How To Cite: Haris, A., Sumardi, S. (2025). Adaptive governance in mitigating hydrometeorological disaster risk in Sinjai Regency. *Publisia: Jurnal Ilmu Administrasi Publik, 10*(1), 94-104
https//doi.org/10.26905/pjiap.v10i1.14345

Jurnal PUBLISIA

Volume 10 Issue 1, 2025

P-ISSN: 2541-2515, **E-ISSN:** 2541-2035

***PUBLISIA**: Jurnal Ilmu Administrasi Publik http://jurnal.unmer.ac.id/index.php/jkpp*

Adaptive governance in mitigating hydrometeorological disaster risk in Sinjai Regency

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Article History:

Received: 27/09/2024

Revised: 21/04/2025

Accepted: 04/06/2025

Published: 10/06/2025

Abstract: This research aims to identify factors that influence the level of vulnerability and risk of hydrometeorological disasters in Sinjai Regency and formulate policies that can be implemented through an adaptive governance approach. This research uses qualitative data collection techniques, including interviews, documentation, and field observations. The collected data was then analyzed using NVivo 12 Plus analysis software. The findings of this study succeeded in mapping the factors that influence the level of vulnerability and risk to hydrometeorological disasters in Sinjai Regency. The topography includes lowlands at high risk of flooding and hills and mountains susceptible to landslides, coupled with climate change, which causes extreme rainfall intensity, increasing the risk of disasters in this region. Poor community preparedness and inadequate disaster management infrastructure exacerbate the impact of disasters, highlighting the need for improvements in early warning systems, drainage networks, and preparedness training. The application of adaptive governance principles, including multi-stakeholder involvement, continuous monitoring and evaluation, capacity development, and responsive spatial planning, is expected to increase the effectiveness of disaster risk mitigation, adapt strategies to local needs and changing environmental conditions, and strengthen collaboration to reduce vulnerability and increasing community resilience to the impacts of disasters in Sinjai Regency.

Keywords:

Adaptive policy; adaptive governance; disaster mitigation; disaster risk; hydrometeorology.

1. Introduction

This background of the research explains a sense of urgency to reduce the threat posed by hydrometeorological disasters in Sinjai Regency. According to Pusdalops BPBD through Disaster Information and Communication Data Center (Pusdatinkom), the Regional Disaster Management Agency, throughout the 2023 review, there were a total of 56 disaster events with 100% hydrometeorological element contents that are flood, landslides, moving land, strong winds, and drought (Bahar, 2023). This condition indicates that the Sinjai Regency is still a vulnerable potential area prone to hydrometeorological disasters. Thus, optimal mitigation actions are the choices that must be undertaken to lessen the issues concerning these disasters' effects on society and ecology. Seeing the high potential threat of natural

disasters in the Sinjai Regency area, all elements need to increase awareness and preparedness and strengthen synergy in mitigating natural disasters.

Hydrometeorological disasters typically have severe and far-reaching societal, environmental, and economic impacts (Leal de Moraes, 2023). Some of the negative impacts of hydrometeorological disasters, in general, are loss of life and injuries to individuals (Paul et al., 2018), damage to infrastructure and property (Dwivedi et al., 2022). Disruption of clean water resources (Wuryanta, 2022), loss of natural habitat for flora and fauna (Mavrouli et al., 2022), as well as economic losses due to the decline of agricultural production, business losses, and high recovery costs (Enerlan, 2023). Concurrently, hydrometeorological disasters are also able to hamper health services, increase vulnerability towards diseases, trigger migration among people, inflict river and coastal ecosystem destruction as well as social conflicts that are associated with economic instability and loss of sources of living (Putri et al., 2022). These effects tend to last and necessitate intensive work in rehabilitation and reconstruction for the best recovery (Jiang et al., 2024).

The imperative of adaptive measures has been raised from the results of several past studies, especially when using the adaptive governance approach for dealing with hydrometeorological disasters (Jeunesse & Larrue, 2019). The framework of adaptive governance acknowledges the complexity and unpredictability of natural disasters and includes representation of propositions by stakeholders to build a consensus (Deeming et al., 2014). These need to recognize the need for adaptability and being responsive, as well as the synergies in incorporating local and scientific understanding into nuanced policy design towards risk reduction (Izumi et al., 2022). Policy responses required are an improved adaptive early warning system (Çamalan et al., 2023). The reinforcement of the community capacity in disaster management (Mutch, 2023). Disaster-proof infrastructure development (Kim et al., 2023), as well as a series of inclusive and sustainable policies in the policy-making mechanism (Al-Wathinani et al., 2023). Adapting governance principles for hydrometeorological hazards is intended to yield policies which are more relevant to local conditions, and therefore better capable of reducing risk and vulnerability in this context.

Although numerous research findings have explained the wisdom of an adaptive governance approach to disaster at an international scale, only a few examples have been analyzed about disaster phenomena at the local level until the present, particularly in Sinjai Regency; therefore, a niche needs to be met (Dinata, 2023; Luthfi et al., 2023; Putra et al., 2023). This proposal for problem-solving presents a better solution than traditional research lines and other scientific tours immersed in hydrometeorological disaster risk mitigation. For one, the proposed adaptive governance framework highlights stakeholder engagement in decision-making, potentially contributing to the enhancement of disaster resilience in the local community (Lung et al., 2022). Furthermore, this proposal takes a holistic view by blending local knowledge with scientific data and encouraging multi-sectoral and inter-jurisdictional collaboration. What is new in this proposal is a combination of the best practices of an effective, pragmatic adaptive governance approach proven in disaster risk mitigation, with a particular locality that Sinjai Regency's specificity could sustainably enhance community resilience against disasters.

The purpose of this study is to determine and examine the major determinants of risk, vulnerability, and hazard related to hydrometeorological disasters in Sinjai Regency. Additionally, especially in the context of adaptive governance, it aims to develop suitable policy proposals to lessen vulnerability and improve community resilience. The research offers a thorough understanding of the region's vulnerability to floods, landslides, and other hydrometeorological events by looking at the topographical, environmental, and socio-institutional aspects of disaster risk. The ultimate objective is to provide infor-

mation for the creation of disaster management policies that are responsive, flexible, and based on local capabilities and conditions. This research is particularly urgent in light of the increasing frequency and intensity of such disasters, emphasizing the need for improved preparedness and preventive measures to protect communities and minimize potential losses.

2. Literature Review

Adaptive Governance

Adaptive governance, as an alternative approach to adaptive management, emphasizes adaptability in the face of non-linear and unpredictable change. Adaptive governance is an idealistic view of adaptive governance (Luthfi & Naufal, 2023; Putra & Jeflin, 2025). The whole system can be characterized by its resilience in responding to and adapting to environmental, social, and economic conditions. The theory is that the environment and society change, so traditional management work models are inhibitive. Adaptive governance involves the interaction of multiple actors who cooperate in a flexible and iterative decision-making process (Hizbaron et al., 2021; Janssen & Voort, 2016; Sainz-santamaria & Martinez-cruz, 2020). This concept also highlighted the importance of participating to enhance policy and programmatic effectiveness and sustainability (Fadeli et al., 2024).

At the same time, adaptive governance is also concerned with questions of learning and innovation relative to emerging challenges. That is, the management system must be capable of being revised in the light of experience and hence get regular scrutiny along with action to mitigate any issues (Avita et al., 2023; Inanda et al., 2022). The nature of adaptive governance, in one sense and another, is a continuous iteration and feedback loop that continuously allows policies and strategies for adaptation based on an outcome following the real conditions or feedback about practices with environmental interaction (Chaffin et al., 2014; Novellie et al., 2016; Rusnaedy et al., 2021). The most significant implication here is that a system resilient to unpredictability puts the system in a better position to become more reactive on short lead times of unanticipated changes and increases its ability to deal with future complexity and uncertainty.

As a result, adaptive governance is seen as a more flexible and responsive means of managing modern society's complex and changing problems. By utilizing the approach as recommended, this stress is replaced by a sense of flexibility that accompanies learning and collaboration to deal with change and uncertainty more easily. By applying principles of adaptive governance, the system can adjust to an often-changed world and learn and evolve in ways that make things better over the long term. This leverages more informed and adaptive decision-making to ensure that policies and programs at multiple levels of government and sectors are implemented to achieve success and sustainment.

Disaster Risk Mitigation

On the other hand, disaster risk mitigation is a process that strives to reduce disaster occurrence by setting up proactive practices. Disaster risk mitigation targets to identify the possible threats, assess vulnerabilities and put in place danger mitigation measures for a risk-free environment. These actions include safe spatial in preparation for the potential of a flood, hardening and improving drainage system infrastructure, and developing an early warning system (AlQahtany & Abubakar, 2020; Amarnath et al., 2021; Haris et al., 2023). Disaster risk mitigation is a crucial aspect of broader disaster risk management, which also includes many concentrations including preparedness, response and recovery.

This should mean that disaster risk mitigation is a comprehensive, risk-informed approach drawing on the dual concepts of prevention and preparedness (Supriadi et al., 2022). The fundamental postulate for disaster risk mitigation is that an intentional intervention by humans in planning and performing those interventions can avoid a disaster or at least discourage disaster causation. Vulnerability assessment involves defining the vulnerability of places and people through scientific data and information and shaping policies and practices to reduce the dependence on society concerning disaster (Hakkim & Deb, 2023; Parker, 2020; Weichselgartner, 2001). The purpose of disaster risk mitigation is to make communities more resilient before disasters or reduce the rate at which we are forced into vulnerability during and after destructive events.

Disaster risk mitigation is also recognized as a crucial mechanism; this aligns with the increasing climate change and human-induced disasters such as biodiversity (Ibrahim et al., 2023; Malik et al., 2023). The impact of disasters will largely lessen by effecting mitigating measures, leading to decreased economic, social and environmental losses. It also helps make development sustainable by helping new homes and infrastructure be built safely, in line with goal Sustainable Development Goals (SDGs) to make cities safe and reduce disaster risk.

In conclusion, a synergy of stakeholder-led commitment backed by an amalgamation of government, private sector, civil society, and community ownership is key to effective disaster risk mitigation. Coordinated interplay among these diverse stakeholders is necessary for developing successful and continuous mitigation measures (Intrieri et al., 2020; Malik et al., 2023; Zhang et al., 2021). Raising awareness, increasing capacity, and developing specific skills for mitigating disaster risk will enable society to become better prepared for various stages that a case study might face, from adequate protection covering lives to critical assets in a disaster (Iskandar et al., 2024; Karinda & Baharuddin, 2024)

3. Research Methods

This study employs a qualitative research method through several data collection strategies. The first step will be interviews with a wide variety of relevant stakeholders (specifically the Regional Disaster Management Agency or BPBD of Sinjai Regency, relevant government sector organisations, and local communities) to understand hydrometeorological disaster risks in more detail, as well as existing practices to mitigate these risks. The second part describes the documentation to obtain historical data, policies, and hydrometeorological disaster statistics in Sinjai Regency (Agus Sholahuddin, 2021). Third, field observation provides first-hand insight into environmental conditions, disaster-impacted areas and existing mitigation approaches in the field.

With various techniques, research can gain an in-depth understanding of mitigating hydrometeorological disaster risk in Sinjai Regency. Such data was transferred into Nvivo 12 Plus analysis software which allowed for a rigorous qualitative analysis process . This may be used as one tool to look for patterns, themes and relationship with hopes of contributing to a more indepth understanding on risk mitigation hydrometeorology disaster in Sinjai Regency. The analyses are then performed on the post processed research results to solve the research questions.

4. Results and Discussion

Factors influencing disaster risk in Sinjai Regency

Based on data from Pusdalops BPBD obtained through the Disaster Information and Communication Data Center (Pusdatinkom), Pusdalops BPBD, there were 56 recorded disasters in 2023, which were

all hydrometeorological (Bahar, 2023). These events can be broad, such as floods and specific ones, including landslides, moving land, and strong winds, which may lead to drought.

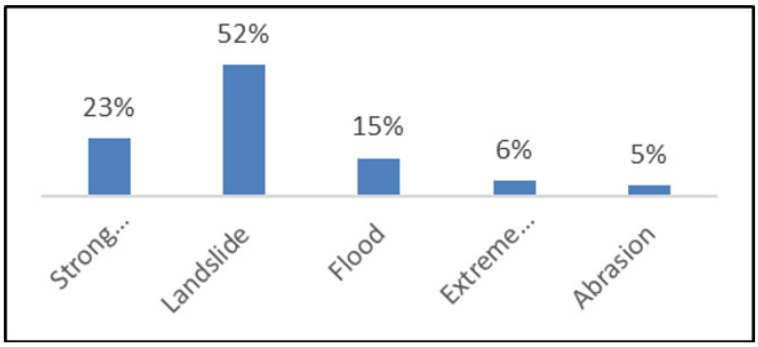

Figure 1. Number of natural disasters in 2024 in Sinjai Regency.
Source: Regional Disaster Management Agency (BPBD) of Sinjai Regency, 2024.

Throughout 2024, Sinjai Regency experienced an increase in the number of natural disasters compared to the previous year, dominated by wet hydrometeorological disasters such as landslides, strong winds, floods, extreme weather, and abrasion. Based on data from the Sinjai Regency Regional Disaster Management Agency (BPBD), landslides were the most frequent disaster, accounting for 52% of the total incidents, followed by strong winds (23%), floods (15%), extreme weather or high waves (6%), and abrasion (5%). These disasters were spread across nine sub-districts, including Central Sinjai, West Sinjai, North Sinjai, and Bulupoddo, which experienced landslides and floods due to high rainfall. The following is the empirical data that can be considered as evidence of the presence of a hydrometeorological disaster.

Figure 2.
One of the impacts of the hydrometeorological disaster in Sinjai Regency

The floods and landslides, which also hit six sub-districts, had affected 339 heads of families (KK), totalling 646 people, the Regional Disaster Management Agency (BPBD) of Sinjai Regency reported.

Also, six houses were damaged due to the disaster (Pramono, 2023). The vulnerability and level of risk for each hydrometeorological disaster in Sinjai Regency are totals from various aspects, and they are linked to all aspects of environmental, social, and infrastructure conditions. A few key points which can be noted are as follows too:

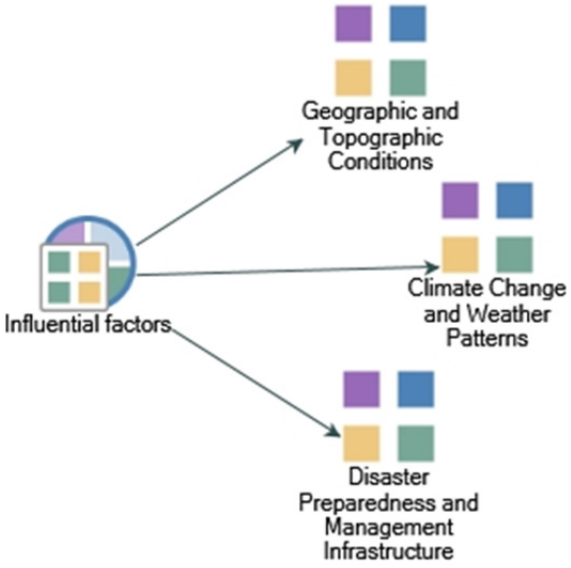

Figure 3.
Factors that influence the level of vulnerability and risk of hydrometeorological disasters in Sinjai Regency
Source: Presented by researchers via Nvivo 12 Plus, 2024

This influenced the large number of Hydrometeorological disasters that occurred in the Sinjai District. The highlands (100-500 meters) still make up more than 55.5% of the area that has potential vulnerability for each type of disaster. There are some significant lowlands around the rivers; however, they are most at risk of flooding when the wet season starts from April to October and overflows the rivers (DPM PTSP, 2023). Otherwise, the hilly and mountainous land, which is a large part of the area of Sinjai Regency, will trigger a landslide if rainfall is high, considering that in these areas (high terrain), soil stability is often affected by intense rainfall patterns.

Global climate change also directly affects local weather patterns in Sinjai Regency. It also impacts rainfall patterns that increase the risk of occurring hydrometeorological disasters, particularly floods. For thousands of years at least, the combination of wet months from April to October and dry ones from October to April (DPM PTSP, 2023), confers some twists upon the east monsoon climate with nightmare impacts relative to extreme rainfall climate change. More intense extreme rainfall can lead to a larger volume of water entering rivers, which increases the vulnerability to flood, and where the flow is concentrated, it tends to erode more material, leading even to landslides. Adaptation and mitigation are necessary to cope with these changes and diminish their impacts on communities and infrastructure.

Community preparedness and the quality of disaster management infrastructure also directly affect the vulnerability to hydrometeorological disasters in Sinjai Regency. When a disaster occurs, areas equipped with early warning systems, good drainage system networks, and disaster shelter facilities can reduce the impact of disasters (Farhan Mohamad Firdaus Joo & Mohd Bukari, 2022). Conversely, poor infrastructure and little preparation will drastically increase the risk and impact of disasters. Furthermore, efforts to build community capacity through training and education on disaster preparedness contribute

greatly to risk reduction and build resilience amongst the residents of a particular geographic location to withstand and absorb disaster impacts more efficiently when they do occur.

Adaptive governance in mitigating hydrometeorological disaster risk

Adaptive governance for hydrometeorological Disaster Risk at Sinjai Regency needs an innovative approach to developing and increasing adaptive governance for a better mitigation effort. There are mostly four points in this regard:

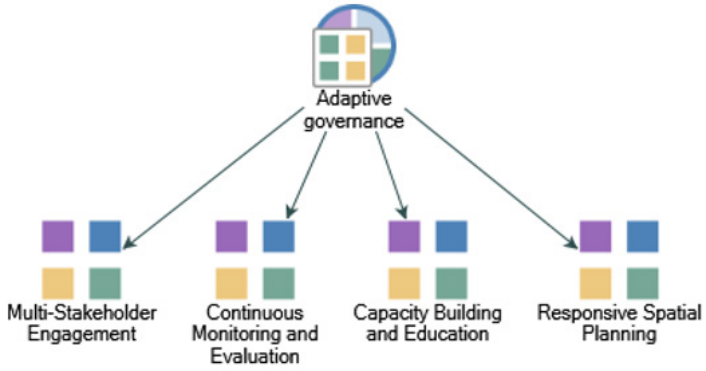

Figure 4.
Adaptive governance in mitigating hydrometeorological disaster risk in Sinjai Regency
Source: Presented by researchers via Nvivo 12 Plus, 2024

Multi-stakeholder engagement in adaptive governance embodies the notions of inclusivity and teamwork that are ideal for disaster risk reduction. A nascent experiment in Sinjai Regency that includes local government, civil society, communities, and the private sector participating together to plan and implement mitigation strategies has demonstrated that a holistic approach rooted in localized knowledge creates positive-sum solutions. In principle, it emphasizes the necessity of incorporating local knowledge and local resources in mitigation to tailor more feasible collective strategies based on contextual and locality-based needs and ensure effective coordination among their stakeholders, forging a holistic outcome. and sustainable (Handayani et al., 2023).

Next, continuous monitoring and evaluation in adaptive governance means regular assessments are used to verify mitigation actions and adapt strategies suitable for changing circumstances. In Sinjai District, this means monitoring weather trends, soil conditions, and disaster incidents for accurate early warning alerts, landscape infrastructure improvements, and recalibration of mitigation policies to remain effective and relevant. In theory, this strategy aligns with the principle of dynamic adaptation; strategies that include identifying changes and revision options can sustainably maintain a synergistic relationship between the environment and community to support disaster risk mitigation.

In addition, adaptive governance seeks to improve the community's ability to resist disaster and its capabilities by promoting capacity building and education through training and counseling. Areas like Sinjai Regency are targeted to reach and train communities in hydrometeorological hazard preparedness, including floods and landslides, as a basic principle of a multi-hazard approach that increases the community's capability in managing risk. This approach theoretically will enhance community empowerment, which enhances the individual and community capacities in disaster preparedness to be more

proactive and adaptive to risks, as well as mitigating the vulnerability of disaster impacts by providing appropriate knowledge and skills that they have at hand (Iskandar et al., 2024).

Another principle of land for disaster risk reduction strategy is an adaptive governance approach to dynamic land development. This demonstrates the key role of responsive spatial planning in reducing disaster through careful land allocation. For Sinjai Regency, this includes considering the exposure to risk of hydrometeorological disasters, such as not building in flood or landslide-prone areas and ensuring all infrastructures are more disaster-resilient. Theoretically, this approach highlights the necessity to embed risk analysis into spatial planning by tailoring policies and land use decisions to current disaster risk profiles to diminish vulnerabilities and enhance resilience against disasters.

Regarding disaster risk mitigation in the Sinjai Regency, applying adaptive governance principles suggests that they build a more efficient, dynamic, and sustainable system in responding to challenges affected by hydrometeorological disasters. Wide stakeholder involvement, ongoing monitoring and evaluation mechanisms, and capacity building will make Sinjai better prepared to face a series of other risks in the future with solutions adapted to the local conditions they currently face. Such practices improve collaboration and available capacity in local (and regional) areas and help make projects more dynamic and appropriate where possible. This is a key factor when considering how to meet the increasing challenges of climate change and extreme weather.

5. Conclusion

Numerous important elements, such as topography and geography, climatic change, community readiness, and the standard of disaster management infrastructure, affect Sinjai Regency's susceptibility and risk of hydrometeorological disasters. The region is particularly vulnerable to disasters because of its varied terrain, which includes lowlands that are prone to flooding as well as hilly and mountainous regions that are vulnerable to landslides. Floods and landslides are more likely as a result of climate change, which intensifies rainfall in both frequency and volume. Furthermore, the negative effects are exacerbated by inadequate infrastructure for disaster management and a lack of community readiness. To increase the region's resilience, these issues highlight the critical need for better drainage systems, stronger early warning systems, and extensive disaster preparedness education.

A drawback of this study is its exclusive qualitative methodology, which leaves out important details about the severity and scope of hydrometeorological disasters in the region. Future studies should use quantitative techniques, such as statistical analyses of disaster data and organized community surveys, to gather more thorough, impartial, and useful information. These methods would improve the validity and dependability of study findings by making it possible to spot patterns and trends that qualitative data alone would miss. Including quantitative data will also help Sinjai Regency create evidence-based mitigation policies and better disaster risk reduction plans.

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