SUSTAINABILITY CHALLENGES OF SHRIMP FARMING ON COASTAL LANDS: ARCHETYPAL INTERPLAYS OF DISASTERS, ECOSYSTEMS AND LIVELIHOODS

ABSTRACT

People's livelihoods have also evolved in response to environmental changes, more specifically, climate disasters. Yet at times they end up increasing people's vulnerability to climate risks, ecological degradation, and economic uncertainty. A case in point is the shrimp farming on coastal landscapes in the state of Odisha, India. This paper applies a systems thinking lens to the sustainability challenges of shrimp farming on India's cyclone- and flood-prone coasts, with particular reference to Jagatsinghpur district in Odisha. The rapid growth of shrimp farming has also affected mangrove land and agricultural land. Driven by market demand but often at the cost of local ecological and economic stability. In regions such as Ersamsa, Jagatsinghpur, Odisha, this expansion has attracted farmers and investors seeking quick profits, but has also exposed communities to mounting risks from climate disasters and ecological degradation. We conceptualise the shrimp sector as a coupled social–ecological–economic system structured by endogenous feedbacks (disease, soil salinisation, debt cycles, market volatility) and shaped by exogenous triggers (cyclones, sea-level rise, regulatory shifts, global demand). Using causal loop diagrams and archetypes, we identify key system traps—including "Tragedy of the Commons," "Success to the Successful," and "Fixes that Backfire"—that concentrate risks on marginalised coastal communities and erode their long-term resilience. The paper argues that acknowledging the likelihood of compounding climate shocks, while still acting to reduce harm and expand livelihood options, can reorient the shrimp sector away from only risk reduction toward building coastal resilience. We also cite the potential of the Deep Adaptation framework as an operational tool for resilience building.

Introduction

Over the past four decades, farmed shrimp has shifted from a niche product to a major global commodity, with production increasing from a few thousand tons in the mid-twentieth century to several million tons today. This growth has been enabled by the rapid conversion of coastal wetlands, agricultural lands and mangroves into shrimp ponds. In India, states such as Andhra Pradesh, Odisha, Tamil Nadu and West Bengal have seen a dramatic rise in shrimp aquaculture, with promises of quick profits attracting farmers, investors and intermediaries into the sector.

At the same time, coastal regions are experiencing intensified climate-related hazards, including more frequent and intense cyclones, saline water intrusion, storm surges, and irregular rainfall, which compound existing livelihood vulnerabilities. Shrimp ponds, often located directly in the coastal regulation zone or on low-lying farmlands behind embankments, are highly exposed to these hazards, while also degrading protective ecosystems such as mangroves and coastal agriculture. The result is a complex, dynamic interplay between disasters, climate, and livelihoods, in which short-term gains from shrimp farming may unintentionally amplify long-term systemic risk.

This paper focuses on how endogenous feedbacks and exogenous shocks interact to shape the sustainability of shrimp farming on coastal lands, and what leverage points emerge when we view this problem through a systems thinking lens. The study applies systems thinking through desk research, field research and working with field-based organisations to unpack the interplays between disasters, ecosystems and livelihood.

Coastal Ecosystems And Livelihood

Coastal social–ecological systems comprise interacting subsystems of geomorphology, hydrology, ecosystems (mangroves, estuaries, wetlands), and human livelihoods (fisheries, agriculture, wage labour, migration, services). Mangrove forests in particular provide multiple regulating and provisioning services, including shoreline stabilisation, storm surge attenuation, nursery habitat for fish and crustaceans, carbon sequestration, and non-timber forest products for local communities.

Shrimp farming reconfigures these interdependencies by altering land cover, water flows, salinity regimes, and access rights. Conversion of mangroves and paddy fields into ponds reduces natural buffers against cyclones and sea-level rise and can lead to salinisation of adjacent soils and groundwater, undermining rice cultivation and drinking water sources. Farmers drawn into shrimp aquaculture often shift labour and capital away from diverse livelihood portfolios towards a more specialised, high-risk enterprise that is tightly coupled to external input suppliers, processors, and global markets.

In places like coastal Odisha, this reconfiguration is neither uniform nor uncontested. Smallholders, landless labourers, traditional fishers, women's self-help groups, and forest-dependent communities experience both new income opportunities and new forms of exclusion, debt, and ecological loss. Challenges around land use, embankment maintenance, pollution, and mangrove conservation have become recurrent.

Climate change is altering hazard profiles in coastal belts worldwide, including those dominated by shrimp aquaculture. Rising sea levels, subsidence related to groundwater extraction and sediment starvation, more intense cyclones, and erratic rainfall increase the likelihood of flooding, saline intrusion, and embankment failures that directly threaten shrimp ponds, adjacent agriculture, and settlements. In India's eastern coast, repeated cyclones have caused large-scale losses in ponds and infrastructure, leaving farmers indebted and prompting government relief and rehabilitation efforts.

Shrimp farming itself modifies vulnerability pathways. The removal of mangroves diminishes the landscape's ability to absorb wave energy and storm surges, while pond embankments, canals and sluice gates can redirect floodwaters and exacerbate drainage congestion. Saline seepage from ponds into surrounding farmlands and shallow aquifers can lead to long-term productivity declines in crops, effectively locking communities into dependence on shrimp or other saline-tolerant enterprises.

Disease dynamics, such as outbreaks of White Spot Syndrome Virus and Early Mortality Syndrome, interact with climatic stress, water quality degradation, and density of stocking to produce cascading losses. Farmers whose ponds fail face not just immediate income loss but also loan defaults, asset distress sales, and reduced capacity to invest in future cycles, amplifying socio-economic vulnerability. These interacting ecological and economic shocks can be viewed as a set of feedback loops that gradually erode resilience if not counterbalanced by proactive interventions and livelihood diversification.

Nature of Disasters

Rapid Onset Disasters

Rapid-onset disasters in the Ersama block are primarily characterised by cyclones, which strike with little warning and cause widespread devastation. The region's proximity to the Bay of Bengal makes it highly susceptible to these intense weather events, as evidenced by major cyclones such as the 1999 Super Cyclone and Cyclone Dana in 2024. These cyclones result in the immediate destruction of essential assets—fishing boats, nets, homes, and other infrastructure—paralysing local livelihoods and forcing entire communities to evacuate to cyclone shelters. The impact is rapid and severe: fishing activities are suspended, crops are lost to flooding, and the fragile kutcha housing is often rendered uninhabitable.

In addition to cyclones, the Ersama block is highly vulnerable to a range of other rapid-onset disasters such as floods, high tides, torrential rains accompanied by strong wind speeds, and lightning. Flooding often results from heavy monsoon downpours and breaches in the fragile embankments, inundating settlements, agricultural fields, and shrimp farms. High tides and storm surges, especially during cyclonic events, exacerbate the risk by pushing seawater deep inland, leading to waterlogging and increased soil salinity. Torrential rains, frequently coupled with high winds, can cause significant structural damage to kutcha houses, uproot trees, and destroy critical assets like fishing boats and nets, further disrupting local livelihoods. Lightning strikes during these intense weather events pose additional dangers to people and livestock, with limited infrastructure and shelter options heightening the community's exposure.

The cumulative impact of these rapid-onset events is profound: agricultural activities suffer due to crop submergence and soil degradation, while fishing and aquaculture operations are halted or irreparably damaged.

Despite receiving timely cyclone alerts and following evacuation protocols, the community receives very little support in terms of food, rations, or relief *during* these periods. The aftermath of each disaster leaves families struggling to recover, often having to sell assets, borrow money, or pawn valuables to survive. This cycle of rapid-onset disasters not only causes immediate hardship but also contributes to long-term vulnerability, as repeated shocks erode the limited financial and social buffers available to the people of Ersama. The lack of adequate infrastructure, insurance, and relief mechanisms further amplifies the impact of these sudden disasters, making *recovery* a prolonged and challenging process for affected households.

Slow-Onset Disasters

In addition to the immediate shocks from cyclones, the community is trapped by slow-onset challenges that steadily erode their resilience. Declining fish catch, shorter fishing seasons due to climate-related changes and restrictions during Olive Ridley turtle nesting, and the increasing salinity of land from repeated seawater ingress have made traditional paddy cultivation unviable. While shrimp farming has emerged as an alternative, it is fraught with risks like flooding and disease outbreaks (such as the red virus), often resulting in total crop loss and further debt. With no formal financial safety nets, youth from the community are compelled to migrate to distant cities in search of daily wage work, making migration a necessity rather than a choice.

The lack of sufficient infrastructure, such as only one tube well for drinking water and the absence of insurance or direct relief for small-scale fishermen, further compounds their hardship. As families struggle to recover from each disaster, their capacity to rebuild diminishes, deepening their dependence on loans and external migration. The combined impact of rapid disasters and slow-onset changes has thus created a vicious cycle where livelihoods become increasingly precarious, and the community's prospects for recovery and stability grow ever slimmer.

Study Context

Ersama is a coastal block in Odisha's Jagatsinghpur district, known for its fertile land and the community's reliance on agriculture, fisheries, and aquaculture. Due to its location and climate, Ersama is prone to cyclones, floods, and salinity intrusion; the devastating 1999 Super Cyclone left lasting effects. Although paddy is still the primary crop, the years following the cyclone saw fisheries and aquaculture emerge as major sources of income. The block continues to face environmental challenges driven by climate change, such as rising sea levels and increasing salinity, which underscore the importance of adaptation and livelihood diversification for residents.

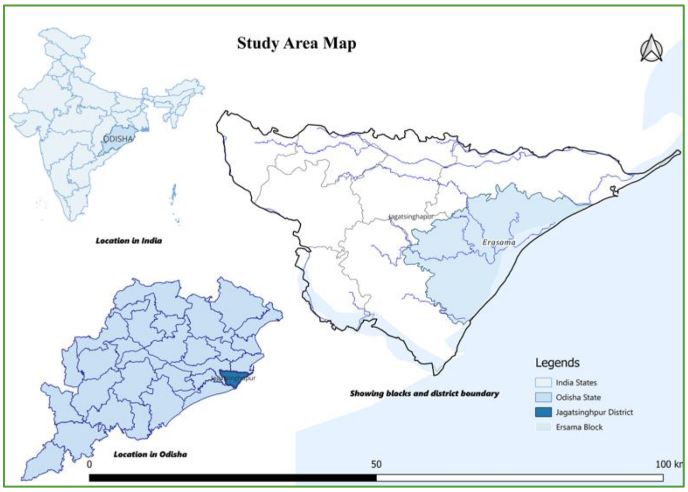

Figure 1: Study Area

Ersama spans 38,434 hectares, making up about 23% of Jagatsinghpur district's total area[1]. There are 87 villages in the block, with a population of roughly 146,273 according to the 2011 census. Paddy cultivation takes advantage of rich alluvial soil and ample monsoon rainfall, while fisheries and aquaculture have grown significantly since 1999. The region receives an annual average rainfall of about 1,491 mm, with the southwest monsoon accounting for approximately 1,110 mm over nearly 48 days. Temperatures generally range from 26.1°C to 33.2°C, and humidity stays high year-round between 60% and 99%.

The study focuses on mapping the dynamic interrelations between shrimp aquaculture, environmental changes, and socio-economic responses, especially in the context of rapid-onset and slow-onset disasters that impact the community. Through this approach, the research seeks to identify recurring patterns and systems archetypes that influence resilience and vulnerability, providing a foundation for exploring transformative frameworks such as Deep Adaptation to enable meaningful systems change and enhance adaptive capacities.

Problem Articulation

The current efforts in disaster management are driven by achieving the goal of having zero casualties. This leads to a focus on relief and recovery. The current efforts have yielded positive results as the casualties have been reduced and in some cases (especially Cyclone), it has been reduced to zero. But zero casualties do not always correspond to zero impact. People's lives and livelihoods do get impacted by disasters, and how they respond in turn changes their own adaptive capacities. Thus, it is crucial to unpack this system and identify areas for long-term resilience building.

Disasters are typically seen as exogenous to the system and act as external triggers that impact the system. Meteorological events – cyclones, torrential rainfall, thunderstorms, and lightning – cause socio-economic impacts to the people and the landscapes. In response to these disasters, people act and cope with them via different means. They may choose to outmigrate, switch to other forms of livelihood, increase their reliance on natural resources or get caught up in debt cycles. The way they respond either increases or decreases their vulnerability, e.g., an increase in debt would lead to lower financial capacities to cope with a disaster. Thus, how the system responds to the external trigger often determines whether the vulnerability and capacities are eroding over time or improving over time.

While an intuitive response is to develop better early warning systems that can inform us about the disaster, more focus is also needed to understand how the resilience of the system is changing over time. In the case of Jagatsinghpur, the proliferation of Shrimp Farming on the coast is increasing people's vulnerabilities (due to income instability and also exposure to cyclones). In addition, depleting fresh water availability, increasing soil salinity, coastal erosion and loss of mangrove are making matters worse for them. All this is currently shaping their vulnerability, and with the growing effects of climate change, the intensity and frequency of climate disasters are increasing. All efforts towards disaster risk reduction must now include a focus on building the resilience and adaptive capacities of the people.

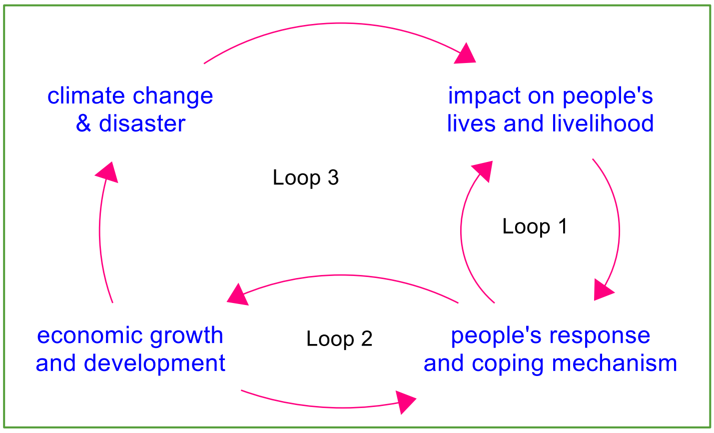

Figure 2:Systems Thinking Framework For Disaster Resilience Building

Figure 1 highlights the key high-order interactions in the system and the feedback loops shaping their resilience and vulnerability.

[1] https://odisha.villagecodes.in/jagatsinghapur/ersama-38002938/ersama-02938397376/

Loop 1: Climate and disaster risks impact people and their livelihoods. How they respond in turn affects their own vulnerability. It could either increase or decrease depending on the nature of the response. Ideally, the feedback loop should lead to a more resilient system that recovers more effectively from impacts. However, the current reality is a little far away from this state. Current responses of people (proliferation of Shrimp farming, out migration, over reliance on a single crop, over extraction of groundwater, etc.) are helping them cope in the short run, but in the long run, it is increasing their vulnerability to disasters. Thus, this loop is currently reinforcing the problem.

Loop 2: Economic growth and development also shape people's aspirations and their responses. In search of better livelihood and quality of life, the youngsters are outmigrating to cities. This is partly driven by the disaster impacts and partly by their own aspirations. As the flow of capital investments increases, it is leading to land conversion (loss of Mangroves and growth of Shrimp ponds) and an increase in the use of pesticides and fertilisers. This further leads to the growth of investments and economic development. Creating a reinforcing cycle, leading to long-term erosion of their adaptive capacities.

Loop 3: Over time, due to increasing emissions and changes in land use (erosion of vegetation and soil loss), there is an increase in the impacts of climate change. This further contributes to the growing frequency and intensity of disasters. Thus, the system is driven by feedback. The way we respond to impacts, both individually and collectively, determines the degree of future impact.

Desired State of The System

To develop resilience, we need to break out of this current cycle and move the system towards a desirable dynamic equilibrium, that of healthy natural resources (which also act as natural barriers on the coast), sustainability of resource-based livelihood (not over-relying on single crops, groundwater or shrimp farming) and developing resilient infrastructure (not just cyclone shelter homes but also climate resilient houses for people). In the above diagram, Loop 1 should produce people's responses that lower the impact and thereby create a balancing effect (More impact, better response, lower impact). In Loop 2, economic growth should reinforce positive responses of the people, thereby providing them with adaptive capacities. In Loop 3, the nature of economic growth and development must lead to a reduction in emissions and conservation of natural resources. Thereby weakening its impact on climate change.

The future of disaster risk reduction must also be informed by the goals of resilience and deep adaptation to climate change, disaster risks and natural resource depletion.

In this paper, we explain how the study has attempted to unpack the dynamics of some of these loops.

Methodology

The study process involves mapping interplays in the local system, engaging stakeholders, and identifying leverage points for intervention. Participatory approaches are used to understand context-specific feedback for Ersamsa.

The systems thinking exercise underpinning this paper proceeds in three steps.

Step 1: Problem identification:

The process began with desk research, reviewing secondary literature, government reports, District Disaster Management Plans (DDMPs), cyclone and flood impact data, and programme documents related to fisheries, agriculture, social welfare, irrigation, and disaster risk reduction in Jagatsinghpur. This was followed by stakeholder mapping to identify key actors across the community, gram panchayat (GP), block, and district levels. Stakeholders included fishing communities, farmers, Self-Help Groups (SHGs), Climate Champions, Shelter Management Committees, line departments (Agriculture, Animal Husbandry, Social Welfare, Irrigation), and block and district officials.

Primary data collection was carried out through six Focus Group Discussions (FGDs) and five Key Informant Interviews (KIIs) across coastal and inland locations. FGDs were organised as relatively homogeneous groups, such as fishermen, farmers, women SHGs, and Climate Champions, to encourage open discussion and peer validation. Each FGD included approximately 15–20 participants, totalling to an approximate 90-100 community and local institutional participants. KIIs were conducted with key decision-makers and technical officials.

Step 2: Causal Loop Diagramming (CLD) based on desk research and field research

In the second step, qualitative data collected from both desk research and field engagements—including Focus Group Discussions and Key Informant Interviews—were systematically examined using a systems thinking perspective. This analysis enabled the identification of feedback loops and interconnections among various factors influencing disaster risk and resource management in the local context. These diagrams facilitate a holistic understanding of how different elements within the system interact, helping to pinpoint areas where targeted actions can yield meaningful improvements in resilience and adaptation.

Step 3: Archetype identification

Key stories derived from the Causal Loop Diagrams (CLDs) were aligned with generic system archetypes to uncover the system traps affecting both the community and the broader system. Through this systems thinking approach, different archetypes—essentially structural traps—were identified. These traps provided valuable insights into the underlying socio-ecological and economic challenges. By mapping these archetypes, the analysis highlighted how feedback loops and reinforcing mechanisms perpetuate issues such as resource depletion, livelihood conflicts, and unintended consequences of interventions. This lens enabled a deeper understanding of where the system is stuck, guiding stakeholders towards more holistic and sustainable solutions to address structural problems within the local context.

Results

System Archetypes (System Traps) In Coastal Shrimp Farming

A. Tragedy of the Commons – Water and Human Health

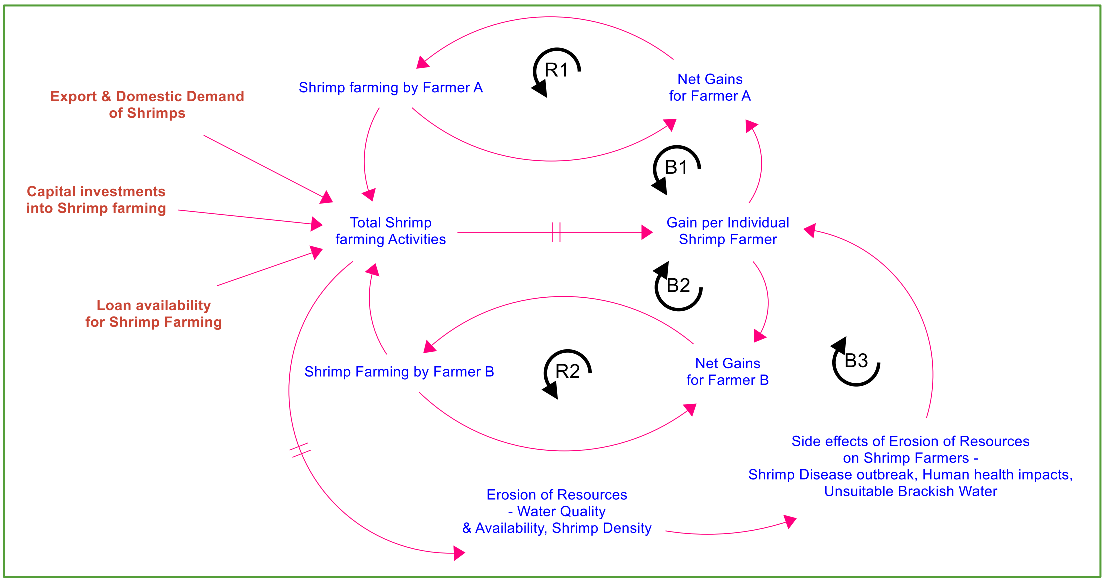

Figure 3: Tragedy Of Commons Archetype In Coastal Shrimp Farming

Figure 3, illustrates an adapted version of the Tragedy of the Commons archetype [2] focused on shared surface and groundwater used by multiple shrimp farmers and nearby communities. As the area under shrimp farming expands,

[2] https://thesystemsthinker.com/tragedy-of-the-commons-all-for-one-and-none-for-all/ , accessed on 18-03-2026

effluents and chemicals (antibiotics, chlorine, medicines) are discharged into common canals and ponds, while blocked natural drainage slows flushing. This degrades surface freshwater quality and availability and, through leaching, also contaminates groundwater used for drinking and domestic purposes.

Shrimp cultivators are directly exposed to polluted pond water, and households consuming contaminated groundwater experience rising health problems, yet these costs are diffused and weakly internalised in individual farm decisions. The diagram shows reinforcing loops where higher shrimp profitability drives more ponds (R1, R2). This, in the long run, results in erosion of resources like freshwater and hitting the limits to Shrimp density. The erosion leads to delayed side effects in the form of increasing probability of disease outbreak in Shrimp ponds, human health impact due to poor water quality and the water becoming unsuitable for Shrimp farming (B3). Ultimately limiting the gains per farm (B1 & B2). This pattern typifies a commons trap in which short-term private gains from using a shared water body for effluent disposal undermine long-term collective health and water security.

B. Success to the Successful – Dominance of Shrimp over Alternate Livelihoods

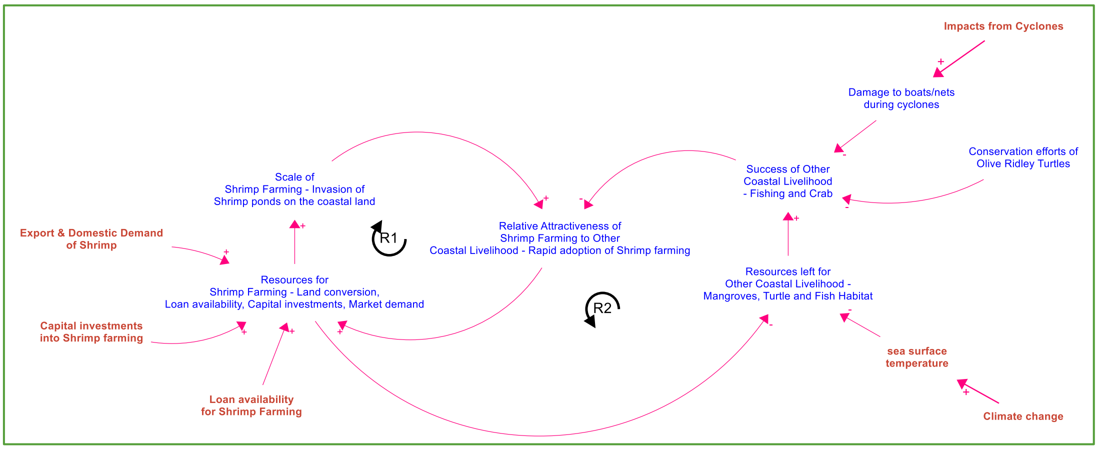

Figure 4: Success To The Successful Archetype In Coastal Shrimp Farming

Figure 4, represents an adapted version of the Success to the Successful archetype[3] in which profitable shrimp farming systematically outcompetes fishing and conservation-compatible livelihoods. Rising export and domestic demand for shrimp, coupled with loan availability and high market prices, increases capital investments in ponds and encourages fishers to lease land for shrimp cultivation. As shrimp profitability increases, the area under shrimp cultivation (including unregistered farms) expands, reinforcing further investment and income (R1 "attractiveness of shrimp farming").

This success comes at the expense of alternative livelihoods and ecosystems. Conversion of mangroves into ponds impacts the fish/crab breeding grounds. This reduced the availability of fish and crab for fishermen, ultimately reducing their livelihood income. This prompts them to search for other forms of livelihood and ultimately shift towards Shrimp farming. Coupled with cyclone damage to boats and nets and seasonal fishing bans for Olive Ridley conservation, it erodes fishing livelihoods and deepens livelihood–conservation conflict. Over time, capital, labour and policy attention are increasingly allocated to shrimp, while fishing, crab collection and conservation-linked activities lose the fishing resource base and viability. The figure thus captures how early advantages in shrimp create reinforcing loops that concentrate benefits and marginalise other livelihoods, characteristic of "Success to the Successful".

C. Fixes that Backfire – Amplification of Disasters and Side Effects

Figure 5, represents an adapted version of the Fixes that Backfire, after a Delay archetype[4]. In this specific case, the side effect (backfire) of land conversion for growing Shrimp farming is resulting in a cascading impact on ecosystems.

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[3] https://thesystemsthinker.com/success-to-the-successful-self-fulfilling-prophecies/ , accessed on 18-03-2026

[4] https://thesystemsthinker.com/wp-content/uploads/2016/03/Applying-Systems-Archetypes-IMS002Epk.pdf , accessed on 18-03-2026

This is resulting in amplification of disaster impacts, which in turn are negatively impacting the shrimp farming profitability. The side effects pattern appears to be consistent with the "Fixes that Backfire" archetype. Short-term responses to income needs —such as expanding shrimp ponds, converting paddy land and mangrove land, and increasing dependence on groundwater—initially appear to fix livelihood problems by raising shrimp production and profitability (R1). However, land conversion, shrimp-related pollution, and blocked natural drainage channels progressively reduce soil fertility, freshwater availability, and natural buffers such as mangroves and sand dunes. As climate change drives sea-level rise, erratic rainfall, and higher cyclone intensity, these weakened buffers and degraded soils amplify cyclone and flooding impacts, coastal erosion, seawater logging, and groundwater stress (R2). In response, actors invest in further "fixes" such as more embankments, land conversion, and freshwater pumping and flushing, which can themselves worsen long-term vulnerabilities by locking the system into higher dependence on shrimp and hard infrastructure. The diagram, therefore, shows an amplification of risk impacts driven by the " fixes-that-backfire loop: interventions that seem to solve immediate livelihood and water problems inadvertently increase exposure to disasters over time.

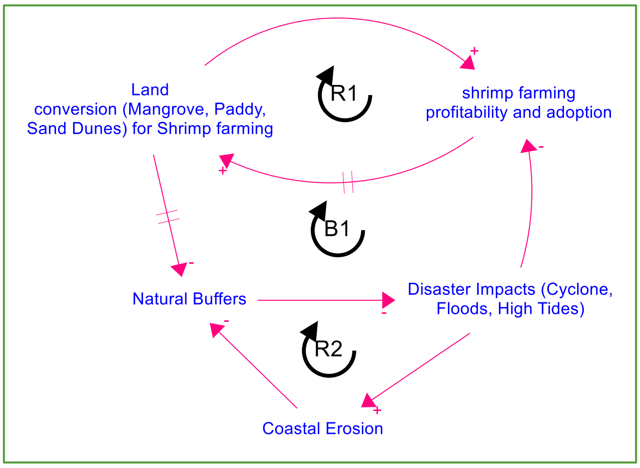

Figure 5: Fixes That Backfire Archetype In Coastal Shrimp Farming

Way Forward

Transitioning towards sustainable shrimp farming in Ersamsa requires regulatory reforms, livelihood diversification, ecosystem restoration, and participatory governance. A potential framework to guide this process could be the Deep Adaptation approach. It focuses on resilience, relinquishment, restoration, and reconciliation. It can help communities respond proactively to compounding climate shocks and systemic risks.

Deep Adaptation As A Transition Lens

The Deep Adaptation framework invites communities and institutions to plan for resilience, relinquishment, restoration and reconciliation. Applying this lens to shrimp-based coastal systems can expand the view beyond risk management to a less vulnerable system. Below, we describe each of these.

Resilience - Resilience here refers not only to maintaining shrimp production under stress but to safeguarding core functions and values of coastal communities, such as food security, social cohesion, and cultural ties to land and water. Investing in adaptive infrastructure, early warning systems, diversified livelihoods and social protection can help communities absorb shocks without being forced into distress migration or labour.

Relinquishment – Relinquishment involves consciously letting go of assets, behaviours or expectations that are unsustainable under deepening climate stress. In some highly exposed areas, this may mean planning for phased retreat of ponds from the most vulnerable zones, halting new pond approvals in ecologically critical belts, or redesigning embankments to prioritise human safety and ecosystem function over protecting every pond.

Restoration – Restoration calls for regenerating ecosystems and social relations that enhance long-term viability. This includes large-scale mangrove afforestation, wetland rehabilitation, and the revival of traditional water management and agroecological practices that can coexist with more carefully sited and regulated aquaculture. Restoration efforts should be co-designed with local communities and recognise the knowledge of fishers, farmers and forest-dependent households.

Reconciliation – Reconciliation entails acknowledging past harms and addressing conflicts between conservation, development and justice objectives. In settings where illegal pond demolition, displacement, or pollution have created deep grievances, processes for dialogue, compensation, and joint planning can help rebuild trust. Integrating Deep Adaptation into coastal planning thus offers a way to hold the tension between accepting profound risk and still acting decisively to reduce suffering and expand collective agency.

CONCLUSION

Employing systems thinking reveals that coastal shrimp farming is shaped by interconnected feedback loops, linking ecological degradation, climate vulnerability, and precarious livelihoods. Notable system archetypes, such as "Success to the Successful" and "Tragedy of the Commons", illustrate how interventions, if not carefully designed, can inadvertently exacerbate sustainability challenges. To shift towards resilience, it is crucial to integrate policy reform, participatory commons management, diverse livelihood alternatives, and ecosystem restoration—guided by the principles of Deep Adaptation.

Next steps involve expanding multistakeholder engagements at both community and policy levels to strengthen collaborative action and ensure inclusive coastal governance.

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