



Advances in Inland Fisheries for Sustainable Fish Production and Economic Development

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Inland fisheries are an important source of food, nutrition, and rural income, and are increasingly shifting from traditional practices to modern, technology-based aquaculture systems. This review highlights major advances in inland fisheries for sustainable fish production and economic development, including biofloc technology, recirculatory aquaculture systems (RAS), aquaponics, cage culture, and integrated fish farming. Supporting practices such as water quality management, improved nutrition, genetic enhancement, probiotics, and disease diagnostics are also discussed. The integration of modern technologies like GIS, sensors, and digital tools has further improved farm efficiency and productivity. However, challenges such as high setup costs, limited technical knowledge, and disease risks still restrict large-scale adoption. Overall, modern inland fisheries offer strong potential for sustainable production and rural economic growth.

Keywords: Inland fisheries, aquaculture, biofloc, RAS, aquaponics, cage culture, integrated fish farming, sustainability, fish production.

Introduction

Inland fisheries have become an important part of rural development and food production in India. The country has a large network of ponds, reservoirs, rivers, lakes, canals, and wetlands that provide excellent opportunities for fish farming. Earlier, fish culture was mostly practised using traditional methods with low inputs and limited scientific management. However, increasing demand for fish and better market opportunities have encouraged farmers to adopt modern aquaculture techniques for higher production and income. Fish is considered one of the most nutritious and affordable sources of animal protein. It contains essential nutrients, vitamins, and minerals important for human health. As the population continues to grow, the demand for fish and fishery products is also increasing rapidly. Modern inland fisheries techniques are therefore becoming essential not only for improving fish production but also for supporting food security and rural livelihoods (FAO, 2022).

Growth of Modern Inland Fisheries

Over the last few years, inland fisheries have changed significantly due to the adoption of scientific management practices. Farmers are now more aware about the importance of quality fish seed, balanced feed, proper stocking density, and water quality management. Fisheries training programs conducted by universities and government departments have also helped improve technical knowledge among fish farmers. Modern aquaculture systems are helping farmers produce more fish in less space and within shorter culture periods. Many

young entrepreneurs are entering the fisheries sector because fish farming is now considered a profitable business activity. Scientific fish farming practices have improved productivity and increased farmers' income in many parts of the country (Kumar et al., 2018).

Biofloc Technology

Biofloc technology is one of the most popular modern fish farming methods used today. In this system, beneficial microorganisms convert fish waste and leftover feed into microbial protein, which can again be consumed by fish. This process helps maintain water quality and reduces feed wastage. The main advantage of biofloc farming is that it requires very little water exchange compared to traditional pond culture. Fish can be cultured at higher stocking densities, allowing farmers to produce more fish in smaller areas. Species such as tilapia and catfish perform well under biofloc conditions. Farmers are increasingly adopting biofloc technology because it enhances fish production efficiency, improves resource utilization, and lowers water and feed management costs in aquaculture systems (Emerenciano et al., 2013).

Recirculatory Aquaculture System (RAS)

The Recirculatory Aquaculture System (RAS) is an advanced aquaculture technology where water is continuously filtered and reused within the culture system. Mechanical and biological filtration units remove solid wastes and toxic compounds from the water, maintaining suitable conditions for fish growth (Timmons and Ebeling, 2013). RAS is considered highly sustainable because it requires very little water exchange and allows fish farming under controlled environmental conditions. Farmers can regulate water quality, temperature, oxygen levels, and feeding more effectively in RAS units. This system is particularly beneficial in areas with limited water availability and high land costs.

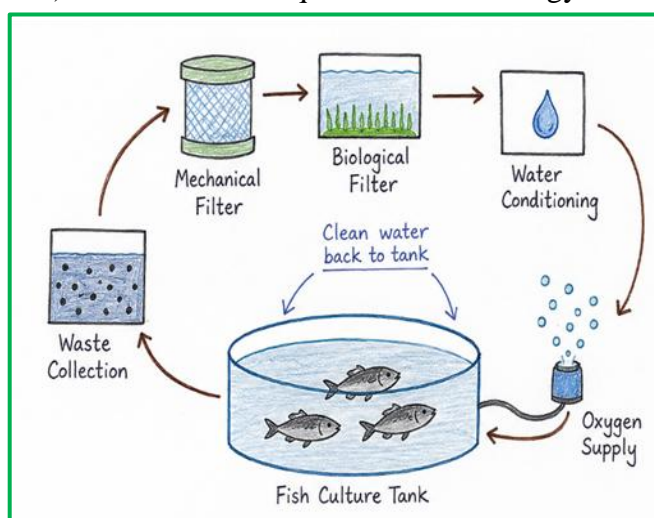


Fig 1. Working of Recirculatory Aquaculture System (RAS) (Tawfik et al., 2023)

Aquaponics System

Aquaponics is an integrated farming system that combines aquaculture with hydroponic plant cultivation. In this method, nutrient-rich water from fish tanks is used for growing plants, while the plants naturally filter and purify the water before it returns to the fish culture tank. This system reduces water usage and allows farmers to produce fish and vegetables simultaneously in limited space. Aquaponics is increasingly recognized as a sustainable farming approach because it efficiently recycles nutrients, conserves water resources, and reduces environmental pollution. The integrated production of fish and plants also provides additional economic opportunities for small-scale farmers and urban growers (Goddek et al., 2019).

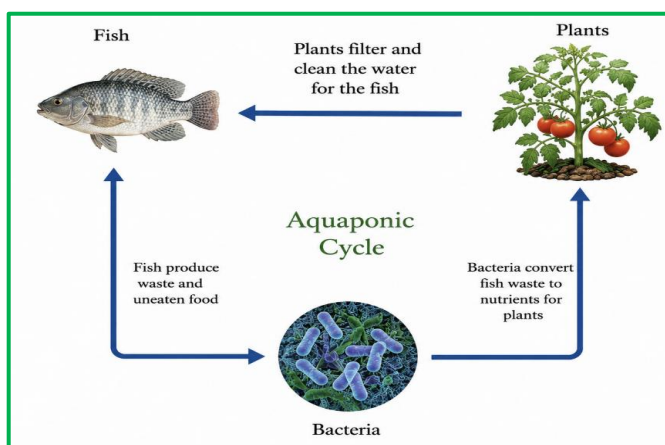


Fig 2. Cyclic process of aquaponics, integrating aquaculture and hydroponics (Debroy et al., 2025)

Cage Culture in Reservoirs

Cage culture is another important modern aquaculture technique gaining popularity in inland fisheries. In this system, fish are reared inside floating cages installed in reservoirs, lakes, or large water bodies. Cage farming helps utilize open water resources that often remain underused. This method has created livelihood opportunities for people living near reservoirs and dams. Fish species such as pangasius, tilapia, and carp are commonly cultured in cages. Cage farming also allows easier monitoring, feeding, and harvesting of fish

Integrated Fish Farming

Integrated fish farming is considered one of the most practical and sustainable methods for rural areas. In this system, fish culture is combined with agriculture, poultry farming, duck farming, or livestock rearing. Waste generated from one farming activity is utilized in another, reducing production costs and improving resource utilization. For example, poultry droppings can be used as organic manure in fish ponds to improve natural productivity. Farmers practicing integrated farming often earn income from multiple sources such as fish, vegetables, eggs, and livestock products. This system helps improve economic stability while reducing environmental waste.

Water Quality Management

Water quality management plays a major role in successful fish farming. Fish growth and survival directly depend on the quality of water in which they are cultured. Important water parameters such as dissolved oxygen, pH, temperature, and ammonia levels should be monitored regularly.

Nowadays, many fish farmers are using aerators and water testing kits to maintain healthy pond conditions. Aerators improve oxygen availability, especially in intensive fish farming systems where fish stocking density is high. Proper water management reduces stress in fish and helps prevent disease outbreaks (Boyd & Tucker, 2012).

Fish Feed and Nutrition

Feed management is another important factor influencing fish production and profitability. Earlier, fish farmers mainly depended on traditional feed ingredients such as rice bran and oil cakes. However, modern fish farming increasingly uses balanced pellet feeds containing proteins, vitamins, and minerals necessary for fish growth. Scientific feeding practices improve feed conversion efficiency and reduce feed wastage. Some intensive fish farms are also using automatic feeding systems for better feed management. Proper nutrition not only improves fish growth but also enhances fish health and disease resistance.

Genetic Improvement and Selective Breeding

Selective breeding programs are helping improve fish growth, disease resistance, and adaptability to environmental conditions. Genetically improved fish strains such as Genetically Improved Farmed Tilapia (GIFT) have shown faster growth and better survival rates compared to normal strains. Improved breeding techniques help farmers achieve higher productivity and better profitability. Scientific hatchery management and broodstock improvement are therefore becoming important parts of modern inland fisheries development (Eknath and Hulata, 2009).

Use of Probiotics in Aquaculture

Probiotics are beneficial microorganisms used in aquaculture to improve fish health and water quality. These microorganisms help control harmful bacteria, improve digestion, and enhance the immune system of cultured fish. Probiotics are increasingly being used as an alternative to antibiotics in modern fish farming systems. The use of probiotics improves feed utilization and reduces disease outbreaks in aquaculture ponds. Farmers using probiotic-based management practices often observe better survival and growth performance in fish. This technique is becoming popular because it supports eco-friendly and sustainable aquaculture production (Newaj-Fyzul and Austin, 2015).

Disease Management in Aquaculture

Disease outbreaks are one of the major problems in intensive fish farming systems. Poor water quality, overcrowding, and stress conditions increase the risk of diseases among cultured fish. Therefore, modern fisheries management focuses more on disease prevention than treatment. Biotechnology tools such as PCR-based disease diagnosis are now being used for early identification of fish pathogens. Farmers are also using probiotics and immune-boosting supplements to improve fish health naturally. Modern disease management strategies in aquaculture significantly reduce fish mortality, improve health status, and enhance overall productivity through early diagnosis, biosecurity measures, and better farm management practices (Zafar et al., 2023).

Role of Technology in Inland Fisheries

Technology is rapidly changing the fisheries sector. Modern tools such as Geographic Information Systems (GIS), sensors, and mobile applications are helping farmers manage fish ponds more efficiently. Farmers can now monitor water quality, weather conditions, and fish growth more accurately. Digital technologies are also improving communication between farmers, researchers, and fisheries departments. Mobile applications provide information related to fish farming practices, disease management, and market prices. These innovations are making inland fisheries more scientific and profitable.

Economic Importance of Modern Fisheries

Modern inland fisheries techniques are helping farmers improve production and increase income significantly. Scientific fish farming practices reduce production losses and improve survival rates. Farmers adopting technologies such as biofloc systems and cage culture are often earning higher profits than those following traditional fish culture methods.

The fisheries sector also generates employment opportunities in hatcheries, feed industries, fish processing units, transportation, and marketing sectors. Women and rural youth are increasingly participating in fisheries-related activities, contributing to rural economic development and livelihood improvement.

Challenges in Modern Inland Fisheries

Despite several advantages, modern inland fisheries still face many challenges. High initial investment costs for technologies such as biofloc systems and advanced aquaculture equipment discourage small-scale farmers. Lack of technical knowledge and proper training also limits the adoption of scientific fish farming practices. Water pollution, climate change, rising feed costs, and disease outbreaks are additional challenges affecting sustainable aquaculture development. Therefore, awareness programs, financial support, and regular training are essential for promoting modern inland fisheries techniques.

Conclusion

Modern inland fisheries techniques are transforming traditional fish farming into a more productive, profitable, and sustainable activity. Practices such as biofloc farming, cage culture, integrated farming, scientific feeding, and water quality management are helping farmers increase fish production and generate higher income. At the same time, sustainable management practices are important for protecting aquatic ecosystems and maintaining long-term productivity. With proper awareness, scientific training, and technological support, inland fisheries can play an important role in food security, employment generation, and rural economic development. The adoption of modern and eco-friendly fisheries techniques will continue to strengthen the future of the aquaculture sector.

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