

Regional Educational Conditions and Childhood Stunting in East Nusa Tenggara: Spatial Evidence for Developmental Inequality

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ABSTRACT:

Childhood stunting remains a persistent public health and developmental challenge in East Nusa Tenggara (NTT), Indonesia, where educational disparities may contribute to unequal nutritional outcomes across regions. This study examined global, local, and spatial relationships between educational conditions and childhood stunting across 22 districts and municipalities in NTT. District-level secondary data were analyzed using Ordinary Least Squares (OLS), Geographically Weighted Regression (GWR), and Spatial Autoregressive (SAR) models. The educational indicators included mean years of schooling, educational resource availability, and community reading behavior. The OLS model explained 23.9% of the variation in stunting prevalence, with an adjusted (R^2) of 11.2%, indicating relatively limited explanatory capacity when a single global relationship was assumed. GWR produced geographically varying local coefficient estimates and reduced residual spatial autocorrelation; however, Monte Carlo tests did not provide statistically significant evidence of coefficient non-stationarity. The SAR model further identified significant spatial dependence in stunting prevalence $\rho = 0.578$, $p = 0.0005$. After accounting for this dependence, mean years of schooling showed a significant negative association with stunting $\beta = -3.899$, $p = 0.0056$, whereas educational resource availability $\beta = -1.392$, $p = 0.1028$ and community reading behavior $\beta = -1.071$, $p = 0.1747$ were not statistically significant. These findings indicate that local coefficient estimates varied descriptively across NTT, although statistically significant coefficient non-stationarity was not detected. In contrast, stunting prevalence exhibited clear spatial dependence, while mean years of schooling was the only educational indicator significantly associated with stunting after spatial dependence was taken into account.

Keywords: Stunting, Education, GWR, SAR, East Nusa Tenggara.

1. Introduction

Childhood stunting remains an important developmental challenge because its implications extend beyond impaired physical growth. Prolonged nutritional deprivation and repeated health constraints during early childhood may

affect developmental trajectories that are directly relevant to later learning and participation in education. Recent meta-analytic evidence indicates that childhood stunting is associated with disadvantages in several cognitive and developmental domains, including intelligence,

executive functioning, visuospatial ability, cognition, and socio-emotional development, although the magnitude and consistency of these associations vary across geographical and socioeconomic contexts (Sideropoulos et al., 2025). These findings suggest that stunting should not be viewed solely as a nutritional or health indicator, but also as a condition embedded within the broader environments in which children develop and eventually enter educational systems. Importantly, stunting should not be equated with disability; rather, its potential developmental consequences make the prevention of stunting relevant to educational equity and to efforts aimed at reducing early developmental disadvantages.

This issue is particularly important in East Nusa Tenggara (Nusa Tenggara Timur, NTT), an archipelagic province of Indonesia characterized by considerable geographical and socioeconomic diversity. Provincial data for 2025 recorded 66,195 children under five experiencing stunting, corresponding to an overall prevalence of 20.07%. However, the provincial average masks substantial differences across the 22 regencies and municipality. Stunting prevalence ranged from 8.09% in Ende and 8.17% in Manggarai Timur to 38.50% in Sumba Barat Daya and 41.36% in Timor Tengah Selatan (BPS Provinsi Nusa Tenggara Timur, 2026). This marked subregional variation demonstrates substantial geographic inequality in the burden of childhood stunting and provides a strong rationale for district-level spatial analysis.

Education represents one important dimension of this developmental environment. Evidence from Indonesia has consistently linked parental educational attainment with childhood nutritional outcomes. Soekatri et al., (2020) found that stunting among Indonesian children was strongly associated with parental education and socioeconomic status, while (Laksono et al., 2022), using a large national sample of children under two years, reported progressively greater odds of stunting among children whose mothers had lower levels of education. Education may operate through several pathways, including

access to information, health-related decision making, caregiving practices, use of health services, household resources, and the capacity to translate nutritional information into everyday practices. Earlier evidence from Indonesia also suggested that higher parental education was associated with protective caregiving behaviours such as childhood immunisation, vitamin A supplementation, sanitation, and use of iodised salt. Consequently, education can be conceptualized not merely as an individual characteristic but also as part of the social and informational environment surrounding child development (Alfaqeeh et al., 2026; Laksono et al., 2022; Mahmudiono et al., 2018).

Recent studies reinforce the need to consider these broader contexts. In Timor-Leste, identified maternal knowledge, household income, cultural practices, infectious disease, and breastfeeding as significant correlates of childhood stunting (Fabiola et al., 2026). Research published in Indonesia has similarly highlighted the importance of communication, community participation, local knowledge, and culturally embedded behaviours in stunting prevention (Laksono et al., 2022; Soekatri et al., 2020). In NTT specifically, Picauly et al., (2024) demonstrated that stunting in the province's dryland and island context was associated with a combination of child, household, sanitation, social protection, and residential characteristics. Taken together, these studies indicate that stunting is produced within a multilayered developmental context. However, education in the existing literature has commonly been represented by maternal or parental schooling or knowledge, leaving regional educational conditions themselves comparatively underexplored.

A second limitation concerns geography. Stunting prevalence is unlikely to be randomly distributed across space because neighbouring regions may share infrastructure, socioeconomic conditions, cultural practices, public services, labour markets, and patterns of access to information. Previous spatial studies in Indonesia have provided evidence of such geographical

structuring. Analysing 514 Indonesian districts and cities, Eryando et al., (2022) identified spatial autocorrelation in stunting and applied a Spatial Autoregressive model to account for dependence among neighbouring areas. Studies focused specifically on NTT have also demonstrated substantial geographical variation. Nashriyah et al., (2023) reported spatial differences in the relationships between environmental and economic conditions and stunting, whereas Bele et al., (2022) applied Geographically Weighted Regression (GWR) and found that the determinants of stunting varied across NTT districts, including differences associated with female educational attainment. More recently, GWR has also been applied at the national level to identify geographically varying determinants of stunting across Indonesian provinces (Kurniawati et al., 2025).

Nevertheless, spatial dependence and spatial heterogeneity represent different processes and therefore require different analytical perspectives. A conventional global regression model assumes that the association between educational conditions and stunting is constant across all regions. GWR relaxes this assumption by allowing regression coefficients to vary geographically, thereby revealing potential local differences in educational associations. In contrast, a Spatial Autoregressive (SAR) model explicitly incorporates spatial dependence in the outcome and allows assessment of whether stunting prevalence in one region is associated with the prevalence observed in neighbouring regions. However, few studies in NTT have examined global educational associations, local coefficient patterns, and spatial dependence within a single analytical framework centered specifically on regional educational conditions. Consequently, relatively little attention has been given to examining global relationships, geographically varying relationships, and spatial dependence processes within a single analytical framework, particularly when education is placed at the centre of the analysis rather than treated as one control variable among numerous health and socioeconomic determinants.

The present study addresses this gap by examining the relationship between regional educational conditions and childhood stunting prevalence across the 22 regencies and municipality of East Nusa Tenggara. Educational conditions are represented by three complementary dimensions: mean years of schooling, reflecting accumulated educational attainment; basic-education teacher resources relative to student numbers, reflecting regional educational resource availability; and the community reading-interest level, representing the broader literacy and informational environment. These variables are examined as ecological characteristics of districts and should therefore be interpreted as regional educational correlates rather than individual-level or causal determinants of childhood stunting. The study first estimates an Ordinary Least Squares (OLS) model to assess the global relationship between educational conditions and stunting. It then employs GWR to explore whether these relationships vary geographically and a SAR model was used to assess spatial dependence in childhood stunting across neighboring areas (Picauly et al., 2024; Rachmi et al., 2016; Rizal & van Doorslaer, 2019).

Accordingly, this study aims to (1) examine the global associations between educational conditions and childhood stunting prevalence in East Nusa Tenggara; (2) investigate whether these associations exhibit geographical variation across districts and municipalities; and (3) assess whether childhood stunting demonstrates spatial dependence across neighboring areas after educational conditions are taken into account. By integrating global, local, and spatial-dependence perspectives, the study seeks to extend the discussion of childhood stunting beyond individual nutritional and household determinants toward the broader regional educational environments in which children grow and develop. The findings are expected to provide a more geographically sensitive evidence base for understanding how educational conditions may relate to stunting patterns and for informing integrated policies addressing

educational development, child nutrition, and early developmental inequalities.

2. Methodology

2.1 Design

This study employed a quantitative, ecological, cross-sectional spatial design to examine the relationships between regional educational conditions and childhood stunting across East Nusa Tenggara (Nusa Tenggara Timur, NTT), Indonesia. The unit of analysis was the regency/municipality rather than individual children or households. The study integrated three complementary modelling perspectives. Ordinary Least Squares (OLS) regression was used to estimate global relationships, Geographically Weighted Regression (GWR) was applied to explore geographical variation in the relationships, and a Spatial Autoregressive (SAR) model was used to assess spatial dependence and potential spillover patterns in childhood stunting across neighbouring areas.

The analysis relied entirely on secondary aggregate data for 2025 and the 2025/2026 academic year obtained from Nusa Tenggara Timur Province in Figures 2026, published by BPS-Statistics Nusa Tenggara Timur Province (BPS Provinsi Nusa Tenggara Timur, 2026). The BPS publication compiles official socioeconomic, educational, demographic, and health statistics for the province. Because the study used publicly available aggregate regional statistics and did not involve individual participants, personal identifiers, interventions, or direct human-subject

data collection, individual informed consent was not applicable.

2.2 Participants/Sample

The study covered all 22 administrative areas of East Nusa Tenggara, consisting of 21 regencies and one municipality (Kupang Municipality). A total-enumeration approach was therefore used rather than probabilistic sampling. An administrative area was eligible for inclusion when complete district-level information was available for childhood stunting prevalence and the three selected educational indicators. All 22 areas had complete observations for the final set of variables and were retained in the analysis.

The dependent variable was childhood stunting prevalence (%) among children under five years of age in 2025. Three educational indicators were included as independent variables. Mean Years of Schooling (MYS) represented accumulated educational attainment within the adult population. BPS defines mean years of schooling as the average number of years spent in formal education by residents aged 25 years and older. Educational Resource Availability represented the availability of educators relative to the number of students in basic education. Level of Society's Reading Fondness (TGM) represented the broader regional literacy and reading environment. BPS defines TGM as an index reflecting community reading engagement at the national, provincial, and regency/municipality levels.

Table 1. Variable Definition

Variable	Definition	Unit
Stunting	Children under five classified as stunted	%
MYS	Mean formal schooling, age ≥ 25	years
Educational Resource Availability	Basic-education educators per 100 students	educators/100 students
TGM	Community reading index	index score

Thus, the analytical framework was specified as:

$$Y = \text{Childhood Stunting Prevalence}$$

$$X_1 = \text{Mean Years of Schooling}$$

$$X_2 = \text{Educational Resource Availability}$$

$$X_3 = \text{Level of Society's Reading Fondness.}$$

2.3 Instruments

No questionnaire, psychological test, or direct measurement instrument was administered because the study was based on secondary administrative statistics. A structured data-extraction framework was used to compile the required variables from the official BPS publication.

Mean Years of Schooling was taken directly from the district-level human development statistics. Educational Resource Availability (ERA) was constructed from the number of educators and enrolled students in formal basic education, covering elementary and junior-secondary education in both general and religious school systems (SD, MI, SMP, and MTs). Educator and student counts were aggregated across SD, MI, SMP, and MTs and calculated as:

$$ERA_i = 100 \times \frac{\sum_l E_{il}}{\sum_l S_{il}},$$

where E_{il} and S_{il} denote the numbers of educators and enrolled students, respectively, in district/municipality i at education level l , with l representing SD, MI, SMP, and MTs. A higher ERA_i value indicates greater educator availability relative to student enrollment.

The literacy environment was represented by the official Level of Society's Reading Fondness (TGM) index. The BPS documentation indicates that TGM comprises pre-reading, reading, and post-reading dimensions, weighted as follows:

$$\begin{aligned} TGM = & (0.15 \times \text{PreReading}) \\ & + (0.50 \times \text{Reading}) \\ & + (0.35 \times \text{PostReading}). \end{aligned}$$

The indicator is officially reported at the regency/municipality level and was available for all 22 areas in 2025.

For spatial analysis, an administrative boundary dataset at the regency/municipality level was used to link statistical observations with geographic locations. Geographic centroids of the 22 administrative units were used to construct the spatial relationships among areas.

2.4 Procedure

The study was conducted in several sequential stages. First, district-level data on stunting and educational indicators were extracted from the 2026 BPS publication and harmonized using official regency/municipality names. The completeness and consistency of the data were checked before analysis. The Educational Resource Availability variable was subsequently calculated by aggregating educator and student counts across SD, MI, SMP, and MTs and expressing the resulting ratio as educators per 100 students.

Second, the tabular dataset was linked to the regency/municipality spatial boundary layer. Geographic centroids were generated to characterize the relative locations of the 22 administrative areas. Given the archipelagic geography of East Nusa Tenggara, where direct boundary-based contiguity may leave island areas without connected neighbours, spatial proximity was represented using a k-nearest-neighbour (KNN) spatial weights matrix with $k = 4$. The weights were row-standardized so that the weights associated with the neighbours of each administrative unit summed to one.

Third, descriptive statistics and thematic mapping were used to examine the distribution of childhood stunting and educational conditions. A global OLS regression model was subsequently estimated as the baseline specification:

$$Y_i = \beta_0 + \beta_1 MYS_i + \beta_2 ER_i + \beta_3 TGM_i + \varepsilon_i.$$

Model assumptions and spatial diagnostics were then evaluated. Multicollinearity was assessed using the Variance Inflation Factor (VIF), while the Breusch–Pagan test was used to examine heteroskedasticity in the residual variance. Global Moran's I was calculated for childhood stunting and for the OLS residuals to determine whether statistically significant spatial autocorrelation remained after the educational variables were incorporated.

Fourth, GWR was estimated to explore whether the associations between educational conditions and childhood stunting varied geographically. Finally, spatial dependence diagnostics, including

Lagrange Multiplier tests, were used to evaluate the need for an explicitly spatial regression specification. A SAR model was then estimated to assess spatial dependence in stunting prevalence, while a Spatial Error Model (SEM) was considered as a competing spatial specification for model-comparison purposes.

2.5 Data Analysis

Descriptive analysis included the mean, standard deviation, minimum, maximum, and spatial distribution of each variable. Bivariate associations among the educational indicators were inspected before multivariable modelling, and VIF values were used to identify potential multicollinearity (Kurniawati et al., 2025; Yudono et al., 2021).

OLS regression served as the global benchmark model. Individual regression coefficients were assessed using t-tests, while overall model significance was evaluated using the F-test. Model

The GWR model was specified as:

$$Y_i = \beta_0(u_i, v_i) + \beta_1(u_i, v_i)MYS_i + \beta_2(u_i, v_i)ER_i + \beta_3(u_i, v_i)TGM_i + \varepsilon_i,$$

where (u_i, v_i) represents the geographic location of administrative area i . An adaptive bi-square kernel was used because administrative units in East Nusa Tenggara are geographically uneven and distributed across multiple islands. Geographic distance was calculated between regional centroids, and the optimal adaptive bandwidth was determined by minimizing the corrected Akaike Information Criterion (AICc). GWR results were summarized using local regression coefficients, local R^2 , residual statistics, RMSE, and AICc. The spatial variability of local coefficients was additionally assessed using a Monte Carlo test of coefficient non-stationarity. GWR was interpreted primarily as an exploratory model for identifying geographical variation rather than as evidence of causal regional effects (Du et al., 2020; Leung et al., 2000).

To distinguish residual spatial dependence from geographically varying relationships, Lagrange Multiplier (LM) diagnostics were applied to the OLS model. LM-Lag and LM-Error tests,

fit was summarized using R^2 , adjusted R^2 , Root Mean Squared Error (RMSE), and information criteria. Statistical significance was evaluated at $\alpha = 0.05$ (Bele et al., 2022; Eryando et al., 2022; Hermawan et al., 2024). Spatial autocorrelation was assessed using Global Moran's I:

$$I = \frac{n}{S_0} \frac{\sum_i \sum_j w_{ij} (y_i - \bar{y})(y_j - \bar{y})}{\sum_i (y_i - \bar{y})^2},$$

where w_{ij} represents the spatial relationship between areas i and j , and S_0 is the sum of all spatial weights. Positive and statistically significant Moran's I values were interpreted as evidence that areas with similar stunting prevalence tended to cluster geographically. Permutation-based inference was used to assess statistical significance. Moran's I was also applied to OLS residuals to determine whether the global regression left unexplained spatial structure (Rahardianto et al., 2024).

together with their robust counterparts, were examined to differentiate between spatial lag and spatial error processes. A SAR model was subsequently specified as:

$$Y = \rho WY + X\beta + \varepsilon$$

where WY represents the spatially lagged childhood stunting prevalence and ρ is the spatial autoregressive parameter. A positive and significant ρ indicates that stunting prevalence is spatially associated with the prevalence observed in neighbouring areas after controlling for educational conditions.

The SAR model was estimated using maximum likelihood. For model selection, OLS, GWR, SAR, and the competing SEM specification were compared based on model fit, information criteria, and residual spatial autocorrelation. The SAR specification was used to evaluate whether childhood stunting prevalence exhibited spatial dependence after controlling for the selected educational indicators.

$$(I - \rho W)^{-1}.$$

Accordingly, the three modelling approaches addressed complementary analytical questions. OLS estimated province-wide educational associations, GWR explored descriptive variation in local coefficient estimates, and SAR evaluated spatial dependence in childhood stunting across neighbouring districts (Fotheringham et al., 2002; Leung et al., 2000).

3.1 Descriptive Statistics

Table 2. Descriptive Statistics of Study Variables

Variable	N	Mean	Std. Deviation	Minimum	Maximum
Childhood Stunting Prevalence (%)	22	19.338	9.017	8.090	41.360
Mean Years of Schooling (years)	22	8.075	0.994	6.470	11.660
Educational Resource Availability	22	9.754	1.596	7.302	13.199
Level of Society's Reading Fondness (TGM)	22	62.118	1.775	58.430	65.600

Descriptive statistics are presented in Table 1. Across the 22 regencies and municipality, childhood stunting prevalence averaged 19.34% (SD = 9.02), ranging from 8.09% to 41.36%. Mean years of schooling averaged 8.07 years (SD = 0.99). Educational resource availability averaged 9.75 educators per 100 students (SD = 1.60), while the mean Level of Society's Reading Fondness was 62.12 (SD = 1.77).

3. Results

Childhood stunting prevalence varied across the 22 regencies/municipality of East Nusa Tenggara. Spatial analysis indicated significant positive spatial autocorrelation in stunting prevalence, with Global Moran's $I = 0.355$ and $p = 0.005$.

3.2 Global OLS Model

The OLS model included Mean Years of Schooling (MYS), Educational Resource Availability, and the Level of Society's Reading Fondness (TGM). The model explained 23.85% of the variation in district-level stunting prevalence

Table 3. Results of the Global OLS Regression Model

Variable	Coefficient	SE	t	p-value
Constant	97.240	72.730	1.337	0.198
Mean Years of Schooling	-3.409	1.939	-1.758	0.096
Educational Resource Availability	-1.636	1.170	-1.398	0.179
Level of Society's Reading Fondness	-0.554	1.084	-0.511	0.615

$$R^2 = 0.239, \text{ Adjusted } R^2 = 0.112$$

$$F = 1.879, p = 0.169$$

The overall OLS model was not statistically significant, $F(3, 18) = 1.879, p = 0.169$. No predictor was statistically significant at the 5% level in the OLS model. The VIF values ranged from 1.014 to 1.079. Spatial autocorrelation remained in the OLS residuals:

$$\text{Moran's } I = 0.408, p = 0.002$$

3.2 Geographically Weighted Regression

The GWR model was estimated using an adaptive bi-square kernel. The optimal adaptive bandwidth was 22 nearest observations.

Table 4. Comparison of OLS and GWR Model Fit

Criterion	OLS	GWR
R^2	0.239	0.542
Adjusted R^2	0.112	0.301
RMSE	7.688	5.965
RSS	1,300.26	782.85
AICc	165.93	167.57
Residual Moran's I	0.408	0.098
Residual Moran p-value	0.002	0.502

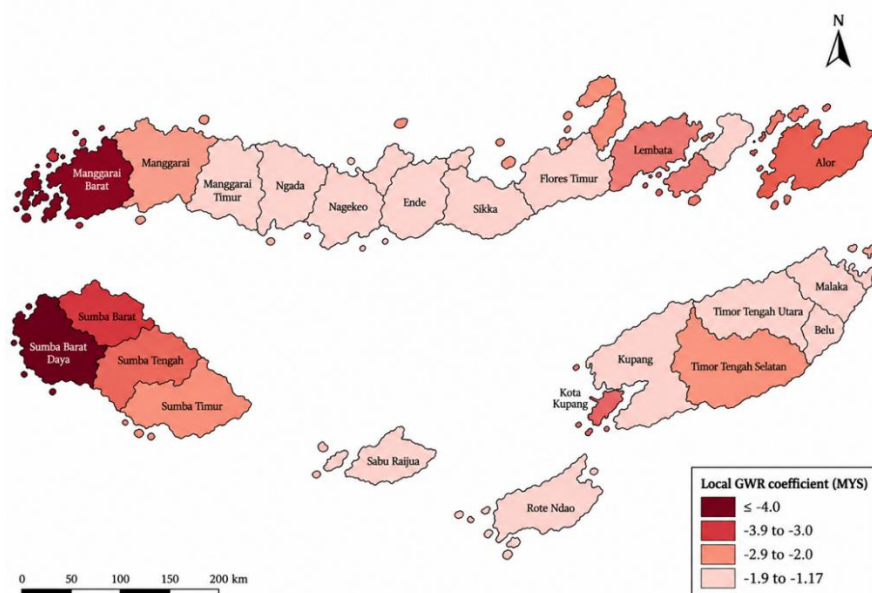
The local coefficients ranged from -4.972 to -1.172 for MYS, -2.616 to -0.947 for Educational Resource Availability, and -0.980 to 0.118 for TGM. Although the local estimates varied numerically across districts, Monte Carlo tests did not indicate statistically significant coefficient non-stationarity for MYS ($p = 0.578$), Educational Resource Availability ($p = 0.520$), or TGM ($p = 0.799$). Therefore, the local patterns were interpreted descriptively rather than as evidence of statistically significant spatial heterogeneity.

Although GWR produced higher R^2 , lower RMSE, and substantially reduced residual spatial autocorrelation, its AICc (167.57) was slightly higher than that of OLS (165.93). Moreover, the optimal adaptive bandwidth included all 22 observations, and Monte Carlo tests provided no significant evidence of coefficient non-stationarity. Therefore, the GWR results were interpreted as exploratory descriptions of local coefficient patterns rather than evidence of statistically distinct district-specific relationships.

However, the Monte Carlo tests of spatial variability were not statistically significant.

Table 5. Monte Carlo tests of spatial variability

Variable	Monte Carlo p-value
MYS	0.578
Educational Resource Availability	0.520
TGM	0.799

**Figure 1. Local GWR Coefficients for Mean Years of Schooling Across East Nusa Tenggara**

3.3 Spatial Autoregressive Model

Spatial diagnostic tests supported further examination of a spatial lag specification. Both LM-Lag and LM-Error were significant, although

their robust counterparts were not significant at the 5% level.

Table 6. Spatial Diagnostic Tests

Test	Statistic p-value	
LM-Lag	10.378	0.001
LM-Error	8.040	0.005
Robust LM-Lag	2.859	0.091
Robust LM-Error	0.521	0.471

Both classical LM tests were significant, whereas the robust tests were not significant at the 5% level, providing evidence of spatial dependence but not a definitive distinction between lag and error processes. SAR and SEM were therefore estimated as competing specifications.

Table 7. Spatial Autoregressive Model Results

Variable	Coefficient	SE	z	p-value
Constant	119.613	52.696	2.270	0.023
Mean Years of Schooling	-3.899	1.406	-2.773	0.006
Educational Resource Availability	-1.392	0.853	-1.631	0.103
Level of Society's Reading Fondness	-1.071	0.789	-1.357	0.175
Spatial lag, ρ	0.578	0.166	3.473	<0.001

Model statistics were:

$$LogLik = -72.250$$

$$AIC = 154.50$$

For comparison:

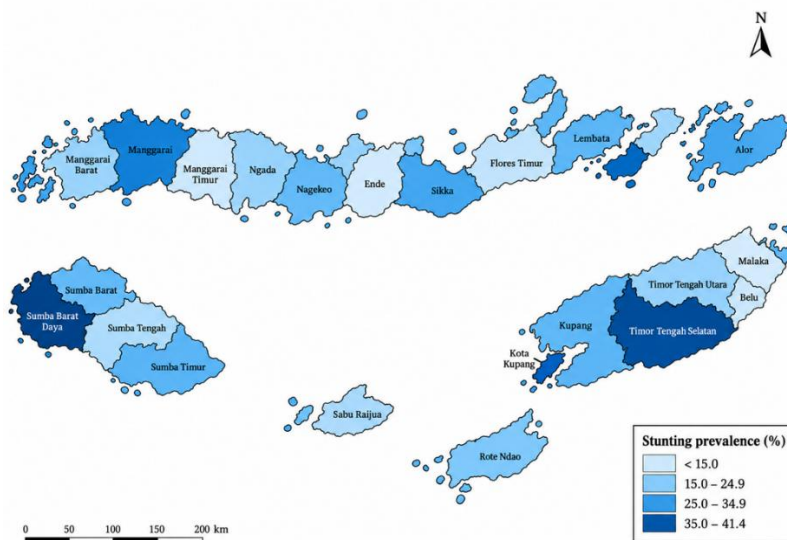
$$AIC_{OLS} = 160.18,$$

$$AIC_{SEM} = 155.34,$$

$$AIC_{SAR} = 154.50.$$

The significant spatial autoregressive parameter ($\rho = .578, p < .001$) indicates that district-level stunting prevalence is spatially dependent. Figure 2 illustrates the geographic distribution of childhood stunting across NTT, highlighting the

marked differences among districts that underlie the spatial structure identified by the model. The SAR model yielded the lowest AIC, although its advantage over SEM was modest ($\Delta AIC = 0.84$)

**Figure 2. Spatial Distribution of Childhood Stunting Prevalence Across East Nusa Tenggara**

4. Discussion

This study examined the relationship between educational conditions and childhood stunting across 22 districts and municipalities in East Nusa Tenggara (NTT) by integrating Ordinary Least Squares (OLS), Geographically Weighted Regression (GWR), and Spatial Autoregressive (SAR) models. The three approaches provide complementary rather than competing interpretations. OLS describes the average province-wide relationship, GWR identifies geographical variation in that relationship, and SAR evaluates whether stunting prevalence in one district is associated with conditions in neighboring districts. Taken together, the findings indicate that the relationship between education and childhood stunting in NTT is not spatially uniform and that stunting itself is geographically interconnected.

4.1. Global relationship between educational conditions and stunting

The OLS model explained approximately 23.9% of the variation in district-level stunting prevalence, with an adjusted (R^2) of 11.2%. The educational indicators generally showed negative coefficient directions, suggesting that districts with more favorable educational conditions tended to have lower stunting prevalence. The overall model was not statistically significant ($p = .169$), indicating that the selected educational indicators alone provided limited global explanatory power. However, the relatively modest explanatory power of the global model indicates that educational conditions alone cannot fully explain the geographical variation in stunting across NTT.

This result is reasonable because childhood stunting is a multidimensional outcome shaped by interacting biological, household, socioeconomic, environmental, and healthcare factors. A comprehensive review of Indonesian evidence identified maternal education and household socioeconomic status as important determinants of stunting, but also highlighted the roles of birth characteristics, breastfeeding, sanitation, drinking water, healthcare access, and

rural residence (Beal et al., 2018). Similarly, multilevel analyses in Indonesia have demonstrated that child-, maternal-, household-, and community-level characteristics jointly contribute to stunting risk (Titalay et al., 2019). Therefore, the relatively low explanatory power of an education-focused OLS model should not be interpreted as indicating that education is unimportant. Rather, it suggests that education represents one structural component within a broader system of stunting determinants.

The negative direction of the educational associations observed in this study is consistent with previous Indonesian research. Laksono et al., using a large national sample of children under two years of age, reported that lower maternal educational attainment was associated with a substantially greater likelihood of childhood stunting (Laksono et al., 2022). Earlier evidence from Indonesia also demonstrated that additional years of maternal and paternal formal education were associated with progressively lower odds of child stunting (Semba et al., 2008). Furthermore, (Soekatri et al., 2020) found that stunting among Indonesian children was strongly associated with parental education, socioeconomic status, and morbidity.

Evidence specifically from NTT supports this interpretation. Suratri et al. (2023) identified low maternal education among the important risk factors associated with stunting among children under five in NTT. Picauly et al., (2024) further demonstrated that stunting in the dryland areas of NTT is associated with a broad combination of child and household characteristics, including birth conditions, feeding practices, sanitation, health insurance, socioeconomic assistance, and residential context. These findings reinforce the interpretation that education is relevant to stunting but operates alongside multiple contextual determinants.

Education may influence nutritional outcomes through several mechanisms. Greater educational attainment can improve the ability to acquire, understand, and apply information concerning maternal nutrition, breastfeeding, complementary feeding, hygiene, sanitation,

disease prevention, and child growth monitoring. Education may also improve employment opportunities, household income, autonomy in health-related decision-making, and the ability to navigate healthcare systems. Therefore, education is better interpreted as a structural determinant that can influence several intermediate pathways rather than as an isolated direct cause of childhood stunting (Beal et al., 2018; Laksono et al., 2022; Semba et al., 2008).

4.2. Exploratory local patterns from GWR

One of the most important findings of this study is that the relationships between educational conditions and stunting were not geographically constant across NTT. Local coefficients differ numerically, but there is no statistical evidence that the coefficients vary geographically. This finding explains, at least partly, why the global OLS coefficients were relatively weak: a single province-wide coefficient averages relationships that may be stronger in some locations and weaker in others.

This finding differs from Bele et al. (2022), who reported stronger evidence of geographic heterogeneity in stunting determinants across NTT. Several methodological differences may explain the discrepancy, including the study period, predictor composition, and the highly smoothed GWR specification in the present analysis, for which the optimal adaptive bandwidth included all 22 areas. Bele et al. (2022) applied GWR to district-level stunting data in NTT and identified substantial spatial heterogeneity in the determinants of stunting. Their GWR model produced a substantially higher coefficient of determination than the corresponding OLS model, demonstrating that allowing regression parameters to vary geographically provided a better representation of stunting patterns in the province. Although the predictors and study period differ from those used in the present study, the similarity in the methodological conclusion is important: the determinants of stunting in NTT should not be assumed to operate uniformly across space.

A similar pattern has been reported at the national level. Hermawan et al. (2024) applied GWR to Indonesian stunting data and emphasized the contribution of regional proximity and local characteristics to variations in stunting prevalence. More recently, (Kurniawati et al., 2025) also used GWR to investigate spatial determinants of stunting across Indonesia, providing further evidence that the strength of relationships between stunting and its determinants differs geographically.

Spatial heterogeneity is particularly plausible in NTT because the province consists of numerous islands and geographically separated administrative areas. Differences in transportation networks, accessibility of health and educational services, rurality, economic opportunities, food systems, water availability, sanitation infrastructure, and local sociocultural conditions may modify the extent to which educational improvements translate into improved child nutrition. Nashriyah et al., (2023) for example, demonstrated spatial relationships between environmental and economic conditions and stunting prevalence within NTT. Picauly et al. (2024) similarly emphasized the importance of household and residential characteristics in the province's dryland context.

Consequently, an identical increase in educational attainment or educational resources may not produce the same nutritional benefit in every district. In a district with adequate healthcare, sanitation, transportation, and food accessibility, improvements in education may be more effectively translated into healthy feeding and healthcare practices. In another district where households continue to face severe geographical isolation, poverty, food insecurity, or inadequate health services, improvements in education alone may have a weaker observable relationship with stunting.

The GWR findings therefore provide an important substantive contribution. They suggest that educational interventions should not be expected to have geographically homogeneous effects. Instead, educational conditions interact

with the broader local environment, supporting a place-based interpretation of childhood stunting.

4.3. Spatial dependence in stunting prevalence

The SAR model adds another important dimension to the analysis. The spatial autoregressive parameter was positive and statistically significant ($\rho=0.578$), ($p=0.0005$), providing strong evidence of spatial dependence in stunting prevalence across NTT. This means that the prevalence observed in one district cannot be regarded as completely independent of prevalence in surrounding or spatially connected districts.

This finding is consistent with Eryando et al., (2022), who investigated stunting across 514 Indonesian districts and municipalities and identified significant spatial autocorrelation. Their study demonstrated that neighboring areas tend to exhibit related stunting conditions and showed that spatial autoregressive modelling can provide important information for determining intervention priorities. The present findings therefore extend this evidence to the specific context of NTT.

Spatial dependence in stunting can arise through several mechanisms. Neighboring districts may share similar food markets, transportation infrastructure, ecological conditions, healthcare referral systems, economic structures, cultural practices, sanitation conditions, and access to public services. Population movement and inter-district economic activity may further connect nutritional environments across administrative boundaries. Consequently, an area with poor nutritional and socioeconomic conditions may be embedded within a broader cluster of similarly disadvantaged districts.

The finding also complements the spatial patterns reported by Nashriyah et al. (2023), who demonstrated that environmental and economic factors associated with stunting in NTT display clear geographical patterns. Together, these studies suggest that administrative boundaries should not be interpreted as barriers separating independent stunting processes.

The significant spatial parameter has an important policy implication. The spatial dependence suggests that district-level stunting outcomes are embedded within broader regional processes that may be shared across neighboring areas, such as food systems, transportation networks, health-service access, sanitation conditions, and socioeconomic environments. Conversely, persistent disadvantage in surrounding districts may limit the effectiveness of interventions implemented within a single district. Stunting reduction in NTT should therefore be viewed partly as an inter-district or regional challenge rather than solely as a collection of independent district problems.

4.4. Mean years of schooling as the most robust educational correlate

After spatial dependence was incorporated into the SAR model, mean years of schooling emerged as the strongest educational predictor, with a negative and statistically significant coefficient ($\beta=-3.899$), ($p=0.0056$). This finding indicates that higher accumulated educational attainment at the district level is associated with lower stunting prevalence after accounting for the spatial structure of the outcome.

This result is consistent with the broader evidence linking educational attainment to child nutritional status. Semba et al. (2008) demonstrated a graded relationship between additional years of parental education and reduced odds of childhood stunting in Indonesia. Soekatri et al. (2020) similarly reported significant relationships between parental education and stunting, while Laksono et al. (2022) showed that lower maternal educational attainment substantially increased the likelihood of stunting among Indonesian children under two years.

Evidence from NTT itself provides additional support. Suratri et al. (2023) identified low maternal educational attainment as one of the risk factors for childhood stunting in the province. Thus, the significant MYS coefficient in the present ecological analysis is broadly consistent with evidence obtained from individual- and household-level studies.

Mean years of schooling may capture a relatively broad dimension of accumulated human capital. Unlike an indicator describing only the availability of schools or teachers, MYS reflects the extent to which the population has actually remained within the formal education system. Higher average schooling may therefore represent a combination of literacy, knowledge acquisition, socioeconomic opportunity, ability to access information, and capacity to interact effectively with public institutions.

Nevertheless, the SAR coefficient should be interpreted carefully. Because the model includes a spatially lagged dependent variable, the coefficient of MYS should not simply be described as implying that a one-unit increase in MYS causes an exact 3.899-percentage-point decline in stunting prevalence. In a spatial lag model, a change in one district may influence neighboring districts and subsequently feed back into the original district. Thus, the coefficient is more appropriately interpreted as evidence of a strong negative spatially adjusted association. A complete decomposition into direct, indirect, and total impacts would be required to quantify the magnitude of local and spillover effects precisely.

4.5. Educational Resource Availability and TGM

Educational Resource Availability also showed a negative association with stunting in the SAR model ($\beta = -1.392$), although the relationship was not statistically significant at the conventional 5% level ($p = 0.1028$). This finding suggests that a greater supply of educational personnel relative to students may be favorable but is not sufficient, by itself, to explain differences in stunting prevalence across NTT.

Several explanations are plausible. First, the availability of teachers or educational personnel measures educational capacity rather than educational outcomes. A district may have relatively favorable educator-to-student ratios while still experiencing problems related to school attendance, dropout, learning quality, household poverty, or geographical accessibility. Second, current educational resources may have

delayed effects on stunting. Improvements in education among today's school-aged population may influence child nutrition more strongly when that population enters adulthood and becomes the next generation of parents.

This distinction may explain why MYS was statistically more robust than Educational Resource Availability. MYS represents accumulated realized educational attainment, whereas resource availability reflects the capacity of the educational system at a particular point in time.

TGM also exhibited a negative but statistically non-significant association with stunting ($\beta = -1.071$), ($p = 0.1747$). One possible explanation is that general reading activity does not necessarily translate into nutrition-specific knowledge or health literacy. The ability or willingness to read can improve access to information, but nutritional benefit depends on the content of that information, its credibility, comprehension, household decision-making capacity, and the availability of resources required to act upon it.

Therefore, the non-significant TGM coefficient should not be interpreted as evidence that literacy or access to information is irrelevant to nutrition. Instead, it may suggest that general reading behavior is too distal a proxy to capture the specific pathways connecting health literacy to childhood nutritional outcomes. This interpretation is consistent with the broader literature showing that formal educational attainment has a more consistently demonstrated association with stunting than general information-access indicators (Beal et al., 2018; Laksono et al., 2022; Semba et al., 2008).

4.6. Theoretical implications

The findings support a spatially embedded social-determinants perspective on childhood stunting. Education appears to matter not only as an individual characteristic but also as a contextual form of human capital operating within local socioeconomic, health, and environmental systems.

The progression from OLS to GWR and SAR is theoretically informative. The relatively modest

OLS model suggests that there is no single province-wide educational relationship sufficient to explain stunting. The analytical comparison suggests that spatial dependence was more strongly supported than coefficient non-stationarity. OLS left substantial spatial autocorrelation, GWR produced descriptive local variation but no statistically significant non-stationarity, while SAR identified a strong and statistically significant spatial lag parameter. Accordingly, the findings suggest two simultaneous spatial processes:

1. Spatial heterogeneity, in which the strength of the relationship between education and stunting varies across districts; and
2. Spatial dependence, in which the stunting condition of one district is associated with conditions in spatially connected districts.

These concepts should be distinguished. GWR addresses the first process, whereas SAR primarily addresses the second. Combining the two perspectives provides a richer explanation of stunting than relying solely on a conventional global regression model.

4.7. Implications for practice and policy

The findings have several practical implications for stunting reduction in NTT. First, the significant negative association between MYS and stunting suggests that strategies aimed at improving educational attainment should be regarded as part of long-term stunting prevention. Nutrition-specific interventions during pregnancy and the first 1,000 days of life remain essential, but they should be complemented by nutrition-sensitive investments in education.

Policies that reduce school dropout, improve progression to secondary education, and increase educational attainment, particularly among girls and future mothers, may generate long-term benefits for maternal and child nutrition. This recommendation is supported by the consistent relationship between parental education and childhood stunting reported in Indonesia (Laksono et al., 2022; Semba et al., 2008; Soekatri et al., 2020)

Second, The descriptive GWR patterns may be useful for generating hypotheses about local differences, but they should not by themselves be used to justify district-specific causal interventions. In districts where educational associations are weaker, policy makers should investigate whether poverty, sanitation, food insecurity, healthcare accessibility, maternal health, or geographical isolation represent more immediate constraints.

Third, the significant SAR parameter suggests that intervention planning should consider spatial clusters rather than districts in isolation. Neighboring districts experiencing persistently high stunting prevalence may benefit from coordinated programs involving health services, education, sanitation, food security, transportation, and social protection. This approach is consistent with the spatial-intervention perspective proposed by Eryando et al. (2022).

Fourth, the findings support stronger integration between the education and health sectors. Schools and community learning systems may serve as platforms for reproductive-health education, nutritional literacy, maternal health awareness, sanitation behavior, and preparation for future parenthood. Such interventions could potentially strengthen the pathway through which educational attainment contributes to improved nutritional outcomes.

4.8. Study limitations and directions for future research

Several limitations should be considered. First, the study included only 22 districts and municipalities. Although these units represent the complete administrative coverage of NTT, the small number of observations limits statistical power and increases uncertainty in multivariable and local spatial modelling. Non-significant coefficients should therefore not automatically be interpreted as evidence of no relationship.

Second, the analysis was conducted using aggregate district-level data. Consequently, associations observed between district educational characteristics and stunting

prevalence cannot automatically be transferred to individuals. The significant negative relationship between MYS and stunting, for example, does not establish that every additional year of schooling for an individual caregiver will produce the district-level effect estimated by the model. This ecological limitation should be recognized explicitly.

Third, the cross-sectional design prevents strong causal inference. Educational attainment is likely to influence nutritional outcomes through long-term and potentially intergenerational pathways, which are difficult to capture using observations from a single period.

Fourth, important determinants of stunting were not simultaneously incorporated into the education-focused models. Previous studies in Indonesia and NTT have identified household socioeconomic status, sanitation, water access, birth characteristics, feeding practices, healthcare access, and residential conditions as important determinants (Beal et al., 2018; Picauly et al., 2024; Titaley et al., 2019; Torlesse et al., 2016). Omitted variables may therefore account for part of the unexplained spatial variation.

Fifth, spatial regression results depend partly on the specification of the spatial weight matrix. Different definitions of neighborhood connectivity can alter the estimated magnitude of spatial dependence. Future research should conduct sensitivity analyses using alternative spatial-weight structures.

Sixth, GWR results should be interpreted as exploratory evidence of local coefficient variation rather than statistically confirmed spatial heterogeneity, because the Monte Carlo tests of non-stationarity were not significant. With only 22 spatial units, local coefficient estimates may also be sensitive to bandwidth selection and individual observations. Future studies with larger spatial datasets could consider multiscale GWR to determine whether different predictors operate at different spatial scales.

Finally, future research should extend the present framework using longitudinal or spatiotemporal data. Spatial panel models could distinguish

persistent geographical disparities from temporal changes in education and stunting. Spatial Durbin or related models could also be considered to investigate whether educational conditions in neighboring districts have additional spillover relationships with local stunting prevalence. For the SAR model, decomposition into direct, indirect, and total effects would provide a more precise interpretation of the spatial transmission mechanism.

Overall, this study demonstrates that the association between education and childhood stunting in NTT cannot be fully understood through a non-spatial global model alone. The modest global relationship identified by OLS, the local variation revealed by GWR, and the significant spatial dependence identified by SAR collectively indicate that stunting is both geographically heterogeneous and spatially interconnected. Among the educational indicators examined, mean years of schooling showed the strongest spatially adjusted association with stunting. These findings reinforce the importance of combining long-term educational development with geographically targeted, multisectoral, and cross-district strategies for reducing childhood stunting in East Nusa Tenggara.

5. Conclusion

This study examined the relationship between educational conditions and childhood stunting across 22 districts and municipalities in East Nusa Tenggara using OLS, GWR, and SAR models. The findings show that educational conditions alone explained only a limited proportion of the district-level variation in childhood stunting. The OLS model indicated generally negative associations between the educational indicators and stunting, although the overall model showed relatively limited explanatory power. The GWR analysis revealed descriptive variation in local coefficient estimates across districts; however, Monte Carlo tests did not provide statistically significant evidence of coefficient non-stationarity. In contrast, the SAR model provided clear evidence of spatial dependence in childhood stunting, indicating that stunting prevalence in

one district was associated with conditions in spatially connected districts.

The SAR model further demonstrated that childhood stunting in NTT exhibits significant spatial dependence, indicating that stunting conditions in one district are associated with conditions in neighboring areas. After accounting for this spatial dependence, mean years of schooling emerged as the most robust educational predictor, showing a significant negative association with stunting prevalence. In contrast, Educational Resource Availability and TGM showed negative but statistically non-significant associations. These findings suggest that accumulated educational attainment may be more strongly connected to population-level nutritional outcomes than educational resource availability or general reading behavior alone.

From a policy perspective, stunting reduction strategies in NTT should therefore combine nutrition-specific interventions with longer-term education-sensitive policies. Efforts to increase school participation, reduce school dropout, improve secondary-school completion, and strengthen educational attainment may contribute to improved maternal and child health outcomes over time. Because substantial spatial

dependence was identified, interventions should also consider clusters of neighboring districts rather than treating each district as an independent policy unit. Cross-district coordination among education, health, nutrition, sanitation, food-security, and social-protection programs may be particularly important in areas with persistently high stunting prevalence.

Future research should extend this analysis by incorporating longitudinal or spatiotemporal data, a broader range of socioeconomic, health, environmental, and food-security determinants, and alternative spatial-weight specifications. Studies using larger spatial datasets or multilevel individual and regional data would also help distinguish household-level mechanisms from contextual district-level effects. In addition, future spatial studies should estimate direct, indirect, and total impacts to provide a more detailed understanding of how improvements in education and other structural determinants may generate spillover benefits across neighboring areas. Overall, the findings emphasize that childhood stunting in NTT is not only a nutritional problem but also a spatially structured development issue that requires geographically targeted and multisectoral intervention.

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