

Study on Community Settlement Resilience in Flood-Prone Areas of Batu Bara Regency Using an Environmental Adaptation Approach

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ABSTRACT

This study aims to analyze the resilience of community settlements in flood-prone areas in Kwala Sikasim Village, Sei Balai District, Batu Bara Regency, using an environmental adaptation approach. Frequent flooding in this region has resulted in significant losses across various aspects of community life, including housing, economy, and health. Therefore, this research examines how communities adapt to environmentally vulnerable conditions and identifies strategies that can enhance their resilience. This study employs a descriptive method with both quantitative and qualitative approaches. Data were collected through surveys involving 175 respondents, in-depth interviews with policymakers, and field observations. The analysis technique used is SWOT analysis to identify the strengths, weaknesses, opportunities, and threats in the community's flood adaptation efforts. The findings reveal that the community has implemented various adaptation strategies, such as elevating houses, independently constructing embankments, and altering livelihood patterns. However, there are still challenges, including economic limitations and inadequate flood control infrastructure. The SWOT analysis indicates that although the community has a relatively high awareness of flood risks, they remain highly dependent on government assistance for post-disaster recovery. Therefore, there is a need for increased investment in flood control infrastructure, strengthening early warning systems, and continuous public education on disaster mitigation. With the implementation of appropriate strategies and support from various stakeholders, the resilience of settlements in flood-prone areas can be significantly improved.

Keywords: *Settlement resilience, Flood, SWOT*

Introduction

Batu Bara Regency in North Sumatra Province is one of the regions highly vulnerable to flood disasters. In recent years, the frequency and intensity of floods in this area have significantly increased. One of the major flood events occurred in January 2025, affecting 1,591 houses and 212 hectares of rice fields, with floodwaters reaching a height of up to 30 centimeters. This flood impacted four sub-districts—Sei Balai, Datuk Tanah Datar, Talawi, and Medang Deras—with villages such as Kwala Sikasim, Sei Muka, and Benteng experiencing severe damage.

The recurring flood phenomenon has created various critical challenges for the local communities, particularly in terms of material losses, disruption of economic activities, and threats to public health and safety (Sugiarto et al., 2023). Material losses include damage to housing infrastructure, public facilities, and agricultural land, which serves as the main source of livelihood for the majority of the population (Nuraini, 2019, 2024). Economic disruption arises from impeded transportation and distribution access, while health risks emerge due to the potential spread of diseases stemming from unsanitary post-flood conditions.

Kwala Sikasim Village in Sei Balai Sub-District is one of the most severely affected areas. During the January 2025 flood, the village was inundated, submerging 326 houses and 86 hectares of rice fields. This situation forced residents to undertake various adaptation efforts to sustain their livelihoods amid the ongoing threat of recurrent flooding. Community adaptation to flood disasters is a crucial aspect to be examined in order to understand the resilience of community organization and the effectiveness of the adaptation strategies applied (Linda et al., 2024). Previous studies have investigated various forms of adaptation undertaken by communities in flood-prone areas. For instance, Dewi and Setiawan (2021) found that residents of Pudahoa Village, South Konawe, implemented adaptation strategies such as constructing embankments, raising house foundations, and disseminating flood warnings through sirens or traditional bells. Similar findings were presented by Susanto and Wibowo (2022) in Trucuk Sub-District, where communities built two-story houses, installed water barriers, and elevated house foundations as mitigation measures. More specific strategies were identified by Rahayu and Firmansyah (2023) in Sayung Sub-District, where coastal communities responded to tidal flooding by constructing embankments, elevating houses, and modifying their livelihoods to better adapt to environmental conditions.

Comparable studies have also been conducted in various countries with different geographic conditions but similar challenges. Dewi (2007), in her study on urban flooding in Semarang, emphasized a community-based approach with strong community participation in planning and implementing adaptation strategies. Meanwhile, Rahman and Alam (2022) explored flood risk perception and adaptation strategies among coastal communities in Bangladesh, highlighting the significant role of social and economic factors in determining appropriate adaptation responses. In the Netherlands, Van der Brugge and Rotmans (2021) examined flood risk management strategies that combine both technical and non-technical approaches with active community engagement. This aligns with the findings of Brown and Wilson (2020), who explored factors influencing community decisions to either relocate or rebuild in the same location after flood disasters. Additionally, Yusuf and Rahayu (2023) in Kampung Melayu, Jakarta, demonstrated that residents in flood-prone areas undertake various home modifications and alternative livelihood strategies to survive in uncertain environmental conditions.

Although numerous studies have been conducted, research specifically addressing community adaptation in Batu Bara Regency—particularly in Kwala Sikasim Village—remains limited. Therefore, this study is essential for understanding the local dynamics of communities in coping with floods and identifying effective environmental-based adaptation strategies to enhance community resilience in flood-prone areas.

Literature Review

A. Grand Theory: Human Ecology Theory

The Human Ecology Theory was first developed by Bronfenbrenner (1979) and emphasizes that the interaction between humans and their environment shapes sustainable patterns of adaptation. In this study, the theory is used to explain how the community in Kwala Sikasim Village adapts to flood-prone environmental conditions through strategies such as elevating houses, constructing community-built embankments, and diversifying livelihoods. This theory posits that the community's adaptive capacity to disasters depends on three main factors: economic, social, and institutional.

In the context of this research, it was found that although the community possesses a high level of awareness regarding flood risks, they face economic limitations and a lack of institutional support. Consistent with the findings of Setiawan and Prasetyo (2021), communities with strong social engagement tend to be more capable of developing effective adaptation strategies.

B. Middle-Range Theory: Adaptive Capacity Theory

The Adaptive Capacity Theory was developed within the field of social-ecological resilience studies and explains how individuals or communities possess the ability to anticipate, respond to, and recover from external disturbances such as natural disasters (Smit & Wandel, 2006). Adaptive capacity includes economic, social, and institutional factors that influence how communities respond to environmental threats.

In the study by Susanto and Wibowo (2022), the adaptive capacity of communities to floods in Trucuk Sub-District was linked to economic factors (financial capability to elevate homes), social factors (community readiness to share information and resources), and institutional factors (government support through mitigation policies). Similar factors were identified in the study by Van der Brugge and Rotmans (2021), which examined adaptation strategies in the Netherlands, where infrastructure support and disaster mitigation policies played a key role in enhancing community adaptive capacity.

In the context of Batu Bara Regency, adaptive capacity can be measured by the community's preparedness in facing floods, such as improving housing infrastructure, diversifying livelihoods, and participating in disaster mitigation programs. The study by Rahayu and Firmansyah (2023) demonstrated that these strategies are effective in reducing disaster impacts and enhancing community resilience.

C. Applied Theory: Settlement Adaptation Model to Floods (Flood Adaptation Model)

In the applied theory of adaptation to flood disasters, the organizational adaptation model developed by Yusuf and Rahayu (2023) serves as an approach applicable to this study. This model categorizes organizational adaptation into three main components:

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1. Structural Adaptation

This type of adaptation includes physical measures such as elevating houses, constructing embankments, and using water-resistant materials in home construction. According to the study by Fadillah and Prasetyo (2021), communities in Bojongloa Village applied these techniques to reduce the impact of recurring floods.

2. Social Adaptation

Social adaptation involves changes in community behavior patterns, such as increased awareness of flood risks and the formation of community-based mutual aid groups for disaster mitigation (Dewi, 2007). For example, in a study of Kampung Melayu, Jakarta, Yusuf and Rahayu (2023) found that community cooperation played a crucial role in enhancing flood resilience.

3. Economic Adaptation

This adaptation includes diversifying income sources and utilizing local resources to minimize flood-related losses. In the study by Nurdin and Lestari (2020), it was found that residents of Kuala Terusan Village developed salted fish processing businesses as a form of economic adaptation during the flood season. The application of organizational models to floods in Batu Bara Regency can help identify the most effective strategies in increasing community resilience. By understanding these various forms of adaptation, this study is expected to provide applicable recommendations for organizational management in disaster-prone areas.

The application of the organizational adaptation model to flood conditions in Batu Bara Regency can help identify the most effective strategies for enhancing community resilience. By understanding these various forms of adaptation, this study aims to provide practical recommendations for organizational management in disaster-prone areas.

Results and Discussion

A. General Overview of the Study Area

This research was conducted in Kwala Sikasim Village, Sei Balai Sub-District, Batu Bara Regency, which is one of the areas with a high level of flood vulnerability. The village frequently experiences flooding due to high rainfall, suboptimal drainage systems, and rising water levels from the Asahan River, which flows near the village. According to data from the Regional Disaster Management Agency (BPBD) of Batu Bara Regency, the most recent flood in January 2025 inundated more than 326 houses and 86 hectares of agricultural land. The geographical condition of Kwala Sikasim Village, located in a lowland area, causes water to accumulate easily, while flood control infrastructure such as embankments and drainage channels remains limited. The majority of the village population works in the agriculture and fisheries sectors, making flooding highly disruptive to their livelihoods.

B. Respondent Survey Results

The survey was conducted on 175 respondents, consisting of flood-affected residents, village officials, disaster experts, and volunteers. The following are the analyzed survey results:

Table 1. Respondent Characteristics

Aspect	Category	Percentage (%)
Education Level	Low education level (Elementary–Junior High)	24%
Occupation	Majority informal workers	22%
Monthly Income	Income below IDR 2 million/month	46%

Source: Author, 2025

Based on the survey results, most respondents have a low level of education and work in the informal sector, with incomes below IDR 2 million per month. This indicates limited access to resources and flood mitigation information.

Table 2. Infrastructure Readiness and Community Adaptation

Aspect	Category	Percentage (%)
Infrastructure Readiness	Availability of flood-resistant infrastructure	36%
Awareness of Flood Risk	Risk awareness and preparedness	60%
Participation in Mitigation Programs	Participation in mitigation training	50%

Source: Author, 2025

About 60% of respondents reported a high level of awareness of flood risks; however, only 36% have access to flood-resistant infrastructure. Meanwhile, community participation in mitigation programs remains relatively moderate at 50%.

Table 3. Community Flood Adaptation Strategies

Adaptation Strategy	Percentage (%)
Elevating Houses	72%
Building Community-Based Embankments	50%
Changing Livelihoods	40%

Source: Author, 2025

The majority of residents have implemented structural adaptation strategies, such as elevating their houses (72%) and constructing embankments independently (50%). However, only 40% have changed their livelihoods to reduce economic impacts from flooding.

Table 4. SWOT Analysis of Settlement Resilience to Flooding

Factor	Aspect
Strengths	High community awareness
	Initiative to build community-based embankments
Weaknesses	Limited flood control infrastructure
	Low household income
Opportunities	Government aid programs

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	Development of adaptation technologies
Threats	Increasing flood intensity
	Lack of government attention

Source: Author, 2025

The results of the survey indicate that 72% of the community have implemented house elevation as a structural adaptation strategy against flooding, while 50% have constructed community-built embankments to protect their settlements. These strategies demonstrate a high level of awareness among residents regarding flood risks and their efforts to carry out mitigation using available resources. This finding aligns with the study by Setiawan & Prasetyo (2021), which showed that communities in Central Java also employed similar approaches, where house elevation was the primary measure taken to cope with seasonal flooding.

However, when compared with the study conducted in Kampung Melayu, Jakarta by Yusuf & Rahayu (2023), it was found that urban communities tend to adopt different adaptation strategies, such as the use of water-barrier doors and the construction of stilt houses with water-resistant materials. These choices are influenced by limited land availability, which restricts the possibility of constructing embankments independently.

Additionally, a study by Faisal et al. (2022) in coastal areas of Sumatra revealed that communities in those regions relied more heavily on government assistance in the form of permanent embankment construction, rather than self-initiated efforts as observed in Kwala Sikasim Village. This highlights that community adaptation to flooding is highly dependent on economic factors and infrastructural support from local governments. However, in this study, only 40% of respondents reported changing their livelihoods as a form of economic adaptation, indicating that the majority still depend heavily on agriculture and fisheries—sectors that are particularly vulnerable to flood impacts. In contrast, Nasution et al. (2024) found that communities in Eastern Indonesia were more likely to diversify economically by shifting to trade and service sectors, which more effectively reduced the economic impact of flooding.

C. Link Between SWOT Analysis and Existing Flood Mitigation Policies

The SWOT analysis in this study revealed that although the community possesses a high level of awareness of flood risks and has implemented various adaptation strategies, there are still significant constraints, particularly in terms of infrastructure and economic capacity. One of the key weaknesses identified is the limited access to adequate flood control infrastructure, which forces the community to rely on individual mitigation efforts, such as building their own embankments or elevating their homes.

In relation to government policy, several flood mitigation programs are currently in place, including:

1. Flood Infrastructure Rehabilitation and Reconstruction Program – The local government has allocated funds for drainage system improvements and embankment construction. However, the program has not yet covered all affected areas, leaving many communities to build embankments independently.
2. Flood Mitigation Education and Awareness Program – This program aims to raise community awareness about flood risks and mitigation measures. However, its effectiveness remains limited, as reflected in survey data showing that only 50% of respondents reported having attended disaster mitigation training.

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3. Post-Flood Recovery Financial Assistance – The government has provided aid for flood victims; however, the funds are often insufficient to rebuild flood-resilient infrastructure.

In comparison to flood mitigation programs in the Netherlands, which apply the "Room for the River" approach (Van der Brugge & Rotmans, 2021), it is evident that the Dutch government implements relocation policies for settlements in high-risk flood areas to safer zones. This differs from the approach in Indonesia, which is still more focused on constructing embankments and flood control infrastructure. In the context of this study, a similar policy could be adapted through incentive-based relocation, whereby communities are given financial support to move to safer areas.

Furthermore, compared to Japan's mitigation model (Mizutani et al., 2022), which has adopted technology-based early warning systems, this study reveals that early warning systems in Kwala Sikasim Village are still very limited. Therefore, one of the key recommendations is to integrate SMS- and mobile application-based early warning systems, as successfully implemented in several other countries.

Based on the SWOT analysis, it can be concluded that although the community has demonstrated a high level of adaptation to flooding, there is still a need for more effective policy interventions. These include more equitable infrastructure development, enhancement of education and disaster mitigation programs, and the application of technology in early warning systems. With a more comprehensive strategy, community resilience to flooding can be significantly and sustainably improved.

Conclusion

Based on the research conducted in Kwala Sikasim Village, Sei Balai Sub-District, Batu Bara Regency, it can be concluded that the community in this area possesses a relatively high level of awareness regarding flood risks and has implemented various adaptation strategies, such as elevating houses (72%) and constructing community-built embankments (50%) as mitigation measures. However, economic limitations and inadequate flood control infrastructure remain major obstacles to enhancing organizational resilience against flood disasters.

The SWOT analysis results show that although the community demonstrates strong initiative in adapting to environmental challenges, they still heavily depend on government assistance for post-disaster recovery. The existing flood mitigation programs, such as infrastructure rehabilitation and social assistance, have not yet effectively reached all affected populations. Furthermore, compared to other regions in Indonesia that have adopted community- and technology-based adaptation strategies, the preparedness level of Kwala Sikasim's residents still needs improvement, particularly in terms of disaster education and economic diversification.

To strengthen organizational resilience to floods, more targeted and policy-based mitigation strategies are required. The following recommendations can be applied:

1. Sustainable Development of Flood-Resilient Infrastructure
 - a. Strengthening community-based drainage systems, where the government and local communities collaborate in building and maintaining more efficient systems to prevent waterlogging.
 - b. Constructing stronger and more durable embankments using a community-based approach to encourage local participation in planning and maintenance.

- c. Applying water-resistant materials in house construction, as has been done in some coastal areas of Indonesia to reduce flood impacts on homes.
2. Relocation of Settlements in High-Risk Flood Areas
 - a. Adapting the “Room for the River” policy model from the Netherlands (Van der Brugge & Rotmans, 2021) with an incentive-based relocation concept, where the government offers support and facilities for residents willing to move to safer locations.
 - b. Providing flood-resistant vertical housing in urban areas to reduce flood risk for communities that cannot be relocated.
3. Strengthening Technology-Based Early Warning Systems
 - a. Referring to Japan’s mitigation system (Mizutani et al., 2022), the government can develop **sensor-based early warning systems** capable of detecting rising water levels and sending alerts via **SMS and mobile applications**.
 - b. Implementing community-based warning systems, encouraging local residents to participate in early detection and coordination for localized response efforts.
4. Economic Diversification and Strengthening Community Adaptive Capacity
 - a. Providing alternative livelihood training for flood-affected residents so they are not solely reliant on the disaster-vulnerable agricultural sector.
 - b. Implementing **disaster insurance schemes** to protect households from economic losses caused by floods, similar to initiatives adopted in several ASEAN countries through **economically focused disaster mitigation programs**.
5. Multi-Stakeholder Collaboration in Flood Mitigation
 - a. Engaging **private sectors and non-governmental organizations (NGOs)** in rehabilitation programs and infrastructure development for flood mitigation.
 - b. Utilizing the Community-Based Disaster Risk Management (CBDRM) approach, as successfully applied in Bangladesh (Rahman & Alam, 2022), to enhance local capacity through training and disaster simulations.

With the implementation of these strategies, it is expected that community resilience to flood disasters can be significantly strengthened. The integration of community-based policies, technological innovations in disaster mitigation, and economic diversification initiatives represents a long-term adaptive approach to reducing the social and economic impacts of flooding.

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