Impact of Land Use Dynamics and Settlement Preferences on Flood Risk in River Basin Areas

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ABSTRACT
Ecosystem transformation in the Asahan Regency Watershed shows a striking pattern of degradation, indicating a drastic change in the land-use structure that triggers an escalation of flood risk. The selection of settlement sites that are not based on disaster mitigation exacerbates these conditions, creating a complex synergy between ecological pressures and less adaptive human decisions. This study adopts a SWOT analysis approach to identify the linkages between internal and external factors in the dynamics of these changes. The findings of the study revealed that despite mitigation efforts through spatial planning policies and restoration projects, inadequate infrastructure and weak public awareness remain the main obstacles in reducing the intensity of disasters. By integrating community-based ecological strategies and capacity building in development policies, it is hoped that an environment that is more resilient to future flood risks can be created.

Keywords: *SWOT, Residential Preferences, Watersheds (DAS)*

Introduction

Flood disasters are one of the increasing threats in various regions in Indonesia, including Asahan Regency, North Sumatra Province. The district is located in a low-lying area with a topography that is mostly crossed by the Asahan Watershed, which makes it vulnerable to flooding. In recent years, the intensity and frequency of floods in Asahan Regency have increased, causing significant social, economic, and environmental impacts. In November 2024, major floods hit Sei Dua Hulu Village and Simpang Empat Village in Simpang Empat District, causing damage to 1,427 houses, six bridges, and two worship facilities. This flood also caused road abrasion and forced more than 5,000 residents to evacuate (Liputan6, 2024). Previously, in October 2024, Pematang Sei Baru Village in Tanjungbalai District was flooded with a height of 30 cm, inundating 165 houses and three schools, forcing several residents to evacuate (Tribun Medan, 2024). In September 2024, floods in Sei Dadap District reached a height of 150 cm, resulting in infrastructure conditions and disrupting the community's economic activities (Kedaulatan Post, 2024). This series of events reflects the increased risk of flooding in the region.

The increased risk of flooding in Asahan Regency is caused by several factors. One of the main factors is the significant change in land use in the watershed area. The transfer of land functions from forests to oil palm plantations, agriculture, and settlements has led to a reduction in land capacity to absorb rainwater, thereby increasing surface runoff. A study by Juniati et al. (2023) revealed that land conversion in watershed areas in Indonesia significantly increases flood risk by reducing groundwater retention capacity. Another study by Tarigan et al. (2018) in the Batang Toru watershed showed that intensive deforestation leads to an increase in peak flow volume by up to 50% and increases the frequency of floods. In addition to changes in land use, residential preferences that do not pay attention to the aspect of disaster risk are also the main cause (Nuraini, 2019; Nuraini et al., 2023). The development of settlements in flood-prone areas, such as lowlands near river flows, increases the vulnerability of communities to the impact of floods (Rahmadhani et al., 2023; Sugiarto & Kustiah Ramadania, 2024). Research by Deany and Rusdiana (2021) in Genuk District, Semarang City, shows that the development of settlements in areas with a high risk of flooding without mitigation is able to cause large material losses, including property damage and disruption of community economic activities.

On the other hand, global climate change factors also contribute significantly to the increased risk of flooding. Changes in rainfall patterns and an increase in the intensity of extreme rainfall exacerbate the situation. A report from the Meteorology, Climatology, and Geophysics Agency (BMKG) noted that the intensity of extreme rainfall in North Sumatra has increased by 15% in the last decade, which has largely contributed to the occurrence of flooding in this region (BMKG, 2023). This phenomenon demonstrates the need for an integrated approach to managing flood risk. These approaches include sustainable land use management, disaster risk-based spatial planning, and strengthening community capacity in dealing with disasters. This study aims to analyze the impact of land use dynamics and settlement preferences on flood risk in the Asahan Regency watershed area. By understanding the relationship between land use, settlement preferences, and flood risk, it is hoped that this study can provide strategic recommendations to reduce the impact of flooding and support sustainable development in the region.

Literature Review

A. Land Use in Watersheds (DAS)

Land use in watersheds (watersheds) has an important role in maintaining ecosystem balance. Changes in land use, such as the conversion of forest use to plantations, agricultural land, or residential areas, can affect water retention capacity and increase the risk of flooding (Juniati et al., 2023). Research by Tarigan et al. (2018) in the Batang Toru watershed showed that deforestation increases surface flow by up to 50%, leading to an increase in peak flow volume during extreme rainfall. In addition, land-use change often ignores the hydrological functions of watersheds, such as water absorption ability and protection against soil erosion. Previous studies have shown that an integrated watershed management approach is needed to mitigate flood risk. According to Susilo et al. (2021), vegetation restoration in watershed areas can increase groundwater storage capacity by up to 30%. This shows the importance of preserving natural land cover in maintaining the stability of the watershed ecosystem.

B. Settlement Preferences and Flood Risk

People's preference for building settlements in low-lying areas often increases the risk of flooding. Research by Deany and Rusdiana (2021) shows that residential development in flood-prone areas, such as in Genuk District, Semarang City, without paying attention to risk-based spatial planning, causes significant material and non-material losses. Factors such as accessibility, relatively low land prices, and the urgent need for housing often override flood risk considerations. Another study by Kusuma et al. (2022) found that most people living in flood-prone areas do not have adequate knowledge about disaster mitigation. Therefore, public education is needed about the importance of choosing safe settlement locations and the implementation of disaster mitigation strategies, such as the use of flood-resistant building technology.

C. Impact of Floods on Social and Economic

Floods have a significant social and economic impact, especially in areas with inadequate infrastructure. A study by Prasetyo et al. (2023) shows that floods in Bekasi Regency cause economic losses of up to IDR 50 billion in one year due to damage to infrastructure, property, and disruption of economic activities. Socially, floods can cause population displacement, disrupted access to health and education facilities, and an increased risk of disease due to an unhygienic environment (BMKG, 2023). In addition, low-income communities are often the most affected due to limited access to resources and disaster mitigation.

D. Climate Change and Increased Flood Risk

Global climate change also contributes to increased flood risk through changes in rainfall patterns and the intensity of extreme rainfall. BMKG (2023) noted that extreme rainfall in North Sumatra has increased by 15% in the last decade, which has a direct impact on the frequency of flooding. A study by the IPCC (2022) shows that a 1.5°C increase in global temperature can cause an increase in the intensity of extreme rainfall by up to 20%. This condition requires more systematic adaptation steps, such as increasing drainage capacity, ecosystem-based watershed management, and spatial planning that is adaptive to climate change.

Research Conceptual Framework

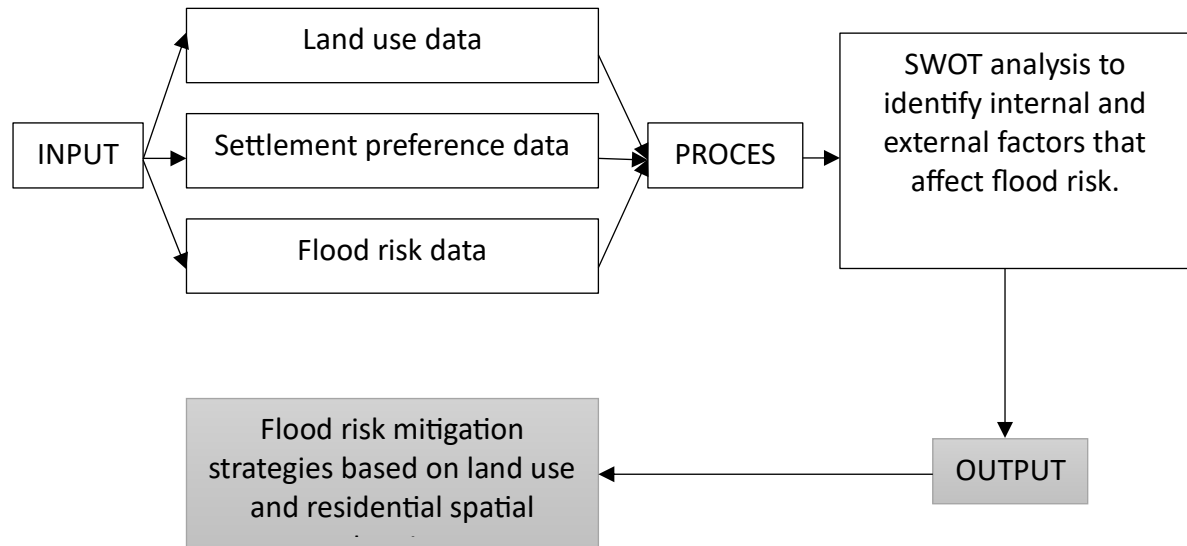The conceptual framework of this research is described as follows:

Figure 1. Conceptual Framework for Research on the Impact of Land Use Dynamics and Settlement Preferences on Flood Risk in Watershed Areas
Source : Researcher, 2025

Results and Discussion

A. Current Conditions in the Watershed Area of Asahan Regency

The Asahan Regency Watershed Area (DAS) is currently facing major challenges due to uncontrolled land use changes. Based on field observations and data from the National Land Agency (BPN) and the Asahan Regency Environment Office, most of the forest areas in the watershed area have been converted into oil palm plantations (45%), agriculture (30%), and settlements (15%). This conversion of functions has led to a decrease in groundwater absorption capacity, which has contributed to an increase in the frequency of floods in the last five years. Hydrological data from BMKG (2023) shows that the average rainfall in Asahan Regency reaches 2,200 mm per year, with the peak of rain intensity occurring from November to January. The combination of extreme rainfall and reduced vegetation worsens the condition of water flow in the watershed, which often overflows into low-lying settlements.

Tabel 1. Changes in Land Cover in the Asahan Regency Watershed (2019-2024)

Land Type	Area (ha) in 2019	Area (Ha) in 2024	Change (%)
Forest	12.000	6.600	-45.0
Perkebunan	8.000	12.000	+50.0
Agriculture	5.000	6.500	+30.0
Settlement	3.000	4.500	+50.0
Miscellaneous	2.000	1.400	-30.0

Sumber : Dinas Lingkungan Hidup Kabupaten Asahan (2024), BMKG (2024).

B. Residential Preferences in Flood-prone Areas

Interviews with 150 local community respondents showed that 60% of respondents chose to live in low-lying areas despite having a high risk of flooding. The main factors that influence this preference include:

    a. Affordable land prices: Lowland areas tend to have cheaper land prices.

    b. Accessibility: The area is closer to public facilities such as markets, schools, and health centers.

    c. Lack of understanding of flood risk: The majority of people do not have adequate information about flood risk and mitigation measures.

Table 2. Community Settlement Location Preferences

Settlement Location	Number of Respondents (%)	Number of Respondents (n)	Main Reasons
Lowland	60	90	Low land prices, good accessibility
Plateau	25	37.5	Safe from flooding, cooler air
Central Region	15	22.5	A combination of accessibility and security

Source : Interview Results, December 2024

C. SWOT Analysis Results

The results of the SWOT analysis provide an overview of the strengths, weaknesses, opportunities, and threats related to flood risk mitigation in the Asahan Regency watershed. Based on field data and interviews, the SWOT details are as follows:

Table 3. Flood Risk Mitigation SWOT Matrix

Internal Factors	External Factors	Strategy
Strengths	Availability of water resources	Increase water retention capacity through watershed greening
	Awareness of some people	Engaging local communities for watershed restoration
Weaknesses	High land conversion	Integrating risk-based spatial policies
	Minimal drainage infrastructure	Improvement and maintenance of drainage systems
Opportunities	Government policy support	Promoting disaster mitigation education programs to the community
	Funding from NGOs	Building adaptive infrastructure with donor support
Threats	Global climate change	Strengthening adaptive infrastructure against flooding
	Rapid population growth	Spatial planning-based settlement planning

Source : Researcher, 2025

Based on the results of the SWOT analysis, the recommended flood risk mitigation strategies include:

1. Land Restoration: Restoring the function of forests as water catchment areas in the upstream part of the watershed.
2. Strengthening Spatial Planning Policy: Integrating flood risk maps in regional spatial planning.
3. Community Education: Increase public awareness about the importance of choosing safe settlement locations and implementing mitigation measures.
4. Infrastructure Improvement: Build and improve drainage systems in flood-prone areas.

D. Validate Results through Focused Group Discussions

Focus Group Discussions were conducted to validate the results of the research. Discussion participants consisted of community representatives, local governments, and academics. The results of the discussion emphasized the importance of collaboration between various parties to implement the mitigation strategies that have been formulated.

Table 4. Strategic Recommendations and Responses of Discussion Participants

Key Strategies	Participant Consent (%)	Suggestions and Feedback
Forest land restoration	85	Focus on greening upstream areas
Public education	75	Involve local schools and communities
Strengthening spatial planning policies	90	Accelerate the integration of risk maps in regulation
Infrastructure upgrades	80	Prioritizing flood-prone residential areas

Source: FGD Results, December 2024

Discussion

A. Analysis of Current Conditions in the Watershed Area of Asahan Regency

Based on the results of the study, the watershed area of Asahan Regency has experienced significant environmental degradation due to land use changes. A 45% reduction in forest cover in the last five years has resulted in an increased risk of flooding. This is in line with research by Juniati et al. (2023) which showed that deforestation in watershed areas increases surface flow by up to 50%, thus increasing the likelihood of flooding. In addition, the high rainfall recorded by BMKG (2023) exacerbated the situation with more frequent flooding intensity. People's preference to live in low-lying areas is also a factor that increases flood risk. A study by Deany and Rusdiana (2021) revealed that people tend to choose flood-prone areas for economic and accessibility reasons. This result is strengthened by the findings of Kusuma et al. (2022), who stated that the lack of public education about flood risk also contributes to the high vulnerability of the community. However, there are some studies that show different results. Research by Tarigan et al. (2018) in the Batang Toru watershed states that deforestation does not always lead to increased flooding if there is good water management. This shows that effective watershed management can reduce disaster risk despite changes in land use.

B. Discussion of Settlement Preferences in Flood-prone Areas

The results of the interviews show that the majority of people choose to live in low-lying areas for the reason of affordable land prices and accessibility. This preference is consistent with research by Prasetyo et al. (2023), which found that economic factors are often the top priority for communities in choosing residential locations, even though they are high-risk. However, research by Nugraha et al. (2021) in flood-prone areas in Yogyakarta found that with adequate education, people tend to choose safer residential locations. This shows that interventions in the form of increasing public awareness can change residential location preferences to be more adaptive to disaster risks.

C. Discussion of SWOT Analysis Results

The results of the SWOT analysis provide a comprehensive overview of internal and external factors that affect flood risk mitigation. Forest restoration as a key strategy has been proven to be effective based on research by Sari et al. (2020), which stated that reforestation of watershed areas can increase water retention capacity by up to 30%. Government policy support, such as risk-based spatial integration, is also relevant. A study by Rahman et al. (2022) emphasizes the importance of spatial regulation to reduce disaster vulnerability. However, other research such as by Lestari et al. (2021) show that such policies are ineffective if their implementation is weak or not accompanied by adequate supervision.

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