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Pond dyke utilization: An innovative means for enhancing productivity and income under Integrated Farming System in North East Hill Region of India

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ABSTRACT

Integrated farming system (IFS) is a sustainable and effective means for improving rural economy due to its cumulative cost effectiveness, low investment and higher profitability. IFS has greater role for livelihood improvement in north eastern region (NER) of India where most of the farmers are small and marginal. Farm pond for multiple uses is the integral part of IFS system in the region. In a typical farm pond, about 40-60% area is given to dyke, which is generally very productive area due to water and organic matter availability in the vicinity. In-spite of its high production potential, pond dykes are seldom effectively utilized. Fish pond dyke intensification with crops and poultry can play a significant role in increasing manifold production, income, nutrition and employment opportunities of rural populations. In present study, three different components like fish, poultry and sequential vegetables production were employed in at ICAR Research Complex for NEH Region, Umiam, Meghalaya (980 amsl). The results indicated that in integrated pond management, two additional enterprises, viz. poultry and year round vegetable cultivation exhibited production and income enhanced over traditional practice. Integration of fish-poultry and year round vegetable production recorded 750% higher system production efficiency and 858.6% higher average profitability over the traditional practice. Furthermore, pond dyke intensification and poultry production also recorded 600% higher employment generation over non-integration. The utilization of family labour round the year in pond based integrated production system increases the production as well as employment opportunities for income generation. The overall results revealed that the integrated pond management with poultry, fish and vegetables on pond dyke is an excellent approach for sustainable production as well as income and employment generation for the resource poor rural households.

Key words: Integrated fish farming, Livelihood security, Poultry rearing, System productivity, Vertical intensification

In present era of shrinking natural resources, food security is the major concern to feed the galloping population of hilly region of north east India. Equilibrium between effectual and productive agricultural enterprise and environmental sustainability is important to make agriculture sector more productive and economically viable (Yadav *et al.* 2013). In this context, integration of fish farming with other farming enterprises under integrated farming system (IFS) is advocated to achieve the optimum productivity, increase resource-use efficiency and employment (Barg *et al.* 2000). Integrated fish farming systems comprise various complimentary enterprises that leads to maximization of productivity through optimum resource use, hence resilient to climatic variability (Lightfoot *et al.* 1993) and reduces the production cost (New 1991, Nanda and Bandopadhyay 2011). Pond based IFS with frugal investment is economically sound, environmentally feasible and socially acceptable (Biswas and Sahu 2013). Water is most crucial and precious resource in IFS under rainfed situations for sustainable production. Pond adds value to the farming activities as a source of water to crops and other enterprises. In a farm pond, about 40-60% area is under pond dykes. In most cases pond dykes are either under-utilized or left fallow. But these unutilized spaces could be used for intensive production of high value vegetable crops especially for creeper types round the year since; water is available throughout the year. Farmers mostly cultivate some indigenous fish in a non-scientific way and don't apply

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any fish feed and fertilizers, as a result they are not getting targeted yield and income. However, these feed and fertilizer could easily be supplemented by poultry droppings, if poultry shed is constructed above fish pond (vertical intensification). This practice can increase the production efficiency of both poultry and fish culture through judicious utilization of feed wastes (Vincke 1988). Furthermore, the integration of fish with poultry and vegetables holds a significant potential for supplementing production of animal protein, employment generation and improvement of livelihood security of resource poor tribal farmers in hilly ecosystem of north east India. Hence, under limited arable land and water supply condition, the integrated fish-poultry- seasonal vegetables are not only technologically feasible and socially acceptable but economically sustainable too.

Waste recycling or by-product in which the waste of one system becomes the input of another system thereby reducing the amount of waste generated and input resources, efficient utilization of farm space for multiple production, provision of steady source of income all year round to the farmer (Onada and Ogunola 2016). Hence, it was hypothesized that by adopting intensive integrated fish production technology, farmers could be able to increase their farm productivity; employment and income through optimum utilization of limited available resources. Innovative agro-eco-techniques, i.e. fish pond-poultry-year round vegetables production system was evaluated at Farming System Research Project Site, ICAR Research Complex for NEH Region, Umiam during 2015-17 under AICRP-IFS project to make full use of available land and water resources which in turn help maximize the return from their investments in the dyke-pond ecosystems under IFS. Moreover, the introduction of innovative production method ''intensification of pond dykes under IFS'' may help restoring the natural productive capacity of the delicate land-water ecosystems in the region in an integrated fashion. Therefore, the objective of the current study is to assess the productivity, profitability and employment generation efficiency of integrated fish with poultry and year round vegetable production over traditional fish farming practices in north east region of India

MATERIALS AND METHODS

Farming System Research Project, ICAR Research Complex for NEH Region, Umiam situated at latitude $25^0 41'21''$N and longitude $91^0 55'25''$ E, at an altitude of 980 amsl. Umiam enjoys a tropical monsoon climate and 70% of the total rainfall is received during July to September. December to March is the extreme dry period during which crop suffers from water scarcity. April is the hottest month, with average minimum and maximum temperatures of 17.3 ºC and 29.4 ºC, respectively. The coldest month is December where the average minimum and maximum temperatures are 7.6 ºC and 20.4 ºC, respectively. The experimental site received total rainfall of 2217 mm/annum during 2015-17. The variation in maximum temperature was observed across the years; during 2015-17 maximum temperature was recorded in April (28.6°C). Although minimum temperature remained constant and lowest temperature in all the three years was recorded in January.

A farm pond of 822 sq m area was established under AICRP-IFS at Farming System Research Project site, ICAR Research Complex for NEH Region, Umiam. Out of the 822 sq m area, fish pond covers an area of 500 sq m having average depth of 1.5 m, lined with 250 micron polythene sheet. Composite fish culture was adopted in farm pond and 500 fingerlings of 3 different species, viz. silver carp (surface feeder), common carp (bottom feeder) and grass carp (column and marginal areas feeder) were released in the fish pond with the stocking ratio of 5:4:1. These carp species have different feeding zone and food habitats, therefore these species were selected to avoid competition for food among them. As a result, the food available in all columns of the water bodies in the pond is used efficiently. On an average, 1 kg concentrate fish feed was given in pond at every alternate day. In addition, liming to maintain soil or water pH, application of FYM, tender vegetable leaves, etc. was practiced for better fish growth through on farm resource recycling. Fish feed contains a mixture of crushed maize, wheat bran, rice polish, mineral mixture, groundnut cake (GNC), mustard oil cake (MOC), salt, etc.

The dyke occupied an area of 322 sq m and was utilized for cultivation of vegetable crops throughout the year as per season. During *kharif*, an innovative concept of aqua-verti farming is adopted to grow cucurbitaceous crops (bottle gourd, ridge gourd, cucumber and pumpkin) in such a way that their vines will go to a raised structure constructed about 2 m above water surface (*machan*) and other pond dyke area was utilized for cultivation of tomato and chillies/capsicum. With regards to the cucurbitaceous crops, three to four seeds were sown in the pits (30 cm × 30 cm × 30 cm) at 2.5 to 3 cm depth in April with a spacing of 2.5 m × 2.0 m. Before sowing, the seeds were treated with *Pseudomonas florescence* @ 10 g/kg and *Trichoderma viride* @ 4 g/kg of seed. With regards to the manuring, 5 kg FYM/pit 20 days before sowing and 0.5 kg vermicompost/pit at time of sowing as a basal was applied. In addition to this *Azospirillum, Phosphobacteria* and *Pseudomonas* @ 70 g each (2 kg/ha) mixed with FYM and applied one week before sowing. A "Bamboo Machan" about 3 m width, 15-20 m length and 1.5 to 2 m height was constructed on two sides of the pond for providing support for the cucurbitaceous crop. The durability of *Bamboo Machan* is about 3 years and only annual maintenance was done for safeguarding the structure. For proper utilization of *Bamboo Machan* after harvest of cucurbitaceous crops, the basins were made on pond dyke and 1 kg vermicompost + 5 kg FYM per basin was applied after proper mixing with soil one week before sowing of local beans (Lablab). After that 4-5 seeds of local beans per basin was sown at a depth of 5-6 cm during post *kharif* period. Inoculation of seeds with *Rhizobium* spp. was also done to facilitate quick root nodulation, and help in the fixation of atmospheric nitrogen. No major insect pest infestation was observed due to wider spacing of local beans, which facilitated easy air circulations. Lablab beans took about 3 months for first harvest after that 9-10 pickings were taken at 7 days intervals. Fully grown green pods were harvested.

Pond dyke was manually tilled (leaving the sides of pond dyke) to minimize the soil erosion before the planting of *pre-kharif* vegetables (tomato and capsicum). After cleaning and a manual spading, pits were prepared at a spacing of 60 cm × 45 cm. About 25 to 30 days old seedlings of tomato and capsicum were transplanted. For proper supply of nutrients to the crop, 5 kg FYM + 1 kg vermicompost/ sq m was applied after proper mixing before one week of planting. Necessary manual weeding and watering were done as and when required. Tomato and capsicum became ready to harvest in 80-90 days after planting; subsequent pickings were done at weekly interval. After harvest of *pre-kharif* crops, *rabi* vegetables (coriander, fenugreek, cabbage and broccoli) were grown. The field was tilled manually with the help of spade to break the soil clods and then 5 kg FYM/ sq m was mixed for adequate nutrition to the vegetable crops. Then, 30 days old cabbage/broccoli seedlings were transplanted with a spacing of 60 cm × 45 cm. The harvested rainwater from the pond was lifted with 1 HP water pump and used for irrigating the crops on the dyke during *rabi*. With regards to the fenugreek and coriander, 5 kg FYM + 1 kg vermicompost was mixed and applied to the soil at the time of land preparation for providing of proper nutrition to the crops. Guinea grass, a perennial fodder grass was grown on side slopes of pond dykes to check soil and water erosion and generate additional income.

Poultry rearing was integrated with fish culture to reduce costs on nutrition for crops and feeds in fish culture and maximize the benefits. Poultry shed was constructed over water surface adjacent to the pond embankments in a way that the poultry dropping go directly in the fish pond and recycled as a feed to the fish culture. Poultry rearing above the fish ponds facilitated effective use of space; saved labour in transporting manure to the ponds and the poultry house was more hygienic. A low cost poultry house (about 150 sq feet area) was constructed over the pond at 0.5 m on side of the embankment. Each broiler bird requires 1.5 sq feet space (50 birds require 150 sq feet area). The house was made of bamboo, and roof was covered with old unused asbestos and gunny bags. The roof was constructed in a way that the rainwater should not stagnate above the roof surface. Proper cross ventilation was maintained for adequate air circulation. Floor was constructed with bamboo slits, with 0.5-0.75 cm gap, to allow excreta to fall into pond, but not very wide for the chicken's feet to get caught in between and injured. Fifteen days old fast growing locally adoptable broiler birds were purchased from market for rearing purpose in each cycle. To maintain the required temperature range, the chicks were surrounded in bamboo fence and 2-3 electric bulbs (200 W) were provided. In respect to the feeding management, starter and finisher were given for 1-4 weeks and 5-8 weeks, in unrestricted amount, respectively. Consistent water supply was ensured for chicks. Temperature in the poultry house was maintained at 20-22°C. Whenever the temperature dipped below this level, two 200-watt bulbs were hanged. As poultry production is very disease sensitive, hence, in order to keep flock diseases free proper vaccination against, important diseases like Ranikhet, fowl pox and Mareks diseases was ensured as per schedule. Broilers reached marketable size of 2.0-2.5 kg in 50-60 days and six batches of broiler chicken were reared in a year (Table 1).

Table 1 Brief description of broiler production technology

Parameters	Value
System of rearing	Ventilated house above water surface
Batch size	50 +5% extra
Batch interval	50 days-(+7 days cleaning period) 57 days
Mortality of birds	5%
Cycle size	50
Cost of day old chicks (₹)	30
Cost of per kg feed (₹)	30
Cost of equipment (water tray, feeders etc.)	₹ 12/bird
Cost of medicine vaccine etc.	₹ 1/bird
No of batches/year	6
Average age of selling	45-50 days
Average weight at sale time	2.5 kg
Feed requirement to attain the weight of 2.5 kg	3.5-4.0 kg/bird

The generated data were computed in terms of productivity of the fishery and vegetable cultivation practices, their gross return, net return and ultimate B:C ratio. Different economic efficiencies like system productivity (kg/ unit), system production efficiency (kg/unit/day), system profitability (₹/unit/day), and relative production efficiency (%) and relative economic generation efficiency (%) were calculated with the formulas suggested by Babu *et al.* (2016).

RESULTS AND DISCUSSION

Economic analysis of pond dyke intensification under integrated farming system

Economics of fish production: The 125 kg fish was harvested from 822 gross area (500 sq m effective area) in eighteen month and sell in the market @ ₹ 130/kg (Table 2).The economic analysis revealed that cost of per kg composite fish production in IFS was about ₹ 76.8 and the gross and net returns per sq m ₹ 32.5 and ₹ 13.3, respectively.

Table 2 Economic analysis of fish production

Total fingerling (Nos.)	Total production cost (₹)	Total production (kg)	Selling price (₹/kg)	Gross returns (₹)	Net returns (₹)	B:C ratio
500	9600	125	130	16250	6650	1.69

With regards to the net returns per rupees invested, fish production in IFS pond recorded ₹ 1.69 at the cost of one rupee invested. The fish yield was relatively poor due to low temperature especially during winter season.

Economics of poultry rearing

The integration of fish with livestock has emerged as an effective alternative, highly sustainable farming system with concomitant reduction of production cost. Poultry rearing above the fish pond in IFS is more attractive and remunerative. Cost and returns of poultry production from the IFS ponds of area 822 sq m with carrying capacity of 50 broiler birds were calculated in 12 months duration (Table 3). The average economic selling age of broiler birds is 45 days, at which a bird attains about 2.5 kg weight. A total six batches of broiler birds reared in 12 month duration. The benefit: cost structure of the poultry rearing in fish pond has been presented in Table 3. Total operational cost for rearing the 300 broiler birds in six batches (50 birds in each batch) was ₹ 55650.0, including yearly construction cost of 150 sq feet poultry house. Hence, recurring cost accounted major share in production. These results are corroborated with the findings of Sharma *et al.* (1998). Gross return was calculated as per the local market price (₹ 120/kg live weight). The total and net returns from the poultry rearing above fish ponds were ₹ 90000.0 and ₹ 34350.0, respectively with 1.62 B:C ratio. The integration of poultry rearing with fish farming in IFS is potential tool for enhancing farmer's income and nutritional security (Vincke 1991). Similar results of income enhancement due to integration of poultry and fish in IFS has been reported by Delmendo (1980).

Table 3 Economics of poultry rearing above fish pond

Particulars/ Details	Amount (₹)
Expenditure	
Capital cost	
Construction of low cost poultry house 1.5 sq. ft/ bird for 50 birds @₹150/sq ft (Average durability= five years)	11250.0
Electrification and electrical installation	500.0
Total	11750.0
Average expenditure for one year in making low cost poultry house	2350.0
Recurring cost	
Equipments for 50 birds @ ₹ 10/bird	500.0
Cost of chicks @ ₹ 30/chick	9000.0
Cost of concentrate feed @3.8 kg/bird for 300 birds @30/kg	34200.0
Misc. expenditure, *i.e.* electricity, vaccine medicine, etc. including veterinary aid @ ₹ 2/bird	600.0
Labour charges for 45 man days @ 200/ man-day	9000.0
Total (Capital cost (total cost divided in five years)+ Recurring cost)	55650.0
Income	
Live weight of chicken 750 kg, selling price @ ₹ 120/kg live weight	90000.0
Gross income	90000.0
Net income= Gross income- cost of production	34350.0
B:C ratio= gross income/cost of production	162

Economics of crops cultivated on pond dyke

Vegetable cultivation on the bamboo made trellis and dykes is an additional component of farming which helps in maximizing profit from unit area. Total average vegetables production under integrated pond management system was recorded 1919.5 kg from an area of 322 sq m which was encouraging for the stakeholders. Resource poor small and marginal farmers inhabited in remote area of north east India do not have access to sufficient vegetables round the year for their nutrition. In this regard, vegetables production on pond dyke in integrated pond management system can increase the year round availability of vegetables for household consumption and play a pivotal role for ensuring nutritional security of hill farmers in the region. Furthermore, cash from selling of additional vegetables contributed to increased total income of the households. Economic analysis of year round vegetable production on pond dyke revealed that year round vegetable production (Table 4) incurred cultivation cost of ₹ 8398 and resulted in gross and net returns of ₹ 30705 and ₹ 22336, respectively. Similar results were also reported by Alam *et al.* (2009). Hence, this approach for vegetables production may have a remarkable impact on the resource poor farmers for income generation and family nutrition.

Economics of non-integrated fish pond vis-a-vis integrated fish production in IFS

The results indicated that integrated fish production technique recorded 1289.6 kg fish equivalent yield (FEY) and net returns of ₹ 63334 from 822 sq m area, leading to 742.7 and 852.25 times higher FEY and net returns over the existing non-integrated fish cultivation practices in IFS, respectively (Table 5). Similarly, pond dyke intensification recorded 750% and 858.56% higher system production efficiency and profitability over the traditional fish production techniques in IFS, respectively. Furthermore, integrated fish production system recorded 65.12% higher B:C ratio over existing system of fish production in the region. Similar results of higher income from integration of crop-fish-livestocks under IFS than traditional IFS have been previously reported by Shang and Cost-Pierce (1983) and Lovshin *et al.* (1986). The pond dyke intensification technique has potential to increase income and living standard of small-scale farmers (Vincke 1991). This was due to the fact that multi activities in integrated fish pond system resulted in multi commodities production throughout the year leading to higher economic efficiencies and employment generation. Furthermore, recycling of wastes and residues from one component to other components reduced the dependence on external inputs for successful

Table 4 Economics of various crop cultivated on pond dyke

Crops	Pond dyke area (sq m)	Number of plants	Production (kg)	Cost of production (₹)	Gross returns (₹)	Net returns (₹)	B:C ratio
Kharif season							
Cucurbits	322	70	515	1350	5150	3802	3.82
Lablab beans		45	30	500	900	400	1.80
Tomato/Capsicum		1192	515	3000	15450	12450	5.15
Rabi season							
Cabbage	270	1052	780	2870	7800	4930	2.72
Broccoli	38	141	71.0	436	1065	629	2.44
Coriander (Leafs)	15		8.50	215	340	125	1.58
Total			1919.5	8371	30705	22336	3.66

Price of crop: Cucurbits- ₹ 10, Lablab beans- ₹ 30, Capsicum-₹ 30, Tomato- ₹ 30, Cabbage- ₹ 10, Broccoli-₹ 15, Coriander- ₹ 40

production. Ecological consideration is of paramount importance in integrated fish farming as it allows recycling, and maximum utilization of resources without wastage (Gabriel 2007)

Thus, the study suggested that integrated fish production with poultry and pond dyke intensification is a sustainable novel agricultural production system for sustaining the livelihood security and income of hill farmers and also maximize the utilization of the available limited resources. The major economic benefits of this technique are enhancement of food production and self-sufficiency, making farmers self-reliant and occupied most time of the year which generally does not happens in conventional systems of farming. Hence, raising poultry directly above the fish pond in low cost poultry house in such a way that the poultry excreta should drop directly into the fish pond along with sequential cultivation of vegetables on the pond dykes is a profitable option for enhancing farm income in north east India.

Table 5 Economic comparison of integrated and non-integrated fish production in IFS

Particulars	Production systems	
	Non-integrated fish production in IFS	Integrated fish production in IFS
System cost of production (₹)	9600.0	73621.0
System fish equivalent yield (kg)	125.0	1053.43
System gross returns (₹)	16250.0	136946.0
System net returns (₹)	6650.0	63325.0
System B:C ratio	1.69	1.86
System production efficiency (FEY (kg)/day/822 sq m)	0.34	2.89
Relative production efficiency (%)		750
System profitability (₹/day/822 m^2)	18.1	173.5
Employment generation (Man-days)	10	70
Relative employment generation efficiency (%)		600

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