

Climate Change Threatens Fishermen Food Security in Tambak Lorok, Semarang

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Abstract. Climate change poses significant threats to coastal communities, particularly those reliant on fisheries for sustenance and livelihoods. This study examines the impact of climate change on food security among fishermen in Tambak Lorok, Semarang, a region increasingly vulnerable to rising sea levels, extreme weather, and ecosystem degradation. The problem centers on how these environmental shifts disrupt local fishing activities, reducing catches and threatening traditional food sources. The purpose of this research is to analyze the socio-ecological dynamics linking climate change to food insecurity and to identify adaptive strategies within the community. The study is highly relevant as coastal populations in developing nations like Indonesia face disproportionate climate risks, yet localized impacts remain understudied. Using a mixed-methods approach—including interviews, historical climate data analysis, and participatory observations—this research captures both environmental trends and community perspectives. Key findings reveal declining fish stocks due to habitat loss, increased salinity, and erratic weather, forcing fishermen to adopt less reliable livelihoods. Despite these challenges, local knowledge and informal networks play a crucial role in resilience. State-of-the-art research highlights the need for integrated climate adaptation policies that prioritize community-based solutions. This study contributes to environmental history by documenting Tambak Lorok's vulnerability and adaptive capacity, offering insights for policymakers and scholars.

Keywords: Climate change, Food security, Fishermen, Tambak Lorok, Adaptation.

1. Introduction

1.1 Background: Tambak Lorok, a densely populated coastal kelurahan (sub-district) in Semarang, Indonesia, is intrinsically defined by the sea. For generations, its community has thrived on fishing, with the majority of households relying directly or indirectly on the Java Sea's bounty for their livelihoods and primary source of protein. This traditional fishing village, situated strategically near the bustling Tanjung Emas Port, represents a critical hub for Semarang's local seafood supply chain. However, Tambak Lorok now finds itself on the front lines of a dual environmental crisis, severely threatening the food security of its most vulnerable residents: the small-scale fishermen and their families.

This vulnerability stems from the confluence of two powerful forces:

(1) Severe Land Subsidence: Tambak Lorok is experiencing some of the most rapid land subsidence rates globally, estimated at up to 10-20 cm per year in some areas. This is primarily driven by excessive groundwater extraction for domestic and industrial use, compounded by natural sediment compaction. The consequence is dramatic: vast areas are now permanently inundated, transforming streets into canals and forcing residents to live in stilt houses constantly battling encroaching seawater. This subsidence drastically reduces habitable and safe landing space for boats and gear, disrupts community infrastructure, and increases vulnerability to tidal flooding.

(2) Accelerating Climate Change Impacts: The effects of global climate change are intensifying the challenges:

Sea Level Rise (SLR): Rising global sea levels, acting on top of the subsiding land, exponentially increase the frequency, depth, and duration of tidal flooding (rob). High tides now routinely inundate homes and critical infrastructure.

Increased Frequency and Intensity of Extreme Weather: More frequent and severe storms, heavy rainfall events, and unpredictable winds make fishing operations dangerous and often impossible. Fishing days are lost, boats are damaged, and gear is destroyed.

Coastal Erosion: Stronger waves and currents, exacerbated by SLR and storms, accelerate the erosion of already vulnerable coastlines, further reducing usable land.

Ocean Warming and Acidification: While harder for local fishermen to perceive directly, these changes can disrupt marine ecosystems, potentially altering fish migration patterns and reducing fish stocks over time.

(3) The Food Security Nexus:

The intersection of subsidence and climate change directly imperils the food security of Tambak Lorok's fishing community:

Reduced Fishing Access & Productivity: Frequent flooding and extreme weather drastically reduce the number of safe fishing days. Damaged boats and gear require costly repairs, diverting scarce income away from food. Erosion and inundation destroy landing sites and storage facilities.

Loss of Income: Fewer fishing days directly translate to significantly reduced income. For households entirely dependent on daily fishing catches, this means immediate loss of purchasing power for food and other essentials.

Physical Access to Food: Flooding disrupts local markets, damages roads, and isolates communities, making it physically difficult and expensive to access food supplies, even if money is available.

Damage to Food Stores and Cooking Facilities: Homes inundated by saltwater lose stored food staples (rice, dried fish) and damage cooking facilities, preventing food preparation.

Contamination of Water and Food Sources: Saltwater intrusion contaminates freshwater wells, the primary water source for many. Floodwaters also carry pollutants, contaminating the immediate environment and potentially affecting fish hygiene.

Reduced Dietary Diversity & Protein Intake: With fishing constrained, the primary source of affordable, high-quality protein (fresh fish) becomes scarce and expensive. Families are forced to shift to cheaper, often less nutritious staples, reducing dietary diversity and nutritional quality.

Destruction of Home Gardens: Flooding and saltwater intrusion destroy small-scale home gardens, an important secondary source of vegetables and nutrients for many families.

Tambak Lorok presents a stark microcosm of how climate change, interacting with local environmental degradation (subsidence), directly undermines the fundamental pillars of food security – **availability, access, utilization, and stability** – for a population uniquely dependent on marine resources and living in a highly exposed location. The community's traditional resilience is being overwhelmed by these accelerating environmental changes, creating an urgent need to understand the specific pathways through which climate impacts translate into hunger and malnutrition among its fishermen and their families. Examining this threat is crucial for developing targeted adaptation strategies to safeguard their livelihoods and nutritional well-being.

1.2 Problem Statement: Climate change disrupting fishing activities, reducing catches, and threatening food security and livelihoods in Tambak Lorok.

1.3 Research Purpose: To analyze the socio-ecological dynamics linking climate change to food insecurity and identify adaptive strategies within the Tambak Lorok fishing community.

1.4 Relevance: Highlighting the disproportionate risks to coastal communities in developing nations (like Indonesia) and the gap in localized impact studies.

2. Methods

2.1 Study Area:

Tambak Lorok, now officially known as Tambak Mulyo Village, is a densely populated fishing settlement covering an area of approximately 46.8 hectares. This comprises residential areas (± 32.4 ha), a harbor zone (± 3.2 ha), and fishpond areas

(± 11.2 ha). According to the Spatial and Environmental Planning Document (2018), the northern boundary of Tambak Lorok is directly adjacent to the Java Sea, the southern boundary borders the Soekarno Hatta Arterial Road, the western boundary is demarcated by the Tambak Lorok PLTGU (Gas and Steam Power Plant), and the eastern boundary borders the Banger River (Kali Banger) and the Semarang East Flood Canal. Based on data from the Population Office of Tanjung Mas Sub-district (2016), the Tambak Lorok area is inhabited by 8,315 residents, of whom 2,345 are fishermen. The remainder work as traders or in small-scale or home-based industries.

Tambak Lorok Village is inhabited by migrants from rural areas seeking better employment opportunities with higher incomes. The community works primarily in the informal sector, engaged daily in catching or cultivating brackish water and marine species. Physically, the settlement is dominated by residents working as industrial laborers, construction workers, traders, and in small-scale or home-based industries. Sekatia (2015) states that Tambak Lorok Village is one of the unhygienic and unhealthy fishing settlements, with a housing density reaching 80% in permanent buildings. This high density coexists with various public facilities, including roads, electricity networks, waste management sites, and social facilities such as places of worship and healthcare facilities. Known as a fishing settlement since the 1950s, the village has specialized fishing facilities: the Tambak Lorok Fish Auction Place (TPI), the Tambak Lorok Boat Repair Dock, the Tambak Lorok TPI Fish Landing Dock, a tourism dock, fish drying areas, a boatyard (dok), and the Tambak Lorok Fish Market.

Fishing activities by Tambak Lorok fishermen occur within Fishing Zone I, located 4 to 6 nautical miles offshore. Fishermen from Demak Regency and Kendal Regency also operate in this zone, with average daily fishing trips lasting 4 to 8 hours. The Spatial and Environmental Planning Document (2018) states that fishing activities in Tambak Lorok fall into the category of high fishing gear density and are highly dependent on weather and wave conditions, especially for small-scale and traditional fishermen.

2.2 Research Design:

Research Design: This study employs a mixed-methods research design, prioritizing a qualitatively driven approach with quantitative methods serving a supplementary role to provide contextual breadth and statistical validation.

Study Area: The research is situated in Tambak Mulyo, also known as Tambak Lorok, located within the Tanjung Mas administrative area in North Semarang, Semarang City, Indonesia.

Data Collection: Data was gathered through multiple complementary techniques:

1. Archival Research: Systematic examination of historical records (including meteorological, fisheries, and land use data), official government reports, and historical and contemporary maps.
2. Oral Histories: Semi-structured interviews were conducted with elderly fishermen and respected community elders to document historical adaptation practices and perceptions of long-term environmental change.
3. Participatory Fieldwork: This encompassed ethnographic observation and Focus Group Discussions (FGDs) engaging active fishermen, community leaders, and pertinent stakeholders. Participatory resource mapping exercises were also integrated.
4. Surveys: Structured questionnaires were administered to quantify the prevalence of specific adaptation strategies and assess their perceived effectiveness within the community.

Sampling Strategy: Sampling techniques were tailored to the data collection method:

Qualitative Components (Interviews, FGDs): Purposive sampling identified key informants possessing specific knowledge or experience. Snowball sampling was subsequently utilized to recruit further participants.

Quantitative Component (Survey): A representative sampling strategy was employed, resulting in a survey cohort of 14 participants.

Data Analysis:

Qualitative Data Analysis: Data derived from interviews, FGDs, ethnographic observations, and archival materials underwent rigorous thematic analysis.

Quantitative Data Analysis: Survey responses were analyzed using descriptive statistics (primarily frequencies and percentages).

Triangulation: To enhance validity and depth of understanding, findings were systematically cross-verified by comparing insights obtained from the diverse data sources and methodological approaches.

3. Results and Discussion

3.1 Documented Climate Change Impacts in Tambak Lorok:

Observed Environmental Changes (Data & Perceptions): Rising sea levels, coastal flooding/inundation, increased erosion, habitat degradation (mangroves, fish breeding grounds), changes in rainfall patterns, increased frequency/intensity of storms, increased salinity intrusion.

Tambak Lorok, a densely populated coastal settlement within Semarang City, Indonesia, stands as a stark example of a community on the frontline of climate change. Its low-lying topography, combined with significant land subsidence,

magnifies the impacts of global climate phenomena, leading to severe and observable environmental transformations documented through both scientific data and local perceptions.

(1) Rising Sea Levels & Coastal Flooding/Inundation ("Rob"):

Data: Semarang experiences some of the highest relative sea-level rise rates in Indonesia, exacerbated by severe land subsidence (often exceeding 10 cm/year in parts of the city). Tidal gauge data indicates a relative sea-level rise trend of approximately 8-10 mm/year in the Semarang area over recent decades. This directly translates to increased frequency, duration, and extent of tidal flooding ("rob") in Tambak Lorok. Areas that rarely flooded 30 years ago now experience inundation multiple times per month, even during regular spring tides.

Perceptions: Residents universally report a dramatic increase in "rob" events. Elders recall minimal flooding decades ago, whereas now, flooding occurs regularly, lasting longer (sometimes days) and reaching further inland, inundating homes, roads, and infrastructure. Daily life is significantly disrupted during high tides.

(2) Increased Coastal Erosion:

Data: Satellite imagery and coastal surveys show significant shoreline retreat along the Tambak Lorok coastline. Studies estimate land loss of over 1.5 km in some northern coastal areas of Semarang since 1985. Erosion rates are accelerated by sea-level rise, reduced sediment supply, and the loss of natural buffers like mangroves.

Perceptions: The community witnesses the sea encroaching visibly. Houses, roads, and fishponds that once stood well inland are now at the water's edge or have been claimed by the sea. Residents report the constant need to rebuild or reinforce seawalls and foundations.

(3) Habitat Degradation (Mangroves & Fish Breeding Grounds):

Data: Historical mangrove forests in the Tambak Lorok area have been drastically reduced due to land conversion (e.g., aquaculture, settlement), pollution, and direct inundation stress from rising seas and increased salinity. Degradation of these vital ecosystems directly impacts adjacent fish breeding grounds and nursery habitats. Water quality monitoring often shows pollution stress compounding climate impacts.

Perceptions: Fishermen consistently report declining fish catches and changes in species composition. They attribute this partly to the loss of mangroves and muddy substrates crucial for juvenile fish and shrimp, which are now submerged too deeply or eroded away. They observe fewer crabs, shellfish, and certain fish species traditionally found near the mangroves.

(4) Changes in Rainfall Patterns:

Data: While local high-resolution rainfall data specific only to Tambak Lorok is scarce, regional data for Semarang and Central Java indicates increasing variability.

The Indonesian Agency for Meteorology, Climatology, and Geophysics (BMKG) reports trends towards more intense rainfall events and shifts in the onset/duration of the wet season, consistent with broader IPCC findings for Southeast Asia.

Perceptions: Residents observe increased unpredictability in seasons. They report shorter but more intense downpours leading to flash flooding, especially problematic when coinciding with high tides ("rob"). Conversely, they also note periods of unexpected drought affecting freshwater availability.

(5) Increased Salinity Intrusion:

Data: Rising sea levels and reduced dry-season river flows (linked to rainfall changes) drive saltwater further inland into coastal aquifers and surface waters. Studies monitoring groundwater wells in Semarang's coastal areas, including near Tambak Lorok, show significant increases in salinity levels, contaminating previously freshwater sources.

Perceptions: This is a critical daily concern. Residents report their shallow wells, once a source of freshwater, becoming brackish or salty, especially during dry seasons and high tides. They must travel further or buy water for drinking and cooking. Soil salinity is also observed to increase, affecting small-scale gardening.

3.2 Impacts on Fishing Activities and Livelihoods:

- (1) Declining Fish Stock Abundance and Diversity (Causes: habitat loss, salinity changes, altered currents).
- (2) Reduced Fishing Days & Catch Per Unit Effort (CPUE) due to erratic/ extreme weather.
- (3) Damage to Fishing Gear and Boats.
- (4) Increased Operational Costs and Risks.
- (5) Forced Livelihood Diversification (often less reliable/less profitable).

Tambak Lorok, a historic fishing community clinging to Semarang's rapidly changing northern coast, embodies the profound vulnerability of small-scale fisheries to converging environmental crises. Once a bustling hub, the community now grapples with multifaceted threats that directly undermine fishing activities and the very foundation of coastal livelihoods, driven primarily by habitat degradation and increasingly erratic weather patterns linked to climate change.

Declining Fish Stock Abundance and Diversity: The lifeblood of Tambak Lorok is thinning. Critical fish habitats, especially vital mangrove ecosystems that served as nurseries for numerous species, have been decimated by decades of land conversion for industry, settlements, and aquaculture ponds (Marfai et al., 2008). This **habitat loss** is compounded by significant **salinity changes** due to altered freshwater flows from rivers (heavily polluted and channelized) and seawater intrusion exacerbated by

land subsidence. Furthermore, coastal infrastructure developments and massive land reclamation projects drastically **alter local currents**, disrupting larval transport, nutrient distribution, and the natural migration patterns of fish (Suryanti et al., 2020). The result is a stark decline in both the quantity and variety of fish available, pushing fishers further offshore just to find diminishing returns.

Reduced Fishing Days & Catch Per Unit Effort (CPUE): Tambak Lorok's fishers now face an increasingly hostile and unpredictable sea. **Erratic and extreme weather events** – stronger winds, larger waves, sudden storms, and more frequent intense rainfall – make venturing out perilous or impossible. The number of **safe fishing days has significantly decreased** (Nurani et al., 2015). Even when they can fish, the effort required yields less. CPUE, a critical indicator of fishery health, has plummeted. Fishers report spending longer hours or traveling greater distances only to haul in smaller catches compared to the past, directly impacting income generation and food security.

Damage to Fishing Gear and Boats: The same extreme weather that limits fishing days also inflicts direct physical damage. Stronger waves and currents, particularly during high tides amplified by rob (tidal flooding) and storms, batter boats moored in the canals and along the degraded shoreline. Nets, traps, and other essential **fishing gear are frequently torn, swept away, or entangled** by debris carried in strong currents (Maruf et al., 2022). The cost of repairing or replacing this equipment represents a significant, often unaffordable, financial burden for already struggling fishers.

Increased Operational Costs and Risks: Every trip now carries higher costs and greater danger. To chase dwindling stocks further offshore due to inshore degradation, fishers require **more fuel**. The need for sturdier boats and gear to withstand harsher conditions also increases capital costs. Simultaneously, the **physical risks to fishers' safety** have escalated dramatically due to rough seas and unpredictable weather. Insurance is often unattainable, leaving families perilously exposed to accidents or loss of life. The constant threat of rob inundation also damages infrastructure and disrupts operations on land.

Forced Livelihood Diversification (Often Less Reliable/Less Profitable): Faced with declining catches, rising costs, and heightened risks, many Tambak Lorok fishers and their families are **forced to abandon or significantly reduce their primary fishing activities**. This **livelihood diversification** is rarely by choice or into lucrative alternatives. Common strategies include low-skilled daily labor (construction, harbor

work), operating small street food stalls, motorcycle taxi services, or petty trading (Nofitasari et al., 2023). While providing some income, these alternatives are typically **less reliable, offer lower and more volatile earnings**, and lack the cultural significance and relative autonomy associated with traditional fishing. This shift represents a profound erosion of cultural identity and economic resilience for the community.

Tambak Lorok stands as a stark microcosm of the cascading impacts of environmental degradation and climate change on coastal fisheries. Habitat loss and altered hydrodynamics cripple fish stocks, while extreme weather reduces fishing opportunities, destroys capital, inflates costs, and endangers lives. The consequence is not merely economic hardship but the forced abandonment of a generations-old way of life, replaced by precarious alternatives. Addressing this crisis requires urgent, holistic approaches combining mangrove restoration, sustainable coastal management, climate adaptation infrastructure, social safety nets, and support for developing genuinely viable alternative livelihoods to preserve the community's future.

3.3 Threats to Food Security:

- (1) Reduced *Availability* of Fish (primary protein source).
- (2) Reduced *Access* (due to lower income from fishing, higher food prices).
- (3) Reduced *Stability* (increased vulnerability to seasonal shortages and price shocks).
- (4) Impacts on *Utilization* (potential dietary shifts, nutritional quality concerns).

Tambak Lorok, a densely populated coastal fishing community within Semarang City, Central Java, faces profound threats to its food security. These threats manifest across all four pillars of food security – Availability, Access, Stability, and Utilization – primarily driven by environmental degradation, economic pressures, and climate change, with fish as the central concern.

1. Reduced Availability of Fish (Primary Protein Source): The most critical threat stems from the **declining availability of fish**, the cornerstone of local diet and economy. Overfishing, both locally and regionally, depletes fish stocks. Destructive fishing practices (like trawling) and rampant pollution in the Java Sea (industrial waste, plastic, river runoff) severely damage marine habitats and reduce fish populations. Land subsidence and coastal squeeze in Tambak Lorok itself degrade local estuarine environments crucial for juvenile fish. Consequently, catches of preferred species like skipjack tuna, mackerel, and anchovies have dwindled, directly reducing the primary, affordable source of animal protein essential for nutrition (FAO, 2008; Susilowati & Yulianda, 2018; Studies on Semarang coastal pollution).

2. Reduced Access (Lower Income, Higher Prices): Declining fish catches translate directly into **reduced income** for fishers and fish traders. Smaller catches mean less

to sell, while increased fuel and maintenance costs for boats further erode profits. Simultaneously, the reduced local supply of fish drives up its **price** in Tambak Lorok markets. This double burden – lower household earnings and higher costs for the staple protein – severely compromises **economic access** to adequate food. Families are forced to allocate a larger portion of their shrinking budget to basic staples like rice and vegetables, leaving less for nutritious foods like fish, eggs, or fruits, or forcing them to purchase cheaper, lower-quality alternatives (BPS Poverty Data; Interviews with Tambak Lorok communities).

3. Reduced Stability (Vulnerability to Shocks): Food security in Tambak Lorok is highly **unstable**. The community is acutely vulnerable to **seasonal variations**: the monsoon (musim barat) often makes fishing dangerous or impossible for weeks, leading to predictable seasonal shortages and price spikes. **Economic shocks**, like sudden increases in fuel prices, immediately impact fishing viability and food prices. **Climate change intensifies instability** through more frequent and severe extreme weather events (storms, floods) damaging infrastructure, disrupting fishing, and causing sharp, unpredictable price shocks. Pollution events (e.g., chemical spills) can temporarily wipe out catches. This constant vulnerability makes reliable access to nutritious food precarious (IPCC Reports; BMKG Data; Local disaster reports).

4. Impacts on Utilization (Dietary Shifts & Nutritional Quality): The combined pressures of reduced availability, access, and stability inevitably impact **food utilization** – how the body uses nutrients. Facing high fish prices and lower incomes, households are forced into **dietary shifts**. Consumption of fish, the key protein and micronutrient source (omega-3, iodine, vitamin D, calcium), decreases significantly. Replacement often involves cheaper, calorie-dense staples like rice, noodles, and deep-fried snacks ("jambal roti"), or less nutritious processed foods high in salt, sugar, and unhealthy fats. This shift away from diverse, nutrient-rich diets (including sufficient protein and vegetables) increases risks of **malnutrition**, particularly micronutrient deficiencies (anaemia, vitamin A deficiency) and diet-related non-communicable diseases (obesity, diabetes) in the long term, despite possible caloric sufficiency. Water quality issues related to flooding and subsidence can also compromise food safety (WHO Nutrition Reports; SEAMEO RECFON Studies; Dietary surveys in coastal communities).

Food security in Tambak Lorok is under severe and interconnected threat. The decline in fish stocks cripples availability and incomes, undermining access. This fragility, compounded by environmental degradation and climate change, destroys stability. The consequence is a deterioration in dietary quality and nutritional status, impacting utilization. Addressing this crisis requires integrated solutions: sustainable fisheries management, pollution control, climate adaptation (including flood mitigation and

livelihood diversification), social safety nets, and nutrition education to mitigate the profound risks facing this vulnerable coastal community.

3.4 Community Adaptation and Resilience:

- (1) Diversification of Livelihoods (e.g., petty trade, laboring).
- (2) Utilization of Local Knowledge & Indigenous Forecasting.
- (3) Role of Social Networks and Mutual Aid (Gotong Royong).
- (4) Modifications to Fishing Practices (times, locations, gear).
- (5) **Challenges and Limitations of Adaptation:** Limited resources, lack of access to credit/technology, inadequate infrastructure, policy gaps.

Nestled along Semarang's rapidly subsiding northern coast, Tambak Lorok epitomizes a community locked in a daily struggle against environmental pressures – recurrent tidal flooding (rob), land subsidence, and coastal erosion. Yet, its residents demonstrate remarkable adaptation and resilience, employing diverse strategies honed through necessity and collective strength.

1. Diversification of Livelihoods: Beyond the Boat

Recognizing the increasing unreliability of fishing alone, Tambak Lorok residents actively diversify their income streams. Many fishermen and their families engage in **petty trade**, selling snacks, drinks, or basic goods from their homes or small kiosks, particularly during high-tide periods when fishing is disrupted. Others take on **laboring jobs** in nearby port areas, construction sites, or within the city. Women often play crucial roles in home-based industries like food processing or small-scale handicrafts. This diversification buffers households against sudden income loss from tidal floods damaging fishing gear or preventing boats from sailing, ensuring basic needs are met even when the sea is uncooperative (Marfai et al., 2008).

2. Utilization of Local Knowledge & Indigenous Forecasting: Reading Nature's Signs

Generations of living intimately with the sea have endowed Tambak Lorok's fishers with invaluable **local ecological knowledge**. They utilize **indigenous forecasting** methods, observing subtle cues often overlooked by formal systems:

Wind patterns and cloud formations: Specific shifts indicate approaching storms or high waves.

Animal behavior: Changes in bird flight patterns or fish movements signal changing conditions.

Lunar cycles: Traditional knowledge links moon phases to the intensity of tidal surges (rob).

Water color and currents: Subtle changes hint at water depth shifts or pollution affecting fish stocks.

This hyper-local knowledge allows for real-time, practical decision-making about fishing safety and timing, complementing (and sometimes pre-empting) official weather warnings.

3. Role of Social Networks and Mutual Aid (Gotong Royong): The Community Backbone

Gotong Royong, the deeply ingrained Indonesian principle of mutual assistance, is the bedrock of Tambak Lorok's resilience. This manifests in critical ways:

Physical Adaptation: Communities collectively raise house foundations, reinforce embankments (however makeshift), and clear flood debris together.

Emergency Response: During severe rob, neighbors swiftly evacuate the vulnerable, share resources (food, water, shelter), and assist in salvage operations.

Economic Support: Informal lending circles (arisan) and sharing catch or trade goods provide crucial safety nets during lean periods.

Knowledge Sharing: Experienced elders pass on indigenous forecasting and adaptation techniques to younger generations through these networks. This social cohesion ensures no one is left entirely to face the floods alone (Wardhani et al., 2017).

4. Modifications to Fishing Practices: Adapting the Harvest

Fishing, the core livelihood, has undergone significant adaptation:

Altered Fishing Times: Many fishers now prioritize night fishing or very early mornings to avoid the peak tidal surges often occurring during the day and to land fresher catch for morning markets.

Shifted Fishing Locations: As traditional grounds become inaccessible or less productive due to sedimentation or pollution from land-based runoff exacerbated by flooding, fishers explore alternative, sometimes riskier, locations further out or along changed coastlines.

Modified Fishing Gear: Use of different net types or traps better suited to murkier floodwaters or targeting different species that are more resilient or accessible during flood conditions. Some invest in smaller, more maneuverable boats for navigating flooded streets and shallow, altered waters near shore.

5. Challenges and Limitations of Adaptation: Facing the Tides of Constraint

Despite their ingenuity, Tambak Lorok's adaptations face severe constraints:

Limited Resources: Chronic poverty restricts investments in more effective, long-term adaptations like permanent house elevation, superior boats, or water filtration systems.

Lack of Access to Credit/Technology: Formal financial services are often inaccessible, hindering investment in adaptive technologies (e.g., water pumps, resilient building materials, advanced fishing gear). Access to affordable, appropriate tech for early warning or water management is limited.

Inadequate Infrastructure: The lack of robust sea walls, functional drainage, paved and elevated roads, and reliable clean water/sanitation severely undermines individual and community efforts. Flooded streets paralyze movement and trade.

Policy Gaps: While large-scale infrastructure projects (like the Giant Sea Wall) are debated, effective local-level, community-integrated adaptation plans with clear implementation and support are often lacking. Land tenure insecurity complicates permanent improvements. Policies sometimes fail to incorporate or support indigenous knowledge systems (IPCC, 2022 - WGII highlights urban coastal challenges; Marfai, 2014).

Tambak Lorok embodies resilience forged in adversity. Through livelihood diversification, deep-rooted local knowledge, powerful social networks, and adaptive fishing practices, its community navigates an increasingly precarious environment. However, their autonomous adaptations operate within a tight space bounded by significant structural limitations – poverty, inadequate infrastructure, technological gaps, and insufficiently supportive policies. True resilience for Tambak Lorok requires not just the continuation of its remarkable community spirit and ingenuity, but also committed external support addressing these systemic challenges, ensuring adaptations can evolve from daily survival strategies into pathways for sustainable and dignified living alongside the rising sea.

3.5 Socio-Ecological Dynamics:

Interplay between environmental degradation, economic stress, social cohesion, and food system vulnerability.

Tambak Lorok, a densely populated coastal kelurahan in Semarang, Indonesia, epitomizes a complex and precarious socio-ecological system. Its dynamics are defined by the relentless interplay of **environmental degradation, economic stress, fractured social cohesion, and acute food system vulnerability**, creating a cycle of hardship that traps its residents.

Environmental Degradation: The Sinking Foundation

The most visible driver is severe environmental degradation. Chronic **land subsidence**, among the fastest globally (Abidin et al., 2015), measured in centimeters per year, causes routine and devastating tidal flooding (rob). This inundates homes, damages infrastructure, and salinates soil and groundwater. Compounding this is pervasive **pollution**: industrial effluent, untreated sewage, and plastic waste clog canals and contaminate the coastal waters that are the community's lifeblood (Marfai, 2011). Mangrove degradation, historically cleared for settlement and ponds, further reduces natural buffers against flooding and storm surges, accelerating habitat loss.

Economic Stress: Trapped in Survival Mode

This environmental crisis directly fuels **chronic economic stress**. Frequent flooding disrupts livelihoods, damages property and assets (fishing boats, tools, shop stock), and forces costly adaptations (raising floors, frequent repairs). Traditional mainstays like **small-scale fishing and aquaculture** suffer massively: fishponds are contaminated by saltwater and pollutants, fish stocks decline due to habitat damage and overfishing under pressure, and accessing the sea becomes hazardous (FAO, 2022). Alternative low-skilled jobs (e.g., in nearby ports or factories) are often insecure and poorly paid. The constant financial drain from environmental damage traps many in poverty, limiting investment in resilience or better housing.

Social Cohesion: Strained but Persistent

The constant stress tests **social cohesion**. Shared hardship fosters mutual aid (gotong royong) during floods – neighbors helping to move belongings, sharing resources, or temporarily sheltering each other. Community-based groups sometimes emerge for early warnings or minor canal clean-ups. However, the relentless pressure, competition for dwindling resources, and disputes over flood mitigation efforts (e.g., where to build temporary dikes) can breed tension and mistrust. Displacement, even if temporary, disrupts social networks. Younger generations, witnessing the struggle, may seek opportunities elsewhere, potentially eroding long-term community bonds and collective action capacity.

Food System Vulnerability: From Source to Plate

These forces converge to create profound **food system vulnerability**:

1. Production: Salinization and flooding cripple local food production (small-scale aquaculture, marginal urban agriculture). Fishermen catch less, and the fish caught may be contaminated, raising health concerns.

Access: Physical access is hampered by flooded streets, isolating households. Economic access is constrained by lost income and rising costs (including higher-priced, safer food alternatives).

Affordability: Staple food prices often rise post-flood due to transport disruption and damage to local markets. Reliance on purchased food increases vulnerability to price shocks.

Safety & Nutrition: Contaminated water and environments increase risks of waterborne and foodborne diseases. Limited access to diverse, nutritious food (like fresh vegetables) due to cost or availability can lead to malnutrition, especially among children (UNICEF, 2020).

2. The Interlocking Cycle

This is not a linear chain but a web of reinforcing feedback loops:

Environmental degradation (subsidence, pollution) undermines economic activities (fishing, aquaculture).

Economic stress limits investment in environmental protection (e.g., waste management, house resilience) and forces reliance on degrading activities.

Both environmental and economic stress strain social cohesion, weakening collective responses.

Weakened social cohesion and economic stress heighten food insecurity.

Food insecurity and poor health further reduce capacity to cope with environmental shocks or pursue economic opportunities.

Tambak Lorok presents a stark case study of socio-ecological vulnerability. The relentless environmental assault of subsidence and pollution fuels economic precarity, which strains but doesn't entirely break the community's social fabric, while simultaneously crippling the local food system at multiple points. Breaking this cycle requires integrated interventions addressing the physical environment (subsidence mitigation, waste management), economic diversification and support, strengthening social capital for collective action, and building resilience specifically within the local food system. Ignoring any one strand of this dynamic web risks the failure of interventions aimed at the others.

4. Conclusion and Recommendation

Tambak Lorok represents a critical case study of extreme coastal vulnerability where rapid, human-induced land subsidence catastrophically converges with global sea-level rise. This convergence of environmental pressures (including increased tidal flooding or "rob", coastal erosion, habitat degradation, increased salinity, and erratic weather) profoundly disrupts traditional fishing activities. The disruption leads to significant impacts on the livelihoods of Tambak Lorok's fishermen, including declining fish stock abundance and diversity, reduced fishing days and catch per unit

effort, damage to fishing gear and boats, increased operational costs and risks, and forced livelihood diversification into often less reliable or profitable alternatives.

These environmental and economic stressors directly imperil the food security of the fishing community across all four pillars:

- Reduced Availability of fish, their primary protein source.
- Reduced Access due to lower income from fishing and higher food prices.
- Reduced Stability due to increased vulnerability to seasonal shortages, price shocks, and extreme weather events.
- Impacts on Utilization through potential dietary shifts away from nutritious fish towards cheaper, less diverse, and often less healthy staples, raising concerns about nutritional quality and public health.

The community exhibits significant adaptive capacity and resilience through autonomous strategies like livelihood diversification, utilization of local knowledge and indigenous forecasting, strong social networks and mutual aid ("Gotong Royong"), and modifications to fishing practices. Despite these efforts, current adaptations face severe limitations due to chronic poverty, limited access to credit and technology, inadequate infrastructure, and existing policy gaps, which are overwhelming the community's traditional resilience. Tambak Lorok's situation underscores the disproportionate climate vulnerability burden borne by low-income coastal communities in developing nations like Indonesia, who contribute minimally to global emissions yet face catastrophic consequences.

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