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Examining the Impact of Abrasion on the Livelihood of Fishermen and Aquaculture Farmers: Empirical Study on the North Coast of Central Java Province

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ABSTRACT

The coastal area along the North Coast of Central Java is facing complex environmental dynamics, making it vulnerable to pressures from both human activities and natural phenomena that occur on land and at sea. Abrasion along this coastline has significant impacts on the livelihoods of aquaculture farmers and fishermen. Therefore, this study aimed to examine whether the impact of abrasion on the livelihood of aquaculture farmers and fishermen was consistently detrimental when viewed from various perspectives. Both quantitative and qualitative methods were adopted, and data were collected to compare conditions before and during the impact of abrasion, focusing on economic, social, environmental, and institutional aspects. The study was conducted purposively in three coastal regencies/cities most affected by abrasion, including Demak, Brebes, and Semarang City. A total of 180 respondents, comprising aquaculture farmers and fishermen, were selected by using snowball sampling based on certain criteria. The collected data were analyzed using the descriptive-analytical method. The results showed that abrasion caused significant changes in the livelihoods of the affected communities. Many aquaculture farmers have transitioned to non-fishery or non-marine sectors as an adaptation strategy. Additionally, aquaculture production has changed, with shrimp farming often replaced by milkfish or seaweed cultivation, and in some cases, by green mussels. Socially, abrasion has resulted in psychological disorders, reduced mutual cooperation, and other challenges. Despite these changes, the communities have managed to maintain harmony. Abrasion also altered the coastline and degraded the quality of settlements in the affected areas. This had led to a decline in the role of aquaculture farmers and fishermen groups, as many individuals have shifted to alternative livelihoods. However, the role of relevant government agencies in empowering these groups has increased, providing vital support for adaptation and recovery. To mitigate the negative impacts of abrasion, synergistic cooperation among stakeholders is essential.

1. INTRODUCTION

Fishing is a profession widely practiced by coastal communities, relying on fisheries and aquaculture as a primary source of livelihood. This profession is not only part of a hereditary tradition but also serves as a crucial contributor to the local economy, providing essential income for many communities [1]. The abundance of marine and fishery products supports food security and strengthens the fisheries sector. As an archipelagic country, Indonesia's fisheries sector significantly impacts its economy by contributing to food security, employment, and export revenues [2]. However, the sustainability of this profession is greatly influenced by the condition of the coastal environment. Coastal ecosystems, located between land and sea, have complex environmental dynamics and are highly vulnerable to various pressures [3], from both human activities and natural phenomena [4]. On land, activities such as settlement development, agricultural expansion, aquaculture practices, and natural resource exploitation frequently lead to coastal ecosystem degradation. Additionally, natural phenomena, including erosion and sedimentation of river flows and flood disasters, contribute to environmental challenges. In marine environments, hydrodynamic processes such as tides, waves, currents, and storms triggered by global climate change, add significant pressure to coastal areas [5].

One of the most prominent impacts of coastal degradation is abrasion, also known as coastal erosion. Abrasion is a natural phenomenon that occurs due to erosion of the coastline caused by waves, currents, and sea tides. This phenomenon can also be described as a condition of land compaction which causes the coastline to gradually retreat [6]. In recent years, abrasion has tended to increase in various regions. The North Coast of Central Java is one of the areas that is mostly affected

by abrasion, with significant impacts observed in Brebes Regency, Demak Regency, and Semarang City [7]. From 1995 to 2020, Brebes was affected by abrasion of over 2,391.95 hectares, while Demak lost 2,218.23 hectares from 1984 to 2020. Similarly, Semarang lost approximately 1,919.57 hectares from 2005 to 2020 [8].

The impacts of abrasion in Brebes Regency, Demak Regency, and Semarang City are diverse, including changes in economic, social, environmental, and institutional conditions. Social vulnerability, ecological sensitivity, and long-term effects on sustainable livelihood are key issues contributing to a decline in the community's quality of life [9]. Despite these challenges, some fishermen affected by abrasion continue to remain in the impacted areas [7] due to various factors, warranting an in-depth investigation. Understanding the impacts of abrasion is essential for developing effective mitigation policies and strategies. This is specifically crucial as the affected areas continue to expand annually, while many fishermen and aquaculture farmers choose to stay rather than migrate to other areas. Based on the background above, this study examines the changes brought about by coastal abrasion across multiple dimensions, such as economic, social, environmental, and institutional. The research aims to assess the before-and-after conditions experienced by fishermen and aquaculture farmers in relation to abrasion and to uncover the phenomena occurring within each of these four dimensions. Therefore, the findings are expected to serve as a foundation for formulating long-term sustainable adaptation strategies. The analysis results are expected to provide valuable insights for addressing the impact of abrasion, contributing to the sustainable development of community welfare.

2. RESEARCH METHODS

This study used a combination of quantitative and qualitative methods in natural conditions [10]. It avoided manipulating or intervening in the study object but rather conducted an in-depth analysis of the conditions before and during the impact of abrasion, focusing on economic, social, environmental, and institutional aspects [1]. The quantitative approach was employed to assess changes in economic dimensions, including alterations in pond area, average operational costs, average catch volume, and average income, by comparing conditions before and after the occurrence of abrasion. Meanwhile, the qualitative approach was applied through in-depth interviews using structured questionnaires to capture nuanced insights from respondents.

The study was purposively conducted in three areas along the North Coast of Central Java, namely Demak Regency, Brebes Regency, and Semarang City [8]. Each area was represented by one district with the largest area affected by abrasion. These districts included Sayung, Brebes, and Tugu Districts. From each district, three villages or sub-districts with the largest impacts were selected, resulting in a total of nine study locations. The villages included Randusanga Kulon Village, Randusanga Wetan Village, Kaliwlingi Village, Mangun Harjo Village, Mangkang Kulon Sub-district, Mangkang Wetan Sub-district, Sriwulan Village, Timbulsloko Village, and Bedono Village. The sample selection followed a purposive sampling method, with each village represented by 20 aquaculture farmers and fishermen, making a total of 180 respondents. The respondents were further determined using snowball sampling [11] by considering the established criteria. These criteria included being present in the study location at the time of the survey, possessing knowledge and insight in answering questions, and having at least 15 years of experience as fishermen and aquaculture farmers.

Data collection relied on a validated questionnaire designed to reflect real conditions. The data focused on conditions before and after the occurrence of abrasion, analyzing its economic, social, environmental, and institutional impacts on the households of fishermen and aquaculture farmers [12]. These aspects provided a comprehensive understanding of the livelihoods of fishermen and aquaculture farmers. Data collection was conducted between April and September 2024 through surveys, observations, and recordings [7].

Data analysis used the descriptive-analytical method to examine the relationship between observed phenomena and the underlying factors causing these occurrences [13]. The analysis compared conditions before and during the abrasion, using pre-2010 data as the baseline for conditions prior to the impact. Secondary data were sourced from relevant agency publications, while primary data were collected directly from aquaculture farmers covering economic, social, environmental, and institutional aspects. The ability of aquaculture farmers to explain these aspects would enhance the depth and comprehensiveness of the study [14].

The research stages flow as follows (Figure 1):

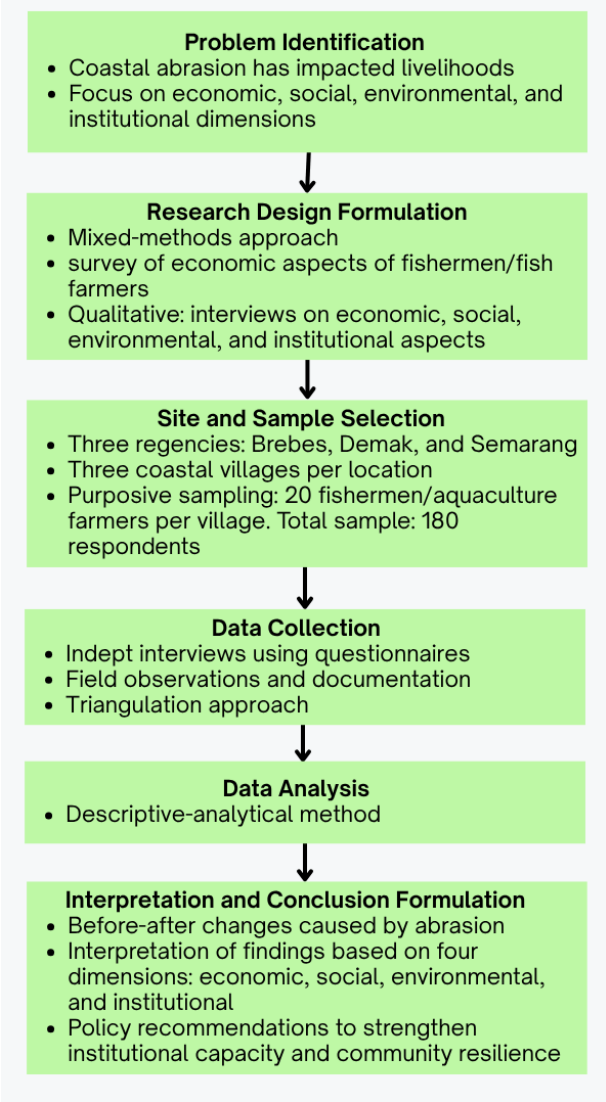


Figure 1. Research design

3. RESULTS AND DISCUSSION

The abrasion in the nine villages studied was highly concerning as it significantly affected the livelihoods of aquaculture farmers. In line with the study of Chaerul and Firdaus [15] in the coastal area of North Galengsong, abrasion eliminated fish ponds, displaced community settlements, destroyed public facilities, and eroded coastal areas. The severe conditions have compelled some residents to migrate to safer places, to escape tidal flooding while others have adapted to the challenging situation [16, 17]. Abrasion has also caused changes in most of the livelihoods of the community, with many shifting to the non-fishery or marine sector [7]. The following section presents a comprehensive discussion of the impacts of abrasion.

3.1 Economic impact

The average area of fish ponds managed by aquaculture farmers has decreased from 21,475 m² to 15,437 m² due to abrasion, as shown in Table 1. This was in line with the results of Wisha et al. [18], who observed similar changes in pond areas along the coast of West Sumatra. The decrease in pond size was attributed to the destruction of embankments and mangroves, which served as natural barriers. Without these protective structures, ponds were transformed into waterlogged areas [19]. The most severe impact was observed in Demak Regency, where most of the ponds were inundated by seawater and subsequently converted into water bodies. In response, aquaculture farmers have resorted to marking their former pond boundaries with bamboo nets to indicate the ownership [7].

The fishing range of fishermen in Pantura, Central Java, has decreased from 17.81 km to 14.82 km due to abrasion. The shrinking coastline in Semarang, Brebes, and Demak has brought the sea closer to the moored boats, reducing the need for fishermen to venture offshore [20]. However, the turbid water conditions have led to a significant decline in plankton and coral reefs, resulting in a decrease in the number of fish and catches. This was in line with the study of Chaijaroen [21], who reported that warm temperatures caused coral bleaching to damage certain habitats and forced species to move to new areas, thereby decreasing fishermen's income. The increase in the range of fishing resulted in an increase in the costs incurred.

The operational costs of aquaculture farmers per production cycle increased to IDR 9,979,711 due to expenses related to ponds repair costs, net installation, and routine monitoring during abrasion [17, 22]. Meanwhile, fishermen's operational costs per trip increased by IDR 207,288 as a result of rising fuel prices and boat maintenance caused by high waves [23].

During the abrasion period, each seed-spreading cycle in pond production decreased drastically from 1,703 kg to 845 kg. In response, many aquaculture farmers switched from shrimp to milkfish cultivation as a strategy to reduce the risks of tidal flooding and theft. Damage to ponds and overflowing seawater often resulted in fish and shrimp seeds being washed away by sea currents. When tidal flood lasted for a long time, the ponds became unusable, significantly reducing the production [24]. This tidal flood occurred mainly between May and July, posing a high risk of pond cultivation which could result in losses.

Table 1. Economic impact on the livelihoods of fishermen and aquaculture farmers

Description		Before Abrasion Occurs	During Abrasion Occurs
Fishing range (km)	Fisherman	17.81 km	17.81 km
Area of cultivated ponds	Aquaculture farmer	21,475 m^2	15,437 m^2
Types of fish caught/cultivated	Fisherman	Snapper, Grouper, Crab, Crab Mullet, Squid, Shrimp	Snapper, Mullet, Crab and Milkfish
	Aquaculture farmer	Snapper, Grouper, Crab, Crab, Milkfish and Shrimp	Milkfish, Seaweed, Green Mussels
Average operational costs per fishing trip	Fisherman	IDR 181,102	IDR 207,288
	Aquaculture farmer per seed stocking	IDR 7,083,471	IDR 9,979,711
Average fish catch (kg) per fishing trip or harvest	Fisherman	30.78 kg	20.24 kg
	Aquaculture farmer	1,703 kg	845 kg
Types of fish caught Price per kg of fish	Fisherman	Snapper/grouper: IDR 44,167 Mullet: IDR 21,000 Swimming crab: IDR 41,579 Crab: IDR 82,000 Squid: IDR 42,143	Snapper/grouper: IDR 39,000 Mullet: IDR 30,000 Swimming crab: IDR 49,000 Crab: IDR 102,500
	Aquaculture farmer	Milkfish: IDR 15,560 Shrimp: IDR 62,750	Milkfish: IDR 21,386 Seaweed: IDR 5,038 Shell: IDR 17,000
Average income per catch or harvest	Fisherman	IDR 1,250,169	IDR 515,254
	Aquaculture farmer	IDR 2,029,110	IDR 1,145,446
Time required for one fishing trip/pond production	Fisherman	1 day	1 day
	Aquaculture farmer	Milkfish: 138 days Shrimp: 84 days	Milkfish: 173 days Shell: 180 days Seaweed: 66 days
Distance of boat from residence	Fisherman	812 meter	442 meter
Number of fishermen fishing, whether more or less	Fisherman	Per boat 1 person Total: 47	Per boat 1 person Total: 47
	Aquaculture farmer	Average manpower: 2	Average manpower: 2
Return of credit to banking or credit institutions	Fisherman	Smooth	Less smooth experiencing delays
	Aquaculture farmer	Smooth	Less smooth experiencing delays

The catch of fishermen decreased from 30.78 kg to 20.24 kg during abrasion. Similar challenges were observed among fishermen in South Kenya, as reported by Mcclanahan et al. [25]. This decline was attributed to changes in the coastal environment, which caused fish to migrate to more favorable waters with better conditions and food sources. While fishermen in Brebes reported benefiting from fish congregating in the remaining mangrove environment, those in Semarang and Demak faced challenges. Poor water quality and sea dredging activities forced fish to migrate to deeper seas, making fishing more difficult. Abrasion had a major impact on the income of aquaculture farmers and fishermen in Pantura, Central Java. Farmers' incomes declined significantly due to damage to ponds affected by abrasion and tidal floods [26]. Similarly, fishermen experienced a decrease in income, from an average of IDR 1,975,362 before abrasion to IDR 1,060,043 during the incident. Although the selling price of fish increased yearly, the low catch caused income to continue to decrease [27].

Most aquaculture farmers in Pantura, Central Java, relied on ponds as their main source of income. However, their earnings were not sufficient to meet household needs, specifically during the period of abrasion. Before the abrasion, the average additional income of ponds farmers was IDR 2,029,110, which decreased to IDR 1,145,446 during the abrasion. While income from other sources was smaller than ponds income, it still helped meet family consumption needs every year [28]. Similarly, fishermen experienced difficulties because their catch was not enough to meet household needs. Abrasion increased expenses, including boat maintenance and house repairs due to tidal flooding, which raised operational costs and further reduced income [23].

Aquaculture farmers in Pantura, Central Java, used additional workers, both from their families and external sources, to help with cultivation in ponds. The average workforce remained at two people before the abrasion, but during the abrasion, there was additional special labor to repair pond barriers due to damage [29]. On the other hand, fishermen typically operate alone to avoid increasing operational costs. Only those with larger boats hire crew members, often fishing in Indonesian open waters with sufficient food supplies and coolers to preserve the catch. These fishermen were not included in the study sample because they were unavailable during the data collection.

During abrasion, the production time for cultivation in ponds increased due to environmental changes, water quality, and reduced plankton, causing fish or shrimp to take longer to reach marketable weight [30]. On the other hand, farmers in Bedono Village, Demak, who lost their ponds, switched to cultivating green mussels. This process took approximately 180 days to harvest and was conducted on former ponds land submerged by seawater, using netting to create barriers. This cultivation had a lower risk because green mussels possessed high adaptability and did not require additional feed, only relying on plankton in their environment [31].

Most fishermen in Semarang, Brebes, and Demak used small boats, with departure times varying based on individual experience and strategies [32]. Motorboats, essential for fishing operations, were registered with the Fisheries Service to qualify for diesel subsidies to reduce operational costs [33]. Fishermen in Brebes and Semarang continued to moor their boats in the same location before and during abrasion. However, those in Demak, who were more severely affected by abrasion, had to move the boats from the Timbulsloko River to areas near their homes for easier monitoring. This relocation was due to shoreline damage, causing tidal water to reach residential areas [34].

Before abrasion, farmers in Pantura, Central Java (Brebes, Semarang, and Demak), produced milkfish and Vaname shrimp. However, during abrasion, milkfish remained the main commodity, with farmers in Brebes adapted by cultivating seaweed [35]. Shrimp farming in Semarang ceased entirely during abrasion, while several farmers in Demak shifted to cultivating green mussels [36]. In this area, fishermen adapted by targeting species with higher market values, such as swimming crabs and crabs [37]. Brebes and Demak fishermen caught mullets, while Semarang fishermen focused more on crabs and mullets. This type of fishing practice was in accordance with the habitat conditions in the study location [38].

Before abrasion, aquaculture farmers were able to pay off loans without any problems. However, during abrasion, they struggled to meet installment payments due to increased production risks and ponds repair costs. This caused a decrease in trust in banking institutions [39]. Similarly, fishermen who had taken out loans to cover operational expenses faced significant financial strain. The continuously decreasing catch and increasing operational costs caused income to decrease, thereby resulting in difficulty in paying installments [40].

The selling price of several ponds commodities and fishermen's catches in Pantura, Central Java, increased during the period of abrasion. This trend was attributed to the increasing demand and development of soft-processed milkfish products [41]. Additionally, the high protein content and ease of processing green mussels [42] made these commodities more appealing to the community, increasing their consumption. Shrimp prices declined due to falling demand and logistical challenges in export processes. Similarly, the price of seaweed decreased as a result of an increase in production where farmers have shifted cultivation to this commodity [43]. Meanwhile, the prices of fishermen's catches, including mullet, crab, squid, and other fish, increased due to inflation and heightened community consumption. The rising popularity of crab-based dishes and the proliferation of crab-focused restaurants contributed to the most significant price hikes, reflecting lifestyle trends and evolving community preferences.

3.2 Social

Abrasion has an impact on the social life of the community, affecting psychological conditions and interpersonal relationships while increasing anxiety about daily life [44]. It caused economic pressure, which has decreased the income of fishermen and aquaculture farmers, triggering social change and psychological disorders such as apathy and anxiety [45]. However, the results of this study reported that the social impact was less severe compared to the conditions reported by Manumono [45], as shown in Table 2.

A significant difference in social impacts was evident in the welfare of fishermen and aquaculture farmers households, conflicts between these groups, a decrease in mutual assistance, and the shift in livelihoods. Community welfare, which was a key component of Sustainable Development Goals and a reflection of the success of economic development [46], has decreased. This decline was characterized by several indicators, including houses submerged in tidal floods, a clean water crisis during floods, poor sanitation, damaged

infrastructure, lack of food during long tidal floods, and the migration of fishermen/aquaculture farmers to safer areas. In addition, reduced income has led to lower purchasing power, resulting in significant changes in consumption patterns. The results were in line with the observation of Chen et al. [47], who highlighted natural instability as a driver of food scarcity due to competition for resources.

Table 2. Social impact on fishermen's livelihoods - aquaculture farmers

Description	Before Abrasion Occurs	During Abrasion Occurs
Household welfare	Prosperous	Their welfare is declining
Social relations with the surrounding community	Good and harmonious	Good and harmonious
Moving from home	Not moving	Some move
Conflicts between fishermen or aquaculture farmers	No conflict	Conflict occurs
Conflicts with related groups/ institutions/ institutions	No conflict	No conflict
Neighborhood harmony	Harmonious	Harmonious
Community cooperation	Maintained	Starting to decrease
Change of livelihood	None	Some become laborers or traders

The uninhabitable condition of several settlements caused by abrasion has forced many residents to migrate to safer places. However, this decision was based on the financial condition of each aquaculture farmer and fisherman household. Households with better finances tended to raise houses, allowing them to remain habitable even though there was a high tidal flood. These households were reluctant to relocate due to their strong emotional ties to the community, closeness to the source of livelihood, and the lack of alternative assets [7].

From a sociological perspective, communities affected by abrasion experience changes in both individual and group life patterns [48]. Conflicts often occur between ponds owners and others who cross or take products from damaged ponds. Ponds inundated by tidal floods without barriers were easily accessible by boat, enabling others to pass through or collect pond products, which often triggered conflicts. Psychologically, aquaculture farmers were very sensitive to any presence near their ponds, often suspecting theft even when the intention was benign [49]. This suspicion persisted because some pond products could be harvested even though the amount was small.

Cooperation, traditionally a hallmark of Indonesian communities, including those along the Pantura coast, has weakened under the pressure of abrasion. Each household has become more focused on safeguarding their lives and property, leading to reduced participation in community-based social cooperation. Although anxiety and discomfort helped in reducing participation in social cooperation, social relations between residents were still well maintained. The emotional relationship in the community continued to foster harmonious interactions between aquaculture farmers and fishermen. This was in line with the report of Shaffril et al. [50], which observed that a sense of brotherhood among fishermen often promoted cooperation and strong social reciprocity. Therefore, the social impacts caused by abrasion at the study location were not entirely negative. It was observed that some indicators have remained unchanged both before and during the period of abrasion.

3.3 Environment

Abrasion causes environmental changes in the coastline due to rising sea levels, ocean currents, and human activities [51, 52]. The main factors of the changes included ocean currents, waves, sea level rise, and land conversion [53, 54]. In addition, abrasion reduced the quality of settlements, making them slummed due to seawater inundation and flooding. Land shrinkage also triggered land ownership disputes as a result of abrasion, resulting in a reduction of available land area, as shown in Table 3.

The village most severely affected by abrasion was Bedono Village in Demak, where three hamlets were relocated due to tidal floods that submerged houses up to their roofs. Despite receiving government assistance, the support was limited, compelling affected residents to seek credit loans to buy or rent homes in new locations. A similar strategy was used by the coastal community in Malaysia, where expanding access to credit proved effective in strengthening fishermen's adaptive capacity and accelerating recovery [50].

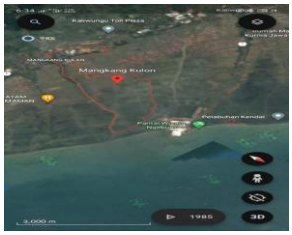
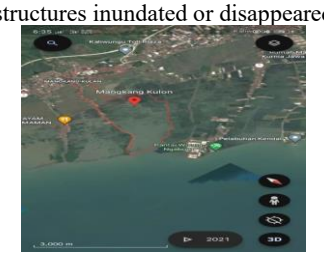
Local governments, aquaculture farmers, fishermen, and communities around the coast have attempted to mitigate the effects of abrasion by planting mangrove seedlings in affected areas such as the Sayung area in Demak [55]. However, these efforts have largely failed due to the loss and death of most of the planted seedlings. The cost of planting mangroves required substantial investment as the seedlings needed special treatment to withstand waves. Some aquaculture farmers planted mangrove seedlings in their ponds once the tidal conditions receded, increasing the chances of successful growth. Mangrove seedlings typically require more than three years to establish strong roots and grow well.

Based on the indicators in this environmental study, the impact of abrasion was detrimental to coastal communities, specifically aquaculture farmers and fishermen. Addressing these challenges required active engagement from various stakeholders. Collaboration among local governments, universities, community-based organizations, aquaculture farmer groups, and fishermen was essential to minimize the impact of abrasion and develop strategies to restore damaged environmental conditions [31].

3.4 Institutions

Fishermen's groups played an important role in empowering coastal fishermen in Pantura. Active participation in group activities enhanced the quality of catches, facilitated access to government assistance, and provided opportunities to share experiences and information. In addition, group members supported each other in difficulties and were aware of the importance of children's education, striving to improve their standard of living [56]. The impact of abrasion has diminished the role of fishermen's groups, as many members have changed professions, including becoming aquaculture farmers, as shown in Table 4. As a result, fishermen and aquaculture farmer groups have become less active in organizing activities. Currently, these groups only focus on recording boat ownership to obtain diesel subsidies, with other activities significantly reduced compared to pre-abrasion levels.

Table 3. Environmental impacts on fishermen's livelihoods - aquaculture farmer

Description	Before Abrasion Occurs	During Abrasion Occurs
Mangrove plants	Brebes, Semarang and Demak: there are 2 types of mangrove plants	Brebes: Most are still well maintained, a small part is damaged and dead Semarang: A small part of the plants are still well-maintained Demak: A very small number of mangrove plants are still well-maintained
Habitat damage around coast	Not yet damaged	Damaged and some coastal areas are lost
Sea water conditions	Shallower and there is still a shoreline	More inland and some of the shoreline is lost
Coastal environmental conditions	 Kaliwlingi Village 1987 Coastline appears advanced with a noticeably wider land area	 Kaliwlingi Village 2021 Coastline shows significant retreat; land area eroded by seawater.
	 Randusanga Kulon Village 1985 Landmass is clearly visible and remains extensive	 Randusanga Kulon Village 2022 Coastal land is barely visible, having transformed into open water
Coastal environmental conditions	 Randusanga Wetan Village 1985 Coastal zone remains broad, especially in the terrestrial portion	 Randusanga Wetan Village 2022 Land area has been largely submerged and replaced by seawater
	 Mangkang Wetan Sub-district 1985 Clear boundary between land and sea; settlements located near the shore remain intact	 Mangkang Wetan Sub-district 2022 Coastline has shifted; several settlements and structures inundated or disappeared
	 Mangkang Kulon Sub-district 1985 Shoreline is clearly defined; surrounding land and infrastructure remain secure	 Mangkang Kulon Sub-district 2021 Significant shoreline shift; land loss and structural disappearance observed

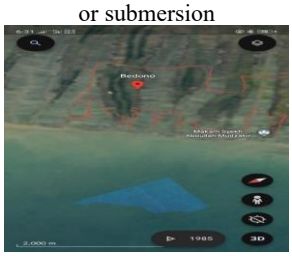
	 Mangun Harjo Sub-district 1984 Coastal area remains stable with no signs of erosion or submersion	 Mangun Harjo Sub-district 2021 Major retreat of shoreline; partial land loss evident
	 Bedono Village 1985 Coastal land remains intact; Sheikh Abdullah Mudzakir's grave remains onshore	 Bedono Village 2021 Large land loss observed; Sheikh Abdullah Mudzakir's grave now surrounded by sea
	 Sriwulan Village 1985 Distinct land-sea boundary; coastal land appears unthreatened	 Sriwulan Village 1985 Most coastal land submerged; some residential areas have disappeared into the sea
	 Timbul Sloko Village 1985 Clear shoreline; coastal land remains in good condition	 Timbul Sloko Village 2021 Shoreline has shifted significantly; visible reduction in land due to seawater intrusion
Number of houses damaged by tidal flooding	Brebes: none	Number of houses damaged by tidal flooding
Condition of coral reefs around coast	Coral reefs are found around coast	No longer present around the coast
Fish drying areas	Brebes: There is a fish drying area	

Table 4. Economic impact on fishermen-aquaculture farmer livelihoods

Description	Before Abrasion Occurs	During Abrasion Occurs
The role of fishermen groups towards their members	Brebes: Yes, regular meetings. Semarang: Yes, regular meetings Demak: some are members and some are not members of fishermen's groups	Brebes: Yes, regular meetings Semarang: Yes, regular meetings and helping with mangrove maintenance Demak: many fishermen are no longer part of fishermen's groups
Material assistance from fishermen groups toward their members	Facilitating diesel subsidies for fishermen	Facilitating diesel subsidies for fishermen
The activity of fishermen's groups	Brebes: active Semarang: active Demak: active	Brebes: still active Semarang: most are inactive Demak: a small number are still active
The role of Fisheries and Marine Service towards fishermen	Brebes: none Semarang: none Demak: none	Brebes: counseling and engine assistance Semarang: providing basic food assistance and subsidies Demak: helping to install breakwaters and provide outreach
Marketing institutions for fish catches	Brebes, Semarang, and Demak: fish auction places	Brebes, Semarang, and Demak: to middlemen
The role of credit/capital institutions	Providing loan assistance to fishermen or aquaculture farmers in need	Providing loan assistance to fishermen or aquaculture farmers in need

The Fisheries and Marine Service was responsible for providing diesel subsidies to registered fishermen, determined through data verification and boat engine capacity. This subsidy reduced fishermen's operational costs and minimized diesel shortages by ensuring distribution at designated fuel stations. Designing an efficient distribution mechanism and implementing strict supervision were crucial to preventing challenges related to distance and limited access to alternative fuels [57]. In addition, the relevant agency organized training programs for seafood processing and provided production equipment for aquaculture farmers and fishermen to obtain added value. For instance, fishermen and aquaculture farmers, particularly in Tugu District, Semarang City, have developed a home industry for processing smoked fish and soft-boned milkfish. This development was supported by the condition that the city has higher consumer demand and serves as a tourist destination, where souvenir centers were spread in various places offering processed seafood.

Before the widespread impact of abrasion, fish auction centers were located near fishing boat moorings. Many of these facilities were destroyed or submerged due to abrasion. Consequently, fishermen and aquaculture farmers now sell seafood directly to middlemen, often comparing prices to select the most favorable option. The marketing of these products has positive and negative effects, depending on the bargaining position of aquaculture farmers and fishermen. A strong bargaining position prevented the middlemen from imposing low prices, and vice versa [31]. The presence of multiple middlemen in the study location benefited aquaculture farmers and fishermen by allowing them to choose buyers who offer higher prices and reliable payment systems.

Credit institutions played an active role in providing loans to fishermen and aquaculture farmers. However, banks exercise caution due to the high business risk associated with abrasion. Credit was only given when fishermen or aquaculture farmers could show positive cash flow for the past 2 years. This measure aimed to reduce the risk of default among aquaculture farmers and fisherman debtors. Despite these efforts, credit assistance did not always help poor fishermen escape poverty, as the stability of such support was short with the risk of unpaid debts [31].

4. CONCLUSION

The findings of this study demonstrate that abrasion has significant and interrelated impacts across four key dimensions: economic, social, environmental, and institutional. In the economic dimension, abrasion has led to the destruction of vital economic assets such as aquaculture pond areas and supporting infrastructure, resulting in income decline and, in some cases, the complete loss of primary livelihoods. In the social dimension, abrasion has affected the psychological well-being of communities, fostering a sense of insecurity and uncertainty about the future. The environmental dimension reveals visible degradation, including the destruction of coastal ecosystems and mangrove forests, threatening the sustainability of natural resources in the affected areas. In the institutional dimension, the response to abrasion has been hindered by weak inter-agency coordination, creating barriers to effective decision-making. Sectoral and fragmented policies have further reduced the effectiveness of sustainable mitigation programs. Therefore, an integrated cross-sectoral approach and community-based collaboration is urgently needed to strengthen local institutions and promote sustainable coastal governance, and improve the resilience and welfare of impacted communities.

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