



Coastal Transformation and Its Impact on Coastal Sustainability: A Case Study Timbulsloko From Timbulsloko Area

Muhammad Aminullah¹ and Irene Sondang Fitrinitia²

¹ Department of Urban Development Studies, School of Strategic and Global Studies, Universitas Indonesia, Jakarta, Indonesia

² Department of Urban Development Studies, School of Strategic and Global Studies, Universitas Indonesia, Jakarta, Indonesia
muhammad.aminullah@ui.ac.id

Abstract. Coastal areas face severe pressures from sea level rise, land subsidence, and tidal flooding, which drive spatial transformations and undermine the sustainability of community livelihoods. Timbulsloko Village in Central Java represents an extreme case where once productive agricultural land has turned into permanently inundated areas. This study aims to analyze how spatial transformation affects coastal livelihood sustainability by employing the Sustainable Livelihood Approach (SLA) framework. Specifically, it examines pressures on the five livelihood capitals: natural, physical, social, human, and financial, and their interconnections in strengthening or weakening community resilience. The study adopts a qualitative case study design, drawing data from focus group discussions (FGDs) involving 64 participants across four hamlets, complemented by in-depth interviews with key informants. Thematic analysis was applied to identify patterns of spatial change and their impacts on livelihood capitals. Findings reveal that spatial transformation in Timbulsloko occurred progressively, shifting from productive farmland to permanently inundated zones. The impacts include ecological degradation, infrastructure damage, declining social interactions, limited access to education and employment, and reduced household income. These pressures are interdependent, where the deterioration of one capital exacerbates vulnerabilities in others. The study concludes that community based adaptation strategies demonstrate local resilience, yet remain insufficient without institutional support. Therefore, integrated interventions through ecosystem restoration, infrastructure strengthening, and cross scale policy measures are urgently needed to safeguard coastal sustainability.

Keywords: Coastal Transformation, Sustainable Livelihoods, Spatial change.

1 Introduction

Coastal cities are currently experiencing profound spatial transformations triggered by sea level rise, which causes erosion, flooding, and land loss (Affandi et al., 2022; de Almeida & Mostafavi, 2016; Isiaka et al., 2023; Laino & Iglesias, 2023). These spatial changes directly affect coastal sustainability by exerting socioeconomic pressures, including infrastructure damage, loss of coastal resources, and population displacement (de Almeida & Mostafavi, 2016; Isiaka et al., 2023).

In Indonesia, sea level rise is further exacerbated by land subsidence. The northern coastal region of Java (Pantura) experiences subsidence of up to 11–20 cm per year, making it one of the fastest subsiding regions in the world (Wuragil, 2022). This condition has led several areas along the Pantura coast to undergo severe spatial transformation, with significant implications for the livelihoods of coastal communities. One of the most affected areas is the Timbulsloko coast, Central Java.

Timbulsloko has undergone substantial physical transformation. Erosion and tidal flooding have reshaped the coastal landscape that, in the 1960s, was still dominated by productive agricultural land and settlements. Today, much of the area is permanently inundated (Purba et al., 2019; Qonita, 2023; Wirawan, 2023). According to a Wetlands International report, the village had already lost between 400 and 1,300 meters of its coastal area by 2013 (Astra et al., 2014).

This ongoing transformation has also reduced the sustainability of community livelihoods. The disappearance of fishponds as the main source of income has severely undermined the economic base of coastal residents (Ismail et al., 2012; Karmilah & Handriana, 2023; Qonita, 2023; Sukamdi, 2019). At the same time, flooding has damaged physical infrastructure, disrupting access to essential services such as education, health care, and employment (Qonita, 2023; Wirawan, 2023).

Previous studies have explored the impacts of coastal change. For example, Suriandjo et al. (2023) found that infrastructure development induced coastal change also affects community socioeconomic conditions. Similarly, Hassan & Rahmat (2016) showed that shoreline retreat contributes to both physical degradation and social impacts. Other studies have emphasized that social pressures arise from the loss of coastal resources, which serve as a primary source of community income (de Almeida & Mostafavi, 2016; Isiaka et al., 2023).

Although these studies link physical coastal changes with broader sustainability concerns, they have yet to fully explain how the process of spatial transformation exerts pressure on coastal livelihoods using the framework of livelihood capitals, the core dimensions of the Sustainable Livelihood Approach (DFID, 1999).

The complexity of coastal livelihoods demands a holistic perspective to evaluate sustainability. Assessing pressures on livelihood capitals, natural, physical, social, human, and financial, is crucial to capture this complexity and to provide a comprehensive understanding (Nayak, 2017; Nef et al., 2023). Such a perspective also offers a foundation for designing effective interventions and opportunities for improvements across various aspects of community life.

Accordingly, this study addresses a gap in the literature by examining spatial transformation and its associated pressures on the livelihood capitals of coastal communities. Specifically, it analyzes how each dimension of livelihood capital is affected by spatial change and how the dimensions interact with one another. The study seeks to answer two central research questions: (1) How does spatial transformation occur in Timbulsloko? (2) How does this transformation affect each dimension of livelihood capital?

2 Methodology

This study was conducted in Timbulsloko Village, Demak Regency, Central Java, over a three-month period. It employed a qualitative case study approach, focusing on the livelihoods of coastal communities in Timbulsloko. The case study method was selected because it enables an in-depth and contextual understanding of phenomena within specific spatial boundaries (Yin, 2018).

Primary data were collected through focus group discussions (FGDs) involving 64 participants from four hamlets: Wonorejo, Bogorame, Karanggeneng, and Timbulsloko. As shown in Table 1, participants represented four socioeconomic categories considered capable of providing diverse perspectives on the issues under study, housewives, students, non-nature based workers, and nature based workers. The FGDs aimed to capture community perceptions, experiences, and adaptation strategies in response to coastal spatial transformation and its impacts on livelihood capitals.

Table 1. FGD Participants.

Group	Participants	Participants per Helmet	Informan Participation	Date
Housewives (H)	16	4	Data on spatial changes and their impacts on livelihood capital of the housewives group	2-3/5/2025
Nature-Based Workers (NBW)	16	4	Data on spatial changes and their impacts on livelihood capital of the nature-based workers group	2-3/5/2025
Non-Nature-Based Workers (NNBW)	16	4	Data on spatial changes and their impacts on livelihood capital of the non-nature-based workers group	2-3/5/2025
Students (S)	16	4	Data on spatial changes and their impacts on livelihood capital of the student group	2-3/5/2025

To complement and validate the FGD findings, in-depth interviews were conducted with four key informants, each representing one hamlet (see Table 2). Informants were

purposively selected based on their knowledge of environmental changes and active roles in community adaptation initiatives, such as the construction of stilt houses, mangrove planting, and road improvements. In-depth interviews allowed for narrative exploration, offering deeper insights into motivations, challenges, and adaptive strategies from the perspective of direct actors (Seidman, 2019).

Table 2. In-Depth Interview Participants.

Informan (Initial)	Age	Informan Background	Informan Contribution	Date
SO	>50	Religious leader and Community leader of Timbulsloko Hamlet	Data on spatial changes and their impacts on livelihood capital of the housewives group	2-3/5/2025
NS	>50	Village official, Community leader of Bogorame Hamlet	Data on spatial changes and their impacts on livelihood capital of the nature-based workers group	2-3/5/2025
SA	>50	Head of community group, Village official, Community leader of Wonorejo Hamlet	Data on spatial changes and their impacts on livelihood capital of the non-nature-based workers group	2-3/5/2025
SY	>50	Village official, Resident of Karanggeneng Hamlet	Data on spatial changes and their impacts on livelihood capital of the student group	2-3/5/2025

All data were analyzed using thematic analysis, following the six steps proposed by Braun & Clarke (2006): (1) familiarization with the data, (2) generating initial codes, (3) searching for themes, (4) reviewing themes, (5) defining and naming themes, and (6) producing the report. This approach was applied to identify patterns of spatial transformation, its impacts on the five livelihood capitals (natural, physical, social, human, and financial), and the interdependent relationships among them.

3 Analytical Framework

In this study, spatial transformation is analyzed primarily through the lens of physical change. Coastal physical transformation is understood as the alteration of spatial form and function driven by environmental pressures such as erosion, tidal flooding, and sea level rise (Affandi et al., 2022). The physical aspects emphasized in the analysis include shoreline changes, land use conversion, and the transformation of housing structures.

In addition, the analysis incorporates a temporal dimension to highlight that coastal spatial transformations occur progressively rather than instantaneously. To examine the

implications of these physical transformations, the study employs the Sustainable Livelihood Approach (SLA) (DFID, 1999) (see Figure 1). SLA emphasizes five interrelated livelihood capitals: natural capital, physical capital, social capital, human capital, financial capital. These five capitals are used as an analytical lens to understand how physical spatial transformation either undermines or reinforces the sustainability of coastal livelihoods.

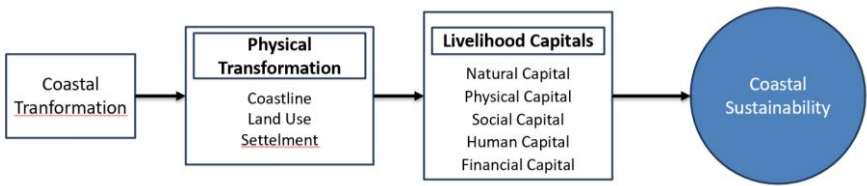


Fig. 1. Analytical Framework

4 Result and Analysis

4.1 Spatial Transformation in Timbulsloko: From Agrarian Abundance to Inundation

As illustrated in Figure 2, the findings reveal that Timbulsloko’s coastal area has undergone gradual spatial transformation, characterized by a fundamental shift from an agrarian landscape to one dominated by permanent seawater inundation. Prior to 2000, the area was primarily composed of fertile rice fields and fishponds that supported local food security, provided diverse agricultural outputs, and formed the economic backbone of the community. These spatial changes are further mapped in Figure 3.

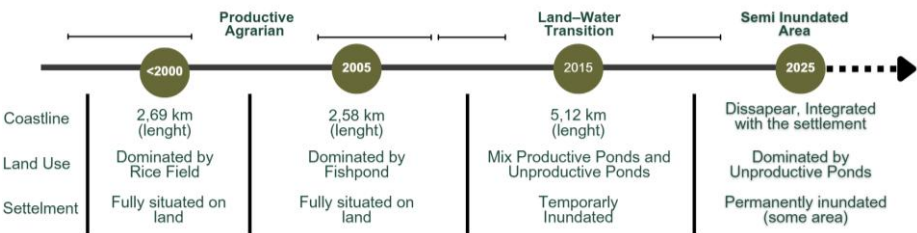


Fig. 2. Spatial Transformation of Timbulsloko Over Time.

During this period, rice cultivation was progressively converted into fishponds, peaking around 2005. Two key drivers were identified: (1) reduced rice field productivity due to saline intrusion into groundwater, and (2) higher profitability of aquaculture compared to agriculture.

"...building fishponds seemed tempting. With only about one million Rupiah in capital, the harvest could reach ten million Rupiah." (SO).

This phase was remembered by residents as *gemah ripah loh jinawi*, a Javanese expression symbolizing abundance, prosperity, and the sufficiency of natural resources to sustain the entire community. Houses at this time were still built as ground based structures with yards.

"Back then, we had crops: rice, chili, fruits, vegetables, coconuts, bananas, mangoes. It was truly gemah ripah loh jinawi. People from outside came here looking for jobs. Everyone wanted to work in Timbulsloko." (NBW).

At the same time, however, residents began noticing shoreline retreat, as coastal erosion gradually encroached upon settlements and fishponds. This was soon followed by tidal flooding, which initially occurred seasonally but eventually became permanent inundation.

By around 2009, flooding had reached Wonorejo Hamlet, submerging large parts of the area, particularly former fishponds. In subsequent years, the shoreline continued to shift inland, with seawater encroaching further into areas previously unaffected. By 2017, Timbulsloko Hamlet itself had become inundated.

"The flooding started in 2009. Wonorejo Hamlet was the first to be affected, while the others had not yet experienced serious impacts." (S)

"By 2016–2017, the village started to sink bit by bit..." (NBW).

This inundation also transformed housing. Inundated areas forced residents to renovate their homes. In Wonorejo and Karanggeneng, houses were elevated with soil, while in Timbulsloko and parts of Bogorame, residents converted ground based houses into stilt houses. Meanwhile, fishponds were completely submerged, leading to declining community income.

"In the past, working in factories was seen as embarrassing here, because we had our own land. Farming and fishponds provided more than enough to support a family, sending children to school, building houses. A single rice field was sufficient. But now, even meeting basic needs is difficult." (NBW).

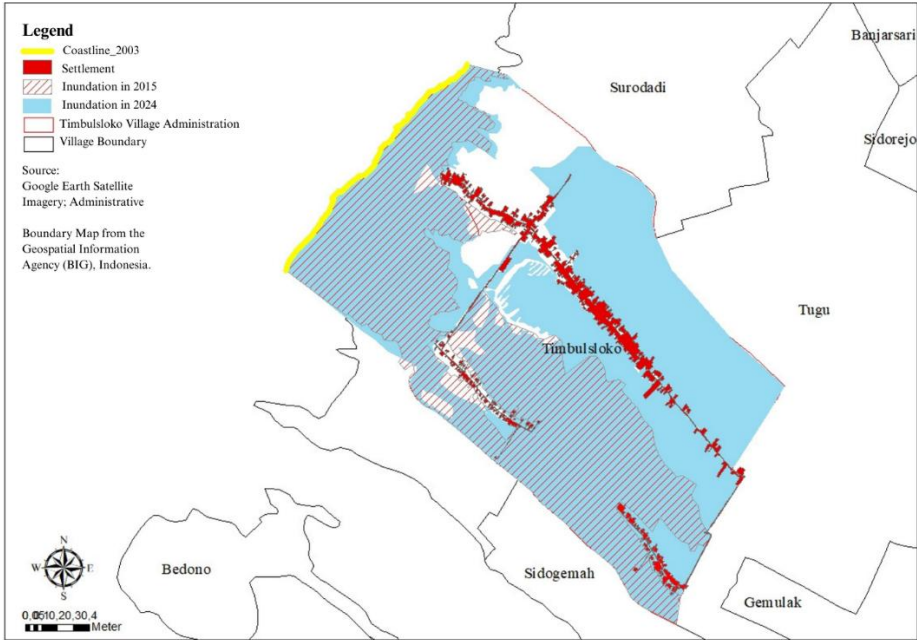


Fig. 3. Map of Physical Transformation in Timbulsloko

4.2 Impact on Livelihood Capitals

As presented in Table 3, the spatial transformation in Timbulsloko has significantly affected all five dimensions of livelihood capital across the hamlets.

Table 3. Field Data Coding Results.

Code	Theme	Concept
Mangrove degradation due to waves and currents	Coastal ecosystem	Natural Capital
Seawater pollution caused by waste		Village official, Community leader of Bogorame Hamlet
Seawater inundating settlements	Tidal inundation	Head of community group, Village official, Community leader of Wonorejo Hamlet
Land rendered unproductive due to inundation	Productive land	Village official, Resident of Karanggeneng Hamlet
Fishponds submerged by seawater	Public facilities	Physical Capital
School buildings damaged by inundation		

Open spaces inundated		
Cemeteries inundated		
Household septic tanks damaged and submerged	Basic household facilities	
Household clean water wells damaged and submerged		
Houses damaged and inundated		
Roads damaged, inundated, and cut off by flooding	Transportation infrastructure	
Vehicles vulnerable to damage due to seawater inundation		
Friendships reduced due to population displacement	Demography and mobility	Social Capital
Population displacement caused by flooding		
Social jealousy over aid distribution	Social tensions	
Bullying from outsiders		
Social activities still maintained	Social participation	
Decline in social activity intensity due to displacement and shrinking space		
Informal lending services available	Access to credit	Financial Capital
Formal lending institutions available		
Increased household expenditures for adaptation	Household income and expenditures	
Household income reduced due to loss of productive land		
Alternative income sources available: <i>njebak</i> (traditional fishing)	Alternative household income	
Community learns and practices <i>njebak</i>	New knowledge	Human Capital
Access to education disrupted by damaged roads	Accessibility of basic needs	
Access to health services disrupted by damaged roads		
Access to employment disrupted by damaged roads		

Natural Capital. Pressures on natural capital are reflected in the degradation of coastal ecosystems, the loss of productive land, and the expansion of tidal inundation. Mangrove ecosystems have been severely damaged by increasingly intense waves, while the encroaching seawater has submerged fishponds and farmland, erasing vital sources of food and income.

“When the ponds were still productive, there were shrimp, milkfish, and crabs. Crops like chili could be planted on the pond ridges. It used to take about 5–6 kilometers to reach the ponds. Now everything is gone, completely submerged.” (NBW).

Physical Capital. The expansion of inundation into residential areas has weakened physical capital, including public facilities, household infrastructure, and transportation systems. Schools and cemeteries have been flooded, open spaces rendered unusable, and basic facilities such as houses, septic tanks, and wells for clean water have been damaged.

Roads have also deteriorated, with some sections submerged or cut off entirely, limiting mobility in and out of the area. Motorcycles and other vehicles, frequently exposed to corrosive seawater, have become increasingly prone to damage.

Social Capital. Tidal flooding has triggered population displacement, reducing the number of residents and narrowing social spaces for interaction. This has weakened social networks, with fewer friendships and declining participation in communal activities.

“Previously, PKH (community group meetings) were held all the way to Timbulor. Now it’s impossible because the road is cut off.” (H).

Social tensions have also emerged, including jealousy over aid distribution and instances of bullying from outsiders, particularly toward students. Nevertheless, some social participation persists, as remaining residents continue certain community activities.

Financial Capital. Household financial capital has come under pressure due to the loss of productive land, which reduced income, while expenditures increased to cover adaptation measures such as elevating houses, frequent motorcycle repairs, and occasional reliance on boats.

“It’s a waste of time and money, paying for parking, daily installments, fixing motorcycles that keep breaking because seawater corrodes the engine. That’s why expenses here are so high.” (NBW).

“Expenses keep rising, but there’s no income...” (NBW)

At the same time, residents have sought alternative sources of livelihood, such as the local practice of *njebak* (traditional fishing), which has become both a coping mechanism and a new form of knowledge. Households also rely on both formal and informal lending institutions

Human Capital. Human capital has been strained by disruptions in access to education, employment, and health services due to flooded roads. Students often arrive late or are unable to attend school when access routes are blocked.

Nevertheless, adaptive learning has emerged, particularly through the practice of *njebak*, which demonstrates the community's capacity to generate new knowledge and strategies in response to environmental change. Despite this, overall human capital remains under significant stress.

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4.3 Interlinkages Among Capitals

The analysis reveals that the impacts of spatial transformation on livelihood capitals are highly interdependent. The deterioration of one capital often amplifies pressures on the others, creating a cascading effect of vulnerability (see Figure 4).

Pressures on natural capital, such as the loss of productive land, were the initial triggers of broader livelihood insecurity. The disappearance of rice fields and fishponds as primary income sources directly undermined financial capital, reducing household income and heightening economic vulnerability.

Similarly, the expansion of tidal inundation into residential areas, another form of natural capital degradation, placed stress on physical capital. Flooding damaged public facilities, household infrastructure, and transportation systems, which in turn restricted access to education, healthcare, and employment, further weakening human capital.

The degradation of physical infrastructure also forced households to increase expenditures for adaptation, such as house elevation and vehicle repairs, thereby intensifying pressures on financial capital. At the same time, the reduction of public spaces and continued outmigration weakened social capital, limiting social interactions and lowering participation in community activities.

Despite these overlapping pressures, adaptive responses emerged. The practice of *njebak* illustrates a positive interlinkage between human capital (new knowledge and skills) and financial capital (alternative income generation). This demonstrates that while the erosion of natural capital triggered vulnerabilities across other dimensions, local adaptive capacity played a role in sustaining livelihoods under severe environmental stress.

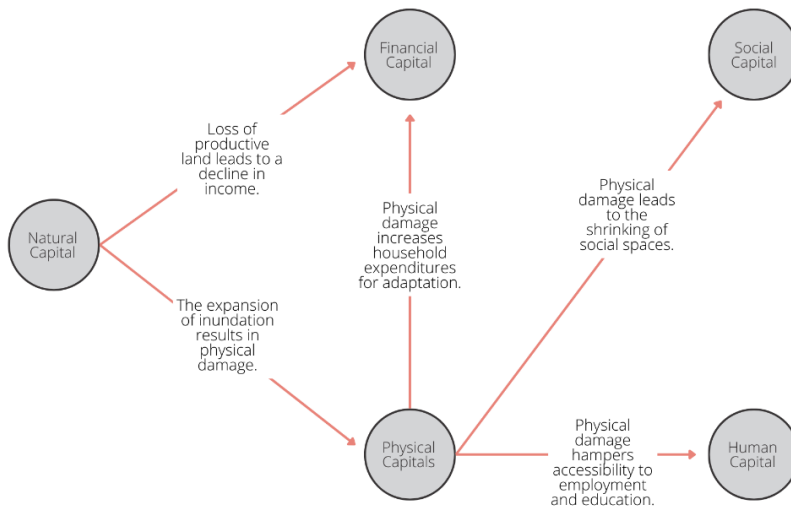


Fig. 4. Interlinkages among Livelihood Capitals.

5 Discussion and Conclusion

5.1 Discussion

The findings of this study indicate that the spatial transformation in the Timbulsloko coastal area occurred gradually and can be divided into several phases. These phases include the terrestrial phase, the land-sea transition phase marked by the initial intrusion of seawater, and the semi inundated phase characterized by the submergence of most coastal areas. This gradual process is consistent with various studies that describe spatial transformation in coastal regions (Suriandjo et al., 2023).

Furthermore, the continuous expansion of inundation, despite early warning signs as early as 2005, illustrates the weakness of coastal planning in anticipating environmental dynamics. This vulnerability was exacerbated by the large scale conversion of rice fields into fishponds, which heightened susceptibility to erosion, as highlighted by Junior et al. (2021).

Another contributing factor is the development of Semarang, a neighboring coastal city, where large scale reclamation projects have been associated with intensified flooding in Timbulsloko (Dewi & Bijker, 2020). According to local accounts, community members observed more frequent and severe tidal flooding following reclamation in Semarang. This suggests that urban coastal development has cross-boundary impacts that require further investigation to prevent similar consequences in other regions.

The study also underscores the importance of strengthening institutional support for community based adaptation strategies. Local responses such as stilt house construction and the practice of *njebak* reflect creativity and resilience. However, without structured policy support, these efforts risk stagnation and may be insufficient to address escalating environmental pressures in the future.

To ensure long term sustainability, integrated coastal protection measures are needed. Ecosystem restoration, particularly mangrove rehabilitation, has been shown in various studies to enhance coastal resilience by trapping sediment, reducing erosion, and improving biodiversity, which can in turn provide alternative livelihood opportunities (Giffin et al., 2021). Strengthening basic infrastructure and diversifying economic sources are equally essential to complement ecological interventions.

5.2 Conclusion

This study demonstrates that transformation in the coastal area of Timbulsloko is not merely a physical phenomenon, but a multidimensional process that progressively undermines the sustainability of coastal livelihoods. The shift from productive agricultural land to permanently inundated areas has generated layered pressures across all livelihood capitals: natural, physical, social, human, and financial. The stress on one capital has been shown to influence the others, thereby accelerating community vulnerability.

Using the Sustainable Livelihood Approach, this research emphasizes that coastal sustainability must be understood through a holistic lens, as ecological and infrastructural degradation ultimately affects social, economic, and adaptive capacities. Community based adaptation strategies, such as the construction of stilt houses or *njebak* practices, reflect local creativity and resilience; however, they remain insufficient without stronger institutional and policy support.

Therefore, efforts to sustain coastal livelihoods should involve multi-scalar interventions, ranging from mangrove ecosystem restoration and basic infrastructure strengthening to economic diversification. This study contributes to a deeper understanding of the interconnections between spatial transformation and livelihood capitals, while underscoring the urgency of integrative actions to ensure the future of coastal communities amid accelerating environmental changes.

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