



Research Article

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Strategies for increasing the adaptive capacity of the community in vulnerable settlement areas impacted by the mudflow disaster

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Abstract

The mudflow disaster has made the surrounding community's residential areas vulnerable, so efforts are needed to strengthen the community's adaptive capacity to reduce vulnerability. This study aims to develop strategies to minimize settlements' vulnerability based on communities' adaptive capacity in areas impacted by the Lapindo mudflow disaster in Sidoarjo, Indonesia. The research method used is the explanatory sequential mixed methods approach with quantitative primary data obtained from structured questionnaires and qualitative data from field surveys and interviews, with analysis in the form of integrating the two databases. The research results showed that the level of community adaptive capacity was moderate, slightly above the average score (3.19). The lowest score was on education level (1.78), and the highest score was on social relations (4.36). The strategies to reduce vulnerability are increasing public education, empowering the community's economy, increasing the availability and capacity of disaster infrastructure, conducting massive reforestation, providing technical assistance, access to banking facilities, clean water networks and distillation, and supporting community activities in social, cultural, and religious fields, as well as strengthening village institutions. This study concludes that social, cultural, and religious variables play a role and become important capital in increasing the community's adaptive capacity, which can later reduce vulnerability in an area towards a disaster-resilient area.

Keywords: mudflow disaster; vulnerability; adaptive capacity; settlement.

Introduction

The worldwide frequency of natural disasters, of which hydrometeorological ones dominate, is increasing. This causes properties, lives, and communities to be affected (Djalante & Thomalla, 2012). Whether natural or non-natural, disasters cause community settlements' vulnerability in all cities worldwide. Meanwhile, victims or the affected people in every disaster have several options: relocating to another place, migrating to another location on their own accord, or staying in the disaster location by adapting and living in harmony with nature. If people choose to stay in a disaster-affected location, they need to adapt to nature, which changes the physical, environmental, and climatic conditions.

The Lapindo hot mudflow disaster that has occurred since May 29, 2006, in Sidoarjo, Indonesia, has unique characteristics. It became the center of world attention due to the extensive impact area and had been going on for quite a long time. Some people in vulnerable locations have been relocated to safer places. However, the rest are staying. Meanwhile, hazards might threaten the environment and society. The hot mudflow submerges the houses of the surrounding residents; gases are emitted, the land cracks, and even vertical and horizontal land movement (Agustawijaya, 2017). The threat, of course, should be the government's concern, which should guarantee a sense of security among community members in disaster-affected areas. However, the cause of this disaster is still an ongoing debate, whether it was due to natural factors or human negligence in private



exploration companies (Schiller et al., 2008).

Figure 1 shows the condition documented in a residential area impacted by the Lapindo mudflow disaster in Sidoarjo. As shown in Figure 1a, the permanently immersed houses in mud puddles have been abandoned by their occupants. Figure 1b is a puddle on the outer edge of the embankment close to the settlement. Meanwhile, in Figure 1c, there are several settlements where the yard is inundated, but the inundation can still recede in a few moments. Figure 1d is a house with a raised courtyard and terrace floor to prevent flooding. The impact of land subsidence in the form of standing water like this can be found in several locations.

The settlements' condition in the areas impacted is still vulnerable. The disaster caused physical and economic vulnerability to settlements (Ekawati & Sulistyowati, 2021). As a result, the community was forced to lose their property and even leave their homeland, which has historical value. However, resettlement is not easy. Many people are still reluctant to move. The consequences of staying afloat certainly require the community members to immediately adapt to the residential environment, which is now designated as a disaster-prone and uninhabitable area (RTRW Sidoarjo 2009-2029). Therefore, efforts are needed to strengthen the adaptive capacity to reduce disaster risk and vulnerability.

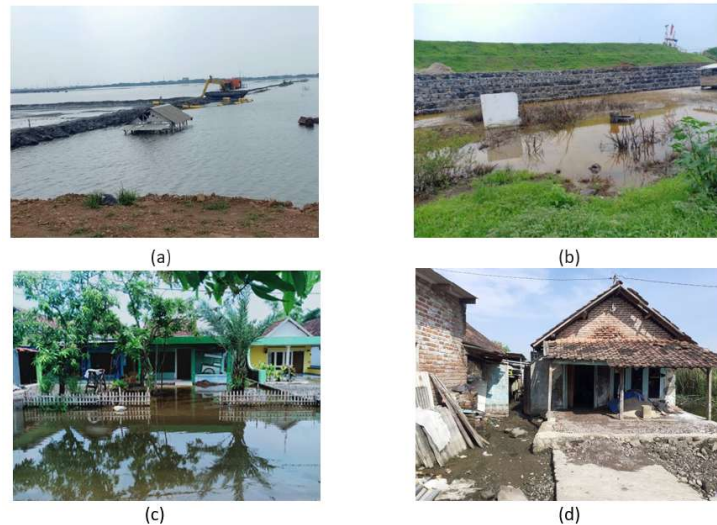


Figure 1. Impact of the mudflow disaster on community settlements. (a) a building drowning in a muddy puddle inside the embankment; (b) a puddle on the outer edge of the embankment; (c) stagnant water around the settlement; (d) a house with raised courtyard and terrace floor (Source: author's documentation, 2020)

This study aims to assess the adaptive capacity level of people living in the area impacted by the Lapindo mudflow disaster in Sidoarjo, Indonesia, and develop strategies to minimize community settlements' vulnerability based on the communities' adaptive capacity. If we look at formula (1) regarding the vulnerability level of an area, then increasing adaptive capacity is important to reduce vulnerability in disaster-affected areas. The indicators that are often used are generally assets and capital. In this research, the authors added social and cultural indicators to the framework as a follow-up to previous research (Ekawati, 2022), where the social and cultural sector is one of the disaster mitigation efforts that the community hopes. The study area is three villages. These three villages have a medium to high level of disaster risk (Ekawati et al., 2020). Even though the community lives in an area at risk of being impacted by the disaster, and the disaster mitigation activities that have been carried out have not met their expectations, the community's participation in these activities is quite good (Ekawati et al., 2022).

Adaptive capacity is important in building social sustainability, which can later support disaster risk reduction (Didham & Ofei-manu, 2020). Adaptive capacity, , vulnerability, resilience, and disaster risk are intercorrelated. Adaptive capacity is an important concept in the literature that bridges vulnerability and resilience (Adger & Vincent, 2005). In a nutshell, adaptive capacity describes the ability to adapt (Engle, 2011). The capacity to adapt is an essential element in the adaptation process; however, there is still uncertainty (Adger & Vincent, 2005; Engle, 2011). Increasing adaptive capacity is important to reduce the vulnerability that occurs in an area. This relates to the previous vulnerability assessment (li et al., 2003; Sariffuddin et al., 2016):

$$\text{Vulnerability} = \frac{\text{Exposure} \times \text{Sensitivity}}{\text{Adaptive Capacity}} \quad (1)$$

In formula (1), adaptive capacity is inversely proportional to vulnerability. This means the higher the adaptive capacity, the lower the vulnerability index. Therefore, the vulnerability index will be high if the adaptive capacity is low. A low level of adaptive capacity will be synonymous with vulnerability, while a high level of adaptive capacity will indicate resilience (Daramola et al., 2016). Formula (1) was used to assess vulnerability in the Genuk area, Semarang City, Indonesia (Sariffuddin et al., 2016). Regarding vulnerability, adaptive capacity is a part or component of the vulnerability assessment. This supports the statement of Adger and Smit (Adger & Vincent, 2005; Barry Smit & Wandel, 2006).

Adaptive capacity is defined as the ability or capacity of a system to modify or change its character to better cope with existing or future pressures (Adger et al., 2005; Wahyono et al., 2013). It is also said that adaptive capacity is the capacity of actors (both individually and collectively) to respond to, create, shape variability, and change the system's status (Adger & Vincent, 2005; Clarvis & Allan, 2014). Adaptive capacity represents potential rather than actual adaptation (Adger et al., 2005) and is considered a vector of resources and assets/capital (Adger & Vincent, 2005; Williamson et al., 2012). Therefore, a system needs time to convert its adaptive capacity into adaptation because adaptation does not happen instantaneously.

The diagram in Figure 2 shows a somewhat different relationship between resilience, vulnerability, and adaptive capacity by Gallopin (Gallopin, 2006), where Adaptive capacity is not part of Vulnerability (Gallopin, 2006). In contrast to Sariffuddin (Sariffuddin et al., 2016), who proposed that vulnerability consists of sensitivity, exposure, and adaptive capacity, Gallopin puts adaptive capacity independently of vulnerability and stands parallel to resilience in the triangle diagram of the conceptual relationship (Gallopin, 2006).

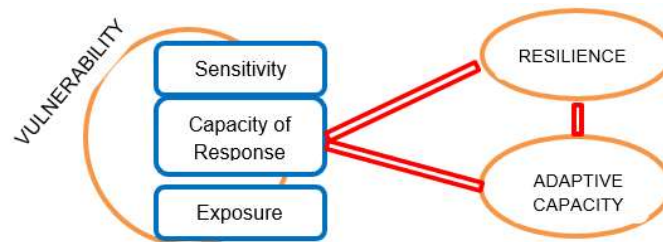


Figure 2. Conceptual relationship diagram between vulnerability, resilience, and adaptive capacity (Source: Gallopin, 2006)

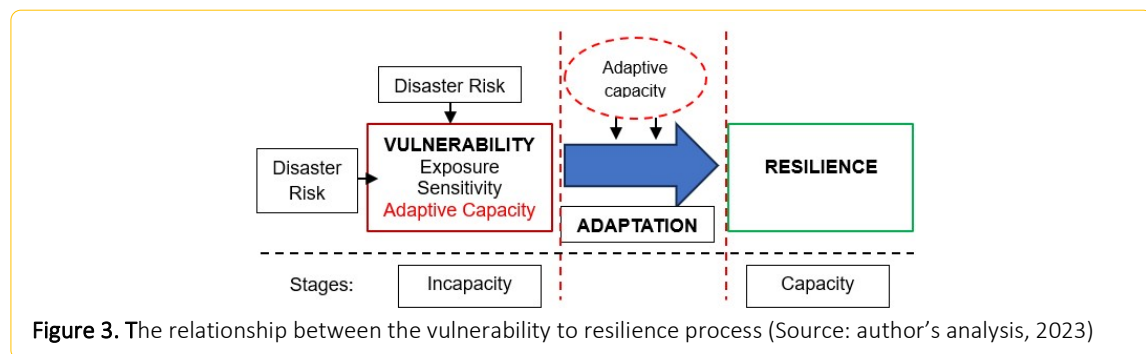
In terms of adaptive capacity assessment, adaptive capacity is an important element in the adaptation process. This adaptability is at the individual and country levels (Adger & Vincent, 2005; Barry Smit & Wandel, 2006). Meanwhile, Gupta (Gupta et al., 2010) sees adaptive capacity as more focused on institutions as social actors for

the long-term handling of climate change by implementing the adaptive capacity wheel. More broadly, adaptive capacity shows the government's reactive efforts to respond to climate change through networking, cooperation, and information (Clarvis & Allan, 2014).

However, in general, it is said that adaptive capacity is the ability of the system to adapt to climate change by reducing the potential for damage by utilizing social and economic resources, technology, access to information related to climate change, and the ability of institutions to adapt (Kumalasari, 2014). Adaptive capacity is the ability of a system to adapt to climate change (including climate variability and extreme climates) to reduce the damage that may occur and take advantage of opportunities to face the consequences that occur (Gallopini, 2006). A system's ability to adjust to climate change so that the potential negative impacts can be reduced and the positive effects maximized is called the level of adaptive capacity (Tarumingkeng et al., 2017).

This study uses the community's adaptive capacity as the operational definition. It is elaborated as the potential capacity or capacity of the community's system that enables the community members to cope with, manage, or adjust to changing conditions, pressures, threats, and disaster risks by reducing the damage potential and utilizing all existing resources. From this definition, in adaptive capacity, it is important to build communities in settlement areas impacted by the disaster by making various adaptation efforts to realize a resilient settlement.

Figure 3 shows that vulnerability is a condition of an area at a stage of having less capacity (incapacity), which is greatly influenced by the level of disaster risk. Communities vulnerable to disasters' impact have the potential for adaptive capacity. This potential adaptive capacity must be developed to reduce vulnerability by adapting to the vulnerability. Adaptive capacity is a form of capital in the adaptation process, allowing communities to enter the capacity stage, create resilience to disasters, and achieve high readiness in the face of future disasters.



In the adaptive capacity assessment, IPCC (2007) proposes several adaptive capacity determinants: economic resources, technology, information and skills, infrastructure, availability of strong and well-organized institutions, and equal access to resources (Purifyingtyas & Wijaya, 2016). Smith and Pilifosova show that adaptive capacity assessment depends on economic resources (financial), availability of technology, the ability of individuals/adapters, management, and performance (Dolan & Walker, 2004). Somewhat different from other researchers, the parameters used to measure the level of adaptive capacity from Tarumingkeng are economic conditions, education level, availability of physical aspects of settlements, and river conditions (Tarumingkeng et al., 2017).

The indicators in the framework used in earlier studies focus more on capital and assets (Dolan & Walker, 2004; Purifyingtyas & Wijaya, 2016; Tarumingkeng et al., 2017). In research on adaptive capacity, culture and religion are rarely used as assessment variables, while risk perception and culture are intrinsically intertwined (Appleby-Arnold et al., 2018). Previous sociological research revealed that the victim community had produced a shared

habitus, which then became a force for survival with the orientation of social, economic, and cultural capital (Suryaningsih & Handayani, 2017). Therefore, as a novelty in this study, the authors include elements of culture and religion as indicators in assessing adaptive capacity at the individual and local community levels.

Methods

The methods used in the adaptive capacity assessment in previous research are quite diverse. These include historical case studies with qualitative and quantitative methods (Keogh *et al.*, 2011; Lockwood *et al.*, 2015), which uses a psychometric approach with statistical analysis; cross-sectional quantitative with regression analysis (Zukowski, 2014), binary logistic regression (Daramola *et al.*, 2016), the grounded theory (Wahyono *et al.*, 2013), a multi-step Geographical Information Systems (GIS) based technique (Chari *et al.*, 2018) and quantitative methods with scoring and descriptive analysis (Kumalasari, 2014; Purifyingtyas & Wijaya, 2016). Several of these methods serve as a reference to ensure the differences between this research and similar existing research.

The method used in this research is a mixed method with an explanatory sequential design approach, where the process is carried out in two phases of data collection; the first stage is quantitative data collection, with data analysis using scoring and descriptive techniques, then the results are used to proceed to the second phase, namely qualitative data and analysis (Cresswell & Cresswell, 2018). This method was chosen because data on the adaptive capacity level of the community is needed to develop a strategy for increasing adaptive capacity. The study area of this research is the Lapindo mudflow disaster-impacted areas, namely Glagaharum Village and Gedang Village (Porong District) and Kalitengah Village (Tanggulangin District), Sidoarjo Regency, Indonesia (Figure 4), where the three villages are directly adjacent to the Lapindo mudflow embankment, but are still inhabited by the community.

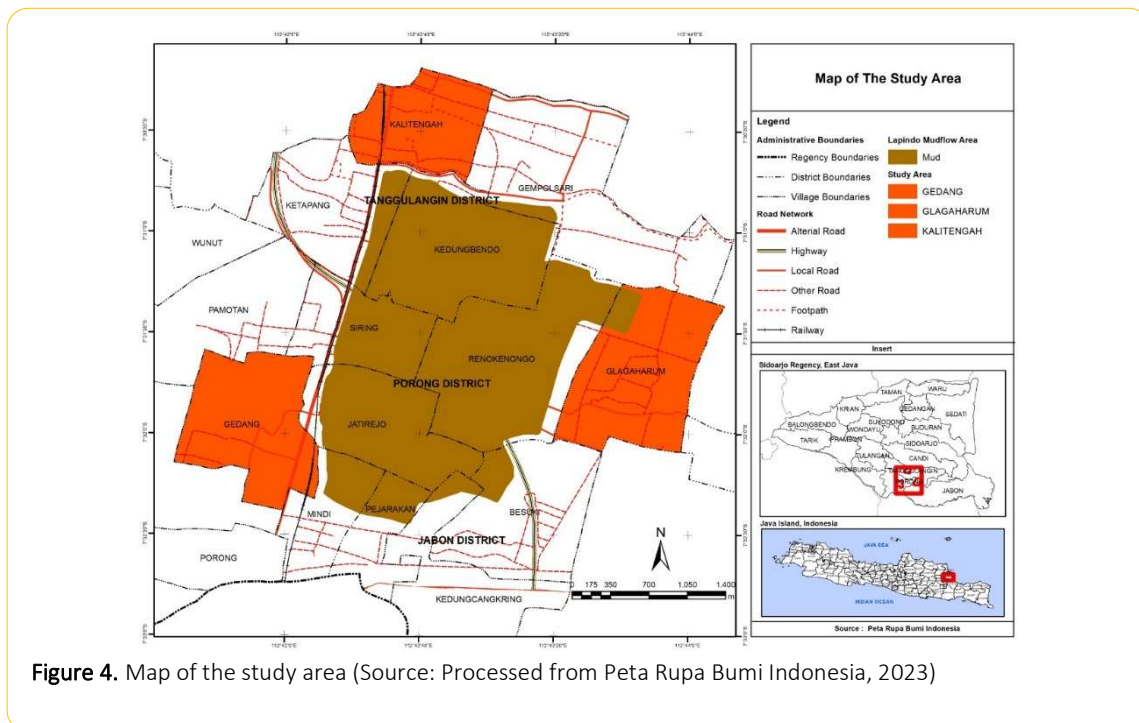


Figure 4. Map of the study area (Source: Processed from Peta Rupa Bumi Indonesia, 2023)

The variables used to assess adaptive capacity in this research are economic capacity, ability/skills/ knowledge of adaptation actors, social, cultural, and religious variables, availability and convenience of technology and information, physical infrastructure, community performance, and capacity as well as disaster management

performance by village or central institutions which can be seen in Table 1. Cultural and religious variables were added to the framework due to previous research on disaster mitigation (Ekawati et al., 2022)

Table 1: Research Variables and Indicators

Variables	Indicators	Sources
Economy	• Income per month • Economic preparedness to face future disasters	Adger et al., 2004; Dolan & Walker, 2004; Purifyingtyas & Wijaya, 2016; B. Smit et al., 1999; Tarumingkeng et al., 2017; Williamson et al., 2012
Social & networks	• Participation in social activities • Social Relations & Communication	Adger et al., 2004; Tarumingkeng et al., 2017; Williamson et al., 2012
Cultural-religious	• Participation in cultural-religious activities • The role of community leaders and religious leaders	
Technology & information	• Availability of telecommunications equipment and signals • Ease and speed of access to the early warning system	Adger et al., 2004; Jones et al., 2010; Purifyingtyas & Wijaya, 2016; B. Smit et al., 1999
Infrastructure	• Availability and capacity of disaster management facilities • Availability and affordability of infrastructure during a disaster emergency	Jones et al., 2010; Purifyingtyas & Wijaya, 2016; B. Smit et al., 1999; Tarumingkeng et al., 2017
Institutions & organizations	• Disaster management • Disaster preparedness	Adger et al., 2004; Jones et al., 2010; B. Smit et al., 1999
Knowledge and performance of community adaptation	• Level of education • Disaster knowledge • Ability to survive and adapt • Current residential conditions • Successful adaptation	Adger et al., 2004; Jones et al., 2010

Source: author's analysis from various sources, 2024

There were 117 valid respondents in this study (34 people from Glagaharum Village, 28 from Gedang Village, and 55 from Kalitengah Village). Respondents were selected using purposive sampling with special criteria, namely adult respondents whose homes were not far from the mud embankment and whose homes were directly affected by the disaster. Initially, this research questionnaire was delivered only through Google Forms with structured question types. However, because some respondents do not have adequate gadgets to access Google Forms, the questionnaire is also given in print so that it is easy to read and answer. We even helped read the questions so some residents could complete the questionnaire. Thus, information from various community backgrounds can still be done well. Respondents of this study were people living in the area from various levels of age, education, and occupation. Therefore, the answers or responses were quite diverse.

Further interviews were conducted with several respondents whose residences were considered to be seriously affected by the disaster, such as being in an uninhabitable area where they should be relocated but refused

(mostly from Kalitengah Village), and some respondents whose homes were located close to a mud embankment or near the boundary fence of an area that had been vacated. Questions asked in the interview related to: a) The impact of the disaster on the family economy; b) Children's education; c) disaster infrastructure; d) damage to the house and readiness to repair it; e) community relations and participation in socio-cultural activities. We also interviewed village heads and several officials from the three villages who have understood the Lapindo mudflow disaster in the past. All informants and respondents welcomed us warmly, even showing us the damage to their homes affected by the disaster with pleasure.

The analysis was carried out by looking at the scores obtained from the questionnaire results as a database and the interview results, which illustrate the community's expectations regarding the vulnerable conditions of their settlements. Data from the questionnaire's results are then presented in bar charts and tables. The attitude scale or respondent assessment results are then analyzed and assessed on a score scale of 1 to 5, as presented in Table 1. The scores are used as an assessment guide, where a low score to a high score indicates the respondent's response, ranging from very bad to very good response, respectively. Then, a strategy was developed to increase the community's adaptive capacity to reduce the vulnerability of settlements based on assessments and interview results.

Results

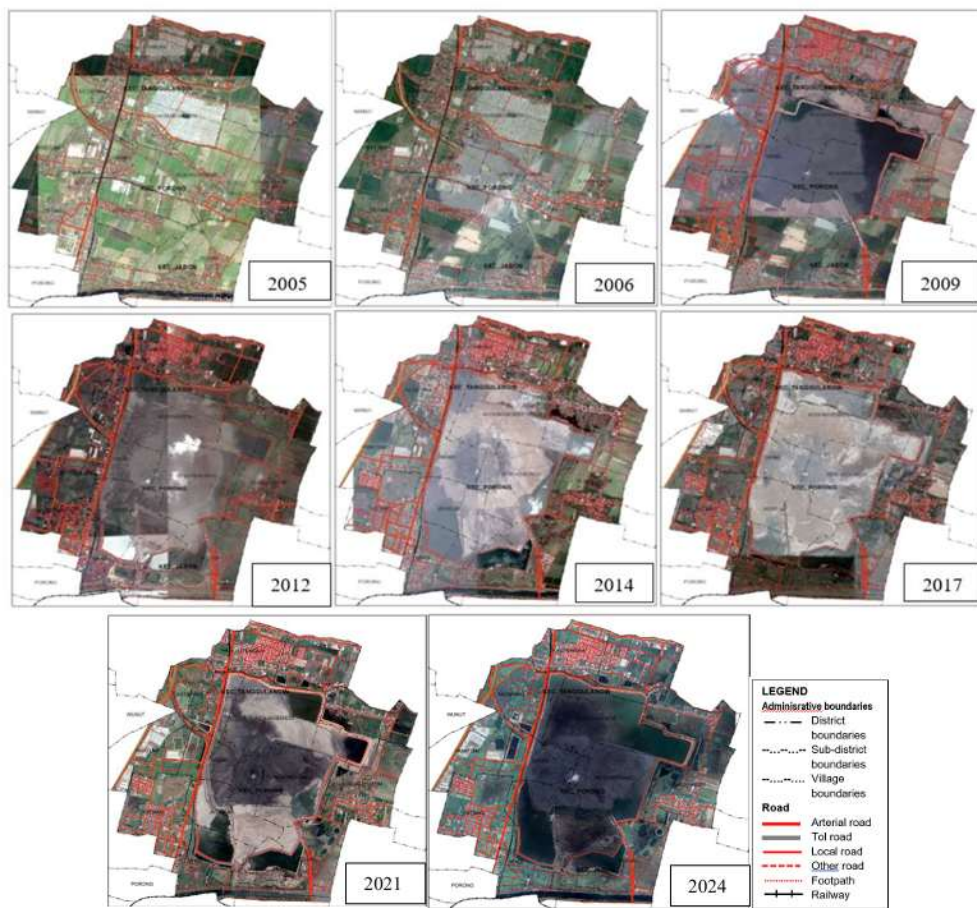


Figure 5. Land Changes of the study area (Source: Processed from www.earthexplorer.usgs.gov, 2025)

This section contains changes that occur in land in areas impacted by the Lapindo mudflow disaster from time to time and describes assessment results of the community's adaptive capacity to support the process of becoming resilient settlements and strategies for increasing adaptive capacity. This assessment includes economic capacity, social-cultural-religion, infrastructure, information technology, institutions, organizations, knowledge, and community adaptation performance. Based on the results obtained from this adaptive capacity assessment, various strategies were formulated to increase the community's adaptive capacity in reducing the vulnerability of their settlements to the impacts of the disaster they are facing.

Land Changes in the Study Area

Figure 5 is satellite imagery processed to show the development of the study area on the Lapindo mud embankment and the surrounding villages. Since 2006, the area of the mud embankment has continued to expand. Before the disaster (in 2005), the area was dominated by agricultural land and gradually turned into a mud storage area enclosed by a retaining embankment wall and uninhabited vacant land. Figure 5 shows that the mud embankment underwent massive expansion from 2006 to 2017, so many community settlements had to be relocated. For 2017-2024, there will be no more expansion of the mud embankment area. Many of the occupants abandoned their houses. Most residents did this because their homes were submerged in mud. Some did because their homes were located in locations included in the disaster-affected map made by the government. However, some residents were unwilling to move and remained in their homes even though their homes in the area were vulnerable to damage due to disasters, such as flooding and land subsidence, and were included in disaster-affected maps from the government (Figure 6).



Figure 6. The boundary fence of the land included in the disaster-affected map from the government in Kalitengah Village (Source: Author documentation, 2022)

The expanding submerged or affected areas certainly raise public concern. Floods often submerge settlements whenever it rains. Several pump units have been set up at the location. However, people are still worried and must face the risk of floodwater entering their homes. On the other hand, from the field observation, some people still choose to live in their settlements rather than move to other locations (Figure 6), where several houses and mosques remain even though they are within the fence of the area that should be vacated. Many people have their compensation for moving to another location. However, they only moved to the surrounding villages. Some only moved to different locations in the same village. as in the study site, namely Kalitengah, Gedang, and Glagaharum villages.

Respondent Profile

Some profile data collected from respondents related to adaptive capacity (Table 2) include education level, occupation, work location, and income per month, with the following options:

- Education level: 1) Elementary; 2) Junior High; 3) Senior High; 4) Undergraduate; 5) Post Graduate.
- Occupation: 1) Farmer/Informal Worker/non-permanent worker; 2) Student/College Student; 3) Entrepreneur; 4) Private worker; 5) Government officers/BUMN.

- Income per month: 1) Very inadequate; 2) Inadequate; 3) Sufficient; 4) Adequate; 5) Very adequate
- Family spending per month: 1) greatly decreased; 2) decreased; 3) constant; 4) increased; 5) greatly increased.
- Workplace location: 1) very far; 2) far; 3) moderate; 4) near; 5) very near.

The respondents selected for this study were adults who had lived in their homes for quite some time. From Table 2, most of the respondents of this study have an education at the elementary level (40,41%), junior high school level (21.92%), and senior high school level (17,12%). Only 1 person has a bachelor's degree (0.68%). This is undoubtedly less beneficial for society's level of adaptive capacity. The interview results also found that some people have economic difficulties in improving their children's education to the undergraduate level because, in addition to their homes being physically affected by the disaster, many have been economically affected by the COVID-19 pandemic. This requires support from the government to provide educational scholarships for children affected by the disaster and experiencing economic difficulties, as well as encouraging informal education for adults.

Table 2: Percentage of Respondent's Profile

Respondent's Profile	Percentage				
	1	2	3	4	5
1. Education Level	40.41	21.92	17.12	0.68	0
2. Occupation	76.92	1.71	0	20.51	0.85
3. Income per month	12.26	30.97	36.77	19.35	0.65
4. Family spending per month	2.56	22.22	48.72	18.80	7.69
5. Work location	5.13	20.51	46.15	24.79	3.41

Source: author's analysis from questionnaire, 2024

The structure of the people's income in Table 2 shows that the respondents' income is still very inadequate and inadequate, with the largest income range being between IDR 2-3 million per month. This means it is less than the regional minimum wage in Sidoarjo Regency of Rp 4.638.582,00 per month, based on the Governor of East Java Decree number 188/656/KPTS/013/2023, concerning Regency / City Minimum Wages in East Java in 2024 (Bappeda Jatim, 2023). This income structure is influenced by the type of work of the respondents, where the largest respondents' type of work was farmers/informal/non-permanent workers at 76.92%, private workers at 20.5%, Government Officers at 0.85%, and students at 1.7%.

Adaptive Capacity of Local Community

The assessment scoring guide in each indicator in Table 3 uses a 1-5 score scale, which indicates the range from very bad to very good; we get the average score of each indicator and the total average score of all indicators, where a score of 1.00-1.99 means very bad, a score of 2.00-2.99 means bad, a score of 3.00-3.99 means good, and a score of 4.00-5.00 means very good.

Table 3. The average score of each adaptive capacity indicator

Adaptive Capacity		Average Score		Explanation
Variable	Indicator	Individual	Community	
Economic	Income per month	2.753		The community's income level is below the average, but respondents consider their economic readiness to be quite good in a disaster.
	Economic readiness in the event of a disaster	3.144	3.055	
Social-cultural -religious	Participation in social, cultural, and religious activities	4.199	3.863	Excellent levels of community participation and social relations are the capital in building adaptive capacity.
	Close social relations and communication between community members	4.651	4.363	
Technology & information systems	Availability and affordability of telecommunications equipment and signals	2.890	3.089	The absence of an early warning system for which the government is responsible has led to a lack of assessment scores on technical performance in the region.
	Ease and speed of access to the early warning system	2.657	2.808	
Adaptability & Performance	Education level	1.748		The average score in the ability and success of community adaptation is quite good. However, the current level of education and assessment of the condition of settlements and the surrounding environment is below average.
	Knowledge of disasters that hit residential areas	3.336	3.130	
	The ability of the community to survive and adapt to emergency conditions in this region	3.520	3.548	
	Current housing and environmental conditions	2.774	2.815	
	The success of the community's adaptation	3.329	3.452	

	efforts since the disaster occurred			
Disaster Infrastructure	Availability and capacity of disaster management facilities	2.479	2.829	Respondents considered that the infrastructure related to disaster emergencies was still not good.
	Availability and affordability of infrastructure in an emergency	2.582	3.014	
Disaster Management	Preparedness for future disasters	3.007	3.075	Respondents' assessment of disaster management in their village is still not good, but the disaster preparedness assessment is considered sufficient.
	Disaster management in the village now	2.788	2.842	
Total Mean		3.151	3.188	

Source: author's analysis from questionnaire, 2024

From Table 3, in general, the average score of the adaptive capacity level at the community level is slightly better than the adaptive capacity at the individual respondent level, with a score difference of 0.037. This is mainly supported by indicators in the variables of technology and information systems, infrastructure, and disaster management, which average scores are better than capacity at the individual level. Meanwhile, the average score indicator that significantly reduces the adaptive capacity score at the individual level is adaptation capacity and disaster infrastructure.

From the average score obtained from the responses to each indicator, the best score is in the social, cultural, and religious fields, where the level of community participation in social, cultural, and religious activities is very high, with an average score of 4,119 and the relationship between social community has a score of 4,651. This is, undoubtedly, an advantageous asset in building the community's adaptive capacity.

On the other hand, the lowest average score indicates the respondent's education level, which is 1,748 (50.43% of the respondents have an elementary education). This indicates that, in general, local people with elementary-level education are more dominant. This condition is certainly not favorable in assessing adaptive capacity because a high level of education will further increase the community's adaptive capacity in the adaptation process to disaster risk and reduce their vulnerability. As for several other indicators that received poor ratings, such as disaster management, disaster infrastructure, disaster management facilities, housing conditions, and family income, government agencies should immediately intervene by intensifying disaster mitigation.

If carefully examined, scores above 3 (fair) are mostly obtained from individual and community indicators. Meanwhile, scores for government agencies' indicators, such as infrastructure, information technology, and disaster management, are below 3 or less. This means that the performance of disaster management by government institutions from the village level to the medium level still needs to be improved and has not met the community's expectations. However, the overall average score is taken (without looking at the education level

score, which is only obtained at the individual level). In that case, the adaptive capacity score at the community level is slightly higher by 0,037 than the adaptive capacity at the individual level. Higher scores were mainly obtained on information technology capacity, adaptability and performance, disaster infrastructure, and disaster management.

Strategies for Increasing Adaptive Capacity to Reduce the Vulnerability of Settlements to Disaster Risk

In terms of building resilience, adaptive capacity is an important element and one of the key roles supporting disaster risk reduction and management (Didham & Ofei-manu, 2020; Marfai & Hizbaron, 2011). Referring to formula (1), the author agrees with Daramola (Daramola et al., 2016) that a low level of adaptive capacity would be synonymous with vulnerability. In contrast, a high level of adaptive capacity would indicate resilience.

The interviews with local communities revealed that disaster mitigation carried out around community settlement areas was more reactive, only carried out in the early post-disaster phase. This is often the case in other disaster sites worldwide, such as Nigeria (Daramola et al., 2016), which reveals a lack of preparedness for possible future disasters. Therefore, to reduce the vulnerability of settlements in areas affected by the hot mudflow disaster, efforts to increase adaptive capacity are urgently needed if the community chooses to remain in these locations.

Based on the results of the adaptive capacity assessment score described in Table 3, as well as the results of in-depth interviews with community elements that have been carried out, a strategy is formulated for disaster risk reduction, especially the vulnerability of settlements based on the adaptive capacity of communities in Table 4:

Table 4. Government Roles and Strategies in Reducing Vulnerability of Settlements

Adaptive Capacity	Government roles	Strategies in increasing adaptive capacity
Economic	Provide skills training, incentives, and access to banking	• Skills training and community empowerment are needed to increase family income. • There needs to be incentives from the government or access to banking facilities for venture capital. • Establishment of cooperatives at the village level that can assist in community financial management
Social-cultural-religious	Empowering community leaders to strengthen social, cultural, and religious activities	• Social, cultural, and religious activities involving the community need to be strengthened and increased in frequency to increase knowledge, insight, mental strength, and community resilience.
Technology & information systems	Provide an early warning system that is reliable and easily accessible to the public.	• The government needs to provide an early warning system to make people feel safer and more comfortable about the disaster risk threat in their villages.
Adaptability & Performance	Provide facilities and instructors to improve knowledge, education, and skills through formal and informal channels, giving	• The government needs to intensify the campaign for compulsory education for school-age children and adults to increase the community's capacity, insight, knowledge, skills, and education level through formal and informal channels.

	scholarships to affected children.	• Technical and financial assistance from the government is needed to repair damaged and uninhabitable houses. • Various skills training and disaster mitigation counseling can continue to be provided to broaden people's knowledge.
Disaster Infrastructure	Add infrastructure and disaster emergency facilities needed	• The existing infrastructure for the structural handling of the mudflow embankment walls is good enough. However, disaster emergency infrastructure (water pumps and early warning systems) and clean water networks or water purification around community settlements must be provided. • Building safe temporary shelters for residents and providing affordable evacuation routes in an emergency is necessary.
Disaster Management	Provide disaster mitigation training regularly at the school and community levels. Increase the capacity of institutions at the village level to manage structural and non-structural mitigation programs better.	• Continuously strengthen disaster mitigation programs at the village level in all areas by engaging community and religious leaders to enhance effectiveness and meet community expectations. • Increasing disaster management capacity at the village and regional levels so that the programs implemented align with the community's needs.

Source: author's analysis, 2024

From Table 4, for economic variables, the role of the government is expected to help the economic difficulties of people affected by disasters and even those losing their jobs during the COVID-19 pandemic. These economic difficulties also impact their ability to finance their children's schooling. Therefore, the central government's policy to provide scholarship assistance for children and policies in empowering communities through providing business skills training are greatly needed, especially for community groups whose incomes are decreasing. In social-cultural and religious variables, the role of religious leaders and community leaders is important, especially for the mental recovery of the community after a disaster. Therefore, empowering them in social and religious activities must be increased because it significantly increases the community's adaptive capacity. This can be implemented in local government policies by supporting funds for learning activities to recite the Quran for children, community religious activities, and providing incentives for teachers.

The strategy developed in this study is based on an assessment of the adaptive capacity obtained from a questionnaire distributed to the disaster-affected community. Time constraints and the absence of a resource person from BPLS (*Badan Penanggulangan Lumpur Sidoarjo*), the government agency tasked with handling the Lapindo mudflow disaster, are limitations in the completeness of the data we collect.

Discussion

The economic level of the community plays a significant role in supporting adaptive capacity and resilience (Adger et al., 2005). However, the results of this study reveal interesting and different things. In economic sector

indicators (Table 2), the community's economic readiness assessment has a good score (above 3) even though the average community has a low-income level. This shows a positive attitude from the community regarding their economic readiness to face disasters in the future. In other words, family income is essential, but it is not a determining indicator in assessing economic readiness or the community's adaptive capacity to face future disasters. Data from previous research (Sulistiyowati & Ekawati, 2021) revealed something quite interesting. 10-35% of the people said they experienced a decreased income after the disaster, but more than 94% increased their family savings. This data reveals that disasters affect the increasing public awareness of the importance of family savings as a form of economic preparedness against the possibility of disaster experiencing a significant increase.

From the results of in-depth interviews in the social, cultural, and religious fields, it was found that people are reluctant to move from their residential areas for many reasons. These include cultural reasons, namely maintaining the heritage house of their parents who want to maintain their existence, emotional and historical attachment to their homeland, and concerns about their adapting difficulty to a new environment. The consequences of the choice to survive certainly require the community to immediately adapt to their residential environment, which is now designated as a disaster-prone area (RTRW Sidoarjo, 2009). The closeness of social relations in the community and participation in every social, cultural, and religious activity held in the village is so good that various information and collective efforts to reduce vulnerability can always be communicated in these forums.

In this study, it was found that a powerful factor driving the high adaptive capacity of the community was in the social, cultural, and religious fields, and also in their social relations and willingness to participate in social, cultural, and religious activities held in their village. Meanwhile, in the Philippines, the strength of the social relations of the people living in the disaster area can also help reduce vulnerability in the community (Usamah et al., 2014). The Indonesian people, including the Javanese, are characterized as having high collectivism and low individualism culturally (Nadar, 2007), which indicates a strong need among community members to be close to each other. Strong social ties or relationships that become social identities are meaningful capital for strengthening the adaptive capacity of communities trying to maintain their settlements. This strengthens previous research (Farida, 2014), which revealed that the sustainability of a community's life is also determined by the community's social identity, not only by the quality of the surrounding environment (Farida, 2014). As a strategy to reduce vulnerability, social, cultural, and religious activities that involve the community need to be strengthened and increased in frequency because they can simultaneously increase the knowledge and mental strength of the community in the process of adapting to the impact of disasters.

The economic level of the community plays a significant role in supporting adaptive capacity and resilience (Adger et al., 2005). However, the results of this study reveal interesting and different things. In economic sector indicators (Table 2), the community's economic readiness assessment has a good score (above 3), even though the average community has a low-income level. This shows a positive attitude from the community regarding their economic readiness to face disasters in the future. In other words, family income is essential, but it is not a determining indicator in assessing economic readiness or the community's adaptive capacity to face future disasters. Data from previous research (Sulistiyowati & Ekawati, 2021) revealed something quite interesting: 10-35% of the people said they experienced a decreased income after the disaster. However, more than 94% increased their family savings. This data reveals that disasters affect the increasing public awareness of the importance of family savings as a form of economic preparedness against the possibility of a disaster, experiencing a very significant increase.

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Conclusions

This study concludes that the adaptive capacity of the community living in the area impacted by the Lapindo mudflow disaster in Sidoarjo, at the individual and community level, is medium in scores of 3.10-3.20. It means that although the respondents' average educational level and economic level are not good (50.43% have an elementary education level, and 46% have inadequate income), the level of adaptive capacity in total is still slightly above the average score (3.19). The most significant indicators to increase the adaptive capacity score are community participation in social, cultural, and religious activities (score of 3.86) and the strength of social ties and community communication (score of 4.36) in the study sites. This shows the importance of social, cultural, and religious variables in increasing adaptive capacity, which can later reduce regional vulnerability. These variables are also important capital for adapting to a disaster-resilient area. Meanwhile, other variables that have not been implemented well, such as education and community economy, can still be improved with sustainable and more targeted efforts.

The strategies that need to be emphasized to reduce the vulnerability of settlements within the framework of structural and non-structural disaster mitigation programs include: improving the education and knowledge of children and adults in the study areas through formal and informal channels and also scholarships to broaden the horizons and employment opportunities or entrepreneurship of the community; empowering community in the economic sector through skills training and business capital assistance; providing access to banking facilities and technical assistance to renovate houses damaged by the disaster; as well as increasing the availability and capacity of disaster infrastructure in community settlement areas such as early warning systems, strengthening the mud embankment wall structure; providing clean water networks and distillation; strengthening of disaster management institutions at the village level; and massive reforesting around community settlements to absorb

air pollution that has the potential to harm respiratory problems and public health in the study area due to gas explosions that are still happening up to now.

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