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Determining Stunting Risk Areas Using a Combined AHP-GIS approach: A Case Study of Pesawaran Regency, Lampung, Indonesia

Prayudhy Yushananta[1*], Mei Ahyanti[1]

[1] Department of Environmental Health, Politeknik Kesehatan Tanjung Karang, Lampung, Indonesia

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A B S T R A C T

Considering the highly detrimental future impacts of stunting, a risk map is needed. It will serve as a basis to design stunting control strategies. This study aims to determine stunting risk areas by combining the Analytical Hierarchy Process (AHP) and Geographic Information System (GIS). This study used ecological design, with a case being studied was Pesawaran Regency, Lampung Province. All secondary data were aggregate, and used sub-districts as spatial boundaries. Study variables comprised access to safe drinking water, healthy sanitation, exclusive breastfeeding, complete immunization, diarrhea, number of health facilities, fourth visit during pregnancy (ANC-K4), and child growth and development monitoring. The map was developed by employing Weighted Sum Overlay (WSO) technique. Determining weights involving multiple criteria was conducted by using AHP. The AHP yielded weighted values for each variable, namely exclusive breastfeeding (22.9%), ANC-K4 (14.4%), monitoring of child growth and development (11.7%), access to safe drinking water (11.0%), diarrhea (10.8%), number of health facilities (10.1%), complete basic immunization (10.1%), and healthy sanitation (9.0%). WSO technique revealed that three out of eleven sub-districts were included in the high-risk category for stunting (Tegineneng, Kedondong, and Padang Cermin). Meanwhile, the remaining areas were included in the medium category (Way Khilau, Marga Punduh, and Punduh Pedada) and low category (Negara Katon, Gedong Tataan, Way Lima, Way Ratai, and Teluk Pandan). GIS and AHP methods were applied to determine stunting risk areas. Areas with a high risk of stunting category are Tegineneng, Kedondong, and Padang Cermin. Suggested fundamental programs to control stunting are improvement in exclusive breastfeeding, ANC-K4 visit, monitoring of children growth and development, access to drinking water, and prevention of diarrhea.

Mengingat dampak masa depan yang sangat merugikan, diperlukan peta risiko stunting yang dapat dijadikan dasar dalam penyusunan strategi pengendalian. Penelitian bertujuan untuk menentukan daerah risiko stunting dengan menggabungkan metode *AHP* dan *GIS*. Penelitian menggunakan rancangan *ecological study*, dengan studi kasus di wilayah Kabupaten Pesawaran, Provinsi Lampung. Keseluruhan data sekunder bersifat agregat, dan menggunakan kecamatan sebagai batas spatial. Variabel yang diteliti adalah akses air minum aman, akses sanitasi layak, pemberian ASI eksklusif, imunisasi lengkap, diare, jumlah fasilitas kesehatan, kunjungan keempat pada masa kehamilan (ANC-K4), dan pemantauan tumbuh kembang anak. Pengembangan peta menggunakan teknik *Weighted Sum Overlay (WSO).* Sedangkan penentuan bobot yang melibatkan multi kriteria dapat dilakukan dengan metode *AHP*. Hasil AHP mendapatkan nilai bobot pada setiap variabel, yaitu pemberian ASI eksklusif (22,9%), ANC-K4 (14,4%), pemantauan tumbuh kembang balita (11,7%), akses air minum aman (11,0%), diare (10,8%), jumlah fasilitas pelayanan kesehatan (10,1%), imunisasi dasar lengkap (10,1%), dan jamban sehat (9,0%). Berdasarkan teknik *Weighted Sum Overlay*, diperoleh tiga dari sebelas kecamatan masuk dalam kategori risiko tinggi stunting (Tegineneng, Kedondong, dan Padang Cermin). Sedangkan sisanya masuk dalam kategori sedang (Way Khilau, Marga Punduh, dan Punduh Pedada) dan rendah (Negeri Katon, Gedong Tataan, Way Lima, Way Ratai, dan Teluk Pandang). Metoda AHP dan GIS telah diterapkan untuk menetapkan daerah risiko stunting. Hasilnya, tiga dari sebelas kecamatan di Kabupaten Pesawaran masuk dalam kategori risiko tinggi stunting, yaitu Tegineneng, Kedondong, dan Padang Cermin. Peningkatan pemberian ASI eksklusif, ANC-K4, pemantauan tumbuh kembang balita, meningkatkan akses air minum, serta mencegah diare menjadi program utama untuk pengendalian stunting.

* Corresponding author: Prayudhy Yushananta
Department of Environmental Health, Politeknik Kesehatan Tanjung Karang, Lampung, Indonesia
Email: prayudhyyushananta@gmail.com

1. Introduction

Stunting remains a critical public health problem in Indonesia, given its significant adverse effects in the future. Stunting deteriorates cognitive and physical development, increases child morbidity and mortality, and increases the risk of obesity, coronary heart disease, hypertension, and decreases productivity (Adedeji et al., 2017; He et al., 2018; Hidayah et al., 2019; Widyaningsih et al., 2018; Yushananta & Ahyanti, 2022). Recently, the prevalence of stunting in Indonesia ranks 27th out of 154 countries and 5th among countries in Asia (WHO, 2023)..

Based on Indonesian Nutritional Status Study, prevalence of stunting in Indonesia decreased from 24.4% (2021) to 21.6% (2022). The trend was also observed in Lampung Province, from 18.5% (2021) to 15.2% (2022) (Ministry of Health Republic Indonesia, 2022a). However, Yushananta et al. (2023), reported that three districts in Lampung exceeded national average prevalence, namely Pesawaran (25.1%), North Lampung (24.7%), and Mesuji (22.5%). This condition greatly exceeds beyond target of 14.0% in 2024 (Ministry of Health Republic Indonesia, 2022b).

Stunting is a chronic nutritional problem often associated with morbidity, infectious diseases, and environmental health problems (He et al., 2018; Semba et al., 2008; Yushananta & Ahyanti, 2022). It is also associated with socioeconomic inequality, geographical differences, suboptimal feeding practices, food availability, education, childhood morbidity, and health services (Adedeji et al., 2017; Anwar et al., 2020; He et al., 2018; Hidayah et al., 2019; Indah Nurdin et al., 2019; Widyaningsih et al., 2018; Yushananta et al., 2023; Yushananta & Ahyanti, 2022). However, control of stunting has not been thoroughly carried out based on evidence and facts. As a result, disparity in the incidence rate based on region is observed (Eryando et al., 2022).

According to Development Initiatives Poverty Research (2018), stunting control must be strategic, focused, and targeted based on its determinants. Therefore, determining risk areas is the first essential step in planning its control (Eryando et al., 2022; Pfeiffer et al., 2008; WHO, 2023). However, to date, no stunting risk map is available, which is fundamental as a basis for formulating a control strategy.

Geographical Information Systems (GIS) uses Weighted Sum Overlay (WSO) technique to determine susceptible areas because it can provide accurate and visually informative maps that incorporate multiple criteria (Aykut, 2021, 2021; Baite et al., 2024; Basharat et al., 2016; Ding et al., 2018; Sahin et al., 2020). Meanwhile, determining the relative importance or weight of each criterion in research with multiple criteria can be addressed effectively using the Analytical Hierarchy Process (AHP) method. AHP widely recognized for its suitability in multi-criteria decision-making, particularly in complex problems involving both quantitative and qualitative factors (Aykut, 2021; T. L. Saaty, 2008). Therefore, this study aims to determine stunting risk areas in Pesawaran Regency, Lampung, Indonesia by applying a combined AHP-GIS approach.

2. Methods

This study employed an ecological design based on aggregate data at the sub-district level in Pesawaran Regency. Data were obtained from the 2024 Pesawaran Regency Health Profile, Pesawaran Regency People's Welfare Statistics 2024, and Pesawaran Regency in Figures 2024 reports. The unit of analysis comprised all 11 sub-districts in Pesawaran Regency (Figure 1).

The study adopted the UNICEF conceptual framework (Leroy & Frongillo, 2019; World Health Organization, 2013), which was adjusted to the data availability. The selected indicators inluded: 1) percentage of households with access to clean drinking water, 2) percentage of households with access to clean sanitation, 3) percentage of toddlers receiving breast milk for at least six months, 4) percentage of toddlers receiving complete immunization, 5) percentage of toddlers suffering from diarrhea, 6) percentage of toddlers monitored for growth and development, 7) percentage of fourth antenatal care visits (ANC-K4), and 8) number of health facilities.

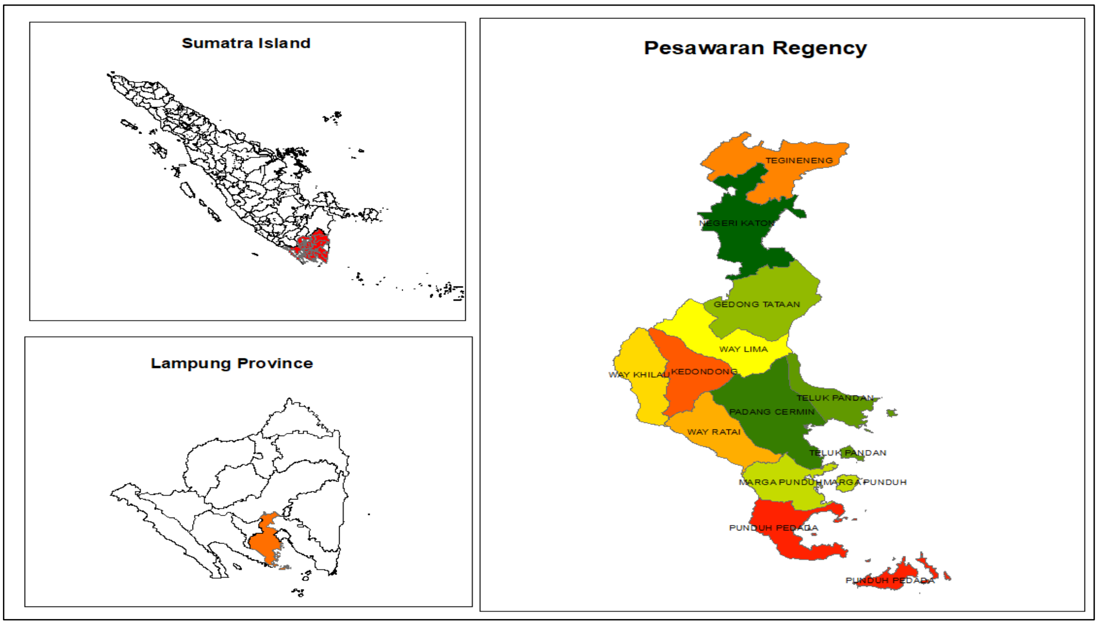

Figure 1. The study area

The AHP method was applied to determine the weight of each criterion (risk factor). AHP is a multi-criteria decision-making method that enables the prioritization of alternatives by evaluating and comparing several related criteria (Aykut, 2021; R. W. Saaty, 1987; T. L. Saaty, 2008). The resulting weights were then used as a basis for the map overlay process. Twenty experts from diverse disciplines (including public health, midwives, nurses, epidemiology, environmental science, women's empowerment, community empowerment, nutrition, and management) participated in determining the weight of each criterion. Each informant conducted pairwise comparison of the criteria based on their perceived level of importance. Following Saaty (2008), the level of importance value ranges from 1 (equally important) to 9 (very important).

Table 1 The fundamental scale of absolute numbers (T. L. Saaty, 2008)

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgment slightly favor
4	Moderate plus	
5	Strong importance	Experience and judgment strongly favor
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favored very strongly over another; its dominance is demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation.

The results of each informant's assessment were entered into a pairwise comparison matrix, following the reciprocal axiom principle. For example, if criterion A is considered five times more important than criterion B, then the relative importance of criterion B to A is 1/5. Given that there were 20 informants, the geometric mean

(Formula 1) was used to obtain the final value for each matrix cell.

Matrix consistency was assessed to ensure reliability. According to Saaty (2008), a comparison matrix is declared consistent if the Consistency Ratio (CR) is less than or equal to 10%. The CR calculation uses Formulas 2 and 3.

The stunting risk map was developed using Weighted Sum Overlay (WSO) technique, which applies weights derived from the result of the previous AHP analysis. First, all maps of the eight variables were converted into raster format. The raster maps were then sequentially entered into overlay calculation, incorporating their corresponding weight and classification values (high = 3, medium = 2, and low = 1). This process resulted in a composite map that incorporated all variables and their respected classification. The resulting raster map was then converted to shapefile format. The stunting risk map was classified into three risk categories, each represented by a different color: high risk (red), medium risk (yellow), and low risk (green).

$$Geometric\ Mean = \left(\prod_{i=1}^{n} xi\right)^{1/n} = \sqrt[n]{x1.x2 \ldots .xn} \qquad \text{(1)}$$

$$Consistency\ Ratio = \frac{CI}{RI} \qquad \text{(2)}$$

$$Consistency\ Index = \frac{(Eigen\ value - n)}{(n-1)} \qquad \text{(3)}$$

3. Results

3.1. Spatial distribution of variables

Based on the percentage of households with access to clean drinking water (Figure 2.A), three sub-districts (Kedondong, Way Khilau, and Marga Punduh) fell into the low-access category, with values ranging from 40.2% to 50.3%. In contrast, Gedong Tataan, Teluk Pandan, and Punduh Pedada were classified as high-access sub-districts, with coverage ranging from 80.2% to 91.4%.

Figure 2.B presents the percentage of households with access to sanitary toilet facilities in two sub-districts classified as low access (53.1%-63.1%), namely Marga Punduh and Punduh Pedada. In contrast, six sub-districts (Tegineneng, Negeri Katon, Gedong Tataan, Way Lima, Teluk Pandan, and Way Ratai) were classified in the high-access category, with coverage ranging from 79.8% to 92.3%.

Figure 2.C illustrates the distribution of sub-districts based on the percentage of toddlers who receive exclusive breastfeeding. Four sub-districts (Tegineneng, Kedondong, Padang Cermin, and Punduh Pedada) were classified as low-coverage area (63.7-75.8%). Five sub-districts (Gedong Tataan, Way Lima, Teluk Pandan, Way Ratai, and Marga Punduh) were classified as high-coverage area (89.4-100.0%). The remaining two subdistricts were classified in the medium category, with coverage ranging from 75.8% to 9.4%.

Based on the percentage of toddlers receiving complete immunization (Figure 2.D), two sub-districts (Kedondong and Way Khilau) were categorized into low-coverage category (44.1% - 50.3%). On the other hand, Way Ratai and Punduh Pedada were categorized as high-coverage category (76.8-100.0%).

Figure 2E illustrates the spatial distribution of toddlers experiencing diarrhea. Three sub-districts (Way Lima, Kedondong, and Padang Cermin) were categorized as high-risk area with incidence rates ranging from 20.0% to 30.0%. In contrast, Tegineneng, Way Khilau, and Teluk Pandan were categorized as the low-risk ares, with diarrhea prevalence between 0.6% and 8.6%.

As shown in Figure 2.F, Negeri Katon was the only sub-district categorized as high in terms of the percentage of toddlers monitored for growth and development, with values ranging from 84.4% to 151.5%. Meanwhile, Tegineneng, Gedong Tatataan, and Padang Cermin.fell into the low category, with monitoring rates ranging from 9.9% to 76.9%.

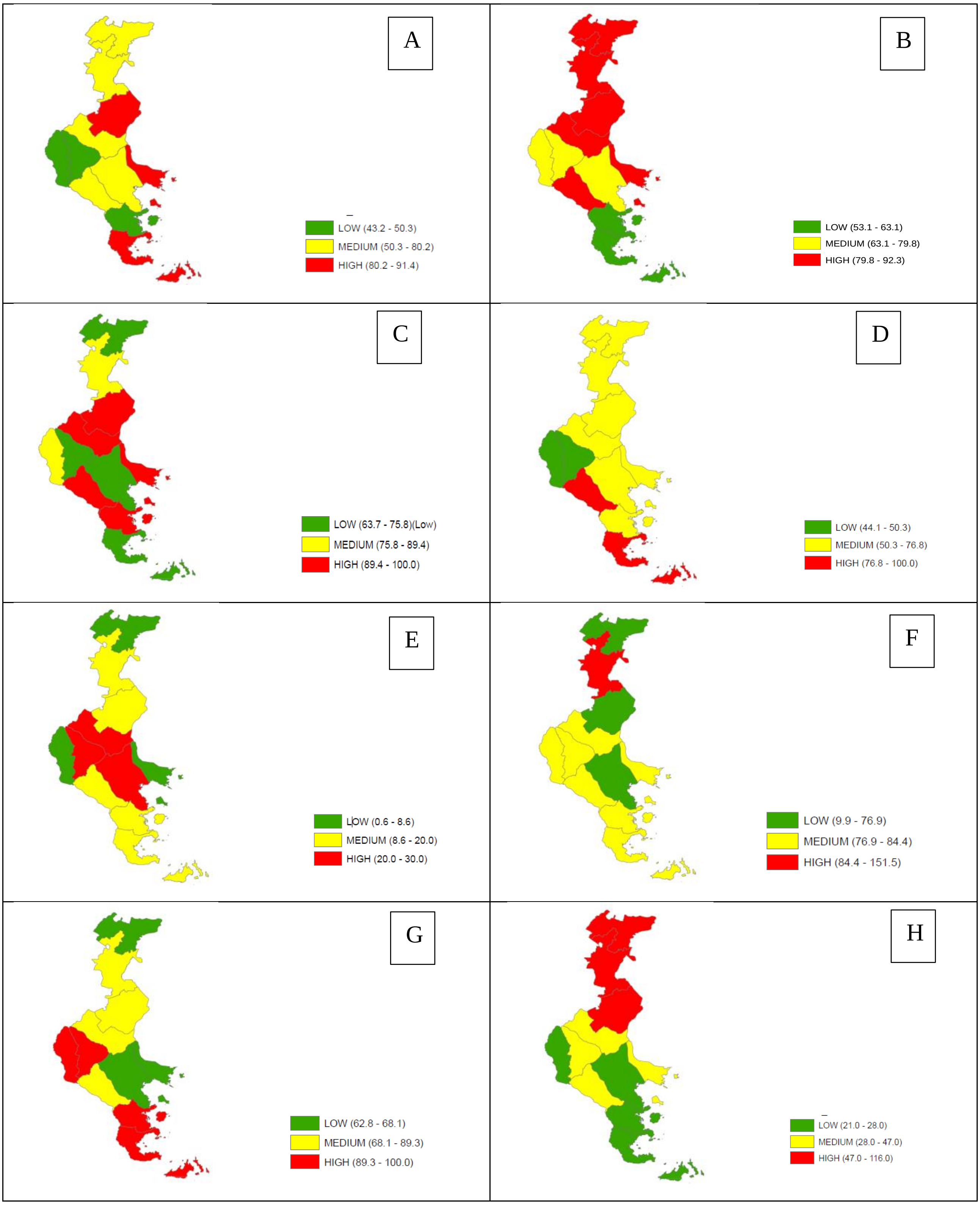

Figure 2. Spatial distribution variables (Safe Drinking Water (A); Healthy Toilet (B); Exclusive Breastfeeding (C); Complete Immunization (D); Diarrhea (E); Growth Monitoring (F); ANC-K4 (G); Health Facilities (H)).

Regarding the percentage of the fourth antenatal care (ANC-K4) visits (Figure 2.G), three sub-districts (Tegineneng, Padang Cermin, and Teluk Pandan) were in the low category. Conversely, four sub-districts (Kedondong, Way

Khilau, Marga Punduh, and Punduh Pedada) were classified in the high category.

Figure 2H presents the distribution of health facilities coverage. Sub-districts with the lowest number of health facilities (21.0-28.0%) included Way Khilau, Padang Cermin, Marga Punduh, and Punduh Pedada. The highest facility coverage (47.0% - 116.0%) was observed in Tegineneng, Negeri Katon, Gedong Tataan (Figure 2.H).

3.2. AHP

AHP was applied to determine the weight of each criterion (risk factor). In this study, 20 informants were involved in determining the weight of each criterion. Table 2 shows the geometric mean of 20 informants' responses.

Table 2. Weighted geometric mean of participants

	1	2	3	4	5	6	7	8	Explanation
1		1.202	0.765	0.955	0.64	0.985	0.566	0.625	*1= Health Facilities*
2	0.832		0.82	1,404	1.31	1.675	1,516	1,636	*2= ANC-K4*
3	1,308	1.22		2,656	3,843	2.698	1,894	1,808	*3= Exclusive Breastfeeding*
4	1,047	0.712	0.377		1	0.977	1,047	1.23	*4= Complete Immunization*
5	1,562	0.764	0.26	1		1,739	1.259	1.36	*5= Growth Monitoring*
6	1,015	0.597	0.371	1,024	0.575		1,754	1,754	*6= Diarrhea*
7	1,766	0.66	0.528	0.955	0.794	0.57		1,864	*7= Safe Drinking Water*
8	1,599	0.611	0.553	0.813	0.735	0.57	0.536		*8= Healthy Toilet*

Figure 3 shows that the criterion with the highest weigh is exclusive breastfeeding (22.9%), followed by ANC-K4 visit (14.4%) and growth monitoring (11.8%). The remaining five variables have relatively similar weights, ranging between 9.0% and 11.0%. The CR was 4%, indicating that the comparison matrix satisfies the consistency requirement.

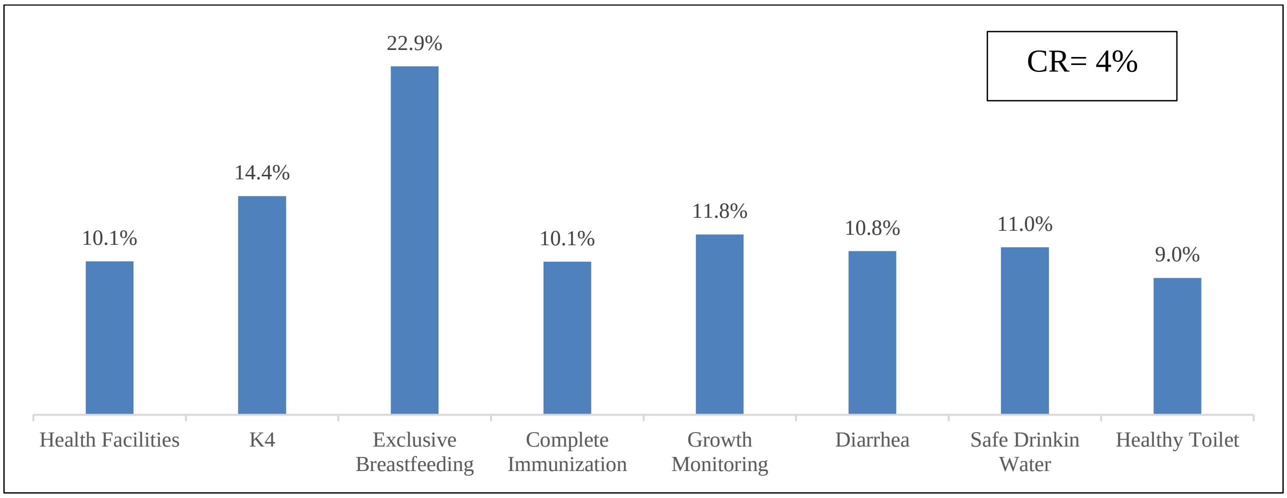

Figure 3. Weighted variables

3.3. Stunting risk map

The stunting risk map was developed using the overlay technique, using weights from the AHP calculation results. The study results (Figure 4) show that three sub-districts (Tegineneng, Kedondong, and Padang Cermin) are included in the high-risk stunting category. Three sub-districts included in the moderate category were Way Khilau, Marga Punduh, and Punduh Pedada. Finally, the remaining five sub-districts identified in the low category were Negeri Katon, Gedong Tataan, Way Lima, Way Ratai, and Teluk Pandan.

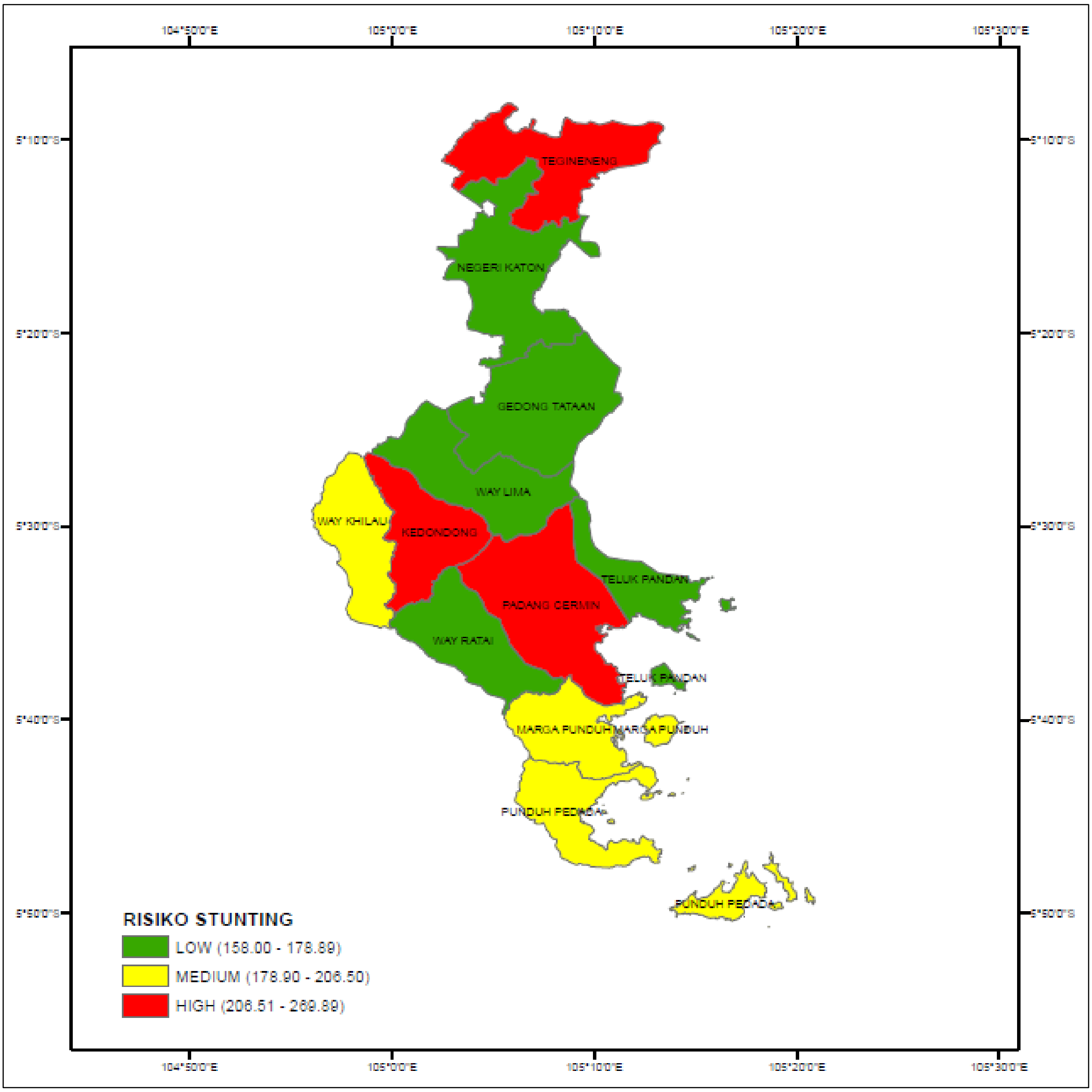

Figure 4. Stunting risk map of Pesawaran Regency, Lampung Province

There is a tendency for spatial autocorrelation based on the distribution of risk areas. For this reason, we calculated the Moran Index value. The calculation yielded a Moran Index value of 0.717953 (P = 0.047) as displayed in Figure 5 indicating a spatial influence on the incidence of stunting based on the research variables.

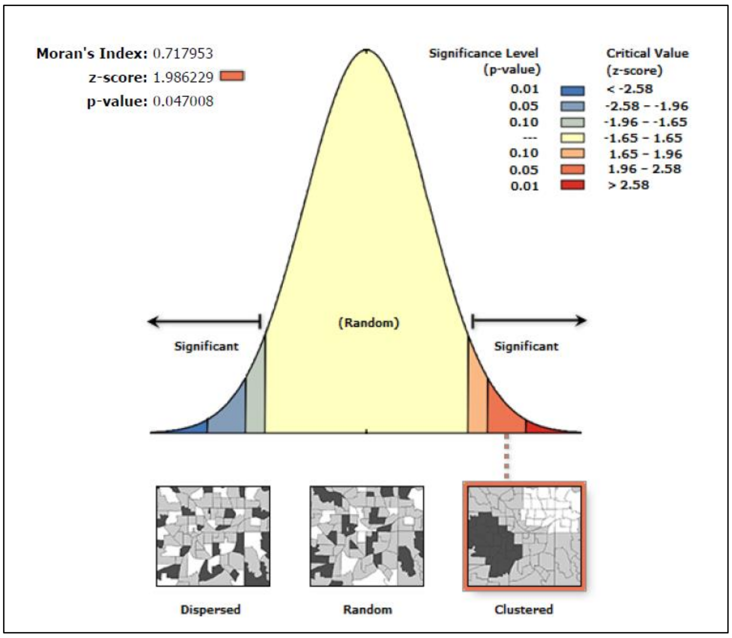

Figure 5. Spatial autocorrelation

4. Discussion

Stunting remains a major public-health concern in Indonesia because of its long-term consequences. Beyond impairing cognitive and physical development, stunting is also associated with an increased risk of obesity, coronary heart disease, and hypertension (Adedeji et al., 2017; He et al., 2018; Hidayah et al., 2019; Widyaningsih et al., 2018; Yushananta & Ahyanti, 2022). As of 2023, the prevalence of stunting in Indonesia stands at 21.25%, placing the country 27th among 154 countries globally and 5th among Asian countries (WHO, 2023).

Concerns over the potential emergence of a lost generation have prompted the Indonesian government to implement a national program aimed at accelerating stunting reduction efforts. This initiative also aligns with global commitments, including the World Health Assembly to reduce the prevalence of stunting by 40% by the year 2025 (Indonesian Government, 2021; Ministry of the State Secretariat, 2021). The national strategy for stunting prevention is built upon five key pillars: (1) strong commitment and vision from the highest level of national leadership; (2) a nationwide campaign promoting behavioral change, political commitment and accountability; (3) convergence, coordination, and consolidation of national, regional, and community programs; (4) support for food security policies; and (5) robust systems for monitoring and evaluation (Ministry of the State Secretariat, 2021). Stunting control must be strategic, focused, and targeted based on its determinants (Development Initiatives Poverty Research, 2018). Therefore, a risk map is needed to plan its control (Eryando et al., 2022; Pfeiffer et al., 2008; WHO, 2023).

Previous studies identified risk factors of stunting (including socioeconomic inequality, practices of feeding, food insecurity, education, childhood morbidity, infection, parenting, and environment) as stated by Adedeji et al. (2017); He et al. (2018); Rahman (2018); Semba et al. (2008); Yushananta & Ahyanti, (2022, 2024). However, they employ statistical approach to determine stunting risk factors, while this study combined AHP and GIS to develop a stunting risk map in Pesawaran Regency, Lampung Province.

This study employed the AHP to assign relative importance to each stunting-related risk factor. AHP, as introduced by R. W. Saaty (1987) and later expanded by T. L. Saaty (2008), is particularly effective for structuring and analyzing complex decision-making scenario involving multiple interrelated criteria. Its use in health and environmental research has been validated in studies by Díaz-Alcaide & Martínez-Santos (2019) and Zabihi et al. (2019). The application of AHP in this study followed four sequential steps outlined earlier.

A total of 20 informants from diverse professional backgrounds contributed to determining the weight of each variable (risk factor). The AHP results (Figure 3) generated weight values for each variable as follows: exclusive breastfeeding (22.9%), ANC-K4 (14.4%), monitoring of child growth and development (11.7%), access to safe drinking water (11.0%), incidence of diarrhea (10.8%), number of health service facilities (10.1%), complete basic immunization (10.1%), and access to healthy sanitation (9.0%). The calculated CR was below 10%, indicating acceptable consistency in the comparison matrix (T. L. Saaty, 2008).

The analysis (Figure 4) identified three sub-districts in the high-risk category for stunting: Tegineneng, Kedondong, and Padang Cermin. Three other sub-districts (Way Khilau, Marga Punduh, and Punduh Pedada) were classified as medium-risk. The remaining sub-districts (Negeri Katon, Gedong Tataan, Way Lima, Way Ratai, and Teluk Pandan) were categorized as low-risk areas.

To further understand the characteristics of each high-risk sub-district, the stunting risk map (Figure 4) was compared with the distribution of individual risk factors (Figure 2). The findings revealed that Padang Cermin Sub-district exhibited the greatest number of contributing risk factors (six variables), followed by Tegineneng and Padang Cermin, each with three key risk variables.

Figure 2 illustrates that Padang Cermin Sub-district exhibits six risk factors categorized as poor: limited access to safe drinking water, low rates of exclusive breastfeeding, inadequate growth and development monitoring, low coverage of ANC-K4 visits, insufficient health facilities, and a high incidence of diarrhea. In Tegineneng Sub-district, the identified risk factors are exclusive breastfeeding, growth and development monitoring, and ANC-K4 visits. Meanwhile, in Kedondong, the three contributing risk factors include exclusive breastfeeding, immunization, and diarrhea. When these are aligned with respective AHP weight values, the cumulative risk burden is highest in Padang Cermin (81.0%), followed by Tegineneng (49.1%), and Kedondong (43.8%). These findings suggest that the constructed stunting risk map accurately reflects the actual risk distribution and can be considered valid.

Moran's I shows significant spatial autocorrelation of stunting prevalence between sub-districts (Figure 5). This indicates that the stunting prevalence in one area - either high or low - does not occur randomly but is related to the stunting prevalence in neighbouring sub-districts. We found a tendency for stunting prevalence in an area to be more similar to prevalence in areas that are closer than in areas that are further away. This is in accordance with the basic concept stated in Tobler's Law, that '*everything is related to everything else, but things that are close are more related than things that are far away*' (Pfeiffer et al., 2008; Souris, 2019). In the context of spatial analysis, autocorrelation indicates similarities that vary with distance between locations (Fotheringham & Rogerson, 2008).

Despite the careful designed of this study, certain limitations should be acknowledge. Primarily, the analysis relied on secondary data, which may have implications for data validity and precision. To address this, a data triangulation process was conducted by comparing data from multiple credible sources. In case of discrepancies, efforts were made to trace and verify the data through the original sources.

Moreover, several important factors known to influence stunting, such as poverty, family food security, and parenting practices were not included in this analysis because of the unavailability of reliable data at the sub-district level. Future studies should incorporate these variables, particularly when examining stunting risk in different regions, to provide a more complex understanding of contributing determinants.

5. Conclusions

The availability of risk maps is crucial for planning strategic, targeted, and determinant-based programs for stunting control. This study integrated the AHP with GIS to develop a stunting risk map based on eight identified risk factors. The findings indicate that three out of eleven sub-districts in Pesawaran Regency (Tegineneng, Kedondong, and Padang Cermin) fall into the high-risk category. Based on the weighted analysis, key priority programs for stunting mitigation should focus on promoting exclusive breastfeeding, ensuring adequate ANC-K4 visit, enhancing monitoring of children growth and development, expanding access to safe drinking water, and preventing diarrheal diseases.

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