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Blue Foods for Indonesia: A Human & Planetary Health Action Lab

Aquaculture:

Lessons Learned for Silvofishery Expansion in Indonesia

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Executive Summary

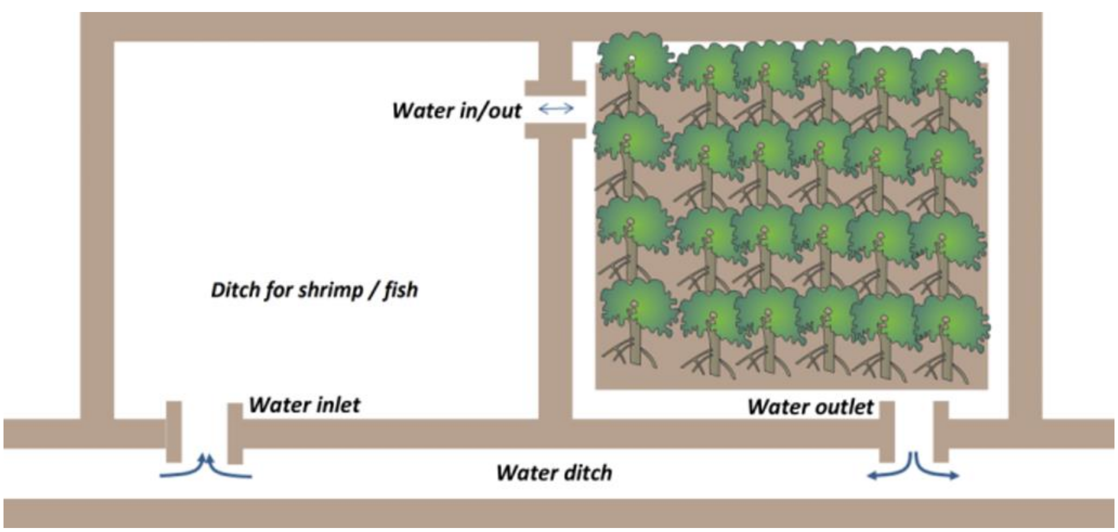
In the following report, we present and analyze silvofishery, an integrated shrimp-mangrove farming method, for its ability to boost Indonesia's aquaculture sector while minimizing disease risk and protecting mangrove forests. The first section of the report provides important background and context on silvofishery as well as an extensive review of existing silvofishery systems in Indonesia. Based on this information, we then conduct a comparative analysis between silvofishery and intensive shrimp farming, focusing on criteria of economic improvement, disease risk, and mangrove protection. We note potential for silvofishery expansion, in alignment with Indonesia's goal of boosting shrimp aquaculture through greater land utilization, high growth targets per sector, and increased export volumes and values. Aside from improving aquaculture value chains, silvofishery expansion will also aid Indonesia's efforts to restore natural coastlines, revitalize unproductive ponds, and protect mangrove forests. We highlight potential limitations of silvofishery, including the scalability of its methods and the training demanded for implementation. Our report concludes with an applied assessment of Vietnam's silvofishery in which we examine policy pathways for silvofishery adoption and programs for increasing export value of aquaculture products.

1. Introduction

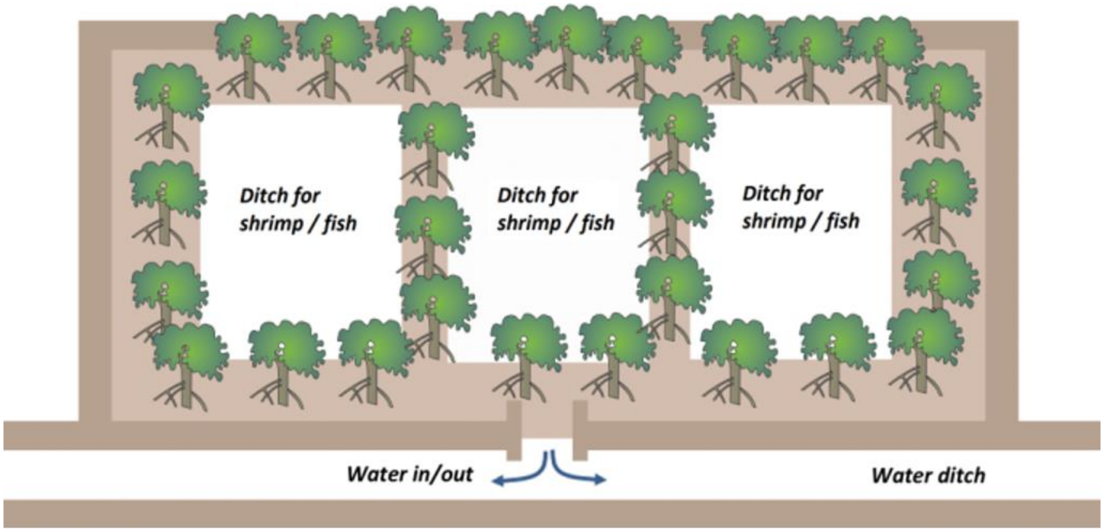
Integrated shrimp-mangrove management, or silvofishery, is a polyculture farming method that incorporates multiple species alongside mangrove forests to mimic natural processes. These systems promote the conservation of mangroves, which in turn provide the habitat, feed, and cover needed for farmed species to flourish as well as extensive ecosystem services on the local, national, and global level. Silvofishery is therefore an attractive farming method that offers a wide range of benefits – from sustainable, low-cost food production to disease mitigation and mangrove conservation. Importantly, as an extensive form of aquaculture, silvofishery does not meet the scale of shrimp production or the profit margins that intensive farming typically boasts. And, with complex farming methods that require adequate training, silvofisheries can be difficult to adopt and their success is heavily dependent on farmer perception.

Silvofishery Background

The silvofishery pond network – which rears multiple aquatic species and mangrove trees alongside one another – is coastally-based and has access to the tides. This system is known as *tambak tumpangsari*, and it can take on multiple forms, such as *empang parit* (pond trenches) and *komplang*. The two systems differ based on mangrove forest placement: in the empang parit system (Figure 1, Type I), mangroves are located at the center of the pond, whereas in komplang system (Figure 1, Type I) they are found at the edges. (Takashima 2000).



(TYPE I)



(TYPE II)

Figure 1. Schematic comparison between Type I (above) and Type II (below) Silvofishery Systems (Bengen 2004; van Oudenhoven et al. 2015).

In the Type I model, the farming area consists of between 60-80% mangrove cover and 20-40% canal pond water for aquatic species. Although the Type II model has the same mangrove to water ratio, mangrove placement occurs strategically in strips, rather than at the center of the farming area. In order to promote coastward surface flow runoff, these strips are placed perpendicular to one another. The Type II silvofishery model has several advantages over the Type I model, including stronger pond management, higher production potential, and lower costs for farmers. Additionally, due to the increased flow associated with mangrove strip placement, there are reduced levels of tannin, a toxin that can secrete into the system from mangrove areas. (Fitzgerald and Others 2000).

Both models are polycultural systems, and farmed species include milkfish, tilapia, mullet, sea bass, black tiger shrimp, and mudcrabs. Farmers are able to bring to market all of these products boosting farm resilience. Productivity for wild shrimp is higher in brackish ponds with greater mangrove cover. Ponds with no mangrove cover produce 171 kg/ha/year of wild shrimp while ponds with greater than 80% mangrove cover can produce 414 kg/ha/year of wild shrimp (Takashima 2000). The greater productivity and diversity of products creates resilience for the farmer due to ability to absorb market shocks because of product differentiation.

Key Takeaways from Existing Indonesian Silvofisheries

In the following section, we present a thorough survey of existing silvofishery systems in Indonesia, focusing particularly on regions with high wild-capture and aquaculture production. Our takeaways, which are based on the available literature and expert consultations, aim to provide essential knowledge on the barriers to and drivers of successful silvofishery implementation.

As part of Indonesia's pond revitalization plan, studies were conducted in Situbondo to understand the feasibility and potential of silvofishery in these coastal areas for the revitalization of unproductive farm ponds (Musa, Mahmudi, et al. 2020). The authors found that silvofishery could benefit sustainable fisheries culture, and is fundamentally easy to control. **Unproductivity of these farms were attributed to poor water quality driven by livestock sewage, domestic activity and boat parking.** These findings were further corroborated by studies that demonstrated the effectiveness of silvofishery systems in improving water quality (Musa, Lusiana, et al. 2020), which suggests that **silvofishery systems could also be used to ameliorate regions with poor water quality or serve as water treatment for intensive aquaculture waste.**

Many countries involved in shrimp production have experienced disease outbreaks as a result of mangrove deforestation due to intensive shrimp cultivation (Fisheries and Others 2016; Malik, Mertz, and Fensholt 2017). The effluents from intensive shrimp cultivation have also been known to affect neighboring farms and nearby mangrove forests causing increased occurrences of disease and further environmental degradation (Stokstad 2010; Bui, Maier, and Austin 2014). The no-feed/low inputs to maintain silvofishery systems and their intrinsic ability to enhance farming ecosystems allows it to achieve a higher level of disease resistance in shrimp (Ifoam 2012; Naturland 2002). Other epidemiological research has also shown that alongside best aquaculture practices, the presence of mangrove forests is important for **decreasing the frequency and impact of disease outbreaks** (Tendencia, Bosma, and Verreth 2011). Additional research should be done to identify local aquatic species in these filter ponds, that could aid in further decreasing risk of disease in shrimp and in further diversifying farmers income.

Takeaway: Silvofishery systems offer an avenue for the revitalization of previously unproductive farms and can improve surrounding water quality.

Silvofishery has been suggested as a strategy to promote both economic development and mangrove restoration. Integrated mangrove forests and aquaculture systems have already been implemented in locations such as Sinjai in South Sulawesi, Indonesia. Born in 1984 as a cooperative project between the Ministry of Forest, the District Government, and the University of Hasanuddin, silvofishery was initially part of a community-led mangrove replanting program aimed at minimizing coastal erosion of the local fishing village (Fitzgerald and Others 2000). In addition, the Southern Sulawesi Province Fisheries Office in the 1990s tested out empang parit designs in Luwu and Kwandang in Sulawesi, as well as in Cikiong and Blanakan in West Java under the Island Sustainability, Livelihood and Equity Program as an attempt to improve aquaculture production of the empang parit system. Some initial results showed that introducing crab culture had better water flushing conditions compared to pens located in the canal.

Unfortunately, the collection of data and an economic analysis of the empang parit designs in Luwu and Kwandang in Sulawesi is incredibly limited. One study performed an economic evaluation on silvofishery farms in Cangkring and Blanakan in West Java. Both sites utilized the traditional empang parit' system with an 8:2 model of mangrove to water channels. The authors found that annual net income was US$408/ha (1,000,700 Rp/ha) and US$248/ha (608,500 Rp /ha) respectively, with the difference mainly attributing to the species cultured (Tilapia for Blanakan sites and Milkfish for Cangkring sites) (Widiarti and Effendi 1989). All together, the success of silvofishery systems is highly dependent on a series of various factors including: **1) density of mangroves to pond, 2) species of mangroves chosen, 3) cultivation chosen and 4) type of silvofishery system adopted**. Incorrect implementation of silvofishery systems has often resulted in unproductive farms, harmful algal blooms and poor water quality. Adequate training knowledge is therefore required to understand appropriate models of adoption, proper species based on site characteristics, and suitable mangrove:pond ratios for maximizing pond productivity. Selection for the most appropriate silvofishery model is often site-dependent and heavily influenced by the state of the mangrove system (Fitzgerald and Others 2000; Musa, Mahmudi, et al. 2020; Umilia and Asbar 2016). Implementation should be carried out alongside an area-wide integrated coastal management approach to prevent situations of environmental degradation (Musa, Mahmudi, et al. 2020). Existing studies have pointed to silvofishery as a "complex social-ecological system" requiring the intersection of government management, land use policy, and regulation to enable both sustainable shrimp production while maintaining the ecological function of mangrove ecosystems (T. T. T. Ha, van Dijk, and Bush 2012; T. T. P. Ha, van Dijk, and Visser 2014; Bush et al. 2010). When implemented properly, silvofishery systems are an avenue for low-input sustainable aquaculture.

Previous studies have shown the factors that affect the successful adoption of silvofishery systems. Understanding farmers' perceptions of silvofishery systems is also important in order to necessitate adoption – one study found that while **60% of mangrove cover is recommended to maximize productivity** in integrated mangrove shrimp farming systems, farmers have a preference for mangrove coverage between 30-50%, with most farmers choosing 30% mangrove cover as most suitable for shrimp development. Further, a small percentage of interviewees perceived shrimp productivity to decrease as mangroves matured (Nguyen et al. 2022). While overly heavy mangrove cover (> 60%) can lead to losses in productivity, studies have shown increases in both pond productivity and economic value for silvofishery systems with mangroves (Suwarto et al. 2022).

While the benefits of silvofishery in Indonesia has been well-documented (Takashima 2000; Sukardjo 2000), **lack of silvofishery adoption could be attributed to lack of education, aversion to new techniques and disbeliefs that the new system could increase incomes** (Susilo et al. 2018). Studies surveying differences between adopters and non-adopters of silvofishery within the Mahakam Delta found that **most adopters are a part of farming cooperatives, have attended aquaculture training, and received a higher number of visits from extension agents** (Susilo et al. 2018). To ensure that small-scale farmers practicing silvofishery will be successful, it is essential that farmers are equipped with the technical capabilities to handle both mangroves and shrimp in terms of nutrition, disease control and general husbandry since these factors will greatly affect productivity.

While certain forestry policies have helped silvofishery implementation spread in Vietnam, some studies have shown that implementing regional rehabilitation and conservation policies, such as the Regional Regulation No. 8 of 1999, have seen **conflicts of interest between communities**

and local governments. These conflicts are primarily due to the lack of direct contribution of rehabilitation efforts to people's income (Umilia and Asbar 2016). Thus, while the government can incentivize farmers through public sector institutions, farmers tend to have more trust in cooperatives.

Another study examined the effectiveness of an Indonesian multi-level governmental program, Pengelolaan Irigasi Tambak Partisipatif (PITAP), for four aquaculture farms in Lombok (Paramita et al. 2023). The overall goal was to support small-scale and traditional aquaculture farmers in repairing tertiary irrigation canals by enhancing community participation with labor incentives and simple tools. These four farms differed in socio-ecological characteristics that influenced collective action, briefly summarized into these categories: 1) farm ownership, 2) potential sources of pollution, 3) dependence on aquaculture as a basis of livelihood, and 4) aquaculture type. The authors found stark differences in the success of PITAP across the four locations in Lombok that can be categorized into **five main findings**:

1. The establishment of aquaculture cooperatives that should be supported by the government, especially at MMAF, provincial and district levels in the Marine and Fisheries Department.
2. Integrating capacity building for farmers through training on effective and efficient traditional small-scale aquaculture systems as well as good knowledge of the resource system so that farmers understand how to manage or improve their system efficiently and effectively together (North 2008; Fujiie, Hayami, and Kikuchi 2005).
3. Regular communication forums to build both trust and social capital, in order to ensure that farmers are committed to pursuing collective action goals
4. Access to technical support that allows farmers to get training on maintenance techniques suitable for each village's system
5. Supporting the establishment of aquaculture farmer cooperatives

Takeaway: Implementation of silvofishery requires expert knowledge, effective outreach to communities and extensive aquaculture training (as articulated by the authors' five main findings above).

When evaluating studies that compare shrimp farming systems with and without mangrove cover, farmers with integrated shrimp-mangrove farming cite **lower capital provisions, diversification of livelihoods from polyculture, and benefits from the recognition of organic farming practices** (Basyuni, Yani, and Hartini 2018). Mangrove forests provide naturally growing aquatic bioata, fodder for cattle and livestock, and coastal protection for villages. A study in Indonesia's Mahakam Delta found in surveys of extensive shrimp pond farmers that over 40% of households' livelihoods could be linked back to the mangrove estuarine environment (Bosma et al. 2012a). While the initial set-up of an integrated mangrove system requires a sizable capital (Fitzgerald and Others 2000), a **no-feed system suggests fewer additional input,** unlike integrated shrimp farming practices where close to 53% and 22% of the annual costs are attributed to feed and medicine (Nguyen et al. 2022). In Vietnam, shrimp farmers remain robust to market fluctuations of shrimp costs through on-farm diversification, off-farm labor (i.e., additional employment through construction work or agricultural farming), as well as the culture of other fish or salt production. However, it is important to note that the transition for fishers and pond farmers to diverse livelihoods may be difficult to achieve and require labor market support for adequate income diversification.

Silvofishery systems also benefit from **intentional knowledge on the selection of mangrove species and fish/crustaceans raised** (Basyuni, Yani, and Hartini 2018; Budihastuti, Anggoro, and Saputra 2013). Careful consideration needs to be placed on which types of mangrove species and densities that would be beneficial for the characteristics of the site and its productivity. One study explored the impacts of different mangrove species on aquaculture systems in North Sumatra and found that *Rhizophora mucronata* promotes plankton growth and provides higher nutrients than other types of mangrove strands. *Avicennia marina* serves as a coastal protection and *Rhizophora stylosa* leaves could serve as both feed and shade for livestock (Basyuni, Yani, and Hartini 2018).

A comparative study between traditional, extensive and integrated mangrove-shrimp farming found overall profits were the highest for integrated shrimp-mangrove farming by at least six-fold, at $68,923 USD compared to $11,259 USD and $1,288 USD for extensive and traditional shrimp farming systems (Bunting et al. 2013). A portion of these profits were attributable to higher mean shrimp harvest weight, higher shrimp stocking densities, and higher shrimp survival. Taken together, the increased profits, low additional input costs, and the diversification of income associated with integrated shrimp-mangrove farming highlight the comparative economic benefit that silvofishery systems offer. Yet, importantly, the cost of pond construction may make empang parit systems less economically attractive than traditional brackish pond culture (Bunting et al. 2013). Hence, government subsidies (through low-cost lease and a package of technical and capital assistance) may be an attractive option to meet the needs of farmers while encouraging mangrove rehabilitation (Fitzgerald and Others 2000).

Takeaway: Integrated mangrove aquaculture systems (Silvofishery) provide greater economic benefits to the farmer and greater environmental benefits to the natural system when compared to traditional extensive farming practices. Capital investment for construction costs is an impeding factor for silvofishery adoption that can be navigated through government actions.

Silvofishery should not be encouraged in areas with intact mangrove forests since the **ecosystem and economic potential of intact mangrove forests still far outweighs that of similar sized shrimp ponds** (Farley et al. 2010). While integrated mangrove aquaculture has shown considerable evidence in facilitating better water quality and increased production as compared to traditional extensive farming, **fragmentation of mangrove forests still does not function similarly and cannot replace the ecosystem services that intact mangrove forests provide** (Joffre et al. 2015; Koch et al. 2009). One study noted that the lack of regular water exchange in some integrated mangrove aquaculture prevents predatory fish from foraging and juvenile fish from using tidal exchanges to seek shelter and forage (Layman et al. 2004; Harborne, Talwar, and Brooks 2016). However, facilitated design of integrated-mangrove aquaculture could circumvent this problem. Specific attention could be focused on revitalizing abandoned shrimp farms in mangrove areas and can only be done to convert extensive farming systems since the soils that support healthy mangrove forests are typically highly organic and potentially acidic, making it unproductive for conversion to semi-intensive or intensive farming (McSherry et al. 2023; Fitzgerald and Others 2000).

Takeaway: Silvofishery can be used as a means for revitalization or to convert existing extensive farming systems, when applicable.

Integrated mangrove aquaculture systems offer a means of livelihood for those with limited financial capacity. The costs associated with integrated mangrove aquaculture can mostly be attributed to small material expenses for harvesting and the purchase of larvae, if applicable. A comparative study across extensive and intensive farms found that integrated mangrove aquaculture was the least expensive in terms of investment (Nguyen et al. 2022). Most mangrove-shrimp households also rely on income diversification as a way to enable resilience to market fluctuations. The same study found that total revenues are similar when compared to traditional extensive farming, but shrimp from integrated mangrove aquaculture was reported to fetch higher prices given its bigger size and absence of antibiotics (Nguyen et al. 2022).

Integrated mangrove farming has already been recognized as an organic aquaculture method. Silvofishery products could likely fetch even higher prices if they are certified as organic. Integrated mangrove aquaculture farms could potentially buy into organic certification programs or programs such as the REDD+ (Reducing emissions from avoided deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries) scheme. However, even REDD+ schemes are often not feasible for mangrove areas smaller than 500 ha and the price of carbon credits (<7 USD tCO_2, assuming that a 500 hectare mangrove farm sequesters 3 tCO_2 / ha / year) is not at a point that allows farmers to rely solely on carbon credits (McNally, McEwin, and Holland 2011). Finally, shrimps cultivated under mangroves reported higher survival rates and reduced disease outbreaks since mangroves played an important role in improving overall water quality.

Takeaway: Silvofishery represents an important source of livelihood and provides opportunities for poverty alleviation.

2. Methods & Evaluative Criteria

The following section reviews the methods and approach guiding the comparative analysis between silvofishery and intensive farming methods that is presented in section 3 of this report. Specifically, we explain the logic and process behind our selection of the following three evaluative criteria: economic improvement, disease risk, and mangrove cover.

The first two criteria were highlighted by the Indonesian Ministry of Marine Affairs and Fisheries (MMAF) in their Strategic Plan for 2020–2024, and it is expected that the goals of the next term, 2025-2030, will maintain continuity with previous years (Rositawati, pers. comm). Protecting and recovering mangrove cover is an important aim for Indonesian biodiversity and climate resilience efforts, and it has been a top priority for the Indonesia Biodiversity Strategy and Action Plan (IBSAP). While economic improvement and increasing mangrove cover might be seen as being 'at-odds' with each other, we highlight potential avenues that could enable shrimp aquaculture to be productive, profitable, and sustainable. Data from other countries such as India and Vietnam suggest that comparing trade-offs from different shrimp farming systems is urgent and timely in the context of Indonesia's growth goals for this sector. Bhattacharya and Ninan (2011) write,

> "*Although intensive shrimp farming yields high returns as compared to traditional shrimp farming, when the opportunity costs and environmental costs of shrimp farming, including disease risk, are accounted for, intensive shrimp farming loses its advantage.*"

The aim of this analysis was to improve clarity about whether the same conclusions might be drawn for Indonesia.

We gathered data for our comparative analysis from over twenty peer-reviewed research papers and reports found using google scholar and google search with the keywords: *shrimp farming, indonesia, intensive, silvofishery, comparison, profit/revenue/economics, disease, water quality*.

Economic Improvement

Boosting economic output is a key target for shrimp aquaculture in Indonesia. Government documentation calls for 2 million tons of shrimp production per year and increasing export value by 250% (Klinger 2024). Furthermore, there is a desire to boost overall acreage dedicated to shrimp production. Shrimp production can improve the overall wealth of communities and increasing economic improvement from shrimp production is a core aspect of Indonesia's goals of becoming a high income by 2045.

Shrimp can also provide a key source of nutrition for communities, improving economic well-being. Indonesia suffers from a high stunting rate of 21.6%. This rate increases in less developed parts of the nation, reaching 35.3% in Nusa Tenggara Timur (Juwana 2024). Shrimp production can help solve this problem. Shrimp is high in Vitamin B12 and Calcium (Golden et al. 2021). These two micronutrients combined with greater caloric intake due to increased local production can be a part of solutions to help solve nutritional problems in Indonesia.

With the set targets of boosting economic well being, both from a monetary and a nutritional perspective, it is important that shrimp aquaculture meets these targets. These are the criteria by which silvofishery will be judged against to ensure that it meets these targets.

Disease Risk

Disease is one of the biggest concerns in shrimp aquaculture. Disease can destroy whole farms and spread between farms wrecking the crop of a production region. Export losses due to disease in Thailand's Mahachai Market were estimated to be $4.2 billion. In Vietnam's Mekong Delta, in just 2015 alone, losses due to disease were estimated to be over $37 million (Shinn et al. 2018).

Historically, disease between farms has been viral-bourne. The most common viral pathogens were yellow head virus (YHV), Taura syndrome virus (TSV), and white-sport syndrome (WSSV) (Shinn et al. 2018). These viral pathogens were largely responsible for shrimp production crashes of the late 1980s and 1990s (Shinn et al. 2018). More recently, since 2010, there has been the emergence of bacterial and fungal agents, hepatopancreatic necrosis disease (VP) and *Enterocytozoon hepatopenaei* (EHP), respectively (Shinn et al. 2018).

Disease continues to negatively affect shrimp farms. From 2010-2015, production averages in Asia decreased by -2.87% per year and the annual growth rate decreased by -4.69% per year (Shinn et al. 2018). The decline in production over just half a decade indicates the significant negative effect that disease has on shrimp. Thus, if the economic targets listed above are going to be met, a shrimp aquaculture method needs to reduce disease risk as much as possible. Silvofishery should be measured against this.

Mangrove Ecosystems

Indonesia hosts the largest mangrove cover in the world holding 22% of global mangrove cover (Sasmito et al. 2023). Yet, over the last 30 years, nearly 40%, or 800,000ha, of mangroves have been lost. Roughly half of this loss is due to land conversion for shrimp and fish farms (Fisheries and Others 2016). Indonesia has set the robust goal of restoring 600,000ha of mangroves by 2024 (Sasmito et al. 2023).

Mangrove forests provide many ecosystem service functions. Mangroves capture and store carbon as well as regulate aquatic nutrient cycles. Mangroves additionally provide smaller-scale benefits such as protecting communities for storms, provide essential fuel and timber supplies, and support key breeding grounds for wild fisheries (Getzner and Islam 2020).
On the shrimp farming front, mangrove deforestation is having a perverse effect. Surveys of communities in India and Vietnam found increased coastal erosion, salinity intrusion, decline in post-larvae shrimp density, decreased mud crab abundance, and further acidification of shrimp aquaculture ponds (Getzner and Islam 2020). These impacts point to the critical role that mangroves play in local shrimp farming communities. As these services decline, the challenges of running a successful shrimp farm may increase (Getzner and Islam 2020). Zoomed out to the community level, community surveys stated that decline of mangroves affected local employment, led to poor health, and increased fuelwood challenges.

Due to the positive benefits that mangroves provide, the growing desire to conserve them, and the negative effect that shrimp farms can have on mangrove forests, it is of critical importance that future shrimp farms factor in mangrove conservation. Thus, silvofishery will be judged against this criterion and compared to the other possible shrimp farming methods.

3. Comparative Analysis: Silvofishery and Intensive Farming

3a) Economic Improvement

Revenue Over Time

Total revenue directly contributes to GDP and is an easily accessible statistic describing the efficacy of different farming techniques. In a given year, intensive farming is known to produce a higher yield of shrimp per hectare, resulting in greater economic returns for farmers. However, these results can be misleading in that they fail to account for the long-term returns associated with intensive farming, which can drop steeply after 3 years due to diseases eradicating shrimp populations (Basyuni, Yani, and Hartini 2018). By contrast, silvofishery systems produce less shrimp in the short-term, but, given their resilience to disease and superior quality of product, there are greater profits associated with these systems in the long-term.

Profit Over Time

Perhaps a more important measure than total revenue for farmers' livelihoods and long-term economic growth is individual profit. To this end, intensive farming requires much more capital investment since machines are usually needed to clear-cut mangroves and dig ditches to create ponds, and more machinery needs to be installed to maintain the water circulation and monitoring of the water quality and other pond metrics. For intensive shrimp farming systems, 20-50% of annual costs are attributed to feed and shrimp disease treatment (Nguyen et al. 2022). Economic analysis of profitability for different Indonesian shrimp farming systems across multiple locations and years lead Kusumastanto, Jolly, and Bailey (1998) to conclude that "intensive systems of production pose significant economic as well as ecological risks" especially to smallholder farmers.

By contrast, silvofishery systems do not require feed or external pumps to circulate water. There is higher plankton load in silvofishery ponds, which means that feed/nutrition/biomass is obtained " for free" by farmers (Sahidin et al., n.d.). A comparative study across extensive, integrated-mangrove and intensive farms found that integrated-mangrove aquaculture was the least expensive in terms of investment (Nguyen et al. 2022). The main costs associated with this fishery are labor costs for pond upkeep, including trimming back mangroves to an optimal percentage cover. Additionally, silvofishery ponds take a number of years to “mature” and reach their maximum productivity, a fact that is easily missed by the majority of studies aiming to assess the productivity of silvofishery ponds, which only collect data in the first few months following implementation. Table 1 in the Appendix summarizes the costs associated with Indonesian silvofishery farms of different sizes.

Quality of Product (Export Value)

Low meat quality is one of the primary barriers to Indonesian shrimp exports. In many cases, shrimp are rejected from intensive farms are rejected for export due to the presence of chemical contamination from antibiotics or hormones that are used to treat ponds or feed shrimp. Exporting farmers will also receive different prices based on size and homogeneity of their product. **Silvofishery farmed shrimp are larger and have less chemical contamination than intensively farmed shrimp, which can allow farmers to access price premiums that are not attainable with intensively farmed shrimp.**

- *Chemical contamination:* Silvofishery performs much better than intensive farming for this metric because silvofishery does not require the addition of chemicals that can cause export batches to be rejected. If a silvofishery system is located near an intensive fishery system, runoff from the intensive farm can negatively affect the quality of the silvofishery product. Conversely, silvofishery systems can help to improve the water quality of intensive farm systems (Musa, Lusiana, et al. 2020).
- *Size:* In Indonesia, silvofishery-farmed shrimp are routinely recorded as larger than intensively farmed shrimp (Asmild et al. 2024). In some cases this is because the species that is adapted to silvofishery (*P.monodon*) naturally grows larger than the species adapted for intensive farming (*L.vannamei*). Yet some studies also show that the lower densities and varied diet resulting from polyculture in the silvofishery system allows shrimp adequate space and nutrition to attain a larger size.
- *Market Trends:* The shrimp aquaculture market is increasingly competitive. Indian shrimp aquaculture has grown significantly and now accounts for 14% of global shrimp production (Rubel et al., 2021). The flood of Indian shrimp has driven the prices down, reducing profits for Indonesian farmers. If Indonesia farms attempt to sell shrimp at the

same rate as their Indian counterparts, Indonesia farms would barely make a profit (Rubel et al., 2021). Yet, concurrently, US and EU consumers demand greater sustainability and transparency for seafood products. Previous analysis has shown that capturing this market trend could allow Indonesia to maintain market share in the face of a more competitive export landscape (Rubel et al., 2021).

Income Diversification

Income diversification provides an important economic buffer for small-scale farmers in the face of market fluctuations. For example, shrimp prices have decreased by 33% globally, from a high of $10.75/kg in March 2014 to $7.15/kg in 2024 (International Monetary Fund 2024). Therefore, many farmers rely on other livelihoods, such as construction, to ensure a minimum daily income of ~ Rp 50,000-100,000 (Paramita et al. 2023). Whereas intensive does not provide diverse income options to farmers, silvofishery offers alternative opportunities for income from the sale of milkfish, seaweed, crabs, all of which are co-cultured with shrimp. Additionally, mangroves in the pond, which need to be trimmed and cut-back regularly, can be used as firewood and fodder for livestock, providing further support and economic stability for farmers.

3b) Disease Risk

Disease Treatment (Antibiotics/Medicines)

Shrimp disease directly affects the productivity of a pond, and treatment for these diseases has shown growing antibiotic resistance. Intensive farmers have increasingly focused on only one species of shrimp (*L. vannamei*) in order to concentrate efforts for developing new medicines (Amelia, Yustiati, and Andriani, n.d.). Many intensive farms have to be abandoned because of disease outbreaks that run out of control, with declining profitability from disease outbreaks in ponds (Asche et al. 2021).

Disease Prevention (Water Quality)

Because shrimp disease treatment is difficult and uncertain, shrimp farmers usually focus on the prevention of disease, which is largely dependent on water quality (Thitiwan Patanasatienkul, Milan Gautam, K. Larry Hammell, Dimas Gilang, Marina K. V. C. Delphino, Holly Burnley, Nikmatun Aliyah Salsabila, Krishna K. Thakur 2023). For this reason, intensive farms invest heavily into powerful pumps for water circulation and monitoring instruments for pH and other pond water metrics. Silvofishery systems do not use water pumps, instead relying on the natural filtering capacity of mangrove roots to remove contamination and stabilize pH. Shrimp used in silvofishery systems (*P. monodon)* are naturally more resistant to poor water quality conditions (Hukom et al. 2020).

3c) Mangrove Cover

In one economic analysis of Net Present Value of mangrove forests and commercial aquaculture in South Sulawesi, authors suggest that the "conversion of mangroves into commercial aquaculture was not economically beneficial when the analysis was expanded to cover the costs of environmental and forest rehabilitation" (Malik, Fensholt, and Mertz 2015). As an alternative solution, silvofishery systems allow for mangrove forests to exist alongside, and even within, the shrimp farming operation, continuing to perform vital ecosystem services such as storm protection (Harefa et al. 12 2019). These mangroves need to be managed so that they do not overgrow the entire pond, but their existence in appreciable numbers is crucial for the correct functioning of the system. A silvofishery system conserves 30–60% of mangroves which would otherwise be permanently felled within an semi-intensive or intensive system.

4. Case Study: Silvofishery in Vietnam

4a) Silvofishery Context

In 2013, Vietnam's Ministry of Agriculture and Rural Development issued a master plan for the development of the shrimp industry with an ambitious target to produce 1.3 million metric tons of farmed shrimp and to achieve USD $12 billion in export revenue by 2030 (Rubel et al. 2021). Vietnam is the third largest global shrimp producer and exports its shrimp stocks to Canada, the United States of America, the European Union, China, South Korea, and Japan (Rubel et al. 2021). Compared to the historic yet community-specific implementation of silvofishery in Indonesia, silvofishery is extensively adopted in certain regions of Vietnam such as the Mekong

Delta in the Ca Mau region (Hai et al. 2020). Vietnam and Indonesia are both global producers of shrimp, maintain similar geographies and climates in Southeast Asia, and share many similar challenges in the sustainability of shrimp farming. Exploring the policy landscape that enabled Vietnam's rapid expansion of silvofishery, as well as the challenges and successes of adoption, is valuable in informing the potential of silvofishery to expand as a practice in Indonesia.

The Ca Mau region is the leading producer of shrimp in Vietnam, with 265,153 hectares of ponds producing 99,600 million metric tons, or 25% of the country's total production (Ha 2012). Between 1983 and 1995, in Minh Hai province, the area covered by shrimp culture increased from 3000 hectares to more than 76,000 hectares, and more than 66,000 hectares of mangrove forest were converted into shrimp ponds ("Management of the Integrated Mangrove-Aquaculture Farming Systems in the Mekong Delta of Vietnam," n.d.). In 2009, integrated mangrove-shrimp farming accounted for 17.5% of the cultivated area in Ca Mau province (Joffre et al. 2015). During the American-Vietnam War, more than 2.2 million hectares of land in South Vietnam, including 150,000 hectares of mangroves, were heavily damaged by bombing and toxic chemical defoliants.

4b) Policies Relevant to Silvofishery

Mangroves are a major source of timber and thatching for houses and other buildings Ca Mau, as well as a source of fuel. However, the most serious decline in forest cover occurred after the war, corresponding to a major increase in the prices of aquatic products in national and international markets that caused people to convert forestland to aquaculture. To respond to the rapid destruction of mangroves in the region, national and provincial-level decisions were made to control forest production.

Of these provincial policies, the most significant policy that spurred the implementation of silvofishery in Vietnam is Decision No. 64 of 1991 by the Minh Hai government which allocated 70% of land for mangrove forests, 20% for ponds, and 10% for housing and other domestic purposes. By thinning mangroves per government policy and harvesting mangroves in 20-year cycles, farmers receive up to 80% of the profit from final harvest and 100% of the profit from thinning mangroves. These land use allocations were further specified by Decision No. 24 of

2002, where for each household with an area of 3–10 hectares, 50–70% of the land must be reserved for mangrove forest, 20–40% of land for ponds, and 10% for housing (T. T. P. Ha, van Dijk, and Visser 2014). In line with national policy goals in Vietnam to increase provincial aquaculture exports, the provincial government modified these guidelines to increase the proportion of land used for agriculture, housing, and other domestic purposes to 40% of land area in Decision No. 10 of 2010. Although there is a profit-sharing mechanism for timber harvest, the implementation of mangrove-integrated shrimp farming systems is more of a response to a restriction rather than a choice made by shrimp farmers in the region. More than 90% of these integrated mangrove-shrimp farms are contracted by a State Forest Enterprise or Forest Management Board, which provide farmers with short-term leases of 20 years and stipulates a specific forest-to-pond ratio, tree plantation density, and timber market. Failure to meet these requirements results in the lease being revoked after the 20-year lease expires (Barry Clough et al. 2000).

These integrated shrimp-mangrove systems are extensive and generally rely on passively collected natural seed stocks and use supplementary stocking of postlarvae shrimp from hatcheries to stock at a low density of 1 to 1.5 postlarvae shrimp per square meter. Additionally, mangrove trees are planted at intervals of 10 to 20 years and are replanted for timber harvest (Bridson, n.d.). In the Mekong Delta, there are two types of integrated mangrove-shrimp farming. One type is a mixed system with mangrove trees planted on raised beds, or bunds, within the system, and the second type is a separated system with a larger mangrove area inside the farm's water area (Figure 1, Appendix).

4c) Policy Implications

The extensive production system is typically smallholders who raise black tiger shrimp and generally have low access to capital, infrastructure, and electricity. These smallholders make up 90% of total shrimp production in the Ca Mau area and 60% of the total volume produced in the region (Barry Clough et al. 2000). About 75% of extensive shrimp farmers in the region are indebted after acquiring formal and informal loans from relatives and suppliers, and generally rely solely on the income from shrimp harvest (Barry Clough et al. 2000). These farms are rarely upgraded to semi-intensive or intensive farms due to poor access to finances and the capital to transition, as well as a lack of knowledge to successfully operate an intensive system (Joffre et al. 2015).

Although there has been a push for semi-intensive and intensive shrimp aquaculture due to national policy pushing for higher productivity, semi-intensive aquaculture is more capital-intensive and carries a higher risk of financial loss. Many small-scale farmers in the extensive system do not have the capital to invest in semi-intensive aquaculture and already have little experience with culturing *P. monodon* successfully (Barry Clough et al. 2000). Extensive systems in Ca Mau province that integrate the cultivation of mangrove trees have lower production levels per area than other extensive systems in the area but also demonstrate a lower overall risk of crop loss (Tran Thi Phung 2012). Shrimp production benefits from the water filtration and shading provided by the integrated mixed system and timber harvest provides additional income, but these systems are characterized by low shrimp yields (Table 1). However, these lower yields are also associated with an important trade-off with owner inputs and lower virulence of white spot syndrome virus (WSSV), the most serious viral pathogen of cultured shrimp, which results in lower incidence of disease and lower mortality rates (Tendencia et al. 2012; T. T. P. Ha, van Dijk, and Visser 2014; Hoa et al. 2011).

Table 1. Main characteristics of shrimp farms in the Mekong Delta with incomes based on prices in 2007 and 2008 (Joffre and Bosma 2009; Son et al. 2011; Ha 2012a and Ha 2012b; Joffre et al. 2015).

	Unit	**Integrated Mangrove-Shrimp System**	**Extensive Shrimp**	**Intensive Shrimp**
Farm/% pond area to total farm area	ha	5 to 15/40%	2 to 4/90%	.2 to 3/90%
Water exchange		Bi-monthly tidal	Bi-monthly tidal or pumping	Limited
Stocking density and stocking frequency	Post Larvae/m^2	1–3; 5–8 times a year	1.7–3 at initial stocking + monthly 10% of initial stocking	15–30 in single stocking
Yield *P. monodon*	kg/ha/year	228–365	242–475	2400-2600
Proportion of annual farm income from other aquatic products than shrimp	%	28	9	0

Range of annual income	$US/hectare /year	700-850	1050-2050	340–12,300
% of total shrimp area in Ca Mau Province	%	17.5	82	.5
% of total shrimp area in the Mekong Delta	%	8.5	82.5	9

Surveys of Ca Mau farmers under the integrated mangrove-shrimp system indicate general dissatisfaction with existing mangrove-to-pond area restrictions. In a survey conducted by Clough et al. in 2000, compared to the annual profit from a good shrimp harvest, the profits from a mangrove plot after a 20-year waiting period do not seem to be attractive to farmers. Farmers are unsure about the potential profit from mangroves because the cost outlay is unclear for them– mangroves are seen as more of a liability than a future income source. These attitudes are attributed to a general lack of awareness about the ecological importance of mangroves. Additionally, farmers would rather have a larger area allocated to shrimp farms than mangroves, which makes them dissatisfied with the current land use restrictions (Barry Clough et al. 2000). Moreover, mangroves are planted and harvested in 20-year cycles. In the structure of a 20-year lease, farmers who plant mangroves in their first year can expect to harvest within the final period of their lease, whereas farmers who do not plant in the first year of their lease can only benefit from harvest if their lease is renewed. This is a strong disincentive for farmers to manage their allocated area of mangrove forest (Barry Clough et al. 2000). Additionally, farmers report that shrimp yields decrease when mangroves within ponds reach 8-10 years of age due to the lack of light through shading of pond canals by the forest canopy, and mangrove leaves decompose in pond canals, introducing high levels of tannin to the pond bottom where shrimp usually feed.

A study by Joffre et al. in 2015 studied how to provide Ca Mau farmers with the best conditions under which they can decide to transition to an integrated mangrove-shrimp system. There are a multitude of factors that influence a farmer's decision to transition to an integrated mangrove-shrimp farm from an extensive shrimp farm (Figure 2). On the side of the value chain and international export market, a major draw of the integrated system is that it allows producers to access niche markets through certification and offering a price premium in export markets (Joffre et al. 2015)). In Vietnam, mangrove-shrimp farming can be recognized as an organic aquaculture practice. Farmers who participate in an organic certification program, such as NaturLand, Aquaculture Stewardship Council (ASC), and Best Aquaculture Practices (BAP) from the Global Seafood Alliance (GSA), are eligible to receive a premium price for certified shrimps. This started when the People's Committee of Ca Mau Province promulgated Decision No 111/QD-UBND, which enables farmers to receive three potential economic benefits, including a higher shrimp price for natural shrimps, a premium by using a certified organic brand, and payment for forest ecosystem services for mangrove-shrimp farming ("Supplementing land use planning of Hiep Hoa district in 2020," n.d.).

A major draw to farmers to transition to an integrated system is the price premium available through organic certification. A study conducted in Ca Mau province in 2022 compared organically certified mangrove-shrimp farming systems to mangrove-shrimp systems without organic certification. For 50 organic farms and 50 non-organic farms that utilized integrated mangrove-shrimp farming, the study found that average mangrove coverage was 54.1% in the organic integrated system and significantly different from the non-organic integrated system (Cong and Khanh 2022). Additionally, the organic integrated system increased shrimp yield, total income, and total profits, and the selling shrimp price increased by 10% compared to the conventional price. Integrated mangrove-shrimp system offers the potential to diversify farm revenue with timber production from mangroves, and overall, an integrated polyculture system diversifies the source of household income (Tran Thi Phung 2012; T. T. P. Ha, van Dijk, and Visser 2014). The availability of capacity and capital is also a significant driver of a farmer's decision to adopt an integrated system. For example, joining a cluster of farms that collectively shift to a mangrove-shrimp production saves operational costs, improves bargaining power, and facilitates knowledge-sharing between farmers (T. T. P. Ha et al. 2013). Access to training and knowledge is critical to enable farmers to create successful conditions for a productive mangrove-shrimp farm.

In addition to market and infrastructure conditions, regulatory frameworks and policy play a critical role in influencing farmers to adopt a mangrove-shrimp system. Subsidies and services such as Payments for Ecosystem Services (PES) and REDD+ (Reducing Emissions from

Deforestation and Forest Degradation in Developing Countries) from government agencies and the private sector provide a financial incentive for farmers to plant mangrove forests (Schmitt et al. 2011; M. H. Ha, Van Noordwijk, and Thuy, n.d.; Pham et al. 2020). Under Decision No 111/QD-UBND, farmers currently receive at least US$22 per hectare of mangrove forest (exchange rate in 2021) as a payment for ecosystem services ("Supplementing land use planning of Hiep Hoa district in 2020," n.d.). REDD+ in Vietnam suggests that the price per ton of carbon should be from US $7 to US $8 for a minimum area of 1,000 hectares or above $US 10 for an area of 500 hectares (Pham et al. 2019). REDD + is less promising for small-scale shrimp farmers who farm much smaller areas ranging from around 2-15 hectares. Besides regulatory incentives, access to loans from collectives, private lenders, and banks is key for farmers to acquire the capital for investment in an integrated mangrove-shrimp system (Tran Thi Phung 2012). Most shrimp farmers maintain varying levels of debt in Ca Mau province and do not have the capital to transition to a new system without loans and subsidies.

Finally, the environmental conditions of the area that a farmer operates in will drive their decision to adopt an integrated mangrove-shrimp farming system. First, a farmer who has historically struggled with a high incidence of disease will be more likely to transition to an integrated mangrove system due to the higher resilience to disease in an integrated system (Tendencia, Bosma, and Verreth 2010, 2011). Similarly, farms that face issues of low water quality have a higher likelihood of planting mangroves to improve water quality in a pond (Tendencia et al. 2012). In addition to pre-existing issues with water quality and disease, a farm with mangrove forest in the neighborhood or some degree of existing mangrove cover on the plot of land will be more likely to plant mangroves. Farms without mangrove forests in the area will have less incentive to plant mangroves. To operate a productive integrated mangrove-shrimp farm, there must be enough tidal fluctuation to sustain the mangrove (B. Clough et al. 2004). Finally, farmers that stock P. monodon multiple times a year will spread revenue over the year with multiple harvests, thereby reducing income shocks in the case of a virus and increasing the likelihood of adopting an integrated system (Tran Thi Phung 2012).

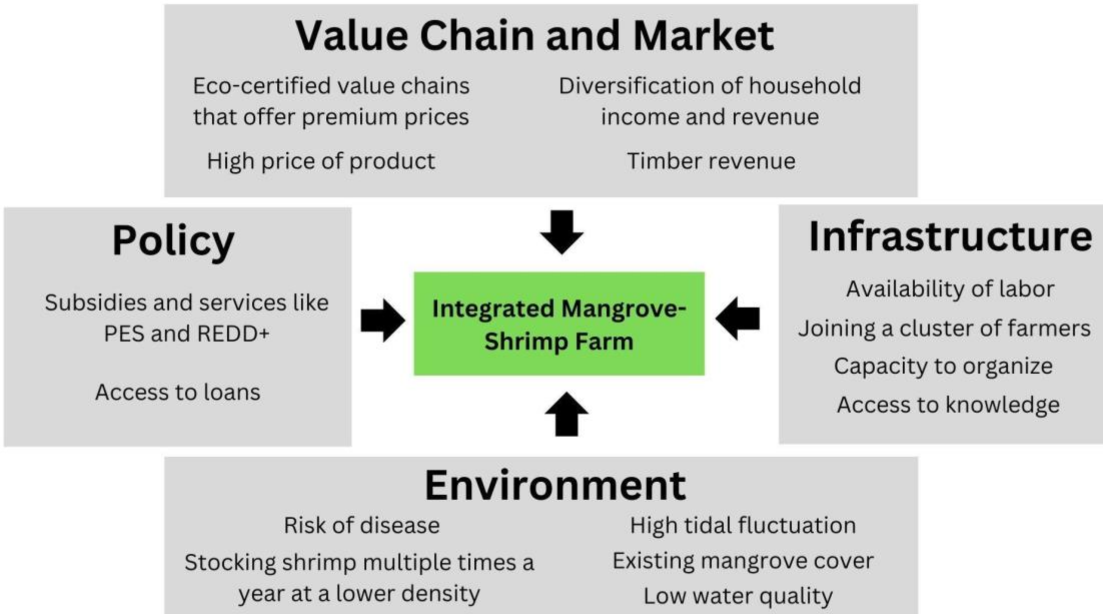


Figure 2. Main drivers influencing a farmer's decision-making to shift to an integrated mangrove-shrimp system.

In addition to the factors that drive a farmer to adopt an integrated mangrove-shrimp system, several factors disincentivize a farmer to transition (Figure 3). On the side of the value chain and export market, the organic value chain is often characterized by delays of payments to farmers of several weeks, a lack of transparency in the calculation of premium prices, and unattractive premium prices (Ho 2012). Ha et al. 2012 detail that in the shrimp value chain, premium prices are at times only 6% instead of the expected 20% markup (Tran Thi Phung 2012). Additionally, a low market price of crab or fish will be an obstacle for farmers to plant mangroves and shift to a polyculture model where they raise shrimp, fish, and crab (Gunawan 2012). In regards to infrastructure, a lack of labor, capital, knowledge, and community are major barriers to the implementation of an integrated system. Without the knowledge-sharing associated with the specific conditions to operate a productive integrated shrimp-mangrove farm, farmers will not achieve returns that are comparable to an extensive system and may not reap the benefits of price premiums and associated ecosystem services. On the side of policy and regulation, the mangrove-to-pond area regulation is unattractive to farmers who do not understand the potential benefits of such a policy and would rather have a larger pond area instead of mangroves. Additionally, the existing complex, non-transparent mechanism for mangrove exploitation by the government and its guidelines reduce the incentive for farmers to properly manage their forest cover (T. T. T. Ha, van Dijk, and Bush 2012). Benefits from forest exploitation in an integrated mangrove-shrimp system are estimated to be seven times lower than the value on the auction market for a system sold independently of the State Forest Enterprise government (T. T. P. Ha, van Dijk, and Visser 2014).

Environmental factors also may deter a farmer from adopting an integrated shrimp-mangrove system. Farmers that control their water exchange and water quality using water treatment and pond preparation are less likely to transition to the integrated system if they are already able to control their water quality and water exchange well in their existing system (T. T. P. Ha et al. 2013). A focus on water quality management by farmers is also associated with a higher intensity of stocking of shrimp. Finally, farms that already have low tidal fluctuation will not be able to achieve healthy mangroves and a highly productive mangrove-integrated system, which decreases a farmer's likelihood of investing in converting to an integrated system.

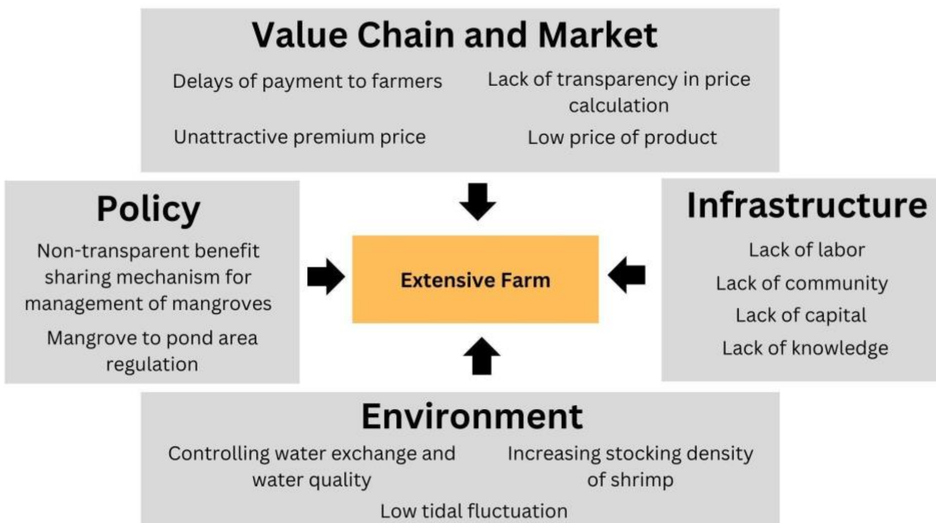


Figure 3. Main drivers influencing a farmer's decision-making to continue with the existing extensive farming system.

Although there are varying levels of success in the implementation of mangrove-shrimp farming in Ca Mau province in Vietnam, the implementation of the Selva Shrimp Initiative, an aquaculture improvement initiative developed by Switzerland-based Blueyou Consulting, has recently taken off in Vietnam. The project, which started in 2008, promotes silvofishery with a focus on the extensive production of *P. monodon.* The Selva Shrimp Initiative set up a traceability and quality assurance system for small-scale silvofishery producers that is audited by a third party, which includes Naturland, the EU Organic Aquaculture Regulation, the

Aquaculture Stewardship Council (ASC), and the Fair Trade USA Seafood Program (Fletcher 2020); Benguerel 2024).

To achieve certification through the Selva Shrimp Initiative, farmers must have at least 40% of their ponds covered in mangroves, and farmers are not allowed to use supplementary feed, medicine, or fertilizers. Shrimp post-larvae must come from hatcheries and there is no allowance for wild-caught post-larvae, which differs from systems which use wild-caught seed. There is a maximum stocking density of 22 post-larvae per square meter and shrimp are harvested every two weeks, the first harvest taking place three months after the post-larvae are stocked in the pond. Currently, 3,350 farmers in Vietnam operate under the Selva Shrimp standard in an area covering 17,000 hectares of Vietnam and these produce on average 250 kg of shrimp per hectare per year (Fletcher 2020). Selva Shrimp are currently exported to the United States, Canada, and Japan, and is funded by the IUCN.

The Selva Shrimp Initiative has recently expanded to Kalimantan in Indonesia with hopes of halting mangrove deforestation in the country. However, there are several barriers to implementation in Kalimantan. In the traditional *tambak* system in Kalimantan, ponds are between 20 and 100 hectares, which is much bigger than Vietnam, and there are no mangroves and low yields. Farmers generally do not invest significant capital and labor in pond management which causes ponds to silt over time and water temperatures to swing widely in shallow areas with low oxygen levels. These water quality issues are exacerbated by fertilizer use which is common in polycultures with milkfish that feed on algae (Fletcher 2020). Farmers that adopt silvofishery and Selva Shrimp certification in Indonesia will need to increase the rate of water exchange to account for the amount of organic matter introduced to the system by litter from mangroves and support a healthy environment for mangrove growth. In January of 2024, eight partner farmers joined the program, contributing 103 hectares of shrimp ponds and planting 23,950 mangrove propagules in the ponds ("Kalimantan Mangrove Shrimp Project" 2021). However, it has been difficult for the Selva Shrimp Initiative to sign formal agreements with pond owners due to resistance to adapting current farming methods without seeing a proof-of-concept at a local shrimp farm ("Blue Natural Capital" 2020). The hesitancy of farmers to transition from an extensive to an integrated mangrove-shrimp farm highlights the importance of the environmental, market, regulatory, and infrastructural pre-conditions necessary to incentivize farmers to adopt a silvofishery system.

4d) Policy Options for Silvofishery in Indonesia

In Indonesia, mangrove forests are generally designated into Forest Areas (FA), which are managed by the Ministry of Environment and Forestry, and Areas for Other Uses (APL) that are managed by the Ministry of Marine Affairs and Fisheries. However, this arrangement became more complicated in 2021 when the Peat and Mangrove Restoration Agency was established at the national level, which was tasked to coordinate with national government agencies in implementing peatland and mangrove restoration. The governing bureaucracies all follow their own regulatory frameworks.

There are many policies concerning mangroves in Indonesia, yet an absence of strong and clear regulatory frameworks dedicated to the protection and conservation of mangroves in Indonesia. Due to the increasing economic value of mangrove ecosystems, local and central governments have implemented their own policy priorities and management concepts which are often overlapping and sometimes conflict. Institutions related to mangrove utilization, management, and conservation should be synchronized by strong regulatory frameworks that overcome sectoral boundaries (Mursyid et al. 2021; Arifanti et al. 2022).

Ca Mau province in Vietnam contrasts from Indonesian mangrove policy in that it has enforced significant and centralized policies to halt mangrove deforestation whereas Indonesia’s existing mangrove policies lack strong and clear regulatory frameworks. The major policy mechanism that drove the implementation of integrated mangrove-shrimp farming in Vietnam was Decision No. 64 of 1991 which allocated 70% of farmland area for mangroves and 30% for ponds and housing, but implementation has also been driven by certification schemes and Payments for Ecosystem Service (PES) financial incentives. Indonesia has implemented a financial incentive bio-rights scheme for mangrove conservation but has not yet implemented REDD+ and PES for mangrove ecosystem services in the country. These incentives could be implemented in Indonesia. Additionally, a major barrier to farmers in implementing a silvofishery system is a lack of access to financing infrastructure in Vietnam and also Indonesia. Policy options for mangrove conservation and the implementation of silvofishery in Indonesia come from policies that have facilitated the widespread adoption of integrated mangrove-shrimp farming in Vietnam and lessons learned from Indonesia and Vietnam (Figure 4).

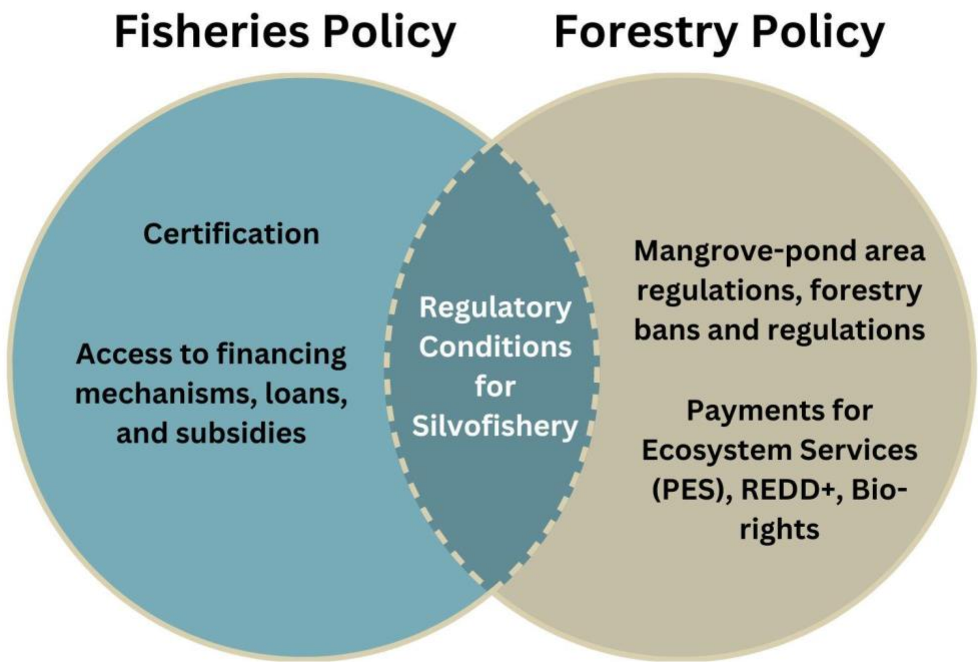


Figure 4. Potential regulatory policy pathways to increase silvofishery in Indonesia.

4e) Policy Pathways

Policy Pathway 1: Mangrove-Pond Area Regulation, Forestry Bans, and Regulations

- **Summary**: Similarly to Vietnam, Indonesia could implement a regulatory policy such as a mangrove-to-pond area regulation, forestry bans, or other forestry regulations to halt the rate of mangrove deforestation and drive a transition to a silvofishery system. This type of policy has been the major contributor to the widespread prevalence of integrated mangrove-shrimp farming in Ca Mau Province, Vietnam.
- **Tradeoffs:** Indonesia's mangroves are covered by 22 different laws and are governed by at least 18 different agencies, which results in complicated, conflicting, or unclear policy contexts and decisions (Wever et al. 2012; Sukardjo 2012). Implementing a central policy for mangrove protection in Indonesia is impeded under the decentralized structure of the political system. Additionally, Indonesia faces major issues with oversight–for example, nationally mandated Tanjung Panjang Nature Reserve has continued to be severely deforested due to its remoteness and a lack of national oversight (Friess et al. 2016). A

mangrove-to-pond area regulation or forestry ban must be implemented at a local scale with consistent and strong oversight in order to be successful in Indonesia. Additionally, such a regulatory policy must be implemented with complementary policies that offer financial incentives for mangrove conservation for shrimp farmers. As evidenced from Ca Mau Province in Vietnam, although integrated shrimp-mangrove farming has a high uptake in the region, there is low farmer satisfaction due to a lack of incentives and training for farmers to operate productive farms.

Policy Pathway 2: Financial Incentives for Mangrove Conservation (PES, REDD+, Bio-Rights)

- **Summary**: Overall, Indonesia has demonstrated interest in PES, REDD+, and Bio-rights schemes with varying degrees of success and prevalence, although pilot projects have been implemented in these three categories. Including a strong policy framework in national and provincial law is key to ensuring the success of these financial incentives for mangrove conservation and restoration.
- **PES (Payments for Ecosystem Services):** Payments for ecosystem services (PES) schemes have operated in Indonesia for more than a decade and are relatively widely accepted, ranging from pilot programs to more established schemes (Landell-Mills, Porras, and International Institute for Environment and Development 2002); (Suyanto et al. 2005). Indonesia has not implemented a widespread PES framework for mangrove conservation and restoration, but has implemented PES schemes in places like Lombok, West Nusa Tenggara and Sumber Jaya, Lampung Province. The PES scheme in Lombok, West Nusa Tenggara aims to increase watershed protection in the upstream forest area and compensate farmers for planting trees and preserving water resources. Funding to farmers was provided by downstream tap water users and is mandated by local regulation as *Pembayaran Jasa Lingkungan (Fauzi and Anna 2013)*. In the PES scheme in Sumber Jaya, Lampung Province, a hydropower company paid upstream farmers with its Corporate Social Responsibility (CSR) funding to reduce sedimentation and rehabilitate forested areas (Fauzi and Anna 2013).
- **REDD+ (Reduced Emissions from Deforestation and Forest Degradation):** Indonesia has historically been enthusiastic about REDD+ since the adoption of the 2007 Bali

Action Plan and has actively participated in international REDD+ negotiations. In 2013, the REDD+ Agency was established by Presidential Decree No. 62/2013 (Harada et al. 2015). So far, national parks have been the main target of REDD+ efforts in Indonesia, such as the REDD+ project in Meru Betiri National Park. The implementation of REDD+ in the park demonstrated high local interest in joining the project to generate a form of alternative income–a similar approach could drive mangrove conservation (Harada et al. 2015). Yet, there are issues related to the implementation of REDD+ in Indonesia, which include a lack of local community involvement in the management of state forests and conflict over state forest property rights (Muttaqin 2012). Studies show that to successfully implement REDD+ in Indonesia, there must be land tenure reforms devolving property rights, communities should be given partial rights to forest resources, or communities are paid for their contribution to forest conservation (Tacconi, Mahanty, and Suich 2010).

- **Bio-Rights:** Bio-rights is a financing scheme for reconciling poverty alleviation and environmental conservation, whereby providing micro-credits for sustainable development, local communities refrain from unsustainable practices ("Biorights in Theory and Practice: A Financing Mechanism for Linking Poverty Alleviation and Environmental Conservation" 2009). Bio-rights was introduced to Pesantren Village in Central Java in 1998 to re-green land that had been converted to shrimp aquaculture ponds. Micro-credits were provided to community groups to develop activities that can develop a sustainable income, and loan repayments were replaced by conservation services such as reforestation and habitat protection. It was found that bio-rights incentives can encourage communities to participate actively in mangrove restoration, and Pesantren Village benefited from improvement in livelihoods and environmental conditions (Suharti 2017).
- **Tradeoffs:** The recognition of PES schemes in regional and national laws will eventually make PES schemes mandatory rather than voluntary. In Indonesia, voluntary initiatives for conserving forests are weak, so encouraging local governments to initiate more PES-like initiatives is important. For existing PES schemes like in Lampung and Lombok, there are issues in fiscal arrangements and the transaction costs of these schemes. At present, there is not a fiscal system to accommodate the revenue from environmental

services, which is further hindered by the decentralization of natural resource management in Indonesia. Despite these issues, there has been high levels of governmental interest in PES, which has the potential to couple poverty alleviation with environmental conservation, a major goal of silvofishery (Fauzi and Anna 2013). Due to the decentralized structure of Indonesia, engagement with stakeholders has been an issue in the implementation of REDD+ (Mulyani and Jepson 2013). Developing strong streamlined frameworks and campaigns for financial incentives for mangrove conservation is of key importance.

Policy Pathway 3: Certification

- **Summary**: A major driver of silvofishery in Indonesia could be the adoption of organic certification and price premiums for shrimp that are raised in a silvofishery system. Certification programs like the Selva shrimp standard have demonstrated widespread success in adoption across Ca Mau province and are in the process of implementation in Vietnam. Third-party certifications like ASC, BAP, and GSA have the potential to set a standard for integrated mangrove-shrimp farming by implementing a mangrove conservation criterion into their certification for shrimp farming. Some certifications such as the ASC shrimp standard, which is being implemented in East Java and Kalimantan, already includes a standard for restoring mangroves (Friess et al. 2016). Moreover, the implementation of IndoGAP in the country offers the opportunity to implement a widespread national criteria for mangrove certification. Indonesia stands at a crossroads where the country may opt for its current volume goal of shrimp, which is similar to India, or it may pivot to a goal of quality and reputation, similarly to Ecuador.
- **Tradeoffs:** At present, initial interest in the ASC shrimp standard, which has a mangrove criteria, is low. Traditional aquaculturists are unlikely to be able to afford certification and do not believe that mangroves contribute to increased productivity. If farmers were to be presented with various certification options, and some did not offer a mangrove conservation criteria, it is more likely that a farmer would choose the less strict certification criteria to access premium prices. In order to be successful, all major certifications in Indonesia, including IndoGAP, would need to implement a mangrove restoration criteria. Additionally, these criteria should be paired with education and

training for farmers to implement a productive silvofishery system and understand the value of mangroves.

Policy Pathway 4: Access to Financing Mechanisms, Subsidies, and Loans

- **Summary**: Case studies in Vietnam and Indonesia highlight that a major barrier to shrimp farmers is a lack of access to financing mechanisms and capital. A majority of shrimp farmers in Indonesia maintain some level of debt to a bank, a private lender, or a cooperative. A major barrier to the implementation of silvofishery is a lack of capital, infrastructure, and labor to make the transition from an extensive to silvofishery system. Thus, implementing subsidies, loans, bio-rights schemes (see above in Policy Option 1) and accessible financing mechanisms to farmers is key to increasing silvofishery in Vietnam. The success of eFishery in Indonesia offers a potential pathway for financial security for farmers by opening access to Kabayan financial services (Kasih, Bayar Nanti) which provide saprokan facilities with payment systems of up to 6 months (Zainudin et al. 2023). eFishery cooperates with both financial institutions and the government, opening up avenues for public-private partnerships that may benefit farmers. In 2022, the Asian Development Bank (ADB) approved a US $93 million loan to advance shrimp farming for smallholder shrimp farmers in Bali, Banten, Central JAva, East Java, Lampung, Nanggroe Aceh Darussalam, and South Sulawesi. The loan is expected to benefit 5,200 smallholder farmers from infrastructure and capacity improvements, and an additional 35,000 smallholders with increased access to quality feed and shrimp fry, as well as capacity building programs ("ADB Pours $93m Loan to Advance Indonesia's Shrimp Farming - Economy," n.d.).
- **Tradeoffs:** The impacts of the ADB loan and eFishery program in Indonesia has yet to be evaluated. Additionally, these financing mechanisms are largely driven by the private sector through government partnerships, but it is unclear how governmental policy and regulations will support further access to these loans and financing mechanisms.

5. Conclusion

We believe that silvofishery can be considered as a sustainable and viable solution for Indonesian shrimp farmers hoping to expand production and compete in global export markets.

Overall, silvofishery is a sustainable shrimp-aquaculture method that has the potential to meet Indonesia's growth and conservation objectives. In comparison with intensive shrimp farming, silvofishery offers competitive economic advantages, reductions in disease risk, and opportunities for mangrove conservation. Additionally, silvofishery can help farmers to maintain cultural ties and incorporate local knowledge of ponds and waters. Silvofishery farms provide an attractive option for small-scale farmers because of their lower capital investment and cost-base (e.g no feed, no water pumping infrastructure, no antibiotics) as compared with more intensive methods. Silvofishery methods can also help to buffer farmers from price volatility in international shrimp markets by providing alternate forms of revenue from the other species co-cultured in the farm, and allowing farmers to receive a price premium for their larger-sized and less-chemically-contaminated shrimp.

Key challenges regarding the adoption of silvofishery are, at a high level, the need to prioritize long-run profits and valuation of mangrove ecosystems in order to fully account for the benefits of silvofishery shrimp compared to intensively farmed shrimp. In terms of implementation, there is also a need for technical and place-based expertise to tailor individual silvofishery systems to their immediate environment.

In Vietnam, there are four major policy areas that support the adoption of silvofishery: mangrove conservation regulation, financial incentives, product certification, and streamlined investment access. To this end, Indonesia already has policy pathways to promote silvofishery adoption, with opportunities for growth in the other three areas.

Future research on this topic could engage in a more thorough and detailed comparison of the long-run profits from intensive farming systems versus silvofishery (taking into account disease boom-and-bust; rejection in international export markets; inflation and exchange rates). We would also benefit from better understanding how price premiums for silvofishery farmers shrimp can be achieved through certification schemes in the Indonesian context. To this end, more case studies for different shrimp farming systems could be amassed from other countries including Bangladesh, Ecuador, Thailand and the Philippines, and then compared to the current state of policy/regulation/implementation across Indonesia. Further research could also be conducted to understand the national silvofishery landscape and the ways in which it might address other priorities of the Indonesian government, such as reducing stunting and improving the nutrition of coastal communities.

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7. Appendices

Appendix Table 1. Calculated costs and revenue of silvofishery ponds in Indonesia using data from Rusdi & Jasin 1994 (cited in Takashima 2000)

Table 3. **Costs-and-returns of silvofishery** (rupiah/ha/year)

Item	Pond covered by dense mangrove trees (> 80%)		Pond covered by sparse mangrove trees (40-60%)	
Farm (area)	6 ha	3 ha	4 ha	8 ha
Operational costs	172,550	609,200	501,000	2,353,700
Variable costs				
Seeds	0	191,400	217,500	360,000
Fertilizer	0	53,000	40,500	50,400
Chemicals	0	29,000	30,000	0
Harvesting	37,500	40,000	25,000	41,300
Fixed costs	1,688,000	295,800	284,000	1,902,000
Gross revenue	360,000	1,235,000	1,128,000	1,385,000
Net revenue	154,000	625,000	529,000	933,000
Total net revenue	924,000	1,875,000	2,116,000	7,464,000

Appendix Figure 1. Diagram of integrated mangrove-shrimp farm system in Ca Mau, Vietnam (Barry Clough et al. 2000)