

Socio-Ecological Resilience of a Coastal Community Facing Coastal Erosion in Bangboler Hamlet, Sikka Regency, Indonesia

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ARTICLE INFORMATION	ABSTRACT
Article History: Received: 2026-06-18 Accepted: 2026-09-17 Published: 2026-09-30 Keywords: Asymmetric socio-ecological resilience; Coastal erosion; Coastal governance in Bangboler; Community adaptation; Corresponding author: Sunimbar Email: sunimbar@staf.undana.ac.id DOI: 10.37905/jgej.v7i2.39919 Copyright © 2026 The Authors  This open-access article is distributed under a Creative Commons Attribution-NonCommercial (CC-BY-NC) 4.0 International License	Coastal erosion continues to recur and threatens the sustainability of coastal communities' living spaces, yet how social capital (trust, networks, and cooperative practices within broader social response capacity) interacts with ecological conditions and institutional support in building socio-ecological resilience remains insufficiently explained. This study aims to analyze the impacts of coastal erosion, community adaptation strategies, and the relationship among social response capacity, ecological recovery, and institutional support. The study uses a qualitative approach with a case study design in Bangboler Hamlet, Hepang Village, Sikka Regency. Data were obtained from 20 informants representing affected households, local livelihood actors, and community and coastal-management actors through semi-structured interviews, field observation, and documentation. Data were analyzed through six-phase reflexive thematic analysis using a contextualist, hybrid inductive and theory-informed orientation. The findings show that coastal erosion triggers cascading changes in the coast, vegetation, settlements, water sources, mobility, and livelihoods. The community responds through mutual assistance, local knowledge, livelihood flexibility, and screw-pine planting. Although social responses were mobilized rapidly, participants perceived ecological recovery as slower, while institutional support was described as episodic and fragmented. Community participation has not yet been fully transformed into a long-term preventive strategy that is maintained technically and institutionally. These differences in function, strength, and time scale are interpreted as asymmetric socio-ecological resilience, a case-based conceptual synthesis rather than a validated general theory. This study proposes that coastal resilience be assessed through relationships among capacities and that governance align community mobilization with ecologically informed rehabilitation, financing, maintenance, monitoring, and institutional coordination.

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1. Introduction

Coastal erosion is a process of coastal change that brings broad consequences for ecosystems, infrastructure, settlements, and the sustainability of community life. A global analysis for 1984–2015 shows that changes in coastal morphology occurred widely and that land loss due to erosion exceeded land gain through accretion (Mentaschi et al., 2018). This pressure is projected to increase along with sea-level rise, extreme events, changes in sediment supply, the loss of protective vegetation, and coastal development (Vousdoukas et al., 2020). At the landscape level, modern marine transgression links sea-level rise with erosion, ecosystem transitions, and the displacement of human living spaces (Hein & Kirwan, 2024). For communities that reside in and depend on coastal resources for their livelihoods, shoreline retreat means changes in living space, access to resources, settlement security, and livelihood sustainability. Thus, coastal erosion constitutes a socio-ecological issue because coastal biophysical processes interact directly with the social and economic lives of communities.

The impacts of coastal erosion extend beyond shoreline change into the various spaces that support everyday life. Coastal damage can increase the exposure of settlements, disrupt mobility routes, alter access to water sources, reduce protective vegetation, and affect production locations. Tran et al. (2021) show that coastal erosion affects infrastructure, subsistence practices, cultural traditions, and communities' attachment to place. This relationship indicates that vulnerability is formed through a sequence of changes linking coastal ecosystems with domestic space, social space, and livelihood space. Each change in one part of the system can produce further consequences in other parts, particularly in rural settlements with a high dependence on local resources.

Coastal communities develop various strategies to sustain life when facing these changes. These strategies include mobilizing assistance among residents, using local knowledge, adjusting livelihoods, changing routines, protecting assets, and participating in ecosystem rehabilitation. Cinner et al. (2018) identify assets, flexibility, social organization, learning, and agency as the five main domains of coastal communities' adaptive capacity. Meanwhile, Whitney et al. (2017) explain that coastal adaptive capacity is formed through the relationship between social capacity, ecological capacity, and the processes that connect them across scales. Social networks also shape opportunities for adaptive and transformative responses to emerge (Barnes et al., 2020). In this study, social capital refers to trust, networks, and cooperative practices and is treated as a relational component of broader social response capacity, alongside local knowledge, livelihood flexibility, leadership, learning, and agency (Carmen et al., 2022). Evidence from coastal settings further indicates that network structure and community leadership shape whether these resources translate into adaptive action (Gisevius et al., 2025; Salgueiro-Otero et al., 2022). In the Indonesian coastal context, the integration of local knowledge, formal rules, and intergroup collaboration can also strengthen collective action and produce coastal-resource management that is more adaptive to local dynamics (Hendra et al., 2025).

Some community strategies emerge as direct practical adjustments to the pressures residents face. Castro (2024) refers to this pattern as ad hoc adaptation, namely changes in habits, work, housing, and resource use undertaken on the basis of local experience and available capacities. This type of adaptation can provide short-term protection and help households maintain daily activities. However, global mapping shows that many adaptation actions remain local, fragmented, and incremental, while evidence regarding long-term risk reduction remains limited (Berrang-Ford et al., 2021). Because adaptation interventions may either reduce or reproduce vulnerability depending on their design and context (Eriksen et al., 2021), their long-term influence depends on access to resources, institutional support, and connections with more organized strategies. Distinguishing between the capacity to respond to damage and the capacity to anticipate disturbances is important because the two involve different forms of action, resources, and time scales.

The concept of socio-ecological resilience provides a basis for explaining these differences. Coastal resilience is formed through the capacity of social and ecological systems to face disturbances, maintain key functions, learn from change, and reorganize the relationship between communities and their environment (Adger et al., 2005; Folke et al., 2021). Resilience also concerns well-being, power, and the distributional consequences of change, so persistence alone should not be treated as a sufficient outcome (Hoque et al., 2017). Resilience is further related to management scale, knowledge exchange, shared goals, and the capacity to connect local action with institutional support (Rölfer et al., 2022). A global assessment shows that households most frequently undertake adaptation, while governments appear more often in planning and funding; consequently, the distribution of roles and responsibilities among actors becomes an important issue (Petzold et al., 2023). Resources, leadership, bonding and bridging social capital, and support from institutions at higher levels are also factors that enable adaptation to move from capacity to action (Brullo et al., 2024). The temporal dimension further clarifies this relationship. Social responses can occur quickly through networks among residents, whereas ecological recovery proceeds more slowly because it depends on vegetation growth, the suitability of biophysical conditions, maintenance, monitoring, and governance continuity. Lacoste et al. (2026) show that the resilience trajectories of coastal systems are influenced by the speed of environmental change and by the process of institutionalizing external interventions within local systems.

The development of coastal adaptation remains uneven across risk knowledge, planning, action, capacity, evidence of risk reduction, and long-term pathway strategies. An assessment of 61 coastal cases shows that rural areas tend to achieve lower adaptation outcomes than urban areas, particularly in long-term strategies (Magnan et al., 2023). A study across coastal cities also found that adaptation progress remains slow, narrow, and fragmented, although urban contexts cannot be directly equated with rural settlements (Wannewitz et al., 2024). A review of 650 empirical studies confirms that coastal adaptation is influenced by the interconnection of knowledge, participation, learning, resources, and institutional arrangements (Cabana et al., 2023). Place-based traditional knowledge can increase the acceptance and sustainability of adaptation strategies when it is given space alongside scientific knowledge (Nunn et al., 2024). A study of the Torosiaje community also shows that attachment to the sea and community-based ocean literacy can strengthen community commitment to the sustainability of coastal ecosystems. At the same time, evidence on nature-based solutions shows that their effectiveness differs according to hazard type, ecological conditions, design, and implementation context

(Chausson et al., 2020); therefore, rehabilitation cannot be reduced to planting activities without ecological integrity, social safeguards, and long-term management (Seddon et al., 2021). In Indonesia, community-based adaptation in Brebes demonstrates the dominance of reactive responses, limited coordination among stakeholders, and weak understanding of coastal physical processes (Nguyen et al., 2022). Research on the coast of Central Java also shows that the success of community-based rehabilitation differs among locations according to management approaches, long-term maintenance, vegetation conditions, and wave-energy-reduction measures (Damastuti et al., 2023).

Existing studies have explained the impacts of coastal erosion, adaptive capacity, vegetation rehabilitation, and coastal governance from various perspectives. However, empirical explanations of the relationship between rapid social responses, slower ecological recovery, and episodic institutional support have received limited attention. A community's capacity to address damage can develop alongside continuing ecosystem degradation. Strong social mobilization during emergency response can also produce different outcomes when directed toward preventive mitigation and rehabilitation maintenance. Therefore, resilience needs to be explored as a configuration of capacities that develop with different strengths and time scales.

Bangboler in Hepang Village, Lela District, Sikka Regency, East Nusa Tenggara, provides a relevant empirical context for examining this issue. Recurrent coastal erosion since approximately 2013 has affected coastal conditions, vegetation, settlements, mobility routes, household water sources, and community livelihood spaces. Residents respond to these changes through mutual assistance, work adjustments, the use of knowledge about seasons and waves, and participation in coastal vegetation planting. At the same time, the implementation of rehabilitation is related to program cycles, support from external institutions, coastal biophysical conditions, and maintenance continuity. These characteristics make Bangboler a case capable of demonstrating the relationship between community collective capacity, ecological recovery trajectories, and institutional organization in a rural coastal settlement in eastern Indonesia.

Accordingly, this study aims to analyze the impacts of coastal erosion on the living spaces and livelihoods of the Bangboler community, identify adaptation strategies developed by the community, and explain the relationship between social response capacity, ecological recovery, and institutional support in shaping socio-ecological resilience. The study is guided by three questions: (1) how does recurrent coastal erosion alter the living spaces and livelihoods of the Bangboler community; (2) how does the community develop adaptation through mutual assistance, livelihood adjustments, local knowledge, and coastal rehabilitation; and (3) how does the relationship between social response capacity, ecological recovery, and institutional support shape Bangboler's socio-ecological resilience? Socio-ecological resilience served as a sensitizing framework during theme development; asymmetric socio-ecological resilience was not used as an a priori coding category. The term was developed after the construction of the three themes as a case-based analytical synthesis of differences in strength, function, and time scale among capacities. It is presented as a proposition for interpreting this case rather than as a general theory.

2. Method

This study uses a qualitative approach with a single-case study design to understand the socio-ecological resilience of a coastal community in facing recurrent coastal erosion. The case is bounded to the community of Bangboler Hamlet, which is administratively located in Hepang Village, Lela District, Sikka Regency, East Nusa Tenggara. The case study design is used to trace the relationship between changes in coastal conditions, community experiences, adaptation strategies, ecological recovery, and institutional support within the context of local community life. Fieldwork was conducted from January to March 2026.

Participants were selected purposively on the basis of direct experience with coastal erosion, knowledge of changes in the coastal environment, and involvement in the social or economic life of the Bangboler community. Snowball sampling was used to obtain additional participants with relevant knowledge. The study involved 20 people, consisting of affected residents, fishers, women, community leaders, customary leaders, village officials, and other actors with relevant knowledge. The 6–7–7 distribution in Table 1 was used to ensure coverage of three perspectives, not as a statistical quota or as evidence of saturation. Recruitment ended when all research-question foci were represented across the three groups and the corpus contained sufficiently specific and varied accounts to support within-case

thematic interpretation. Accordingly, sample adequacy was judged from the relevance and diversity of information within the bounded case rather than from the numerical composition alone. Each participant was assigned an anonymous code, P01–P20. These codes were stored in a separate linkage list to trace the relationship among anonymous identities, transcripts, analytical matrices, and the quotations used.

The primary data were collected through semi-structured interviews. The interview questions covered changes in the shoreline and ecosystems, coastal vegetation conditions, changes in resources and livelihoods, environmental recovery processes, solidarity, trust, community participation, and relationships with external institutions. The interviews were conducted in Indonesian, lasted 45-60 minutes, were recorded with the participants' consent, and were transcribed verbatim in Indonesian. Quotations selected for this English-language manuscript were translated by the research team and checked against their Indonesian source passages for semantic equivalence. Minor syntactic adjustments were limited to readability and did not change the substantive meaning. The researcher acted as the primary instrument in preparing the guide, conducting interviews and observations, coding, and interpreting the data. Fieldwork implementation was coordinated with the Hepang Village Government. Ethical procedures included explaining the purpose of the study, voluntary participation, the right to decline or discontinue an interview, consent to recording, identity anonymization, and restricted access to the code-linkage list.

Non-participant observation was conducted to record coastal conditions, vegetation, settlements, access routes, and rehabilitation sites and activities relevant to participants' experiences. Field notes and visual documentation were used to strengthen understanding of the case context and to compare information from the interviews.

The interview results were organized into two matrices: an ecological resilience matrix and a social resilience matrix. The data audit identified 399 indexed response segments, consisting of 210 ecological segments and 189 social segments. A segment was treated as a technical duplicate only when its wording, participant or source code, and transcript location were identical, indicating repeated indexing of the same source passage rather than repeated testimony across participants. Removing the 20 technical duplicates reduced the matrix index to 379 unique segments, while the original transcripts and all substantively repeated accounts from different participants were retained for analysis. Entries with blank identities, inconsistent numbering, repeated tables, or unclear ecological terms were flagged for source checking and were not counted as independent evidence unless they could be traced to an original source.

Table 1. Informant Characteristics

Informants	Perspectives Represented	Number
Affected residents and households	Experiences of shoreline retreat, inundation around houses, changes in well water, damage to access routes, and mutual assistance among residents	6
Local livelihood actors	Changes in marine yields, fishing locations, income, livelihood diversification, knowledge of coastal conditions, and participation in mitigation activities	7
Community actors and coastal-management stakeholders	Community mobilization, vegetation rehabilitation, plant maintenance, institutional coordination, external assistance, and program continuity	7
Total		20

Each text unit was assigned a source-location code. The prefix RE indicates that the data originated from the ecological resilience matrix, whereas RS indicates the social resilience matrix. The subsequent code indicates the question aspect and the position of the response in the matrix. The RE and RS codes were used to maintain traceability between the presentation of the findings and the data sources, not as participant identity codes. Participant identities were stored through a separate linkage list connecting participant codes, roles, transcripts, and the quotations used. In presenting the findings, the participant code and matrix-location code are included together, for example P01/RE-KL-01, so that the source of a quotation can be traced without revealing personal identity.

The researchers analyzed the data using reflexive thematic analysis by [Braun and Clarke \(2006\)](#). This approach was selected to develop patterns of meaning concerning the relationship among experiences of coastal erosion, community collective action, livelihood change, ecological recovery, and institutional

support within a single contextually bounded case. The analysis used a contextualist orientation and a hybrid approach: initial coding was primarily inductive and close to the explicit meanings of the data, whereas theme development and conceptual synthesis were informed by a socio-ecological resilience perspective. The ecological and social resilience matrices were used to organize and trace data sources, not as themes established in advance.

The analysis proceeded iteratively through six phases. First, the researcher became familiar with the data corpus through repeated readings of interview transcripts, field notes, and relevant documents while writing initial analytical notes. Second, segments related to the research questions were assigned initial codes, without restricting the codes to the structure of the interview questions or the division between the ecological and social matrices. Third, the codes were compared to develop patterns of meaning and construct candidate themes. Fourth, the candidate themes were reviewed against the coded quotations and the entire corpus to assess internal coherence, distinctions among themes, and their relationship to the research questions. Fifth, the scope, central organizing concept, and name of each theme were clarified. Sixth, the themes were organized into an analytical narrative and supported by representative quotations. This process was not linear because the researcher moved back and forth among the data, codes, themes, and interpretations during the analysis.

The 379 unique segments served as a traceability index rather than as independent observations. During coding, each segment was read together with its statement context and source transcript. Recurrence across different participants was retained because it could contribute to pattern development.

The six-phase analysis generated three themes: (1) coastal erosion spreads disturbance from coastal conditions into living spaces and livelihoods; (2) rapid social responses maintain the functions of life but have not fully reduced exposure; and (3) participant-perceived ecological recovery and episodic institutional support sustain long-term vulnerability. For reporting, these themes were organized through eight qualitative indicators: coastal-margin and protective-vegetation change; settlement and household-water exposure; mobility and livelihood disruption; mutual assistance and emergency response; local knowledge and livelihood flexibility; preventive participation and maintenance; vegetation recovery; and institutional continuity. These indicators structure the evidence and are not standardized or numerically scored. The term asymmetric socio-ecological resilience was developed only after theme construction as a case-based analytical proposition.

Representative quotations were selected on the basis of their relevance to the themes, specificity of information, capacity to show participants' experiences, and traceability to the source. Each quotation was checked again against the original transcript to ensure the accuracy of its wording, anonymous identity, and statement context. Corrections to spelling and punctuation were made only to improve readability without altering the substantive meaning of the statement.

Data credibility was strengthened through source triangulation by comparing the experiences of participants from different backgrounds and through method triangulation by comparing interviews, observation notes, and field documentation. Participant confirmation was not conducted; therefore, claims of credibility were not based on that procedure but on cross-source comparison, checking quotations against transcripts, and tracing the context of statements. Reflexivity was maintained through analytical notes and re-examination of the influence of the researcher's prior knowledge on coding and interpretation. Dependability and confirmability were maintained by retaining the anonymous participant list, data matrices, coding notes, duplication list, theme-development decisions, and a traceability matrix between quotations and their original sources.

3. Results and Discussion

3.1 Results

The findings are organized into three themes and eight qualitative indicators. The first theme examines coastal-margin and protective-vegetation change, settlement and household-water exposure, and mobility and livelihood disruption. The second examines mutual assistance and emergency response, local knowledge and livelihood flexibility, and preventive participation and maintenance. The third examines vegetation recovery and institutional continuity. These indicators organize the presentation of specific findings; they are not quantitative scores.

3.1.1 Cascading Changes in Living and Livelihood Spaces

For the indicator of coastal-margin and protective-vegetation change, coastal erosion was not experienced as an isolated change at the shoreline, but as a sequence of spatial disturbances extending from the coast into settlement space, water access, mobility routes, and livelihood areas. Participants consistently described an increasingly narrow beach, the loss of land and protective vegetation, and wave activity moving closer to everyday activities. One account summarizes the visible changes along the coastal margin:

"After coastal erosion occurred in Hepang Village, the shoreline retreated farther. Several coconut trees that used to be far from the sea have now fallen because the soil was eroded by the waves. The beach has also become narrower than it was several years ago." (P01/RE-KL-01)

For the indicator of settlement and household-water exposure, the contraction of the coastal margin was accompanied by a shift in the boundary between the sea and domestic space. Residents reported that tidal water now reaches house yards more frequently than before. One participant stated, "Now seawater enters the yard more frequently during high tide. Events like this rarely occurred in the past, but now we experience them almost every month" (P02/RE-PE-02). The impact also extended below the surface through changes in household water quality: "The well water that used to be fresh is now beginning to taste salty. We suspect that seawater has entered the ground because the condition of the coast is becoming more damaged" (P06/RE-PE-06). These accounts show that exposure is no longer limited to the coast but has entered spaces needed for everyday household life.

For the indicator of mobility and livelihood disruption, shoreline change damaged local access routes. Footpaths leading to the coast were damaged when rain and high waves occurred simultaneously, forcing residents to use alternative routes:

"Coastal erosion damaged several footpaths leading to the beach. When the rainy season and high waves occur at the same time, the damage becomes more severe, so the community has to find another route." (P06/RE-KL-06)

The same process also affected livelihood spaces. Fishing locations that had previously been used were reported to have been damaged or covered by sand as a result of shoreline change. One participant explained, "Several locations that used to be fishing places are now damaged or covered by sand because of shoreline change. We have to find new locations that are farther away" (P09/RE-SDA-09). The displacement of fishing activities increased travel distances, while declining catches reduced household income. Some fishers responded by combining fishing with farming or working as laborers to meet household needs (P08/RE-SDA-08). Thus, coastal erosion generated a sequence of interrelated impacts: the physical retreat of the coast narrowed usable beach space, extended exposure into domestic space, disrupted access, and displaced livelihood activities farther from settlements.

3.1.2 Adaptation through Mutual Assistance, Livelihood Flexibility, and Local Rehabilitation

The second theme was examined through three indicators: mutual assistance and emergency response, local knowledge and livelihood flexibility, and preventive participation and maintenance. For the first indicator, the fastest response relied on mutual assistance among residents. During severe coastal erosion, the community mobilized locally available materials to reduce further damage:

"During the coastal erosion season several years ago, many residents lost parts of their yards. The community worked together to build an emergency barrier from sandbags and stones so that the damage would not become more severe." (P14/RS-SOL-04)

The same pattern was evident when boats and houses were damaged. Residents explained that they helped one another carry out repairs before outside assistance arrived: "If a boat is damaged by large waves or a house near the coast is damaged, residents work together to help repair it. They do not wait for assistance from the government first" (P12/RS-RESP-02). This response enabled rapid action during a crisis, particularly when household assets and livelihood equipment were under threat.

Local knowledge and livelihood flexibility were expressed through situational decisions rather than formal plans. Participants linked visible changes in shoreline and marine conditions to moving to more distant fishing grounds (P09/RE-SDA-09) and combining fishing with farming or wage labor when catches declined (P08/RE-SDA-08). These coded accounts provide the empirical basis for interpreting

experiential knowledge and work adjustments as connected adaptive capacities; they do not establish a measured change in ecological conditions.

For the indicator of preventive participation and maintenance, levels of participation differed between emergency response and preventive mitigation. Spontaneous mutual assistance was widely reported after damage occurred or during bad weather, whereas participation before an event was less consistent. One participant clearly explained this difference:

"When a disaster or bad weather occurs, the community helps one another without being asked. However, for mitigation activities before a disaster, not all residents participate because some feel that it is the government's responsibility." (P13/RS-MIT-03)

Preventive activities were more likely to take place when initiated by the village government or an external program. Residents generally participated when they received invitations and information, but independently organized mitigation was considered rare (P11/RS-MIT-01). A similar pattern was evident in vegetation planting. Initial attendance by residents was fairly high, but fewer residents continued maintenance: "When there is a planting program, quite a large number of community members attend, but after the activity is completed, only a small number continue to maintain the plants" (P04/RE-PART-04). Thus, the adaptation repertoire was layered but uneven. Mutual assistance, temporary barriers, and livelihood diversification supported the capacity to endure in the short term, whereas preventive action and post-program maintenance occurred less regularly.

3.1.3 Uneven Social and Ecological Capacities in Sustaining Resilience

The third theme was examined through the indicators of institutional continuity and vegetation recovery. Strong internal cooperation enabled residents to respond quickly, but the ecological and institutional conditions required for sustained recovery remained weak. External cooperation was repeatedly described as project-based rather than continuous. A community leader explained:

"Cooperation does exist, but it is still based on particular programs. When a program ends, the activities also stop. There is not yet cooperation that operates routinely every year." (P16/RS-JAR-06)

Delays in external support further increased dependence on immediate assistance within the community. A fisher stated, "When it comes to assistance during coastal erosion or high waves, it is not always quick. Sometimes we first help one another among residents before assistance from outside the village arrives" (P13/RS-INF-03). These data show a strong capacity to mobilize local relationships during disturbances, but the capacity to sustain action across institutions between events remained weaker.

Ecological recovery showed the same discontinuity. Residents acknowledged localized improvements after screw-pine planting but considered the restored area smaller than the area that remained damaged:

"There has been a slight improvement at several points because of screw-pine planting activities. However, the area that has been damaged is still larger than the area that has been restored." (P08/RE-KINI-08)

The survival of newly planted vegetation was also uncertain because seedlings were often washed away before they could grow well (P03/RE-HAM-03). Participants linked these ecological constraints to fragmented implementation among institutions: "Sometimes the village government, government agencies, and community groups operate separately, so rehabilitation activities are not sustained" (P04/RE-HAM-04). Another account emphasized that the cumulative loss of protective trees and coastal habitats continued despite rehabilitation efforts:

"Coastal erosion is occurring more frequently, protective trees are becoming fewer, and several habitats of coastal biota are beginning to disappear. Although rehabilitation efforts have been made, the results have not been able to restore conditions to what they were before." (P10/RE-KINI-10)

Indicator synthesis: Coastal-margin contraction, household exposure, and livelihood displacement show the spatial spread of erosion; mutual assistance and livelihood adjustment show the immediate availability of social responses; and lower preventive participation, uncertain seedling survival, and

project-based cooperation show limits to sustained risk reduction. Taken together, the eight indicators show a qualitative, participant-reported asymmetry: social response capacity was more immediately available than ecological recovery and institutional continuity. Because the study did not measure shoreline-change rates or vegetation survival, this synthesis describes the pattern in participant accounts and field observations rather than a quantified temporal trajectory.

3.2 Discussion

The findings show that coastal erosion in Bangboler operates through a sequence of changes linking coastal conditions, living space, livelihoods, collective action, and institutional support. Coastal erosion reduces the protective function of the coast while increasing the exposure of settlements and community activities. Residents respond to direct impacts through mutual assistance, local knowledge, work adjustments, and vegetation rehabilitation. Within the cross-sectional qualitative evidence, social mobilization was reported as more immediate than participant-perceived ecological recovery and program institutionalization. This relationship is interpreted as asymmetric socio-ecological resilience: social capacity supports the continuity of life in the short term, while ecological and institutional conditions sustain vulnerability over a longer term.

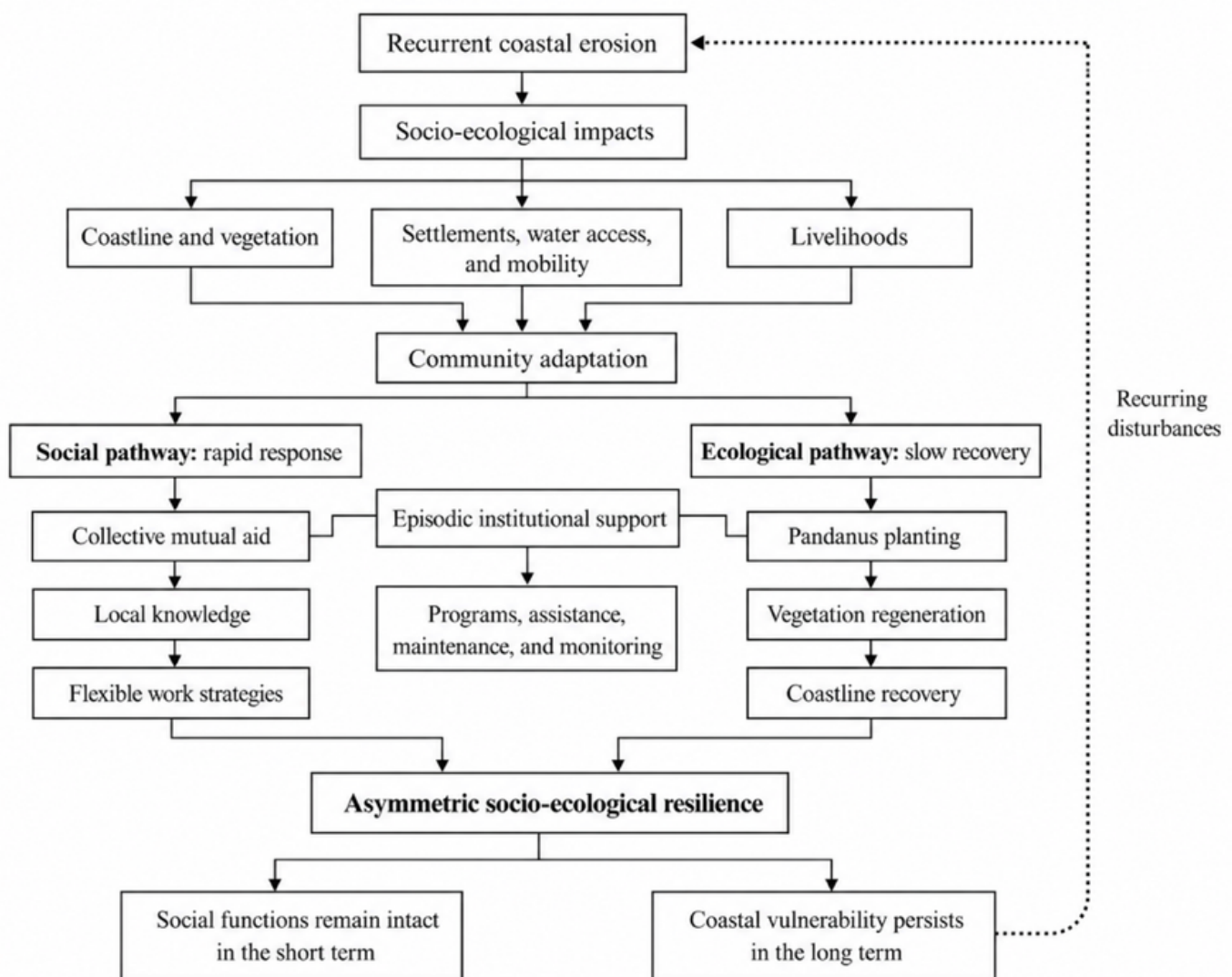


Figure 1. Asymmetric Socio-Ecological Resilience of the Bangboler Coastal Community

3.2.1 Coastal Erosion and Cascading Changes in Living Spaces and Livelihoods

Recurrent coastal erosion in Bangboler has developed from a physical change in the shoreline into a disturbance of the various spaces that support community life. Shoreline retreat, reduced vegetation, and damage to protective infrastructure decrease the distance between the source of the hazard and the

houses closest to the shoreline. The study did not systematically map exposure by RT unit; therefore, the spatial interpretation is limited to proximity patterns reported by participants and recorded during field observation. The impacts then extend to mobility routes, household water sources, locations of economic activity, and the community's sense of security. This pattern shows that coastal erosion is a socio-ecological process linking changes in coastal conditions with changes in how the community uses and maintains its living space.

This sequence of impacts is consistent with [Tran et al. \(2021\)](#), who show that coastal erosion can affect infrastructure, subsistence practices, social spaces, and communities' relationships with place. In the Bangboler case, coastal change becomes the starting point for disturbances in domestic and production spaces. The reduced distance between houses and the coast increases physical exposure, while the decline in vegetation reduces the buffering function that previously helped separate settlements from wave dynamics. A change in one ecological element therefore produces further consequences for social and economic elements.

Reported and observed differences in proximity to the shoreline indicate spatially differentiated exposure, although this study does not rank or quantify vulnerability among neighborhood units. The proximity of houses to the shoreline, uneven vegetation conditions, coastal characteristics, and the presence of protective infrastructure can create different levels of exposure across locations. Communities living closer to the coast face more direct disturbances to their homes, access, and daily activities. This finding develops the global account by [Mentaschi et al. \(2018\)](#) of the extent of shoreline change by showing how the process is experienced differently at the settlement scale.

Impacts on water sources and livelihoods extend coastal erosion from a shoreline issue into a matter of household sustainability. Perceived changes in well water show the relationship between coastal dynamics and domestic resources, while disruptions to the location and timing of work affect income stability. This study did not conduct hydrological testing to determine the cause of the water changes; therefore, the finding is positioned as the community's experience of changes in the quality of living space. In the livelihood domain, dependence on marine conditions makes changes in seasons, waves, and coastal conditions factors that influence work decisions.

The relationship between living space and livelihoods explains why coastal erosion produces multilevel impacts. Coastal damage increases the exposure of settlements; this exposure disrupts household routines; and disruptions to routines then affect mobility, resource use, and income-earning strategies. Community resilience therefore depends on the capacity to face this entire sequence. Shoreline recovery, settlement security, access to resources, and livelihood sustainability are interrelated parts of the same system.

3.2.2 Community Adaptation Orientation: Collective Responses and Limited Anticipation

The Bangboler community adapts through collective action, local knowledge, livelihood flexibility, and involvement in coastal rehabilitation. These forms demonstrate several dimensions of adaptive capacity identified by [Cinner et al. \(2018\)](#), particularly social organization, flexibility, learning, and agency. Their main strength lies in residents' capacity to activate social relationships and local experience when disturbances occur. Mutual assistance enables labor, time, information, and aid to be mobilized rapidly without waiting for formal organization.

Collective action has an important function in reducing immediate disturbances. Residents help one another secure houses, address damage, and restore activities after waves or coastal erosion occur. Local leadership helps connect residents and direct the division of labor. These social networks function as response infrastructure available within the community. Under conditions of limited material resources and formal support, the capacity to organize assistance among residents becomes the main buffer for the continuity of everyday life.

Within the local-knowledge and livelihood-flexibility indicator, the empirical basis lies in participants' decisions to relocate fishing grounds and combine fishing with farming or wage labor as coastal and marine conditions changed. These decisions show experiential interpretation of environmental signals rather than a formally measured knowledge system. Similar livelihood diversification has been documented as a survival strategy among fishing households in Indonesia ([Hasriyanti & Hendra, 2021](#)). This interpretation is therefore tied to the coded evidence presented in Results and is not treated as a separate quantified capacity.

The character of Bangboler adaptation is close to [Castro's \(2024\)](#) concept of ad hoc adaptation. Actions develop from practical experience and resources that the community can use immediately.

These actions focus more strongly on addressing impacts and restoring activities after disturbances. This response capacity helps the community endure, but its influence on the source of exposure depends on preventive action, ecosystem rehabilitation, and sustained institutional support. This difference in orientation explains why the capacity to face coastal erosion events can grow while the level of coastal vulnerability remains high.

Screw-pine planting demonstrates the community's effort to develop more anticipatory action. The vegetation is intended to restore coastal cover and strengthen natural protection. Vegetation has developed at several sites, while seedlings at other locations were washed away before they could grow. These different outcomes show that social mobilization and the implementation of planting represent the capacity to act, whereas ecological success is determined by site suitability, wave dynamics, planting time, rehabilitation techniques, maintenance, and monitoring.

This finding is consistent with Damastuti et al. (2023), who show that the effectiveness of community-based coastal vegetation management differs according to ecological conditions, management practices, and maintenance continuity. The rehabilitation experience in Bangboler also supports the finding by Nguyen et al. (2022) that community responses to coastal erosion can be dominated by reactive action when understanding of coastal physical processes, coordination, and long-term strategies remains limited. The dependence of participation on externally initiated programs is also consistent with evidence that government-led mitigation can mobilize communities without necessarily securing continuous local engagement (Buchori et al., 2022). The number of planting activities and the extent of community participation indicate the strength of social mobilization, whereas plant survival, site suitability, and maintenance continuity are more direct indicators of the ecological recovery trajectory.

Adaptation in Bangboler therefore combines capacities with different functions. Mutual assistance reduces immediate impacts, local knowledge supports decision-making, work flexibility maintains income, and vegetation rehabilitation is directed toward reducing exposure. The strength of social responses gives the community the capacity to sustain life after disturbances. Anticipatory capacity develops to a more limited degree because it depends on technical resources, continuity of maintenance, and organization across institutions.

3.2.3 Asymmetric Socio-Ecological Resilience

The relationship among social capacity, ecological recovery, and institutional support indicates that Bangboler's resilience develops asymmetrically. Participants reported that social capacity operated relatively quickly through networks among residents, local leadership, experience in facing coastal erosion, and livelihood flexibility. Ecological recovery was perceived as operating over a longer time scale because participants linked it to vegetation growth, coastal characteristics, wave strength, maintenance, and repeated evaluation; the study did not measure that trajectory longitudinally. Institutional support lies between these two processes, but its implementation still follows particular program and assistance cycles.

This asymmetry clarifies the difference between the system's capacity to maintain social functions and the ecosystem's capacity to reduce exposure. Residents can repair damage, help one another, adjust work, and continue activities within a relatively short period. Coastal vegetation requires time to grow and develop a protective function. When some seedlings are washed away and the rehabilitation area is smaller than the degraded area, increased social capacity is not immediately followed by increased ecological capacity. The community remains able to carry out daily life while coastal conditions continue along a trajectory of vulnerability.

These findings develop Whitney et al.'s (2017) argument that coastal adaptive capacity is formed through the relationship among social capacity, ecological capacity, and the processes connecting them. The Bangboler case shows that these capacities can move at different speeds and strengths. Resilience in one domain can also coexist with weakness in another. Folke et al. (2021) position the interconnectedness of social and ecological processes as the foundation of resilience, while Bangboler demonstrates the consequences when the development of the two processes occurs unevenly.

Institutional support acts as a mechanism that can connect social mobilization with ecological recovery. Planting programs, material assistance, and government involvement provide resources that are difficult for the community to gather fully on its own. The continuity of these efforts is still influenced by program duration, the division of responsibilities, and the relationship among the village government, government agencies, and community groups. When programs end, the intensity of

maintenance and monitoring also declines. This fragmentation of roles hinders the transformation of episodic rehabilitation activities into a routine coastal-management mechanism.

This situation supports Rölfer et al. (2022), who position knowledge exchange, shared goals, cross-scale coordination, and institutional navigation capacity as important elements of coastal governance. Cabana et al. (2023) also show that coastal adaptation is influenced by the relationship among knowledge, participation, learning, resources, and institutional arrangements. In the Bangboler case, community participation is already present, while the connecting function among local knowledge, technical support, financing, maintenance, and evaluation remains fragmented. This condition explains why high community mobilization produces social outcomes more rapidly than ecological outcomes.

This asymmetry forms a cycle of vulnerability. Coastal erosion triggers damage and increases exposure. Residents respond through mutual assistance and adjustments to activities so that social functions can be restored. Vegetation rehabilitation is then carried out through community mobilization and program support. When maintenance weakens and some vegetation fails to grow, the coastal protective function develops slowly. Persistent exposure generates the next disturbance and reactivates the collective response. This cycle repeatedly directs social energy toward addressing damage, while the reduction of the sources of vulnerability proceeds more slowly.

This temporal dimension is consistent with Lacoste et al. (2026), who show that coastal resilience trajectories are influenced by the speed of environmental change, community responses, and the process of institutionalizing external interventions. The Bangboler findings add qualitative evidence that participants experienced different time scales in collective response, vegetation development, and program support; they do not establish comparative recovery rates. Short-term resilience emerges through the capacity to sustain life after disturbances, while long-term vulnerability is associated with participant-perceived slow ecological recovery and interrupted maintenance.

Rather than proposing a universal new theory, this study offers asymmetric socio-ecological resilience as a case-based conceptual refinement and a basis for future theory development. It denotes the empirically observed misalignment in function, strength, and time scale among rapid collective response, participant-perceived ecological recovery, and episodic institutional support. This concept differs from broad accounts of uneven adaptation outcomes (Magnan et al., 2023) by tracing relationships among capacities within one community, and from cross-scale governance perspectives (Rölfer et al., 2022) by foregrounding the temporal mismatch among community mobilization, vegetation development, and program continuity. The concept should therefore be treated as an analytical proposition requiring examination in additional coastal cases.

This finding also provides an empirical explanation of the inequality of coastal adaptation identified by Magnan et al. (2023). Adaptation outcomes in rural areas are related to the capacity to transform risk knowledge and community participation into long-term strategies. Bangboler shows that social participation is a strong initial asset, but the final outcome depends on the capacity to connect collective action with rehabilitation techniques, financing, maintenance, monitoring, and cross-institutional governance.

Its governance implications point toward aligning social, ecological, and institutional time scales. Rehabilitation can be organized as a continuous sequence that includes site determination, vegetation selection, planting techniques, the division of maintenance responsibilities, survival-rate monitoring, and periodic evaluation. Community knowledge of seasons and waves can be combined with technical assessments of coastal conditions. Where site conditions require it, evaluation should also compare natural, engineered, and hybrid protection options and assess both protective performance and ecological co-benefits (Huynh et al., 2024; Reidenbach et al., 2026). The village government, government agencies, and community groups can hold clear functions from planning through evaluation. Such arrangements enable already-strong social capacity to be directed toward exposure reduction and long-term ecological recovery.

Overall, the study findings explain the mechanisms linking social, ecological, and institutional processes on the basis of community experience, field observation, and Bangboler's institutional context. This study has not measured the rate of shoreline change, water quality, vegetation survival rates, or the biophysical effectiveness of coastal protection. Therefore, the identified asymmetry describes the relationship among observed social capacity, experiences of ecological change, and the continuity of institutional support. Combining qualitative data with shoreline measurements, vegetation monitoring, and hydrological analysis in future research can clarify ecological trajectories and test the development of this asymmetry over the long term.

4. Conclusion

Coastal erosion in Bangboler causes cascading changes in coastal conditions, living space, water sources, mobility, and community livelihoods. The community sustains life through mutual assistance, local knowledge of marine conditions, livelihood flexibility, and the rehabilitation of coastal vegetation. Screw-pine planting shows the existence of anticipatory efforts, but its outcomes remain influenced by site suitability, wave dynamics, rehabilitation techniques, maintenance, and monitoring. Within the limits of cross-sectional qualitative evidence, participant accounts and field observations indicate that social response capacity was more immediately available than participant-perceived ecological recovery and the continuity of institutional support. This uneven relationship is interpreted as asymmetric socio-ecological resilience. The term is offered as a case-based analytical proposition and a basis for future theory development, not as a universally validated theory. It directs attention to relationships, functions, strengths, and differences in time scale among social, ecological, and institutional capacities.

These findings direct coastal governance toward the need to align community mobilization with ecological rehabilitation and sustained institutional support. Village governments, relevant government agencies, and community groups need to establish clear responsibilities for site and vegetation selection, planting, maintenance, plant-survival monitoring, and periodic evaluation. Local knowledge of seasons and waves also needs to be combined with technical assessments of coastal conditions so that already-strong social capacity can produce exposure reduction and long-term ecological recovery. This study has not measured shoreline change, water quality, vegetation survival rates, or the biophysical effectiveness of coastal protection. Future research can combine social data with monitoring of shorelines, vegetation, hydrology, and program sustainability to test the development of asymmetric socio-ecological resilience in Bangboler and other coastal areas.

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