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A Comprehensive Flood Risk Analysis in Senior High Schools

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Abstract

Flood disasters are a serious threat to various regions in Indonesia, one of which is Klaten Regency. On February 15, 2023, flooding occurred in Klaten Regency after being hit by heavy rain for 2 days which caused rivers to overflow and embankments to break, entering villages and also several schools, one of which is SMKN 1 Rota Bayat. At this time the flood problem is clearly visible, therefore it is necessary to analyze the level of danger, vulnerability, and risk of flood disasters in Klaten Regency to reduce the risk of flood disasters, especially in school environments. Flood disaster analysis was carried out by utilizing InaRISK data which was then processed and applied using Geographic Information Systems (GIS) through software in the form of ArcGIS. The research method is quantitative research with a survey research design. The results of this study indicate (1) The level of flood danger in Klaten Regency shows that the highest flood danger is found in 5 schools in the south and east, while in the north and west there are 67 schools that are relatively safe from the threat of flooding. (2) There are 39 Senior High Schools and equivalent in Klaten Regency that have a high level of social vulnerability to flood hazards. There are 53 schools with a low level of physical vulnerability to flood hazards. Based on this, it shows that Senior High Schools and equivalent in Klaten Regency are in the high or medium category of vulnerability to flood hazards. (3) The risk of flood disasters in Klaten Regency is categorized into the medium-low class, namely there are 67 schools. It is hoped that this research can determine the level of flood disaster risk in Senior High Schools in Klaten Regency.

Keywords: Flood Disaster, Hazard, Vulnerability, Risk

A. Background

Indonesia is the world's largest archipelagic country and is highly vulnerable to natural disasters. According to the 2023 World Risk Index (WRI), Indonesia ranks second among countries with the highest risk of natural disasters. According to Indonesian Disaster Information Data, 170 disasters were recorded in various regions of Indonesia in July 2024 (BNPB, 2024). A disaster is defined by Law No. 24, 2007, as an event that threatens and disrupts people's daily lives, caused by both natural and non-natural factors, resulting in loss of life, environmental damage, property loss, and psychological impacts.

Natural disasters are caused by a range of phenomena, including floods, landslides, tsunamis, earthquakes, volcanic eruptions, and tornadoes. Natural factors primarily cause natural disasters, but human error is also possible. Non-natural disasters are those caused by human actions, such as industrial accidents, oil leaks, technological failures, and disease outbreaks(Wilujeng & Suryaningsih, 2022). Among the various types of disasters, flooding is one of the most frequent and has a broad impact in Indonesia, especially in densely populated urban and rural areas.

Flooding is a widespread inundation of water, ranging from the smallest to the largest, that can disrupt human activities. Flooding is caused by several factors, both natural (such as heavy rainfall that causes rivers to overflow into residential areas) and human (such as dumping garbage into rivers and building houses near rivers;(Sulaiman et al., 2020)). Rainfall that can cause flooding occurs when it rains for less than an hour at 1.5 mm/hour or greater, resulting in flooding in the area (Sunarhadi, 2001). Flooding not only damages public infrastructure but also affects the education sector, particularly schools. Physical damage to school buildings, such as classrooms, laboratories, and electrical systems, is often severe and is often accompanied by environmental pollution. Furthermore, flooded roads to schools hinder the attendance of students, teachers, and staff, disrupting the teaching and learning process and reducing the quality of education (Farid et al., 2021).

Schools are the primary institutions responsible for providing disaster education. Their role is to increase students' knowledge and understanding of disasters, which in turn affects their environmental awareness and preparedness in facing disaster threats (Ansori & Santoso, 2020). The necessary knowledge and skills can be imparted to children through various means within schools, including practical training and skills development (Muñoz et al., 2020). Students are a vulnerable

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group because they spend a significant amount of time at school, and their activities, especially within the school environment, are exposed to the potential for disasters. Students' knowledge of flooding in their surroundings, both at school and at home, remains very low. Therefore, disaster education in schools is an urgent need to build resilience in the younger generation (Rosida & Adi, 2017).

Schools located in disaster-prone areas may increase safety risks for students, teachers, and other educational staff, while disrupting teaching and learning. To address this, schools in disaster-prone areas must be prepared with adequate preparedness facilities, such as increased disaster knowledge, evacuation simulations, and risk-sensitive school building design (Jendela Pendidikan, & Kebudayaan, 2022). For example, global frameworks such as the Hyogo Framework for Action (HFA) implemented in Japan from 2005 to 2015, and later replaced by the Sendai Framework for Disaster Risk Reduction (SFDRR) from 2015 to 2030 in Sendai, Japan, emphasise the importance of education and community engagement in building a culture of safety and resilience. This framework encourages integrating disaster risk education into the school curriculum, teacher training, and student involvement in community emergency management planning from an early age (HFA, 2007). Thus, disaster risk management can begin before an event occurs, for example, through a comprehensive flood risk analysis to strengthen school resilience and support the continuity of education amidst increasingly diverse threats.

Effective disaster risk management begins with a thorough understanding of the basic elements: hazard, vulnerability, and risk. A hazard is any condition, action, or potential that could cause harm to people, property, activities, or the environment (Supriyadi et al., 2015). Flood hazard can be identified by mapping areas prone to flooding, whether from surface runoff, rainfall, or river flow (Widiawaty & Dede, 2018). Flood hazards not only threaten life but can also cause significant economic losses, worsen sanitation conditions, and impact long-term quality of life. Areas located near rivers or low-lying areas are often the most vulnerable to flooding (Muallif, 2024).

Vulnerability is the level of a community's lack of capacity to prevent, mitigate, achieve preparedness, and respond to the impacts of a particular hazard. Vulnerability encompasses social, cultural, physical, economic, and environmental factors, which can be caused by various factors (BNPB, 2019). Social vulnerability is associated with age and gender. Economic vulnerability relates to employment, poverty, and dependence on natural resources. Physical vulnerability relates to infrastructure, building quality, structure, and age. Environmental vulnerability relates to environmental conditions and limited natural resources. The interaction between hazards and vulnerabilities creates disaster risk, posing a real threat to the continuity of life.

Disaster risk is defined as the potential loss resulting from a disaster occurring in a specific area within a specific timeframe, including death, injury, illness, threat to life, loss of security, displacement, damage or loss of property, and disruption of community activities (BNPB, 2019). Disaster risk results from human actions interacting with nature. Human behaviour is a significant factor in increasing vulnerability and triggering disasters (Hamid et al., 2021). Flood risk can be assessed by evaluating the likelihood of a flood and its severity. Considering risk management through both physical infrastructure and non-physical policies can help mitigate the impact of flooding (USACE, 2016). Flood risk analysis consists of mapping flood hazards, vulnerability, and risk analysis (Kellens et al., 2013).

Areas prone to flooding exhibit various risk characteristics influenced by conditions of elements at risk, such as topography, land use, rainfall, soil type, slope, and proximity to water bodies or inadequate drainage systems. In school environments, crucial risk components (elements at risk) are the school community, including students, teachers, and staff. This risk can stem from internal school factors, such as unsafe behaviour, lack of safety awareness, substandard facilities, or vulnerable building conditions (Indriasari & Kusuma, 2020). Therefore, disaster risk assessments need to be carried out at the spatial (area-based) and unit (school-based) levels so that prepared handling plans are more targeted and effective.

Klaten Regency is one of the areas with a high level of vulnerability to flooding. Based on the Indonesian Disaster Information Data (DIBI) from 2020 to 2024, Klaten Regency experienced 13 floods, resulting in 1 injury, 4,225 people suffering, 648 people displaced, 1 house severely damaged, 1 house lightly damaged, and 593 houses submerged. One such event was heavy rain on Wednesday, February 15, 2023, which caused flooding that reached villages and also inundated several schools, including SMK N 1 Rota Bayat. The flooding inundated the school environment and office space due to the school's location in low-lying areas and to overflowing irrigation channels caused by a broken embankment, which allowed water to enter the school grounds. As a result, teaching and learning activities were temporarily suspended, and students were given time off and switched to online learning (Sunantri, 2023). In Klaten Regency alone, there are 2,037 schools spread across various sub-districts, including 603 kindergartens, 711 elementary schools, 117 junior high schools, 26 senior high schools, 50 vocational high schools, and 88 Islamic elementary schools (DAPODIK, 2024).

Given Klaten Regency's history of flooding, which frequently disrupts access and school facilities in low-lying areas, flood risk analysis for educational institutions is increasingly urgent. Therefore, this study is crucial to determine the flood risk to these educational institutions. Research on the level of flood risk in schools in Klaten Regency has not been conducted. However, this research is relevant to a recent study (Rinaldi & Permana, 2019)that examined disaster vulnerability in schools in Bandung City. Research (A'yun & Handawati, 2022) examined the vulnerability of buildings to flooding in Cakung District, East Jakarta. Research (Dahlia & Fadiarman, 2020) examined flood risk analysis for educational facilities in DKI Jakarta. Research analysing flood risk in educational settings is crucial, yet remains rare. This study aims to analyse the levels of danger, vulnerability, and flooding risk in senior high schools in Klaten Regency. This research is expected to contribute to the development of flood risk reduction in school settings.

B. Method

1. *Research Location*

This research was conducted at senior high schools in Klaten Regency, Central Java, at the coordinates -7.674623, 110.5403396. The research location encompasses 72 senior high schools, both public and private, spread across 26 sub-districts in Klaten Regency.

2. *Data Collection Technique*

a. Population

Population refers to the entire group with specific characteristics that is the focus of the research, which can be the entire group of people, objects, or events relevant to the research objectives (Wajdi et al., 2024). The population used includes high schools and their equivalents spread across Klaten Regency. The flood-prone areas are the primary focus of this study, including the districts of Jogonalan, Wedi, and Karanganom, which are located along the Bengawan Solo River and often experience flooding from river overflow during the rainy season (BPS, 2023).

b. Sample

A sample is a small portion of a population selected for observation or measurement in a study. Sampling in this study used a stratified random sampling technique, where the population is divided into strata (groups based on the characteristics of the inarisk flood hazard level). From each stratum, samples were randomly selected in appropriate proportions (Sugiyono, 2021). The sample used in this study was 72 schools. Validation of the flood hazard raster sampling, in which location points were extracted from the inarisk flood hazard level data, ensured that the sample spanned a range of flood risk levels from very low to very high.

c. Research Instrument

1) Hazard

Flood hazard is assessed using Inarik's flood hazard classification, which has been reclassified into five classes. The results of this classification are used to create a temporary map of flood hazard zones. Subsequently, direct field observations and brief interviews regarding flooding events are conducted to ensure the map data aligns with actual conditions.

Table 1. Interview Guidelines

No.	Indicators
1.	Flood occurrence
2.	Time of flood occurrence
3.	Flood height
4.	Flood impact

2) School Vulnerability

A flood vulnerability analysis of senior high schools in Klaten Regency was conducted using physical, social, and total vulnerability parameters derived from 2024 Dapodik data, which were subsequently refined based on field validation results. Field validation was conducted through a site survey and analysis of slope gradient, land use, and distance from the river.

Table 2. School Vulnerability Validation Observation Sheet

Variable	Parameter	Amount	Weight	Infomation	source
Social Vulnerability (0.6)	School Community	people	0,6	The greater the number of school residents (students, teachers, and educational staff), the greater the potential for flooding if inundation occurs within the school environment.	Basic Education Data/ Data Pokok Pendidikan (DAPODIK)
	Student Gender Ratio	people	0,1	The male-to-female student ratio is used to assess differences in vulnerability to flooding.	Basic Education Data/ Data Pokok Pendidikan (DAPODIK)
	Teacher and Staff Gender Ratio	people	0,3	The ratio of male to female teachers and educational staff reflects social capacity and preparedness for flooding.	Basic Education Data/ Data Pokok Pendidikan (DAPODIK)
Social Vulnerability (0.6)	Buildings Above Flood Levels	Unit	0,4	School buildings located in flood-prone areas or low-lying areas are at risk of inundation.	Field survey

	Drainage	Unit		The availability and condition of drainage channels around the school environment affect the speed of water flow during heavy rain.	Field survey
	Building Materials	Unit		The type of materials used in school buildings, such as walls, wood, or a mixture, determines the level of resistance to inundation.	Field survey
	Foundation	Unit		The strength and stability of the school building's foundation against water pressure or erosion caused by flooding.	Field survey
	Building Age	Unit		The older the building, the more vulnerable it is to flood damage.	Field survey
	Building Top	Unit		The condition of the roof and superstructure can affect the potential for leaks or damage during heavy rain and flooding.	Field survey

3. *Data Analysis Techniques*

a. *Flood Hazard Analysis*

1) Using Inarisk: Inarisk is a disaster risk assessment portal that displays information on disaster threats, vulnerabilities (population, physical, economic, and environmental losses), capacity, and disaster risks. Inarisk can also display disaster risk index monitoring (BNPB). The results of this analysis are displayed as a flood hazard map.
2) The stages include:
   a) Reclassify: The process of reclassifying data based on flood hazard parameters (e.g., rainfall, elevation, and river flow patterns). The data are then divided into five hazard levels: very low, low, moderate, high, and very high.
   b) Tentative Flood Map: The results of this classification are used to create a temporary map of flood hazard zones.
   c) Field Survey: Direct field observations are conducted to ensure the map data matches actual conditions.
   d) Final Flood Hazard Map: The flood hazard map is refined based on field observations.

b. *Flood Vulnerability Analysis*

Flood vulnerability analysis is a crucial step in disaster risk reduction efforts, considering various factors such as social, economic, physical, and environmental. A school's social vulnerability to flooding encompasses factors such as the school community, the student gender ratio, and the gender ratios of teachers and other educational staff. A school's physical vulnerability to flooding involves the condition of its buildings and supporting infrastructure, as well as its geographic location. A vulnerability analysis will reveal how students, teachers, and school assets are likely to be exposed to flood hazards and how to identify risk factors that can be avoided. The results of this analysis will be displayed as a flood vulnerability map.

c. *Flood Risk Analysis*

Flood risk analysis aims to quantify potential losses and impacts from flooding in the school environment. The risk analysis is assessed by calculating the flood hazard value, the vulnerability level, and the school's capacity to address it. The hazard, vulnerability, and flood risk analyses are then compiled into a framework for flood disaster risk analysis. The results of this analysis will be displayed as a flood risk map. In this study, risk analysis is calculated using the risk matrix in Figure 1, derived from the hazard and vulnerability analysis results.

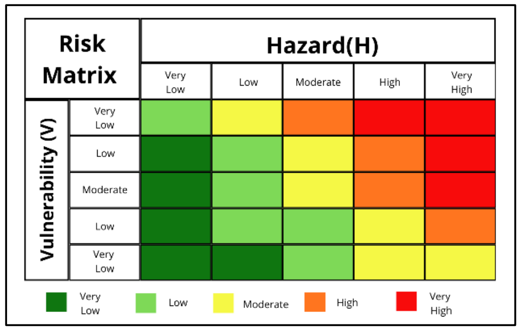

Figure 1. Risk Matrix

C. Results and Discussion

1. *Flood Hazard*

a. Broad Hazard Class

The results of the flood hazard analysis using the InaRisk map in Klaten Regency show the areas likely to experience flood impacts. The very low category covers an area of 25.7 km. It is generally located on higher ground, so the possibility of waterlogging is very minimal, as seen in Karangnom, Ngawen, Kemalang, and Jatinom Districts. The low category covers an area of 39.5 km, characterised by areas with good slopes and natural drainage systems that are still effective in accommodating flowing rainwater, such as Polanharjo, North Klaten, Kebonarum, Manisrenggo, Prambanan, Karangnongko, and Delanggu Districts. The medium category covers an area of 63.5 km in the Pedan, Ceper, Kalikotes, and Jogonalan Districts, as well as parts of Central Klaten and South Klaten. The high category covers an area of 61.1 km, including the Kalikotes, Trucuk, Pedan, and Wonosari districts. The very high category covers an area of 42.6 km, including the districts of Karandowo, Cawas, Bayat, Wedi, and Gantiwarno.

b. *Map per parameter*

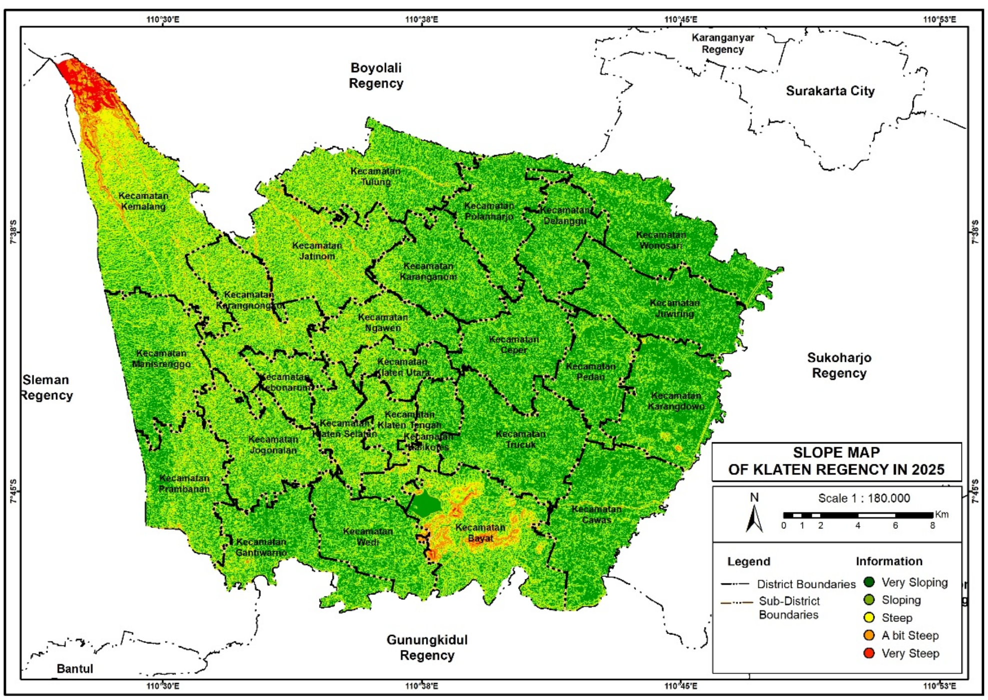

Figure 2. Slope Map

c. *InaRisk Flood Hazard Map*

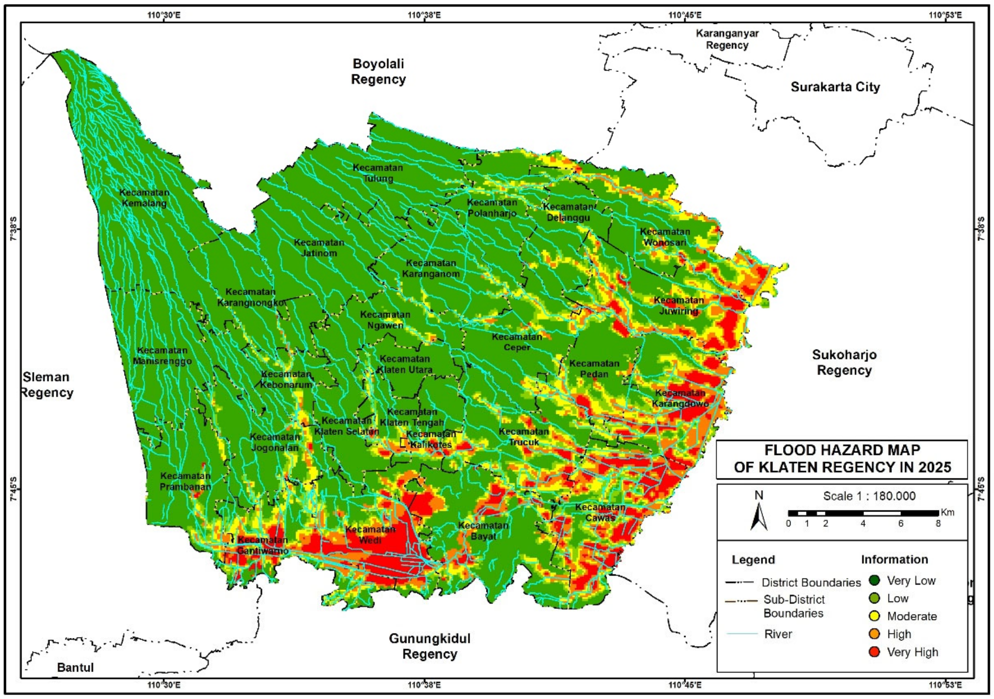

Figure 3. Flood Hazard Map

The flood hazard analysis results are based on the reclassification of InaRisk data. The flood hazard level in Klaten Regency shows that the southern and eastern regions are the most at risk, while the northern and western regions are relatively safe from flooding. Very high flood hazard levels are found in the districts of Wedi, Bayat, Cawas, Juwiring, Karangdowo, and Gantiwarno, and in parts of Trucuk and Wonosari. High flood hazard levels are found in areas with a high hazard level. Moderate flood hazard levels are found around the districts of Pedan, Ceper, Kalikotes, and Jogonalan, as well as parts of Central and South Klaten. Low and very low flood hazard levels are found in the northern and western regions, such as the districts of Polanharjo, Karangnom, North Klaten, Ngawen, Kemalang, Jatinom, Tulung, Manisrenggo, Kebonarum, Prambanan, Karangnongko, and Delanggu. Based on this, the majority of flood hazard levels in Klaten Regency indicate that the highest flood hazard is found in the southern and eastern regions.

In contrast, the northern and western regions are relatively safe from flooding. The flood hazard level is very high because this area is a lowland near the Dengkeng River, the main irrigation channel for agriculture in Klaten, which originates at Mount Merapi. This river receives numerous tributaries and irrigation channels, so its discharge is influenced by rainfall intensity upstream and drainage activities in the surrounding area. High-hazard areas are along the main river's flow path; they often receive runoff from upstream areas and the main river. Settlements located in basin areas can also be vulnerable to seasonal flooding, even though they are not near large bodies of water or floodplains (Khan et al., 2025). The medium hazard level is more widespread in areas around tributaries and irrigation channels that flow into the Dengkeng River. Low-hazard levels are around areas that are relatively higher and farther from the river. The very low level of danger is found in hilly areas with higher topography and not crossed by large rivers; even though they are on gentle slopes, they also contribute to determining the region's vulnerability pattern (Musiyam, 2020).

d. *Field Validation*

The results of the field validation analysis using *Inarisk* map show that the flood hazard level is very high in Klaten Regency. 8 points experienced flooding, and 2 did not. The high flood hazard level is 3 points experiencing flooding and 4 points not experiencing flooding; the moderate flood hazard level is 3 points experiencing flooding and 4 points not experiencing flooding. The low flood hazard level is 2 points (experiencing flooding) and 3 points (not experiencing flooding). The very low hazard level is 2 points for experiencing flooding and 3 points for not experiencing flooding. The validation results show that areas that have experienced flooding are areas around the large Dengkeng River, usually occurring when continuous rain causes water to overflow into settlements, including Cawas, Bayat, Wedi, and Gantiwarno Regencies.

2. *School vulnerability*

a. *Social Vulnerability*

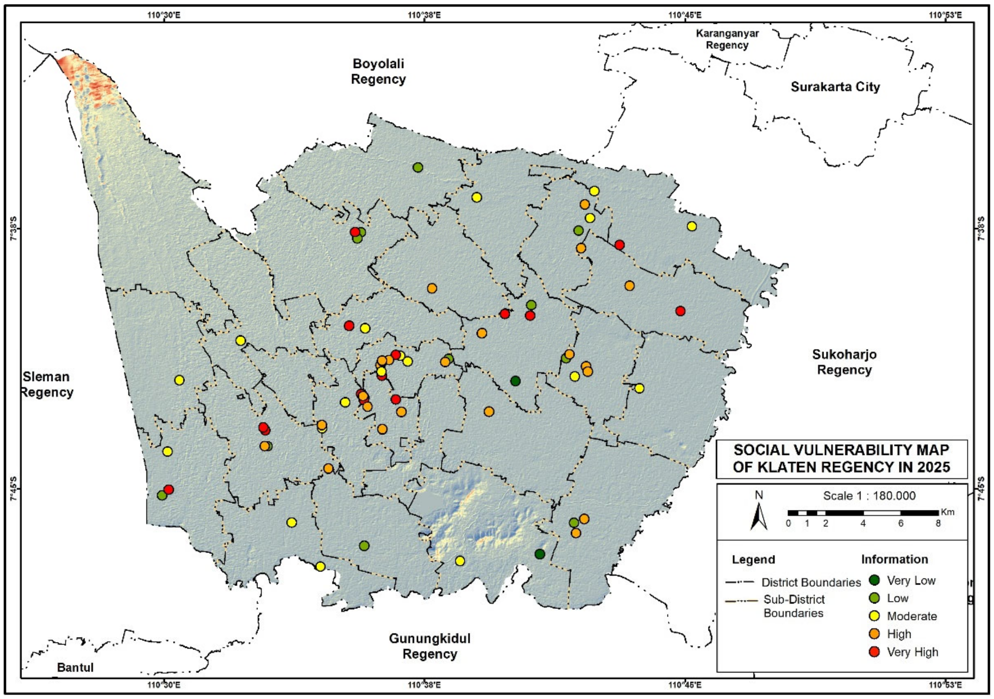

Figure 4. Social Vurnerability Map

Table 3. Social Vulnerability Result

Class	Number of Schools (Units)
Very high	15
High	24
Moderate	20
Low	11
Very Low	2

The results of the social vulnerability analysis are based on calculations from Dapodik data. Using the following parameters: School Community, Student Gender Ratio, Teacher and Staff Gender Ratio, the level of social vulnerability in the school environment appears quite alarming. 15 schools were found to have very high levels of social vulnerability, and 24 had high levels, indicating that most schools still have significant levels of social vulnerability. Meanwhile, 20 schools had moderate levels of social vulnerability, 11 had low levels, and only 2 had very low levels. Girls are often considered more vulnerable during disasters.

The social vulnerability of high schools in Klaten Regency is high, indicating a high risk of flooding. It is based on the age and gender ratio of students, teachers, and staff. Boys tend to be more responsive during disasters, but girls are more adaptive over the long term. Schools are vulnerable to flooding due to factors such as their proximity to large rivers, limited disaster simulation training, and a lack of flood-prevention facilities. Therefore, starting with the simplest things, namely by increasing awareness from all parties, both the community and schools, conducting disaster simulation training at least twice a year, creating an early warning system, making preparedness plans, and mobilising resources. Disaster knowledge needs to be emphasised by all schools, not only for students but for all school residents. However, focusing solely on knowledge requires self-awareness, as it directly influences responses to emergencies (Hafida, 2018). Disaster knowledge is not differentiated for male or female students. Disaster learning can take the form of the latest disaster materials, with fun and varied learning methods and unique yet enjoyable learning media (Dewi et al., 2025).

b. *Physical Vulnerability*

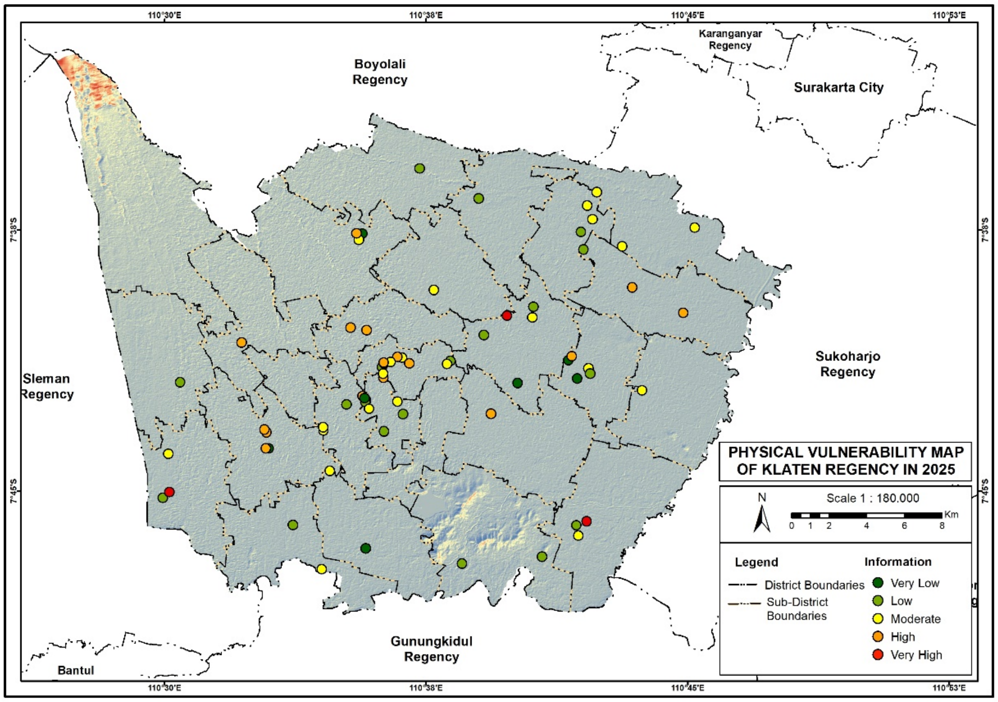

Figure 5. Physical Vulnerability Map

Table 4. Social Vulnerability Result

Class	Number of Schools (Units)
Very high	15
High	24
Moderate	20
Low	11
Very Low	2

The results of the physical vulnerability analysis are based on calculations from Dapodik data. Using the following parameters: the number of classrooms, laboratories, mosques, and libraries, and the structural condition of the buildings, the level of social vulnerability in the school environment appears quite alarming. Three schools were found to have very high levels of physical vulnerability, and 16 schools had high levels, indicating that most schools still have significant levels of physical vulnerability. Meanwhile, 26 schools had moderate levels of physical vulnerability, 20 had low levels, and only 7 had very low levels.

The physical vulnerability of high schools and their equivalents in Klaten Regency is low, indicating a low risk of flooding. This is based on school buildings that have adapted to flood conditions, such as being built with two or three stories, elevated foundations, and a smooth drainage system (Alfarizi et al., 2024). Good facilities and building foundations can benefit the entire school community in the event of a disaster, such as halls/fields that can be used as assembly points and evacuation sites. The school is not vulnerable to flooding because of its location, which is far from the river. Good school facilities and foundations can benefit the entire school community and the community in the event of a disaster, such as a hall or field that can be used as a gathering point or evacuation site (Wibowo et al., 2024).

c. *Total Vulnerabillity*

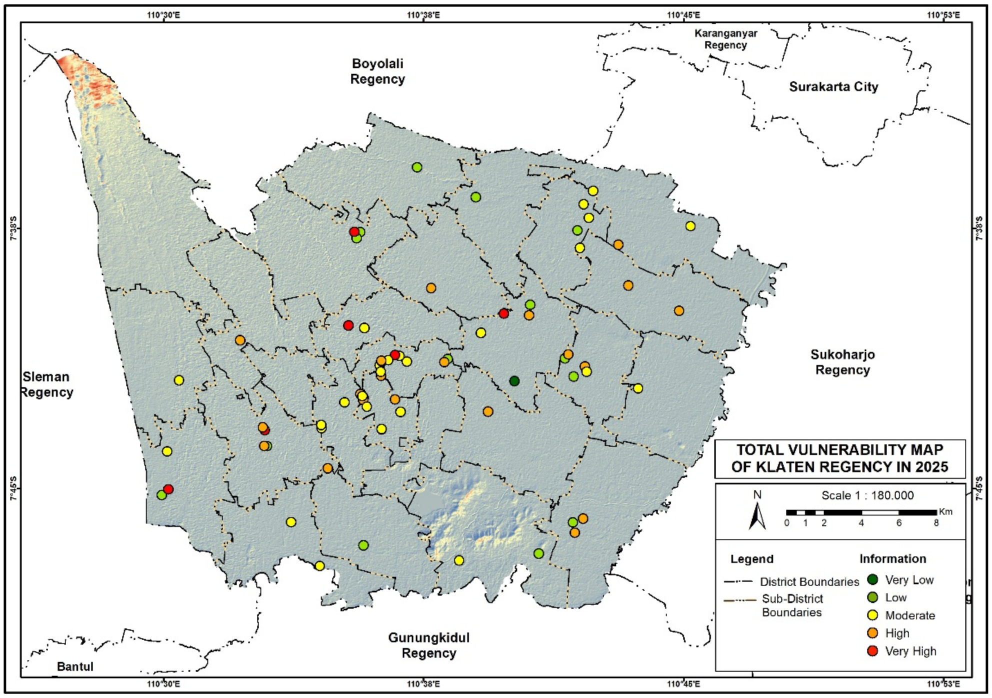

Figure 6. Total Vulnerability Map

Table 5. Total Vulnerability Results

Class	Number of Schools (Units)
Very high	6
High	22
Moderate	29
Low	14
Very Low	1

The total vulnerability analysis, based on Dapodik data, indicates that the total vulnerability of senior high schools and equivalents in Klaten Regency falls in the high or moderate category. Six schools have very high vulnerability, and 22 schools have high vulnerability, indicating that most schools still have significant levels of vulnerability. Meanwhile, 29 schools have moderate vulnerability, 14 schools have low vulnerability, and only one school has very low vulnerability.

The total vulnerability of Klaten Regency remains serious, requiring close attention, especially for schools with high to moderate vulnerability levels. Therefore, it is necessary to re-emphasise the importance of improving school resilience, including strengthening infrastructure, conducting regular evaluations, improving supporting facilities, conducting disaster simulation training for all school members, updating preparedness programs, and fostering collaboration among schools, the government, and the community. It can reduce the impact of vulnerability and create a disaster-safe environment for all students.

3. *Flood Disaster Risk*

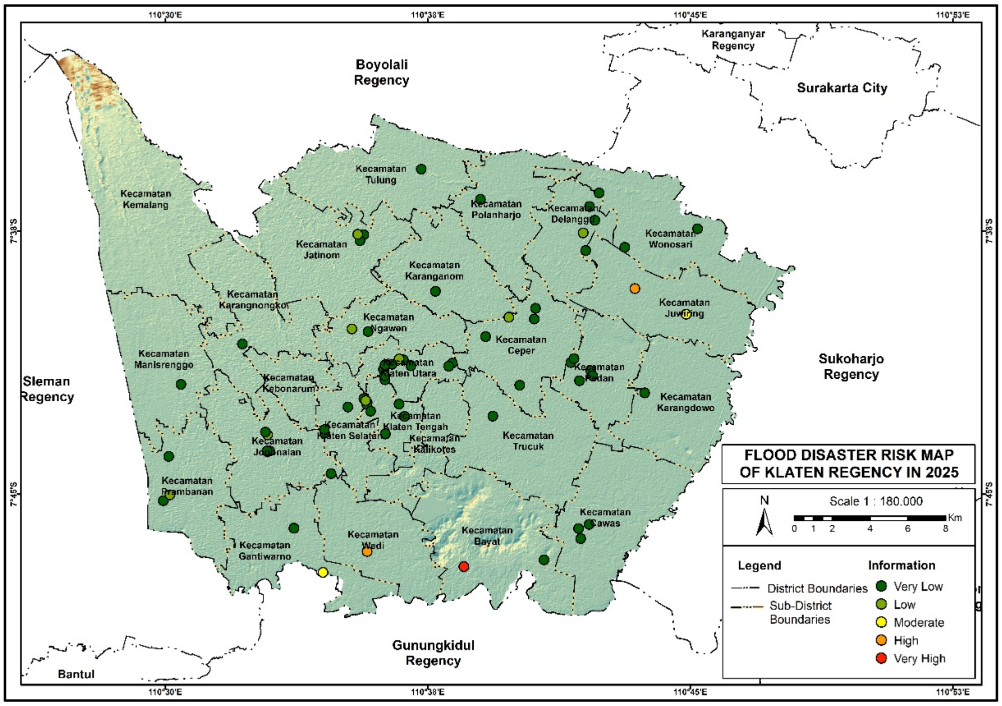

Figure 7. Flood Risk Maps

Table 6. Flood Disaster Risk Results

Class	Number of Schools (Units)
Very high	6
High	22
Moderate	29
Low	14
Very Low	1

The risk analysis results are based on hazard and vulnerability data calculations adjusted for the disaster risk analysis matrix. These data indicate that the disaster risk analysis for high schools and their equivalents in Klaten Regency appears good. One school has a very high risk level, and two schools have a high risk level, indicating that most schools still face a significant level of risk. Meanwhile, two schools have a moderate risk level, eight schools have a low risk level, and only 59 schools have a very low risk level.

It indicates that the flood risk level for high schools and their equivalents in Klaten Regency is categorised as medium-low. Previous mitigation efforts have been quite effective in reducing potential losses. Flood hazards are influenced by geographical factors such as land elevation and drainage systems. Therefore, each school is advised to improve infrastructure development and conduct preparedness training at least twice a year to minimise adverse impacts on school facilities, learning activities, and the safety of all school members. Although some schools still face an exceptionally high flood risk.

D. Conclusion

Based on the data analysis presented above, it can be concluded that 1) the highest level of flood danger in Klaten Regency is in the southern and eastern regions. At the same time, the northern and western parts are relatively safe from flooding. The highest level of flood danger is spread across the Districts of Wedi, Bayat, Cawas, Juwiring, Karangdowo, Gantiwarno, and part of Trucuk, as well as Wonosari. Meanwhile, the lowest level of flood danger is around a very low spread in the northern and western regions, such as the Districts of Polanharjo, Karangnom, North Klaten, Ngawen, Kemalang, Jatinom, Tulung, Manisrenggo, Kebonarum, Prambanan, Karangnongko, and Delanggu. 2) Social vulnerability of Senior High Schools and equivalent in Klaten Regency shows that they have a high level of vulnerability to flood danger, where all school residents need disaster simulation training that is carried out routinely at least 2x in 1 year. The physical vulnerability of high schools and equivalent schools in Klaten Regency is low, indicating a need for regular inspections of school buildings, adequate facilities, and routine cleaning of drainage systems. The calculation of social and physical vulnerability yields a total vulnerability score, with high schools and equivalent schools in Klaten Regency falling into the high or medium categories of vulnerability to flooding. 3) The risk of flooding in Klaten Regency is categorised as medium-low. Although the risk level is moderate, regular inspections of buildings and facilities, drainage repairs, catchment area rehabilitation, and strengthening disaster education for all school residents and the community are still needed.

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