



# AGRI MAGAZINE

(International E-Magazine for Agricultural Articles)

Volume: 03, Issue: 06 (June, 2026)

Available online at <http://www.agrimagazine.in>

© Agri Magazine, ISSN: 3048-8656



## Integrated Mangrove-Shrimp Farming: A Nature-Based Pathway for Sustainable Aquaculture

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The rapid expansion of shrimp aquaculture has contributed significantly to global seafood production and rural livelihoods. However, the conversion of mangrove forests into shrimp ponds has emerged as a major environmental concern, leading to biodiversity loss, coastal degradation, and increased carbon emissions. Integrated Mangrove Aquaculture (IMA), also known as silvofisheries, combines shrimp farming with mangrove conservation and restoration. This approach enhances ecological sustainability while maintaining farm productivity and profitability. The present article reviews the importance of mangrove ecosystems, the impacts of conventional shrimp farming, and the potential of integrated mangrove-shrimp farming as a sustainable aquaculture strategy.

**Keywords:** Mangroves, Shrimp farming, Silvofisheries, Blue carbon, Sustainable aquaculture, Climate change

### Introduction

Aquaculture is one of the fastest-growing food production sectors globally, contributing substantially to food security and economic development. Shrimp farming accounts for a major share of crustacean aquaculture production, with countries such as China, India, Indonesia, Vietnam, and the Philippines being leading producers. In India, shrimp culture expanded rapidly during the late 1980s due to increasing global demand and export opportunities. Despite its economic success, intensive shrimp farming has been associated with several environmental issues, including habitat destruction, disease outbreaks, coastal erosion, salinization of agricultural land, and loss of biodiversity (Boyd and McNevin, 2015). Among these impacts, the destruction of mangrove ecosystems remains one of the most significant environmental concerns.

### Mangroves: Ecological Importance and Global Status

Mangroves are salt-tolerant forests that occupy tropical and subtropical intertidal regions. They serve as an ecological interface between terrestrial and marine ecosystems and provide a wide range of ecosystem services. Mangroves support fisheries, protect coastlines from storm surges, improve water quality, and act as important carbon sinks (Donato et al., 2011). Studies indicate that mangroves store three to four times more carbon per unit area than most tropical forests, making them one of the most carbon-rich ecosystems on Earth. These ecosystems contribute nearly 30% of global blue carbon sequestration despite occupying a relatively small geographic area (Ahmed et al. 2017).

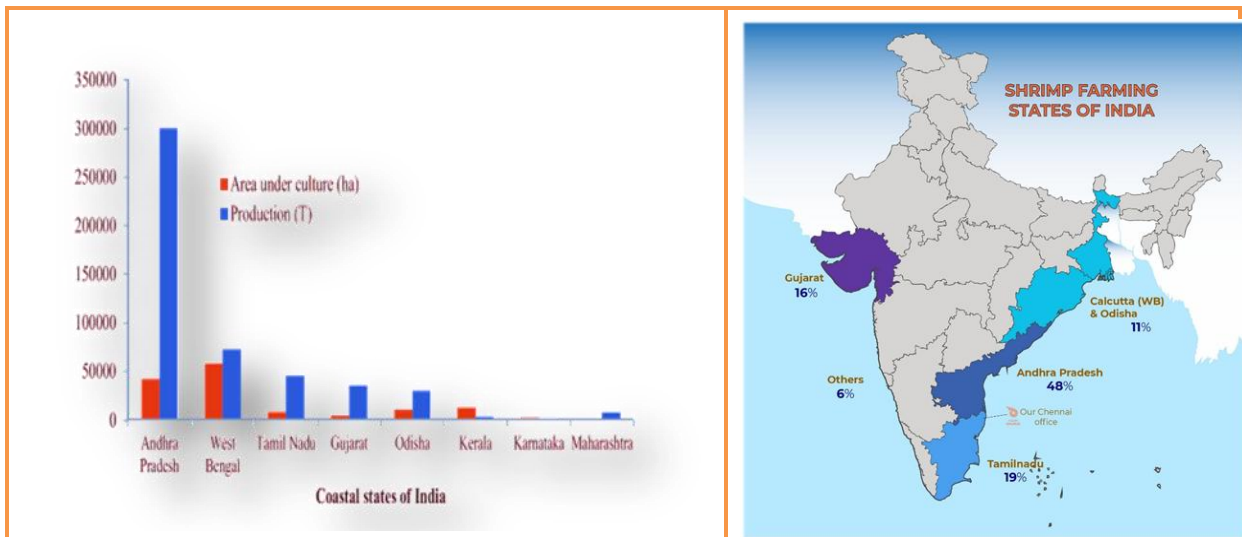


Figure 1. Global shrimp production and major shrimp-producing countries.

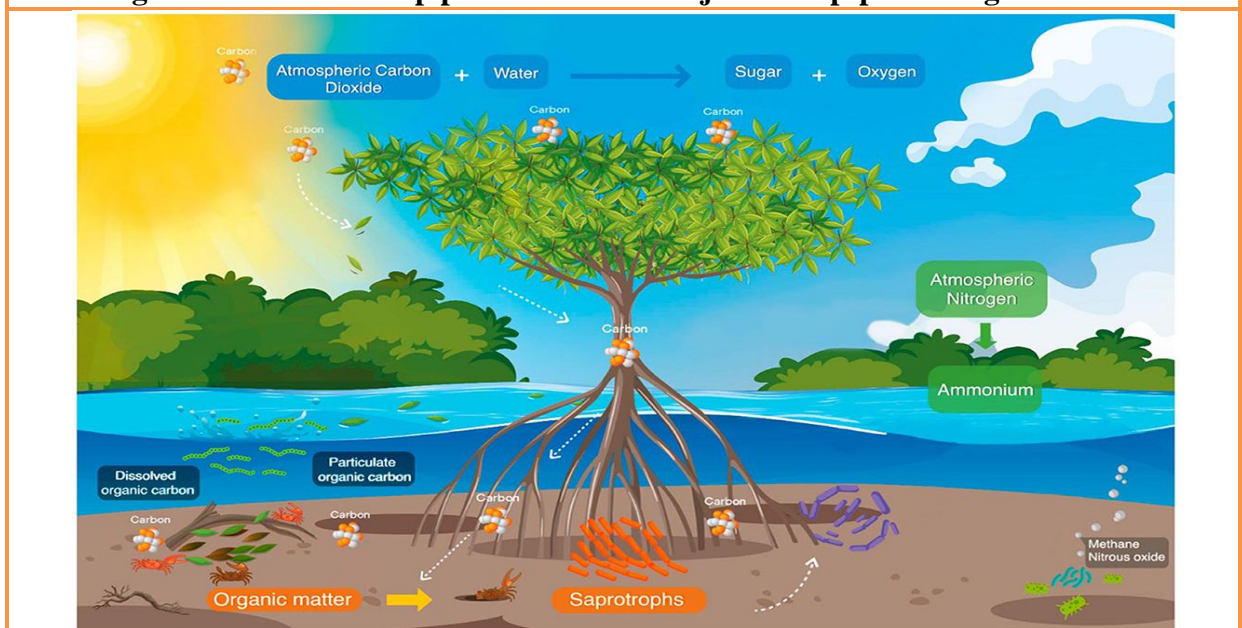


Figure 2. Carbon dynamics and ecosystem services of mangrove forests

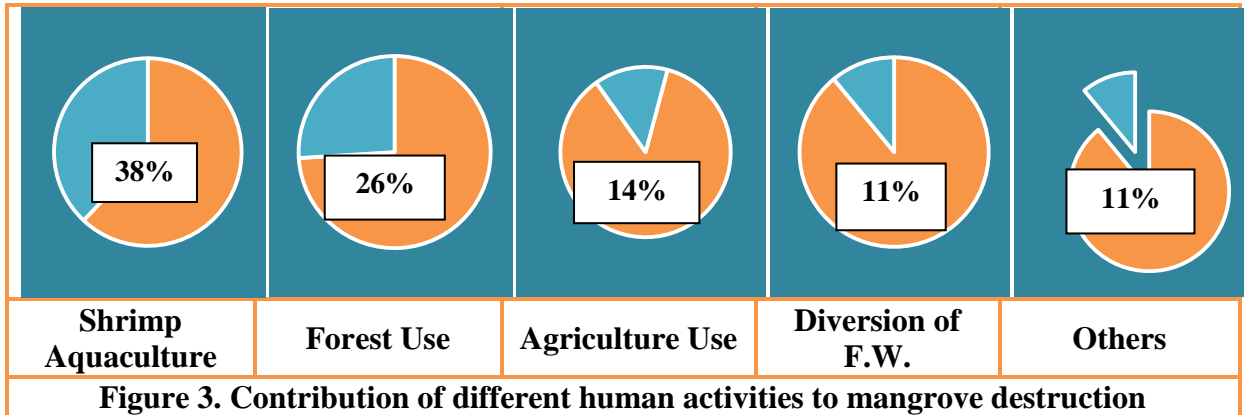
Table 1. Top countries with mangrove cover worldwide

Country	Area(km <sup>2</sup> )	Proportion of global total (%)
Indonesia	31,894	20.9
Brazil	13,000	8.5
Australia	9910	6.5
Mexico	7701	5.1
Nigeria	7356	4.8
Malaysia	5029	3.3
Bangladesh	4951	3.2
Cuba	4944	3.2
<b>India</b>	4326	2.8
Papua New Guinea	4265	2.8
Colombia	4079	2.7
Total	1,04,552	68.5

India possesses approximately 4,975 km<sup>2</sup> of mangrove forests, with West Bengal and Gujarat accounting for the largest share. However, significant areas of mangroves have been lost due to aquaculture expansion and other developmental activities (Goldberg et al., 2020).

### Impact of Shrimp Aquaculture on Mangrove Ecosystems

The conversion of mangrove forests into shrimp ponds has been identified as a major driver of coastal ecosystem degradation. Globally, shrimp farming is responsible for approximately 38% of total mangrove loss (Friess et al., 2019). Large-scale mangrove deforestation has been reported in Indonesia, Bangladesh, Thailand, Vietnam, India, and the Philippines. The removal of mangroves not only reduces biodiversity but also releases significant quantities of stored carbon into the atmosphere, thereby contributing to climate change (Hamilton, 2013).



The environmental consequences of mangrove conversion include:

- Increased coastal erosion
- Reduced fish and shrimp nursery habitats
- Deterioration of water quality
- Loss of biodiversity
- Enhanced greenhouse gas emissions
- Greater vulnerability to cyclones and storm surges

### Integrated Mangrove Aquaculture: A Sustainable Alternative

Integrated Mangrove Aquaculture (IMA), commonly referred to as silvofisheries, is an environmentally friendly farming system that combines aquaculture with mangrove conservation. The concept aims to balance economic production with ecosystem protection.

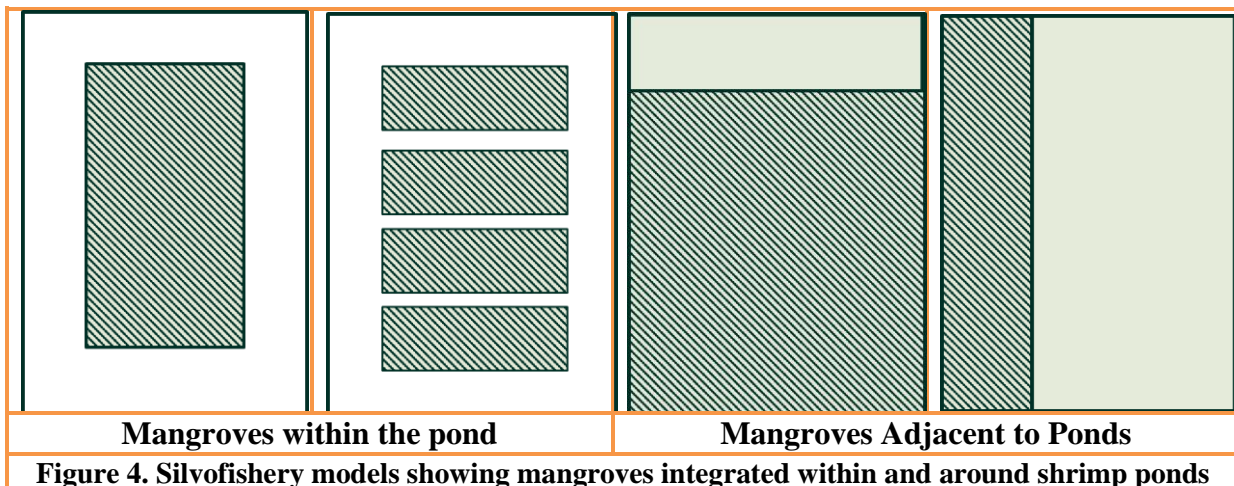
Two major silvofishery designs are commonly practiced:

#### Type I: Mangroves Within the Pond

In this system, mangroves occupy approximately 60–80% of the farm area, while shrimp are cultured in channels surrounding the trees.

#### Type II: Mangroves Adjacent to Ponds

Mangroves are planted along pond embankments or adjacent areas while shrimp are cultured in separate water bodies.



Countries such as Vietnam, Indonesia, Thailand, Malaysia, Kenya, and the Philippines have successfully adopted these systems as sustainable aquaculture models.

## Ecological and Economic Benefits of Integrated Mangrove-Shrimp Farming

Mangroves perform several ecological functions within aquaculture systems. Their root networks trap sediments, improve water quality, and provide habitat for aquatic organisms. Mangrove litter contributes natural nutrients and food sources for cultured species.

Studies have shown that integrated systems produce multiple environmental benefits, including:

- Enhanced biodiversity conservation
- Improved nutrient recycling
- Reduced farm effluent discharge
- Increased carbon sequestration
- Coastal protection against extreme weather events

Economically, integrated mangrove-shrimp systems often provide stable returns with lower production risks. Bosma et al. (2016) reported shrimp productivity ranging from 175–398 kg ha/ year under integrated systems. Research conducted in Vietnam demonstrated that farms maintaining 30–50% mangrove cover achieved higher economic returns and better benefit-cost ratios compared with conventional systems (Johnston et al., 2000).

## Integrated Mangrove Farming and Climate Change Mitigation

Mangroves are recognized as one of the most efficient blue carbon ecosystems. They capture atmospheric carbon dioxide and store it in biomass and sediments over long periods. According to Ahmed et al. (2017), mangrove ecosystems can store between 160 and 360 tonnes of carbon per hectare. Conversely, the conversion of mangroves into shrimp ponds can release between 661 and 1135 tonnes of carbon per hectare.

## Future Prospects

Growing concerns regarding climate change, biodiversity conservation, and sustainable food production have increased global interest in nature-based aquaculture solutions. Integrated mangrove-shrimp farming aligns with international sustainability goals by enhancing food security while restoring coastal ecosystems.

Future development should focus on:

- Mangrove restoration programs
- Adoption of organic shrimp farming practices
- Financial incentives for ecosystem conservation
- Farmer awareness and training programs
- Blue carbon credit mechanisms

These measures can enhance the adoption and long-term success of integrated mangrove aquaculture systems.

## Conclusion

Integrated mangrove-shrimp farming represents a practical and sustainable approach to aquaculture development. By combining shrimp production with mangrove conservation, the system offers ecological, economic, and social benefits. It improves water quality, enhances biodiversity, increases carbon sequestration, and provides stable livelihoods for coastal communities. As global demand for seafood continues to rise, integrated mangrove aquaculture offers a promising pathway toward environmentally responsible and climate-resilient aquaculture.

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