The Vulnerability of Settlements in the Areas Impacted by Lapindo Mudflow Disaster, Sidoarjo

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Abstract. The Lapindo Hot Mudflow Disaster is a disaster case that occurred in 2006 in Sidoarjo Regency, East Java, and has become a hot issue at the national, even international level. After 14 years, it turns out that until now the impact of the disaster has not completely subsided. The settlements that were impacted by the mudflow disaster but still inhabited by the community looked vulnerable because many were damaged, cracked and the floors slowly subsided due to land subsidence. This study aims to determine the level of vulnerability of community settlements in areas impacted by the Lapindo mudflow disaster, which uses quantitative analysis methods by collecting data using questionnaires in 3 study villages, namely Glagaharum Village, Gedang Village and Kalitengah Village. The results of research data analysis using scoring techniques using 2 formulas as well as Statistic Descriptives and Means Plots show that the three villages have a moderate level of vulnerability and Kalitengah village has the highest level of vulnerability. The results of data analysis with the Kruskal Wallis statistical test show that the Village Location factor has a significant effect on the Vulnerability Level in this study, which means that the closer the village is to the mud embankment, the level of vulnerability will also increase. From the results of this vulnerability study, data on the condition and availability of disaster emergency infrastructure, which is part of the adaptive capacity variable, still needs to be improved, because it can be a factor in reducing the level of vulnerability to support disaster risk reduction programs and strengthening community resilience to disaster that may arise in the future.

Keywords: Disaster, Vulnerability Level, Settlements, Land Subsidence, Adaptive Capacity, Resilience

1. Introduction

1.1 Background

The Lapindo hot mudflow disaster is a disaster case that occurred in 2006 in Sidoarjo Regency, East Java province, and has become a hot issue at the national, even international level. Many debates also involve international experts regarding the causes of disasters, whether they are natural disasters or due to human negligence. But until now (2020) the bursting cannot be stopped and has become a serious threat to the surrounding community, and no one can even predict when this burst will end [1].

Sidoarjo Regency, which is located in the Delta Brantas area, was never a natural disaster prone area before. However, currently Sidoarjo is included in the area with a high disaster risk index (BNPB, 2013). The Lapindo
mudflow has inundated an area of more than 740 ha including industrial estates, agricultural areas, the Surabaya-Gempol toll road, and densely populated settlements [2]. The inundated villages include Renokenongo, Siring, Jatirejo, Kedungbendo, Ketapang, and Besuki which are located in the administrative area of three sub-districts, namely Tanggulangin, Porong, and Jabon. Over the years victims in the affected areas have experienced the uncertainty of the fate and status of their deprived social, economic and cultural rights [3]. After the disaster, the community also found it difficult to find replacement houses due to the reduced supply of houses in the 2006-2010 period [4] and soaring house rental prices.

In addition to having an impact on the economy, social, community culture as well as physical and infrastructure, there have been several ecological impacts, namely deformation and ground movement, flammable gas bursts, and degradation of groundwater and air quality [5]. After 14 years of the disaster, it turns out that until now the impact of the disaster has not completely subsided and the people who were not relocated are still feeling the effects. The victims who have been relocated have already received compensation, but settlements in the three study areas are still vulnerable to being affected by the mudflow. Many houses for residents in the vicinity are physically damaged and are often flooded (Figure 1).

Some experts suspect that mud disasters have also occurred in the past and have drowned the sites of the Majapahit and Jenggala kingdoms, whose seat of government is also in the Brantas Delta area. With this assumption, the mudflow phenomenon in the past means submerging cultural sites [6], as is the case today. Several houses belonging to residents are also slowly sinking due to land subsidence. Puddles of water that the community had never felt before, now often occur. Many residents’ well water is polluted, cloudy and even blackish in color, and smells strong.

The current condition of the community is not under threat of death, but the changes experienced by the mudflow disaster and the uncertainty of the future make them vulnerable to health problems, including physical, psychological, social, cultural and spiritual health problems [7]. Moreover, the social impacts that occur include changes in community social relations, a decrease in spiritual activity, and existing social support. Therefore, a review of the social, cultural and religious conditions of the community should also be part of the vulnerability assessment.

Researchers on the vulnerability of settlements in areas impacted by the Lapindo mudflow disaster is important to do considering the post-disaster environmental conditions of the settlements are quite apprehensive. Several times the mud retaining embankment wall collapsed or cracked until it expanded and was elevated. The threat of flood overflow from mud storage ponds often befalls settlements, especially during the rainy season. The impact that residents also complained about was the pungent smell of gas so that people felt uncomfortable in their daily lives. These problems are fundamental issues and are important to be studied in order to formulate disaster mitigation strategies and policies in the future so that they can be continued with disaster risk reduction programs.

In an effort to adapt to disaster-affected residential environments, the community needs to be increased in its capacity to survive amid existing vulnerabilities. The research questions are: What is the level of vulnerability of settlements in the areas affected by the Lapindo Sidoarjo mud disaster? What factors have a significant influence on the level of vulnerability? What recommendations can be made regarding the level of vulnerability that exists? This study aims to determine the level of vulnerability of community settlements in areas affected by the Lapindo mud disaster, Sidoarjo, which can later be used as input for disaster risk reduction programs and strengthening community resilience to impacts that may arise in the future.
1.2 Vulnerability of Settlement

Law of the Republic of Indonesia Number 24 of 2007 concerning Disaster Management states that the territory of the Unitary State of the Republic of Indonesia has geographic, geological, hydrological, and demographic conditions that allow disasters, whether caused by natural factors, non-natural factors or human factors that cause casualties, human life, environmental damage, property loss, and psychological impacts which in certain circumstances can hinder national development. In connection with disaster events that result in vulnerability to community settlements in areas impacted by the Lapindo mudflow disaster, there are five elements associated with a disaster for humans [8]: Disaster, Hazards Vulnerability, Capacity and resilience, and Culture. In other words, cultural capital as the ability to understand nature and overcome natural problems will greatly affect all human efforts in dealing with a disaster.

For operations in this study, the IPCC (Intergovernmental Panel on Climate Change) “Vulnerability” definition is used which is a concept in the Disaster Risk Reduction (DRR) paradigm as a function and environmental exposure, sensitivity and adaptive capacity [9–11]. It can be said that there are three components of vulnerability forming, namely the level of sensitivity of the internal conditions of the system which indicates the level of vulnerability to intervene, the level of exposure which indicates the amount of opportunity for a system to come into contact with interference [12] and the adaptive capacity or the ability of the system to adapt to changes, environmental or policy changes so that the potential negative impacts can be mitigated and the positive impacts maximized.

From research that conducted vulnerability assessments, it was found that researchers did not use the same methods and equations, such as the static Vulnerability equation (1) by Frazier [13] and the other equation (2) by Turner [10] followed by Sariffuddin [11] for Vulnerability Assessment as follows:

\[
V = (E + S) - AC
\]

\[
Vulnerability = \frac{Exposure \times Sensitivity}{Adaptive Capacity}
\]

where \(E\) = Exposure (Paparan), \(S\) = Sensitivity, dan \(AC\) = Adaptif capacity.

As a state of the art in this study, the authors try to apply the two formulas above and compare the measurement results so that it can be seen and concluded which formula is more suitable to be applied in the data analysis of this study.

![Figure 2](image-url)  
**Figure 2. Vulnerability Classification according to The Coping Capacity Index** [11]

The results of the Vulnerability assessment are then grouped into five based on the index of adaptive capacity (IAC) and the index of exposure and sensitivity (IES), with IAC on the X axis while IES on the Y axis. However, the vulnerability matrix shown in Figure 2 [11,14] is rather difficult to understand because the highest index position is in quadrant II while the lowest index is in quadrant IV. Rochmayanto [15] used a coordinate system in quadrant I to classify the level of community vulnerability, where the exposure level is the Y axis and the sensitivity / adaptation capacity is the X axis, as shown in Figure 3 below:
Figure 3. Vulnerability Level of Community to Climate Change [15]

Cutter et al [16] stated that Place Vulnerability is divided into two (2): Biophysical Vulnerabilities and Social Vulnerabilities. When referring to Cutter's Social Vulnerability, which used 11 dimensions as an indicator of social vulnerability, the variables and assessment methods used by Gallopin, Frazier, Turner and Sarifuddin [9–11,13] are different. Cutter's SoVI (Social Vulnerability Index) is a composite score of the Social Vulnerability Index for each county with 5 categories (-1 for the lower category and +1 for the higher category).

In order to enrich and broaden the knowledge and methods of data analysis and to find research gaps, additional relevant journals are still needed from previous studies. Various data analysis methods were used including: (a) Logistic regression analysis [17]; (b) The use of participatory-GIS (Geographic Information System) approaches, Participatory Vulnerability Assessment (PVA) and Vulnerability and Capacity Assessment (VCA) for flood inundation height data and the level of physical damage to buildings obtained from the community [18]; (c) Use of the BNPB Regulation for the calculation of the vulnerability index [19]; (d) Analysis with a weighted normalization test [20]. From these journals it can be seen that each researcher has his own method of analysis that can be accounted for for the purpose of assessing the level of vulnerability of a disaster-prone area.

Urban communities are usually at the highest risk in the event of natural disasters because settlement locations are occupied by low-income people [21]. Whereas settlements are often located in disaster prone areas such as floods, landslides, fires, lack of infrastructure, and housing that is prone to damage. Government Regulation of the Republic of Indonesia Number 26 of 2008 concerning National Territory Spatial Planning Article 71 has stipulated three important criteria as requirements for a residential environment, namely (1) to be outside the area designated as a disaster-prone area; (2) have access to community activity centers outside the area; and (3) have complete supporting infrastructure, facilities and utilities.

Culture as a determinant factor in vulnerability will increase understanding of community vulnerability to disaster risk [22], where (traditional) people have local wisdom to protect their area from damage and hazards or disasters. Local wisdom is a collective understanding, knowledge and wisdom that influences the decision to resolve or overcome a life problem [23].

The inclusion of culture as an indicator in vulnerability assessment has not been considered in other similar studies, and this is the state of the art of this study. The importance of this cultural factor is also reinforced by the results of previous sociological research at the same location where the affected communities have produced a common habitus, which then with the orientation of social, economic and cultural capital becomes the strength to survive in Glagaharum village, one of the study sites that was also affected by the Lapindo mudflow disaster [24]. In addition, there is a need for continuous education through various media from various circles in cultivating awareness of its disaster-prone geographical conditions to the community [25].
2. Method

![Map of study site in the area impacted by the Lapindo mudflow disaster, Sidoarjo, East Java Province, Indonesia (Source: Processed from Peta Rupa Bumi Indonesia, 2020)](image)

This research used a quantitative method which was carried out in three areas of the villages affected by the Lapindo mudflow disaster (as in Figure 4): Kalitengah Village (Tanggulangin District) and Glagaharum Village and Gedang Village (Porong District). These three villages were chosen because they have medium and high risk of disasters, but are still inhabited by most of the residents [26]. In these three villages, there were also several residents whose houses were included in the disaster-affected map prepared by BPLS (Sidoarjo Mudflow Management Agency) and were supposed to be relocated, but apparently were unwilling to be relocated for various reasons.

The study, which aims to assess the vulnerability of settlements in areas affected by the Lapindo mud disaster, Sidoarjo, was conducted by collecting primary data using questionnaires, field surveys and in-depth interviews with people living in the three study locations villages. Data analysis was performed using scoring techniques and Kruskal Wallis statistical analysis on predefined indicators. In Figure 5, there is a flow chart of this study starting from the start and study of literature to data analysis and research findings.

The sampling method was carried out by purposive sampling, which is a sample selection based on certain criteria, so that each village is not evenly represented by residents in each RT or RW. The criteria taken are: 1) The respondent's house is not far from the mud retaining embankment wall; 2) The respondent's house appears to be in poor condition, damaged or cracked due to the impact of the disaster; 3) The respondent's house was affected by flooding or land subsidence/ uplift; 4) The house is affected by the smell of gas or the groundwater is not suitable.
The number of respondents from this study was 124 people based on calculations with the formula $n = \frac{N}{Nd^2 + 1}$ where $n =$ number of samples, $N =$ number of population, and $d =$ precision (taken 10% of the population). From this formula, the minimum number of respondents is 100 people (Glagaharum Village: 18 people and Gedang Village: 27 people Kalitengah Village: 55 people). However, 7 respondents were invalid because they did not live in the three study villages, so the valid respondent data were 117 people with details of 34 respondents from Glagaharum Village, 28 respondents from Gedang Village and 55 respondents from Kalitengah Village whose distribution can be seen in table 1. Respondents from Glagaharum Village, it was decided to make additions because of the large number of community settlements that are located close to the embankment wall so that it is very at risk of being affected by disasters in the future.

Table 1. Distribution of research respondents

| Village       | Number of Population in 2019 | Number of Respondents Planned | Sum Respondents |
|---------------|------------------------------|-------------------------------|----------------|
| Kalitengah    | 12,978                       | 55                            | 55             |
| Glagaharum    | 4,144                        | 18                            | 34             |
| Gedang        | 6,325                        | 27                            | 28             |
| Other impacted village | --             |                               | 7              |
| Total number  | 23,447                       | 100                           | 124            |

Source: Processed from Villages data, 2020

For vulnerability assessment, there are 3 groups of independent variables that are taken into account, namely Exposure, Sensitivity and Adaptive Capacity, where each variable has several indicators as shown in table 2:
Table 2: Variables and Indicator of Vulnerability

| Exposure                                                                 | Sensitivity                                                                 | Adaptive Capacity                                                                 |
|-------------------------------------------------------------------------|------------------------------------------------------------------------------|----------------------------------------------------------------------------------|
| • The distance of the house from the edge of the mud embankment wall    | • The physical condition of house/infrastructure (roads, houses of worship, education & health facilities) | • Long lived                                                                       |
| • Houses affected by flooding                                           | • Social (location of public facilities, community relationship, security system, community activities) | • Changes in welfare & home condition                                               |
| • Houses and yards affected by land subsidence/uplift (cracks, damage)  | • Economics (income, workplace, expenses, savings)                            | • Condition & availability of disaster emergency infrastructure                    |
| • Houses affected by gas bursts (health and fire risk)                  | • Culture & Religion (religious & cultural activities, community enthusiasm, the existence of institution, local wisdom, community attitude) | • Socialities & community participation in social activities                        |
| • Ground/well water conditions (cloudy, salty / strong odor)            | • Environment (clean water, garbage, sewer, trees)                           | • The role of social, cultural and religious institutions                            |
| • Long lived                                                            | • Knowledge of the mudflow disaster                                           | • Community cultural & religious activities and values                              |
| • Changes in welfare & home condition                                    | • Physical condition of mud embankment wall                                  | • The role of village government in dealing with disaster                           |
| • Condition & availability of disaster emergency infrastructure          | • Physical condition of mud embankment wall                                  | • Community prepearednes for disasters                                              |
| • Social ties & community participation in social activities            | • Physical condition of mud embankment wall                                  | • Success in adaptation efforts                                                    |
| • The role of village government in dealing with disaster               | • Physical condition of mud embankment wall                                  |                                                                                  |
| • Cultural & religi activity                                             | • Physical condition of mud embankment wall                                  |                                                                                  |
| • Environment (clean water, garbage, sewer, trees)                      | • Physical condition of mud embankment wall                                  |                                                                                  |

The indicators used for the Exposure variable in this study are based on the results of previous studies[26], field surveys and interviews with the community. Meanwhile, data analysis used 2 methods: scoring methods and statistical analysis. For the scoring method, the average score obtained from each indicator is sought which is then grouped into each variable for each village. The scores obtained (scores 1 to 5) are divided equally into 5 categories as in table 3 which is then divided evenly into 5 categories so that the exposure level, sensitivity level and adaptive capacity level are obtained. This score is entered into the vulnerability formula to get the total score of the vulnerability level.

Table 3: The score scale of the research respondents' attitudes

| Mean scores | Each variable level |
|-------------|---------------------|
| 1.00-1.80   | Very low            |
| 1.81-2.60   | Low                 |
| 2.61-3.40   | Medium              |
| 3.41-4.20   | High                |
| 4.21-5.00   | Very high           |

3. Result and Discussion

3.1 Field Observation Result

Field observations were carried out to see directly the impact of the mudflow disaster on the physical conditions of community settlements and the surrounding environment. The results of observations on the vulnerability of community settlements are data in the form of photographs of settlements in the study area consisting of: 1) the physical condition of the mud embankment, both on the walls of the embankment, on the inside of the embankment, as well as on the outside or around the embankment wall; 2) physical condition of community houses; 3) groundwater and surface water conditions around the settlement.

Physical Condition of the Mud Embankment

The physical condition of the mud embankment wall is as shown in figure 6, in Figure 6a: some parts of the embankment wall have subsided. According to information from the community in Kalitengah Village, the embankment walls are still often elevated by adding several trucks of sand. On the outside of the embankment wall, there is a puddle of water as shown in Figure 6b. While on the inside of the embankment, most of the land is still inundated by mud (Figure 6c), but there are some parts that appear dry. This is due to the movement of the
land, some of which are land subsidence, but some are uplifted so that water inundates the parts that are experiencing land subsidence.

**Physical Condition of Community House Buildings**

In figure 7, you can see some damage to the community house buildings. Damages that were also caused by the movement of the ground included cracked walls (Figure 7a), loose plastering (Figure 7b), damage to the roof and ceiling (Figure 7c), and lowering of the house floor. However, some of the community continued to live in their houses which were unfit for habitation due to the large amount of damage to parts of their houses that were not renovated because they did not have sufficient funds.

**Condition of groundwater and surface water**

The water condition in the study location is equally concerning. In Figure 8a, it appears that the sewer water right on the outside of the embankment is brownish yellow (8a), while the groundwater in community wells is blackish in color (Figure 8b). Another problem related to this water is the stagnation in several community settlement locations as shown in Figure 8c. Stagnant water conditions especially occur in the rainy season due to the water not flowing into the ditch as a result of the inundated yard of the residents' houses which may experience land subsidence so that water cannot rise to enter the ditch if it is not assisted by a pump.
3.2 Land Use Changes

The water condition in the study location is equally concerning. In Figure 8a, it appears that the sewer water right on the outside of the embankment is brownish yellow, while the groundwater in community wells is cloudy and blackish in color (Figure 8b). Another problem related to this water is the stagnation in several community settlement locations as shown in Figure 8c. Stagnant water conditions especially occur in the rainy season due to the water not flowing into the ditch as a result of the inundated yard of the residents’ houses which may experience land subsidence so that water cannot rise to enter the ditch if it is not assisted by a pump.

3.3 The Result of the questionnaire

Primary data from research results obtained from questionnaires and then processed and analyzed using scoring techniques, where each answer is given a score to facilitate assessment. The discussion for the assessment of the level of vulnerability is carried out on the three factors of vulnerability, which consists of an assessment of the level of exposure, level of sensitivity and level of adaptive capacity. After using scoring techniques, it is followed by statistical analysis using statistical descriptive methods, normality test and Kruskal Wallis Test.

Assessment of Vulnerability Level

Based on the data obtained from the three variables (exposure, sensitivity and adaptive capacity), the average score of the three variables can be applied to formulas (1) and (2) as shown in table 5. However, to get the category of vulnerability, it is necessary to make distribution of the range of values in each category. For application to formula (1), the resulting range of values is very wide, namely 0.2 (lowest) to 25 (highest), so that if it is divided into 5 categories, each category is in the range of 4.96. By using formula (2) the lowest value (-3) and the highest value are obtained (9), it can be easily made a range of values for 5 categories, namely very low, low, medium, high and very high as in table 4.
Table 4. Score scale of the Vulnerability Level

| Vulnerable Level | Mean scores |
|------------------|-------------|
| Very vulnerable  | -3.00--0.60 |
| Invulnerable      | -0.61-1.80  |
| Almost vulnerable | 1.81-4.20   |
| Vulnerable        | 4.21-6.60   |
| Very vulnerable   | 6.61-9.00   |

Table 5. Mean score of variables and Vulnerability level/category

| Villages     | Exposure | Sensitivity | Adaptive Capacity | $V = \frac{E \times S}{AC}$ | $V = \frac{[E+S]-AC}{AC}$ | Category         |
|--------------|----------|-------------|-------------------|-----------------------------|-----------------------------|------------------|
| Glagaharum   | 2.618    | 2.843       | 3.249             | 2.291                       | 2.212                       | Almost vulnerable|
| Gedang       | 1.896    | 3.061       | 3.194             | 1.817                       | 1.763                       | Invulnerable /   |
|              |          |             |                   |                             |                             | Almost vulnerable |
| Kalitengah   | 2.772    | 3.206       | 3.445             | 2.580                       | 2.553                       | Almost vulnerable|

From the results of the assessment using formulas (1) and (2) in table 8, it turns out that in this study the scores were not significantly different. The vulnerability categories of the three villages are at moderate or almost vulnerable levels. Kalitengah village received the highest vulnerability score (2.553) because the exposure and sensitivity level scores were also the highest. However, with high adaptive capacity, the score for the level of vulnerability in Kalitengah Village can be reduced. The description of the categories for each variable can be seen in Figure 10, where the vulnerability categories in the three variables in each village can easily be visualized.

Statistical Analysis

Analysis with statistical tests (Descriptives, Normality test and Kruskal Wallis test) in this study was conducted to strengthen the results of the assessment that had previously been carried out with the scoring method. The Kruskal Wallis test is a ranking-based non-parametric statistical test method that aims to determine whether there is a statistically significant difference between two or more groups of dependent variables on the numeric scale and the ordinal scale.

Table 6. Descriptives Statistic

| Village     | Descriptives | Statistic |
|-------------|--------------|-----------|
| Glagaharum  | Mean         | 2.2147    |
| Gedang      | Mean         | 1.7268    |
| Kalitengah  | Mean         | 2.2755    |

LEGEND:
- = mud area
- = very high
- = high
- = medium
- = low
- = very low

Figure 10: Index of the three vulnerability variables (Source: Processed from Author’s Analysis, 2020)
The test results with statistical descriptives can be seen in Table 5 where Kalitengah Village has the greatest mean vulnerability score, then Glagaharum Village and Gedang Village. For the Normality Test (Table 6), it can be seen that only Gedang Village meets the normality assumption with a significance value of 0.200. Meanwhile, the villages of Glagaharum and Kalitengah do not meet the normality assumption because each has a significance value of less than 0.05. Furthermore, to find out the indicators that have a statistically significant effect on susceptibility, a Kruskal Wallis Test was conducted as shown in Table 8 and Table 9.

The Mean Rank value (Table 11) shows the mean rank of each treatment. In the above case, the mean ranking for Kalitengah Village was higher than the mean ranking for Glagaharum Village and the mean ranking for Glagaharum Village was higher than the mean ranking for Gedang Village. The P-Value is indicated by the Asymp value. Sig. If the P-Value< research significance level, the hypothesis decision is to accept H1 and reject H0, which means that there is an effect of the independent variable on the dependent variable. In this case the P-Value of 0.000 is less than the significance level of 0.05 so that it accepts H1 which means that the Village Location has a significant effect on the Vulnerability Level.

4. Discussion

In the Government Regulation of the Republic of Indonesia Number 26 of 2008 concerning National Spatial Planning Article 71, it is stated that three important criteria as requirements for a settlement environment include “the settlement must be located outside the designated disaster-prone areas”, and in accordance with the Regional Regulation of Sidoarjo Regency Number 6/2009 concerning Spatial and Regional Planning for 2009-2029 Article 54 paragraphs (2) and (3) states that “Areas prone to earthquakes, ground movements, and landslides are in: Areas affected by Lapindo Mudflow in Porong, Tanggalangin and Jabon Districts; and Management efforts are carried out by prohibiting the area from being an uninhabitable zone”.

However, the study site which is in the area impacted by the Lapindo mudflow disaster is still inhabited by people with medium to high density. Referring to the two rules regarding spatial planning above, the area has been designated as a disaster-prone area because it is prone to earthquakes, land movements and landslides, making it an uninhabitable zone. This is certainly a cause for concern because residents still live in disaster-prone locations and are unfit for habitation. The two regulations should have become the legal basis for settlements in the areas affected by the Lapindo mud disaster to be relocated to a safer area and meet the requirements as a residential environment.

Relocation is not an easy matter. The reality shows that some communities are reluctant to leave their settlements even though they have a high risk of disaster. Limited levels of education and skills make it difficult for people to change professions. Many communities, such as farmers, breeders and fish farmers, rely on land as a source of income. In our in-depth interviews, the community expressed concern that difficulties in adapting to new settlements and the close social and kinship between residents are also reasons for people to stay in their villages. According to Suryaningsih's research [24], the community has produced a shared habitus, where the orientation of social, economic and cultural capital becomes the strength of the community to survive and remain...
side by side with the threats posed by the Lapindo mud disaster. Moreover, the data shows that since the Lapindo mud disaster incident in 2006, housing provision for 2006-2010 has also experienced a drastic decline [4], so that the price is increasingly out of reach of the community.

The condition of vulnerability in the areas affected by the Lapindo mudflow disaster to disaster risk is not only due to water overflow mixed with mud, but also ground movement, gas boasting, soil cracks and land subsidence [5,6]. The results of physical observations at the location indicate that the vulnerability of settlements in the study location is mainly due to its location which is close to the mud embankment wall which is not permanent so that it is prone to overflow or water seepage. On the outer edge of the embankment wall (Figure 6b) are water bodies at several locations. The non-permanent embankment wall (Figure 8a) is only a high pile of sand which is compacted and reinforced by gabions on the edges of the walls which are very susceptible to bursts, cracks, risk of water seepage or the impact of physical factors of land subsidence or uplift which are also threatening residents' houses. This is also consistent with the results of the Kruskal Wallis test (table 12), where the location of the village does have a significant effect on the Vulnerability Level.

Taking the definition from the IPCC, vulnerability is defined as a function of three factors: level of exposure, sensitivity and adaptive capacity [9–11,13]. This definition is closer to the biophysical vulnerability than the social vulnerability of Cutter [16]. In accordance with Cutter's idea, Sariffuddin's social vulnerability assessment [11], according to the author's view, is more in line with biophysical vulnerability and not Social Vulnerability using SoVI in its assessment. While the classification or level of vulnerability described in the coordinate system [11,15], shows the functions of exposure, sensitivity and adaptive capacity, but does not describe the level of total vulnerability. Therefore, to make it more informative and easy to understand, the authors present the total vulnerability index in the form of a table, while each variable of the total vulnerability index is presented in a map image with different colors to show the different categories of village vulnerability levels according to the assessment that has been made.

As Wisner mentions, 5 elements related to humans in a disaster, namely Disaster, Hazards Vulnerability, Capacity and Resilience, and Culture [8], the cultural capital owned by the community will greatly influence all efforts in dealing with a disaster. This statement was reinforced by Salami who stated that culture is a determinant factor in vulnerability which will increase understanding of people's vulnerability to disaster risk [22]. From observations and interviews, it is known that the influence of culture and religion on people's lives in the study area is still very strong. This is in line with the results of previous studies which state that family support and belief in God are able to calm people from psychological burdens [7]. As in Renokenongo Village, which has sunk, the people continue to carry out social and religious activities such as the slametan and kenduren traditions in their new settlement locations [27].

By including cultural and religious indicators in the adaptive capacity variable, the stronger the community's desire to maintain cultural and religious activities in the study area will increase the level of their adaptive capacity. The results of the assessment of adaptive capacity in the study area showed that culture and religion contributed a fairly high average score to the level of adaptive capacity in the three villages, namely 3.06 (Glagaharum), 3.57 (Gedang) and 3.35 (Kalitengah). According to the vulnerability formulas (1) and (2), this high adaptive capacity will reduce the level of vulnerability of community settlements. Therefore, although the three villages have quite high vulnerability in terms of location, the level of vulnerability is reduced due to high adaptive capacity. These results reinforce Suryaningsih's (2017) research which states that culture is one of the strengths for the survival of people in residential areas affected by this disaster.

Likewise, the success factor for the adaptation of the people in their settlements since the disaster (table 6) achieved a fairly good average score, namely 3.85 (Glagaharum), 3.29 (Gedang) and 3.89 (Kalitengah). This causes the adaptive capacity score in the three study location villages as a whole is quite good. This data is very interesting to observe and can become the basis for further research on the topic of adaptation of settlements to disasters and the adaptive capacity of their communities. Theoretically, it has been formulated that the level of vulnerability is inversely related to adaptive capacity [10,11], and a community needs to be “prepared” and “less vulnerable” in order to achieve a high level of resilience [28]. Therefore, the adaptation efforts made by the community with their local wisdom will reduce the level of vulnerability and increase their preparedness and even the level of resilience in areas impacted by the Lapindo mudflow disaster, Sidoarjo.
5. Conclusion

In accordance with the assessment of the results of this research questionnaire with the scoring method, statistical descriptive, mean plots and the Kruskal Wallis test described above, it can be concluded that the level of vulnerability of community settlements in areas impacted by the Lapindo mudflow disaster, Sidoarjo, is medium (almost vulnerable) with the location is a factor that has a significant effect on the level of vulnerability, which means that the closer the village is to the mud embankment, the level of vulnerability will also increase.

The role of cultural and religious indicators together with other indicators, namely long lived, successful adaptation and the role of village institutions / government, have a significant effect on the high level of community adaptive capacity. However, the condition and availability of disaster emergency infrastructure in the area affected by the Lapindo mud disaster still needs to be improved by the related institutions because it has the lowest assessment from the community compared to other indicators in the adaptive capacity variable.

It is difficult to control the level of exposure to disasters in disaster-affected residential areas. Therefore, efforts to increase the adaptive capacity of the community need to be the main concern of all related parties because it can be a factor in reducing the level of vulnerability of settlements and supporting disaster risk reduction programs and strengthening community resilience to disasters that may arise in the future.

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