An Analysis of Elementary School Vulnerability in Flood-prone Areas, Sukoharjo, Indonesia

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ABSTRACT
The impact of the flood not only resulted in paralyzed social, economic, and community activities but also resulted in stopping educational activities. Unfortunately, few studies have examined the vulnerability of the school environment in flood-prone areas. This study aims to analyze the vulnerability of elementary schools in flood-prone areas, Grogol sub-district, Sukoharjo, Indonesia. The sample in this study were all elementary schools located in flood-prone areas, Grogol, Sukoharjo, Indonesia. Vulnerability variables in this study are social and physical variables that are in accordance with the actual conditions of the school. The data analysis technique used in this research is classification and weighting using standard deviation and average deviation. Each variable consists of parameters analyzed, weighted, and classified according to the magnitude of the effect on vulnerability or potential loss if a flood occurs. The results of data analysis show that Kadokan 1, Madegondo 1, Pandeyan 1, Pandeyan 2 State Elementary School belong to the very high vulnerability class, and Madegondo 3 State Elementary School belongs to the high vulnerability class. These results indicate the need for efforts to increase school capacity in dealing with flood disasters.

Keywords: Capacity, disaster, flood, school Safe, vulnerability

1. INTRODUCTION

Flood disaster is one of the disasters that occurs every year in several regions in Indonesia [1] [2]. One of the causes of flooding is the flow rate that exceeds the capacity of the river/channel, causing inundation in the downstream area [3]. In 2020 there have been 641 flood disasters in Indonesia, resulting in 49 dead and missing, 18 injured, 627,825 victims affected and displaced, 917 houses heavily damaged, 2,123 houses moderately damaged, and 9,084 houses lightly damaged, 88,668 houses submerged (BNPB, 2020). In addition, the disaster also damaged public facilities, including 23 health facilities, 75 worship facilities, and 87 educational facilities.

Central Java is one of the provinces in Indonesia that is most frequently affected by floods. According to data from http://dibi.bnpb.go.id/, in 2020, the number of flood disasters in Central Java was 235 incidents, these incidents resulted in four deaths and missing and 758 displaced. The victims affected include the elderly, adults, and children. Furthermore, the flood disaster caused casualties and damaged public facilities or

buildings. Therefore, efforts to reduce disaster risk are needed in flood-prone areas.

Vulnerability studies in flood-prone areas can be used as a basis for disaster risk analysis [5]. They can be used as a basis for determining disaster risk reduction priorities. Vulnerability is a community condition starting from physical and non-physical processes [6]. Vulnerability is a characteristic of an aspect of a problem of concern, such as a community, system, or asset independent of the level of exposure [7] [8]. The susceptibility parameters of each region are not always the same. Therefore, vulnerability parameters are determined based on the condition of an area or community.

Community vulnerability starts from environmental, physical, social, and economic conditions that pose a risk to the community [7].Internal and external dynamic pressures cause this unsafe condition. Dynamic stress occurs because of an underlying problem [5]. Internal problems are usually caused by the inability of society to obtain the resources desired by humans, and the economy is not externally appropriate. Therefore, disaster management must be carried out entirely by

increasing capacity and addressing the causes of total risk reduction (Setyowati, 2019).

One of the priorities in disaster risk reduction is the primary school environment. The primary school environment is very vulnerable due to the structural conditions of the building, the knowledge of the teacher and student community, and the capacity of the teacher and student community. To increase the capacity of school residents, it is necessary to develop a disaster-resilient community. The development of disaster-resilient communities can be done through education in schools called Disaster Risk Reduction Education (DRR). Through education, disaster risk reduction efforts are expected to introduce disaster knowledge to students earlier (Setyowati, 2019).

Sukoharjo Regency is one of the regencies in Central Java province that floods can affect. According to BNPB data in 2019, Sukoharjo Regency was affected by floods that involved 905 people, 550 of whom had to evacuate. Based on the Regional Regulation on RTRW of Sukoharjo Regency, the flood-prone area of Sukoharjo Regency includes several sub-districts, namely Weru, Sukoharjo, Polokarto, Mojolaban, and Grogol Districts. Grogol sub-district is prone to flooding because it is traversed by the Bengawan Solo River, the longest river on the island of Java. The floods that hit Grogol District several times were caused by the overflow of the Bengawan Solo River [10]. The flood incident caused Cemani, Madegondo, Banaran, Sanggrahan, Pandeyan, and Kadokan to be flooded [11].

One of the most significant flood events occurred in December 2007. The flood incident significantly disrupted community activities because of economic, social, and educational infrastructure. The paralysis of educational activities is very much against the principle of education, in which under any circumstances, education must still be implemented. Therefore, it is necessary to increase the capacity of school residents in the Grogol District.

Grogol sub-district has 44 elementary schools. Many primary schools make school residents vulnerable if they are not equipped with good disaster capacity. Indeed, not all of these elementary schools are located in flood-prone areas. Still, it does not rule out the possibility of experiencing the effects of flooding, even if not directly. Furthermore, in a specific return period, flooding may occur with tremendous intensity and cause the affected area to become more comprehensive.

The survey results and identification are based on a map of flood-prone areas in the Sukoharjo Regency. There are five elementary schools located in the regions prone to flooding. SDN Madegondo 01, SDN Madegondo 03, SDN Kadokan 01, SDN Pandean 01, and SDN Pandean 02. These schools do not yet have the status of a Disaster Safe Education Unit (SPAB), so the integration of disaster materials has not been massively carried out. Therefore, it is necessary to study the elementary school environment's vulnerability. The

results can be used as one of the bases for the proposal to establish a Disaster Safe Education Unit (SPAB). The vulnerability assessment results can also be used as a basis for determining appropriate disaster risk reduction priorities for these schools.

Vulnerability studies that have been carried out previously have primarily analyzed the Vulnerability of the area or the community's Vulnerability research on the vulnerability of the school environment has not been widely carried out in Indonesia. Therefore, it is necessary to carry out a vulnerability assessment in the primary school environment to ensure the continuity of education in disaster-prone areas. This study aims to analyze the vulnerability of elementary schools in flood-prone areas of the Sukoharjo Regency. The vulnerability parameters were adjusted to school conditions and benchmarking results from several previous studies. The determination of the weight and score of each vulnerability parameter is a modified result of the BNPB Perka, 2012. The results of this study are expected to be used as a basis for decision-making to reduce disaster risk in the elementary school environment.

2. METHOD

The approach in this research is quantitative with a survey design. Data collection techniques used are interviews and documentation. The instruments used are interview guidelines and questionnaires. This research was conducted in the Flood Disaster Area, Grogol District, Sukoharjo Regency. The subjects of this study were elementary schools located in flood-prone areas (KRB) in Grogol District, while the object of this study was the vulnerability of elementary schools to flood disasters. The sample was determined based on the Sukoharjo Regency Flood Prone Area Map published by the Sukoharjo Regency Spatial Plan. The sample used is all elementary schools located in flood-prone areas in Grogol District. The schools are Kadokan 1, Madegondo 1, Madegondo 3, Pandeyan 1, and Pandeyan 2 State Elementary School.

Vulnerability variables in this study are social and physical variables. Social variables are related to human or community aspects in schools, while physical variables are physical and structural aspects of school buildings. Each of these variables is adjusted to the conditions of the school and components that are potentially exposed to hazards. The social and physical variables in this study are composed of parameters that are very crucial in disaster management in schools.

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Table 1. the vulnerability variable and parameters of elementary schools

Vulnerability variables	Vulnerability Variable Weight (%)	Vulnerability parameter (element at risk)	Weighted parameters in each variable of vulnerability (%)	Data source
Social	60	Number of school residents including principals, teachers, teaching staff (people)	60	Field survey and interview
		Teacher sex ratio (%)	10	Field survey and interview
		Student sex ratio (%)	30	Field survey and interview
Physical	40	Number of classrooms (units)	40	Field survey and interview
		Number of laboratory rooms, libraries, teacher rooms, and other rooms other than classrooms (units)	20	Field survey and interview
		The structural condition of school buildings	40	Field survey and interview

Source: [12] and field survey, 2021

Elementary school vulnerability analysis was carried out by grouping the social and physical vulnerability variables' vulnerability parameters (element at-risk) based on their class. Each vulnerability parameter (element at risk) is classified into five categories. The class is obtained from calculations using the average deviation and standard deviation equations.

Standard deviation: $\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$ (1)

Average deviation: $S = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - x)}$-2 (2)

Table 2. Vulnerability levels, scores, and weights

Classes	Score	Weights
Very high	5	4.2 - 5
High	4	3.4 – 4.2
Moderate	3	2.6 – 3.4
Low	2	1.8 – 2.6
Very low	1	< 1.8

Source: Data analysis, 2021

Each social and physical vulnerability variable component is given a score according to its classification. The score given is between 1, 2, 3, 4, or 5, depending on the calculations that have been done previously. Furthermore, the score is then multiplied by the weight of each risk component in each vulnerability variable. The multiplication results are then added up according to each vulnerability variable (social and physical). The total weight (score x weight of the risk component) on each vulnerability variable (social and physical) is summed. The results are used to determine the total vulnerability class. The whole vulnerability class is calculated by the average and standard deviations equation, such as deciding each vulnerability variable's class of risk components/parameters. The conversion of the environmental vulnerability index of elementary schools in flood-prone areas is presented in the following equation:

Total vulnerability = (0.6 × social vulnerability score) + (0.4 × physical vulnerability score)

3. RESULT AND DISCUSSION

3.1. Result

3.1.1. Social Vulnerability

Social Vulnerability in this study consists of the parameters of the number of school residents and the sex ratio of school residents. School residents include school principals, teachers, education staff, and students. At the same time, the gender ratio is the number of female school residents to male school residents. The determination of these parameters was adapted from the decree of the Indonesian National Disaster Management Agency (BNPB) number 12, 2012, and adapted to school conditions. School vulnerability based on the parameters of school residents shows different classes (Table 3). There are three schools with a very high vulnerability class and a high and low vulnerability class, one school each.

Table 3. Schools vulnerability based on school community parameters

Schools	Number of School Community			Total	Score	Weight	Level
	Principal and teacher	Staff	Students				
Kadokan 1 State Elementary School	9	2	168	179	5	3	Very high
Madegondo 1 State Elementary School	19	0	326	345	5	3	Very high
Madegondo 3 State Elementary School	10	0	47	57	2	1.2	Low
Pandeyan 1 State Elementary School	11	2	126	139	5	3	Very high
Pandeyan 2 State Elementary School	9	0	100	109	4	2.4	High

Source: Analysis, 2021

There are variables in the gender ratio parameter, including the number of teacher and student sex ratios. Teacher Gender Ratio is the ratio between the number of male and female teachers. The results of data analysis show that all schools in the flood-prone area of the Grogol sub-district are included in the very high vulnerability class (Table 4).

Table 4. Schools vulnerability based on Teacher Gender Ratio Parameters

Schools	Total	Score	Weight	Level
Kadokan 1 State Elementary School	81.82	5	0.5	Very high
Madegondo 1 State Elementary School	68.42	5	0.5	Very high
Madegondo 3 State Elementary School	100.00	5	0.5	Very high
Pandeyan 1 State Elementary School	50.00	5	0.5	Very high
Pandeyan 2 State Elementary School	55.56	5	0.5	Very high

Source: Analysis, 2021

Student Gender Ratio is the ratio between male and female students. The results of data analysis show that the five schools are included in the very high vulnerability class (Table 5). This indicates that female students are more dominant than male students.

Table 5. Schools vulnerability based on Student Gender Ratio Parameters

Schools	Total	Score	Weight	Level
Kadokan 1 State Elementary School	42.68	5	1.5	Very high
Madegondo 1 State Elementary School	50.47	5	1.5	Very high
Madegondo 3 State Elementary School	37.68	5	1.5	Very high
Pandeyan 1 State Elementary School	43.10	5	1.5	Very high
Pandeyan 2 State Elementary School	42.34	5	1.5	Very high

Source: Analysis, 2021

The level of vulnerability is based on social vulnerability variables consisting of school residents' weight and the sex ratio of teachers and students. Table 6 shows the very high vulnerability class in Kadokan 1, Madegondo 1, Pandeyan 1, and Pandeyan 2 State Elementary School with a 5 and 4.4. At the same time, Madegondo 3 has a medium-class with a weight of 3.3.

The weight is determined utilizing the score multiplied by 0.6.

Table 6. Schools vulnerability based on social variable

Schools	School Community Parameters		Teacher Gender Ratio Parameters		Student Sex Ratio Parameter		Social Vulnerability	
	Weight	Level	Weight	Level	Weight	Level	Weight	Level
Kadokan 1 State Elementary School	3	Very high	0.5	Very high	1.5	Very high	5	Very high
Madegondo 1 State Elementary School	3	Very high	0.5	Very high	1.5	Very high	5	Very high
Madegondo 3 State Elementary School	1.3	Low	0.5	Very high	1.5	Very high	3.3	Medium
Pandeyan 1 State Elementary School	3	Very high	0.5	Very high	1.5	Very high	5	Very high
Pandeyan 2 State Elementary School	2.4	High	0.5	Very high	1.5	Very high	4.4	Very high

Source: Analysis, 2021

3.1.2. Physical Vulnerability

Parameters of school facilities consist of the number of classrooms and the number of laboratory rooms, libraries, and other rooms besides classrooms. These facilities are calculated using a formula and classified according to the data analysis technique presented in the research methods section. The results of the vulnerability data analysis based on the number of classrooms showed that the five schools were included in the very high vulnerability class (Table 7). These results were obtained by calculating the score multiplied by the weight of the classroom parameters (0.4).

Table 7. Schools vulnerability based on classroom parameters

Schools	Number of Class Room								Total	Score	Weight	Level
	1	2	3	4	5	6	Inclusive Class	Christian Religious Room				
Kadokan 1 State Elementary School	1	1	1	1	1	1	1	0	7	5	2	Very high
Madegondo 1 State Elementary School	2	2	2	2	2	2	0	0	12	5	2	Very high
Madegondo 3 State Elementary School	1	1	1	1	1	1	0	1	7	5	2	Very high
Pandeyan 1 State Elementary School	1	1	1	1	1	1	0	0	6	5	2	Very high
Pandeyan 2 State Elementary School	1	1	1	1	1	1	0	0	6	5	2	Very high

Source: Analysis, 2021

Table 8 shows that the parameters of school facilities are variable in the number of laboratories, library rooms, and others. The table shows very high vulnerability in all schools. Determining the weight using a score of multiplied 0.2 and the multiplication results shows that the variable number of laboratories, library rooms, and other schools is 1.

Table 8. Schools vulnerability based on school facility parameters

Schools	Facility			Total	Score	Weight	Level
	Laboratory	Library	Mosque				
Kadokan 1 State Elementary School	1	1	1	3	5	1	Very high
Madegondo 1 State Elementary School	1	1	1	3	5	1	Very high
Madegondo 3 State Elementary School	1	1	1	3	5	1	Very high
Pandeyan 1 State Elementary School	0	1	1	2	5	1	Very high
Pandeyan 2 State Elementary School	0	1	1	2	5	1	Very high

Source: Analysis, 2021

School Structural condition parameters were obtained from the calculation of primary data. The primary data were obtained from observations and interviews with the principal. The question indicators consist of the location of the school building, drainage conditions, materials used, age of the school building, floor height from ground level, baseboard height, foundation material used, wall material, and roofing material used. Table 9 shows the very high vulnerability class in all schools.

Table 9. Schools vulnerability based on structural condition parameters

Schools	Total	Score	Weight	Level
Kadokan 1 State Elementary School	10	5	2	Very high
Madegondo 1 State Elementary School	9	5	2	Very high
Madegondo 3 State Elementary School	10	5	2	Very high
Pandeyan 1 State Elementary School	9	5	2	Very high
Pandeyan 2 State Elementary School	11	5	2	Very high

Source: Analysis, 2021

Physical vulnerability in this study was obtained from the results of calculations and weighting of the condition of the school building both from the number of rooms and structural conditions. The results of the data analysis show that the five schools are included in the very high vulnerability class (Table 10). These conditions indicate that serious attention is needed to increase elementary schools' physical capacity in flood-prone areas, Grogol sub-district.

Table 10. Physical Vulnerability

Schools	Classroom		Facility		Structural condition		Physical Vulnerability	
	Weight	Level	Weight	Level	Weight	Level	Weight	Level
Kadokan 1 State Elementary School	2	Very high	1	Very high	2	Very high	5	Very high
Madegondo 1 State Elementary School	2	Very high	1	Very high	2	Very high	5	Very high
Madegondo 3 State Elementary School	2	Very high	1	Very high	2	Very high	5	Very high
Pandeyan 1 State Elementary School	2	Very high	1	Very high	2	Very high	5	Very high
Pandeyan 2 State Elementary School	2	Very high	1	Very high	2	Very high	5	Very high

Source: Analysis, 2021

3.1.3. vulnerability of elementary schools

Table 11 shows that the five schools located in flood-prone areas in Grogol District, Sukoharjo Regency are included in very high and high .

vulnerability classes. This study calculates and weighs social and physical variables in total vulnerability. Madegondo 3 has a high grade, and Kadokan 1, Madegondo 1, Pandeyan 1, and Pandeyan 2 State Elementary School have a very high grade.

Table 11. Total Vulnerability

Schools	Social (60%)		Physical (40%)		Total Vulnerability	Level
	Weight	Level	Weight	Level		
Kadokan 1 State Elementary School	5	Very high	5	Very high	5	Very high
Madegondo 1 State Elementary School	5	Very high	5	Very high	5	Very high
Madegondo 3 State Elementary School	3.3	Medium	5	Very high	4	High
Pandeyan 1 State Elementary School	5	Very high	5	Very high	5	Very high
Pandeyan 2 State Elementary School	4.4	Very high	5	Very high	4.6	Very high

Source: Analysis, 2021

3.2. Discussion

Based on the research results above, there are several parameters for social vulnerability, including School Community, Teacher, and Student Gender Ratio.

Social Vulnerability can show vulnerability in an area [13]. One of the social vulnerability factors is population density [14] In this study, population density is perceived as school residents, including principals, teachers, staff, and students. The results of data analysis

showed that the level of vulnerability to flooding at Kadokan 1, Madegondo 1, Pandeyan 1, and Pandeyan 2 State Elementary School showed a very high class (Figure 1).

In contrast, Madegondo 3 showed a medium class. Madegondo 3 belongs to the medium class because it has fewer school communities than the other four schools. Madegondo 1 shows a very high class because the number of school communities is more than

Madegondo 3, Pandean 1, Pandean 2, and Kadokan 1. The school has a reasonably large number of students, as many as 317. There are 19 teachers at Madegondo 1, including the principal. Madegondo 3 is classified as very high because the teacher sex ratio shows at 100%. SD Madegondo 3 has teachers who are almost all female. Previous research [15] stated that one of the parameters of social vulnerability is the sex ratio, especially the female sex ratio.

Figure 1 The social vulnerability of elementary schools in flood-prone areas, Grogol, Sukoharjo
(Source: [16] and data analysis, 2021)

The physical vulnerability consists of several parameters, including school facilities, classrooms, laboratory rooms, libraries, etc. Another parameter is the structural condition that reflects the five schools' conditions. The results of data analysis show that all schools have a very high vulnerability class. Based on previous research [6], the denser the buildings in the area, the higher the value of physical vulnerability and also seen from the structural condition of the building. Kadokan 1, Madegondo 1, and Madegondo 3 are

classed very high because they have laboratory facilities, a library, and a prayer room, each with one room (Figure 2). In contrast, Pandean 1 and Pandean 2 do not have laboratory space. They only have a library and a prayer room, each totaling one. Classroom facilities in each school show a very high vulnerability class. Compared to other schools, Madegondo 1 has 12 classrooms due to many students. The classroom is divided into two classrooms in each class, as class 1 is

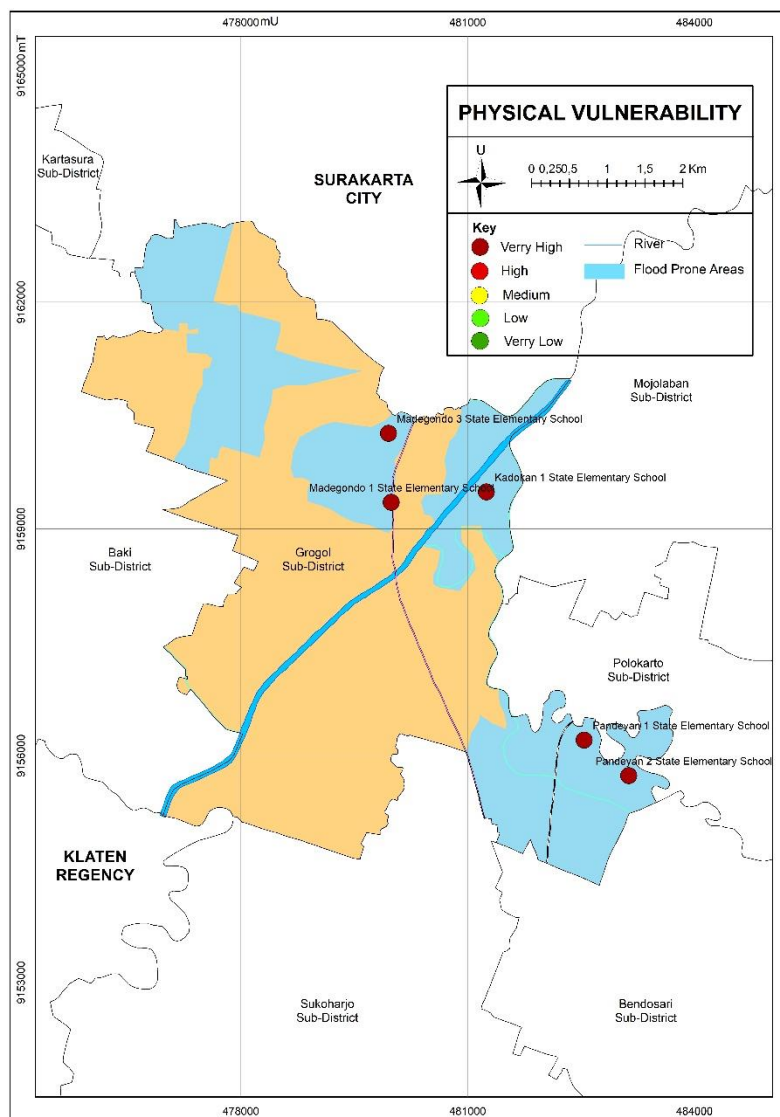divided into class A and B, and so on. Each class has a capacity of 30-35 students.

Figure 2 The physical vulnerability of elementary schools in flood-prone areas, Grogol, Sukoharjo
(Source: [16] and data analysis, 2021)

Structural conditions of school buildings are measured based on several parameters consisting of the location of the school building, drainage conditions, materials used, age of school buildings, floor height from ground level, baseboard height, foundation materials used, wall materials, and roofing materials used [17]. The implementation of disaster safe schools, there are fundamental aspects, one of which is the structural framework[18]. The results of data analysis showed that all of these schools were in the very high vulnerability class. The schools built on a floodplain were Kadokan 1, Madegondo 3, Pandean 1, and Pandean 2, while Madegondo 1 was not built on a floodplain. Based on the 2021 field survey, Madegondo 1 is near the main road and far from the Bengawan Solo

River. Based on interviews by researchers with senior teachers, Kadokan 1 was once affected by a 1-meter high flood caused by overflowing water from the Bengawan Solo river in 2007 due to the collapse of the Bengawan Solo river embankment. SD Pandean 1 and SD Pandean 2 were also built on a floodplain, and there have been several flood disasters, namely in 2007 and 2017, with a flood thickness of 1 meter. The most significant flood occurred in the SD Pandean 1 and 2 areas in 2007. The overflowing of the Samin river caused the flood. SD Madegondo 3 has also experienced a flood disaster caused by the overflow of the Bengawan Solo tributary, which is 1 meter from the school location.
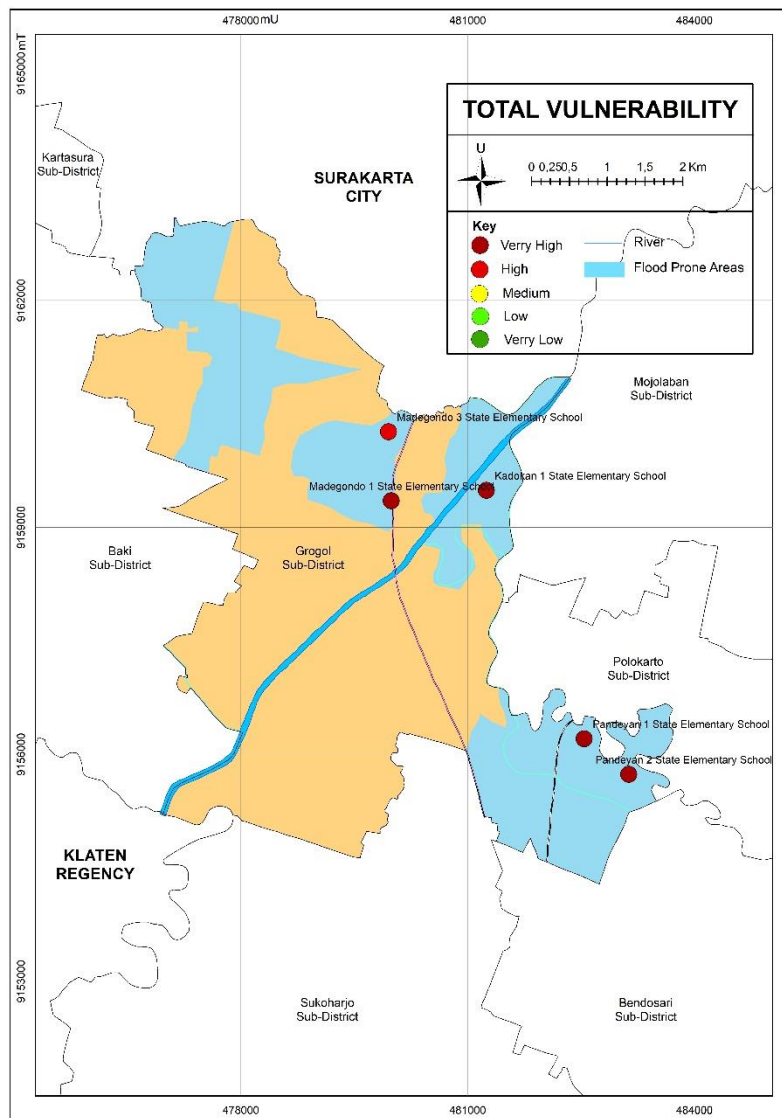
Figure 3 The total vulnerability of elementary schools in flood-prone areas, Grogol, Sukoharjo
(Source: [16] and data analysis, 2021)

Drainage conditions also affect the potential for flood disasters in each school. Drainage in all schools is smooth except SD Pandean 2. Based on direct observation, the drainage conditions of the school are clogged with clay and fallen dry leaves. This causes the flow of water to be not smooth when the flood occurs so that the water increases and causes inundation at the school location.

The age of the building is influential on the vulnerability of the school. The age of the school building can be used to assess whether it is strong or not if a flood disaster strikes the school building. The structures of all schools are more than 20 years old and

need strengthening and repairs in some parts to make them resistant to flooding. In addition to the age of the building, the materials used to build the school also affect dealing with flood disasters. The materials used to construct the school use permanent materials in bricks, sand, and cement. The floor height from the ground level of all schools is more than 1 meter, so it is good enough to anticipate the occurrence of inundation. The height of the baseboards at SD Kadokan 1 and SD Pandean 2 is more than 1 meter, while at Madegondo 1, Madegondo 3, and Pandean 1, it is less than 1 meter. The foundation material used in Kadokan 1 and Pandean 1 is river stone, while Madegondo 1 uses

bricks because the school building was a former palace building. Madegondo 3 and Pandean 2 use river stone and brick as foundation materials. The wall materials used to build the five schools were bricks and cement, while the roofing materials used for the five schools were wood and clay or tile.

The total vulnerability is obtained from social Vulnerability and physical vulnerability weights. The weighting results show that Kadokan 1, Madegondo 1, Pandean 1, Pandean 2 are in a very high class, while Madegondo 3 is in the high vulnerability class because the social vulnerability variable is in the medium category (Figure 3). The social variable that affects Madegondo 3 is the number of school residents. Social variables have a dominant weight of 60% of the total weight of the total vulnerability so that it will directly affect the vulnerability class. Therefore, it can be concluded that the higher the weight of a vulnerability parameter, the more dominant the influence will be. Furthermore, if viewed from a disaster risk study, the higher the level of vulnerability, the higher the disaster risk and vice versa. One way to reduce disaster risk is to increase physical and knowledge capacity.

4. CONCLUSION

Based on the study results, it can be concluded that Kadokan 1, Madegondo 1, Pandeyan 1, and Pandeyan 2 State Elementary School belong to the very high vulnerability class. Madegondo 3 State Elementary School belongs to the high vulnerability class. This fact shows that school as a place for students to study and transform knowledge and values is not entirely safe from disaster. Therefore, serious attention is needed to increase the capacity of schools in dealing with flood disasters. This research is not simply perfect, the vulnerability parameters need to be detailed again, and multitemporal measurements are required to get accurate results. It is hoped that further researchers can deepen research with similar themes to improve efforts to reduce disaster risk in the school environment.

ACKNOWLEDGMENTS

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