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Level of School Preparedness in Facing the Threat of a Tsunami Disaster on the South Coast of Kebumen Regency

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ABSTRACT

The southern coastal area of Kebumen Regency has a high potential tsunami threat because it is located in the tectonically active southern Java megathrust zone, with many schools located less than 2 km from the coast on flat topography, making them highly vulnerable. This study aims to analyze the characteristics of the physical environment of schools and the level of school preparedness in facing the threat of a tsunami disaster. This study uses a quantitative analytical descriptive method through observation, questionnaires, and interviews. The physical characteristics of schools are assessed from the distance to the coast, topographic conditions, and tsunami hazard zones, while the level of preparedness is measured based on the five parameters of the Disaster Safe Education Unit (SPAB). The results show that most schools are located in the red (high) and yellow (moderate) tsunami hazard zones. The level of school preparedness varies: 16.7% are very prepared, 26.7% are prepared, 40% are moderately prepared, and 16.7% are less prepared. More prepared schools generally have formal policies, complete evacuation facilities, and regularly conduct simulations with external parties such as the Regional Disaster Management Agency (BPBD), the Indonesian Red Cross (PMI), and village/sub-district officials. While schools with low preparedness have minimal facilities, limited evacuation routes, and rarely conduct simulations. These findings confirm that preparedness is influenced not only by geographic risk but also by the school's internal capacity and partnership network. Therefore, strengthening policies, improving infrastructure, and conducting regular training and simulations involving all stakeholders are necessary.

Keywords: environmental characteristics, school preparedness, tsunami, SPAB

INTRODUCTION

Indonesia is known as one of the countries with the highest level of natural disaster vulnerability in the world. Its geographical location at the confluence of three major plates: the Eurasian Plate, the Indo-Australian Plate, and the Pacific Plate, makes this region vulnerable to various geological disasters, such as earthquakes, tsunamis, landslides, and volcanic eruptions (Tjandra, K., 2014). This high tectonic activity has triggered various major disasters, including the 1994 Banyuwangi tsunami, the 2004 Aceh tsunami, the 2006 Pangandaran tsunami, the 2010 Padang

tsunami, and the 2018 Donggala and Sunda Strait tsunamis (Alviani, P., 2021). These events confirm that tsunamis pose a real threat to coastal areas in Indonesia, with impacts that can claim thousands of lives in a short time.

Kebumen Regency, located on the southern coast of Central Java Province, is one of the areas with a very high tsunami risk. This region faces directly onto the Indian Ocean and lies along the southern Java megathrust zone, a tectonically active collision zone between the Indo-Australian and Eurasian Plates. Based on tsunami hazard maps issued by the National Disaster Management Agency (BNPB) and the Kebumen Regional Disaster Management Agency (BPBD), several districts, including Mirit, Ambal, Puring, Petanahan, and Ayah, are categorized as red zones for tsunami risk (BPBD Kebumen, 2020). The coastline in this area is generally sloping and open, allowing tsunami waves to travel far inland. This situation further increases vulnerability, especially as tsunami waves can arrive in this area less than 30 minutes after an earthquake, as is typical for local tsunamis in Indonesia (Kurniasih, Marin, & Setyawan, 2020).

Tsunami vulnerability along the Kebumen coast threatens not only residential areas but also schools, some of which are very close to the coast. Schools in the danger zone have the potential to be directly impacted, both in terms of student safety and the continuity of learning. Therefore, preparedness is key, given the limited evacuation time. Law Number 24 of 2007 emphasizes the importance of integrating disaster risk reduction into education, as schools play a strategic role in instilling a culture of disaster awareness. Research also shows that disaster education in schools is effective in raising awareness and changing community behavior (Hamid, N., 2020).

School preparedness encompasses various aspects, from policies and planning, the presence of disaster preparedness teams, evacuation routes and points, supporting infrastructure, to the implementation of regular simulations and training (BNPB, 2019; Ministry of Education and Culture, 2019). For areas such as the southern coast of Kebumen, which are at high risk of tsunamis, a comprehensive study of school preparedness is crucial. This study aims not only to capture the existing state of preparedness but also to identify the physical environmental factors that influence it, such as distance from the coast, topography, and tsunami hazard zones.

Based on this background, this study focuses on two main objectives: 1) To analyze the characteristics of the physical environment of schools in the southern coastal area of Kebumen Regency. 2) To determine the level of school preparedness in facing the threat of a tsunami disaster in the southern coastal areas of Kebumen Regency. The results of this study are expected to contribute to strengthening the Disaster-Safe Education Unit (SPAB) program in coastal areas, as well as serve as a practical reference for local governments, schools, and other stakeholders in designing disaster mitigation policies and strategies that are data-driven and appropriate to local conditions. This will create a safe, resilient, and adaptive learning environment to future tsunami threats.

LITERATURE REVIEW

Disaster preparedness is a crucial phase in disaster risk management, encompassing a series of activities to anticipate potential disasters through appropriate and effective measures, as stipulated in Law No. 24 of 2007. According to the International Strategy for Disaster Reduction (ISDR, 2009 in ADRRN, 2010), preparedness is understood as the knowledge and capacity developed by governments, organizations, communities, and individuals to anticipate, respond to, and recover effectively from the impacts of disasters. In the context of schools, preparedness includes policy planning, the formation of disaster preparedness teams, the provision of supporting facilities and infrastructure, evacuation routes and points, and the

implementation of regular simulations (BNPB, 2019; Ministry of Education and Culture, 2019). Similar findings were also demonstrated by research by Kusuma, Setyowati, & Suhandini (2016), which emphasized that social change in disaster-affected areas is also influenced by the preparedness of communities and educational institutions in responding to threats. The Disaster-Safe Education Unit (SPAB) policy is a systematic effort designed to create safe, resilient, and disaster-prepared educational units. Adapted from the Comprehensive School Safety Framework (UNDRR), the SPAB contains three main pillars: safe learning facilities, disaster management in schools, and disaster risk reduction education (BNPB, 2019; Ministry of Education and Culture, 2019). The five indicators used in this study are derived from the three SPAB pillars: policy and planning, disaster preparedness teams, evacuation routes and points, supporting infrastructure, and simulations and training. Saba, U. U (2024) emphasize that institutional policies are a critical foundation for building a culture of safety in schools, while Perera et al. (2020) highlights the integration of evacuation routes with early warning systems as a determining factor in successful evacuations. Research in Banda Aceh also showed that schools in tsunami-affected areas demonstrated higher levels of preparedness than schools in unaffected areas, primarily due to direct experience and participation in preparedness training (Kamil, Utaya, & Utomo, 2020).

The southern coast of Java, including Kebumen, is at high risk of tsunamis due to its location in an active megathrust zone (Jumadi et al., 2025). In Indonesia, most tsunamis are local in nature with a rapid arrival time of 10–60 minutes (Rasyif & Kato, 2015). Kebumen's flat and open coastline makes it vulnerable, as evidenced by the 2006 tsunami (Pamungkas, Mardiatno, & Retnowati, 2023). The low preparedness of coastal schools due to limited early warning systems, as also found in Aceh, underscores the need to improve school capacity in tsunami-prone areas (Rizky, Zuraidi, & Aulia, 2025).

Physical factors such as distance from the coast, topography, and hazard zones significantly determine risk (Le Cozannet et al., 2013). Schools within a radius of <1 km from the coast require higher preparedness (Desiana, Afdhal, & Bina, 2023). GIS-based spatial analysis can be used to map the relationship between physical factors and preparedness (Parizi, Taleai, & Sharifi, 2022). Furthermore, strengthening school building structures has been shown to increase earthquake and tsunami resilience, making them safer for emergency evacuation (Oktari et al., 2018).

MATERIALS & METHODS

This study employed a quantitative method with a descriptive-analytical approach, aiming to comprehensively describe the characteristics of the school's physical environment and its level of preparedness for the threat of a tsunami. Data analysis utilized Geographic Information Systems (GIS) technology to identify and analyze the relationship between physical environmental factors and school preparedness.

The study location was in the southern coastal area of Kebumen Regency, Central Java Province, encompassing six sub-districts: Mirit, Ambal, Buluspesantren, Klirong, Petanahan, and Puring. All schools within the tsunami hazard zone were studied. The study was conducted in July 2025. A map of the study location is presented below.

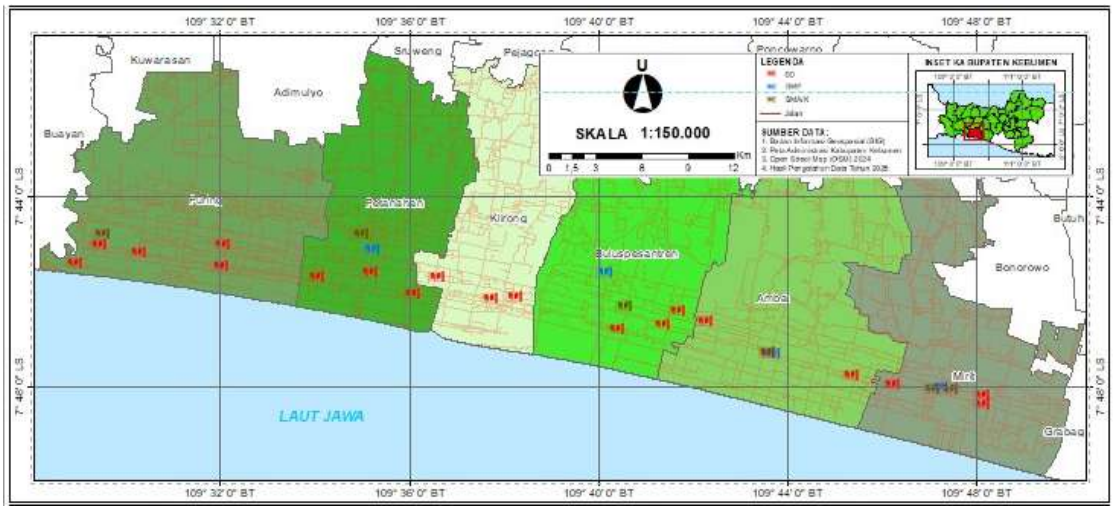

Figure 1. Map of Tsunami-Prone School Research Locations in Kebumen Regency, Central Java, Indonesia

Source: Researcher analysis, 2025

The study population included 30 schools (elementary, junior high, and senior high schools) in tsunami-prone zones, with principals and teachers as subjects. Data were obtained through field observations to map location, distance from the coast, topographic conditions, and infrastructure; a questionnaire based on five indicators of school preparedness according to the SPAB pillars with a Likert scale of 1–4; and in-depth interviews related to policies, evacuation, and obstacles. Analysis was conducted descriptively to describe the physical conditions and level of preparedness, and spatially using GIS through ArcGIS to map the distribution of school preparedness on the southern coast of Kebumen Regency.

RESULT

Characteristics of the Physical Environment of Schools in the South Coastal Area of Kebumen Regency

School preparedness for a tsunami disaster is not only determined by internal factors but also influenced by external conditions related to the surrounding environment. The physical environment in which a school is located plays a crucial role in determining the extent of the risks it may face. Physical environmental characteristics are a key factor influencing the level of vulnerability to a tsunami. These characteristics encompass three main aspects: the school's distance from the coast, elevation (topography), and tsunami-prone zone classification. These three aspects are interrelated in determining the level of risk exposure a school faces. The following is an explanation of the indicators of physical environmental characteristics.

Table 1. Physical Environmental Characteristics Indicators

Aspects observed	Indicator	Description
Distance of School from the Coastline	School location relative to the beach (from map/GPS)	Shows how close the school is to the coast to identify potential tsunami risks.
School Topography	Height of the school from sea level	Describes the topographic conditions of the school, whether it is in low, medium or high land.
Tsunami Hazard Zone	Red/yellow/green zones based on BPBD maps	Determine the tsunami threat level based on the location of the school on the official BPBD map.

Source: Researcher analysis, 2025

This study analyzed 30 schools in the coastal area of the South Coast of Kebumen Regency. Data were collected and analyzed using Geographic Information System (GIS)-based spatial analysis. This method utilizes school location coordinates integrated with topographic maps and tsunami-prone zoning maps to generate information on the distance, elevation, and risk classification of each school.

The results of the GIS spatial analysis indicate that the distance of schools from the coast ranges from 340.47 meters to 2.67 km, with most located less than 2 km, thus placing them at high risk of tsunamis. Topographically, schools with elevations of 6–14 meters above sea level indicate that the majority are located in low-lying areas, vulnerable to direct tsunami impacts.

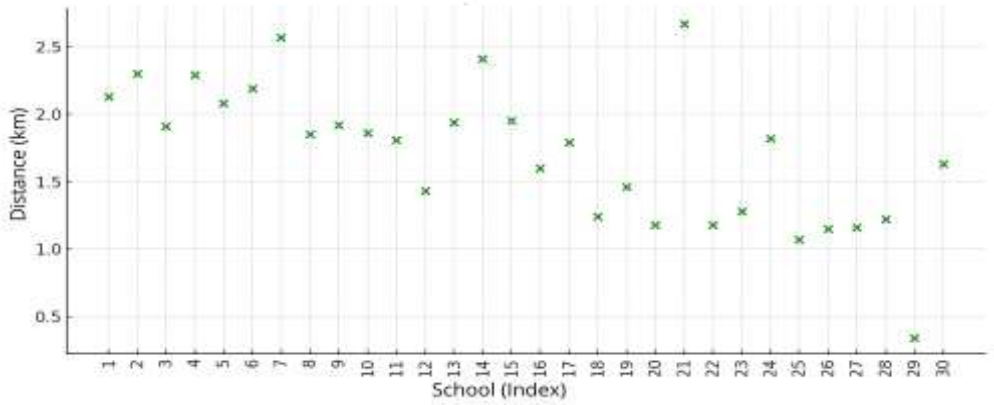

Figure 2. Scatter Plot of Distance from School to Beach
Source: Researcher analysis, 2025

This scatterplot displays the distance of each individual school to the coast, with the horizontal axis representing the school's serial number and the vertical axis showing the distance in kilometers. The graph shows the variation in distance between schools, ranging from the very close, only about 0.34 km, to the farthest, about 2.67 km. The points on the graph indicate that most schools are located between 1 and 2 kilometers, with the highest concentration in the 1.5–2 km (11 schools) and 1–1.5 km (10 schools) groups. Some schools are further from the coast (6 schools in the 2–2.5 km group), and only 2 schools are more than 2.5 km away. This scatterplot provides a more detailed picture than a histogram because it shows the position of each individual school, making it easier to identify the closest and furthest schools from the coast, which is important in tsunami risk analysis.

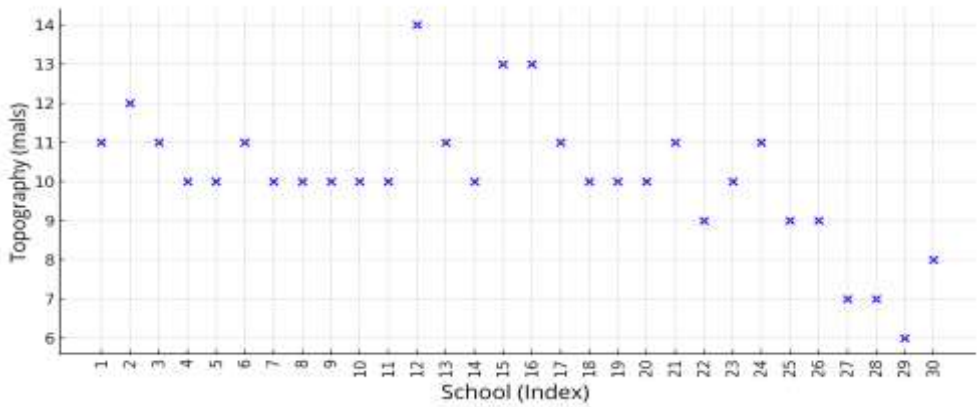

Figure 3. School Topography Scatter Plot
Source: Researcher analysis, 2025

This scatterplot shows the topography of each school in meters above sea level (masl). The horizontal axis represents the school's serial number, while the vertical axis shows the school's elevation in masl. The graph shows that most schools are located between 10 and 11 masl, indicating that many are located in flat or low-lying areas. Some schools are higher, for example, reaching 13–14 masl, and some are at lower elevations, around 6–9 masl. Overall, all schools fall into the flat topography category, indicating that most are located on low, flat surfaces, making them more vulnerable to tsunami risk.

The percentage of tsunami-prone areas for schools is presented below.

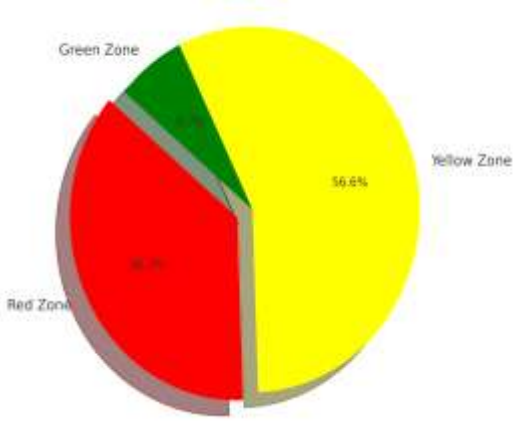

Figure 4. Percentage of Tsunami-Prone Zones
Source: Researcher analysis, 2025

Based on the results of an overlay with the Kebumen Regency Regional Disaster Management Agency (BPBD) tsunami hazard map, 36.7% of schools are located in the Red Zone (high risk), 56.7% in the Yellow Zone (moderate risk), and only 6.6% in the Green Zone (low risk). This distribution pattern indicates that the majority of schools are located in areas with moderate to high levels of vulnerability. This finding emphasizes the importance of prioritizing mitigation programs, such as preparing evacuation routes, installing early warning systems, and conducting regular disaster simulations, especially for schools in the Red and Yellow Zones.

Level of School Preparedness in Facing the Threat of Tsunami Disaster in the South Coastal Area of Kebumen Regency.

School tsunami preparedness is a school's ability to respond quickly and appropriately when a tsunami threat occurs, with the goal of minimizing casualties and losses. Preparedness encompasses various aspects, from policies and planning to the formation of standby teams, the availability of evacuation facilities and infrastructure, to the implementation of regular training and simulations. A good level of preparedness will increase the chances of safety for the school community when a disaster occurs. In this study, the level of school preparedness was measured using the Disaster-Safe Education Unit (SPAB) indicators, as described in the table below.

Table 2. Indicator SPAB

Indicator	Description
Preparedness Policy and Planning	This includes the existence of policy documents, emergency response plans, and the integration of preparedness programs into school work plans.
School Disaster Preparedness Team	Includes team formation, membership completion, and active participation in preparedness activities.
Evacuation Routes and Points	Includes marking evacuation routes, determining safe assembly points, and installing evacuation signs.
Supporting Facilities and Infrastructure	Includes the availability of evacuation equipment, early warning systems, and evacuation route maps.
Simulation and Training	This includes implementing evacuation simulations, training with relevant agencies, and involving the entire school community.

Source: Researcher analysis, 2025

The following is an explanation of the research findings on school preparedness, as measured using the SPAB indicators:

1. Preparedness Policy and Planning

Several schools in southern Kebumen already have official disaster preparedness policy documents that have been disseminated to the school community, although emergency SOPs are not yet widely available. Policy evaluations have been conducted, but only in some schools, resulting in differing levels of preparedness across schools. In terms of planning, preparedness programs are generally included in the School Work Plan. In the curriculum, high schools have a dedicated module, while elementary and junior high schools integrate mitigation material into several subjects, with some even incorporating it into almost all subjects. However, some schools have not integrated disaster material at all, resulting in uneven student awareness at all levels.

2. School Disaster Preparedness Team

Most schools have formed Disaster Preparedness Teams, consisting of teachers, students, and staff, and conduct training, report on activities, and provide guidebooks. However, the level of implementation varies, with some schools lacking a team at all. Further efforts are needed to ensure that all schools have an active and structured team.

3. Evacuation Routes and Points

Evacuation routes and assembly points have been designated, particularly around schools in red and yellow zones, and some have been signposted. Evacuation routes from the school to safe locations outside the school are clearly marked and free from physical obstacles, making it easy for all school members to move quickly in the event of an emergency. Evacuation assembly points outside the school have also been designated, are known to all school members, and are clearly marked.

Evacuation signs installed by external agencies, such as district, village, sub-district, or BPBD (Regional Disaster Management Agency), are readily available and clearly visible around the school. Furthermore, an early warning system, including alarms, sirens, or loudspeakers installed by external parties, can be heard from the school grounds when activated, allowing all school members to respond quickly and orderly. The BPBD has 14 tsunami early warning sirens, spread across all sub-districts in the southern part of Kebumen Regency. Below is a map of the locations of the tsunami early warning sirens.

4. Supporting Facilities and Infrastructure

Some schools already have preparedness facilities, such as stretchers, first aid kits, early warning systems, evacuation route maps, and disaster posters that help the school community understand emergency response procedures. Evacuation routes are generally clear and lead to safe assembly points. However, some schools still have limited equipment, suboptimal warning systems, uneven evacuation maps, and evacuation routes and assembly points that are not fully understood by the school community. Therefore, comprehensive infrastructure improvements are needed.

5. Simulations and Training

Some schools have involved teachers and staff in basic disaster training, developing standard operating procedures (SOPs), and conducting preparedness simulations with students. These activities are generally carried out in collaboration with the Indonesian Red Cross (PMI), the Regional Disaster Management Agency (BPBD), and other agencies. Some schools also support this through extracurricular activities such as the Red Cross (Red Cross). However, there are still schools that have never conducted simulations or have not received training from relevant parties. Routine training is more common in schools in red zones, so equitable access to training and simulations is needed for all schools to optimize disaster preparedness.

This study used a questionnaire with 30 questions, each scored from 1 to 4, with the

score adjusted for each question. The questionnaire was completed by the principal or teacher based on the actual conditions at the school. The total actual score was converted into a preparedness index (%) using an index formula where the total actual score is divided by the maximum score and multiplied by 100, resulting in a maximum score of 120. The calculated results were categorized as Very Prepared (80–100), Ready (65–79), Moderately Prepared (55–64), Less Prepared (40–54), and Not Prepared (<40) according to the SPAB classification.

Based on the analysis of tsunami disaster preparedness levels in the 30 schools selected for the study, it was found that each school had varying levels of preparedness, as measured by the five Disaster Safe School (SPAB) indicators. These variations in preparedness levels were then mapped to show the spatial distribution of schools categorized as Very Prepared, Ready, Moderately Prepared, and Less Prepared. This mapping aims to visualize tsunami-prone school areas and demonstrate the differences in preparedness levels across schools geographically. The following map presents the level of preparedness of tsunami-prone schools.

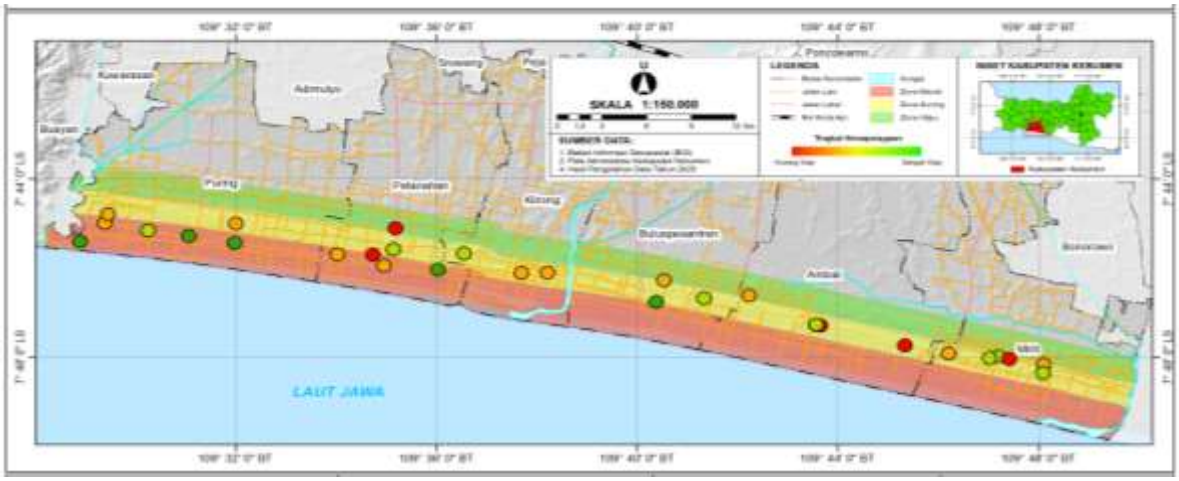

Figure 5. Map of Tsunami-Prone School Preparedness Levels in Kebumen Regency, Central Java, Indonesia

Source: Researcher analysis, 2025

The data obtained is then presented in the form of a pie chart showing the percentage of school preparedness levels. The pie chart below shows the percentage of school preparedness levels.

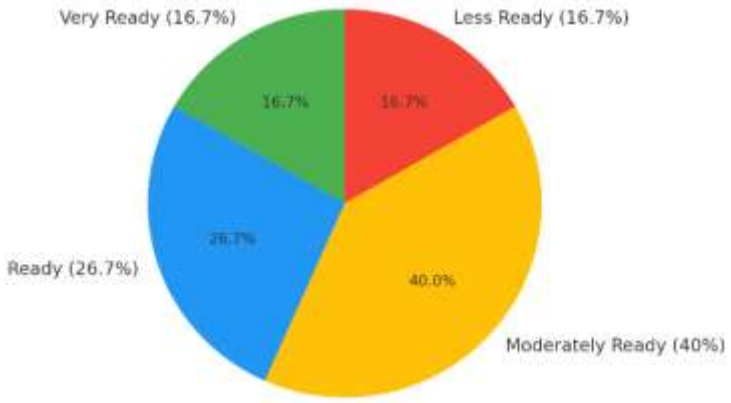

Figure 6. Percentage of School Preparedness Level
Source: Researcher analysis, 2025

The index calculation results show that five schools (16.7%) are categorized as Very Ready, with an index score above 80% and optimally meeting the SPAB indicators. These include SD Negeri 2 Setrojenar, SD Negeri Tegalretno, SD Negeri 2 Waluyorejo, SD Negeri 1 Surorejan, and SD Negeri 3 Tambakmulyo.

Eight schools (26.7%) are categorized as Ready, with an index score of 65–79%, indicating that most SPAB indicators have been met, although there are still deficiencies in certain aspects, such as the completeness of facilities or the implementation of routine simulations. The Moderately Ready category includes 12 schools (40%) with an index score of 55–64%, indicating partial fulfillment of SPAB indicators, for example, evacuation routes are not fully clear or the standby team is not yet optimally active. Meanwhile, five schools (16.7%) are categorized as Less Ready, with an index score of 40–54%, indicating a lack of policy documents, infrastructure, and training or simulations.

When compared to the tsunami hazard zones based on the Kebumen Regency Regional Disaster Management Agency (BPBD) risk map, interesting variations were found. Not all schools in the red zone had a high level of preparedness. Some schools in the red zone were indeed "Very Prepared," such as SD Negeri 2 Setrojenar, SD Negeri Tegalretno, SD Negeri 2 Waluyorejo, SD Negeri 1 Surorejan, and SD Negeri 3 Tambakmulyo. However, there were also schools in the red zone that were in the "Sufficiently Prepared" or even "Less Prepared" category, such as SD Negeri 3 Karangrejo (Quite Prepared), SDN 1 Karanggadung (Quite Prepared), SD Negeri 2 Tambakmulyo (Quite Prepared), and SDN 2 Karanggadung (Less Prepared).

A similar situation also occurred at schools in the yellow zone. Although this zone generally carries a lower risk than the red zone, some schools have reached the "Ready" category, such as SMA Negeri 1 Mirit and SMK Negeri 1 Ambal. However, there are also schools in the yellow zone that are categorized as Less Prepared, such as SMK Al-Ghazali Mirit, SD Negeri Sumberjati, and SMP Negeri 1 Ambal.

In the green zone, which is topographically relatively far from the coastline and has a lower tsunami risk, there are still schools categorized as Less Prepared, such as SMP Negeri 1 Petanahan. This indicates that the level of preparedness is not solely determined by the area's risk level, but also by internal school factors such as policies, completeness of infrastructure, the presence of a standby team, and the frequency of training or simulations.

These findings indicate that although the red zone requires high preparedness, efforts to increase school capacity are still necessary in all zones. This approach is crucial to ensure equitable preparedness, so that all schools have optimal capacity to face potential tsunami threats, regardless of their location's risk level. The following graph shows the level of school preparedness per tsunami hazard zone.

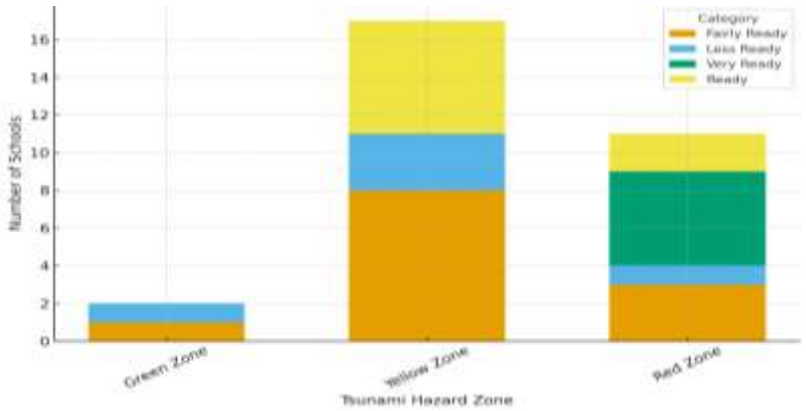

Figure 7. Distribution of School Preparedness Levels per Tsunami Hazard Zone
Source: Researcher analysis, 2025

The graph shows the distribution of school preparedness levels based on tsunami hazard zones in the study area. In the red zone, which has the highest tsunami risk, there was a variation in preparedness categories ranging from Very Prepared, Ready, to Less Prepared. While the majority of schools in the red zone were in the Very Prepared category, there were still some schools that were only Moderately Prepared and even Less Prepared. This indicates that despite being in a high-risk area, not all schools are optimally prepared. In the yellow zone, the distribution of categories was more diverse, with significant numbers in the Moderately Prepared and Ready categories. However, this zone also had several schools in the Less Prepared category, indicating the need for increased preparedness efforts despite being in a medium-risk zone.

Meanwhile, in the green zone, which has a low risk, there were schools in the Less Prepared category in addition to those that were Moderately Prepared. This indicates that preparedness factors are influenced not only by the regional risk level but also by internal school policies, the availability of infrastructure, the presence of a preparedness team, and the intensity of disaster training or simulations. Overall, this graph confirms that increased preparedness needs to be implemented evenly across all zones, not just in high-risk areas, so that all schools have adequate capacity to face the threat of a tsunami.

DISCUSSION

Characteristics of the Physical Environment of Schools in the South Coastal Area of Kebumen Regency

The southern coastal area of Kebumen Regency has geographic and geological conditions that make it vulnerable to tsunami threats. Based on the tsunami disaster risk map issued by the Kebumen Regency BPBD in 2020, all schools studied are located within the tsunami hazard zone, which is divided into red, yellow, and green zones. The red zone indicates a high level of danger because it is located closest to the coastline and has the potential to be directly impacted by a tsunami. The yellow zone represents a moderate level of danger, meaning areas that are still at risk but are relatively better protected than the red zone. Meanwhile, the green zone represents a low level of danger, where the potential for a tsunami impact is less likely because it is located farther from the coast and at a safer elevation. This region's geographic location directly facing the Indian Ocean places it within the subduction zone of the Indo-Australian and Eurasian plates, thus making it highly susceptible to tectonic earthquakes that trigger tsunamis.

The topography of the coastal area of Kebumen is dominated by lowlands with elevations between 0 and 20 meters above sea level (masl). This characteristic aligns with Akbar et al. (2020) opinion that low-elevation areas are more exposed to tsunamis because waves can travel farther inland. This is evident in school locations in Mirit, Ambal, and Puring Districts, where the distance to the coastline is relatively short and there are no natural barriers such as hills or dense coastal forests.

Most schools in the southern coastal area of Kebumen Regency are located at low elevations and relatively close to the coastline. Many are located along the Daendels Road (Southern Crossing Route), which runs parallel to the coast and has an elevation nearly equal to sea level. This geographic location increases the potential for tsunami exposure, primarily due to the minimal elevation difference and the absence of significant natural barriers nearby. This aligns with Bakhriansyah, Anhar, and Noor (2025) statement that schools located near the coast face particular challenges in evacuation, as time to evacuate is limited. Therefore, location and topography must be primary considerations in disaster risk reduction strategies for coastal schools.

Furthermore, spatial analysis results indicate that variations in school distance from the coastline significantly influence the level of

risk exposure. Schools located less than 1 km from the coast, such as those in Mirit District, are most vulnerable due to the potential for direct impact within a short time after the triggering earthquake. Meanwhile, schools located 1.5–2.5 km away have a relatively longer evacuation time, although they remain categorized as vulnerable due to the low and flat topography of the area. This fact aligns with the findings of Chaudhari et al. (2010), who stated that schools within a radius of <1 km from the coast require a higher level of preparedness, including the provision of fast and safe evacuation routes.

The southern coast of Kebumen, with its sloping and open terrain, increases tsunami risk as waves can travel far inland without natural barriers, similar to the 2006 Pangandaran tsunami. According to Sherly et al. (2015) disaster vulnerability concept, schools in this area are highly vulnerable due to coastal proximity, low topography, and limited adaptive capacity. Therefore, regardless of hazard zone classification (red, yellow, green), all schools require structured and sustainable mitigation interventions.

The physical environmental characteristics of schools in this area also demonstrate uniformity in terms of risk. While there are variations in distance between schools and the coastline, the elevation differences are relatively small, potentially spreading the impact of a tsunami if large waves occur. This means that no school is completely topographically safe without structural or non-structural mitigation interventions. This aligns with the findings of Subardjo and Ario (2016) that physical location and landform play a significant role in determining the vulnerability of coastal communities to disasters.

Therefore, the findings of this study emphasize that geographic and physical environmental factors should be the primary basis for developing disaster risk reduction policies in schools. Possible strategies include the development of vertical evacuation infrastructure, mapping evacuation routes based on Geographic Information Systems (GIS), and integrating spatial data into regional spatial planning. These efforts align with the Perera et al. (2022) recommendations, which emphasize the need for local policy adaptation based on the specific geographic conditions of tsunami-prone areas. Considering these conditions, it can be concluded that the physical environmental characteristics of schools on the southern coast of Kebumen Regency, including proximity to the coastline, low topography, and being in a tsunami hazard zone, place them all in the high-risk category.

Level of School Preparedness in Facing the Threat of Tsunami Disaster in the South Coastal Area of Kebumen Regency.

School preparedness for tsunami disasters is a crucial component of disaster risk reduction strategies, particularly in the southern coastal areas of Kebumen Regency, which face high hazard potential due to its location directly facing the Indian Ocean. Referring to the Disaster-Safe Education Unit (SPAB) framework (BNPB, 2019; Ministry of Education and Culture, 2019), preparedness assessments are based on five main indicators: (1) preparedness policies and planning, (2) the presence of school disaster preparedness teams, (3) evacuation routes and points, (4) supporting facilities and infrastructure, and (5) implementation of preparedness simulations and training.

The research found significant variation in preparedness levels among schools. Several schools are categorized as highly prepared. Examples include SD Negeri 2 Waluyorejo, SD Negeri Tegalretno, SD Negeri 3 Tambakmulyo, SMA Negeri 1 Mirit, and SMK Negeri 1 Ambal. These schools have formal, institutionally approved disaster management policy documents, clear evacuation plans, and permanently signposted evacuation routes. School Disaster Preparedness Teams (TSBS) in these schools have been trained to carry out rapid evacuations, manage assembly points,

and provide first aid. Supporting facilities include first aid kits, emergency communication devices, disaster risk information boards, and easily accessible assembly points.

This preparedness is inseparable from close collaboration with external parties, such as the Regional Disaster Management Agency (BPBD), the Indonesian Red Cross (PMI), village and sub-district officials, and local communities, who provide training, technical support, and assistance in developing evacuation plans. Interestingly, this collaboration comes not only from external parties but also from the schools themselves, actively inviting BPBD, PMI, and local officials to provide outreach, simulations, and training. Routine evacuation simulations are held at least once a year, involving these parties, so that the entire school community has firsthand experience in self-rescue procedures.

These findings align with research by Rico (2019), which emphasized that the existence of formal policies, preparedness teams, adequate facilities, support from external stakeholders, and school proactivity in building partnership networks significantly impacted school emergency response capacity.

Conversely, a number of schools were categorized as underprepared. These schools lacked formal disaster policies, lacked well-marked evacuation routes, and lacked supporting facilities such as emergency communication devices or evacuation information boards. Evacuation simulations, if any, were conducted sporadically and without the involvement of external parties, severely limiting the school community's emergency response skills. This lack of training directly impacted students' and teachers' low understanding of self-rescue procedures. This situation aligns with the findings of Wiratuningsih, Setyowati, and Suhandini (2018) in Semarang, which showed that schools without regular simulation programs had a high rate of evacuation errors, despite being located in areas prone to tidal flooding.

One important finding of this study was that the level of preparedness did not always correspond to the level of geographic risk. Several schools in red zones, where preparedness should be prioritized, actually performed poorly. Conversely, some schools in the yellow zone have high levels of preparedness. This phenomenon indicates that internal school factors, such as principal leadership, active teacher and student involvement, a culture of disaster awareness, and community partnerships, have a significant influence on preparedness. This finding is consistent with a study by Jones et al. (2010), which emphasized that strengthening internal capacity can significantly reduce disaster vulnerability, even in high-risk areas.

Limited resources are a major challenge for schools with low levels of preparedness. Insufficient training budgets, a lack of evacuation equipment, and poor coordination with disaster management agencies hamper efforts to improve school capacity. Research by Setyowati and Rachman (2016) also shows that the successful implementation of community preparedness programs is heavily influenced by the availability of resources, both material and human. Without adequate support, even schools that are aware of the risks struggle to improve their preparedness. Referring to the BMKG, estimate that tsunami waves in southern Java can arrive less than 30 minutes after a triggering earthquake, response speed is crucial. Schools in coastal areas need simple but efficient evacuation procedures, , barrier-free routes, and regular drills that internalize self-rescue reflexes. Without structured drills, the school community's chances of survival will be severely limited given the limited evacuation time.

Considering these findings, strategies to improve school preparedness on the southern coast of Kebumen Regency should focus on three main areas: (1) strengthening formal policies and preparedness institutions at the school level, (2) providing adequate evacuation facilities and infrastructure, and

(3) conducting regular simulations and training involving the entire school community and external parties such as the Regional Disaster Management Agency (BPBD), the Indonesian Red Cross (PMI), and village officials. This approach is not only relevant for Kebumen Regency but can also serve as a model for other coastal areas facing similar tsunami threats.

CONCLUSION

This research shows that the physical environment of schools in the southern coastal area of Kebumen Regency is highly vulnerable to tsunamis. Most schools are located in low-lying areas, close to the coastline, and within the tsunami hazard zone designated by the Regional Disaster Management Agency (BPBD). The uniform topography and lack of natural barriers exacerbate this vulnerability. Therefore, the geography and physical condition of schools must be primary considerations in disaster risk reduction planning in coastal areas.

Schools' tsunami preparedness levels varied, ranging from highly prepared to less prepared. Schools categorized as highly prepared generally have formal policies, adequate infrastructure, and regularly conduct evacuation drills. However, schools still lack a robust preparedness system despite being located in high-risk zones. This indicates that preparedness is influenced not only by geographic location but also by internal school capacities such as leadership, community involvement, and resource availability.

Therefore, a comprehensive and equitable strategy for strengthening preparedness across all schools is needed, including improving human resource capacity, providing evacuation facilities, and integrating disaster education into the curriculum. Collaboration between schools, local governments, and surrounding communities is key to building disaster-safe educational institutions, particularly in coastal areas with a high tsunami threat.

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