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Integrated Mangrove Aquaculture: A Sustainable Approach for Coastal Resource Management

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The growth of coastal aquaculture has boosted seafood production and helped support the livelihoods of millions of people worldwide. But converting mangrove forests into aquaculture ponds has led to environmental problems such as habitat loss, declines in biodiversity, coastal erosion, and damage to ecosystem services. Integrated Mangrove Aquaculture (IMA), also called silvofisheries, has emerged as a sustainable approach that integrates aquaculture with mangrove conservation and restoration. In this system, mangroves are kept within or around aquaculture farms, giving benefits like better water quality, nutrient recycling, coastal protection, and carbon storage. Integrated mangrove aquaculture also helps conserve biodiversity and boosts the productivity and sustainability of aquaculture operations. On top of ecological benefits, it offers economic opportunities and helps improve the livelihoods of coastal communities. This article highlights the concept, benefits, challenges, and future potential of integrated mangrove aquaculture as a sustainable strategy for coastal resource management.

Keywords: Integrated Mangrove Aquaculture, Mangrove Conservation, Sustainable Aquaculture, Coastal Ecosystems

Introduction

Aquaculture has become one of the fastest-growing sectors of food production worldwide, contributing significantly to global fish and shellfish supplies. Coastal aquaculture, particularly shrimp farming, has expanded rapidly over the past few decades due to increasing market demand. While this growth has generated substantial economic benefits, it has also led to the large-scale destruction of mangrove forests in many tropical and subtropical regions. Mangroves are among the most productive ecosystems on Earth and provide numerous ecological services, including shoreline stabilisation, nutrient cycling, biodiversity conservation, and protection against storms and tidal surges. The conversion of mangrove forests into aquaculture ponds has disrupted these valuable ecosystem functions and has raised concerns regarding the long-term sustainability of conventional aquaculture practices. To address these issues, researchers and policymakers have promoted Integrated Mangrove Aquaculture (IMA), a system that combines aquaculture production with mangrove conservation. By integrating mangrove vegetation within or around aquaculture farms, this approach seeks to balance economic productivity with environmental sustainability. Integrated mangrove aquaculture is increasingly recognised as a nature-based solution that can enhance resilience to climate change while supporting sustainable livelihoods for coastal communities.

Concept of Integrated Mangrove Aquaculture

Integrated Mangrove Aquaculture refers to a farming system in which aquaculture activities are combined with the conservation, restoration, or cultivation of mangrove forests. Instead

of clearing mangroves for pond construction, mangrove trees are retained or replanted within aquaculture areas. The system allows cultured aquatic organisms to benefit from the natural productivity and ecological functions of mangrove ecosystems. The integration of mangroves and aquaculture creates a mutually beneficial relationship. Mangroves improve environmental conditions within aquaculture ponds by filtering pollutants, stabilising sediments, and enhancing nutrient cycling. In return, aquaculture activities provide economic returns that encourage the protection and sustainable management of mangrove resources.

Types of Integrated Mangrove Aquaculture Systems

Mixed Mangrove-Pond System: In this system, mangrove trees are maintained within aquaculture ponds. The pond area contains both water and mangrove vegetation, allowing direct interaction between cultured species and the mangrove ecosystem. Shrimp, fish, and crabs are commonly cultured in these ponds.

Peripheral Mangrove System: Mangrove trees are planted along pond embankments and surrounding areas. The vegetation protects pond structures from erosion while providing ecological benefits such as shade, habitat, and nutrient recycling.

Separate Mangrove-Aquaculture Zones: In this approach, aquaculture ponds and mangrove forests are maintained as adjacent but separate units. Water exchange between the two systems allows the benefits of mangrove filtration and nutrient cycling to support aquaculture production. These systems are collectively referred to as silvofisheries and are widely practised in countries such as Indonesia, Vietnam, Bangladesh, India, Thailand, and the Philippines.

Aquaculture Species Cultured in Integrated Mangrove Systems

A variety of aquatic species can be cultured within integrated mangrove aquaculture systems. Shrimp farming is one of the most common applications, particularly involving tiger shrimp (*Penaeus monodon*) and whiteleg shrimp (*Litopenaeus vannamei*). Various finfish species such as milkfish, mullets, seabass, and tilapia, are also cultured successfully in mangrove-associated ponds. Mud crabs are highly suitable for these systems because mangrove habitats provide ideal shelter and feeding conditions. In addition, shellfish such as oysters and mussels may be cultivated in mangrove waters, contributing to both production and ecosystem health.

Production Process in Integrated Mangrove Aquaculture

The production process begins with the selection of a suitable coastal area where mangrove vegetation can be conserved or restored. Mangrove trees are either retained or planted within and around aquaculture ponds. The desired aquatic species are then stocked at appropriate densities. Water exchange is managed carefully to maintain suitable environmental conditions while benefiting from the natural filtration provided by mangroves. Regular monitoring of water quality, fish or shrimp health, and mangrove growth is conducted to ensure sustainability. Harvesting is carried out after the culture period, while mangrove vegetation continues to provide long-term ecological benefits.

Mangrove conservation/restoration → Pond preparation → Stocking of aquatic species → Water quality management → Growth and monitoring → Harvesting → Sustainable production

Ecological Benefits: Integrated mangrove aquaculture helps protect the environment while supporting aquaculture production. Mangroves naturally filter water, improve water quality, and provide shelter and breeding grounds for many aquatic species. Their roots prevent coastal erosion and reduce the impact of storms and tidal waves. Mangroves also absorb and store carbon, helping to combat climate change and maintain healthy coastal ecosystems.

Economic Benefits: This system provides income from multiple sources, including fish, shrimp, crabs, shellfish, honey, and other mangrove products. Since mangroves naturally supply food and improve water quality, farmers can spend less on feeds and chemicals.

Sustainable products from these systems may also earn higher prices in the market, improving farmers' incomes.

Social Benefits: Integrated mangrove aquaculture creates employment opportunities and supports the livelihoods of coastal communities. It improves food security by producing nutritious seafood and encourages people to participate in mangrove conservation. By combining environmental protection with economic benefits, the system promotes sustainable development and strengthens community resilience.

Challenges and Constraints

Despite its numerous benefits, integrated mangrove aquaculture faces several challenges. One major limitation is lower production yields compared to intensive aquaculture systems. Maintaining mangrove cover within aquaculture farms may reduce the area available for production. Additionally, managing the balance between aquaculture operations and mangrove conservation requires technical expertise and careful planning. Other challenges include land tenure conflicts, limited access to financial resources, inadequate technical support, and difficulties in obtaining certification for eco-friendly products. Climate change, sea-level rise, and extreme weather events may also affect the sustainability of these systems.

Future Prospects

The future of integrated mangrove aquaculture is promising as governments, researchers, and international organisations increasingly promote ecosystem-based approaches to aquaculture development. Advances in farm design, environmental monitoring, and sustainable management practices are expected to improve productivity while maintaining ecological benefits. Restoration of degraded mangrove areas, expansion of blue carbon initiatives, and the development of incentive programs for conservation are likely to enhance the adoption of integrated mangrove aquaculture. Increased awareness of sustainable seafood production and environmental stewardship will further support the growth of this innovative farming system.

Conclusion

Integrated Mangrove Aquaculture represents a sustainable approach to coastal aquaculture that successfully combines food production with environmental conservation. By integrating mangrove forests with aquaculture operations, the system enhances water quality, conserves biodiversity, protects coastlines, and contributes to climate change mitigation. It also provides economic opportunities and supports the livelihoods of coastal communities. Although challenges remain regarding productivity, management, and implementation, ongoing research and policy support are expected to strengthen the viability of integrated mangrove aquaculture. As the demand for sustainable seafood production continues to grow, integrated mangrove aquaculture has the potential to become a key component of environmentally responsible coastal development.

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