International Journal of Public Health Science (IJPHS)
Vol. 15, No. 1, March 2026, pp. 110~117
ISSN: 2252-8806, DOI: 10.11591/ijphs.v15i1.23216

Geospatial patterns and determinants of toddler stunting: evidence from geographically weighted regression

Muhammad Anismuslim[1], Henny Pramoedyo[2], Sri Andarini[3], Sudarto[4]
[1]Master's Program of Environmental Resource Management and Development, Brawijaya University, Malang, Indonesia
[2]Faculty of Mathematics and Natural Science, Department of Statistics, Brawijaya University, Malang, Indonesia
[3]Department of Public Health, Faculty of Medicine, Brawijaya University, Malang, Indonesia
[4]Department of Soil Science, Faculty of Agriculture, Brawijaya University, Malang, Indonesia

Article Info

Article history:

Received Mar 27, 2023
Revised Apr 4, 2024
Accepted Nov 29, 2025

Keywords:

Geographically weighted regression
Health care
Health education
Hygiene
Sanitation

ABSTRACT

This study aimed to map and analyze the spatial distribution of toddler stunting in Malang and identify key risk factors that are spatially correlated with stunting incidence across sub-districts and villages. A geospatial modeling approach using geographically weighted regression (GWR) was employed to account for local variations in the influence of risk factors, reflecting the heterogeneity of conditions that contribute to stunting in different areas. The analysis revealed significant spatial autocorrelation, with stunting cases clustering in specific locations. Results indicate that sanitation risks and household waste management practices were the most significant determinants of stunting prevalence among toddlers in Malang. Improper waste segregation, which leads to odors and attracts flies, and ineffective disposal methods, such as open burning or dumping, were strongly associated with higher stunting rates. These findings underscore the importance of targeted interventions addressing environmental health and sanitation at the local level. By integrating geospatial analysis with GWR modeling, this study highlights the spatial heterogeneity of stunting determinants, providing evidence to guide community-specific public health strategies. Improved sanitation practices and proper household waste management are critical to reducing toddler stunting in areas with clustered risk.

Corresponding Author:

Muhammad Anismuslim
Master's Program of Environmental Resource Management and Development, Brawijaya University
Malang, Indonesia
Email: aakken777@gmail.com

1. INTRODUCTION

The goals of the global sustainable development goals (SDGs) include ending hunger, achieving food security and good nutrition, and promoting sustainable agriculture. The goal is to reduce stunting rates to 20% by 2025. The target is in line with the 2020-2024 Medium-Term Development Plan (RPJMN), in which the Indonesian government set a target of reducing stunting rates from 40% in 2015 to 21.1% in 2021 [1]. Due to malnutrition, children's bodies and brains suffer from chronic underdevelopment. Risk factors for developmental delay are complex. In their responses, the (specific) contribution of the health sector was only 30% [2]. In comparison, the (sensitive) non-health sector contributes 70% and includes various sectors such as food security, provision of sanitation facilities, poverty alleviation, education, social, economic, and environmental sectors. East Java is one of the 18 provinces with a proportion of short and very short toddlers with a high prevalence (30%-<40%). Malang is one of the 100 priority districts/cities for stunting federal intervention.

Geographically, the county is divided into three environmental zones: lowland, midland, and highland. Malang has 33 sub-district offices, 12 sub-district offices, and 378 villages, with a total area of 3,534.86 square kilometers and an estimated population of 2,876,596 people in 2021. Depending on risk profile factors in each village, local governments face barriers in handling developmental delay cases. Diversity of socio-economic levels and complexity of environmental geographical conditions. Malang is one of the 100 priority districts/cities for stunting federal intervention. This is because the prevalence trend of the last four years (2018-2021) of stunting cases in Malang Regency tended to increase. Besides, Malang regency is quite large with variations in environmental topography (having low, medium, and highlands. It has a plurality of different social patterns of society. Meanwhile, the problem of stunting is locally specific to the region, such as a village or sub-district. It is assisted by the statistical analysis that can explain the pattern with geographically weighted regression (GWR) analysis.

Good sanitation protects children from developmental delays [3]. Poor environmental hygiene can trigger digestive disorders, causing the energy needed for growth to divert from the body’s ability to defend against infection [4]. Poor environmental health may lead to infectious diseases that can cause nutritional disorders in children [5]. Chronic infections can cause growth retardation in children [6], and those with a history of infectious diseases are at risk of growth retardation [7]. Besides, several studies on the effect of stunting in toddlers have been carried out. Laksono and Megatsari [8] state that four determinant variables cause stunting in toddlers: residence, age, the mother’s age, and the mother’s education level. In addition, the lack of exclusive breastfeeding for infants can increase the chances of short toddlers [9]. According to the research conducted by Pramoedyo *et al.* [10], in Malang, the dominant factors causing stunting are exclusive breastfeeding, which is only given for 1-5 months, access to clean drinking water, access to an integrated healthcare center, and poor hand washing habits.

Research on stunting toddlers using the GWR method was previously conducted by Kartini and Ummah [11]. The research data were taken from toddlers in the city of Bojonegoro. They also used the multivariate adaptive regression splines (MARS) method in their research as a comparison with the GWR method. The results obtained are from using the MARD method. The produced model R-square is better. While the GWR model is bigger than MARS, even though the difference in number is not that great [11]. Putri and Salamah [12] also conducted other research on GWR modeling. The results of their study stated that the GWR model had a higher coefficient of determination (R^2) of 92.25% compared to the OLS, which was only 56.1%. The AIC value generated in the GWR model is also smaller than the AIC in the OLS, which is -64.4284 for the GWR model and -18.7787 for the OLS model [12]. Cholid *et al.* [13] also conducted a study on stunting toddlers using GWR, which stated that the GWR model was better used to model cases of stunting toddlers in Indonesia compared to using the OLS model because spatial diversity is a non-stationary process with varying variance between observation areas with the greater model, which is 67.31%. Therefore, this research aims to examine the distribution of the factors that influence stunting toddlers in Malang and is expected to assist further research in modeling cases of stunting toddlers by considering the area of spatial aspects using GWR, which has not been found in previous studies.

2. METHOD

This research method uses quantitative and qualitative approaches with structured interview data collection techniques by filling out questionnaires and observing objects in the field. This research was conducted in Malang from January to March 2021. The population in this study was housewives or married girls between the ages of 18 to 65 years and toddlers who took part in weighing operations at the integrated healthcare center. Respondents consist of several variables, which are; the respondent's relationship with the head of the family, the respondent's age, the respondent's home status, the respondent's latest education, having the certificate of disability (SKTM) and regional health insurance (JAMKESDA), child ownership, and the member of children grouped by age (<2 years old, 2-5 years old, 6-12 years, and >12 years old). Toddlers who are the object of observation are children aged 24-59 months who have *kartu menuju sehat* (KMS).

The questionnaire was administered to 3,000 people who were randomly selected from 75 districts/villages in 33 districts of Malang. Data on infants with developmental delays were obtained from the results of the 2021 infant weighing operation in the respondent's area and were verified based on residence status and infant medical history. Questionnaire data from respondent interviews were entered into the environmental health risk assessment (EHRA) application in the form of DOSbox 0.74 and EpiData 3.1. The data were then processed using SPSS to obtain different forms of information in the index, tabular, and graphical forms of the health risk areas. The measurement of health risk is expressed in the form of a health risk index, which is defined as the measure or degree of health risk based on the results of an EHRA.

3. RESULTS AND DISCUSSION

The research respondents obtained were the wives of the head of a family of 2,019 people (70.3%), most of the respondents were more than 45 years old, as many as 1.415 people (47.17%), and there were 43 respondents (1.4%) who were less than 20 years old. Toddlers who underwent weighing operations were 36,585 toddlers, for about 5,161 were stunted (7%). The stunting category was obtained from the z-score for TB/U<-2 SD and normal if TB/U≥2 SD. Based on the results of the sanitation risk index (RIS) calculation in Figure 1, it can be seen that the highest risk is in the components of human feces disposal, which shows a value of 66.36. The next highest is the waste component, which shows a value of 51.46. The lowest risk index is for the water source component, which shows a value of 5.5. The relationship between the influence of sanitation risk on the incidence of stunting cases in Malang shows a positive correlation, so with the increasing value of the sanitation risk index, the incidence of stunting has the potential to increase.

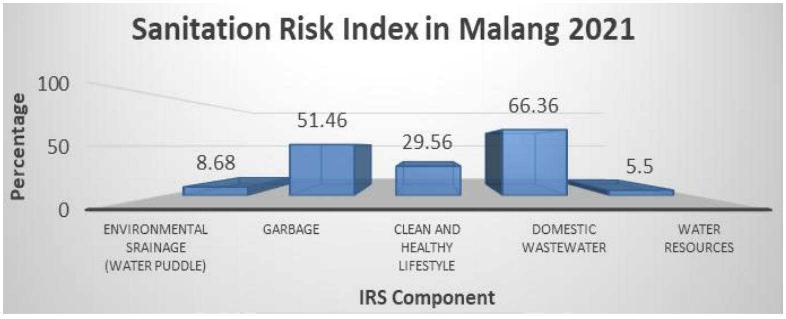


Figure 1. Component diagram of the RIS in Malang 2021

3.1. Analysis of the significant sanitation risk index with the incidence of stunting using the GWR model

The GWR method is an evolution of linear regression in which each parameter is calculated at each location point, such that each geographical point has a different regression parameter value and each observation location has significant local variables. GWR modeling uses fixed Gaussian kernel weights with an optimal bandwidth of 1,8872,555. The bandwidth value indicates that one district/village interacts with another district/village within 18,872 km. The quality of the regression model can be observed in the R^2 values. The R^2 value was larger than that of the comparison model and could better explain the impact of hygiene risks on stunting in Malang. Table 1 shows the linear regression model (ordinary least squares) and the model fit measures generated by the GWR.

Based on Table 1, the comparison of the value criteria and AIC obtained from the two models indicates that the GWR model performs better than the OLS regression model. The GWR model is able to improve the goodness-of-fit value while simultaneously reducing the AIC value. In general, the R^2 value produced by the GWR model is higher than that of the linear regression model (OLS). Specifically, the OLS model yields an R^2 of 32.53%, whereas the GWR model produces an R^2 of 52.25%. This result suggests that the GWR model is more appropriate for modeling the influence of the Sanitation Risk Index on the incidence of stunting among toddlers in Malang. The R^2 value indicates that 52.25% of the variability in stunting incidence can be explained by the Sanitation Risk Index, while the remaining 47.75% is attributed to other factors beyond the variables considered in this study.

To examine the significance of the sanitation risk effect on stunting across different regional groups, a partial test was conducted using the t-test statistic for each parameter in the observation areas (districts/villages). At a significance level of $\alpha = 5\%$, the critical t-value (0.05; 69) is 1.9. The results of the t-test for the significance of sanitation risk grouping on the incidence of stunting in Malang are presented in Figure 2. The significance testing of the GWR model parameters was conducted using the following hypotheses:

$$H0: \beta k\ (ui,vi)= 0$$
$$H1: \beta k(ui,vi) \neq \beta k;\ i=1,2,...,22,\ k=1,2,3 \quad (1)$$

Table 1. Model selection

Model	R^2	AIC
OLS	0.325331	471.594083
GWR	0.522529	463.441509

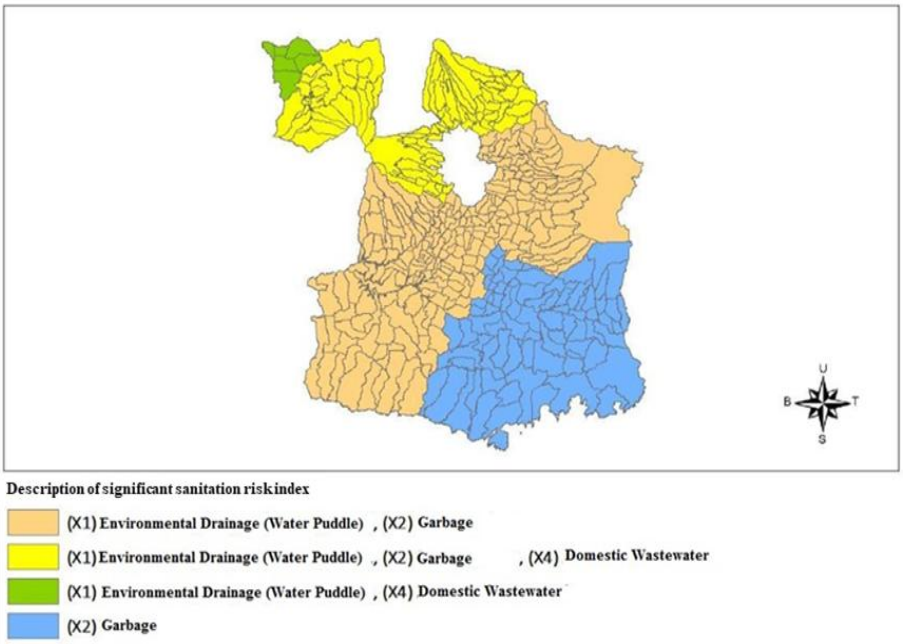


Figure 2. Significant RIS with stunting incidence in Malang

Visualization of geographic information system (GIS) mapping from the t-test of the GWR model parameters in Figure 2 shows that the risk of sanitation, environmental drainage (water puddle) (X1), and solid waste (X2) affects the incidence of stunting in 19 districts or 43 sub-districts of observation. Sanitation environmental drainage (water puddle) (X1), solid waste (X2), and domestic wastewater (X4), which affect 7 districts or 17 sub-districts of observation, sanitation risk environmental drainage (water puddle) (X1) and wastewater domestic (X4) affects 1 district or three sub-districts of observation, and the risk factor for solid waste (X2) affects six districts or 13 sub-districts of observation. The risk factors for a clean and healthy lifestyle (X3) and water resources (X5) have no significant effect in all districts/villages observed.

Judging from the estimated model formed, only one model is produced in linear regression. In contrast, in the GWR model, a model is created for each village that can describe the conditions of cases of stunting under five that occur, so that from the model, significant variables are obtained in each sub-district/village. It is supported by Leonelli and Tempini [14] that GWR results reveal the spatial heterogeneity of the relationship between district-level nutritional status and its drivers is highly location-dependent, varying in direction, magnitude, and intensity across districts.

3.2. Environmental drainage risk factors (water puddle)

Based on the survey results, there are 1,437 respondents (49.37%) who have wastewater sewerage (SPAL) that can flow in an open condition without a cover, as many as 905 respondents (30.17%) have SPAL, but the direction of the flow of the water channel and its estuary is not visible, and 608 respondents (20.27%) did not have SPAL. Drainage channels or SPAL that are not functioning and open are one of the causes of environmental pollution due to the seepage of domestic waste into the ground, and cause diseases, such as diarrhea or diseases caused by animals, such as rats, cockroaches, mosquitoes, or other animals that appear during water inundation for a long time. Domestic waste comes from the bathroom, kitchen, washing water, and other household activities. Domestic wastewater contains not only organic and inorganic pollutants, which can cause water pollution, but also pathogenic microorganisms and parasites, which are very dangerous to human health [15], [16].

Gastrointestinal diseases of unknown etiology and giardiasis are the most common waterborne diseases affecting groundwater and surface water systems [17]. According to on-site observations, most domestic waste is not properly treated before being discharged into the environment, puddles still exist around houses (13.4%), and no drainage ditches can be seen within 10 m of the SPAL and clean water source. It is possible that the channel is cut off so that wastewater seeps into the ground and has the potential to contaminate drinking water sources. The majority of SPAL are rarely cleaned, dirty, and clogged SPAL are found (33.23%). The final disposal of SPAL into infiltration wells adjacent to dug wells, and some are directly disposed of into the rivers that have the potential to contaminate wells and rivers.

Field observations at several locations indicate that the SPAL (wastewater drainage system) has the potential to contaminate the environment due to the mountainous terrain, where pollution sources are located at higher elevations than the water supply. In addition, the incidence of stunting among toddlers is associated with unsafe drinking water sources and the proximity of water sources to waste disposal sites. Environmental contamination from drainage systems may also occur because the walls of SPAL infiltration tanks are not fully watertight, allowing wastewater to seep into the surrounding soil [18], [19]. Furthermore, open SPAL systems can lead to wastewater overflow, resulting in stagnant water around the drainage area. Blocked drainage channels may also serve as breeding sites for disease vectors such as flies, rats, cockroaches, and other pests. A study conducted by Fregonese *et al.* [20] reported that children living in contaminated environments with inadequate sanitation face a 40% risk of stunting, with higher prevalence observed in rural and suburban areas (43% vs 27%) compared to urban areas (5%).

3.3. Waste risk factors

Observation of household waste management practices in Malang shows that 326 respondents (10.87%) stated that waste was collected in a closed, strong, and easy-to-place container, 759 respondents (25.3%) stated that it was collected and disposed of at TPS, and 1,545 respondents (51.5%) stated that it was burned. Other results show that the practice of waste management in the community has not paid attention to environmental health impacts, including 18 respondents (0.6%) throwing garbage into the hole and then filling it with soil, 128 respondents (4.27%) not filling it with soil, 33 respondents (1.1%) throw them into the river, 76 respondents (2.53%) threw the garbage into vacant land and gardens, and eight respondents (0.27%) let the garbage, not at home.

The frequency of garbage collection affects the generation of waste in the environment. The frequency of waste transportation in Malang shows that 438 respondents (15.88%) of garbage is taken every day, 1,090 respondents (39.52%) of waste is picked up several times a week, 275 respondents (9.97%) stated that waste is transported several times a month, and 198 respondents (7.18%) stated that the garbage is taken only once a month. Other observations show that 299 respondents stated that the garbage was never transported, and 1,313 respondents (0.47%) also stated that the collection was not scheduled.

The potential environmental pollution observed in the field is related to waste management issues. Waste collection is not conducted daily, and waste burning is also not performed regularly due to the rainy season and the perception that the accumulated waste volume is insufficient for burning. As a result, piles of household waste around residential areas can increase the density of fly vectors. In general, garbage contains various microorganisms that may lead to digestive infectious diseases in humans, such as diarrhea, environmental enteric dysfunction (EED), and intestinal worm infections. Flies that come into contact with contaminated environments can carry these microorganisms and subsequently transfer them to food and beverages consumed by humans. This contamination may contribute to linear growth disorders, including stunting, among children living in the surrounding environment [18], [21], [22].

A study conducted by Soeracmad [23] reported a relationship between stunting incidence and household waste management. Among respondents who did not implement household waste management, 22 individuals (100%) were included in the stunting case group, while none (0%) were found in the control group. In contrast, among 88 respondents who practiced proper household waste management, 33 individuals (60.0%) were categorized in the stunting case group, and 55 individuals (100%) were included in the control group.

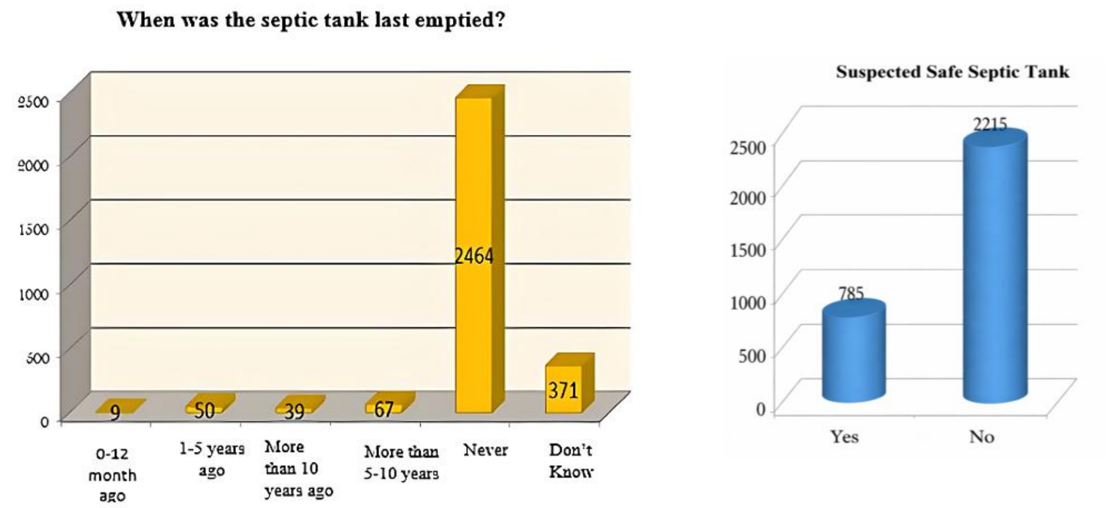
3.4. Domestic wastewater risk factors

Domestic wastewater, which poses a risk of environmental pollution, involves the treatment of human sewage and fecal sludge. Defecation in inadequate facilities may be a factor in increasing public health risks, such as contamination of soil and dietary water sources, and increased transmission of environmental diseases. According to the findings, Malang's domestic waste pollution problems were examined, including the fact that open defecation still exists in the community, fecal storage and treatment facilities are not waterproof, and sources such as the removal of septic tanks near drinking water and septic tanks that have never been emptied. The method of defecation used in this study showed that 2,884 respondents (96.1%) used private toilets, 53 (1.8%) used adjacent toilets, and 38 (1.3%) used rivers. Other results showed that 1,580 respondents (52.7%) used gooseneck toilets with homemade septic tanks, and 785 respondents (26.2%) used gooseneck toilets with Indonesian national standard (SNI) homemade septic tanks. The majority of the respondents, 2,464 (82.1%), had never emptied their septic tanks for more than three years.

Table 2 shows that the septic tank effluent has the potential to cause pollution because the wastewater disposal facility SPAL is declared unsafe, with a percentage of 93.33%. The sewage disposal location from the results of the emptying of the septic tank shows that 73.94% of respondents do not know where the sewage will be disposed of at the fecal waste disposal plant (IPLT). Figure 3 shows the safety from environmental pollution due to the construction of the septic tank used. It was obtained from 2,215 respondents (73.83%) that the construction of the septic tank was suspected to be unsafe, and 785 respondents (26.17%) declared it safe. The construction of an unsafe septic tank is predicted, as the walls are not waterproof, causing seepage of fecal fluid into the ground, and the emptying of the septic tank has never been carried out.

Table 2. Septic tank and SPAL safety

Variable		Total	
		n	%
Suspected safe septic tank	Not safe	2.215	73.83
	Safe	785	26.17
	Total	3.000	100
Pollution due to SPAL	Not safe	154	93.33
	Safe	11	6.67
	Total	165	100



(a) (b)

Figure 3. Analysis of septic tank management and safety: (a) emptying diagram, and (b) septic tank safety diagram

E. coli in groundwater comes from septic tanks and drains near wells and in densely populated areas where on-site sanitation is still used. The use of water containing coliform bacteria can cause diarrhea [19]. In a study by Danaei *et al.* [24], data based on environmental factors (inadequate sanitation and water supply) from 137 developing countries. Statistical test results for these categories showed an OR of 1.37 (95% CI: 1.33-1.41) for inadequate sanitation and an OR of (95%CI: 1.06-1.12) for inadequate sanitation. It means that inadequate sanitation and water pollution are associated with stunting in young children by 1.37 and 1.09 times, respectively. In addition, Rizal and Doorslaer [25] found that households with good sanitation positively contributed to the reduction of stunting and severe stunting in young children in 13 Indonesian provinces between 2007 and 2014. Most of the findings in rural Indonesia were related to toilet facility hygiene, including toilet ownership, toilet type, septic-free toilets, toilet cleanliness, open defecation behavior, and disposal of infant feces outside the toilet. Developmental delays among Indonesian infants are increasingly serious [25]-[28].

Surya and Sharma [29] showed that open defecation was associated with the incidence of stunting among young children in India. This behavior leads to environmental contamination through the spread of pathogenic bacteria in the feces. When a growing child puts their fingers in their mouth and comes into contact with these bacteria, the child can swallow some of the fecal bacteria that can infect the intestines. Intestinal infections in the form of diarrhea and EED can affect children's nutritional status by reducing appetite and impairing nutrient absorption, leading to malnutrition and stunting [29]. The use of unsanitary toilet facilities, open defecation, and disposal of infant feces outside toilets contaminates children, enhances disease transmission through feces, and increases the occurrence of developmental delays in children. According to a Peruvian study, young children's excrement is disposed of in dangerous ways. Diarrhea, intestinal worms, and developmental delays in early children are all increased by improper toileting [30].

4. CONCLUSION

The causes of stunting consist of multiple interacting factors such as water, sanitation, and hygiene. Poor environmental hygiene factors lead to an increase in common diseases such as diarrhea, EED, and helminthiasis/helminth infections. Based on the spatial effect analysis of the GWR model, the health risk factors that significantly affect the incidence of stunting in Malang are environmental drainage (water puddle) (X1), solid waste (X2), and living wastewater (X4). For the risk factors "Clean and healthy lifestyle" (X3) and "Water source" (X5), there may be indirect effects through geographical location and each observation location. To reduce the prevalence of stunting among young children in Malang, sensitive sanitation measures such as integrated solid waste management, improved drainage infrastructure for municipal solid waste disposal, and the construction of public-accessible healthy toilets are required. Education and knowledge on the role of hygiene in health improvement. These activities aim to reduce the frequency of developmental delays in the first 1,000 days of life among young children in Malang, particularly in rural regions, in order to prevent and break the cycle of transmission of environmental diseases.

ACKNOWLEDGEMENTS

The authors would like to thank the Brawijaya University and other parties who have supported this research.

REFERENCES

[1] Dinas Kesehatan Kabupaten Malang, "Laporan pemantauan status gizi balita tahun 2020," Malang, 2020. [Online]. Available: https://dinkes.malangkab.go.id/uploads/dokumen/dinkes-opd-Dinkes LKj Januari - Maret 2021.pdf
[2] R. Amir-ud-Din, S. Fawad, L. Naz, S. Zafar, R. Kumar, and S. Pongpanich, "Nutritional inequalities among under-five children: a geospatial analysis of hotspots and cold spots in 73 low- and middle-income countries," *International Journal for Equity in Health*, vol. 21, no. 1, p. 135, 2022, doi: 10.1186/s12939-022-01733-1.
[3] C. A. Monteiro et al., "Narrowing socioeconomic inequality in child stunting: the Brazilian experience, 1974–2007," *Bulletin of the World Health Organization*, vol. 88, no. 4, pp. 305–311, 2010, doi: 10.2471/BLT.09.069195.
[4] C. W. Schmidt, "Beyond malnutrition: The role of sanitation in stunted growth," *Environmental Health Perspectives*, vol. 122, no. 11, 2014, doi: 10.1289/ehp.122-A298.
[5] M. R. Damanik, I. Ekayanti, and D. Hariyadi, "Analisis pengaruh pendidikan ibu terhadap status gizi balita di provinsi Kalimantan Barat," *Jurnal Gizi dan Pangan*, vol. 5, no. 2, p. 69, 2010, doi: 10.25182/jgp.2010.5.2.69-77.
[6] K. G. Dewey and D. R. Mayers, "Early child growth: how do nutrition and infection interact?," *Maternal & child Nutrition*, vol. 7, pp. 129–142, 2011, doi: 10.1111/j.1740-8709.2011.00357.x.
[7] I. Picauly and S. M. Toy, "Analisis determinan dan pengaruh stunting terhadap prestasi belajar anak sekolah di Kupang dan Sumba Timur, NTT," *Jurnal Gizi dan Pangan*, vol. 8, no. 1, p. 55, 2013, doi: 10.25182/jgp.2013.8.1.55-62.
[8] A. D. Laksono and H. Megatsari, "Determinan balita stunting di Jawa Timur: Analisis data pemantauan status gizi 2017," *Amerta Nutr*, vol. 4, no. 2, p. 109, 2020, doi: 10.20473/amnt.v4i2.2020.109-115.
[9] C. Dewanti, V. Ratnasari, and A. T. Rumiati, "Pemodelan faktor-faktor yang memengaruhi status balita stunting di Provinsi Jawa Timur Menggunakan regresi probit biner," *Jurnal Sains dan Seni ITS*, vol. 8, no. 2, 2020, doi: 10.12962/j23373520.v8i2.48519.
[10] H. Pramoedyo, M. Mudjiono, A. A. Fernandes, D. Ardianti, and K. Septiani, "Determination of stunting risk factors using spatial interpolation geographically weighted regression kriging in Malang," *Jurnal Kedokteran dan Kesehatan*, vol. 20, no. 2, 2020, doi: 10.18196/mm.200250.
[11] A. Y. Kartini and L. N. Ummah, "Pemodelan kejadian balita stunting di Kabupaten Bojonegoro dengan metode geographically weighted regression dan multivariate adaptive regression splines," *Statistika: Jurnal Ilmiah Teori dan Aplikasi Statistika*, vol. 15, no. 1, 2022, doi: 10.36456/jstat.vol15.no1.a5074.
[12] A. Putri and M. Salamah, "Pemodelan kasus balita gizi buruk di kabupaten Bojonegoro dengan geographically weighted regression," *Jurnal Sains dan Seni ITS*, vol. 2, no. 1, 2013, doi: 10.12962/j23373520.v2i1.3203.
[13] F. Cholid, D. Trishnanti, and H. Al Azies, "Pemetaan faktor-faktor yang mempengaruhi stunting pada balita dengan geographically weighted regression (GWR)," *SEMNASKES*, pp. 156-165, 2019, doi: 10.17605/OSF.IO/9MZU7.
[14] S. Leonelli and N. Tempini, *Data journeys in the sciences*, Springer Nature, 2020.
[15] N. Rosliana, "Efektifitas media saring dalam menurunkan kandungan e.coli pada air sungai lamaran Desa Tegalurung Kecamatan Legonkulon Kabupaten Subang," *Jurnal Sehat Masada*, vol. 10, no. 2, 2016.
[16] E. Iloms, O. O. Ololade, H. J. O. Ogola, and R. Selvarajan, "Investigating industrial effluent impact on municipal wastewater treatment plant in Vaal, South Africa," *International Journal of Environmental Research and Public Health*, vol. 17, no. 3, p. 1096, 2020, doi: 10.3390/ijerph17031096.
[17] E. Hoseinzadeh, A. Rostamian, M. Razaghi, and C. Wei, "Waterborne transmission of protozoan parasites: a review of water resources in Iran-An update 2020," *Desalination and Water Treatment*, vol. 213, pp. 91–105, 2021, doi: 10.5004/dwt.2021.26678.
[18] O. Cumming and S. Cairncross, "Can water, sanitation and hygiene help eliminate stunting? Current evidence and policy implications," *Maternal & child nutrition*, vol. 12, pp. 91–105, 2016, doi: 10.1111/mcn.12258.
[19] J. Dodos, B. Mattern, J. Lapegue, M. Altmann, and M. A. Aissa, "Relationship between water, sanitation, hygiene, and nutrition: what do Link NCA nutrition causal analyses say?," *Waterlines*, vol. 36, no. 4, pp. 284–304, 2017, doi: 10.3362/1756-3488.17-00005.
[20] F. Fregonese *et al.*, "Impact of contaminated household environment on stunting in children aged 12–59 months in Burkina Faso," *Epidemiol Community Health*, vol. 71, no. 4, pp. 356–363, 2017, doi: 10.1136/jech-2016-207423.
[21] D. Headey and G. Palloni, "Water, sanitation, and child health: Evidence from subnational panel data in 59 countries," *Demography*, vol. 56, no. 2, pp. 729–752, 2019, doi: 10.1007/s13524-019-00760-y.
[22] C. S. Kwami, S. Godfrey, H. Gavilan, M. Lakhanpaul, and P. Parikh, "Water, sanitation, and hygiene: Linkages with stunting in rural Ethiopia," *International Journal of Environmental Research and Public Health*, vol. 16, no. 20, p. 3793, Oct. 2019, doi: 10.3390/ijerph16203793.

[23] Y. Soeracmad, "Hubungan sanitasi lingkungan rumah tangga dengan kejadian stunting pada anak balita di Puskesmas Wonomulyo Kabupaten Polewali Mandar Tahun 2019," *J-KESMAS: Jurnal Kesehatan Masyarakat*, vol. 5, no. 2, 2019, doi: 10.35329/jkesmas.v5i2.519.
[24] G. Danaei *et al.*, "Risk factors for childhood stunting in 137 developing countries: A comparative risk assessment analysis at global, regional, and country levels," *PLoS Medicine*, vol. 13, no. 11, p. e1002164, Nov. 2016, doi: 10.1371/journal.pmed.1002164.
[25] M. F. Rizal and E. van Doorslaer, "Explaining the fall of socioeconomic inequality in childhood stunting in Indonesia," *SSM-Population Health*, vol. 9, p. 100469, 2019, doi: 10.1016/j.ssmph.2019.100469.
[26] L. Badriyah and A. Syafiq, "The association between sanitation, hygiene, and stunting in children under two-years (An analysis of Indonesia's Basic Health Research, 2013)," *Makara Journal of Health Research*, vol. 21, no. 2, 2017, doi: 10.7454/msk.v21i2.6002.
[27] R. Choirunnisa, T. Indrayani, and F. L. Anshor, "Analysis of factors related to stunting in toddlers aged 25-59 months in Puspasari Village, Puspahiyang, Tasikmalaya 2019," *STRADA: Jurnal Ilmiah Kesehatan*, vol. 9, no. 1, pp. 177–182, 2020, doi: 10.30994/sjik.v9i1.279.
[28] H. Herawati, A. Anwar, and D. L. Setyowati, "Hubungan sarana sanitasi, perilaku penghuni, dan kebiasaan cuci tangan pakai sabun (CTPS) oleh ibu dengan kejadian pendek (stunting) pada batita usia 6-24 bulan di Wilayah Kerja Puskesmas Harapan Baru, Samarinda," *Jurnal Kesehatan Lingkungan Indonesia*, vol. 19, no. 1, p. 7, Apr. 2020, doi: 10.14710/jkli.19.1.7-15.
[29] S. A. V. and R. Sharma, "Understanding the impact of open defaecation on child diarrhoea and nutrition indicators," *Journal of Health Management*, vol. 21, no. 4, pp. 487–496, 2019, doi: 10.1177/0972063419884446.
[30] J. Brown, S. Cairncross, and J. H. J. Ensink, "Water, sanitation, hygiene and enteric infections in children," *Archives of Disease in Childhood*, vol. 98, no. 8, pp. 629–634, 2013, doi: 10.1136/archdischild-2011-301528.

BIOGRAPHIES OF AUTHORS

Muhammad Anismuslim is an administrator of associate health at healthcare office of Malang. He was studying environmental science at Brawijaya University. He is a researcher. He published the articles in national and international journals. He can be contacted at email: aakken777@gmail.com.

Henny Pramoedyo is a full professor of the Department of Statistics at Brawijaya University. He has published fourteen peer-reviewed scientific articles in major journals about statistics. In addition, he published a textbook. One of his rewards is Grants for UB professor research from Universitas Brawijaya 2019. He also joined several community development programs, such as Utilization of Spatial Analysis with ArcGIS Approach for Beginners Mapping Analysis Users in East Java, and REML method training using Genstat for researchers in the Research Institute for Citrus and Subtropic Fruits. He can be contacted at email: pramoedyohp@yahoo.com.

Sri Andarini is a director of Universitas Brawijaya Hospital Employment. She is also a lecturer of public health at Brawijaya University. She is also a researcher and writer. She published her articles in many national and international journals. She can be contacted at email: sriandarini@yahoo.com.

Sudarto is an assistant professor of the agrotechnology department at Brawijaya University. He is a researcher and writer. He has several skills, such as soil, water conservation, and land degradation. He can be contacted at email: sdt-fp@ub.ac.id.