Developing Sustainable Schools in the Shadow of Active Stratovolcano: A Study at Disaster-Prone Areas of Merapi Volcano

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Abstract. Education is a right for people that must be given to children, even in an emergency of eruption disaster. To ensure the sustainable education during the crisis situations, ideas on how to develop a sustainable school system in the stratovolcano area which is prone to eruption disaster are needed. This research was conducted at schools located in the western side of Merapi Volcano, attempting to provide alternative information about the potential and role of schools in providing education during emergency situations of eruption disaster. Data in the study were collected through interviews, observations, remote sensing image interpretations, and documentations. Data were analysed by scoring and spatial analysis using geographic information systems. The results of the study are as follows. First, schools have the potential to provide education during the disaster emergency situations. School potential consists of physical infrastructure and human resource potential in the form of the role of the principal and teachers. Second, most of the level of school preparedness in facing disasters is still in the low category. This needs to be strengthened to ensure that the schools continue to function during the crisis period. Last, a division of roles in the sister school system is needed based on the location of the school towards the eruption centre. The schools in the safe zone act as a buffer for schools in vulnerable areas. Overall, schools have the potential to keep running the learning process during the crisis periods. This requires good management through the sister school system within the framework of sustainable school initiatives.

1. Introduction
The study of improve in the field of eruption disaster risk reduction is still very relevant in Indonesia because Indonesia is one of the countries with the highest volcanic disaster potential in the world [1]. Data from the Indonesian Centre for Volcanology and Geological Hazard Mitigation shows that from January to the beginning of April 2010, there were at least 20 volcanoes that experienced an above normal activity phase, where some volcanoes erupted. Many problems arose then because the areas were included in the Disaster-Prone Areas (DPA) eruption and was occupied by many residents. Lavigne et al [2] explain that the slope of 130 active volcanoes in Indonesia has indeed been inhabited by high density population for thousands of years. Among the various regions in Indonesia, Java Island is the region which has the highest level of volcanism. Historical eruption records show that almost half of the eruptions in Indonesia occurred on Java [1]. On the other hand, Java Island which is only 6.9% of the country’s surface is occupied by 60% of Indonesia's population [3].

Merapi Volcano in Central Java is one of the most active volcanoes in the world [4] characterized by a short eruption range from one to fifteen years [5]. After the VEI 4 scale eruption in 2010, volcanic
activity has increased again in Merapi Volcano in 2018. The increase in volcanic activity is characterized by small-scale eruptions that have occurred repeatedly and continuously from May 2018 to April 2020. The high risk of eruption disaster is not only caused by the level of volcanic activity but also the large number of residents living in those disaster-prone areas. Based on the data from the Global Volcanism Program [6], in the beginning of 2020, the population of the areas around 30 km from Merapi Volcano is not less than 4,348,473 inhabitants. Meanwhile, the Indonesian National Disaster Management Agency [7] explain that the population in the disaster-prone areas of Merapi reaches 226,618 people, with a population density of 720.1 people/km².

Dukun Sub-district in Magelang District, which lies on the western flank of Merapi Volcano, is an area that is greatly affected by eruptions. This is because many eruptions have struck this area since the past time [5]. Repeated eruption disasters offer a great impact on people's lives and livelihoods. In the 2010 eruption, for example, many aspects of life could not run normally when residents had to evacuate for more than one month. The education is among the most affected sector by eruptions. Many schools do not carry out education because they are located in disaster-prone areas and residents are displaced to other places. The disruption of the educational process, as recorded by the Indonesian National Disaster Management Agency [7], has resulted in a loss of 57% which is greater than the loss caused by the damage of the school's infrastructure.

Learning from the experience of the 2010 eruption, it is necessary to formulate strategies for dealing with future crisis conditions so that education can still be run. Based on the data from the Ministry of Education and Culture of the Republic of Indonesia (2020), there are 40 schools from elementary to secondary levels with a total of 4510 students in this region. Some of these schools are included in DPA and some are not. In a disaster emergency situation, schools which are not included in DPA can help schools in the DPA area organize education. Various schools need to work together in developing sustainable school initiatives. As an initial step, it is necessary to identify the potential of the schools, the role of the schools in handling disasters that have been going on so far, and the level of school’s preparedness in dealing with disasters.

The concepts of sustainable and safe schools have developed in the field of disaster risk reduction in various countries. In this concept, schools continue to function properly during the crisis situations [8], even they help manage disaster emergencies [9]. In general, a comprehensive school safety policy has been applied in most countries in the world [10]. Based on this experience, in the disaster-prone area of Merapi Volcano, a sustainable and safe school system needs to be developed to ensure the sustainability of education in crisis and post-disaster recovery situations. At present, in the Dukun Sub-district, a sister village system has been developed between the refugee-contributing villages and refugee-receiving villages. It is better to enhance this sister village with the sister school system in order to realize a sustainable education in those areas.

This research attempts to provide alternative information about the development of sustainable schools in disaster-prone areas. Thus, this research has three goals. First, we illustrate the potential of schools in handling emergency eruption disaster. Second, we describe the level of school preparedness in facing eruption disasters. Third, we discuss the role of schools in disaster prone areas in developing sustainable schools. The rest of this paper is organized as follows. Section 2 describes the research methods, section 3 elaborates the results, section 4 presents the discussions, and section 5 explains the conclusion of this work.

2. Methods

2.1. The Study Area
This research was conducted in the Dukun Sub-district, Magelang Regency, Central Java, which lies on the western flank of Merapi Volcano. Geomorphologically, the study areas cover all parts of the stratovolcano landform from the peak to the volcanic footplain, however the areas which are occupied by residents only spread in the volcanic foot and volcanic footplain. Viewed from its position against
the threat of Merapi Volcano eruption, the area occupied by residents is divided into Disaster-Prone Area (DPA) III, DPA II, DPA I, and non-DPA (Figure 1). This DPA categorization is carried out based on the DPA map published by the Indonesian Center for Volcanology and Geological Hazard Mitigation. DPA III is the area with the highest level of hazard.

![Map of the Study Area](image)

**Figure 1. The Study Area**

The study area has annual rainfall that varies between 295 to 1734 mm. Hydrologically, in the Dukun Sub-district, there are perennial rivers such as Pabelan, Trising, Senowo, Lamat, and Blongkeng [11]. The rivers are perennial because they get a huge water supply from the springs around this area as part of the volcanic spring belt in the Merapi Volcano [12] or Merbabu Volcano area [13]. The Dukun sub-district has varied aquifer conditions, namely aquifers with moderate productivity in volcanic foot to aquifers with high productivity in volcanic footplain [11]. The potential of this good aquifer is due to the types of material in this region. According to the Geology Map Yogyakarta Sheet 1993 [14], the types of material in the study area consist of the Young Merapi Volcano Deposits, the Old Merapi Volcano Deposits, as well as the Lava Dome and Lava Melt. Pyroclastic and lava materials, both old and young deposits, dominate the types of material in this area. This condition influences the existence of widely distributed productive aquifers. The types of land use based on the Indonesian Rupabumi Map of Kaliurang and Muntilan Sheets (2000) consist of settlements, rice fields, dry fields, mixed gardens, forests and shrubs. Rice fields are the most common type of land use whose coverage reach 47% of the area while settlements are only 9%.

Specifically, this research was conducted at all schools in the Dukun Sub-district from elementary to secondary levels. Based on data from the Ministry of Education and Culture of the Republic of Indonesia, the number of schools in this region in 2019 reaches 35 schools, consisting of 28 elementary schools (ES), 5 junior high schools (JHS), and 2 senior high schools (SHS). Ten schools are included in
DPA III, 14 schools belong to in DPA II, two schools are included in DPA I, and 10 other schools are outside of DPA (see Figure 1). The distance from the eruption center ranges from 7 to 16 km (Figure 2). The schools included in DPA III is closer to the eruption center. The total number of students in 2019 was 4850. In DPA III, there were 1,047 students (22%) that spread in 10 schools; in DPA II, there were 2,425 students (50%) that spread in 14 schools; and in non-DPA and DPA I areas, there were 1,378 students (28%) that spread in 11 schools (Figure 3). There are many students in DPA II because there is one junior high school and one senior high school in that region which has a very large number of students since the schools are supported with adequate facilities.

![Figure 2. The boxplot for school distance from the eruption center of Merapi Volcano](image1)

![Figure 3. The boxplot for the number and distribution of students in the study area](image2)
2.2. Data collection and analysis

The data collected in this study include the school’s conditions and school’s preparedness in facing disasters. The data were collected using some techniques such as field observations, interviews, and document searches. In the process of data collection, those three methods mutually complement, support, and validate the data obtained from each method. In collecting data through interviews, 12 schools were taken as samples. The samples were determined purposively by considering the variations in the distribution of schools in DPA III, DPA II, and DPA I or non-DPA, as well as variations in the educational level. The relationship between data types, data collection methods, and instruments used or data sources is presented in Table 1 below.

| No | Type of Data                                    | Data Collection Techniques | Instrument/data source                                                                 |
|----|------------------------------------------------|---------------------------|----------------------------------------------------------------------------------------|
| 1  | School locations                                | Observation               | School location measurement using GPS                                                  |
|    |                                                | Documentation             | Data from the Ministry of Education and Culture of the Republic of Indonesia (2019)   |
| 2  | Eruption hazard level at school location        | Documentation             | Map of Merapi Vulnerable Eruption Eruption Areas. Published by the Indonesian Center for Volcanology and Geological Hazard Mitigation (2002) |
|    |                                                | Observation               | Measurement by GPS on the boundary markers of the hazard area installed by the Regional Disaster Management Agency (BPBD) of Magelang Regency |
| 3  | School distance from the eruption center        | Documentation             | Peta Rupabumi Indonesia (Indonesian Topographical Map) Muntilan Sheet. Published by the National Coordinator for Survey and Mapping Agency of Indonesia (2000) |
| 4  | School distance from main river channel         | Documentation             | Peta Rupabumi Indonesia Muntilan Sheet. The calculation is done with ArcGIS           |
| 5  | School actions in the previous disasters        | Interview                 | Interview with the principal or vice principal using the interview guide instrument    |
| 6  | School involvement in disaster management       | Interview                 | Interview with the school principal or vice principal of facilities and infrastructure |
|    |                                                | Observation               | Data from the Ministry of Education and Culture of the Republic of Indonesia (2019)   |
|    |                                                | Documentation             | Data from the Ministry of Education and Culture of the Republic of Indonesia (2019)   |

In data analysis, there are three stages of analysis carried out based on the three research objectives. First, to investigate the potential of schools in handling emergency eruption disasters, a review and scoring of school infrastructure were carried out. Scoring was performed by considering school infrastructure standards referring to the regulations of the Indonesian Ministry of Education. Second, to examine the level of school preparedness, five-parameters scoring of disaster preparedness schools in Indonesia is conducted which include: (1) knowledge and attitudes, (2) policies and guidelines, (3) emergency response plans, (4) disaster warning systems, and (5) disaster mobilization. Third, to analyze the recommended role of schools in building sustainable schools, an analysis of geographical information systems is carried out by employing buffering, clip, and network techniques.
This analysis used 13 sample schools which were determined purposively representing the schools in DPA III, II, I, and non-DPA as well as the ES, JHS, and SHS categories.

Buffering analysis was performed to determine the position of the school toward the source of danger, both the eruption center and the main river channel. This analysis was supported by plotting the school location of the DPA zone division. The position of this school becomes a consideration whether the school is an affected school or a supporting school. The schools in DPA III definitely must be evacuated. Schools in DPA II can become supporting schools because DPA II is not evacuated except a large scale eruption of VEI 4 occurs as in 2010. Since the range of Merapi eruptions is relatively short but large eruptions occur in a long time span between 150-500 years [15], [16], the schools in DPA II can be categorized as supporting schools. After the eruption in 2010, BPBD Magelang Regency expanded the eruption hazard area where part of the area that was previously included in DPA II was included in DPA III. For this reason, we conducted a re-selection for schools referring to the DPA map in the DPA II area. The schools in DPA II which are located more than 11 km from the eruption center can function as supporting schools. However, the facilities and level of school preparedness must be considered. The percentage of settlements and infrastructure around the school also become a consideration in determining the eligibility criteria of the supporting schools. The percentage of settlements around the school was analyzed utilizing GIS using the clip method. The final step is performing a network analysis. This analysis is used to determine the closest route from affected schools to the supporting schools. All GIS analysis processes are carried out using ArcGIS and QGIS.

3. Results

3.1. The potential of schools in handling emergency eruption disaster

In this section, we illustrate the potential of schools in the Dukun sub-district in handling emergency eruption disasters. School potential is determined based on the infrastructure of the schools as well as human resources including the principal and teachers. There are several aspects of school infrastructure that need to be considered, including the area of school, the ratio of school area to students, classrooms, clean water sources, sanitation, electricity, internet, libraries, and laboratories.

The land area and number of classes are varied, especially at different levels of education such as ES, JHS, and SHS. ES with a higher number of units generally has fewer students because the coverage of student residence is also very limited. In one village area, there is at least one ES. A densely populated village can have several ESs. Meanwhile, the higher the level of education is, the farther the range of student residence will be. Also, the number of schools is increasingly limited along with the higher of the educational level, but the schools has greater area and classrooms in accordance with the number of students in the school.

ES area among 28 schools in the study area varies in the range of 200 m² to 6000 m². Moreover, the number of students varies from 31 to 281 students. Most schools at the ES level has a number of students and area that is relatively similar to one another. The different conditions were found in JHS. Public schools have a larger capacity and area compared to private schools, as indicated by the gap between two public schools and three private schools in the region. The same thing was also found in SHS level. Public schools have more students and areas. But in SHS level, a school type also influences the number of students. There are fewer students in vocational SHS than other SHSs. Overall, based on standards set by the Indonesian Ministry of Education, 77% of schools meet the standards regrading the ratio of school area to student while the aspect of total area only reaches 62%.

In addition, the number of classrooms is not significantly different in ES, but it is quite different in JHS and SHS. This condition influenced by the area and the number of students as explained above. The schools with large area have more capacity so that the number of students is high and the number of classrooms is also large to accommodate the students. According to the Indonesian Ministry of Education standards, all schools should have a minimum number of classrooms which are equal to or more than the number of classes (study groups) in the school. With regard to the classroom quality, 86% of all schools in the study area have feasible classrooms. The schools which have feasible classrooms in
ES category are 86%, JHS is 100%, and SHS is 50%. In the study area, there are two SHSs, one of which only has 40% of feasible classrooms and another one has 100%.

In regard to the ratio of classrooms to students, the range of ratio for ES is between 1:5 to 1:25 with an average 1:15. The ratio range for JHS is between 1:8 to 1:32 with an average of 1:18. In this JHS category, there is a gap on the ratio of classrooms to students for instance the gap regarding the number of classrooms. Meanwhile for the SHS category, there are differences between the two schools, namely 1:33 to 1:57. The number of classrooms and the ratio of classrooms to students shows that the classroom facilities and their use are not too different at the ES level, whereas in they are different in JHS and SHS level. The data distribution of land area, number of students, and classrooms is presented in Table 2, while the correlation between school area and number of classrooms to the number of students is shown in Figure 4.

### Table 2. The school’s facility and user

| School Level                  | ES  | JHS | SHS |
|------------------------------|-----|-----|-----|
| The ratio of school area to  |     |     |     |
| students (m²/students)       |     |     |     |
| N                            | 21  | 5   | 2   |
| Mean                         | 20  | 32  | 12  |
| Median                       | 17  | 24  | 12  |
| SD                           | 12  | 18  | 5   |
| Max                          | 43  | 53  | 15  |
| Min                          | 3   | 13  | 8   |
| School area (m²)             |     |     |     |
| N                            | 21  | 5   | 2   |
| Mean                         | 1798| 3887| 7150|
| Median                       | 1610| 3300| 7150|
| SD                           | 1236| 2929| 7566|
| Max                          | 6000| 7515| 12500|
| Min                          | 200 | 100 | 1800|
| The number of classroom      |     |     |     |
| (unit)                       |     |     |     |
| N                            | 21  | 5   | 2   |
| Mean                         | 7   | 9   | 15  |
| Median                       | 6   | 6   | 15  |
| SD                           | 2   | 6   | 15  |
| Max                          | 13  | 18  | 25  |
| Min                          | 4   | 3   | 4   |
| The ratio of classroom to    |     |     |     |
| students (units/students)    |     |     |     |
| N                            | 21  | 5   | 2   |
| Mean                         | 1:15| 1:18| 1:45|
| Median                       | 1:14| 1:17| 1:45|
| SD                           | 1:6 | 1:9 | 1:17|
| Max                          | 1:25| 1:32| 1:57|
| Min                          | 1:5 | 1:8 | 1:33|

The data on the area and classrooms indicate that the schools in the study area have facilities that meet the needs of their students. In other words, the schools recruit students based on the quota. One school to another at the same level and type show relatively the same condition regarding the area of land and classrooms. To keep running the educational processes during the disaster emergency situations, the schools located outside DPA (maximum in DPA II) can assist the schools located in the most dangerous areas (DPA III) by sharing facilities to keep learning going on. The sister school system
can be designed by involving schools that are close together but in different DPA areas. The schools in non-DPA areas, for example, can facilitate schools from DPA III where the number of students, area, and number of classrooms is relatively similar. This condition will certainly get better if the targeted supporting schools have more areas and classrooms than that of the affected schools.

![Figure 4](image.png)

**Figure 4.** The relationship between the school areas and the number of students (A), the number of classrooms and the number of students (B)

To support the ideal learning activities, many supporting facilities are needed, not only dealing with the area of the school and the number of classrooms. Other facilities such as clean water, sanitation, electricity and internet are also required. In terms of clean water sources, all schools have clean water sources and can fulfill their own needs. The source of clean water mostly comes from the springs (46%), especially in schools that are located in the volcanic foot. In this region, there are indeed many springs related to the position of buckling slope which is the boundary between landforms. Another source of clean water that is widely used is wells (34%), especially in schools that are located in the volcanic footplain. In the sanitation aspect, 9% of schools do not meet the standards set by the Indonesian Ministry of Education. In regard to the electrical energy, there are 23% of schools that do not meet standards. Meanwhile for internet access, 34% of the schools are not connected to the internet network. In relation to utilizing the potential of schools for disaster management, some problems arise because the schools located in safe areas have nonstandard electricity, sanitation and internet facilities. The results of our scoring also showed that 3 of 35 schools in the study area had a nonstandard infrastructure. The three schools are located in a safe zone that should be able to function as an evacuation site for the affected schools.

3.2. The level of school preparedness in facing eruption disaster

Another aspect that needs to be considered in developing a sustainable school in the DPA of Merapi eruption is the degree of school preparedness in facing disasters. The better school preparedness will improve the resilience to face disasters and encourage the successful implementation of schools during the crisis period. The results of the scoring analysis indicate that the level of school preparedness is included in the low and medium categories. 77% of schools are in the low category, 23% are in the medium category, and none is in the high category. There is no variation in preparedness level between ES, JHS, and SHS. The level of preparedness is low and is found in ES, JHS, and SHS. In addition, there is no variation viewed from the location of the schools in the DPA. Some schools in DPA III have low preparedness and some others belong to the medium category in terms of the preparedness. Likewise, in DPA II, DPA I, and non-DPA, some schools have low and medium degree of preparedness.

The reason for the absence of schools with high preparedness is because some elements of preparedness have not yet been fulfilled which include (1) there has not been good coordination with National Disaster Management Agency (BNPB) and Regional Disaster Management Agency (BPBD) as the institutions which are in charge of disaster management, (2) there is no SOP for disaster
management in schools, (3) there is no special fund allocated for disaster management, (4) there are no special teachers assigned as coordinators in disaster management, (5) there is no coordination with student’s parents related to disaster management, and (6) there is no decree which strengthen the tasks and roles in disaster management. The aspects that the schools currently own are presented in Table 3 below.

Table 3. The preparedness aspects owned by the schools

| Preparedness aspects       | Level of preparedness                                                                 |
|----------------------------|---------------------------------------------------------------------------------------|
|                            | Low                                                                                   |
| Knowledge and attitude     | Activating the school health unit / junior doctor, Junior Red Cross and Scouts         |
|                           | Increasing the capacity of teachers relevant to lessons and preparedness activities   |
|                           | Developing cooperation with disaster and education observer institutions              |
| Policies and guidelines    | None                                                                                   |
| Emergency response plan    | Make copies of important school documents and keep them in a safe place               |
|                           | Prepare medicines and first aid kits                                                   |
|                           | Conduct first aid training guided by relevant agencies                                 |
| Disaster warning system    | Prepare communication equipment                                                       |
|                           | Prepare disaster warning equipment                                                    |
| Disaster mobilization      | Conduct training in schools or facilitate school representatives to attend preparedness training |



The aspects of policy and guideline with four sub aspects have not yet been possessed by the schools in the study area due to various administrative and technical constraints faced by schools. In regard to the policy and guidelines, there are currently instructions and directions related to disaster learning in schools from the Magelang Regency Government. However, technically there is no integration of preparedness materials in learning, there is no disaster preparedness group, there is no special funding budget for disaster preparedness activities in schools, and there is no continuous disaster training or simulation. Teachers still need assistance for the integration of disaster materials such as determining the competency standards and developing a lesson plan for learning in class. Because of this obstacle, the teachers are not able to implement disaster learning and still focus on their duty to teach compulsory subjects. In addition, routine disaster evacuation simulations have also not been conducted. The schools that have conducted simulations after the 2010 Merapi eruption disaster were still limited, accompanied by disaster volunteers. This activity is not continuously carried out.

To develop a sustainable school, there are some urgent aspects of preparedness to fulfill, including: (1) making policies related to the implementation of sister schools to realize a sustainable learning, (2) establishing disaster preparedness clusters, not only for handling emergency situations but also for coordinating the organization of learning in crisis situations and coordinating the schools that need assistance, (3) formulating evacuation plans which are equipped with signs and procedures, including the procedure of how one school must evacuate to another school, (4) performing rescue simulation and implementing a learning in crisis situations between two schools within the sister school system.

3.3. Sister Schools: the role of schools in developing sustainable schools

To establish a sustainable school, a collaboration between schools in one region is needed. Among the 35 schools in this study area, 18 of them are in danger areas so that it is not possible to conduct normal learning in these schools during the crisis. Even in the emergency status of alert (level 4), residents in the danger area have to evacuate to other places. Moreover, there are 17 schools that are outside of the danger area. These schools can still organize the learning process. Utilizing the potential of the infrastructure, the schools in safer areas can assist other schools in hazard areas so that learning activities in these schools can still be carried out. Sister school systems in a network of sustainable school initiatives need to be encouraged and developed to facilitate this need.

The sister school system at DPA Merapi Volcano is not something new. In Sleman Regency, which is on the southern side of Merapi Volcano, a sister school has been developed involving 20 schools. Based on this experience, the sister school system can also be developed on the western side of Merapi Volcano by involving schools in the region. Sister schools can be established between schools by paying attention to three important aspects, namely, their proximity, the number of students, and the similar condition of the infrastructure, and the same level of education. Two schools in the danger zone and the safe zone which are located next to one another will enable the process of mobilization between schools easier and more efficient. The relatively same number of students and infrastructure between the two schools will guarantee that supporting schools can meet the needs of the affected schools to organize learning. The same level of education, for example ES and ES, will make it possible to access facilities more effectively. For example, the use of libraries, laboratories, and others.

Based on the scoring analysis, all 18 schools in the danger zone have good facilities. However, schools in this area must totally evacuate to other places. 18 of these schools became affected schools which had to be assisted by supporting schools. The level of preparedness in dealing with disasters is crucial in the mobilization process. However, because the level of preparedness still ranges from low to moderate, this aspect needs to be improved in the future. Furthermore, among the 17 schools in the safe zone, three schools have nonstandard infrastructure. We carried out the re-selection process so that 14 schools were recommended to be supporting schools in the sister school system. Taking into account the distance, infrastructure, and student numbers, the division of school partnerships along with the best route between schools is presented in Figure 5. The learning process during the crisis period is also different from the normal period. During this crisis period, a good coordination between teachers and
parents of students or between the school and the surrounding community is needed. This condition is supported by easy access to reach the settlements around the schools.

4. Discussions
A sustainable school is one of the efforts that can be realized to ensure that education can still be performed during the crisis period in an emergency situation of eruption disaster. The efforts to develop a sustainable educational environment have been carried out in various countries. For example, the Sustainable Campus Initiative developed in Shonan Fujisawa Campus Keio University. To build a sustainable campus, various innovations have been carried out within the campus environment in order to keep the campus function normally during the crisis period [8]. The development of sustainable schools in Merapi eruption prone areas also has the same goal, but it’s carried out in a different way. In developing this sustainable school, the approach used is the regional complex. The collaboration between schools in one region through a network of sister schools is a feature of the development of sustainable schools in the Merapi area, instead of the campus independence initiative as explained by Bai et al [8].

The collaboration between schools is an important factor in determining the realization of a sustainable schools. This is due to the different characteristics of the eruption disaster that pose a threat in this region. The characteristics of the earthquake hazard underlying the development of sustainable campus as explained by Bai et al [8] are different from the eruption disaster. Thus, the approach used in building a sustainable school is also different. In eruption disasters, there is zoning of danger areas that are constantly under threat during the eruption period. In other words, a school cannot function for a long time so it needs to be assisted by other schools so that the learning process can still be running. Based on the experience from the Merapi eruption in 2010, residents of DPA III had to evacuate for

![Map of the Optimal Route for Sister School](image)

**Figure 5.** The sister school system for Dukun Sub-district
several months. In this condition, sustainable learning can only be realized if it joins with other schools, utilizing the existing infrastructure at the school, with adjusted learning hours.

The sister school system is actually not a new concept at DPA Merapi. On the southern side of Merapi, the other part most affected by eruption in 2010, has implemented a sister school system. Mei et al [17] explain that sister school plays an important role in maintaining the student’s safety during the learning process and ensuring a sustainable education during the eruption. The BPBD of Magelang Regency acts as a liaison between the two schools in this sister school system. In addition, a coordination is also carried out with local government, especially with regard to evacuation efforts. Furthermore, Pambudi and Ashari [18] explain that school principals and teachers play a crucial role in organizing disaster preparedness schools. We found that teachers in the study area had also received training on disaster, even at the national level. A disaster training which has ever been experienced by teachers is part of school preparedness. Even schools with a low level of preparedness generally meet this aspect. However, further coordination is still needed so that the teacher’s role can function more optimally. Principals and teachers also play an important role in bridging communication between schools and parents of students, even building cooperation with parents of students [9]. In order to realize this role effectively and efficiently, it is necessary to divide the tasks in the disaster preparedness group. Until now, the formal distribution of tasks between school principals and teachers in disaster preparedness groups needs to be improved. In addition, the principal and teachers are also responsible for providing knowledge about disaster and safety. The teacher can provide knowledge with various methods during the learning process [19].

Spatial analysis that shows the location of schools toward the source of danger and the location and distance between schools is an important part that needs to be considered in building a sister school network in the Merapi eruption disaster area. The location of the school towards the source of danger will ensure that the school is safe enough to continue to carry out education during the eruption period and assist the affected schools. The existence of good school facilities increasingly supports the establishment of safe schools. Green et al [20] emphasizes the need to build safe schools. The experience in various countries also shows that the community can contribute in creating safe schools through community-based school development. Schools that are built together with the community will further enhance the linkages between the school and the surrounding community. The selection of school location must be well considered in a truly safe area. In the Merapi eruption DPA, many schools are in the safe zone. Instead of building new schools, schools in safe zones can be improved both in the quality of their buildings and supporting facilities. At present, many schools in the safe zone lack the supporting facilities especially electricity and internet networks.

Furthermore, Green et al [10] state that the location of schools is an important part of the safe school facility which is included in one of the three pillars in developing safe schools. Beside the location of the school, assessment and retrofitting of the existing schools and their care are also an important part of the pillars of the safe school facility. In DPA Merapi, many schools are located in safe zones but the facilities are inadequate. Therefore, retrofitting schools is needed. In the future, improving facilities and the role of principals and teachers is a very important to be improved. The lack of facilities and the role of the principal and teachers, not only hamper the development of the sister school system but also weakens school preparedness to deal with disasters [21].

5. Conclusion
The eruption disaster of Merapi Volcano can occur in a long period of time. Experience from a major eruption that occurred in 2010 showed that residents in the DPA had to evacuate for several months. This condition causes disruption of the learning process in schools located in DPA. For this reason, the development of sustainable schools is needed. The nature of the eruption disaster that continues to pose threats to DPA has prevented the schools in DPA from functioning normally during this period. For this reason, sustainable schools must be developed through a collaboration between schools within the sister school network. During the crisis period, schools in DPA III and part of DPA II became the affected schools that can continue the learning process in the supporting schools located in safe zones. In this
paper, we propose the possibility of developing sister school networks by considering location, distance, and educational infrastructure factors in schools. Sister school networks can be established but infrastructure improvements and school preparedness are factors that must be seriously managed so that the goals of sustainable school development can be achieved.

For the evaluation process, this research is still limited to the examination on the potential of infrastructure owned by schools for disaster management and disaster preparedness. There are several things that need to be further investigated including school readiness to implement the sister school system, sister school implementation scenarios, and stakeholder support in developing sustainable schools through sister school networks.

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