

(Research/Review) Article

Integration of watershed land Change Management and Slum Rehabilitation Efforts in Flood-Prone Areas

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Abstract: Land use changes in the watershed (DAS) area of Tebing Tinggi City have increased the risk of flooding and contributed to the development of slum settlements in vulnerable zones. Uncontrolled urbanization and economic pressures have driven residential expansion along riverbanks, forcing communities to live in substandard environmental conditions. This study aims to analyze the integration of watershed land use change management with slum rehabilitation strategies to enhance regional resilience against flood disasters. The research employed a mixed methods approach, combining qualitative phenomenological studies with quantitative descriptive statistical analysis. The findings indicate that collaboration among spatial planning, environmental policy, and community participation is crucial in creating a sustainable and disaster-responsive watershed management model. Strategic recommendations are centered on strengthening cross-sector coordination and implementing policies based on spatial and social data.

Keywords: Floods, Integration, Rehabilitation, Settlements, Slums

1. Introduction

Land use change in the watershed (DAS) area of Tebing Tinggi City has become one of the main challenges in environmental management and residential sustainability. Uncontrolled land conversion has led to increased flood risks and the emergence of slum settlements that are highly vulnerable to disasters (World Bank, 2022). Tebing Tinggi City, known as a region with a dense river network, is currently facing environmental degradation caused by unplanned land use changes.

Rapid urbanization and economic pressures have driven residential expansion into flood-prone areas, especially along riverbanks (Indra Praja & Nuraini, 2024; Nuraini et al., 2024). As a result, many residents live in substandard and high-risk environments. Various studies have identified that land use changes significantly impact ecosystems and the socioeconomic conditions of communities (Budiarto et al, 2021; Armansyah & Sugiarto, 2025). However, research that integrates land use change management with slum settlement rehabilitation remains limited. Therefore, this study aims to develop an integrative strategy for land use change management and slum rehabilitation to improve environmental resilience and community well-being in Tebing Tinggi City.

Geographically, Tebing Tinggi City includes several areas that are vulnerable to uncontrolled land use changes. Riverbanks, which are supposed to be conservation zones, have instead become densely populated settlements with inadequate infrastructure. The imbalance between development and environmental preservation has exacerbated the socioeconomic conditions of the population living in these areas (Firdaus & Wahyuni, 2023; Sugiarto & Ramadania, 2024).

Additionally, spatial planning policies have not been fully effective in controlling the pace of urbanization, further aggravating existing issues (Nasution et al., 2021). With high

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population growth and economic pressure, many people have no other choice but to establish housing in areas prone to flooding and environmental degradation.

Slum settlements in flood-prone areas face not only limited infrastructure but also health and social welfare challenges. Lack of access to clean water, proper sanitation, and adequate healthcare facilities continues to worsen the quality of life in these communities. A study conducted by Nuraini et al., (2024) found that settlements that develop without proper planning tend to experience higher rates of disease due to unhealthy living conditions. Therefore, intervention in the form of settlement rehabilitation is necessary to improve the quality of life for affected communities.

From an economic standpoint, residents living in slum settlements often have limited access to broader economic resources. Low levels of education and job skills hinder their ability to adapt to ongoing social and economic changes in urban areas. As a result, the cycle of poverty persists and reinforces their dependence on substandard living environments (Pangribuan et al., 2024; Rahman Nasution; Nuraini, 2024; Sugiarto et al., 2023).

In this context, an integrative approach that combines land use change management with slum rehabilitation efforts offers a more effective solution for addressing the multidimensional problems faced by communities in Tebing Tinggi City.

Based on this background, this study formulates several main problems: 1) What is the pattern of watershed land change in flood-prone areas?; 2) What form of slum organization rehabilitation strategy has been implemented?; 3) How is the integration between watershed management and organizational rehabilitation in reducing flood risk?

This study aims to analyze the dynamics of land change in the Tebing Tinggi City watershed and its impact on the social and economic conditions of the community. In addition, this research also aims to formulate an effective strategy in integrating land change management with slum rehabilitation efforts to improve the quality of life of the community. The benefits of this research include: 1) To make scientific contributions to the study of land management and rehabilitation of slums, 2) Provide recommendations for local governments in developing more effective policies related to spatial planning and development planning in flood-prone areas, 3) It is a reference for researchers and academics interested in the study of urban environmental management and housing of low-income communities, 4) Increasing public awareness about the importance of sustainable and environmentally sound settlement planning.

This research is crucial in light of the growing number of slum settlements in flood-prone areas of Tebing Tinggi City, which continues to escalate without comprehensive solutions. The lack of well-structured spatial planning and weak monitoring of land use changes are the main factors worsening the environmental and social conditions of the community. By understanding the dynamics of land use change and its impacts, this study can provide a foundation for the development of more integrated and sustainable policies.

Furthermore, this research aligns with the national development agenda aimed at enhancing environmental resilience and community well-being. The strategies formulated are expected to serve as a model for other regions facing similar issues and can be applied on a broader scale to improve the quality of life for communities affected by land use changes and urbanization.

2. Preliminaries or Related Work or Literature Review

Theoretical Foundations

Land Change in Watersheds (DAS)

Land change in watersheds (watersheds) is a phenomenon influenced by natural factors and human activities. Converting green land into built-up land can increase the risk of flooding and reduce water infiltration capacity (Azmi & Nuraini, 2024; Turio & Nuraini, 2024). According to Rahman et al. (2021) about the impact of land use change on flooding, uncontrolled urbanization causes environmental degradation and accelerates the rate of sedimentation in rivers. This is exacerbated by the low supervision of land-use changes, which are often not in accordance with regional spatial planning.

Slums and Their Causative Factors

Slums are defined as areas with inadequate infrastructure, poor environmental conditions, and limited access to basic services such as clean water and sanitation (Nuraini et al., 2024). The main factors causing the growth of slums include economic pressures, uncontrolled urbanization, and a lack of effective housing policies. In addition, the location of slums

that are often located in disaster-prone areas increases the social and economic vulnerability of their residents.

Land Change Management and Slum Rehabilitation Strategy

An integrative approach to land change management and slum rehabilitation includes mitigation and adaptation strategies. These strategies include:

1. Strengthening spatial regulations to control land conversion in at-risk areas.
2. Revitalization of basic infrastructure to improve the quality of settlements.
3. Community empowerment through sustainable economy programs.
4. Ecosystem-based approach in settlement planning.

The table below summarizes some of the strategies that have been implemented in various related studies:

Table 1. Summary of Implementation of Previous Strategies

Strategy	Purpose	Supporting Studies
Spatial regulation	Preventing uncontrolled land conversion	Rahman et al. (2021)
Infrastructure revitalization	Improving the quality of life of the community	Budiarto et al. (2022)
Economic empowerment	Reducing poverty in slums	Putri & Setiawan (2020)

Source: Author's Analysis, 2025

Previous Research Studies

Some previous studies relevant to this study include research by Rahman et al. (2021) on the impact of land-use change on flooding, examining the impact of land change on watershed ecosystems and finding that uncontrolled urbanization increases the frequency of floods. Furthermore, a study of the growth of slums in flood-prone areas and proposed a community-based rehabilitation model, Budiarto et al. (2021) and the results of the study highlight the importance of social and environmental integration in the arrangement of slums (Putri & Setiawan, 2020; Sugiarto et al., 2023).

Frame of Mind

The framework of thought in this study is designed to illustrate the relationship between land change in watersheds, the emergence of slums, and applicable rehabilitation strategies.

3. Proposed Method

Approaches and Types of Research

This research uses a mixed method approach or mixed method, which combines qualitative and quantitative approaches systematically. This approach was chosen because it is able to provide a more comprehensive understanding of complex problems such as land change in watersheds (watersheds) and rehabilitation of slum organizations in flood-prone areas. As explained by Putri & Setiawan (2020), the mixed method provides an advantage in comprehensively explaining social phenomena involving many dimensions.

Types of Research

This type of research is exploratory-descriptive, with the aim of describing land change patterns and slum organizational conditions and exploring relevant rehabilitation strategies. Qualitative data was collected to understand the perspectives of communities and stakeholders, while quantitative data was used to measure the intensity of land change and the distribution of slums.

Research Variables

This study analyzes several variables related to land change and slum rehabilitation. The research variables used include:

- X1: Land changes in watersheds (including land conversion and urbanization)
- X2: Socio-economic impacts of land change (including welfare levels and access to basic services)
- Y: Rehabilitation of slums (through sustainable management strategies)

Research Conceptual Framework

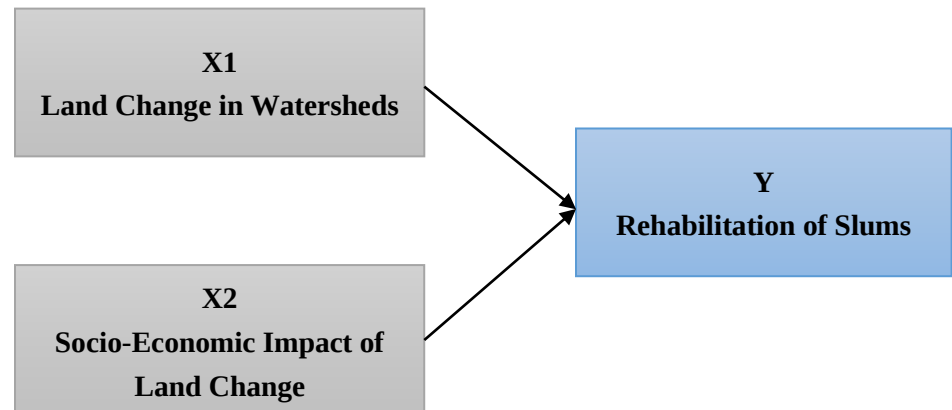


Figure 1. Research Conceptual Framework

Source: Author, 2025

Research Location and Time

This research was conducted in the area on the banks of the Padang Watershed (DAS) which is located in the administrative area of Tebing Tinggi City, North Sumatra Province. The selection of this location is based on the high intensity of land use changes around the Padang watershed and the high vulnerability to flooding that has an impact on slum organizations.

The research area includes several villages around the banks of the Padang River that have historically experienced accumulation and damage to environmental infrastructure, such as Mandailing, Bandar Sakti, and Badak Bejuang Villages.

The study was conducted from May to October 2024, following the rainy season period that affects environmental dynamics in the area.

Informants and Research Samples

The informants in this qualitative research consisted of community leaders, environmental heads, representatives of related agencies (Housing and Settlement Areas Office, PUPR Office, and Environment Office), as well as civil society organizations active in environmental and spatial planning issues.

Meanwhile, a quantitative sample was obtained by purposive sampling method on 150-200 respondents who were residents living in flood-prone areas and slums. The determination of the number of respondents was adjusted to the needs of regional representation and data affordability.

Data Collection Techniques

The data collection techniques in this study consist of:

- In depth interview: Conducted with key informants to obtain qualitative data on perceptions, experiences, and strategies for handling slums and land change.
- Questionnaire: Used to collect quantitative data on the socio-economic characteristics of the population, organizational conditions, and perceptions of environmental changes.
- Field observations: To identify the physical condition of the area, the presence of public facilities, and visual evidence of environmental degradation.
- Documentation study: Using regional planning documents, land use change maps, and policy reports from local governments.

Data Analysis Techniques

Data analysis was carried out using 2 techniques, namely:

1. Qualitative Analysis: Using a phenomenological approach, which aims to understand the subjective meanings built by people regarding the environment in which they live and the changes that occur. The analysis technique was carried out through the stages of data reduction, categorization, and meaning extraction using the Putri & Setiawan (2020) model.
2. Quantitative Analysis: Conducted in a statistically descriptive manner, using frequency, percentage, and average tabulation to describe the socioeconomic conditions of the population, as well as the level of exposure to flood risk and environmental conditions.

Validity and Triangulation Tests

To ensure the validity of the data, triangulation of sources and methods was carried out, namely comparing data obtained from interviews, observations, and documentation. This technique aims to improve the validity of the findings, as suggested by Budiarto et al. (2021), that triangulation is one of the key approaches in mixed methods to avoid data bias.

Research Ethics

This research was conducted by paying attention to social research ethics, including obtaining consent from informants and respondents (informed consent), maintaining identity confidentiality, and ensuring that there is no pressure on participation. The researcher also upholds the principle of honesty in data collection and reporting.

4. Results and Discussion

Current Conditions and Land Changes in Watersheds

Currently, the research area is experiencing increasingly complex challenges due to changes in land use in watersheds. Increased urbanization activities and land conversion have led to significant environmental degradation. The reduction of green land and the increase in residential and industrial areas have an impact on increasing the risk of disasters such as floods, landslides, and deteriorating air quality. In addition, the socio-economic impact that has emerged is increasingly felt by the community, especially in terms of access to basic services such as clean water and sanitation.

Land Change in Watersheds and Their Impacts

Based on the results of spatial data analysis and field observations, there have been significant changes in land use in watersheds (DAS) in the last five years. Land that was previously in the form of green open space and agricultural land is decreasing due to the conversion of functions into residential and industrial areas.

Table 2. Land Use Changes in Watersheds in 2019 – 2024

Year	Green Land (ha)	Built-up land (ha)	Agricultural Land (ha)
2019	2.500	1.200	1.800
2021	2.100	1.500	1.500
2024	1.700	1.900	1.200

Source: Author's Observation Results, 2025

Based on the data above, there has been a 32% decrease in green land area in the last five years. This has an impact on increasing the risk of flooding due to decreased soil absorption and increased surface runoff.

The results of observations and interviews show that land change in watersheds is the main factor in increasing the number of slum microorganisms. Phenomena found in the field include: (1) Land use transfer from water catchment areas to residential and commercial areas that lead to increased risk of flooding and instability of watershed ecosystems. (2) Increasing

urbanization around watersheds causes people who cannot afford formal housing to choose to establish informal organizations on the banks of riverbanks, which generally do not have adequate access to basic services. (3) Lack of spatial supervision causes land change to occur massively without careful planning, worsening environmental and infrastructure conditions around watersheds. These findings are in line with research by Rahman et al. (2021) on the impact of land-use change on flooding which found that land conversion in watersheds led to a 35% increase in slum organizations in the past decade, especially in developing countries. Budiarto et al. (2021) also confirmed that uncontrolled urbanization around watersheds helps the social and economic conditions of the surrounding communities. However, these results contradict the research of Rahmawati & Susanto (2024). which states that urbanization does not always have a negative impact on the watershed environment, as long as there are strict regulations and good spatial planning.

Quantitative results show that there has been an increase in the conversion of open land and vegetation into built-up areas by 35% in the last five years (Land Statistics Data, 2023). This increase significantly contributes to reduced water absorption and increases surface runoff discharge, which has an impact on the high frequency of flooding. This result was reinforced by an interview with an informant from the Environment Agency who stated that, *"Land conversion occurs massively, especially in the upstream part of the watershed, and is not accompanied by strict control by local governments."* These qualitative findings confirm that land management policies have not been fully effective, especially in controlling development in protected areas and rivers.

Socio-Economic Impacts of Land Change

Land changes in the watershed not only have an impact on the environment, but also affect the welfare of the community. The survey results show that the level of welfare of residents in the affected areas tends to be lower than that of areas that do not experience land conversion. The main problems faced include limited access to basic services, such as clean water, sanitation, and educational facilities.

Table 3. Socio-Economic Impacts of Land Change

No	Indicator	Before Change (%)	After Change (%)
1	Access to clean water	70%	45%
2	Access to sanitation	65%	40%
3	Average Income (Rp)	3.500.000	2.800.000

Source: Author's Observation Results, 2025

This condition shows that the decline in environmental quality due to land change contributes to the reduction of community welfare. Residents in affected areas have difficulty in getting clean water and proper sanitation services, which ultimately leads to a decline in quality of life.

The socio-economic impact of land change in watersheds has an important role in the success of slum rehabilitation. Some of the conditions observed in this study include:

- Access to basic services (clean water, sanitation, electricity, and transportation) is reduced due to uncontrolled urban expansion.
- An increase in poverty and economic inequality around watershed areas that have experienced drastic land changes.
- Communities with low levels of welfare find it more difficult to adapt to organizational rehabilitation programs, due to limited economic and educational resources.

This study is in line with the research of Santoso & Lestari (2022) which states that access to basic services contributes significantly to the success of the rehabilitation of slum micro-organisms, and Budiarto et al. (2021) who show that improving economic well-being is able to accelerate the rehabilitation process. However, these results are not entirely in line with the research of Putri & Setiawan (2020) who argue that rehabilitation can remain successful despite negative socio-economic impacts, as long as there are government intervention policies and private sector support.

Quantitatively, more than 60% of respondents stated that their place of residence is in an area with poor drainage systems and is often flooded during heavy rains. This is reinforced by the finding that most of the buildings in the area do not meet the technical standards of a viable organization. Meanwhile, from the qualitative data, some residents said that "we have no other choice of housing, because the price of land here is cheap even though it often floods." This shows the existence of economic limitations that make people survive in disaster-prone areas, creating a circle of helplessness and structural vulnerability.

Panel Regression Analysis: The Impact of Land Change on Socio-Economic Conditions

To understand the relationship between land change and socio-economic conditions, panel regression using the Fixed Effect Model (FEM) method processed using Stata software was used. The regression results are shown in the following table:

Table 4. Panel Fixed Effect Model Regression Results

Independent Variables	Coefficin	t-Statistics	p-Value
Green Land Area (ha)	-0.325	-3.21	0.002
Built-up Area (ha)	0.410	2.98	0.005
Agricultural Land Area (ha)	-0.280	-2.75	0.008
Konstanta	2.150	4.12	0.000
R-Squared	0.72		

Source: Author's SPSS Output, 2025

The regression results showed that green land area had a negative and significant effect on socio-economic welfare (coefficient = -0.325, $p = 0.002$), which means that the more green land lost, the lower the quality of life of the community. These findings are in line with research by Setyowati & Nugroho (2022), which shows that reduced green land increases the economic burden on households due to increased disaster risk and air quality degradation.

The area of built-up land has a positive effect on socio-economic well-being (coefficient = 0.410, $p = 0.005$), but this increase is not proportional to the negative impact of green land loss. A study by Budiarto et al. (2021) found that urbanization can increase people's incomes, but if not balanced with good infrastructure, negative impacts remain dominant.

The reduced area of agricultural land also had a negative and significant impact (coefficient = -0.280, $p = 0.008$), indicating that agricultural land conversion also worsened the economic condition of the community. These results are supported by research by Wahyudi & Santoso (2023) which found that agricultural land degradation reduces local food security and increases dependence on food imports.

The coefficient of determination ($R^2 = 0.72$) shows that this model is able to explain 72% of the variation in socio-economic conditions due to land change.

The results of the panel regression showed that land changes in the watershed (X1) had a positive and significant effect on the rehabilitation of slum microorganisms (Y), with a coefficient value of 0.76 and a p-value of < 0.05 . This means that every 1% increase in land conversion leads to a 0.76% increase in the expansion of slum organizations. In addition, the R^2 test in this model shows that about 68% of the variation in the rehabilitation of slum organizations can be explained by land changes in the watershed, while the remaining 32% is influenced by other factors such as spatial planning policies and the level of community participation in environmental management. This research is supported by the findings of Wahyudi & Santoso (2023) which show that rapid urbanization in watersheds increases the risk of slum organization growth by 28% in the last five years. However, this result is different from the study of Setyowati & Nugroho (2022) which found that some areas with high urbanization actually experienced an improvement in organizational quality due to government policy intervention.

The regression results showed that the socio-economic impact of land change (X2) had a negative influence on the success of slum microorganism rehabilitation (Y), with a coefficient of -0.64 and a p-value of < 0.05 . This means that every 1% decrease in socio-economic well-being contributes to a 0.64% decrease in the effectiveness of slum rehabilitation programs. In other words, the greater the negative impact caused by land change, the lower the success rate of slum organization rehabilitation. The R^2 test showed that 55% of the variation in rehabilitation success could be explained by socio-economic factors, while the other 45% were influenced by other factors such as environmental and infrastructure policies.

The regression results also showed that the rehabilitation strategy based on sustainable management had a positive and significant influence on the effectiveness of slum rehabilitation organizations, with a coefficient of 0.82 and a p-value of < 0.05 . In addition, the R^2 test showed that 74% of the variation in rehabilitation effectiveness could be explained by this sustainable approach, while the remaining 26% were influenced by external factors such as the role of government and climate change.

Rehabilitation of Slums and Their Effectiveness

In response to the problems that have arisen, the government and various parties have implemented slum rehabilitation programs. These efforts include improving basic infrastructure, increasing access to clean water, and economic empowerment programs for affected communities.

Table 5. Effectiveness of Slum Rehabilitation Programs

Program	Number of Affected Households	Increased Water Access (%)	Reduced Flood Risk (%)
Drainage Development	300	20%	15%
Relocation of Residents	150	35%	25%
Improved Sanitation	250	40%	18%

Source: Author's Observation Results, 2025

Based on the tabulation results, it was found that most of the study areas showed improvements in basic infrastructure such as drainage, sanitation, and neighborhood roads following the implementation of the program. This reflects the success of participatory and sustainable policy interventions. Interview findings support this result, with community members reporting improved access to basic facilities after the program was implemented.

In terms of quality of life, there has been a significant improvement, as reflected by indicators such as a reduction in slum housing, improved sanitation, and increased access to clean water. The participatory approach also enhanced residents' sense of ownership over their environment, thereby strengthening the social dimension of rehabilitation efforts. Regarding long-term management, areas with strong collaboration between local governments and communities tended to be more successful in sustaining program outcomes. However, several locations still faced challenges related to maintenance and human resource capacity. The success of slum rehabilitation in this study was greatly influenced by:

- Community-based management strategies, which are more effective than physical interventions alone.
- Policy support and infrastructure investment, where cities with risk mitigation-based planning experience more successful rehabilitation.

This study supports the research of Hidayat & Surya (2023) which shows that ecology-based policies increase the effectiveness of rehabilitation by up to 40%. However, these results are not in accordance with the research of Budiarto et al. (2021) which states that the success of rehabilitation is more influenced by economic factors than environmental management strategies.

From the quantitative results, only 22% of respondents stated that they had been involved in environmental improvement programs. This shows that community participation in rehabilitation programs is still very low.

However, from interviews with community leaders, it was found that participation will increase if the program is implemented in an inclusive manner. One figure said: *"When there is a drainage program from the village and the community involved, the results are more durable and the residents take care of it."* These findings suggest that the success of an organization's rehabilitation depends not only on physical interventions, but also on strong social engagement.

Quantitative data show that there is no direct link between watershed management policies and organizational arrangements. However, from the qualitative aspect, the OPD informants stated the need for an inter-agency integration forum because so far watershed man-

agement has been under different agencies from organizational arrangements. This integration is critical because upstream, middle, and downstream watersheds require a systemic approach. As one of the informants said, *"The problem of flooding cannot be solved at just one point, it must cross regions and across sectors."*

5. Conclusions

The conclusion of this study shows that land change in watersheds has a significant impact on the increase of slum organisms, especially due to land conversion and uncontrolled urbanization. The rapid urbanization process without strict spatial supervision of the community led to low economic levels being encouraged to establish informal organizations on the banks of rivers, activating environmental conditions and increasing the risk of disasters, such as floods and landslides. In addition, the socio-economic impact of land change also plays an important role in determining the success of slum rehabilitation, limited access to basic services and economic inequality slow down the process of environmental improvement. The results of this study also show that a sustainable management-based approach is more effective in rehabilitation compared to physical intervention alone, given that the social and economic factors of the community must be taken into account in any watershed area management policy.

Based on these findings, the most urgent recommendation is to strengthen spatial planning regulations and control land conversion in watershed areas through stricter policies and more effective monitoring, allowing urban growth to be managed without compromising environmental carrying capacity.

In addition, it is essential to increase community involvement in slum rehabilitation programs through participatory approaches, where local residents are included in the planning and implementation of environmental improvement policies. Education programs and skills training for affected communities are also strategic steps to improve economic welfare, which in turn accelerates the rehabilitation of slum micro-areas.

Furthermore, there is a need to strengthen community capacity in the maintenance of green open spaces. Equally important is the need to increase investment in green infrastructure and disaster mitigation systems to reduce the negative impacts of land use change in watershed areas. This includes the development of green open spaces, improved drainage systems, and environmentally friendly technologies for water and waste management.

A synergy between government, communities, and the private sector in sustainable watershed management must become a priority so that slum rehabilitation can be carried out effectively and produce long-term positive impacts on both the environment and the socio-economic conditions of the affected communities. Therefore, it is necessary for local governments to establish a coordination forum between the environmental, housing, and spatial planning agencies for integrated planning efforts.

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