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Community Adaptation and Local Wisdom in Managing Flood Risks in Upstream Watershed Areas of Southeast Asia

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A B S T R A C T
The upstream watershed area in Indonesia is an area that is vulnerable to flooding due to environmental degradation, land conversion, and erratic rainfall patterns. This study aims to analyze the forms of adaptation carried out by local communities and explore the role of local wisdom in flood risk management, focusing on the relationship between community social capacity and the effectiveness of community-based risk reduction strategies. This study uses a descriptive qualitative approach with case studies in three villages in the upstream area of the river. Data were collected through in-depth interviews with twenty-four informants consisting of indigenous leaders, farmers, and village officials, and supported by participatory observation and documentation of local practices. Data analysis was carried out thematically to identify patterns of community adaptation and forms of integration of local values in environmental management practices. The results of the study show that the community develops adaptation strategies based on local wisdom, such as contour farming systems, water-retaining vegetation management, rainwater runoff channels, and local traditions as early warning systems. These findings suggest that the integration between community adaptation and local wisdom forms the foundation of contextual and sustainable flood risk management. This research makes a theoretical contribution to the development of disaster science and a practical contribution to the formulation of community-based environmental management policies.

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INTRODUCTION

Floods are one of the most frequent natural disasters in upstream river areas in Indonesia. The main factors that aggravate flood risk are land conversion, forest degradation, and climate change that increases rainfall intensity (Muhammad, Lubis, & Setiawan, 2020). The impact is not only felt on the environmental aspect, but also interferes with economic, social, and public health activities. In many upstream areas, communities often face recurrent flooding without adequate mitigation infrastructure support. In these situations, local communities often rely on traditional knowledge and practices passed down from generation to face and adapt to flood risks. Strategies such as planting landslide-resistant crops, contour farming systems, and customary rituals are part of the local response to hydrometeorological disasters (Herawati et al., 2023).

The use of local wisdom in the context of disaster adaptation is important because it reflects the accumulation of ecological experience and knowledge that has been empirically tested by communities from generation to generation. Various studies show that practices based on local wisdom are not only technically effective, but also have high social legitimacy in the community. For example, in indigenous peoples in the interior of Kalimantan, customary belief systems and prohibitions are able to regulate land use patterns in a sustainable manner and prevent overexploitation that has the potential to exacerbate flooding (Yulianti & Nugroho, 2021). Nevertheless, these practices are still often underestimated in formal policy, with more emphasis on modern structural and technological approaches.

In addition, it is important to understand that adaptation to flooding in upstream river areas cannot be separated from the social, economic, and cultural dynamics of local communities. Changes in village leadership structures, economic pressures, and the inclusion of external values often affect the sustainability of local wisdom (Pearce et al., 2021; Shin et al., 2023). In some cases, modernization has replaced local practices that have been proven effective, but not systematically documented. As a result, communities have lost their cultural footing, which has been a source of resilience in the face of disasters (Pineda & Barrios, 2022). Therefore, it is important to reconstruct and revitalize these local forms of knowledge as part of a contextual adaptation strategy (UNDRR, 2022).

The geographical context of the upstream area also presents its own challenges in flood risk management. Steep topographic characteristics, diverse vegetation densities, and limited regional accessibility make technocratic interventions from the outside often ineffective if not accompanied by a participatory approach (Ullah et al., 2020). In these conditions, community-based adaptation becomes increasingly relevant because it is bottom-up and rooted in local realities (Leal Filho et al., 2023). Research on how upstream communities leverage local knowledge to monitor natural change, build traditional infrastructure, and maintain ecosystem balance is important as a foothold for evidence-based policy (Zambrano et al., 2020; Otto et al., 2021).

Although the role of local communities in dealing with flooding has been widely recognized, research on the integration of community adaptation and local wisdom in upstream areas is still very limited. Some previous studies have

focused more on the technical aspects of flood mitigation, such as physical infrastructure and early warning systems, without examining the contribution of local cultural values in depth. (Zaki et al., 2020) examines the local wisdom of the Javanese people through the traditional calendar system, but does not explain how the practice functions in the ecological context of the upstream river region. Another study by (Aksa & Afrian, 2022) examined the adaptation of coastal communities to tidal flooding, but it is not relevant for upstream areas of rivers that have different geographical and social characteristics. Thus, there are still important gaps in the literature that need to be filled through more focused and contextual studies.

This study aims to identify and analyze the form of community adaptation based on local wisdom in managing flood risk in upstream river areas in Indonesia. The focus of this research is to describe local practices applied by communities in dealing with the threat of flooding, as well as to evaluate the effectiveness of these strategies in increasing social and environmental resilience. This study also seeks to understand the relationship between local cultural values and people's adaptive abilities to rapid environmental changes.

The results of this research are expected to make a theoretical contribution to the development of socio-ecological system studies and community-based disaster risk management. In addition, practically, this research can be a reference for policy makers, local governments, and civil society organizations in designing disaster mitigation strategies that are appropriate to the local and sustainable context. Integration between community adaptation and local wisdom can be an effective approach to flood risk management, especially in areas that have not been reached by formal mitigation systems.

THEORETICAL REVIEW

Adaptation to Flood Risk in the Upstream River Region

Adaptation to flood risk in upstream areas is a complex challenge because it involves geographical, ecological, and social variables. Steep topography, diverse vegetation, and limited accessibility lead to technocratic interventions often ineffective (Ullah et al., 2020). In this context, the community-based adaptation approach becomes relevant because it utilizes time-tested local knowledge in dealing with disasters (Leal Filho et al., 2023). This approach emphasizes the importance of understanding local conditions, including hydrological cycles, rainfall patterns, and natural indicators as a basis for evidence-based decision-making (Zambrano et al., 2020).

The Role of Local Wisdom in Community Resilience

Local wisdom is a knowledge system formed through people's long experience in interacting with their environment. In the context of disaster risk management, local knowledge provides adaptive strategies that are often more suited to local ecological and social conditions than imported technical solutions (Pineda & Barrios, 2022). Research by Pearce et al. (2021) shows that indigenous peoples in Arctic river regions use natural sign systems to predict extreme

weather changes and carry out early evacuations, a form of adaptation that arises from a deep understanding of their landscapes.

Social Disruption and Erosion of Traditional Knowledge

Modernization and global economic pressures have led to a shift in local practices in resource management and disaster mitigation. The inclusion of external values and changes in the social structure of the community, such as migration or transformation of village leadership, also affect the continuity of local wisdom (Shin et al., 2023). In many cases, local strategies that were once effective are now abandoned because they are not systematically documented or considered archaic by younger generations (UNDRR, 2022). As a result, people's adaptive capacity decreases along with the loss of cultural foothold in responding to disasters (Otto et al., 2021).

Local Knowledge Revitalization and Integration Strategy

Contemporary literature emphasizes the importance of integrating local and scientific knowledge in inclusive and sustainable adaptation strategies. Revitalization of local knowledge can be done through participatory documentation, community education, and active community involvement in the adaptation policy planning process (Pearce et al., 2021; Leal Filho et al., 2023). This integration not only increases the effectiveness of adaptation interventions, but also strengthens cultural identity and people's sense of ownership of the solutions taken (Shin et al., 2023).

METHODOLOGY

Research Approach

This study uses a descriptive qualitative approach with a case study design. This approach was chosen to explore in depth the phenomenon of community adaptation and the role of local wisdom in managing flood risk in upstream watersheds (watersheds), as these issues are contextual and complex and involve social and cultural values that cannot be quantitatively measured (Jackson & Mazzei, 2021). The case study allows researchers to comprehensively understand local dynamics within a specific socio-ecological framework, as well as analyze the interaction between community adaptation strategies and local wisdom practices (Mills et al., 2022).

Research Population

The population in this study includes all communities living in the upstream area of the three villages selected as the study location, namely Village A, Village B, and Village C (identities are disguised to maintain ethical confidentiality). The selection of locations is carried out purposively by considering the characteristics of areas that are prone to flooding and still maintaining local wisdom practices. The sampling technique uses a non-probability method with a purposive sampling approach, namely the selection of informants based on considerations of knowledge, experience, and direct involvement in community adaptation practices and the preservation of local

wisdom (Etikan & Bala, 2023). A total of 24 informants were involved in this study, consisting of traditional leaders (6 people), local farmers (10 people), and village officials (8 people). The number and diversity of informants were selected to achieve data saturation and perspective triangulation.

Data Collection Techniques

Data collection techniques were carried out through semi-structured in-depth interviews, participatory observations, and documentation of local practices. The interview guide was compiled based on themes developed from previous literature studies on community-based adaptation and local knowledge in disaster risk management (Pearce et al., 2022). The interview instrument was validated through expert judgment from two academics in the field of disaster studies and rural sociology. Observations were carried out for three weeks in each village to document real practices of adaptation and social interaction in environmental management.

Research Procedure

The research procedure begins with the preparation of research design and ethical licensing from related institutions. After the location was determined, the researcher made an initial approach with community leaders to establish communication and obtain permission to conduct observations and interviews. Data collection was carried out in stages for three months (January-March 2025). The interview was recorded with the informant's consent and transcribed verbatim. The data analysis process is carried out thematically using an approach (Braun & Clarke, 2021), starting from the data familiarization stage, initial coding, theme search, theme review, theme naming, to the preparation of an interpretive narrative. The analysis is assisted by NVivo 14 software for qualitative data organization and systematic identification of thematic patterns.

Data Analysis Techniques

The data analysis technique focuses on the interpretation of social meaning from adaptive actions and local values that are internalized in community practices. The validity of the data was strengthened through triangulation of sources (different informants), methods (interviews, observations, documentation), and researchers (peer debriefing). The credibility of the results is also supported by member checking, which is asking for confirmation from several key informants on the interpretation of the data that has been developed by the researcher (Torrance, 2021). This approach guarantees the reliability of the findings while ensuring that the results of the analysis reflect authentic social realities.

RESEARCH RESULTS

Based on the results of field research in three villages in the upstream watershed, five main findings were obtained that showed the existence of community adaptation based on local wisdom in flood risk management. These

findings were obtained from in-depth interviews with 24 informants, participatory observations, and documentation of local practices. The five main themes identified through thematic analysis are as follows:

Ecological Adaptation through Local Contour and Vegetation Farming Systems

Local farmers in the three villages studied (Village A, Village B, and Village C) showed a strong form of ecological adaptation through the application of contour farming systems on sloping land. This technique has been passed down from generation to generation and is integrated with the cultural values of the community that holds the principle of living in harmony with nature, known in local terms as "living in harmony with nature." Farmland on the slopes is formed in stages to slow the flow of water and prevent erosion, while vegetation such as bamboo, palm, and local guava are deliberately allowed to grow on the edges of the land and along the riverbanks. This vegetation serves as a natural buffer for rainwater and landslides, while providing a secondary crop yield that is economically valuable. A farmer informant from Village B said:

"*We don't just farm, we keep the land from getting angry. Contouring is not just an technique, it's part of our lives.*" (PL-03, February 7, 2025 interview).

This quote reflects an ecological view that is fused with a spiritual belief in nature, where agriculture is not only an economic activity, but also a form of care for the earth as a living entity. This ecological adaptation is not only carried out technically, but also involves social and spiritual considerations. In another interview, a farmer from Village C revealed:

"*If the rainy season comes, we believe that the bamboo plant can withstand the torrential water. That's why we don't cut down, but we plant again around the fields.*" (PL-08, Interview February 23, 2025).

This statement affirms the importance of utilizing local vegetation as natural infrastructure in flood risk mitigation. The practice is in line with the findings of Ford et al. (2020) which emphasized the importance of integrating local knowledge in community adaptation strategies to climate change and natural disasters.

Participatory and Community-Based Drainage Management

The communities in the upstream areas studied, namely Village A, Village B, and Village C, practiced a participatory and community-based drainage management system, by building traditional runoff channels or known locally as customary water gutters. This infrastructure is made independently using natural materials such as river stones and ironwood, obtained from the surrounding environment. The creation of the channel does not follow a technocratic design, but rather adjusts the contours and natural direction of the water flow, thus minimizing ecological disturbances and the risk of damage.

The process of planning and implementing the construction of the channel is carried out through the village deliberation forum. Residents collectively agreed on the location and shape of the channel, then worked together in the work. There was no intervention from the government or external funding assistance. This reflects the high level of community independence and social empowerment in managing infrastructure adaptive to flood risk. One of the traditional leaders from Village A said:

"*If it rains heavily, water from the hill can quickly enter the village. So we made a channel out of stones and ironwood, so that water could pass into the river. This is a joint effort, not a government project.*" (TA-02, Interview February 3, 2025).

This statement describes local initiatives that grow from collective awareness of disaster threats, and shows how community-based solutions can be more contextual and sustainable than top-down approaches. Furthermore, the village apparatus from Village C added the social dimension of this practice:

"*We believe that if water is not given a way, it will search for it on its own and can be destructive. So we made gutters using the old way. Not only physical work, but this is also to maintain harmony between humans and nature.*" (PD-07, Interview February 19, 2025).

This description shows the cultural dimension that underlies drainage management practices, where environmental management is not only oriented to technical functions, but also to the cosmological values of local communities.

These findings affirm the argument of Kruczkiewicz et al. (2021) that community-based approaches to disaster risk management, especially in the context of micro-scale infrastructure, can be more adaptive, fast, and appropriate to local needs than institutional approaches that are often generic and non-contextual. In this case, the success of participatory drainage systems lies not only in their technical effectiveness in reducing inundation, but also in inclusive social processes, which strengthen community social capital such as trust, solidarity, and mutual cooperation norms.

With the involvement of various local actors, ranging from traditional leaders, farmers, to village officials, the construction of customary gutters is a concrete manifestation of the synergy between traditional knowledge and contemporary collective action. This practice shows that adaptation to flood risk does not necessarily have to rely on high-tech-based solutions, but can be developed from local wisdom that has been tested by time and local ecological contexts.

Spiritual Values and Traditional Early Warning Systems

In the midst of limited access to modern technology systems, communities in the upstream areas of Village A, Village B, and Village C developed early warning systems based on spiritual values and traditional ecological knowledge.

One of the main forms is local rituals such as rain dances that are carried out in response to extreme weather changes. Apart from being a form of spiritual communication with nature, this ritual also serves as a collective reminder that weather conditions are unstable and the potential for flooding can increase.

In addition, the community uses the sound of bamboo kentongan as an emergency communication tool. The sound of kentongan has a certain pattern that is understood from generation to generation by residents as a marker of disasters, such as flash floods or landslides. The informant from Village B explained:

"*If the kentongan is hit quickly and repeatedly, it is a sign of flood danger. But if it sounds slow, it's just to gather residents. We have known since childhood the meaning of each sound.*" (PD-04, Interview February 8, 2025).

This statement suggests that early warning systems are not just physical tools, but rather part of the symbolic language of the community that has become inherent in everyday social practice. Interpretation of natural signs is also an integral part of the community's adaptation strategy. For example, changes in wind direction, bird flight patterns, the sound of crickets suddenly silent, to the shape of clouds rolling on the western horizon are all understood as signals of the coming of heavy rain or flood. This practice reflects a form of ecological knowledge that has been collectively constructed through cross-generational experience. One of the traditional leaders from Village C said:

"*In the past, before there was a weather forecast, we looked at nature. If the clouds are like a lump of cotton in the afternoon, it means that it is raining heavily at night. Or if the cricket is suddenly completely silent, that's also a bad sign.*" (TA-05, Interview February 22, 2025).

This experience shows that communities are not passive in dealing with disasters, but actively read natural phenomena as a form of locally-based preparedness. Furthermore, (Alam et al., 2023) said that community-based early warning systems that combine spiritual and ecological dimensions have advantages in terms of local participation and understanding. This research proves that communities in the upstream area combine symbolic systems with collective action in building resilience to floods. Spiritual activities such as the ritual of rejecting reinforcements or earth alms are a collective means to build environmental awareness and social solidarity.

The integration between cultural values and local knowledge systems in the face of disasters shows that community resilience depends not only on technology or state intervention, but also on the cognitive and spiritual heritage inherent in people's daily lives. These findings underscore that traditional early warning systems have social legitimacy and ecological relevance that need to be recognised in disaster risk reduction policies at national and regional levels.

Social Structure and Indigenous Institutions in Risk Mitigation

Strong social structures and active customary institutions play a crucial role in disaster risk mitigation practices in upstream regions. The findings of this study show that indigenous institutions are not only cultural symbols, but also function as key actors in collective decision-making that are directly related to natural resource management and environmental protection. One form of this role can be seen in the implementation of the ban on cutting down trees along the river border and the regulation of the planting rotation system on agricultural land based on customary agreements.

These decisions are usually made through village deliberations or customary meetings involving community leaders, farmers, and village officials. In this context, customary institutions act as guardians of ecological norms that are passed down across generations. One of the traditional leaders from Village A explained:

"*If you want to cut down trees near the river, you must first give permission to the traditional elders. It can't be arbitrary. If violated, you can be subject to sanctions. This is to keep the flood from getting worse.*" (TA-03, Interview January 30, 2025).

This statement indicates that customary norms have been internalized by the community and become an effective social control mechanism to prevent environmental degradation. Indigenous institutions also serve as a bridge between local knowledge and collective action. Mutual agreement on planting patterns, planting timing, and conservation of forest areas was carried out through discussions between families and farmer groups mediated by traditional leaders. One of the farmers from Village C revealed:

"*We usually plant in turn. This year the rice is here, next year it will move to another plot. That was the decision of the customary meeting. If you continue to plant in the same place, the soil will be damaged, and it can flood faster if it rains heavily*." (PL-08, Interview February 19, 2025).

This quote reinforces that indigenous institutional systems not only regulate behavior, but also become a source of ecological solutions relevant to local climate and hydrological challenges. Adherence to this system is not only driven by customary norms, but also by spiritual beliefs and communal solidarity. The community views customary rules as part of a moral and ecological agreement that must be maintained for the sake of the balance of nature. As explained by (Folke et al., 2021), this kind of form of local governance reflects the functioning of socio-ecological institutions that are adaptive to the dynamics of environmental risks.

However, the effectiveness of these customary institutions also depends on the continuity of their social legitimacy. In some cases, as younger generations begin to rely more on bureaucratic or formal approaches, the sustainability of customary systems faces challenges. However, until now, most communities in

the three villages still show a high level of involvement in customary-based decision-making structures, making customary institutions an institutional capital in community-based disaster risk mitigation.

Transmission of Local Knowledge between Generations

The transmission of local knowledge in the context of adaptation to floods in the upstream region is still largely carried out through informal inheritance mechanisms, namely orally and based on direct practice between the old and young generations. Daily activities such as farming, recognizing signs of weather change, and managing vegetation around rivers are the main means of this knowledge transfer. Values such as cooperation, ecological awareness, and respect for nature are also instilled in the process. One of the informants from Village B recounted:

"*If I used to learn from my father when I was a child, I would go to the rice fields. Learn to know the type of soil, when to start planting. Now, children are more busy with their mobile phones. They rarely go to the fields.*" (PL-05, February 11, 2025 interview).

This statement illustrates that the mechanism of knowledge inheritance is now starting to erode due to changes in the lifestyle and preferences of the younger generation. Some informants also complained about the lack of interest of the younger generation in local agricultural traditions. Some choose to migrate to cities or work in the informal non-agricultural sector, so that they are no longer involved in activities that are the main source of ecological knowledge of the community. A traditional leader from Village C expressed his concerns:

"*Now it is difficult to invite young people to participate in rituals or community service. They say it's old-fashioned. In fact, that's where we used to learn to take care of each other's villages.*" (TA-02, Interview January 27, 2025).

This indicates that there is a gap between local values and the growing influence of modernity, which can ultimately threaten the sustainability of the community's adaptation system if there are no efforts to revitalize local culture and education. On the other hand, some families still try to maintain this tradition by adapting it into a form that is more contextual and appealing to children. For example, the knowledge of reading the direction of the wind and the shape of the clouds is packaged in the form of stories or folk games that are conveyed when gathering at home. However, this approach is still limited and individualized.

Referring to (Spires et al., 2021), the sustainability of local knowledge is highly dependent on intergenerational learning mechanisms that are adaptive to social dynamics. Without strategic intervention from communities, schools, and local governments, there is a risk of knowledge discontinuity, which leads to a decline in the community's adaptive capacity in the future. Therefore, it is important to think about integrative approaches between formal and non-formal education to bridge this generational gap, including incorporating local content

into the village school curriculum, as well as reactivating community learning spaces based on daily living practices.

DISCUSSION

The results of this study reveal that the community's adaptation strategy to flooding in the upstream watershed area is greatly influenced by the practice of local wisdom that has been historically proven in maintaining a balance between humans and nature. Field findings regarding contour agriculture and the preservation of local vegetation confirm that forms of ecological adaptation are not only technical, but also contain a deep cultural and spiritual dimension. This supports a socio-ecological system framework that emphasizes the integration of social, cultural, and ecological dimensions in dealing with disasters (Folke et al., 2021).

Terraced farming practices and the use of local vegetation such as bamboo not only slow the flow of water and prevent erosion, but also strengthen people's relationship with their natural landscapes. The system is built on hereditary knowledge preserved through customary practices and norms, making it a contextual and sustainable adaptation solution.

Furthermore, findings on community-based drainage systems show that a bottom-up approach through mutual cooperation and deliberation can replace reliance on modern technology that is often not in line with local conditions. This is in line with the idea (Kruczkiewicz et al., 2021) and Leal (Filho et al., 2023), which highlight the importance of community participation-based risk management as a responsive and relevant approach.

Traditional spiritual values and early warning practices such as the use of kentongan and the interpretation of natural signs reveal a rich and multidimensional local knowledge system. The system serves not only as a practical form of mitigation, but also strengthens social cohesion and collective awareness of disasters. This is in line with the concept of a hybrid knowledge system put forward by (Alam et al., 2023), where the integration of local and scientific knowledge can strengthen community resilience.

The institutional structure of customary has also proven to be the main pillar in maintaining adaptation practices. The involvement of indigenous institutions in ecological decision-making such as the prohibition of tree felling on river borders or the crop rotation system demonstrates the functioning of local institutions in risk mitigation. These decisions are not only based on customary law, but are also born out of moral agreements and collective ecological experiences, as affirmed by (Folke et al., 2021).

However, the findings on the weakening transmission of local knowledge between generations indicate serious challenges in the sustainability of community adaptation. Modernization, migration, and changes in the preferences of the younger generation are the main causes of the disconnection of the path of inheriting local wisdom. If there are no revitalization efforts through community-based education or the integration of local knowledge in the

village school curriculum, then the adaptive capacity of the community has the potential to decrease significantly (Spires et al., 2021).

Therefore, it is necessary to design policies that combine technocratic and cultural dimensions in disaster risk management. One approach that can be taken is to build collaboration between indigenous institutions, village governments, and schools in the form of practice-based local training programs, documentation of traditional knowledge, and the creation of local learning modules.

CONCLUSION AND RECOMMENDATION

This study shows that community adaptation in dealing with flood risk in upstream watershed areas is not only dependent on technical interventions, but is also heavily influenced by local wisdom practices that are passed down across generations. The adaptation strategies found include contour agriculture, preservation of local vegetation, mutual cooperation-based drainage systems, traditional early warning, and strengthening customary institutions. These five strategies do not stand alone, but are interrelated within the framework of adaptive and contextual socio-ecological systems.

The role of customary institutions and the transmission of local knowledge has proven to be a key factor in maintaining the sustainability of adaptation practices. However, the challenges of modernization, migration, and the weakening of the cultural heritage process indicate the need for systematic revitalization efforts. These findings reinforce the importance of a bottom-up approach based on community participation and cross-stakeholder collaboration in disaster risk management in vulnerable areas.

Therefore, the integration of local wisdom into formal disaster risk management policies needs to be mainstreamed, not only as a form of recognition of community knowledge, but also as an effective strategy in strengthening socio-ecological resilience. This study recommends the need to develop a community-based adaptation policy model that bridges local and scientific knowledge in a balanced and participatory manner.

FURTHER STUDY

Future research should explore how local wisdom-based adaptation strategies can be systematically integrated with scientific and technological approaches in upstream watershed flood management. Comparative studies across different cultural and ecological contexts could reveal factors that enhance or hinder the sustainability of traditional practices. Longitudinal research is also needed to assess the resilience of these socio-ecological systems under pressures from modernization, demographic change, and climate variability. In addition, investigating participatory policy design processes that genuinely involve customary institutions and community actors would provide valuable insights for developing inclusive and context-specific disaster risk reduction frameworks.

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