



Review Paper

Integrated Fish Farming Systems for Sustainable Aquaculture: A Review

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Abstract

A major factor in increasing improved yields of fish as a result of the population explosion is integrated fish farming with animal husbandry. Combined farming practices that comprise at least two distinct but rationally related components of a fish and livestock enterprise are referred to as integrated farming systems. For integrated livestock fish production, fish species that are fed by humans, effectively use phytoplankton and zooplankton and tend to feed on macrophytes are ideal. The fundamental ideas of integrated farming include preservation, especially the full use of leftovers from animals and the harnessing of the synergistic benefits of connected farm activities. Combining fish aquaculture and animal husbandry can increase output, provide jobs and be very rewarding. It is acknowledged that integrated fish farming is a sustainable aquaculture method. In order to increase output as well as efficiency, this paper reviews integrated aquaculture, paying particular attention to the integration of fish and the increase in productivity of aquaculture systems. In addition to fish, integrated fish farming produces meat (chicken, duck, cattle, etc.), milk, vegetables, fruits, eggs, grains, fodder and mushrooms. It also has the ability to improve the socioeconomic standing and productivity of our society's weakest segments.

1. Introduction

Integrated fish farming is the practice of growing fish alongside other organisms. The linkage between two or more farming systems, such as fish along with cattle, fish along with poultry, etc., can be defined as an integrated fish farming system (FAO, 1986). According to (Pillay 1990), the fundamental principles of integrated farming include conservation, which includes full utilization of agricultural wastes and the use of the synergistic effects of related farm activities. It is based on the notion that "there is no waste" and that "trash is merely a misdirected resource that can become a valuable material for another product" (Bhagat et al., 2024).

Fish culture is a component of an ancient method known as integrated fish and livestock husbandry. A long history of integrated farming can be seen in Asia, especially China and it is now practiced on a small scale in Europe, Africa and some Latin American countries (Altieri et al., 2012).

In Asia aquatic plant cultivation and fish farming were combined, according to written accounts from the first and second centuries B.C. (Nash 2010).

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Records date back to the ninth century and describe fish farming in a paddy field. There are records of fish and grass culture being rotated between the fourteenth and sixteenth centuries.

By the 1620s, the mulberry-dike fishpond, the integration of fish and livestock farming and complex systems of numerous enterprises integrated with fish farming had all been developed (FAO 2001). The practices used in integrated fish farming involve raising fish alongside other species.

2. Fish species for integrated livestock-fish farming

The aim of integrated livestock and fish farming is to produce as much protein-rich plankton as possible in the water to feed fish naturally. The best varieties of fish for integrated livestock-fish farming include those that may purify water and consume microorganisms such as zooplankton and phytoplankton (Yi et al. 2003). The fish species for integrated livestock fish culture are those that are preferably consumed by the human population and which effectively use phytoplankton and zooplankton, as well as having a macrophyte-feeding nature (Pillay 2004). According to feeding habits, fish are divided into three groups: bottom feeders, column

feeders and surface feeders. Fish species like the exotic silver carp are surface feeder that feeds on phytoplankton, rohu is column feeder and omnivorous, mrigal and kalabasu are detritivorous, tilapia and the zooplanktivorous, catla are suitable for farming in an integrated system (Fagbenro and Sydenham 1988).

3. Types of Integrated Fish Farming Systems

The integrated fish farming system is mainly two types (Table 1):

- Livestock cum fish integrated farming system
- Agri aquaculture-based integrated system

3.1 Livestock cum fish integrated farming system

Four common systems of integrated fish farming with animal husbandry are identified so far; these are fish cum poultry, fish cum duck, fish cum piggery and fish cum cattle (Gebru 2021). Some common species of fish used in integration systems are common carp (*Cyprinus carpio*), tilapia (*Oreochromis niloticus*), silver carp (*Hypophthalmichthys molitrix*), catla (*Catla catla*), rohu (*Labeo rohita*) and mrigal (*Cirrhinus mrigala*) (Thomas et al., 2020). Combining fish aquaculture and animal husbandry can increase output, provide jobs and be very rewarding (Gebru 2021).

3.1.1 Poultry cum fish farming

In this type of fish culture, the system utilizes poultry droppings of fully built-up poultry litter. It is possible to build a poultry barn next to or above the pond. Utilizing poultry manure as nourishment for fish ponds results in reduced moisture content, fiber content and compounds like tannins that stain water (Yadav and Garg 2011). Because chickens have small digestive tracts, around 0% of the poultry dung is made up of undigested food items (25% dry matter) (Hopkins 1982). Approximately 500 to 600 poultry birds are reared in a pond of area 1 hectare, which has the potential production of fish about 5 thousand kg/ha per year along with 1250 kg of chicken meat and 70000 eggs. Preferred varieties of birds are Rhode Island or Leghorn. They required 0.3 to 0.4 sq meter space per bird. To minimize feed wastage, hoppers are used to feed them. The bird species received diets based on their age; for example, layers were fed breeder, brooder and starter feed.

3.1.2 Duck cum fish culture

The ducks are also considered as biological aerators. The dykes are used to rear them in a low-cost house. A suitable variety for this culture is the Indian Runner and Khaki Campbell. To fertilize 1 hectare of pond, about 300 ducklings are reared (some spp. is reared 450 to 500 in number). Ducks control aquatic weeds (*Azolla*, *Lemna*, etc.), aquatic insects, mollusks, tadpoles, etc., as well as act as live aerators by splashing water with their webbed feet (Jayanthi et al., 2000). Living space required by each duckling is about 0.3 to 0.5 sq meter. Total fish production from this culture system is about 3500 to 5000 kg along with 18000 to 18500 eggs and

600 kg of meat. The droppings of ducks are used to increase the primary productivity of the pond (Rath 2000).

3.1.3 Pig cum fish culture

This system of integration is very common in China, Taiwan, Vietnam, Thailand, Malaysia, Hungary and some European countries. 30-35 pigs produced 1 ton of ammonium sulfate generated by feces for 1 hectare (Odum 1988). Nutrition sources for pigs are kitchen trash, aquatic plants and crop waste. The most popular varieties of pigs used are the bigger white Yorkshire, Landrace and Hampshire (Paulpandi et al., 2024). A pig weighing 70–90 kg requires 3 to 4 m² of room area. The washing of dung and urine is directly discharged in the pond or partially decomposed before applying the application of pig dung in ponds, increasing phytoplankton bloom, which in turn increases zooplankton development, thus increasing productivity of the pond (Rath 2000; Little & Edwards 2003). Pig dung supplies approximately 70% digestible food for fish. Fish yield ranges from 3000 to 4000 kg/ha/yr. A fully developed pig provides 500-600 kg of dung per year, 4500 kg of pig meat per year and 800 piglets every year (Little and Edwards 2003).

3.1.4 Cattle cum fish culture

It is common practice worldwide. A healthy cow excretes around 4000-5000 kg of manure and 3500-4000 liters of urine. A unit of 5 to 6 cows provides enough manure for a 1-hectare pond (Little and Edwards 2003). Cow dung has a low biological oxygen requirement as it is already digested by ruminant microorganisms. Fish species cultivated with cattle are Fish species cultivated with cattle are Rohu (*L. rohita*), Catla (*C. catla*), Mrigal (*C. mrigala*), Silver carp (*H. molitrix*), Grass carp (*C. idella*), Common carp (*C. carpio*), Tilapia (*O. mossambica*), Magur (*C. batrachus*), Java puthi (*P. javanicus*), Kurhi (*L. gonius*), Freshwater prawn (*M. rosenbergii*), etc (Ayyappan & Jena 2001). Cattles should have heat and disease-resistant capacity. In addition to a fish yield of about 3000-4000 kg per year, cows provide about 9000 kg of milk annually. Cattle waste and washing are conveyed through pipes, which can act as good fertilizer. To make cow manure handling easy, the cow shed should be made closer to the fish pond.

3.1.5 Goat cum fish culture

Goat is known as the poor man's cow. Goat excreta is a very excellent source of organic fertilizer. It contains 60% organic carbon, 2.7% nitrogen, 1.78% phosphorus and 2.88% potassium (Patowary and Kalita). 50-60 goats provide a sufficient amount of fertilizer for 1 hectare of pond. The goats should be kept in a dry, safe, comfortable house. Breeds of goat suitable for this system are Jamanpar, Beetal, Barbar, Sirohi and Deccani (Borah et al., 2021). The culture system provides 3500-4000 kg of fish/ha/yr. No supplemental feeding or chemical fertilizer is needed. Goats can improve and maintain grazing and reduce bush encroachment and weeds. *L. rohita* and *C. mrigala* are well cultured with goat excreta. Goats also provide meat, increasing the economy of the culture system (Devendra 2013).

Table 1: Comparative Summary of Integrated Fish–Livestock Farming Systems

Integration Type	Fish Production (kg/ha/year)	Livestock Output	Resource Inputs	Economic Benefit	References
Poultry–fish (<i>Clarias batrachus</i>)	4,462.6	–	20,000 fingerlings/ha; 90 kg dry poultry sweeping/ha/day	Reduced feed & fertiliser cost	Kumar et al., 2012
Poultry manure pond	2,663.5	–	Poultry manure	Higher yield than pig & cow manure	Jhingran & Sharma, 2003
Duck–fish	3,460 (3,500–4,000)	18,000–18,500 eggs; 500–600 kg duck meat	Duck droppings (no feed/fertiliser)	~60% cost reduction	Edwards, 1989
Poultry–fish	2,329	–	Poultry waste	Lower than duck–fish	Edwards, 1989
Pig–tilapia	5,000	150 pigs	Pig faeces + 1.2 T urine/pig (8 months)	Low external input	Little & Edwards, 2003
Pig–fish	2,219 (2,000–5,000 in 6 months)	35–40 pigs	Pig manure	Reduced fertilisation cost	Ayyappan & Jena, 2001
Cow–fish	789	–	100 kg dry matter/ha/day cow manure	Low-input system	Jhingran, 1991
Cow–fish (liquid manure)	31.5–32.7 kg/ha/day	–	Daily liquid cow manure	Feed-free production	Sahu et al., 2014
Duck–fish	4,500–6,000	Eggs and meat	Duck manure	Very high nutrient recycling	FAO, 2010
Pig–fish	3,000–4,000	–	Pork Pig slurry	Low feed requirement	Edwards et al., 2004
Poultry–fish	3,000–4,500	Eggs & meat	Poultry droppings	Higher net profit	Rahman et al., 2008

3.2 Agri-aquaculture-based integrated system

Examples of Agri based fish integration system include rice fish integration, horticulture fish system, mushroom fish system. Apart from these effluents of agro based industries are recycled and used in aquaculture to increase productivity.

3.2.1 Fish- Cum-Paddy Culture

Rice fish culture originated about 2000 years ago in ancient China. Gradually this system spread to many other countries: Indonesia, Vietnam, Thailand and India (Halwart and Gupta 2004). Paddy cum fish culture sites are chosen in low-lying areas with easy access to flowing water. The organic manure-rich soil in the paddy field has a high water-holding capacity. According to numerous publications, integrated rice-fish farming is environmentally sound since fish increase the supply of phosphate and nitrogen in the soil, improving soil fertility (Giap et al., 2005). (Nayak et al., 2018) created

an integrated agricultural system for lowlands fed by medium-shallow rainfall. Paddy fields should remain waterlogged for 3-8 months in a year. Suitable rice varieties for irrigated areas are Naveen, Lalat, IR 36 and IR 64. For medium deep lowlands in the wet season, varieties such as Gayatri, Sarala, Durga and Varsha Dhan are suitable. Stocking at the rate of 10,000 per ha of fish is recommended in paddy-cum-fish culture; this will generate a net revenue of around Rs 35,000–40,000 per hectare per year (Saikia and Das 2008). According to Ofori et al. (2004), rice-fish culture generates 5-11% higher income than rice monoculture. With high-yielding, semi-dwarf variety ornamental fishes are cultured. This system helps in the reduction of various greenhouse gas emissions like N₂O up to 9% as compared to rice monoculture (Sathoria and Roy 2022).

3.2.2 Fish- Cum-horticulture

Top, inner and outer dykes of ponds as well as adjacent lands are used to culture horticulture crops. Pond water

is utilized for irrigation purposes and bottom silt is utilized as base manure in crops, vegetables and fruit-bearing plants. Plants selected for integration are of dwarf variety, evergreen, less shady, seasonal and profitable. Plants on the dyke should not block sunlight for fish (Afiya 2024). During winter, radish, peas, beet, turnip, cauliflower, spinach and carrot are suitable to cultivate, while in summer, cucumber, brinjal, chili, tomato, gourds, lady's finger and watermelon are recommended. Dwarf varieties of fruit-producing plants are mango, banana, papaya, coconut and lime. Mixed culture of carps at the rate of 5,000 fish/ha, in a 50:15:20:15 ratio, generated 3,000 kg/ha/year of fish. This system helps to generate 20-25% higher returns than aquaculture alone. According to Sharma et al. (2016), integrated farming methods have shown that papaya plants may produce 650.00 kg of fruit, generating extra revenue from the cultivation of fish as well as poultry and papaya in the same region. According to Bhuyan and Neog (2018), growing two rows of pineapple along a one-bigha pond produces about five quintals of pineapple in the first one and a half years. According to Chakrabarti and Banerjee (2021), rural families can earn extra money by growing fruit trees and vegetables on pond dikes.

3.2.3 Mushroom-Cum-Fish culture

There are more than 1000 species of edible mushrooms that have been identified, with roughly 200 species found in India. Mushrooms are a rich source of vitamins B, C, D and K, including all essential amino acids and contain a good amount of niacin, pantothenic acid, riboflavin, nicotinic acid and minerals such as potash, calcium and phosphorus (Chauhan et al. 2024). In India, there are 3 varieties of mushrooms being cultivated: European button (*Agaricus bisporus*, paddy straw (*volvariella spp.*) and oyster mushrooms (*Pleurotus spp.*). Mushroom cultivation requires a high level of humidity, so its potential increases when combined with aquaculture (Ghosh 2016).

4. Benefits of Integrated Fish Farming

Resource Efficiency: uses leftover materials from one process—such as cattle manure—as feed for another—such as fish pond fertilization—thus cutting waste and improving resource efficiency. By occurring on the same land as other commercial endeavors, integrated fish farming can optimize resources. A common practice in integrated systems is the closed-loop irrigation of crops with fish pond water. This aids in water conservation by lowering the requirement for additional water sources (Wahab et al. 2008). Farmers can maximize productivity per acre by optimizing the utilization of available land by combining various agricultural strategies.

Increased Productivity: produces a variety of goods (livestock, crops and fish), which expands revenue streams and may increase overall productivity and earnings. Integrated fish farming gave the chance to intensify crop and related operations, increasing economic yield per unit of time. Fish output rises as an

outcome of waste from livestock increasing ponds' biological productivity using a variety of mechanisms (Orhibhabor and Ansa 2006).

Improved Soil Health: Using animal dung, integrated fish aquaculture can improve the fertility of the soil. It is possible to improve soil fertility and lessen the demand for artificial fertilizers by irrigating crops using nutrient-rich fish tank water (Jaies et al., 2024). The need for artificial pesticides and fertilizers can be reduced thanks to the interactions between components that occur naturally. For instance, fish dung can give plants the vital nutrients they require, negating the need for artificial fertilizers. When crops are planted next to fish farms, soil erosion is lessened, preserving the health and integrity of the soil and avoiding sedimentation in water bodies (FAO 2001).

Sustainable Practices: - Encourages environmentally friendly practices by recycling nutrients and lessening the impact on the environment when compared to monoculture farming. It can help in controlling pests naturally, thus reducing chemical load in aquaculture practices. The integrated system provides effective recycling of waste materials from culture systems. According to Pearl and Turker (1995), inefficiently operated integrated systems typically have significant intakes of nutrients, which can have a negative impact on cyanobacterial blooms. For sustainable agriculture to thrive, an environmentally friendly cultural framework is essential (Dhawan and Kaur 2002).

Risk Mitigation: By serving as a safety net in the event that a system component fails, integrated fish farming can lower the risk associated with farm operations. Diversifies sources of income, so even if one product fails, others may still be successful, thereby reducing economic risks. Waste from one component (e.g., livestock manure) is used as input (e.g., pond fertilization), lowering input costs and ensuring sustainability. This closed-loop system buffers against input price volatility and shortages (Edwards 2009). Crop diversification allows farmers to adapt their methods to changing climatic conditions, potentially making integrated systems more resilient to climate uncertainty (Rahman & Alam 2016).

Employment Generation: The income of people living in rural areas can be raised by integrated fish farming. Integrated fish farming provides adequate scope to utilize family labor throughout the year (ICAR 2013). Combining crops with live animal enterprises would boost the labor requirement greatly and would help to reduce the problems of underemployment to a large extent. Integrated fish farming has the potential to boost regional fish and grain processing, adding value and generating additional employment along the supply chain (Edwards 2015). Certain farms might draw tourists who are enthusiastic about environmentally friendly techniques, opening up new revenue streams. Integrated fish farming systems can provide a sustainable approach that strikes a balance between environmental stewardship and economic viability,

appealing to investors and customers alike, as the world's food demands rise (Ahmed & Garnett 2011). Integrated fish farming can help smallholder farmers and boost local economies by offering a variety of revenue streams. Compared to centralized fish farming systems, the varied composition of an integrated fish farm creates additional work opportunities (Huazhu and Baotony 1989).

Environmental Benefits: Fish feces reduces the demand for synthetic fertilizers and minimizes nutrient runoff into surrounding water bodies by acting as a natural fertilizer for crops. Water is frequently recirculated via integrated systems, which lowers total water use (Stevenson 2003). By using fish pond water for irrigation, this valuable resource can be preserved. Combining various species—fish, plants and animals—promotes biodiversity and strengthens the ecosystem's resistance to pests and illnesses. Integrated systems can help reduce greenhouse gas emissions related to agriculture and food transportation by encouraging local food production and minimizing the need for artificial fertilizers (Sakadevan and Nguyen 2017). Organic fertilizers and natural pest management are staples of integrated systems and they can greatly minimize agricultural runoff and water source contamination (Lal 2020).

Social and Nutritional Benefits: Integrated systems increase the availability of a variety of nutrient-dense food, hence reducing food insecurity and malnutrition by raising fish alongside crops and livestock. Farmers can diversify their sources of revenue, which lessens their reliance on market swings and gives their family more reliable means of subsistence (FAO 2018). Farmers collaborate with one another in integrated fish farming, which helps to build a feeling of community and encourages the sharing of agricultural expertise and methods. By giving women and young people the chance to participate in agricultural activities, integrated farming can advance gender equality and youth empowerment (FAO 2020). Traditional agricultural methods are frequently included in integrated fish farming, which aids in the preservation of regional expertise and cultural heritage (Edwards 2005). More fresh vegetables and seafood available means that communities can eat healthier diets, which can enhance general health outcomes. Integrated systems frequently encourage eco-friendly behavior, increasing community members' knowledge of sustainability and conservation. Collaborating on integrated farming projects can improve interpersonal relationships, encouraging a feeling of community and collaboration. The entire community stands to gain when integrated fish farming expands and leads to better transportation and market access in rural areas. To improve the skill sets of local farmers, programs supporting integrated fish farming frequently involve training in sustainable techniques, resource management and business management. Certain integrated aquaculture growth models have had detrimental effects on ecosystems and society (Gabriel et al., 2007).

5. Key Components of an Integrated Fish Farming System

Fish Pond Design: An integrated fish farm's layout should have the main components, like it should make management easier, boost output and provide financial returns. All necessary precautions should be taken to ensure an efficient workflow, including lowering labor intensity, increasing efficiency and safeguarding worker health (Bhatnagar & Devi 2013). Additionally, it should minimize capital construction investment and use fewer materials and human resources. The integrated fish farm is designed with both current and future growth in mind. There should be sufficient space to implement a workable long-term plan in phases, contingent on available resources and labor force (Gill et al., 2009). Fish production is supported by other job types in the integrated environment. The needs of aquaculture determine the size of agricultural and animal output. As a result, the locations and areas of different ponds must be taken into account before those of animal pens, agricultural farming, manufacturing and other facilities (Prein 2002).

Water Management: Water availability is the most important prerequisite for fish production. Water may be used regardless of where it comes from as long as it is plentiful and of a suitable quality (Bhatnagar & Devi 2013). Other water sources should be taken into consideration if the water supply is close to sewage from a mine or plant. The water quality must be tested to determine whether the contents are hazardous to fish. Some food manufacturing mills, such as breweries, slaughterhouses and curd factories, produce wastewater that is rich in organic elements. These materials can be introduced to fish ponds under controlled conditions or used for fermentation and they can also be useful for fish farming (Cripps & Bergheim 2000). To satisfy the need for agriculture and to obtain an initial understanding of seasonal variations in water levels, there should be enough supply of water at a steady level. This is the main factor to take into account while designing fish ponds around the world. Planning for the future has made efficient use and reuse of watersheds a top priority as the governance of water resources becomes a global concern (Singh et al., 1991). The quantity of water available will affect the capacity for production, so pertinent data on hydrology, meteorology, topography, edaphic quality, etc. should be gathered. Then, the amount of water required per unit area for fish ponds based on the amount of water that flows through the seasons can be calculated to guarantee an adequate supply of water for both fish ponds and fields (Gupta &

Roy 2009). The same precautions should be taken to prevent flooding as for small-scale irrigation projects that are not affected by water for 25 years. Above the boundary line, the farm needs to be maintained safely. Finding a location is currently not possible in areas that are flooded by water or have excessive rains.

Waste Recycling: The idea that there is no waste and a well-known technique of "clean" fish husbandry are the foundations of the Integrated Recycling System (FAO 2014). Large plastic tanks inside a greenhouse and hydroponic beds next to the plastic tanks are the two main components of the Integrated Recycling System. In essence, the "waste" that generates revenue by creating a valued product turns into a "resource." Aquaculture goods (fish), bioenergy (gas and heat) and aquatic plant and agricultural products are among the many by-products that can be obtained while processing biological waste generated by animals (Kumar 2002). The reason its dubbed "no waste" is that the fish feed waste is sent into the hydroponic beds, where it slowly circulates tank water to provide nutrients to the plants growing in them. Because it is housed in a greenhouse, this system can adapt to nearly any temperate temperature. The most important thing to remember is that the fish's electrolyte balance depends on the discharge of salted water. The recycling of waste from fish aims to reduce ecological degradation and increase economy (Nash and Brown 1980). This fish farming system's main goal is to raise the productivity of water and related resources while also boosting the output of food fish. The two main advantages of this method are a reduction in the total amount of trash produced by farming activities and the establishment of more ecologically friendly farming practices.

Choice of Fish Species: The variety of crops being produced, the level of dissolved oxygen in the water and the feeding habits of the fish all have a role in the selection of particular fish species for integrated fish farming (Hasan & 2013). Fish that can filter water and feed on bacteria, zooplankton and phytoplankton are the best candidates for integrated livestock-fish farming (Yi & Diana 2003). The goal of integrated livestock and fish farming is to use manuring to create as much plankton as possible in the water. Plankton is high in protein and provides fish with natural food. Fish species that are eaten by humans, effectively use phytoplankton and zooplankton and have a tendency to feed on macrophytes are ideal for integrated livestock fish farming. Fish are

categorized into three groups based on how they feed: surface feeders, column feeders and bottom feeders (Halver & Hardy 2002). The exotic species and zooplankton feeders, Catla (*C. catla*), are included in the integrated system of fish species for farming. The most common instance of a surface feeder is the phytoplankton-consuming silver carp (*H. molitrix*), while the omnivorous Rohu (*L. rohita*) is a column feeder (Jena & Das 2011). *C. carpio*, the common carp, is an omnivorous detritivore, while *C. mrigala*, the mrigal and *L. calbasu*, the kalabasu, are detritivores. Tilapia (*O. niloticus*) and grass carp (*C. idella*), two common fish species raised under integrated fish animal husbandry to increase production, are herbivorous species that cover the surface, column and marginal area of the feeding zone (Fagberno and Sydenham 1988).

6. Challenges in integrated fish farming

Technical competence: Adequate land, water and labor resources are necessary for integrated farming. For integrated farming to be effective, farmers need to have access to these resources.

Capital expenditure: Combining multiple farming systems usually requires a significant capital investment. This could entail investing in infrastructure, such as greenhouses, tanks and ponds, as well as tools and equipment. According to reports, the price of raising fish in rice fields has gone up dramatically recently due to rising prices for labor, feed, fertilizer and fish fingerlings (Ahmed et al., 2011).

Market demand: Farmers may find it challenging to effectively market and promote their products due to the variety of products generated by integrated farming. This is particularly valid in situations where the market demand for a particular product is unstable or low. Currently, rice cultivators are "staying poor to stay secure" (Wood 2003) rather than facing chances by investing in rice-fish farming.

Climate change: Climate change may have a major effect on integrated farming. Variations in temperature and precipitation patterns can have an impact on aquaculture productivity, animal health and crop development. Fish producers experienced difficulties in adapting to climate change due to a lack of funding, expertise and water resources (Mwangi et al., 2024). The impacts of current and projected climate change pose an issue to integrated prawn, fish and rice production in coastal Bangladesh (Ahmed et al., 2014).

Regulatory compliance: Integrated farming operations need to follow a variety of rules and regulations in order to ensure food safety, animal welfare and environmental sustainability. Farmers must be aware of these rules and follow them in order to avoid fines and maintain their certification. When ponds are infrequently cleaned during fish harvest, excess antimicrobials and

antimicrobial residues may build up in integrated fish farms. Antimicrobial-resistant bacteria may be selected for and thrive more readily as a result of such an accumulation (Petersen et al., 2002).

7. Future Prospects and Trends in Integrated Fish Farming

Encourage Research and Development

- Promoting research and development in integrated agricultural systems is crucial, as it involves developing innovative instruments, streamlined processes and enhanced animal and crop types.
- Research can also be utilized to identify new opportunities for integration, like combining the production of agricultural and aquaculture.

Create awareness and training programmes

- These programs, which can be organized at the village level, can include presentations of successful integrated agricultural techniques, capacity-building programs for farmers and training on best practices.
- A skilled integrated fish farmer can guarantee higher fish yields. Training is the key variable influencing people's attitudes, efficiency, advancement and risk reduction, according to (Meenambigai and Seetharaman 2003).
- The degree of training requirements for integrated fish farming may be significantly influenced by the participants' social standing. As they gain more knowledge and expertise in integrated fish farming, they may be able to determine what kind of fish farming training they require (Yeasmin et al., 2013).

Encourage public-private partnerships

- Public-private partnerships have the potential to facilitate the advancement of integrated farming by uniting entities from the public, private and civil society sectors to exchange knowledge, expertise and resources.
- By fostering connections between markets for integrated agricultural products, partnerships can also help farmers have better access to loans and other financial services.
- Promote Market Links
- Integrated farming can assist farmers in diversifying their revenue streams by generating a range of products, including fish, livestock, crops and forest products.
- To increase market connections, create value chains for integrated farm produce, construct marketing infrastructure and provide support for agro-processing and value addition.
- Given that IFS-practicing farmers were dispersed throughout the area, it could be preferable for cluster-wise IFS farmers groups to be established. These associations would be essential in helping the farmers deal with their issues (Kandir 2020).

Integrate ICT Solutions

- Information and communication technology (ICT) solutions can support integrated farming by providing farmers with access to real-time data on weather patterns, market prices and agricultural best practices.
- In addition to improving farmers' access to advising and extension services, ICT solutions can facilitate their usage of e-commerce platforms and other online marketplaces.

8. Conclusion

The need for food and increased security of income is rapidly growing along with the state's population. The integrated farming system's diverse and various strategies to raising crops, fish and animals allow it to share the financial risk of scarce supplies among low-income farmers. When combined with livestock and agriculture, fish cultivation offers small-scale farmers an additional revenue stream. These procedures aid in raising output while requiring little more money. In the near future, it is anticipated that IFF methods—which rely on environmentally benign practices and guarantee higher returns in addition to sustained levels of fish and other bioresource production—will expand in the country's favorable agroclimatic zones. The farmers are self-sufficient and productive all year round since they work in agriculture in one capacity or another. It also generates employment for the vast unemployed rural population. Its environmental significance should be taken into account prior to its potential can be completely realized, as it will determine the rate at which efficient management can be implemented to achieve its maximum yield. Aquaculture's equivalent role in enhancing environmental suitability needs to be developed and communicated to all stakeholders in order to enable effective and efficient ecological management, which will eventually lead to maximum yield. Clear and explicit links between aquaculture and the environment must be established.

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