Extending the European Union Deforestation-free Regulation to Sri Lanka's Land-Based Shrimp Aquaculture: Environmental, Regulatory and Trade Justifications

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Abstract

The European Union Deforestation-free Regulation (EUDR), adopted in 2023, seeks to guarantee that commodities entering the EU are free from deforestation after 31 December 2020, with strict requirements for traceability and due diligence.

While aquaculture is not yet included, this study evaluates the environmental and regulatory dimensions of Sri Lanka's land-based shrimp farming to assess its suitability for future inclusion. Evidence from coastal districts shows that shrimp farming contributes to mangrove loss, carbon emissions, biodiversity decline and reduced coastal ecosystem services; impacts comparable to those of EUDR-regulated commodities.

Regulatory analysis reveals gaps in geolocation-based traceability, legality verification and land-use monitoring. Even though the Sri Lanka's marine resource governance framework offers some protection, the provisions fall short of addressing the conversion of critical habitats for aquaculture and centralized Monitoring, Reporting and Verification (MRV) systems are lacking. Voluntary certifications such as ASC and BAP remain underutilized. The study recommends aligning national governance with EUDR principles through legal reforms, MRV implementation, certification expansion. It also highlights ecological risks from converting regenerating mangroves on abandoned saltern lands, advocating for their consideration within deforestation-free compliance frameworks.

Keywords

European Union Deforestation-free Regulation (EUDR), Land-based shrimp aquaculture, Sri Lanka, Mangrove degradation

Introduction

Deforestation appears to be a key environmental issue which emerged after economic development [1]. Particularly in the tropical regions of the world, has experienced with substantial forest decline in the form of deforestation and degradation, driven by the escalation in destructive human activities over the past decades [2]. As per the [3], accelerated demand for the agricultural and forest products which driven by the increased economic growth, has led towards accelerated deforestation. Supported to that, [4] highlighted that, highly developed countries also experienced with high deforestation rates over many decades.

According to [5], commodity-driven deforestation is the foremost cause of global forest loss, accounting for 5.65 million hectares annually. This deforestation is largely permanent and primarily driven by agriculture mainly including commercial crops.

In contrast developed nations currently experiencing shift in demand on environmental services as their national income rises, reducing deforestation pressures [4]. Due to the fact 95% of global deforestation occurs in tropical regions, findings highlight the urgent need for stronger regulatory mechanisms (Curtis et al., 2018). As per [6], the European Union (EU) was reported as the second-largest contributor of tropical deforestation-related commodities and associated emissions. They recently (2023) took actions on adopted to the European Union Deforestation-free Regulation (EUDR), seeking to eliminate the regulatory gaps bound with legality and sustainability of forest and agricultural supply chains [7] which are link with the European Market.

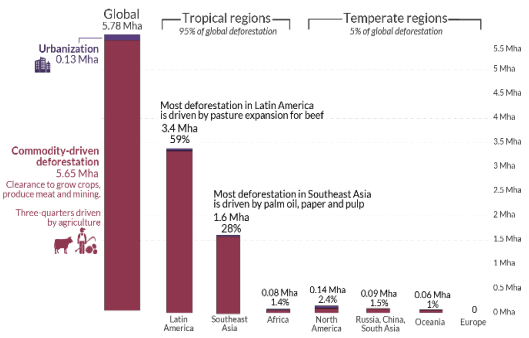

Figure 1: Drivers of global forest loss [8]

As a key economy and consumer of the commodities such as beef, wood, cocoa, soy, palm oil, coffee, rubber and some of derived products (leather, chocolate, tyres or furniture) which are highly linked with deforestation and forest degradation, the regulation consider above mentioned commodities as its scope of apply [9]. By implementing, it assures that supply chains of the products cover under regulation scope are free from deforestation and comply with local environmental laws. Any operator or trader introducing aforementioned commodities into the European Union market or exporting must consist with evidence that the products do not derive from lands which were deforested after 2020 or contribute to forest degradation [9]. Above said, operators or traders must proceed with due diligence, ensuring transparency and traceability within their

sourcing scope.

Even though not taken as a commodity, global deforestation has been greatly intensified by the growth of the land-based seafood sector, especially shrimp aquaculture, which has had a shocking impact on mangrove ecosystems. Shrimp aquaculture has been accountable for around half of all mangrove degradation worldwide since the 1940s [11]. In South Asia, where nations like Bangladesh, India and Sri Lanka have immense coastal ecosystems, shrimp farming has become a main cause of mangrove deforestation [12].

The global seafood industry has faced growing pressure to implement sustainable business practices due to increased concerns over environmental damage and resource exhaustion [13]. In particular, the EU, UK and USA markets have imposed stricter sustainability regulations on imported seafood [14], prompting prominent exporters, inducing them to adjust their business models to meet these standards.

Within just few years, Sri Lankan shrimp farming has grown from its scratch into a significant industry, in terms of both production capacity and economic value, making substantial contribution to the Sri Lanka's foreign exchange earnings. Currently, the shrimp farming has established itself as a leading driver within the fisheries and aquatic resources domain [15]. Despite of this noteworthy progress, shrimp farming is accompanied with several harmful environmental impacts, prominently linked with deforestation in the form of clearance of mangrove ecosystems, salt marshes, seagrass beds and mudflats, along with many of their associated ecosystem services [16].

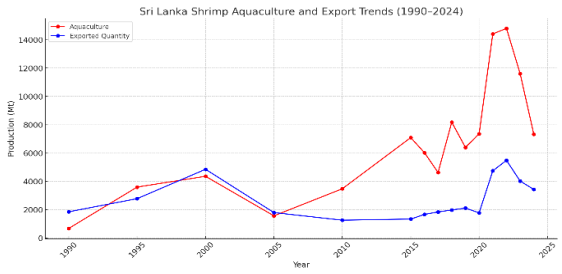

Figure 2:Sri Lanka Shrimp Aquaculture & Export Trends (1990-2024) [17]

Environmental protections, such as sections that either directly or indirectly address habitat degradation, biodiversity loss and deforestation, are becoming more and more integrated into current aquaculture standards. Comprehensive site assessments are essential to avoid ecologically vulnerable areas, such mangroves and certification programs like the Aquaculture Stewardship Council (ASC) and Best Aquaculture Practices (BAP) demand effluent controls and biodiversity conservation measures [18]; [19]. Additionally, these programs encourage ethical sourcing and traceability across aquaculture value chains. In future, global shrimp suppliers must be certified and eco-labelled and certification is becoming universal [20]. The [21] stated that, there is growing number of mandatory, market-specific and niche requirements that seafood products must comply to secure their market access into Europe.

The study aims to evaluate the deforestation & degradation impacts of shrimp aquaculture in Sri Lanka and benchmark them against commodities already regulated under the European Union Deforestation-free Regulation (EUDR). It further identifies regulatory and governance shortcomings in fulfilling EUDR criteria as to strengthen environmental safeguards while enhancing long-term trade competitiveness of Sri Lankan shrimp farming sector.

Materials and Methods

The above evidences an urgent imperative for regulatory frameworks, such as the EUDR, to account for high-impact seafood sectors within tropical value chains.

This study adopts a qualitative, desk-based research approach, combining policy analysis, literature review and benchmarking, in order to assess the rationale for applying the EUDR to Sri Lanka's land-based shrimp aquaculture industry. Following figure 3, provides the flowchart of the research framework.

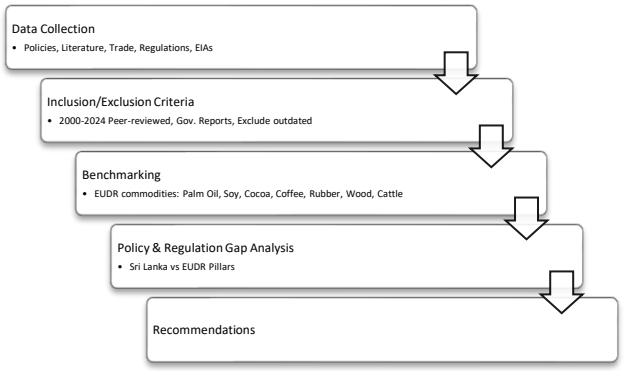

Figure 3: Flowchart of the Research Framework

The data sources were chosen based on an inclusion criterion of secondary data, including peer-reviewed, national policy documents, academic literature, international environmental regulations and commodity governance frameworks, 2000-2024 coverage and exclusion of outdated or unreliable reports.

Peer-reviewed scientific literature utilizing scholarly databases (Google Scholar), environmental impact assessments (EIAs) and reports from national agencies

like the Department of Fisheries and Aquatic Resources (DFAR), National Aquaculture Development Authority (NAQDA) and Coast Conservation and Coastal Resource Management Department (CCD) were reviewed in order to evaluate the environmental impact of shrimp aquaculture on habitat degradation and deforestation. From 2000 to 2024, recorded instances of shrimp farming-related environmental damage, wetland conversion and mangrove clearing were given special consideration as they were directly corelating to EUDR framework.

A systematic policy evaluation was carried out between the current institutional and legal frameworks controlling aquaculture in Sri Lanka and the fundamental regulatory pillars of the EUDR, as stated in Regulation (EU) 2023/1115. The Coast Conservation Act, the Fisheries and Aquatic Resources Act and pertinent sustainability certification programs (such as the Aquaculture Stewardship Council (ASC) and Best Aquaculture Practices (BAP)) that Sri Lankan farmers have incorporated were important sources for this comparison. In areas including traceability, geolocation, due diligence, legality assurance and deforestation risk mitigation, these policies were evaluated for compliance with EUDR regulations.

Secondary policy papers from international environmental organizations such as FAO, UNEP, WWF and IUCN were reviewed in order to bolster the regulatory alignment evaluation. These publications gave a more comprehensive overview of the valuation of ecosystem services, the effects of aquaculture-driven land use change on the climate and global best practices for producing shrimp sustainably. In order to evaluate Sri Lanka's environmental commitments pertinent to EUDR compliance requirements, the country's voluntary reporting to multilateral frameworks including the Sustainable Development Goals (SDGs) and the UNFCCC's National Communications was also examined.

Furthermore, data on Sri Lanka's shrimp aquaculture industry's production and trade were systematically collected from reliable sources, such as the FAO FishStatJ database, the Sri Lanka Export Development Board (EDB) and government of Sri Lanka national budget estimates. Longitudinal insights into changes in shrimp production volumes, export performance, foreign exchange revenues and the sector's increasing economic contribution to the country were offered by these datasets. The study pursued to evaluate the contextual relevance and possible ramifications of expanding the EUDR framework to include Sri Lankan land-based shrimp aquaculture, particularly in terms of compliance feasibility, industry readiness and trade competitiveness, by examining these economic indicators in unification with environmental policy gaps.

A multifaceted appraisal of Sri Lanka's land-based shrimp aquaculture industry in respect to the fundamental tenets and requirements of the EUDR was made possible by the integrated synthesis of environmental, policy and economic facts. The goal of this comparison analysis was to ascertain how closely existing manufacturing methods, regulatory supervision and traceability systems conform to EUDR's deforestation-free standards. Additionally, the analysis looked at how EUDR-aligned regulatory frameworks may be expanded to improve biodiversity conservation, especially in delicate coastal habitats like mangroves and to increase Sri Lanka's access to export markets that care about the environment. The result sheds light on how regulation variation might be used as a two-pronged approach to maintain long-term trade competitiveness and support ecological integrity in the global seafood industry.

To determine whether the environmental risk profiles of Sri Lanka's shrimp aquaculture are similar to those of the commodities presently governed by EUDR namely, palm oil, soy, cattle, coffee, cocoa, rubber and wood, a comparative benchmarking analysis was carried out. The benchmarking criteria were as follows,

1. The extent and duration of land-use change
2. The loss of biodiversity and carbon stock
3. Embedded emissions and traceability issues
4. The presence or lack of assurance systems free from deforestation.

Determining whether the environmental externalities and deforestation dynamics of shrimp aquaculture warrant regulation inclusion under EUDR was the goal of this investigation.

Due to time and budget limitations, the study incorporates primary fieldwork, with stakeholder interviews undertaken as a secondary follow-up component to support and enrich the research findings. Nonetheless, triangulation of several reliable sources was used to guarantee the validity and reliability of the results. The approach offers a thorough framework for assessing the trade-based, legal and environmental justifications for extending deforestation-free commitments to the seafood industry, particularly Sri Lanka's land-based shrimp farming sector.

Results

Over the past decade, shrimp aquaculture has expanded rapidly in Sri Lanka, particularly in the northwestern coastal region. Initiated in the mid-1980s, the sector has developed predominantly through private-sector

investment using local labor and some expatriate expertise. By 1996, over 300 entrepreneurs had established shrimp farms, covering more than 2,000 hectares near lagoons in the northwestern and western provinces [22]. Civil disturbances in 1983 caused operations in the eastern regions to cease.

Production volumes have fluctuated noticeably: from 680 Mt in 1990, rising to 4,360 Mt in 2000, dropping to 1,570 Mt in 2005, and recovering steadily to 14,000 Mt in 2021 and 2022. A decline followed, with production at 11,040 Mt in 2023 and a projected 7,321 Mt for 2024 [23]; [24].

Exports are shown a similar pattern, increasing from 1,855 Mt in 1990 to 4,855 Mt in 2000, then fluctuated until 2015. A steady rise occurred from 2016, peaking at 5,486 Mt in 2022. The subsequent drop to 4,020 Mt in 2023 and a projected 3,432 Mt in 2024 reflects recent production declines and possibly increased regulatory or market challenges. This highlights the sector's dependence on export markets and sensitivity to market, regulatory and environmental pressures.

Shrimp aquaculture in Sri Lanka has greatly contributed towards coastal deforestation, specifically through the extensive clearing of mangrove forests. In areas such as Puttalam, more than half of the mangrove ecosystem was depleted from 1992 to 1998 as a result of swift growth in aquaculture. [25] Land-use analysis revealed that one of the shrimp pond expansion around Puttalam Lagoon triggered a 34% decline in mangrove cover and a loss of over 191,000 tonnes of carbon storage, with 75% of that associated to mangrove clearance [26].

Name Unit	Criteria				Overall
	A	B	C	D	
Agulhas	VU	EN	VU	LC	Endangered
Andaman	LC	LC	LC	LC	Least Concern
Arabian (Persian) Gulf	VU	LC	LC	LC	Vulnerable
Australian Coral Sea	LC	LC	LC	LC	Least Concern
Bay of Bengal	LC	LC	LC	LC	Least Concern
Central pacific	DD	VU	EN	DD	Endangered
East Coral Triangle	LC	LC	EN	LC	Endangered
EC and SE Australian Shelf	EN	LC	VU	LC	Endangered
Galapagos	LC	VU	LC	LC	Vulnerable
Gulf of Guinea - North	LC	LC	LC	LC	Least Concern
Gulf of Guinea - South	VU	LC	NT	LC	Vulnerable
Hawaii	NE	NE	NE	NE	Not Evaluated
Java Transitional	VU	LC	LC	LC	Vulnerable
North Brazil Shelf	LC	LC	LC	LC	Least Concern
New Zealand	LC	LC	LC	LC	Least Concern
NW Australia and Sahul Shelf	LC	LC	LC	LC	Least Concern
Red Sea and Gulf of Aden	NT	LC	EN	LC	Endangered
South China Sea	VU	LC	EN	LC	Endangered
South India, Sri Lanka, and Maldives	VU	LC	CR	LC	Critically Endangered
Sahelian	LC	LC	LC	LC	Least Concern
South Kuroshio	LC	LC	LC	LC	Least Concern
Southeast Polynesia	NE	NE	NE	NE	Not Evaluated
Sunda Shelf	VU	LC	VU	LC	Vulnerable
South West Australian Shelf	LC	LC	LC	LC	Least Concern
Tropical East Pacific	VU	LC	LC	LC	Vulnerable
Tropical Northwestern Atlantic	LC	LC	VU	LC	Vulnerable
Tropical Northwestern Pacific	DD	LC	LC	LC	Least Concern
Tropical Southwestern Atlantic	LC	LC	LC	LC	Least Concern
Tropical Southwestern Pacific	LC	LC	VU	LC	Vulnerable
Western Coral Triangle	VU	LC	VU	LC	Vulnerable
West India and Pakistan	VU	LC	LC	LC	Vulnerable
Western Indian Ocean	LC	LC	LC	LC	Least Concern
Warm Temperate NE Pacific	LC	LC	NT	LC	Near Threatened
Warm Temperate NW Atlantic	EN	LC	CR	LC	Critically Endangered
Warm Temperate NW Pacific	LC	LC	LC	LC	Least Concern
Warm Temperate SW Atlantic	DD	LC	LC	LC	Least Concern

Figure 4: IUCN Red List of Mangrove Ecosystems [27]

According to the IUCN Red List of Ecosystems, Sri Lanka's mangroves are classified as "Critically Endangered" [27]. This reflects their severe historical deterioration, fragmentation and constant threats from aquaculture and coastal development. This status underscores both their ecological vulnerability and the pressing need for reinforced conservation measures and regulatory alignment with global frameworks such as the EUDR.

Mangroves are vital ecosystems in Sri Lanka, offering carbon sequestration (over 500 tonnes per hectare), biodiversity preservation, coastal protection and livelihoods support [28], [29]. Their degradation increases greenhouse gas emissions and weakens resilience to natural disasters, such as the 2004 tsunami [30]. Communities in Puttalam and Batticaloa, which depend on mangroves for fishing and storm protection, are particularly affected [31].

The majority of shrimp farming costs stem from feed, a rapidly growing agricultural sub-sector [32]; [33]. Soy is a major feed component [34], while palm oil is increasingly used as a fish oil substitute [35]. Globally, 75% of soy production is directed toward animal feed [36]. Palm oil volumes continue to rise, despite fish oil production declining since 2000 [37].

Under the EUDR (Regulation EU 2023/1115), soy and its derivatives including, soybean meal used for livestock feed are explicitly listed among the regulated commodities [38]. Soy used in compound animal feed, falls under the same obligation. Businesses involved in the import, processing or distribution of soy-based feed products must maintain supply chain traceability and submit Due Diligence Statements [39]. The regulation requires that any feed given to livestock covered under the EUDR such as cattle, whose derived products like beef and leather are regulated must not be linked to deforestation or forest degradation [38] [39]. To support compliance, traceability platforms such as TraceX Technologies offer blockchain-based systems and geolocation tools that help companies demonstrate that their feed supply chains are deforestation-free [40].

A benchmarking study comparing shrimp farming to EUDR-regulated products like palm oil, soy and cocoa discovered significant environmental similarities. The alteration in land use associated with the construction of shrimp ponds was observed to be slow but continuing, with mangrove loss and wetland conversion over many years rather than occurring through major clearing incidents. [41]. The industry also depends heavily on soymeal and palm oil in feed production [42], both of which are explicitly regulated under the EUDR (European Commission, 2023). Even though shrimp itself

is not yet listed, these direct and indirect deforestation linkages highlight its linkage with the environmental externalities the regulation seeks to address.

A detailed examination of the regulatory landscape reveals significant gaps between the EUDR's core requirements and the existing governance framework of Sri Lanka's land-based shrimp aquaculture sector. The EUDR, codified under Regulation (EU) 2023/1115, mandates that commodities entering the EU market must be proven deforestation-free, legally produced and traceable to geolocated production sites [38]. However, shrimp aquaculture is not currently listed among the seven high-risk commodities under the EUDR [38], despite mounting evidence of its environmental footprint particularly the conversion of mangrove forests and wetlands [26]; [43].

Sri Lanka's longstanding Fisheries and Aquatic Resources Act, No. 2 of 1996, has undertaken multiple amendments, including the Fisheries and Aquatic Resources (Amendment) Act No. 27 of 2023 expanding the legal scope for transparency in marine and coastal resource management [44]. Despite these updates, the legislative framework does not explicitly require geolocation-based farm mapping or traceability systems for aquaculture practices, including shrimp pond operations. While licensing provisions remain under the purview of NAQDA, enforcement of site-specific audits or spatial traceability remains legally unmandated, leaving significant gaps relative to the traceability, legality verification and due diligence expectations of the EUDR.

The Coastal Zone and Coastal Resource Management Plan for Sri Lanka 2024 to 2029, establishes explicit regulatory measures to regulate the growth of aquaculture activities, with a focus on shrimp ponds and salterns, in ecologically sensitive salt marsh regions. According to the Coast Conservation and Coastal Resource Management Act No. 57 of 1981, this plan requires that any new or growing projects within salt marsh areas undergo stringent permitting processes supervised by the Coastal Conservation Department (CCD). This includes site-specific Environmental Impact Assessments (EIA) and zoning approvals that strictly prohibit the conversion of land in intertidal habitats recognized for their significant ecological importance. The plan pressures that development proposals must comply with updated land use zoning maps, avoid areas below an elevation of 5 meters and prove no negative effects on coastal wetlands, mangroves or lagoon systems.

Additionally, developers must stick to Best Management Practices (BMPs) and habitat conservation protocols to reduce biodiversity loss and hydrological disruption. These legal measures align with Sri Lanka's commitment to safeguarding its coastal ecosystems and respond to the rising pressures from unregulated aquaculture expansion detected in recent decades. The plan specifically cautions against informal or small-scale operations that have previously evaded environmental regulations and contributed to the degradation of wetlands. Therefore, the 2024–2029 CZCRMP implies a notable policy transition towards sustainable governance of coastal resources and underscores the importance of stringent environmental due diligence in the expansion of shrimp aquaculture [45].

Accordingly, though national legislation theoretically administrates environmental compliance and licensing, these laws lack obvious provisions addressing the upstream deforestation-related risks and traceability standards embedded in the EUDR framework. The absence of authorized geolocation tracking or EIA-linked legality checks underscores persistent policy misalignment, justifying the need for regulatory reform to link these critical gaps and align Sri Lanka's aquaculture industry with international deforestation-free import requirements.

Historical encroachments into coastal ecosystems have often been facilitated by the informal expansion of small-scale and semi-intensive shrimp farms, many of which remain undocumented or poorly monitored [46]. This results in weak verification mechanisms and impedes the implementation of environmental safeguards and legality assurance protocols.

Furthermore, Sri Lanka currently lacks a centralized Monitoring, Reporting and Verification (MRV) system for aquaculture-related land use changes, which further undermines transparency and accountability, two foundational principles emphasized by the EUDR [47]; [48]. Although global certification schemes like the Aquaculture Stewardship Council (ASC) and Best Aquaculture Practices (BAP) offer structured pathways to sustainability, their voluntary nature and limited national uptake have curtailed their impact [18]; [49].

These policy mismatches ranging from traceability and land-use legality to deforestation risk mitigation and MRV suggest that without regulatory modernization, Sri Lanka's shrimp exports may face significant compliance challenges if the EUDR's commodity scope is broadened. Thus, integrating EUDR-style due diligence systems into national aquaculture governance is both ecologically warranted and economically prudent. Such alignment would safeguard biodiversity, bolster environmental governance and sustain Sri Lanka's long-term access to environmentally sensitive markets.

Discussion

Multiple peer-reviewed studies and NGO reports confirm that nearly half of Sri Lanka's mangroves have suffered degradation or conversion, largely due to aquaculture expansion and other coastal development activities. EIAs, reports by the Department of Fisheries and Aquatic Resources (DFAR), the National Aquaculture Development Authority (NAQDA) and academic literature consistently document mangrove and wetland loss in key districts such as Puttalam, Batticaloa, and Kilinochchi [26]; [50]; [51].

These findings align with the results, which highlights mangrove deforestation trends and the severe loss of carbon storage capacities due to shrimp pond construction. Although these carbon losses may not match the scale of deforestation in palm oil plantations, the per-hectare carbon density of mangroves makes their loss disproportionately impactful [52]; [53].

Historical records evidently indicate that Sri Lanka experienced a substantial deterioration in mangrove extent during the late 1980s and 1990s: a sharp decline from 14,627 ha in 1989 to 8,596 ha by 1998, coinciding with the rapid growth of shrimp aquaculture and other anthropogenic pressures. The 2004 Indian Ocean tsunami further worsened mangrove degradation, reducing national cover to just 8,279 ha. However, successive conservation initiatives, natural regeneration, and targeted restoration programs facilitated a gradual regaining, with mangrove extent increasing to 16,615 ha by 2022 [54]. This dynamic trend reveals both severe historical losses linked to shrimp aquaculture and ongoing recovery initiatives, making it challenging to isolate and measure the exact extent of mangrove areas currently impacted by aquaculture. The overlap between degradation, natural regeneration and restoration efforts underlines the complexity of evaluating long-term aquaculture-driven impacts within Sri Lanka's mangrove sites.

The mismatch between reported farm counts and output indicates likely underreporting of small-scale farms or dominance by a few large producers. These discrepancies present key challenges for assessing land-use impact and ensuring compliance with traceability and deforestation-free requirements under frameworks like the EUDR.

Sri Lanka faces barriers, especially for smallholders, including inadequate awareness, financial limitations and absence of infrastructure for monitoring. Traceability as a major challenge, many shrimp producers, especially smallholders, do not have digital geolocation systems or legal documentation for their production, resulting in gaps in transparency and verification of legality [55]; [56]. Additionally, certification systems that guarantee deforestation-free practices, such as the Aquaculture Stewardship Council (ASC) and Best Aquaculture Practices (BAP) are only adopted by a small portion of the industry, mainly those who export directly to markets with environmental sensitivities [18]; [57].

As highlights in the results, aquaculture feed, particularly soy and palm oil are increasingly analyzed under the EUDR. While Sri Lankan shrimp itself is not currently classified as a regulated commodity, the inputs used in shrimp farming, such as soy-based feed, fall under the scope of the EUDR. This implies that shrimp producers indirectly face compliance pressures via feed supply chains.

Digital solutions like blockchain traceability platforms and geolocation systems are gaining traction among feed producers and exporters to meet EUDR expectations [58]. Hence, ensuring EUDR-compliant feed use is essential, not only for legal adherence but also to align with the regulation's larger goal of decoupling EU consumption from global deforestation.

Sri Lanka's existing governance framework lacks key components mandated by the EUDR. While the Coast Conservation Act and the Fisheries and Aquatic Resources Act provide some environmental safeguards, the provisions fall short of addressing mangrove conversion for shrimp farming, nor do they require traceability systems or geolocated farm maps. NAQDA's licensing mechanisms do not enforce spatial tracking or digital due diligence falling short of EUDR-level expectations.

The country also lacks a centralized Monitoring, Reporting and Verification (MRV) system for aquaculture-related land use changes, which undermines both transparency and accountability [48]; [47]. As noted in the results, the presence of undocumented or informal farms further complicates environmental risk assessments and legality assurance.

This regulatory space poses a risk: if the EUDR commodity list expands to include land-based aquaculture, Sri Lanka's shrimp exports may face compliance barriers without significant policy transformation. Aligning national regulations with international standards, particularly around traceability, land-use legality and MRV, is therefore both ecologically necessary and economically strategic.

Sri Lanka's National Communications to the UNFCCC acknowledge the vulnerability of coastal ecosystems but lack targeted policy measures to address aquaculture-induced deforestation. Similarly, recent documents by the Ministry of Environment and the Sustainable

Development Council recognize shrimp farming and salt pan expansion as environmental threats but stop short of outlining enforcement mechanisms or regulatory reforms [59]; [60].

Publications by FAO, UNEP, IUCN and WWF pressure the need for integrated land-use planning and ecosystem service valuation tools that remain underdeveloped in Sri Lanka's aquaculture management system [23]; [48]; [53].

The European Union remains a key export market for Sri Lankan seafood [24]. As international markets move toward sustainability-driven regulations, compliance with standards like the EUDR is increasingly crucial for maintaining competitiveness [61]. Case studies from Ecuador and Vietnam reveal how aquaculture sectors can align with EU standards through digital traceability, certification schemes and robust public-private cooperation. Although shrimp is not currently covered under EUDR, the regulation explicitly states that the list of commodities will be periodically reviewed and expanded [9].

Market signals already indicate mounting demand for eco-labelling and mandatory certification for seafood products in Europe [20]. The Seafood Trade Intelligence Portal (2025) notes that exporters face a rising number of niche, mandatory and market-specific compliance necessities, reinforcing the urgency for Sri Lankan producers to future-proof their operations through proactive regulatory alignment and sustainable production practices.

A tiered approach to compliance is proposed: in the short term, implement voluntary certifications such as ASC or BAP; in the medium term, arrange geolocation and traceability technologies; and in the long term, propose legal restructurings accompanied by centralized MRV systems.

Conclusion and Recommendations

This study critically inspects the environmental and regulatory dimensions of Sri Lanka's land-based shrimp aquaculture in relation to the EUDR. The findings reveal that although aquaculture is not currently covered under the EUDR's space, shrimp farming shares key environmental externalities with prevailing regulated commodities. Notably deforestation, habitat conversion and carbon emissions arising from mangrove destruction are among them.

Over several decades, shrimp farming in coastal districts such as Puttalam and Batticaloa has significantly contributed to mangrove loss, decline carbon storage, biodiversity and coastal ecosystem services. These ecological consequences reflect those of high-risk commodities like palm oil and soy, which fall straightly under EUDR enforcement. Furthermore, Sri Lanka's shrimp sector exhibits major gaps in traceability, legality verification and monitoring critical conditions embedded in the EUDR framework. Remarkably, most shrimp farms, particularly small-scale and informal operations, lack geolocation systems, while national licensing and permitting mechanisms fall short of mandating deforestation-free sourcing or spatial due diligence.

Despite Sri Lanka's adoption of many environmental policies, including the Coast Conservation Act and the amended Fisheries and Aquatic Resources Act, current regulations fall short of addressing the conversion of critical habitats such as mangroves for aquaculture development. The country also lacks a centralized Monitoring, Reporting and Verification (MRV) framework for aquaculture-related land-use changes. While some export-oriented farms pursue voluntary certifications such as ASC and BAP, these schemes are not compulsory and remain underutilized nationally.

Given these regulatory inconsistencies and environmental risks, the presence of shrimp aquaculture in a future expansion of the EUDR appears both ecologically justifiable and progressively probable. Without targeted improvements, Sri Lankan shrimp exports could face significant compliance challenges, market barring and reputational risks in environmentally regulated export destinations such as the European Union.

To prepare Sri Lanka's land-based shrimp aquaculture sector for potential inclusion under the European Union Deforestation-free Regulation, a multi-tiered strategy is crucial. The national regulatory frameworks better to be revised to mandate geolocation-based traceability, impose deforestation-free sourcing and strengthen Environmental Impact Assessment (EIA) enforcement aligning domestic governance with EUDR's due diligence requirements. The launch of a centralized Monitoring, Reporting and Verification (MRV) system specific to aquaculture land use would help link key data and enforcement gaps. Moreover, Sri Lanka should promote the widespread adoption of internationally recognized voluntary certification schemes such as the Aquaculture Stewardship Council (ASC) and Best Aquaculture Practices (BAP), while gradually integrating these standards into national compliance protocols. Association between the National Aquaculture Development Authority, Coast Conservation Department and trade stakeholders is vital to ensure consistent implementation and capacity-building.

Furthermore, targeted awareness campaigns and incentive mechanisms could support small-scale producers in transitioning toward EUDR-aligned practices, preventing

market exclusion. Proactively aligning with EUDR principles will not only safeguard long-term access to the EU market but also promote sustainable resource management, biodiversity conservation and competitiveness within Sri Lanka's shrimp farming industry. It also recommends to explore the applicability of other land-use changes, such as salterns within the coastal region, under the EUDR framework, as they may hold ecological significance similar to other deforestation-risk areas. In several coastal regions, previously established and later abandoned saltern lands have undergone natural ecological succession, gradually transforming into mangrove-dominated wetland ecosystems. However, these regenerating landscapes are increasingly being taken down for shrimp aquaculture, posing a significant ecological threat. This land-use conversion deviates from the principle of EUDR (forest or wetland ecosystems deforestation) they lead to the loss of carbon-sequestering, biodiversity-depletion within the habitats. Although such transitions may not always trigger deforestation alerts due to spectral similarities in remote sensing data, the on-ground impact includes habitat fragmentation, salinity alteration and disruption of trophic dynamics critical to coastal ecosystem functioning (Bunting et al., 2016; Richards & Friess, 2016). Assessing their environmental value and land-use history is vital to determine whether they should be included within the scope of deforestation-free compliance.

Proactively aligning with the EUDR offers Sri Lanka a triple benefit: continuing long-term EU market access, advancing biodiversity protection through environmentally responsible aquaculture and strengthening its competitive advantage in the global seafood sector by signifying leadership in sustainability.

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