates ranging between 1.0699 and 4.5123 percent, rural poverty is likely to decline by 129.69 Thousand peoples. Furthermore, when a province's agricultural sector growth rate is between 4.5123 and 4.6448 percent, rural poverty tends to decrease by 142.55 Thousand peoples. Finally, if a province's agricultural growth rate exceeds 4.6448 percent, the rural poverty in Indonesia is expected to decrease by 235.75 Thousand peoples.

Assuming village funds (DN), agricultural sector growth (SPT), migration (MG), and unemployment (PNG) are held constant, the regression model describing the relationship between land-use conversion (AL) and rural poverty in Indonesia can be expressed as follows.

$$\widehat{POV} = 14.278674AL_1 + 12.693 (AL_2 + 2590.041) + 17.39146 (AL_3 + 4298.857) + 15.74826 (AL_4 + 5460.735)$$

$$\widehat{POV} = \begin{cases} 14.27867; AL_1 < 2590.041 \\ 26.97167; 2590.041 \leq AL_2 < 4298.857 \\ 44.36313; 4298.857 \leq AL_3 < 5460.735 \\ 60.11139; AL_4 > 5460.735 \end{cases}$$

Based on the regression equation above, four regional clusters are identified among Indonesian provinces according to the land-use conversion (AL) variable, which influences rural poverty. These clusters correspond to the spline segments produced by the model and are illustrated in Figure 4. If a province has a land-use conversion value of less than 2590.041

hectares, the rural poverty in Indonesia tends to increase by 14.28 Thousand peoples. If a province has a land-use conversion value ranging from 2590.041 to 4298.857 hectares, the rural poverty in Indonesia tends to increase by 26.97 Thousand peoples. Furthermore, if a province has a land-use conversion value between 4298.857 and 5460.735 hectares, the rural poverty in Indonesia tends to increase by 44.36 Thousand peoples. Finally, if a province has a land-use conversion value of more than 5460.735 hectares, the rural poverty in Indonesia tends to increase by 60.11139 Thousand peoples.

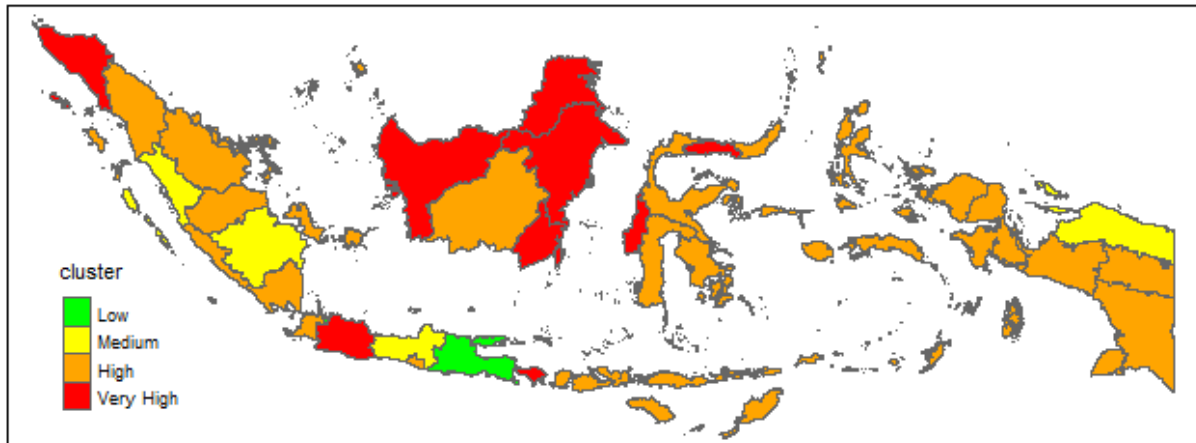


Figure 4. Clustering of Provinces in Indonesia based on Spline Segments Formed for the Land-Use Conversion Variable

Assuming that Village Fund (DN), Agricultural Sector Growth (SPT), Land-use Conversion (AL), and unemployment (PNG) are assumed to be constant, then the model equation formed based on the migration variable (MG) with respect to rural poverty in Indonesia is as follows.

$$\widehat{POV} = -11.58376MG_1 - 42.44964(MG_2 + 1898.993) - 30.93327(MG_3 + 4984.857) - 14.31972(MG_4 + 5103.544)$$

$$\widehat{POV} = \begin{cases} -11.58376; MG_1 < 1898.993 \\ -54.0334; 1898.993 \leq MG_2 < 4984.857 \\ -84.96667; 4984.857 \leq MG_3 < 5103.544 \\ -99.28639; MG_4 > 5103.544 \end{cases}$$

Based on the model equation above, it is observed that four regional clusters are formed across the provinces in Indonesia based on the migration variable, which influences rural poverty in accordance with the Spline segments generated, as illustrated in Figure 5 below. If a province has a migration rate of less than 1889.99 peoples, the rural poverty in Indonesia tends to decrease by 11.58 Thousan peoples. If a province has a migration rate between 1898.99 and 4984.857 peoples, rural poverty tends to decrease by 54.03 Thousand peoples. Furthermore, if a province has a migration rate between 4984.857 and 5104.544 peoples, rural poverty tends to decrease by 84.97 Thousand peoples. Finally, if a province has a migration of more than 5103.544 peoples, rural poverty in Indonesia tends to decrease by 99.27 Thousand peoples.

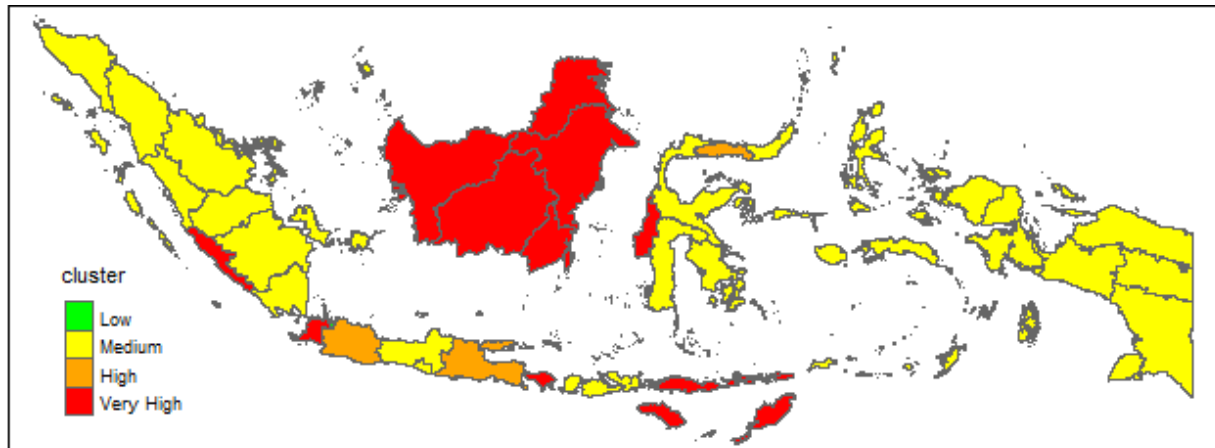


Figure 5. Clustering of Provinces in Indonesia based on Spline Segments Formed for the Migration Variable

Assuming that village funds (DN), agricultural sector growth (SPT), land conversion (AL), and migration (MG) remain constant, the model equation formed based on the unemployment variable (PNG) in relation to rural poverty in Indonesia is as follows.

$$\widehat{POV} = 21.6498PNG_1 + 21.6956 (PNG_2 + 11.8546) + 21.74144 (PNG_3 + 31.1185) + 21.78725 (PNG_4 + 31.85949)$$

$$\widehat{POV} = \begin{cases} 21.6498; PNG_1 < 11.8546 \\ 43.3454; 11.8546 \leq PNG_2 < 31.1185 \\ 65.08684; 31.1185 \leq PNG_3 < 31.85949 \\ 86.87409; PNG_4 > 31.85949 \end{cases}$$

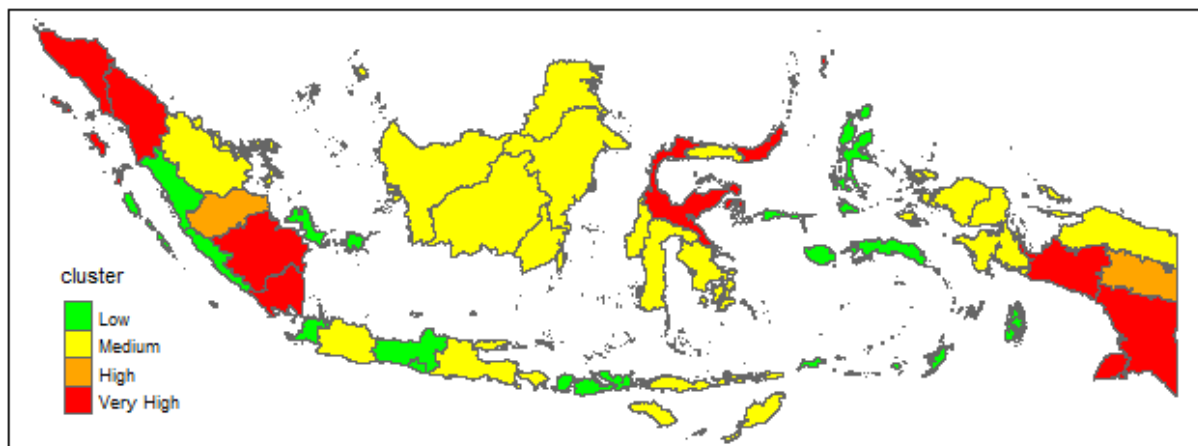


Figure 6. Clustering of Provinces in Indonesia based on Spline Segments Formed for the Unemployment Variables

Based on the model equation above, it is evident that four regional clusters were formed among the provinces in Indonesia based on the unemployment variable, which influences rural poverty in the country, according to the Spline segments generated. If a province has an unemployment rate of less than 11.85 percent, the rural poverty in Indonesia tends to increase by 21.65 Thousand peoples. If a province has an unemployment rate ranging from 11.85 to 31.12 percent, rural poverty tends to increase by 43.35 Thousand peoples. Furthermore, if a

province has an unemployment rate between 31.12 and 31.86 percent, rural poverty tends to increase by 65.09 Thousand peoples. However, if a province has an unemployment rate of more than 31.86 percent, rural poverty in Indonesia tends to decrease by 86.87 Thousand peoples.

Discussion

5.1. Village Funds and Rural Poverty

The findings confirm H1, indicating that higher village fund allocations significantly reduce rural poverty. The spline model reveals clear threshold effects, where poverty reduction accelerates only after allocations exceed minimum levels. This nonlinear pattern suggests that village funds are not immediately effective at low allocation levels, as resources may be insufficient to finance meaningful development interventions. The poverty-reducing impact of village funds operates through several interrelated mechanisms. First, larger allocations allow villages to implement comprehensive infrastructure projects and social assistance programs rather than fragmented activities. Second, the effectiveness of village funds is conditional on local absorptive capacity, including administrative competence, planning quality, and monitoring mechanisms. Third, effective targeting toward poor households amplifies welfare impacts. When these conditions are weak, additional funds generate limited marginal benefits, explaining the weaker effects observed at lower allocation ranges.

These findings are consistent with Artino et al. (2019) and Hartojo et al. (2022), who document positive welfare effects of village funds. However, this study extends the literature by empirically demonstrating nonlinear efficiency gains. In line with Arham and Payu (2020), the results show that fiscal magnitude alone is insufficient; governance readiness determines whether funds translate into poverty reduction. Regional heterogeneity in institutional quality and development priorities likely explains differences in effect magnitude across provinces. From a theoretical perspective, the results reinforce fiscal decentralization theory, which posits that locally managed resources improve welfare only when supported by adequate institutional capacity. This study contributes new insight by identifying explicit thresholds at which decentralization becomes effective, highlighting that fiscal decentralization produces conditional, rather than automatic, welfare gains.

Beyond the identified thresholds, the nonlinear effect of village funds also reflects differences in program composition across allocation levels. At lower funding levels, village governments tend to prioritize routine expenditures or small-scale projects with limited economic spillovers. In contrast, higher allocations allow for capital-intensive investments such as road connectivity, irrigation, and village-owned enterprises (BUMDes), which generate longer-term income effects. This compositional shift explains why poverty reduction accelerates only after allocations surpass critical levels. Furthermore, the effectiveness of village funds is shaped by political economy factors at the village level.

Elite capture, weak accountability, and limited community participation can dilute the intended pro-poor impact of fiscal transfers. In villages with stronger social capital and participatory governance, higher allocations are more likely to be translated into inclusive development outcomes. This suggests that the observed threshold effects are not purely fiscal but institutional in nature. From a policy perspective, these findings imply that increasing village fund allocations without strengthening governance mechanisms may yield diminishing returns. The results highlight the importance of complementary policies, such as capacity-building

programs, transparency initiatives, and performance-based transfers. This provides a new insight for decentralization policy by emphasizing that poverty reduction depends not only on fiscal scale but also on institutional sequencing.

5.2. Agricultural Sector and Rural Poverty

The results support H2, showing that agricultural growth significantly reduces rural poverty, with stronger effects emerging beyond certain productivity thresholds. The spline turning points indicate that marginal improvements in low-productivity regions are insufficient to substantially raise rural incomes, whereas sustained and higher productivity growth activates broader poverty-reducing mechanisms. This relationship operates through several channels. First, productivity growth directly raises farm income, which is the primary livelihood source in rural areas. Second, higher agricultural output stimulates employment in upstream and downstream activities such as input supply, processing, and transportation, generating multiplier effects. Third, productivity gains improve food availability and price stability, reducing household vulnerability to shocks. These mechanisms explain why the poverty-reducing effect intensifies after productivity surpasses minimum levels.

The findings corroborate Drean and Bawono (2021) and Khairiyakh et al. (2015), who emphasize agriculture's central role in rural welfare. However, this study advances the literature by revealing nonlinear dynamics that are often overlooked in linear models. Differences from previous studies may stem from the use of spline regression, longer observation periods, and the incorporation of spatial heterogeneity. The results align with structural transformation theory, which views agricultural productivity growth as a prerequisite for rural development and economic diversification. By identifying productivity thresholds, this study strengthens the theoretical claim that agricultural growth must reach sufficient scale to trigger broader structural and welfare improvements.

The nonlinear poverty-reducing effect of agricultural growth also reflects structural constraints faced by smallholder farmers. In low-productivity settings, gains are often absorbed by rising input costs, market inefficiencies, or price volatility, limiting real income improvements. Only when productivity growth reaches sufficient magnitude can farmers overcome these structural barriers and generate surplus income that meaningfully reduces poverty. The turning points identified in the spline model may capture the transition from subsistence-oriented agriculture to semi-commercial or commercial farming systems. At higher productivity levels, farmers are better integrated into value chains, benefit from economies of scale, and gain improved access to credit and technology. These structural changes amplify the poverty-reducing impact of agricultural growth beyond what linear models can capture. Theoretically, this finding deepens structural transformation theory by demonstrating that agriculture's role in poverty reduction is conditional rather than automatic. Agricultural growth must exceed minimum thresholds to initiate linkages with non-farm rural activities, reinforcing the argument that productivity-led growth is a prerequisite for inclusive rural development.

5.3. Land-Use Conversion and Rural Poverty

The findings support H3, indicating that land-use conversion increases rural poverty, particularly after conversion exceeds critical thresholds. While limited conversion may support development, extensive or speculative conversion sharply raises poverty levels. This effect arises through multiple mechanisms. First, conversion reduces agricultural land availability,

constraining farm-based income and food production. Second, rural labor displacement occurs when households lose access to productive land. Third, unregulated conversion disrupts local food systems and increases livelihood insecurity. These mechanisms intensify once conversion becomes widespread, explaining the steep poverty increase observed at higher levels.

The results are consistent with Brady and Prior (2020), who highlight welfare risks from unplanned land conversion, and with Wu *et al.* (2025), who emphasize the dual nature of land-use change. Indonesia's rapid spatial transformation and uneven land governance likely amplify these negative effects, accounting for stronger impacts relative to some international findings. Theoretically, these findings support spatial transformation and land governance theories, which argue that structural change must be accompanied by institutional safeguards. This study contributes new empirical insight by quantifying thresholds at which land conversion shifts from a development-enhancing process to a poverty-inducing force.

The threshold effects associated with land-use conversion highlight the distinction between planned and unplanned spatial transformation. Moderate conversion aligned with local development plans may enhance economic opportunities, but excessive or speculative conversion often undermines rural livelihoods. Once conversion surpasses certain levels, the loss of agricultural land becomes irreversible, leading to long-term income insecurity. Another important dimension is the distributional impact of land conversion. Benefits from conversion such as rising land values are often captured by landowners or external investors, while landless laborers and smallholders bear the costs. This unequal distribution explains why poverty increases sharply at higher conversion levels, even if aggregate economic indicators appear to improve. These findings extend land governance theory by empirically demonstrating that weak regulatory frameworks exacerbate the poverty impacts of land-use change. The results suggest that effective zoning, compensation mechanisms, and livelihood transition programs are essential to prevent land conversion from becoming a driver of rural impoverishment.

5.4. Migration and Rural Poverty

The findings support H4, showing that migration reduces rural poverty, but with diminishing marginal returns beyond certain thresholds. Moderate migration improves household welfare, while excessive out-migration weakens local production systems. The mechanisms underlying this pattern include remittance inflows that increase household income and smooth consumption, income diversification that reduces vulnerability, and labor reallocation that initially enhances efficiency. However, excessive migration leads to labor shortages, population aging, and declining local productivity, offsetting earlier gains. These opposing effects explain the nonlinear relationship detected by the spline model.

The results are consistent with Resaski and Marta (2024), who identify migration as a poverty-alleviation strategy, and with Steiner *et al.* (2023), who caution against excessive out-migration. Variations across regions may reflect differences in remittance utilization, migrant skill composition, and local labor market resilience. From a theoretical standpoint, the findings support livelihood diversification theory, demonstrating that migration functions as a risk-management strategy. The nonlinear pattern extends the theory by showing that migration benefits are scale-dependent and constrained by local economic balance.

The diminishing returns to migration observed in this study also reflect changes in household dependency structures. At moderate levels, migration diversifies income sources and

strengthens household resilience. However, excessive migration increases dependency ratios in origin areas, as elderly and children are left behind, reducing local labor productivity and increasing social vulnerability. The poverty-reducing impact of migration depends on how remittances are utilized. When remittances are invested in productive activities such as education, farming inputs, or microenterprises, the welfare gains are sustained. Conversely, when remittances are primarily used for consumption, their long-term poverty impact diminishes. These differences help explain why the spline model detects weakening effects beyond certain migration thresholds. From a conceptual standpoint, these findings refine livelihood diversification theory by showing that migration is most effective as a complementary strategy rather than a substitute for local economic development. Balanced migration, rather than large-scale outflows, appears to offer the strongest poverty-reducing potential.

5.5. Open Unemployment and Rural Poverty

The inverted-U relationship indicates that unemployment initially increases rural poverty but reduces poverty after surpassing a threshold, suggesting complex interactions between labor markets and rural livelihoods. At low to moderate levels, unemployment reduces household income and limits access to productive opportunities, directly increasing poverty. However, at higher unemployment levels, adaptive mechanisms emerge. These include absorption into informal activities, expansion of subsistence production, and increased migration, which generates remittances that offset income losses. These dynamics collectively explain the observed inverted-U pattern.

The findings are consistent with Ahmed et al. (2014) and Lyu et al. (2019) regarding the poverty-increasing effects of unemployment. The decline in poverty at higher unemployment levels is less documented, representing a novel contribution. Indonesia's large informal sector and strong internal migration networks likely play a critical buffering role. The results align with labor market segmentation theory, which views the informal sector as a shock absorber during economic distress. This study extends the theory by demonstrating nonlinear poverty responses to unemployment shocks, emphasizing adaptive capacity rather than purely negative labor market effects.

The inverted-U relationship between unemployment and rural poverty reflects adaptive behavior within rural labor markets. At moderate unemployment levels, households lack sufficient coping mechanisms, resulting in higher poverty. However, as unemployment intensifies, households are forced to adopt survival strategies such as informal self-employment, family labor reallocation, or migration. The decline in poverty at higher unemployment levels may also reflect structural shifts toward informal and subsistence-based economic activities that are not captured in official employment statistics. In rural Indonesia, informal work often provides minimal but stable income streams that help households avoid extreme poverty, even in the absence of formal employment. These findings extend labor market segmentation theory by highlighting the resilience of informal rural economies. Rather than functioning solely as a symptom of economic distress, informal employment can act as a poverty-buffering mechanism under certain conditions. This nonlinear perspective offers new insight into how rural labor markets respond to shocks and why unemployment does not uniformly translate into higher poverty.

5. Conclusion

This study provides empirical evidence that rural poverty rates in Indonesia are associated with village fund allocation, agricultural sector growth, land-use conversion, migration, and unemployment. By employing a spline regression approach, the analysis reveals important nonlinear relationships and threshold effects across these variables. In particular, higher village fund allocations and stronger agricultural sector growth are associated with lower rural poverty rates, indicating their relevance in supporting rural welfare. Conversely, excessive land-use conversion and higher unemployment rates are associated with increased rural poverty, while migration exhibits a context-dependent pattern, reflecting both potential economic benefits and demographic pressures across regions.

These findings highlight the multidimensional and nonlinear nature of rural poverty dynamics in Indonesia. Rather than suggesting uniform policy effects, the results indicate that the effectiveness of fiscal, agricultural, and labor-related interventions depends on regional conditions and critical thresholds. This underscores the importance of carefully calibrated and context-specific rural development strategies.

6. Implication of research

The policy implications of this study are directly derived from the empirical results obtained through the spline analysis. First, given the observed association between village fund allocations and lower rural poverty rates beyond certain levels, policymakers should focus not only on increasing allocations but also on ensuring that village funds are effectively targeted toward productive and income-generating activities. Programs such as smallholder empowerment, rural entrepreneurship, and digital agriculture are particularly relevant, as they align with the poverty-reducing segments identified in the spline estimates. Performance-based allocation mechanisms and strengthened administrative capacity may further enhance the effectiveness of fiscal decentralization.

Second, the nonlinear relationship between agricultural sector growth and rural poverty suggests that agricultural revitalization remains a key pathway for poverty reduction, especially when growth surpasses critical thresholds. Policy efforts should therefore prioritize improving access to credit, modern production technologies, and market integration for small farmers. These measures are most likely to yield meaningful poverty-reduction outcomes when agricultural expansion is accompanied by productivity gains rather than land extensification alone. Third, the positive association between land-use conversion and rural poverty at higher conversion levels indicates that uncontrolled transformation of agricultural land can undermine rural livelihoods. Stricter spatial planning regulations and incentives for land conservation and agroforestry are recommended, particularly in provinces experiencing rapid land conversion. These recommendations are grounded in the spline results, which show that the adverse effects intensify beyond specific conversion thresholds.

Fourth, migration and unemployment are found to be associated with rural poverty in a nonlinear manner, implying that their impacts vary across regions and levels. Policies supporting labor mobility, vocational training, and rural non-farm employment should therefore be designed cautiously. While migration can alleviate local labor pressures in some contexts, excessive out-migration or persistent unemployment may exacerbate rural vulnerability. Strengthening rural industries and aligning workforce skills with regional economic potential can help mitigate these

risks. The findings from Indonesia demonstrate that effective rural poverty reduction requires moving beyond simple fiscal transfers to integrate performance-based village funding, threshold-sensitive agricultural support, and regulated land-use planning, offering a replicable model for developing nations. This evidence highlights that uncontrolled land conversion and poorly managed migration can undermine poverty alleviation, reinforcing the global need for spatially conscious policies and balanced rural-urban livelihood strategies. For the international community, these insights underscore the critical importance of context-specific, data-driven approaches to decentralization and rural development in achieving sustainable and inclusive growth worldwide.

7. Limitation of study and future research

Despite its contributions, this study has several limitations that should be acknowledged. First, the analysis is based on a cross-sectional dataset of 37 provinces, which constrains the complexity of models that can be reliably supported and limits the ability to capture dynamic poverty processes over time. Second, although the spline approach allows for flexible functional forms, the results may be sensitive to influential provinces, particularly given the heterogeneous nature of regional development in Indonesia. Third, the study focuses on association patterns rather than causal inference, and the findings should therefore be interpreted with appropriate caution. Future research could address these limitations by extending the analysis to panel data, which would enable the examination of temporal dynamics, improve statistical power, and allow for more extensive robustness analyses. Incorporating additional institutional or environmental variables and exploring alternative nonparametric or semiparametric frameworks may also provide deeper insights into the evolving drivers of rural poverty.

Authors' contributions and responsibilities

Conceptualization: Sri Undai Nurbayani, Abd Rahman Razak. Methodology: Abd Rahman Razak, Aditya Idris. Software: Aditya Idris, Andi Muhammad Arnan Rahman. Validation: Sri Undai Nurbayani. Formal analysis: Sri Undai Nurbayani, Abd Rahman Razak. Investigation: Sri Undai Nurbayani, Aditya Idris. Resources: Abd Rahman Raza. Data curation: Aditya Idris, Andi Muhammad Arnan Rahman. Writing original draft preparation: Sri Undai Nurbayani, Abd Rahman Razak. Writing, review and editing: Sri Undai Nurbayani, Aditya Idris, Andi Muhammad Arnan Rahman. Visualization: Aditya Idris. Supervision: Sri Undai Nurbayani. Project administration: Abd Rahman Razak. Funding acquisition: Sri Undai Nurbayani

Acknowledgement

We would like to thank Hasanuddin University for funding this research.

Competing interests

There are no potential conflicts of interest reported by the authors.

Data availability statement

The data employed in this study were obtained from several reputable international databases to ensure consistency and reliability.

ORCID

Sri Undai Nurbayani <https://orcid.org/0000-0002-9324-0569>

Abd Rahman Razak <https://orcid.org/0009-0008-8336-8084>

Aditya Idris <https://orcid.org/0009-0008-9283-5908>

Andi Muhammad Arnan Rahman <https://orcid.org/0009-0009-1741-7826>

Betania Kartika Muflih <https://orcid.org/0000-0002-0416-5238>

References

- Afriyanti, G., Mariya, A., Natalia, C., Nispuana, S., Wijaya, M. F., & Phalepi, M. Y. (2023). The Role of The Agricultural Sector on Economic Growth in Indonesia. *Indonesian Journal of Multidisciplinary Sciences*, 2(1), 167–179. <http://dx.doi.org/10.59066/ijoms.v2i1.325>
- Alfons, M. E., Nursini, Fatmawati, & Razak, A. R. (2024). Government Expenditure, Human Development Index and Regional Inequality in Indonesia. *Journal of Ecohumanism*, 3(7), 4180–4820. <https://doi.org/10.62754/joe.v3i7.4589>
- Alrakhman, D., Susetyo, D., Taufiq, & Azwardi. (2022). Effect of Economic Growth on Unemployment Rate in Indonesia. *Budapest International Research and Critics Institute (BIRCI-Journal): Humanities and Social Sciences*, 5(2), 10132–10141. <https://doi.org/10.33258/birci.v5i2.4811>
- Amin, M. M., & Rotinsulu, C. N. M. (2023). Unemployment In Indonesia Due To Rising Inflation. *Journal of Management*, 2(2), 78–81. <https://myjournal.or.id/index.php/JOM/article/view/28>
- Arham, M. A., & Payu, B. R. (2020). Village Fund Transfer and Rural Poverty in Indonesia. *Economics Development Analysis Journal*, 8(4), 324–334. <http://dx.doi.org/10.15294/edaj.v8i4.31698>
- Beltran-Peña, A., Rosa, L., & D’Odoric, P. (2020). Global food self-sufficiency in the 21st century under sustainable intensification of agriculture. *Environmental Research Letters*, 15, 095004. <https://doi.org/10.1088/1748-9326/ab9388>
- BPS. (2025). *Statistik Indonesia 2025*.
- Brady, E., & Prior, J. (2020). Environmental aesthetics: A synthetic review. *People and Nature*, 2(2). <http://dx.doi.org/10.1002/pan3.10089>
- Brugnano, L., Giordano, D., Lavernaro, F., & Rubino, G. (2024). An Entropy-Based Approach for a Robust Least Squares Spline Approximation. *Journal of Computational and Applied Mathematics*, 443(115773). <https://doi.org/10.1016/j.cam.2024.115773>
- Bukhtiarova, A., Hayriyan, A., Chentsov, V., & Sokol, S. (2019). Modeling the impact assessment of agricultural sector on economic development as a basis for the country’s investment potential. *Investment Management And Financial Innovations*, 16(3), 229–240. [http://dx.doi.org/10.21511/imfi.16\(3\).2019.21](http://dx.doi.org/10.21511/imfi.16(3).2019.21)
- Diah, M. P. (2020). Pembangunan Pedesaan untuk Mengurangi Kesenjangan Antara Desa dan Kota di Indonesia: Peluang dan Tantangan. *Public Administration Journal of Research*, 2(2), 165–173. <http://dx.doi.org/10.33005/paj.v2i2.45>
- Drean, B., & Bawono, S. (2021). *The Potential of Rural Development in Indonesia based on the perspective of Employment in Agriculture and Economic Value Added in the Agricultural Sector*. https://www.researchgate.net/publication/362846566_The_Potential_of_Rural_Development_in_Indonesia_based_on_the_perspective_of_Employment_in_Agriculture_and_Economic

c_Value_Added_in_the_Agricultural_Sector?enrichId=rgreq-eff18daa090b5322bc796bc0b2fc88df-XX

- Fattah, S., Rahman Razak, A., Amil Yusuf, M., & Fernandes, A. A. R. (2025). Econometric Modelling of the Rural Poverty, Unemployment and the Agricultural Sector Using a Truncated Spline Approach with Longitudinal Data. *Economies*, 13(9), 273. <https://doi.org/10.3390/economies13090273>
- Fitrianti, A. A., Romahan, A. A., & Salahuddin. (2022). Perencanaan Pembangunan Infrastruktur Perdesaan: Kajian Pustaka Terstruktur. *Journal of Regional and Rural Development Planning*, 6(1), 47–64.
- Güney Celbiş, M. (2023). Unemployment in Rural Europe: A Machine Learning Perspective. *Applied Spatial Analysis and Policy*, 16, 1071–1095. <https://doi.org/10.1007/s12061-022-09464-0>
- Hartojo, N., Ikhsan, M., Dartanto, T., & Sumarto, S. (2022). A Growing Light in the Lagging Region in Indonesia: The Impact of Village Fund on Rural Economic Growth. *Economies*, 10(9), 217. <https://doi.org/10.3390/economies10090217>
- Hassoun, S. E. S., & Abdelmadjid, M. (2019). The Impact Of Agricultural Sector On Economic Growth In MENA Countries: A Panel Econometric Approach. *Knowledge of Aggregates Magazine*, 05(02). <http://dx.doi.org/10.37166/2058-005-002-013>
- Herdiana, D. (2022). Kemiskinan, Kesenjangan Sosial dan Pembangunan Desa. *Journal Inovasi Masyarakat*, 2(3), 172–180. <https://doi.org/10.33197/jim.vol2.iss3.2022.985>
- Idris, A., & Rahman Razak, A. (2025). Energy Transition, Green Growth and Emission on Economic Growth using Spline Approach: Evidence From Asia-Pacific Countries. *Economics - Innovative And Economics Research Journal*, 13(2), 139–159. <https://doi.org/10.2478/eoik-2025-0034>
- Inomjonova, F. A. (2024). Assessment of the Impact of Agriculture on Economic Growth. *American Journal of Economics and Business Management*, 7(12), 1304–1312. <http://dx.doi.org/10.31150/ajebm.v7i12.3105>
- Ivani, W. T., & Auwalin, I. (2024). Komposisi sektoral dan pertumbuhan ekonomi: Dampaknya terhadap tingkat kemiskinan perdesaan di 34 Provinsi Indonesia. *Journal of Economics Research and Policy Studies*, 4(2), 353–367. <https://doi.org/10.53088/jerps.v4i2.1077>
- Khairiyakh, R., Irham, & Mulyo, J. H. (2015). Contribution of Agricultural Sector and Sub Sectors on Indonesian Economy. *Agricultural Science*, 18(3), 150–159. <https://doi.org/10.22146/ipas.10616>
- Kurnianto, B. T. (2024). The Future of Agriculture in Indonesia: Facing Climate Change and Globalization. *West Science Agro*, 2(4), 171–177. <https://doi.org/10.58812/wsa.v2i04.1309>
- Lyu, H., Dong, Z., Roobavannan, M., Kandasamy, J., & Pande, S. (2019). Rural unemployment pushes migrants to urban areas in Jiangsu Province, China. *Palgrave Communications*, 9(5). <https://doi.org/10.1057/s41599-019-0302-1>
- Mehraban, N., & Ickowitz, A. (2021). Dietary diversity of rural Indonesian households declines over time with agricultural production diversity even as incomes rise. *Global Food Security*, 28, 100502. <https://doi.org/10.1016/j.gfs.2021.100502>
- Meilvidir, W., & Siman, S. (2023). Masyarakat Adat Perkotaan dan Migrasi: Masalah dan Dampak.

- JPE*, 17(1), 112–118. <https://doi.org/10.19184/jpe.v17i1.38705>
- Naser, A., Badr, A., Henedy, S. N., Ostrowski, K. A., & Imran, H. (2022). Application of Multivariate Adaptive Regression Splines (MARS) Approach in Prediction of Compressive Strength of Eco-Friendly Concrete. *Case Studies in Construction Materials*, 17. <https://doi.org/10.1016/j.cscm.2022.e01262>
- Perperoglou, A., Sauerbrei, W., & Abrahamowicz, M. (2019). A Review of Spline Function Procedures in R. *BMC Res Methodol*, 19, 46. <https://doi.org/10.1186/s12874-019-0666-3>
- Pradana, B. A., Hilman, I., & Indrianeu, T. (2022). Dampak Migrasi Penduduk Terhadap Kondisi Sosial Ekonomi Masyarakat di Desa Patalagan Kecamatan Pancalang Kabupaten Kuningan. *Geoducation: Journal of Geography Education Universitas Siliwangi*, 3(2), 53–60. <https://jurnal.unsil.ac.id/index.php/geoducation/article/view/5900>
- Pratama, A. ., Tanjung, G. ., & Priyanto, M. W. (2023). The the Existence of the Agricultural Sector in the Economic Structure of Central Sulawesi Province. *Agroland and Agricultural Sciences Journal (E-Journal)*. doi: 10.22487/agroland.v0i0.1285
- Pratomo, D. S. (2018). Can Rural-Urban Migrants Escape From Poverty? Evidence From Four Indonesian Cities. *Economics & Sociology*, 11(2), 173–183. <https://doi.org/10.14254/2071>
- Rahman, F., Astagini, A., & Effendy, A. D. F. (2020). Kesenjangan Pembangunan di Tingkat Lokal: Refleksi atas Implementasi Otonomi Daerah di Indonesia. *Journal of Governance Innovation*, 2(2), 93–111. <https://doi.org/10.36636/jogiv.v2i2.422>
- Rahman, H. (2017). Potret Pertumbuhan Ekonomi, Kesenjangan dan Kemiskinan di Indonesia dalam Tinjauan Ekonomi Politik Pembangunan. *Jurnal Ilmu Dan Budaya*, 40(55), 6305–6328. <https://doi.org/10.47313/jib.v40i55.409>
- Rahman Razak, A., Fernandes, A. A. R., & Saifullah, N. I. (2023). Moderation of village funds and mediation of agricultural sector growth on poverty in rural areas. *Economics and Business Research*, 26(4), 463–483.
- Rammohan, A., & Tohari, A. (2023). Rural poverty and labour force participation: Evidence from Indonesia's Village fund program. *PLoS ONE*, 18(6), e0283041. <https://doi.org/10.1371/journal.pone.0283041>
- Resaski, A., & Marta, J. (2024). Pengaruh Migrasi Terhadap Kemiskinan Rumah Tangga Perkotaan di Indonesia. *Media Riset Ekonomi Pembangunan (MedREP)*, 1(3), 304–311. <https://medrep.ppj.unp.ac.id/index.php/MedREP/article/download/78/43/218>
- Rokhim, F. (2023). Factors Influencing Unemployment in Indonesia. *Journal of Scientific, Research, Education, and Technology*, 2(1), 122–131. <http://dx.doi.org/10.58526/jsret.v2i1.51>
- Siregar, A. ., Darwanto, D. ., Irham, Mulyo, J. ., Jamhari, Utami, A. ., Pranyoto, A., Sugiyarto, Perwitasari, H., Wirakusuma, G., Widada, A. ., Fadhliani, Z., & Widjanarko, N. P. . (2024). The Trend of Agricultural Sector Resilience in Indonesia During 2008-2020. *The Journal of Agricultural Sciences - Sri Lanka*, 19(2), 336–357. <https://doi.org/10.4038/jas.v19i2.10154>
- Steiner, A., Calo, F., & Shucksmith, M. (2023). Rurality and social innovation processes and outcomes: A realist evaluation of rural social enterprise activities. *Journal of Rural Studies*, 99, 284–292. <https://doi.org/10.1016/j.jrurstud.2021.04.006>
- Todaro, M. ., & Smith, S. (2012). *Economic Development* (11th Ed.). Harlow: Addison-Wesley,

Pearson. <https://shahroodut.ac.ir/fa/download.php?id=1111128678>

- van Twuijver, M. W., Olmedo, L., O'Shaughnessy, M., & Hennessy, T. (2020). Rural social enterprises in Europe: A systematic literature review. *Local Economy*, 35(2), 026909422090702. <http://dx.doi.org/10.1177/0269094220907024>
- Vos, R., & Cattaneo, A. (2021). Poverty reduction through the development of inclusive food value chains. *Journal of Integrative Agriculture*, 20(4), 964–978. [https://doi.org/10.1016/S2095-3119\(20\)63398-6](https://doi.org/10.1016/S2095-3119(20)63398-6)
- Wardani, H. S., & Rifa'i, A. (2025). Dynamics of Economic Development in Indonesia: Identifying Factors Driving Economic Growth. *ECONOMOUS: Journal of Regional Economic Development*, 1(1), 7–11. <http://dx.doi.org/10.33830/economous.v1i1.11281>
- Widiyanto, D., Istiqomah, A., & Yasnanto. (2021). Upaya Pemberdayaan Masyarakat Desa dalam Perspektif Kesejahteraan Ekonomi. *Jurnal Kalacakra: Ilmu Sosial Dan Pendidikan*, 2(1), 26–33. <http://dx.doi.org/10.31002/kalacakra.v2i1.3621>
- Wu, Z., Huang, X., Liu, X., Meadows, M. E., Chen, R., & Li, L. (2025). Land use changes and their effects on poverty in Inner Mongolia, northern China. *Geography and Sustainability*, 6, 100269. <https://doi.org/10.1016/j.geosus.2025.100269>
- Yusuf, M., & Khoirunurrofik. (2022). The Relationship of Village Funds With Village Economic Development: A Village Level Study in Indonesia. *Jurnal Bina Praja*, 14(3), 493–504. <https://doi.org/10.21787/jbp.14.2022.493-504>