Integrated Fish-Crop Farming: A Climate-Smart Pathway for Sustainable Indian Agriculture

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Abstract

Integrated fish–crop farming has emerged as a promising approach for advancing climate-smart and sustainable agriculture in India. By integrating aquaculture with crop production, these systems improve resource use efficiency, nutrient recycling, farm diversification, and livelihood resilience. This article examines integrated fish–crop farming within the Indian agricultural context, highlighting its role in enhancing productivity, ecological sustainability, and climate adaptation. Major Indian models including rice–fish farming, pond-based integrated systems, and emerging aquaponic approaches are discussed, along with regional experiences from Assam, Kerala, and West Bengal. The article also emphasizes the importance of agricultural extension, institutional support, and policy initiatives in promoting adoption and scaling of integrated systems. Although challenges related to technical knowledge, infrastructure, and management remain, integrated fish–crop farming offers significant potential for supporting resilient, diversified, and environmentally sustainable agricultural development in India.

Keywords: Integrated farming systems; Climate-smart agriculture; Aquaculture; Sustainable agriculture

Introduction

Indian agriculture is operating under mounting pressure. Climate variability, shrinking landholdings, rising input costs, natural resource degradation, and unstable farm profitability are reshaping the realities of farming, particularly for smallholder households. Conventional single-enterprise farming systems often struggle to balance productivity, resilience, and livelihood security under these conditions. As a result, diversified, resource-efficient farming approaches are receiving growing attention within climate-smart agriculture debates in India (FAO, 2017; Vaid & Thakkar 2026; APN, 2023). Within this wider transition toward sustainable agriculture, integrated farming systems are emerging as practical alternatives capable of linking multiple farm enterprises into mutually supportive production systems. At the same time, India's fisheries and aquaculture sector has expanded considerably over the past decade. The country remains one of the world's leading fish-producing nations, with total fish production increasing from approximately 95.79 lakh tonnes in 2013–14 to nearly 197.75 lakh tonnes during FY 2024-25. The sector contributes substantially to agricultural gross value addition, nutritional security, employment generation, and rural livelihoods (Government of India, 2025; FAO, 2024). Recent policy initiatives, particularly the Pradhan Mantri Matsya Sampada Yojana (PMMSY), have further reinforced the national emphasis on sustainable aquaculture expansion, infrastructure development, technological modernisation, and strengthening the fisheries sector (Government of India, Department of Fisheries, 2025). These parallel developments, agricultural vulnerability on one side and rapid aquaculture growth on the other, create an important opportunity for integrated approaches. In this setting, integrated fish-crop farming emerges not simply as another production model but as a diversification strategy that connects agriculture, aquaculture, climate adaptation, and livelihood resilience within a single farming framework.

Integrated agriculture-aquaculture systems combine crop cultivation with fish production through ecological interactions, nutrient recycling, and efficient resource utilisation. Common models include rice-fish farming, pond-based integrated systems, fish-vegetable cultivation, fish-horticulture integration, and emerging aquaponic approaches. Such systems improve resource use efficiency, diversify production, and support food, nutrition, and livelihood security (Sathoria & Roy, 2022; WorldFish, 2021; WeAdapt, 2021).

Understanding Integrated Fish-Crop Farming

Integrated fish–crop farming is based on a simple principle: farm enterprises function more effectively when biological components interact rather than operate independently. In this approach, fish production is combined with crop cultivation within a connected system designed to improve resource use, nutrient cycling, and farm productivity. Unlike conventional monocropping, where enterprises rely heavily on external inputs and function separately, integrated agriculture–aquaculture systems create ecological linkages in which the outputs of one component support another (FAO, 2017; WeAdapt, 2021). The conceptual framework of integrated fish–crop farming is presented in Figure 1, illustrating the interactions among crop production, fish culture, nutrient flows, and climate-smart farming outcomes.

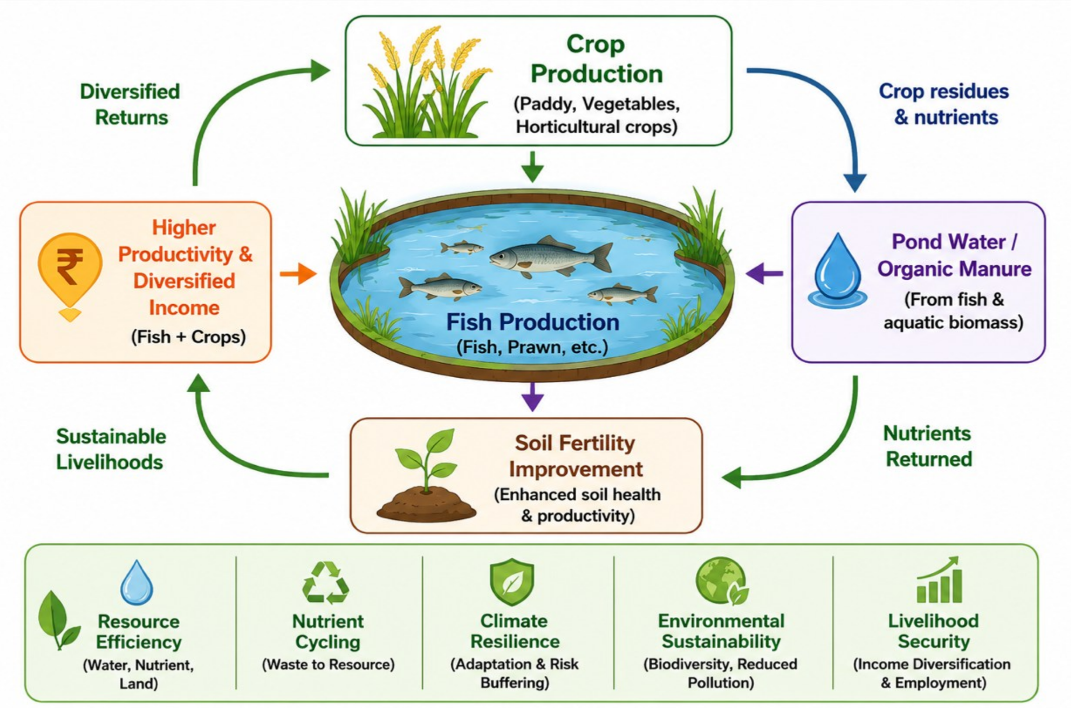

Fig. 1 Integrated fish–crop farming as a climate-smart system

In India, integrated fish–crop farming takes several forms shaped by agro-ecological conditions, water availability, farming traditions, and household livelihood needs. Among these, rice–fish farming remains one of the oldest and most widely documented systems. Fish are reared simultaneously or sequentially within rice fields, creating productive interactions between aquatic and crop components (Sathoria & Roy, 2022). Fish contribute to nutrient cycling, biological pest control, weed regulation, and improved soil–water interactions, while rice fields provide habitat, food resources, and suitable water conditions for aquatic production (WorldFish, 2021).

Beyond rice–fish systems, Indian agriculture supports other forms of integration that broaden production opportunities. Fish–duck farming, practised in parts of Northeast and Eastern India, demonstrates how biological interactions can reduce dependence on external inputs. Duck droppings enrich pond fertility, stimulate natural feed availability, and lower nutrient supplementation requirements, while farmers gain additional returns from duck-based enterprises.

Fish–vegetable and fish–horticulture systems extend integration into surrounding farm spaces. Pond embankments, adjacent land, and nutrient-rich pond resources are used to cultivate vegetables, fruits, and horticultural crops. These arrangements strengthen land use efficiency, encourage nutrient reuse, and support additional farm income (CEEW, 2024; WorldFish, 2021). Pond-based systems frequently build on the same principle by reusing pond water and sediments in crop cultivation, thereby reducing fertilizer dependence and improving internal nutrient cycling. Emerging technologies have added new dimensions to fish–crop integration. Aquaponic systems combine aquaculture and hydroponic cultivation within recirculatory systems where fish waste supplies nutrients for plants. The result is a closed-loop production arrangement characterised by efficient water use, continuous nutrient recovery, and reduced waste generation (CEEW, 2024). The diversity of Indian integrated models and their major functional features is summarized in Figure 2.

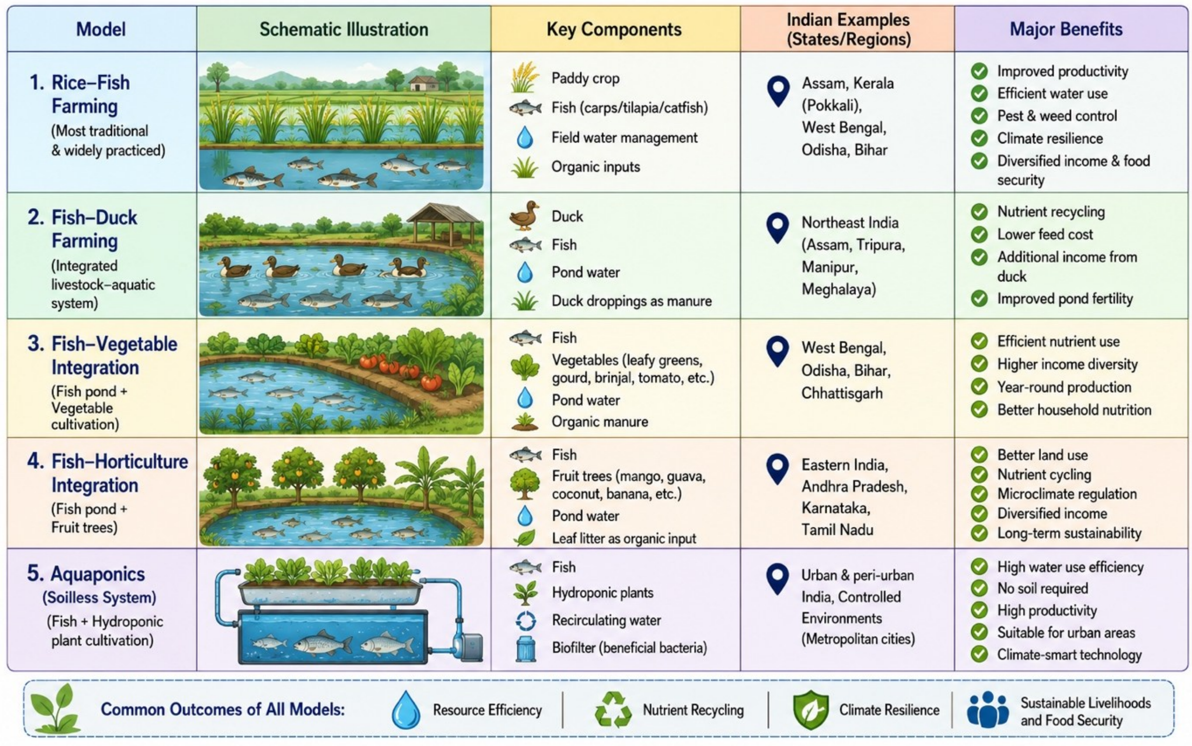

Fig. 2 Major integrated fish–crop farming models practiced in India

Integrated farming systems are increasingly recognised as resource-efficient and climate-responsive agricultural approaches. Diversification across fisheries and crop enterprises can reduce production risks, stabilise farm income, optimise water and nutrient use, and strengthen food and nutritional security, particularly among smallholder households (Vaid & Thakkar 2026; WorldFish, 2021). Studies on ecological rice–fish systems have also reported gains in biodiversity conservation, ecological intensification, and long-term resource sustainability through enhanced nutrient flows and lower dependence on chemical inputs (Xie et al., 2011). Given India's large smallholder population, diverse agro-climatic conditions, and growing emphasis on sustainable intensification, integrated fish–crop farming offers a practical approach for connecting agricultural production, ecological sustainability, and livelihood support within the same farming system.

Integrated Fish–Crop Farming as a Climate-Smart Pathway for Sustainable Agriculture

Integrated fish–crop farming is increasingly gaining relevance within climate-smart agriculture discussions as farming systems face rising climatic uncertainty, production costs, and resource pressures (WorldFish, 2021). The approach aligns closely with the objectives of climate-smart agriculture, which emphasises productivity enhancement, adaptive capacity, and environmental sustainability under changing climatic conditions (FAO, 2017). Rather than treating fisheries and crop production as separate activities, integrated fish–crop farming connects them through shared flows of water, nutrients, biological interactions, and farm resources. As illustrated earlier in Figure 1, the effectiveness of the system lies in its ecological connectivity.

A major advantage of integrated fish-crop farming is its ability to improve resource use within the farm system. Nutrients, crop residues, water, and biological resources are reused rather than functioning as isolated or wasted inputs. In rice–fish systems, fish activity contributes to nutrient cycling, biological pest regulation, and improved soil–water interactions. Likewise, pond-based systems reuse nutrient-rich pond water and sediments in crop cultivation, reducing dependence on external fertilizers and improving input efficiency (Sathoria & Roy, 2022; WorldFish, 2021). For Indian farmers dealing with rising input costs and resource constraints, such internal recycling carries both ecological and economic value.

Climate resilience forms another important dimension of integrated systems. Indian agriculture increasingly faces rainfall irregularities, droughts, floods, heat stress, and fluctuating production conditions. Under these circumstances, dependence on a single enterprise can increase livelihood vulnerability. Integrated fish–crop farming addresses this challenge through production diversification. By combining fisheries with crop cultivation, households create multiple production streams capable of buffering climatic and market shocks. Income diversification and production flexibility make these systems particularly relevant for smallholder farming environments characterised by uncertainty and constrained resources.

The environmental contribution of integrated systems is equally significant. Climate-smart agriculture places growing emphasis on ecological intensification, reduced external input dependence, and sustainable resource management. Integrated fish–crop systems support these objectives through nutrient recycling, biological regulation, reduced waste generation, and improved ecosystem functioning. Studies on ecological rice–fish systems have reported gains in biodiversity conservation, improved nutrient flows, and reduced chemical dependence, highlighting the sustainability potential of integrated agriculture–aquaculture systems (Xie et al., 2011). The practical implications of these systems for farming households are summarized in Table 1.

Table 1. Why integrated fish–crop farming matters for Indian farmers

Dimension	Practical relevance
Diversified income	Multiple production streams reduce dependence on a single enterprise
Nutrient recycling	Improved internal input efficiency through ecological reuse
Reduced production cost	Lower fertilizer, nutrient, and supplementary feed dependence
Climate resilience	Improved buffering against climatic and market shocks
Employment generation	Expanded year-round livelihood and farm activity opportunities

Within the Indian context, integrated fish–crop farming represents more than a sustainability concept. It offers a practical approach for improving productivity, strengthening adaptive capacity, and supporting resilient agricultural livelihoods.

Indian Models and Success Experiences of Integrated Fish–Crop Farming

India's agro-ecological diversity has created favourable conditions for multiple forms of integrated fish–crop farming. Rather than representing a single standardised model, these systems adapt to local ecology, water availability, and livelihood requirements. The diversity of Indian integrated farming approaches was introduced earlier in Figure 2; selected regional experiences further illustrate how these systems operate under field conditions.

Rice–fish farming occupies a central place within India's integrated agriculture–aquaculture landscape. Practised across states such as Assam, West Bengal, Odisha, Kerala, and other parts of Eastern India, rice–fish systems combine paddy cultivation with fish production to improve land use, diversify household production, and strengthen farm sustainability (Sathoria & Roy, 2022).

Assam provides an important example of climate-responsive rice–fish integration within water-rich and flood-affected farming environments. Integrated systems in the state make productive use of seasonal water resources while reducing dependence on single-enterprise agriculture. Farmers benefit from simultaneous crop and aquatic production, improved livelihood diversification, and greater adaptive capacity under climatic uncertainty

(NITI Aayog, 2025). A representative example of Indian rice-fish integration is shown in Plate 1.

Plate 1. Rice–fish farming system in India

Another widely recognised example is Kerala's Pokkali paddy–fish system, a traditional production practice adapted to saline coastal wetlands. The system combines salt-tolerant paddy cultivation with seasonal fish or shrimp production, creating a model of ecological adaptation, biodiversity conservation, and livelihood generation. Its continued relevance illustrates how traditional farming knowledge can align with contemporary climate-smart agriculture discussions.

Integrated systems in India extend beyond rice-based landscapes. In parts of Northeast India, fish-duck farming demonstrates how biological interactions can be translated into practical farm management advantages. Ducks raised around ponds contribute organic manure directly to aquatic systems, improving pond fertility and stimulating natural productivity. Farmers derive returns from fish, duck, and sometimes crop enterprises, making the system particularly suitable for diversified smallholder livelihoods. The operational structure of integrated fish-duck farming is illustrated in Plate 2.

Plate 2. Integrated fish–duck farming system

West Bengal and several parts of Eastern India provide strong examples of pond-based integrated farming. Fish production is frequently combined with vegetables, horticultural crops, or mixed agricultural enterprises organised around efficient use of water and nutrient resources. Farmers often cultivate vegetables on pond bunds using nutrient-rich pond water and sediments, reducing fertilizer dependence while generating complementary crop income (Sathoria & Roy, 2022; WorldFish, 2021)

In Odisha, rice-based integrated systems incorporating fisheries components are increasingly discussed as climate-responsive approaches capable of improving productivity, resource use, and livelihood diversification under variable environmental conditions (ICAR-NRRI, 2024).

Alongside traditional systems, India is also witnessing growing interest in emerging integrated technologies. Aquaponics, biofloc-supported crop integration, and other resource-efficient aquaculture models are increasingly entering discussions on sustainable food production, urban agriculture, and climate-smart innovation. By linking aquaculture with hydroponic cultivation or recirculatory nutrient systems, these approaches extend integrated farming concepts into more technologically intensive production environments.

Taken together, these examples highlight the breadth of integrated fish–crop farming in India. Across traditional, pond-based, and emerging systems, the underlying emphasis remains the same: improving resource use, expanding livelihood options, and adapting agricultural production to diverse farming realities.

Role of Agricultural Extension and Policy Support in Promoting Integrated Fish–Crop Farming

The long-term success of integrated fish–crop farming depends on more than technical feasibility. Adoption is shaped by access to knowledge, training, institutional support, financial incentives, and advisory systems. Because integrated farming combines multiple enterprises within a single production system, farmers often require practical guidance, confidence-building support, and locally relevant technical knowledge during the transition process.

Agricultural extension therefore plays a central role in promoting integrated systems. From an extension perspective, integrated fish–crop farming involves behavioural, managerial, and institutional adaptation rather than simple technology transfer. Participatory approaches such as on-farm demonstrations, farmer field schools, experiential learning programmes, and peer-to-peer knowledge exchange can strengthen farmer understanding and confidence in integrated systems (MANAGE, 2023; APN, 2023). The extension pathway supporting adoption and scaling of integrated fish–crop farming in India is presented in Figure 3.

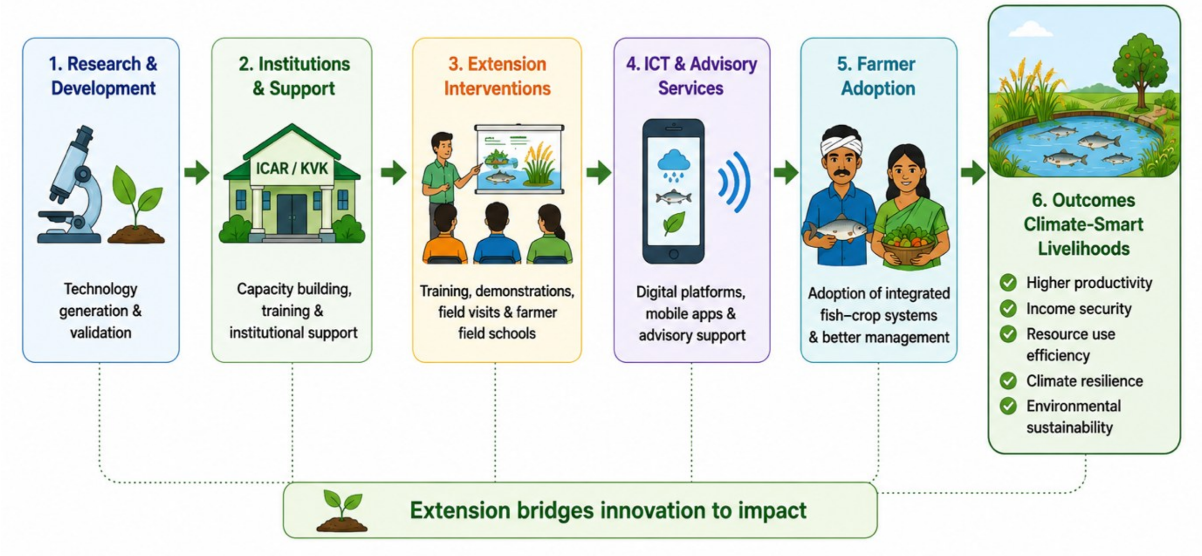

Fig. 3 Role of agricultural extension in scaling integrated fish–crop farming

Several institutions in India already provide an enabling foundation for integrated agriculture–aquaculture development. Organisations such as the Indian Council of Agricultural Research (ICAR), ICAR–Central Institute of Freshwater Aquaculture (ICAR-CIFA), Krishi Vigyan Kendras (KVKs), state fisheries departments, and agricultural universities contribute through research, technical advisories, farmer training, demonstrations, and capacity-building programmes. Their role is particularly important in integrated systems where management practices must be adapted to local agro-ecological and production conditions.

Demonstration-based learning remains especially valuable. Farmers are often more willing to adopt integrated systems when they observe practical field outcomes under conditions similar to their own production environments. KVK demonstrations, community learning platforms, farmer-to-farmer interactions, and adaptive field trials can therefore help reduce uncertainty around integrated fish–crop technologies.

The extension landscape is also evolving. ICT-enabled advisory services, mobile-based climate information systems, digital learning tools, online technical advisories, and farmer collectivisation platforms such as Farmer Producer Organizations (FPOs) are expanding opportunities for knowledge dissemination and coordinated adoption among farming communities (MANAGE, 2023; ICAR-CIFA, 2024).

Policy support represents another important component of integrated farming promotion. National initiatives such as the Pradhan Mantri Matsya Sampada Yojana (PMMSY) have strengthened attention toward fisheries modernisation, sustainable aquaculture development, infrastructure enhancement, entrepreneurship promotion, and capacity building in India (Government of India, 2025). Although not designed exclusively for fish–crop integration, these initiatives create enabling conditions through financial assistance, institutional support, skill development, and improved access to inputs and markets.

Challenges and Future Opportunities

Despite its potential, integrated fish–crop farming faces challenges related to technical knowledge, infrastructure, investment requirements, fragmented advisory delivery, and uneven access to extension services. Small landholdings, water constraints, and environmental uncertainties such as floods, droughts, and salinity can further influence adoption. However, innovations including aquaponics, Biofloc systems, precision aquaculture, and climate-smart technologies offer promising opportunities. Wider scaling will require stronger research, institutional convergence, farmer-centred extension, and supportive policy environments that translate integrated farming concepts into practical solutions for Indian farmers.

Conclusion

Integrated fish-crop farming represents more than an alternative production practice; it offers a practical climate-smart pathway for addressing the interconnected challenges of productivity, resource degradation, livelihood insecurity, and climate uncertainty in Indian agriculture. Experiences from rice-fish, fish-duck, pond-based, and emerging integrated systems demonstrate their potential to strengthen resource efficiency, diversification, and ecological resilience. However, wider adoption will depend on stronger research, participatory extension, institutional convergence, and supportive policy frameworks capable of translating integrated farming concepts into scalable, farmer-centred solutions across diverse Indian agro-ecological contexts.

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