ORIGINAL ARTICLE

Distribution Pattern of Stunting Toddlers with Environmental Health Quality in The Pesawaran Regency

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ABSTRACT

Introduction: Stunting remains a major public health problem in Indonesia with long-term impacts on human capital development. However, spatial evidence at the district level is still limited. This study aims to analyze the spatial distribution of stunted children under five and its association with environmental health determinants in Pesawaran Regency. **Methods:** This study employed an observational design with a spatial approach. Primary data consisted of the geographic coordinates of stunted children under five, collected through field surveys using a Global Positioning System (GPS) in Pesawaran Regency in 2024. Secondary data included stunting prevalence and environmental health determinants, namely access to clean water, ownership of improved sanitation facilities, household waste management, and environmental health behaviors, obtained from primary health centers and the Pesawaran Regency Health Office. Administrative boundary maps were obtained from official government sources. Spatial analyses were conducted using QGIS software, including the Average Nearest Neighbor method. **Results:** The spatial analysis revealed that stunting among children under five in Pesawaran Regency was not randomly distributed but formed statistically significant clusters. Average Nearest Neighbor analysis indicated strong spatial clustering ($p < 0.05$), particularly in several sub-districts. Areas with limited access to clean water, low coverage of improved sanitation, inadequate household waste management, and poor environmental health behaviors showed higher concentrations of stunting cases, highlighting the critical role of environmental health determinants. **Conclusion:** Stunting in Pesawaran Regency clusters spatially and is associated with inadequate water access, sanitation, waste management, and environmental health behaviors, underscoring the need for interventions.
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INTRODUCTION

Stunting remains a serious global public health challenge due to its impacts on child survival, cognitive development, and the quality of future human capital (1). According to the UNICEF–WHO–World Bank Joint Malnutrition Estimates (JME), the prevalence of stunting among children under five years of age declined from 40.2% in 1990 to 22.3% in 2022. Despite this decline, approximately 148.1 million children worldwide were still affected by stunting in 2022, highlighting the persistent challenge of chronic undernutrition. Both the absolute number of affected children and the prevalence of stunting remain important indicators for assessing progress toward the Sustainable Development Goals (SDGs), particularly SDG 2 (Zero Hunger) and SDG 3 (Good Health and Well-being) (2,3). At the national level, Indonesia continues to face a substantial stunting burden, with the goal of reducing the national stunting prevalence to 14.2% by 2029. National reports and data indicate that stunting is not solely the result of inadequate nutritional intake but is also influenced by environmental health determinants, including access to safe drinking water, household sanitation, waste management, and hygiene practices. The relationship between WASH (Water, Sanitation, and Hygiene) conditions and children's linear growth has become a major focus of both international and national research, as inadequate WASH increases the risk of recurrent infections and intestinal disorders that impair nutrient absorption. This relationship is also reflected in Indonesia's nutrition programs and stunting reduction policies (4).

At the local level, Pesawaran Regency (Lampung Province) exhibits spatial variation in stunting prevalence across sub-districts and villages. In 2022, the stunting prevalence in Pesawaran Regency reached 25.1%, representing a significant increase of 17.6%

compared to 2021. Of the 847 children under five recorded, 584 were identified as experiencing stunting (5). Spatial disparities in sanitation coverage, access to clean water, and household hygiene behaviors have the potential to generate observable clusters of stunting cases in certain areas (6). Despite this, evidence from studies that integrate spatial analyses of stunting distribution with environmental health quality indicators at the district level is still scarce (7), Therefore, spatial mapping of stunting distribution and environmental health determinants at the district level in Pesawaran Regency is essential for formulating more focused and context-specific interventions, as well as for supporting the acceleration of stunting reduction in line with national targets and the commitments of the Sustainable Development Goals (SDGs).

Wolf et al. (2023) reported that inadequate environmental health conditions, especially unsafe drinking water sanitation in low-income communities, were associated with a higher incidence of stunting (8). The consequences of poor sanitation, including limited access to clean water, inadequate waste disposal facilities, and improper solid waste management, are closely associated with an increased risk of stunting in children (9). Children living in households with poor sanitation have a 0.6-fold higher risk of stunting compared to those with adequate sanitation (10). Several studies have identified a strong correlation between basic sanitation facilities and the occurrence of stunting (11). In addition, poor personal hygiene practices, including handwashing habits and inadequate skin, hand, and nail hygiene, also contribute to an increased risk of stunting (12). Overall, poor environmental sanitation and inadequate personal hygiene can increase the risk of infectious diseases among children, which in turn may lead to chronic undernutrition and stunting (4). Therefore, improving environmental sanitation and personal hygiene practices is crucial for reducing the prevalence of stunting among children (13).

This study aims to describe the spatial distribution patterns of stunted children under five in Pesawaran Regency and to examine the spatial associations between stunting occurrence and environmental health quality indicators, including access to clean water, coverage of improved sanitation facilities, and household waste management. The findings are expected to provide spatial evidence to support the planning of environmental health programs and nutrition-sensitive interventions targeted at high-risk areas.

MATERIALS AND METHODS

Research Design

This study employed an analytical observational design with a spatial approach. The analysis was conducted to examine the distribution patterns of stunted children under five and the association between stunting occurrence and environmental health quality determinants in Pesawaran Regency, Lampung Province, Indonesia. The regency consists of 11 sub-districts with diverse geographic characteristics, sanitation conditions, and access to clean water, making it suitable for both spatial and statistical analyses (14).

Data Collection

Primary data, in the form of the geographic coordinates of stunted children, were collected through field surveys by trained enumerators using Global Positioning System (GPS) devices. Stunting status was determined based on nutrition program records from community health centers (Puskesmas), in accordance with national anthropometric standards. Secondary data included environmental health determinants, namely improved sanitation facility coverage, access to clean water, household waste management, and environmental health behaviors, obtained from routine reports from community health centers and the Pesawaran Regency Health Office. Administrative maps of Pesawaran Regency (sub-district and village boundaries) were obtained from official government sources, including the Geospatial Information Agency (BPA) and the Central Statistics Agency (BPS), in shapefile format for spatial analysis purposes. Inclusion criteria required that the residential address of each stunted child be identified and geolocated within that household or residence (14). Primary data consisted of the geographic coordinates of stunted children under five, collected through field surveys by trained enumerators using Global Positioning System (GPS) devices. Stunting status was determined based on nutrition program records from primary health centers, in accordance with national anthropometric standards. Secondary data included environmental health determinants, namely coverage of improved sanitation facilities, access to clean water, household waste management, and environmental health behaviors, obtained from routine reports of primary health centers and the Pesawaran Regency Health Office. Administrative maps of Pesawaran Regency (sub-district and village boundaries) were obtained from official government sources, including the Geospatial Information Agency (GIA) and Statistics Indonesia (BPS), in shapefile format for spatial analysis purposes. The inclusion criterion required that the residential address of each stunted child could be identified and geolocated at the household or place of residence.

Data Processing

Spatial analyses were conducted using QGIS software. The distribution pattern of stunted children under five was analyzed using the Average Nearest Neighbor method to determine whether the spatial distribution was clustered, random, or dispersed. Parameters assessed included the nearest neighbor ratio, z-score, and p-value to evaluate the statistical significance of the observed spatial patterns (15).

The results of the analysis were visualized using thematic maps illustrating the spatial distribution of stunted children under five, the locations of health service facilities, and overlays with environmental health determinant indicators. In addition, maps generated from the Average Nearest Neighbor analysis were used to quantitatively and visually demonstrate spatial clustering patterns (16). This approach is consistent with recommendations from international studies that emphasize the need to combine spatial analysis in area-based public health research.

Ethical Approval

This study received ethical approval from the Health Research Ethics Committee of the Faculty of Medicine, University of Lampung, under approval number 4073/UN26.18/PP.05.02.00/2024.

RESULTS

Pesawaran Regency in Lampung covers an area of 1,173.86 km and comprises 11 sub-districts, 148 villages, and three islands. Its tropical climate, suboptimal sanitation conditions, and limited access to clean water increase health risks, particularly among children under five. Figure 1 illustrates the spatial distribution of stunted children under five in 2024, mapped by sub-districts and the locations of primary health centers. Primary health centers in areas with high stunting prevalence play a key role in delivering environmental health services. This finding highlights the critical role of primary health centers in addressing health and environmental factors contributing to stunting. However, several areas with high concentrations of stunted children are located far from primary health centers, indicating a need to strengthen access to health services, including improving environmental health coverage in these areas.

Figure 1 illustrates the spatial distribution pattern of stunted children under five in Pesawaran Regency, forming clusters in the sub-districts of Kedondong, Way Lima, Gedong Tataan, Teluk Pandan, and Punduh Pedada. Figure 2 presents the Average Nearest Neighbor analysis, including parameters such as observed and expected distances, nearest neighbor ratio, z-score, and p-value. This analysis helps assess the statistical significance of spatial clustering patterns and provides insights for targeted intervention planning (17).

Figure 2 presents the Average Nearest Neighbor analysis of the spatial distribution of stunted children under five in Pesawaran Regency. The observed mean distance was 428,840 m, while the expected mean distance was 1,493,508 m, resulting in a nearest neighbor ratio of 0.287136. Because the ratio was less than 1, the distribution pattern indicates spatial clustering. A p-value of 0.001 confirms strong statistical significance ($\alpha < 0.05$), indicating that the observed clustering is unlikely to have occurred by chance (18). The analyzed area covered 4,077.47 km , and the observed clustering suggests that factors such as limited access to sanitation contribute to the concentration of stunting cases in specific areas (19).

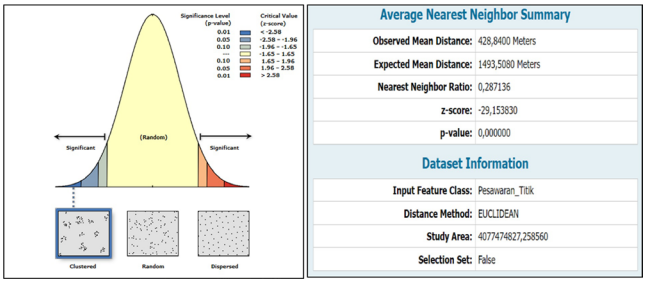

Figure 2: Results of the Average Nearest Neighbor analysis in Pesawaran Regency, 2024

Figure 3 illustrates the distribution of stunting among children under five in relation to community behaviors toward environmental health. These conditions highlight issues related to waste disposal, water use, and sanitation practices that may influence children's nutritional intake. Areas characterized by poor

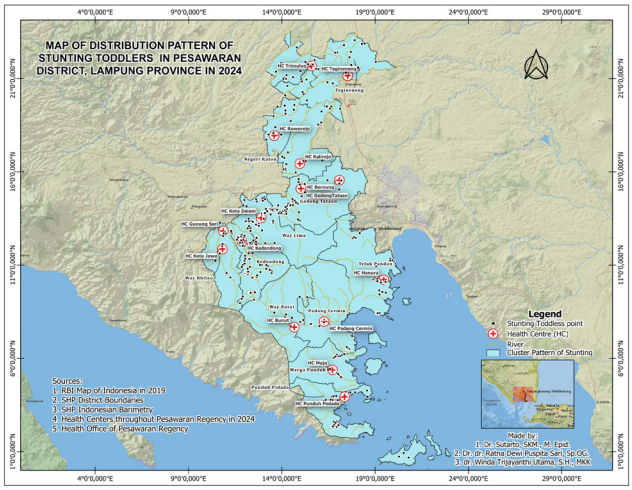

Figure 1: Spatial distribution map of stunted children under five and primary health centers.

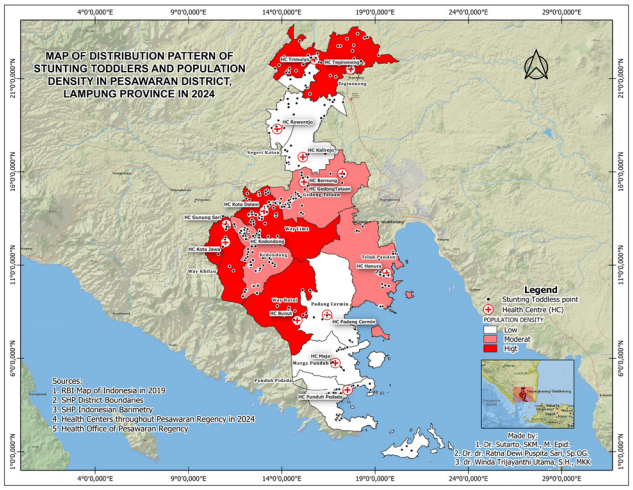

Figure 3: Spatial distribution map of stunted children under five according to population density at the sub-district level.

environmental health behaviors tend to exhibit higher stunting prevalence (20) indicating a strong contextual influence of environmental health on child growth.

Figure 4 highlights the role of community environmental health behaviors in stunting prevention. In sub-districts such as Way Ratai and Way Lima, positive hygiene practices are associated with lower stunting prevalence. In contrast, areas such as Negeri Katon and Padang Cermin, characterized by poor environmental health behaviors, exhibit higher stunting incidence. Even with adequate nutritional intake, exposure to unclean and unhealthy environments may result in nutrient loss through infectious diseases, ultimately leading to stunting. Consequently, behavioral change at the community level is a central component of environmental-based stunting prevention (21)

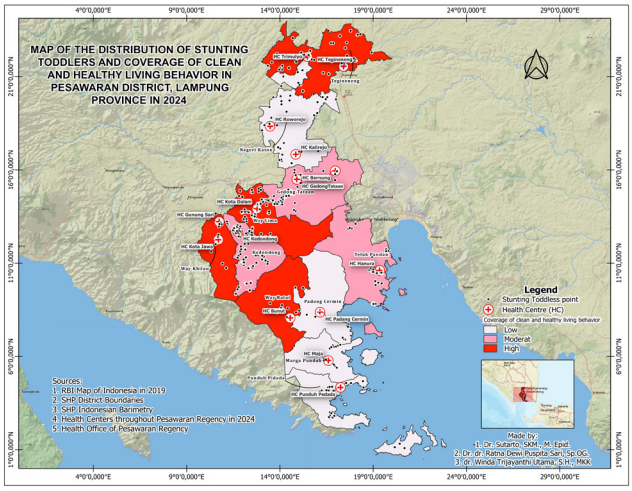

Figure 4: Map of stunted children under five and community environmental health behaviors.

Figure 5 highlights that household-level coverage of improved sanitation facilities strongly influences the health and nutritional status of children under five. Most sub-districts exhibit low sanitation coverage, except for Marga Punduh, which shows a high level of coverage. Poor sanitation increases the risk of infection, thereby contributing to stunting. Negeri Katon, despite having moderate sanitation coverage, continues to face challenges in improving child nutritional status, indicating that sanitation access alone may not be sufficient. Poor environmental health, particularly the lack of improved sanitation facilities, directly contributes to the occurrence of stunting through recurrent infections such as diarrhea and helminth infections (21). Environments without adequate sanitation increase exposure to pathogenic bacteria that damage the intestinal tract of young children, leading to malabsorption and impaired growth (22).

Figure 6 demonstrates that access to clean water affects the nutritional status of children under five. Sub-districts with low clean water coverage face an increased risk of infection, which impairs nutrient absorption and contributes to stunting. Marga Punduh, with high

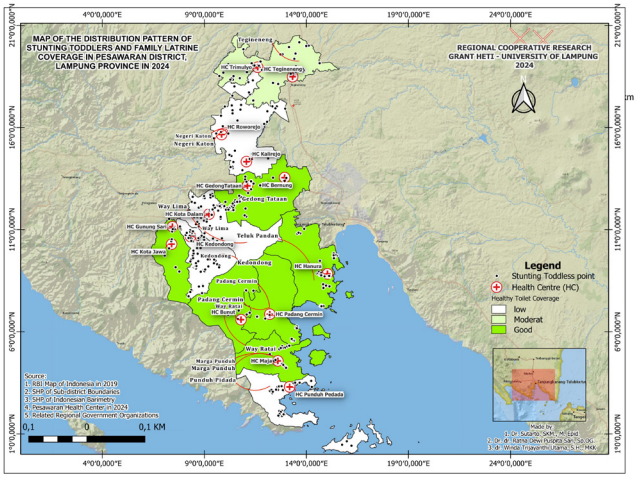

Figure 5: Map of improved sanitation (healthy toilet) coverage among households with stunted children under five.

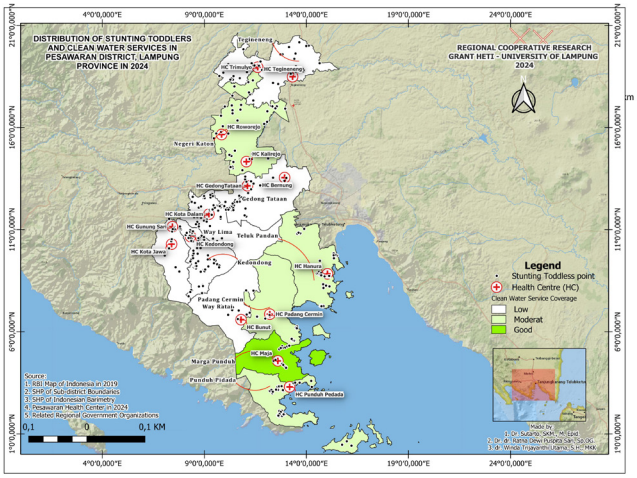

Figure 6: Map of the distribution of stunted children under five by clean water access coverage.

clean water access, exhibits lower stunting prevalence. However, Negeri Katon indicates that other factors, such as water treatment practices and socio-economic context, also influence stunting outcomes (23).

Figure 7 illustrates the impact of household waste management on public health and the distribution of stunting among children under five. Sub-districts with low waste management coverage, such as Way Lima and Tegineneng, exhibit high stunting prevalence. Poor waste management increases the risk of infection, undernutrition, and stunting. However, sub-districts with relatively good waste management still experience high stunting rates, indicating that other factors, particularly nutritional access and healthcare services, also play an important role (24) Children under five living in households with inadequate access to clean water have a higher likelihood of experiencing stunting compared to those with adequate clean water access. Similarly, low ownership of improved sanitation facilities and substandard household waste management are significantly associated with an increased risk of stunting (25).

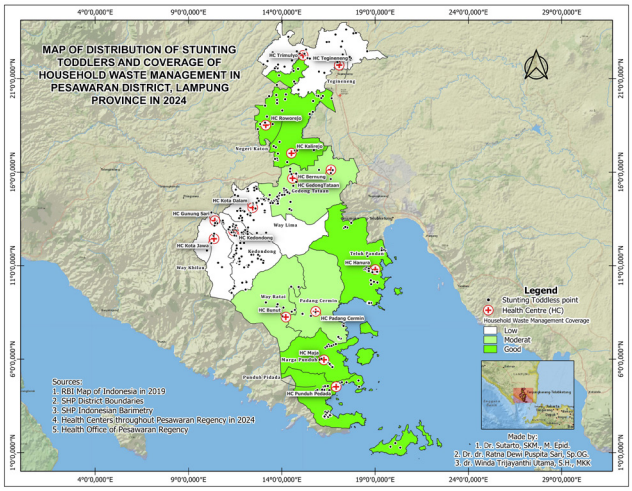

Figure 7: Map of the distribution of stunted children under five in relation to household waste management.

Community environmental health behaviors also showed a statistically significant association with stunting occurrence. Areas characterized by poor environmental hygiene behaviors tended to have a higher proportion of stunted children under five. The regression analysis confirmed the spatial findings obtained from mapping and overlay analyses, thereby strengthening the evidence that environmental health determinants play a critical role in the formation of stunting clusters in Pesawaran Regency.

DISCUSSION

This study demonstrates that the occurrence of stunting among children under five in Pesawaran Regency is not randomly distributed but instead forms statistically significant spatial clusters. This pattern indicates the presence of structural and environmental determinants that jointly influence child nutritional status. The integration of spatial analysis in this study provides stronger evidence than descriptive visual approaches alone.

Geographically, the highest concentration of stunting among children under five was observed in several areas, particularly in the central and northern parts of the regency (26). High concentrations were found near coastal and riverine areas, which provide access to clean drinking water, support agriculture, and offer nutritious food sources such as fish, thereby improving nutritional status and helping to combat stunting (27). Rivers provide essential benefits such as water supply, soil enrichment, and biodiversity; however, they also face challenges including pollution and overexploitation, which reduce water flow, adversely affect agriculture and ecosystems, and increase the risk of stunting (28). Primary health centers should strengthen health services by providing health information to mothers of children under five through health promotion activities and education on environmental sanitation, in order to ensure that living environments meet health standards (4).

Adequate sanitation and access to safe drinking water play a crucial role in preventing stunting. A study found a significant association between drinking water facilities and the occurrence of stunting. In addition, substandard household sanitation is strongly associated with stunting among children under five (29). Studies have shown a strong association between high population density and stunting, as densely populated areas often struggle to provide adequate healthcare services, sanitation, and access to nutritious food. (30). High population density can place pressure on available resources, such as clean water and healthcare services, which are essential for the prevention and management of stunting (31). Economic factors also play a significant role. In densely populated areas, higher levels of poverty are often present, which affect families' ability to provide adequate and nutritious food for their children. Furthermore, limited nutritional knowledge and poor environmental hygiene exacerbate the situation, resulting in a higher risk of stunting (32). The findings underscore the importance of targeted governmental and public health interventions in densely populated areas, emphasizing improvements in healthcare provision, nutrition education, and poverty reduction as strategies to mitigate stunting.

Areas characterized by poor environmental behaviors, limited access to clean water, inadequate sanitation, and open defecation practices increase the risk of chronic infections—such as diarrhea and helminth infections—among children under five. These recurrent illnesses impair nutrient absorption, even when children's dietary intake is adequate (29). Households in high-risk areas often demonstrate poor clean and healthy living behaviors (PHBS), which are positively associated with higher stunting prevalence. Stunting is shaped not only by individual and household-level factors but also by contextual factors such as living environment, housing density, environmental pollution, and access to health services (33). Low socioeconomic areas are frequently associated with suboptimal environmental health behaviors and insufficient resources to develop improved sanitation, thereby contributing to elevated stunting prevalence.

Population-level behaviors play a critical role in determining environmental health and influencing the distribution patterns of stunting among children under five. Poor sanitation, restricted access to clean water, and suboptimal nutritional practices contribute to unhealthy living environments (34). Studies indicate that children under five living in areas with poor sanitation behaviors and low levels of health education tend to experience higher stunting prevalence. This is primarily due to recurrent infections resulting from unhygienic environments, which weaken immune function and disrupt children's growth and development (35). Overall, the association between environmental health and the

spatial distribution of stunting highlights the critical role of household-level healthy behaviors as a mitigation strategy to improve child health and nutritional status (35).

Behavior change–oriented interventions, particularly health education on sanitation, hygiene, and nutrition, have the potential to improve environmental health conditions and reduce stunting in young children (36). Evidence suggests that improved health awareness encourages better hygiene, food preparation, and breastfeeding practices. A clear understanding of the linkage between behavioral factors and environmental health is essential for designing effective policies and interventions to reduce stunting (37). The use of improved sanitation facilities is essential for minimizing disease risk and fostering environments conducive to healthy child development. Observed inter-sub-district disparities highlight the necessity of integrated sanitation and public health interventions (38). Expanding access to improved sanitation in sub-districts with low coverage, supported by sustained monitoring and community-based interventions, is critical for reducing stunting and promoting optimal child growth in future generations (39).

The significant association between access to clean water and stunting occurrence underscores the critical role of a healthy environment in child growth. Inadequate access to safe drinking water increases the risk of gastrointestinal infections and recurrent diarrheal diseases, which ultimately impair nutrient absorption and linear growth in children (40). This finding aligns with international evidence indicating that WASH-related factors contribute to stunting via chronic infections and intestinal dysfunction.

The analysis of the relationship between clean water use coverage and the spatial distribution of stunting among children under five also highlights the need for a multidisciplinary approach in public health research (19). The availability of clean water is not only a component of the broader environmental health system, which also encompasses factors such as sanitation, hygiene, and community health education (9). Although Punduh Pedada exhibits a relatively better stunting profile, in-depth analysis of underlying socioeconomic factors remains necessary. Evidence from other studies has similarly associated inadequate household sanitation with increased stunting incidence in Balangan Regency (29). Similarly, in Ogan Ilir Regency, the quality of clean water, wastewater drainage systems, and sanitation facilities has been found to be significantly associated with stunting incidence (41). Stunting in South Lampung Regency exhibits a clustered pattern, particularly in the Kalianda area, which is influenced by the shared use of unsafe water sources (42). Similarly, in India, geographic clustering of stunting has been consistently observed across several states, with improved sanitation facilities showing a significant association with reduced stunting (43).

Moderate levels of household waste management in Gedong Tataan, Way Lima, and Padang Cermin sub-districts do not necessarily correspond to improved stunting patterns, highlighting the complex relationships among waste management, nutrition, and the social and environmental factors influencing child health (44). Improving sanitation facilities and enhancing community knowledge about sanitation are important interventions for preventing stunting. Recommended actions include expanding access to improved latrines, strengthening sanitation education, and optimizing the role of community leaders in health initiatives (45). Thus, effective sanitation services provided by primary health centers can contribute significantly to stunting prevention efforts within communities. Strengthening sanitation services delivered by primary health centers may play an important role in reducing stunting prevalence (46). Children living in households with inadequate sanitation have a 0.645-fold higher risk of stunting compared to those living in households with adequate sanitation (47). Sanitation-related factors associated with stunting include unhygienic latrines, inadequate wastewater disposal, and substandard waste management (29). Spatial analyses and epidemiological studies have shown that stunting tends to be geographically concentrated and is strongly correlated with poor environmental sanitation conditions (48).

Improved sanitation ownership and proper household waste management are significantly associated with lower stunting risk, as inadequate sanitation promotes infectious diseases that hinder nutrient absorption. Poor sanitation increases the risk of disease transmission among children and contributes to stunting (49). Although some areas exhibit relatively adequate sanitation conditions, stunting remains prevalent, indicating the influence of other factors such as hygiene practices, socioeconomic conditions, and access to healthcare services. The analysis demonstrates that environmental factors identified through spatial mapping are also statistically significant. However, this study has limitations, including the use of a cross-sectional design and a limited set of variables; therefore, further research employing longitudinal designs and more comprehensive variables is required. The use of improved sanitation facilities that meet health standards, such as watertight septic tanks located at a safe distance from water sources, represents a crucial nutrition-sensitive intervention for stunting prevention (50).

The cross-sectional design of this study limits the ability to draw causal inferences between environmental health determinants and stunting occurrence; therefore, the observed relationships should be interpreted as associative rather than causal. Some environmental health variables were derived from aggregated area-

level data, which may introduce ecological fallacy when interpreted at the individual level. In addition, this study did not include all relevant socioeconomic and biological factors that may influence stunting. The spatial analysis was limited to the Average Nearest Neighbor method and did not incorporate more advanced spatial modeling techniques.

CONCLUSION

This study concludes that stunting among children under five in Pesawaran Regency is not randomly distributed but forms statistically significant spatial clusters. These patterns indicate that environmental health determinants, particularly access to clean water, ownership of improved sanitation facilities, household waste management, and community environmental health behaviors, play an important role in shaping the spatial distribution of stunting.

The integration of spatial analysis and statistical modeling provides stronger evidence than descriptive mapping alone and demonstrates that environmental health factors are significantly associated with stunting occurrence. Areas with inadequate sanitation, unsafe water access, poor waste management, and suboptimal hygiene behaviors tend to experience higher stunting prevalence, largely through pathways involving recurrent infections and impaired nutrient absorption.

These findings highlight the need for targeted, area-based interventions that combine nutrition-sensitive approaches with improvements in water, sanitation, hygiene, and community behavior change. Strengthening sanitation services, expanding access to safe drinking water and improved latrines, and enhancing health education through primary health centers are critical strategies for accelerating stunting reduction. Such integrated and context-specific interventions are essential to support national stunting reduction targets and the achievement of the Sustainable Development Goals.

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