Aquasilviculture: A Sustainable Approach to Integrated Coastal Resource Management

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Abstract

Aquasilviculture is an integrated coastal resource management system that combines aquaculture with mangrove conservation or reforestation. This nature-based solution promotes environmental sustainability, economic viability, and social equity in coastal communities. In response to the harmful effects of conventional aquaculture, especially the large-scale clearing of mangroves, aquasilviculture offers a balanced approach that supports both ecological restoration and food production. This review explores the principles, benefits, challenges, pond construction methods, and future prospects of aquasilviculture as a sustainable livelihood strategy and an ecosystem-based adaptation tool.

Introduction

Aquasilviculture is an ecologically sustainable farming practice that integrates aquaculture with the conservation and rehabilitation of mangrove forests. This approach was developed in response to the environmental degradation caused by intensive aquaculture, particularly the widespread clearing of mangroves. It aims to balance economic livelihood with ecosystem preservation. By cultivating aquatic species such as shrimp, fish, or crabs alongside the protection or replanting of mangrove trees, aquasilviculture provides dual benefits: supporting the economic needs of coastal communities while restoring essential coastal habitats. This method enhances biodiversity and water quality, and it strengthens natural defenses against coastal erosion and the impacts of climate change. As a nature-based solution, aquasilviculture is crucial for achieving long-term environmental sustainability and food security in coastal regions.

Principles of Aquasilviculture

Aquasilviculture is founded on the principle of harmonious coexistence between aquaculture and mangrove ecosystems, aiming for ecological balance, economic sustainability, and social equity. This approach typically allocates 60–70% of the farming area to mangrove conservation or reforestation, while the remaining 30–40% is designated for aquaculture ponds. This spatial arrangement facilitates natural tidal exchange and nutrient cycling, reducing the need for artificial inputs such as pumps or chemical treatments. By preserving mangrove cover, the system enhances biodiversity, improves water quality, and provides natural protection against coastal erosion and extreme weather events. Moreover, community participation, the use of native species, and eco-friendly farming practices are central to aquasilviculture, ensuring that both environmental and livelihood needs are met sustainably and
inclusively.

Pond Construction and Layout

The construction and layout of ponds in aquasilviculture systems are meticulously planned to support aquaculture while conserving mangroves. Site selection focuses on low-lying coastal or estuarine areas that naturally experience tidal influences and have the potential for mangrove growth. Typically, the layout follows a 60:40 or 70:30 ratio, Ponds are constructed as shallow earthen basins, generally 0.8 to 1.5 meters deep, featuring well-compacted dikes and integrated water control structures, such as sluice gates, to manage tidal water exchange.

Internal canals and buffer zones are included to ensure effective drainage and promote mangrove growth around the ponds. Mangrove trees are planted along pond embankments and in intertidal zones to stabilize the soil and enhance ecological functions. This integrated design fosters sustainable water management, minimizes environmental impact, and creates a balanced ecosystem that benefits both aquatic and terrestrial productivity.

Species Cultured and Mangrove Compatibility

Aquasilviculture supports a variety of aquatic species that thrive in brackish water and coexist harmoniously with mangrove ecosystems. Commonly cultured species include shrimp *(Penaeus monodon and P. vannamei)*, mud crabs (*Scylla serrata)*, milkfish *(Chanos chanos),* and tilapia (*Oreochromis spp.)*. These species can grow effectively in low-input systems that utilize natural food sources and experience minimal environmental stress, benefiting from the shelter, organic matter, and improved water quality provided by nearby mangroves.

Penaeus vannamei

Penaeus monodon

Mangrove species such as *Rhizophora mucronata, Avicennia marina*, and *Sonneratia alba* are often integrated into aquasilviculture systems due to their robust root structures, high salinity tolerance, and ecological significance. Their presence not only stabilizes pond embankments but also enhances biodiversity and nutrient cycling. This synergy between aquatic and mangrove species ensures the resilience and productivity of the system, making aquasilviculture an ecologically sustainable and economically viable method of coastal aquafarming.

Chanos chanos

Oreochromis spp.

Scylla serrata

Benefits of Aquasilviculture

Aquasilviculture offers numerous environmental, economic, and social benefits, making it a sustainable alternative to traditional coastal aquaculture. Environmentally, it supports the restoration and conservation of mangrove forests, which act as natural water filters, carbon sinks, and protective barriers against storms and coastal erosion. By maintaining ecological balance, this system enhances biodiversity and improves water quality, reducing reliance on chemical inputs.

Economically, aquasilviculture provides diverse income opportunities for coastal communities through the cultivation of fish, shrimp, crabs, and mangrove-based products such as honey, fuelwood, and handicrafts. It also lowers operational costs by utilizing natural ecosystem services like tidal water exchange and organic waste recycling.

Socially, this approach empowers local communities by encouraging their active participation in resource management and conservation initiatives. It enhances food security, creates rural employment, and promotes knowledge sharing, all of which align with the

Avicennia marina

Rhizophora mucronata

Sonneratia alba

broader goals of sustainable development and climate change adaptation.

Challenges and Limitations

Despite its sustainability benefits, aquasilviculture faces several challenges that impede its widespread adoption. One key limitation is its lower productivity compared to intensive aquaculture systems, as the emphasis on ecological balance restricts stocking density and feed input. Additionally, land tenure issues and policy conflicts can arise, particularly in areas where mangroves are protected or ownership rights are ambiguous, creating barriers to long-term investment and management.

Farmers may lack the technical knowledge and training needed to effectively manage integrated systems, especially regarding water quality, species compatibility, and mangrove maintenance. Furthermore, the initial costs and labor required for mangrove planting and infrastructure development may deter smallholders. Regular monitoring and enforcement of sustainable practices are also challenging in community-based settings without adequate support. Addressing these limitations requires strong institutional support, community engagement, access to technical guidance, and policies that promote conservation-oriented aquaculture practices.

Global and Regional Applications

Aquasilviculture has been successfully implemented in various countries, particularly in tropical and subtropical coastal regions where mangroves and aquaculture coexist. In the Philippines, the National Aquasilviculture Program (NAP) has been instrumental in integrating fish and shrimp farming with mangrove reforestation, involving coastal communities in both livelihood development and environmental rehabilitation. Similarly, Vietnam and Indonesia have adopted silvofisheries models within their mangrove-shrimp farming systems, aided by government policies and support from international organizations to combat mangrove loss and promote sustainable aquaculture.

In Bangladesh, integrated mangrove-aquaculture practices have demonstrated potential in enhancing resilience to climate change and improving rural incomes. These regional initiatives illustrate the adaptability of aquasilviculture across different ecological and socioeconomic contexts, providing valuable lessons for scaling up the approach globally. Through community participation, institutional support, and knowledge sharing, aquasilviculture is increasingly recognized as a viable solution for sustainable coastal resource management.

Future Prospects

The future of aquasilviculture looks promising as the world increasingly embraces nature-based solutions to address climate change, biodiversity loss, and food security. With growing awareness of the ecological and economic benefits of mangroves, aquasilviculture offers a scalable approach to sustainable coastal development. Innovations in low-impact aquaculture practices, enhanced mangrove restoration techniques, and digital monitoring tools can improve the efficiency and appeal of these systems.

Furthermore, the rising demand for eco-certified seafood and blue carbon credits creates new economic incentives for communities and investors to adopt integrated approaches. Policymakers are also recognizing the importance of aquasilviculture in national climate adaptation and coastal protection strategies. By fostering community engagement, providing technical support, and integrating effective policies, aquasilviculture has the potential to transform degraded coastlines into productive, resilient ecosystems that support livelihoods and long-term environmental health.

Conclusion

Aquasilviculture is a sustainable and holistic approach to coastal resource management that combines aquaculture with mangrove conservation. It addresses the urgent need to balance environmental preservation with economic development, offering a viable solution to the ecological degradation caused by intensive aquaculture practices.

By prioritizing biodiversity, natural water management, and community involvement, aquasilviculture enhances the resilience of coastal ecosystems while supporting local livelihoods. Although it faces challenges such as lower yields and technical limitations, the long-term environmental, social, and economic benefits make it an appealing model for sustainable development. With increased support from governments, researchers, and international agencies, aquasilviculture has the potential to become a cornerstone of climate-resilient coastal farming and a blueprint for integrated natural resource management worldwide.