Integrated Livestock-Fish Production Models for Livelihood Security in North-eastern India

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Abstract

Agriculture, horticulture and animal husbandry form the mianstay of food production in the hill states of India. A majority of the population lives in rural areas and depends for their livelihood on agriculture and allied enterprises. There is a tremendous pressure to step up the food production for the people of the hill states. However, the area available for cultivation is less owing to the rugged terrain and undulating topography; and there is least scope for horizontal expansion to increase the production. This calls for planned utilization of the agricultural land and water resources with an integrated approach to produce diverse food in large quantities from a unit area. Fishery can play an important role in the economic developmemt of the farming communities. The composite fish culture comprising of both Indian major carps and exotic carps would be a viable proposition and can be practiced in different elevations with suitable modifications in species combination and ratio. However, in a rural set up, fish culture becomes more economical when integrated with other agricultural and allied enterprises. In integrated livestock-fish farming, fish derives benefit from livestock dung and manure and at the same time, the livestock derives benefit from the aquaculture ponds, thus resulting in the overall development.

1. Introduction

Integrated farming systems are probably as old as farming itself if the broader definition of integrated farming is taken into consideration. Integration occurs when outputs (usually by-products) of one production sub-system are used as inputs by another, within the farm unit. Livestock-crop systems (in which crop residues are consumed by livestock and manure is recycled to fertilize the soil) are widespread and rather well documented. Livestock-fish systems, although their main feature is also by-product recycling, however, did not develop at the same pace in other Asian countries except China, and until recently, were poorly understood. In many developed countries, intensive livestock production is now considered as a source of pollution of the environment due to the release of organic matter into the rivers. Intensive farming of pigs and poultry produce large quantities of manure and animal urine which must now be treated in order to prevent serious environmental problems. The most prevalent method of manure disposal is its use as fertilizer on land, but excessive use of fertilizers will lead to eutrophication of inland and coastal waters. There is a possibility of recycling organic wastes, manures and farm effluents in fish ponds. The end product is an improved production of animal protein, particularly needed in developing countries like India.

The aim of integrated farming is the recycling of animal wastes (faeces, urine and spoiled feeds) to serve as fertilizers, and sometimes as food for fish cultured in ponds, enclosures and cages. According to Pillay (1990), the basic principles involved in integrated farming are the utilization of the synergetic effects of inter-related farm activities, and the conservation, including the full utilization, of farm wastes. It is based on the concept that 'there is no waste', and 'waste is only a misplaced resource which can become a valuable material for another product' (FAO, 1977).

2. Integrated Farming of Fish and Livestock

Integrated farming of fish and livestock is consisting of the culture of fish (or shrimp) associated with the husbandry of domesticated animals such as cattle, pigs, ducks, chicken, etc. (plate 1). Integrated farming is traditional in Asia, especially in China and is now also applied in Europe and, on a small scale, in Africa and some Latin American countries. The highest productions obtained so far in integrated fish farming are with pigs, ducks and chicken (Edwards et al., 1986). In some countries, fish farmers also integrate geese, rabbits,

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goats, sheep, cattle and the water buffalo with fish culture, on a smaller scale. The main fish species stocked in animal-fish pond systems, either in mono or polyculture are the common carp and some exotic varieties. Indigenous species such as Catla (*Catla catla*), the surface feeder; Rohu (*Labio rohita*), the column feeder; Mrigal (*Cirrhinus mrigala*) and Kalabasu (*Labio calabasu*), the bottom feeders have been recommended with exotic varieties such as Grass carp (*Ctenopharyngodon idella*), Silver carp (*Hypophthalmichthys molotrix*) and Common carp (*Cyprinus carpio*), hybrid of Tilapia, Grey mullet and Eels are also raised mainly in polyculture. Stocking densities and species composition vary considerably from system to system and sometimes from country to country depending upon several factors. The organic rich livestock wastes are utilized as a substitute of fish feed and pond fertilizers, which can replace about 60% of the input cost in aqua farming. There may be various combinations of integration such as fish-cum-pig, fish-cum-poultry, fish-cum-duck, fish-cum-cattle, etc. The animal housing unit in the system is constructed over pond surface, on pond embankments or vicinity of the pond so that the farm yard waste is available in close proximity.

2.1. Pig-fish integrated system

This method is a classical Chinese integrated fish farming system widely practiced in its original geographical area. This system was well established by immigrant Chinese in several south-east Asian countries (such as Thailand, Malaysia and Singapore and later also in other parts of Asia (India, Nepal and Bhutan). In this system, pigs are reared in pens or sties built on the banks of the fish ponds (wastes are washed out in to the pond) or constructed over the ponds on piles or wooden stilts and have a lattice type of floor (allowing wastes to fall directly into the pond). Generally small pig sties are constructed over the fish ponds and bigger ones on the dykes. Pig manure reaches the pond directly or after being collected and fermented in suitable pits. Fresh pig manure is regarded as highly efficient for pond fertilization and fish can utilize directly the feed spilled by the pigs.

The number of pig ha^{-1} of pond area varies from 40 to 300 depending upon the pig size and water quality of the pond. However, the number of piglets generally recommended is 100 ha^{-1} (or 1 piglet 100 m^{-2} of pond) while adult pigs may range between 30-40 numbers. Piglets are weaned at two months age (average weight 12-15 kg) and are ready for fattening. They reach 70-85 kg after 6-7 months. Exotic pig breeds like Hampshire, Large White Yorkshire, Large Black, Landrace, Berkshire and their crosses are usually preferred for integrated farming system as compared to the local pig breeds since they are highly prolific, having high feed conversion efficiency, large body size and faster growth rate. During the period of one year, two crops of pigs can be raised.

Fish culture is generally practiced at least for 12 months in the integrated pig-fish system. In this period, generally, Catla attains a weight of 800 gm to 1 kg, Rohu 600-800 gm, Mrigal 400-600 gm, Silver carp 1-1.2 kg, Grass carp 1-1.5 kg and common carp 800 gm-1 kg. Total fish production may range between 2.5-3 t ha^{-1}.

2.2. Poultry-fish integrated system

Theoretically, this is the best possible integration system in which poultry are raised on the pond surface, drop their nutrient-rich manure feed in the pond; the fish gather protein-rich natural feed from the pond ecosystem or may consume directly the feed spilled by the ducks. In many countries of south-east Asia, egg laying duck breeds are raised rather than the white Peking type meat ducks to scavenge on rice stubbles without formulated feeds. In most of the cases, it proves to be uneconomical to keep the duck confined to the pond and feed them with complete feeds. The market demand (especially that of the local rural markets) is very limited for the Peking type meat ducks in most of the developing countries. Substituting the duck with geese in the integrated system has proven successful both technically and economically in some countries (China, Hong Kong, Taiwan, Philippines), although this change does not resolve the general problem of having a narrow market niche for the product. Moreover, geese are usually more susceptible to diseases than ducks.

Raising egg laying hen or broiler chicken in poultry houses built above the fish ponds or on the dykes is not a traditional method of integration, but it is becoming popular in countries where formulated poultry feeds are manufactured locally and are available at reasonable prices, e.g. Thailand, India, Malaysia and the Philippines. This type of integration occurs both in large commercial ventures and small farms usually close to urban markets.

2.2.1. Duck-cum-fish farming

The combination of duck and fish farming is considered as a means of reducing the cost of feed for ducks, and a convenient and inexpensive way of fertilizing ponds for the production of fish (Pillay, 1990). In this integrated system, ponds provide living and foraging areas for the ducks and fish (Figure 1). Ducks are reared in shelters built on the banks of the ponds or constructed over the ponds on stilts, or sometimes built on floating platforms. Fish-cum-duck integration is most popular in developing countries but it is not much popular in north-eastern states of India. Among various breeds of duck, Khaki Campbell is recommended for fish-cum-duck integration. Fish pond being a semi-closed biological system with several aquatic animals and plants provides an excellent disease free environment for the ducks. In turn, ducks consume juvenile frogs, tadpoles and dragonfly, etc. thereby making a safe environment for fish. The ducks should be kept away from the dykes of the ponds

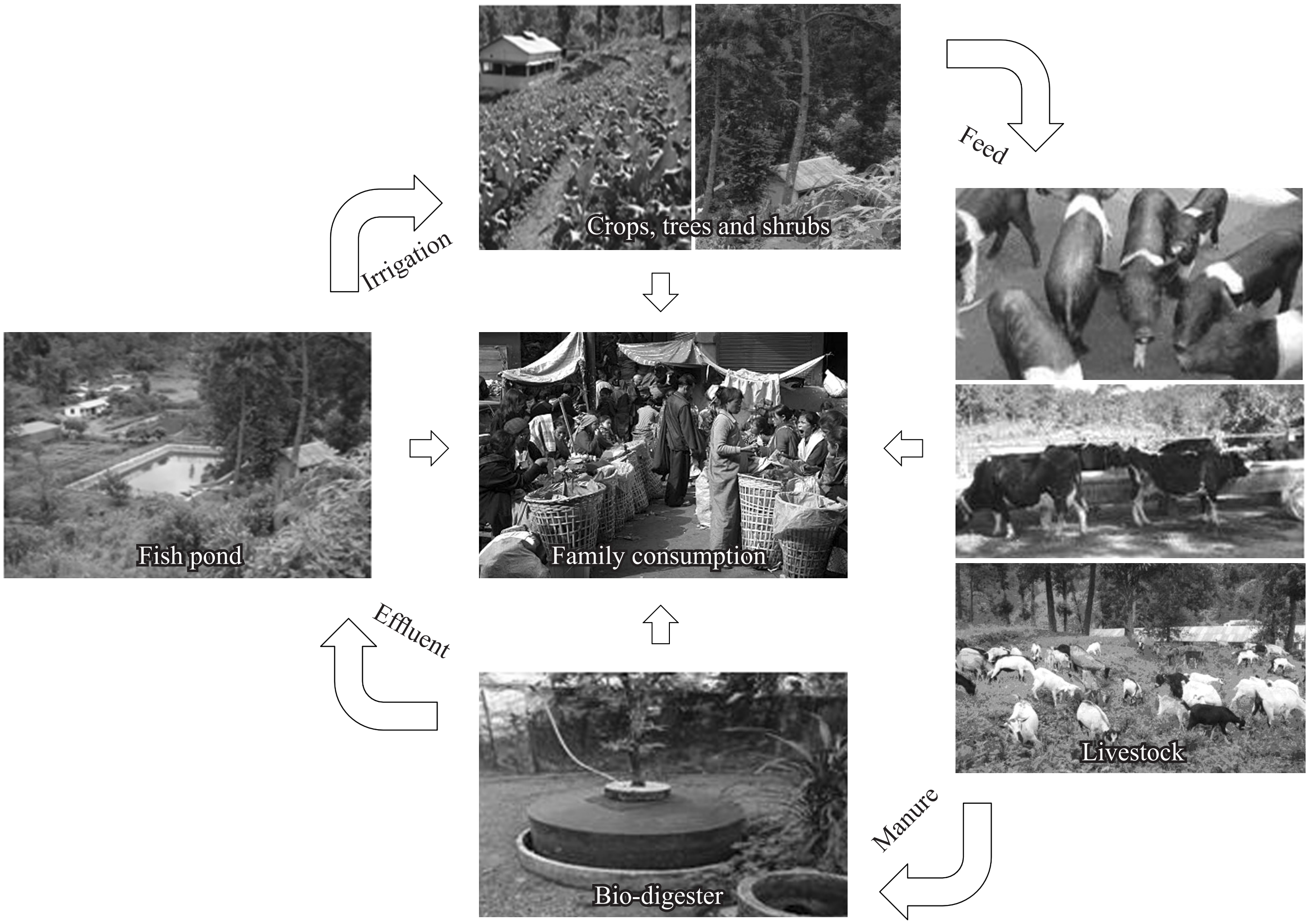

Plate 1: Nutrient recycling in crop-livestock-fish integrated system

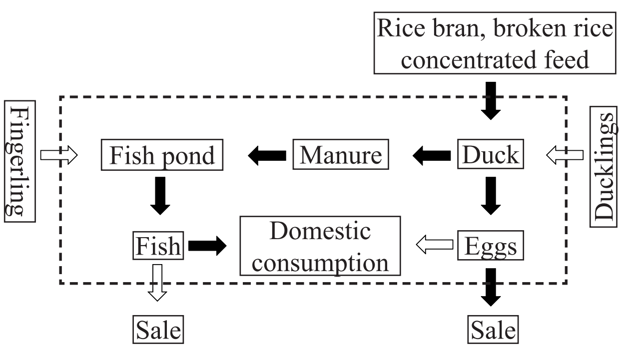

Figure 1: Energy flow in fish-duck integrated system

since they search for insects, frogs and snails, damaging the earthen walls with their beaks and provoking erosion and the collapse of the dykes. Fencing inside the pond is therefore recommended. Ducks are known to eliminate almost all the snails in ponds in depths of up to 30-40 cm, thus controlling the immediate host of Schistosomiasis (parasitic infection by a trematode worm acquired from infested water). There are different duck strains. Peking ducks are used in Central Europe, China, Philippines, Africa and Latin America. The Khaki Campbell strain is raised in Thailand and the Mule duck in Taiwan. Muscuovy ducks are sometimes used in Africa. Each strain has different fattening periods, and a marketable size of 2-2.8 kg is obtained within 7-9 weeks depending on the strain, the size at stocking and feeding.

Ducks are reared at different densities depending on the climatic conditions, method of rearing (extensive or intensive), water quality and other factors. About 300 ducks are enough to fertilize a pond of 1 ha. Demonstration trials conducted in India in polyculture of Indian and common carps (at a stocking density of 6,340 fingerlings ha^{-1}) raised with ducks (100 ha^{-1}) have yielded 4,323 kg of fish ha^{-1} $year^{-1}$, 250 kg of ducks (live weight) and 1,835 eggs (Jhingran and Sharma, 1980).

2.2.2. Chicken-cum-fish farming

The droppings of the birds in this system are utilized to fertilize the pond. Poultry litter recycled in to fish pond produces 4,500-5,000 kg fish ha^{-1} $year^{-1}$. Broiler production provides good and immediate return to the farmers. The poultry litter is applied to the pond in daily doses at the rate of 40-50 kg ha^{-1}. The application of the litter may be deferred during the days when algal blooms appear in the ponds. One adult chicken produces about 25 kg of compost poultry manure year^{-1}. 500-600 birds would provide sufficient manure for fertilization of 1 ha of fish pond.

The fowls of Rhode Island Red or other improved birds (Vanaraja) are suitable for integrated chicken-fish culture. About 8 weeks old birds can be kept in poultry house after proper vaccination and other prophylactic measures. Each poultry house must be provided with some nest boxes for egg laying. Egg production starts after 22 weeks and it becomes regular till 18 months of age. After 18 months eggs production starts declining. Therefore, it is recommended to replace the old stock with fresh one. Fish culture is generally practiced at least for 12 months in the integrated chicken-fish system. In this period, generally, Catla attains a weight of 800 gm to 1 kg, Rohu 600-800 gm, Mrigal 400-600 gm, Silver carp 1-1.2 kg, Grass carp 1-1.5 kg and common carp 800 gm-1 kg. Total fish production may range between 2.3-2.8 t ha^{-1}. Approximately, 100,000 eggs and 1,250 kg of live birds can be expected from 500-600 birds.

2.3. Ruminant-fish integrated system

Large ruminants (cattle and buffalo) are integral part of Asian farms and will remain so in the foreseeable future despite some advances in farm mechanization. However, there are significant obstacles in this respect to integrate them with fish production. First of all, most of these animal are allowed to graze rather than kept and fed in feedlots, their manure is scattered all over the farm and/or the pasture. They may be padlocked at night, but the manure collected in the enclosure is traditionally used to fertilize crops by small farmers. The manure of ruminants contains less nutrients than that of poultry and pig, especially when it is collected from the fields after being dried and/or leached out. For these reasons there are very few true integrated ruminant-fish systems in the region, although cattle and buffalo dung is widely used to fertilize nursery fish ponds.

In some countries, integrated goat-fish and sheep-fish systems were also tested with encouraging results, e.g. in India, Indonesia and the Philippines. However, these systems are not expected to make a significant impact in the region.

3. Rationale of Fish-Livestock Integration

The rationale behind integrating fish with livestock is the large amount of nutrients (N-P-K) present in the feed that is recovered in the manure, with possible proportions of 72-79% nitrogen, 61-87% phosphorus and 82-92% potassium. These act as fertilizers in fish ponds to produce plankton which comprise high-protein natural feed for certain species of fish. Nitrogen and phosphorus are the nutrients most likely to be limiting for plankton growth in the pond but fish yield is probably more directly correlated to manure nitrogen content (Edwards, 1991) since nitrogen is more volatile than phosphorus. Based on the nitrogen content of different manures (2.6% in laying duck, 1.9% in pig, 2.2% in dairy cow and 1.1% in buffalo), it is possible to estimate the stocking density of different livestock species. Comparative effectiveness of the manure on the development of organisms in the feed web and promotion of biological activity in fish ponds are: duck manure>pig manure>raw chicken manure>cattle manure>sheep manure. Manure may contain up to 25% crude protein, but more than half of this is usually non-protein nitrogen, e.g. uric acid, which is not assimilated by fish. Therefore, manure itself is a poor feed for fish. Manures also contain less energy than conventional pelleted feeds. Though many species of fish consume manure directly, it is a low quality feed-stuff compared to conventional pelleted feed and natural plankton.

Another advantage of manure utilization in fish ponds is that since carbon forms about 50% of the biomass of plankton, the high organic content of the manure is an important source of carbon which is released by bacterial respiration. However, depending on the productivity and quality of water and soil, the effectiveness of livestock manure (enriched with cellulose-rich organic matter) in acting as nutrient sources for fish growth and in raising fish yield varies.

Two possibilities have been observed by Schroeder et al., (1990).

a. Application of manure would improve fish yields only under conditions of water and soil which are poor in essential nutrient minerals, e.g. carbonates or organic matter, or pond water of a low pH, or fish ponds receiving very 'soft' waters deficient in minerals, or ponds with a low primary production.

b. Application of manure may be ineffective in raising fish yields above the rates achieved by daily applications of mineral (N-P-K) fertilizers under conditions when the fish pond is receiving daily applications of mineral fertilizers, or where fish ponds are highly productive with very fertile soil naturally enriched with nutrient minerals and carbonates, or fish ponds with nutrient-rich waters resulting in a high concentration of algal-based waste organic matter.

4. Principles of Fish Production in Integrated Farming Systems

Principles pertaining to technology of livestock-fish farming are as follows:

i. Fish production in integrated systems is more complex than the conventional separate aquaculture system, requiring more knowledge and better management practices.

ii. Integrated farming systems may vary in the degree of intensification of the livestock and fish sub-systems varying from extensive, semi-intensive to intensive sub-systems.

iii. Extensive sub-systems utilize natural feed produced without fertilizers; semi-intensive sub-systems require fertilizers to produce natural feed and/or supplementary feed but with a significant component of diet supplied by natural feed; and in intensive sub-systems all the nutritional requirements are provided by artificial feed given to fish with natural feed contributing little or no nutrition.

iv. Fish cultured in an integrated farming system benefits from a significant amount of the nutrition derived from natural feed, which develops in the pond due to the fertilization by organic manures. This suggests the important role of surface algal based feed web which cultivates in fish biomass.

v. The largest contribution of the manure to fish nutrition, therefore, appears to be due to its fertilizing effect in the pond. Bacteria, breaking down the organic matter in the manure, release nutrients which lead to the production of phytoplankton and zooplankton.

vi. In a manure-fed fish pond, fish nutrition may also be derived from direct consumption of the manure. However, a detritus feed web has a secondary role in fish biomass production, as compared with the algal-based feed web.

vii. The direct nutritional value of manure for fish is by its content of spilled animal feed. A large proportion of the nutrients in livestock feed are not assimilated, but are voided in the excreta, particularly in pig excreta.

viii. Over-fertilization with manure may lead to poor water quality of fish pond, particularly leading to depletion of dissolved oxygen resulting in increased fish mortality.

ix. Management of water quality is needed to overcome fish mortality due to oxygen depletion and extreme fluctuation of dissolved oxygen levels. The strategy is to promote a growing biomass of phytoplankton which will generate sufficient oxygen to maintain relatively high dissolved oxygen. It is essential to maintain a positive net photosynthesis.

x. Criteria for selection of fish species for stocking into manure-fed fish ponds should be based on the ability of fish species to (a) filter and feed on plankton (bacteria, phytoplankton and zooplankton), and (b) tolerate low levels of dissolved oxygen (<2 mg l^{-1} minimum as defined by 'Criteria for the Protection of Aquatic Life').

xi. Determination and recommendation of the optimal stocking density of fish consider differences in local circumstances such as the fish species, manure type and inputs to the pond, addition of other off-farm feed, and water quality of the pond.

xii. Ways to intensify fish production from integrated farming systems involve management inputs to stock a higher initial fish biomass, followed by harvesting the fish intermediately when the growth curve of stocked fish starts to slow down.

xiii. There is a need for a more complex marketing system to handle the inputs and products from two sub-systems as opposed to a single sub-system.

xiv. Integrated farming on the one hand enables the distribution of risk (both biological and economic), since two sub-systems are involved as opposed to one in a single-commodity farming system; on the other hand, the failure of one sub-system can adversely affect the other.

5. Conclusion

Using integrated livestock-fish systems to resolve the environmentally safe manure disposal of feed lot type animal husbandry farms will certainly gain momentum in India with the proliferation of such ventures. It is likely that fish farming combined with animal husbandry can be developed on large-scale in India where small-scale rural fish farming already exists. The integrated farming systems are potentially important in raising the income level as well as the standard of living of small-scale farmers. Most of the farmers are lacking technical knowledge which must be remedied by realistic technical assistance. Small farmers will need further support in extension services, credit and marketing in developing socially and economically sound integrated livestock-fish systems in carefully selected areas (usually close to urban centers). More commercial types of integrated fish farming systems will certainly keep expanding through the efforts of the Indian Council of Agricultural Research, State Governments, NGOs and private sectors by providing technical and financial support to the small farmers in adopting and operating such systems.

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