Can rice-fish farming provide food security in Bangladesh?

Ahmed, N.[1,2] and Luong-Van, J.[2]

1. Department of Fisheries Management, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh; e-mail: nesar_2000@yahoo.com; 2. School of Environmental and Life Sciences, Charles Darwin University, Darwin, NT 0909, Australia; e-mail: jim.luong-van@cdu.edu.au.

Introduction

Bangladesh is one of the poorest and most densely populated countries in the world. More than 140 million people occupy the country's 144,000 km^2 of area, consuming rice and fish as staple foods. Bangladeshi people are popularly referred to as "Macche-Bhate Bangali" or "fish and rice makes a Bengali." Rice and fish have been an essential part of the life of Bangladeshi people from time immemorial. Rice farming is the single most important livelihood for a vast majority of the rural poor. The annual rice production is estimated to be 26.53 million tonnes[1], while fish production is 2.32 million tonnes[2]. The demand for rice and fish is constantly rising, with the population increasing by more than three million people each year. However, the land available for rice and fish farming is not expanding. Nevertheless, fish farming in rice fields offers a solution to this problem, contributing to food production and income generation.

The total area of rice fields in Bangladesh is about 10.14 million ha and there are a further 2.83 million ha of seasonal rice fields where water remains for four to six months of the year[3,4]. These inundated rice fields can play an important role in increasing fish production through integration of aquaculture. There are several positive effects of fish farming in rice yields. Integrated rice-fish production can optimise resource use through the complementary utilisation of land and water[5]. Integration of fish with rice farming improves diversification, intensification, productivity and sustainability[6,7,8]. Rice-fish farming is also being regarded as an important approach to integrated pest management (IPM).

The adoption of rice-fish farming in Bangladesh remains rather marginal to date due to socio-economic, environmental, technological and institutional constraints[9]. Traditionally wild fish have been harvested from rice fields. The green revolution of agriculture has become a constraint for the development of rice-fish farming. With the introduction of high yielding varieties (HYV) of rice, the pest control strategy has preferred chemical pesticides[10,11]. Nevertheless, reducing pesticide has taken place through IPM. The introduction of IPM with fish farming in rice fields becoming popular in many Asian countries, such as China, Philippines, Thailand and Vietnam[12].

In order to increase food production, a small number of farmers were encouraged to take up rice-fish farming in Bangladesh. Nevertheless, a number of issues are important for rice-fish farming including production technology, socio-economic and environmental aspects. This paper highlights key issues for sustainable rice-fish farming, to meet challenges for food security for the people of Bangladesh.

Silver carp is a common species in rice-fish farming systems.

Methodology

Field research was conducted for a period of six months from December 2007 to May 2008. The research design included selection of the study area, identification of target groups and selection of research tools for data collection (Figure 1). The method of data collection depends upon the nature, aim and objectives of the study. Selection of particular method depends on nature of the research problems, duration of fieldwork and distance of the research site. In order to assess the rice-fish farming systems relevant to farmers' concepts and understanding, a participatory research method was employed. The major advantage of this method is that its coverage is much wider. However, one of the major risks is that the investigation has to depend solely upon the memory of the respondents. This was, however, overcome by applying a combination of data collection methods.

The study was conducted in the Mymensingh area of north-central Bangladesh which is one of the rice bowls of the country. Geographically Mymensingh has been identified as the most important and promising area for rice-fish culture, because of favourable resources and climatic conditions, such as the availability of low-lying agricultural land, warm climate, fertile soil, and cheap and abundant labour. Hydrological conditions are also favourable for rice-fish farming as this area is located within the monsoon tropics with an average annual rainfall of 2,500 mm[13]. Moreover, conditions are highly encouraging for the expansion of rice-fish farming as the quantity of fish seed produced has risen rapidly in recent years from around 70 private hatcheries. Nevertheless, a small number of farmers (around 100) are involved in rice-fish farming in Gauripur and Phulpur sub-districts. These farmers received training from the Mymensingh Aquaculture Extension Project, funded by Danish International Development Assistance. Gauripur and Phulpur sub-districts were therefore selected for the study.

A combination of participatory, qualitative and quantitative methods was employed for primary data collection. A total of 80 rice-fish farmers, 40 in each sub-district, were interviewed at their houses and/or farm sites. The interviews, lasting about an hour, focused on rice-fish farming systems, culture practices, productivity and constraints of rice-fish farming. A Participatory Rural Appraisal tool - focus group discussion (FGD) was conducted with rice-fish and rice-only farmers to obtain qualitative information. FGD sessions were held in front of village shops, under large trees, in farmers' houses and on school premises, where participants could sit, feel comfortable and were easily observed. Finally, cross-check interviews were conducted with district and sub-district fisheries officers, agricultural extension officers, school teachers, researchers, policy makers and relevant non-government organisation (NGO) workers. Data from questionnaire interviews were analysed using Microsoft Excel software to produce descriptive statistics.

Farming systems

There are two types of rice-fish farming systems in the Mymensingh area depending on the source of fish: culture and capture. In the capture system, wild fish enter the rice fields from adjacent floodplains during the monsoon and reproduce in inundated rice fields. On the other hand, rice fields are deliberately stocked with fish in the culture system. Fish farming in rice fields can be broadly classified as concurrent (integrated) and rotational (alternate). In the concurrent system, rice and fish are grown together, while in the rotational system they are grown alternately. According to the survey, 54% of farmers practiced concurrent rice-fish farming and the rest (46%) cultured rotationally. In general, the concurrent rice-fish culture system is practiced in plainlands and medium lowlands, while the rotational system is performed in deeply flooded lowlands. The average farm size was found to be 0.33 ha and 0.29 ha in the concurrent and rotational system, respectively.

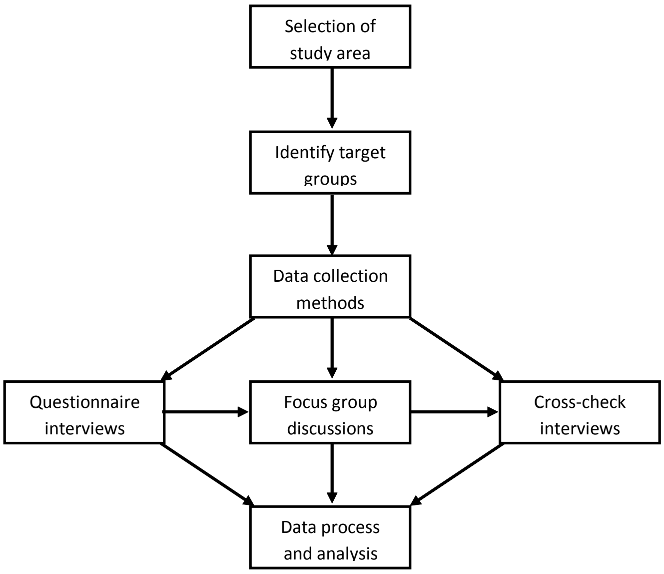
Two types of rice crops are cultivated in the concurrent system: boro and aman. Farmers cultivate boro rice during the dry season from January to April, and the monsoon season aman rice during June to October. The aman rice culture takes place in either deep or flooded water conditions with fish, and with a fish culture period of around 4 months. In the rotational system, farmers produce fish during the monsoon. Fish fingerlings are stocked in May to June and are harvested primarily from November to December, a culture

Rice fields are an important environmental landscape in Bangladesh.

A typical concurrent rice-fish farm.

A typical rotational rice-fish farm.

Figure 1. Research design for field survey of rice-fish farming.



period of around 5 to 8 months. Rotational farmers avoid cultivation of aman rice with fish due to high water levels. On the other hand, farmers avoid fish culture with boro rice because of water scarcity and lower availability of fingerlings.

A wide range of fish species are cultured in rice fields. The selection of species depends on farming systems. According to the survey, concurrent farmers mainly stocked common carp (*Cyprinus carpio*), silver barb (*Barbonymus gonionotus*), Nile tilapia (*Oreochromis niloticus*) and silver carp (*Hypophthalmichthys molitrix*). In rotational culture, on the other hand, the most common fish species stocked were catla (*Catla catla*), rohu (*Labeo rohita*), mrigal (*Cirrhina cirrhosus*), silver carp (*H. molitrix*), grass carp (*Ctenopharyngodon idella*) and bighead carp (*Aristichthys nobilis*). The average annual stocking density of fingerlings were 2,857 per ha in the concurrent system, while it was 4,917 per ha in the rotational system. The average size of fingerlings stocked varied between 4 and 8 cm in the concurrent system, and 6 to 10 cm in the rotational system.

Although small-scale fish farming in rice fields is an extensive aquaculture system that relies on the natural food (phytoplankton, zooplankton, periphyton, benthos), supplemental feeds are used by most respondents. In the concurrent system, farmers mainly use on-farm inputs, such as rice bran, wheat bran and mustard oilcake. On the other hand, a few rotational farmers apply fishmeal and industrially manufactured pelleted feeds, in addition to on-farm inputs. Farmers reported higher fish yields when feeding pelleted feed rather than on-farm inputs. The most common feeding frequency in the rotational system was once a day, while it was once or twice a week in the concurrent system. There was a substantial difference in feeding rate among culture systems.

In order to increase rice and fish production, a variety of fertilisers such as urea, triple super phosphate (TSP) and muriate of potash (MP) are used by the farmers. The fertiliser quantity used is related to farming system (Table 1). Concurrent farmers with two rice crops used less fertilisers on an annual basis than did rotational farmers of one rice crop because the presence of fish increased soil fertility.

The average annual yield of rice was higher in concurrent farming compared to rotational farming, because of two rice crops. Table 1 shows that concurrent farmers had a higher aman rice yield than boro rice as the stocking of fish affected the aman rice yield positively. Nevertheless, boro rice yield was slightly higher in rotational farming than that of concurrent farming.

The average annual yield of fish reported by respondents was 259 kg/ha in concurrent farming, while 1,108 kg/ha in rotational farming. The yield of fish was higher in rotational farming due to higher inputs of fish seed, feed and fertiliser. In addition, rotational farmers stocked larger fingerlings which could have a positive effect on survival and growth, and thus also the yield. Comparatively larger size fish was harvested in rotational farming due to longer culture period.

Constraints and opportunities

A number of constraints were reported by respondents for fish farming in rice fields, including lack of technical knowledge, natural disasters (flood, drought), high production costs and poor water quality. Regardless of farming systems, 42% of respondents identified lack of technical knowledge as their single most important constraint. The proportion of respondents identifying high production costs was 34%. Cost of fish farming in rice fields was reported to have increased significantly in recent years as a result of increased fish seed, feed, fertiliser and labour cost. The prices of both fish fry and feed have increased dramatically since fish farming has

Table 1. Inputs and outputs of fish farming in rice fields by culture systems in 2007.

Input and output	Concurrent farming		Rotational farming	
	Mean	SD	Mean	SD
Farm size (ha)	0.33	0.11	0.29	0.09
Fish stocking (fingerlings/ha/year)	2,857	453	4,917	721
Fish feeding (kg/ha/year)	491	128	1,373	217
Fertilisation (kg/ha/year)				
Urea	177	38	211	39
TSP	152	42	179	36
MP	38	12	67	18
Rice yield (kg/ha/ year)				
Boro	4,917	278	4,986	332
Aman	5,261	312	-	-
Fish yield (kg/ha/year)	259	98	1,108	217

SD: standard deviation

become widespread in pond systems. Inadequate finance can therefore be a significant constraint for fish farming in rice fields. Only 19% and 5% of farmers identified flood and poor water quality to be the most important constraint, respectively. Preventing fish escape is very difficult during the flood, especially for small farmers who are reluctant to raise their low and narrow dikes. Farmers also reported higher fish mortality occurred due to poor water quality as a result of water pollution, turbidity, low water levels and high water temperature. A few concurrent farmers noted that they had high fish mortalities when their neighbours used pesticides indiscriminately.

It seems that rice-only farmers quite unwilling to switch to rice-fish farming due to lack of technical knowledge. Farmers suggested that rice yields decrease due to space occupied by refuge. In addition, farmers perceived that fish damage rice plants and pesticide use for rice crops have negative impacts on fish production. Rice farmers are also reluctant to adopt rice-fish farming because of risks. It was found that better-off farmers are active in rice-fish farming due to the taking risk as they described "there is no gain without risk."

In spite of several constraints, there are opportunities for rice-fish culture development in Bangladesh. A SWOT (strengths, weaknesses, opportunities and threats) analysis was carried out with farmers to identify for its sustainable development (Table 2).

Environmental impacts

Rice-fish farming provides a sustainable alternative to rice monoculture, if farmers can take advantage of the natural productivity of the rice field ecosystem. Concurrent rice-fish farming is ecologically sound and a good method of diversification where fish regenerate nitrogen and phosphorus to improve soil fertility. Fish release nutrients by stirring the sediments in rice fields. Foraging and movement of fish in rice fields causes the aeration of the water, which increases photosynthesis[5,14]. Fish also predate on flies, snails and insects, and can help to control malaria mosquitoes and water-borne diseases. On the other hand, rice fields offer fish planktonic, periphytic and benthic food. Shading by rice plants also maintains the water temperature favourable for fish during the summer[4,15].

There is less use of fertilisers in concurrent rice-fish farming than rice monoculture. Fish wastes and the extra feed given to fish increase the amount of organic fertiliser in rice fields. Moreover, fish plays a significant role in controlling pests. They eat aquatic weeds and algae, act as hosts for pests and compete with rice for nutrients[12,16]. As a result, farmers need less fertiliser and pesticide leading to an improved environment. Thus, concurrent rice-fish farming is an organic method that maintains environmental sustainability.

Many fish species prefer to reproduce in rice fields. Such natural aggregations of fish in rice fields inspire rice-fish farming for increased productivity. Rice-fish interaction can indeed increase the rice yield. It has been reported that the cultivation of fish in rice fields increases rice yields by 8 to 15%[17].

Water management is an important issue for raising fish in rice fields.

Irrigation facilities can help to expand rice-fish farming.

A farmer with a silver carp - fish are an important source of animal protein for people in Bangladesh.

Table 2. SWOT analysis for the development of rice-fish culture in Bangladesh.

Strengths	Weakness
• Available low-lying rice fields • Large number of farmers involved in rice farming • Rice-fish farming is environment friendly • Integrated pest management • Rice and fish are staple foods • Available family labour	• Lack of technical knowledge • Water management problems • Inadequate technical support • Lack of irrigation facilities • Poor socio-economic conditions • Lack of credit facilities
Opportunities	**Threats**
• Increased rice and fish production • Optimum resource utilisation of land and water • Diversified and intensified cropping systems • Employment opportunities • Increased income and food supply • Improvement of socio-economic conditions	• Climate change (flood and drought) • Poor water quality • High fish mortality • Increasing production costs • Reducing culture areas • Increasing population

Food security

The switch from rice monoculture to rice-fish farming is not merely a change in cropping system, more importantly it is a shift to production of a more balanced diet (i.e. rice and fish). Not only the adequate supply of carbohydrate, but also the supply of animal protein is therefore a critical factor for the health and well-being of farming households. As a result of rice-fish farming, they are able to eat rice three times a day with fish. Rice fields are potentially a source of protein for fish farming households. Among the farming systems, concurrent farmers had a significantly higher share of fresh fish in their diet than rotational farmers. In the rotational system, fish farming was a cash crop and thus 80% of the production was sold to local markets while the rest was consumed by the households. In contrast, farmers of the concurrent system considered fish as a secondary farm product in terms of economic return. Thus, 40% of the fish production was consumed by the households while the remaining was sold to local markets. It was found that households of farmers tend to eat small fish than sell them. In addition to animal protein, small fish are a valuable source of micronutrients, vitamins and minerals. Small fish has also particular importance for the diets of children and lactating mothers to avoid child blindness and reduce infant mortality.

In order to meet the soaring demand for food, there is a need for increased food production in Bangladesh. However, intensive rice monoculture cannot provide a sustainable food supply at the cost of long-term environmental sustainability[12]. Among the farming systems, concurrent rice-fish farming is the best in terms of food supply. Increased rice-fish farming could be a significant approach to increase food production. Concurrent rice-fish farming could provide social, economic and environmental benefits. This farming positively affects the rice yield and makes the rice field a more efficient ecosystem for environmentally sound production of rice and fish. Thus, concurrent rice-fish farming offers a sustainable alternative to rice monoculture.

If rice-fish farming is expanded to 2.83 million ha of seasonal floodplains in Bangladesh, food production would be significantly higher than its present level. Moreover, farmers' income and local food supply will increase substantially. It is therefore assumed that integrated rice-fish farming can ensure food security for the people of Bangladesh.

Sustainability

While there is a great potential for rice-fish farming, a number of issues were identified affecting its sustainability including the lack of technical knowledge of farmers, high production costs and natural disasters (flood and drought). Moreover, rice-fish farming technology has not yet contributed substantially to food security in Bangladesh due to its low level of adoption. The lower levels of rice-fish farming adoption were found among poorer households. It seems that the benefits of rice-fish farming technology accumulate to better-off farmers unless institutional and organisational support is provided to resource-poor farmers. It is therefore worthwhile to find means of providing institutional and organisational support to poorer farmers, in terms of training facilities and extension services for sustainable rice-fish farming. Training and technical support would help to improve profitability and reduce risks. The provision of low-interest credit would also help to reduce risks for resource-poor farmers. Finally, a positive government policy can help to promote sustainable development of rice-fish farming throughout the country.

Acknowledgements

The study was supported through the Australian Government Endeavour Research Fellowship. The opinions expressed herein are those of the authors and do not necessarily reflect the views of the Endeavour Fellowship Programme. The authors express their gratitude to all farmers those have given a lot of valuable information without which the study could not have been realised.

References

1. BRKB. (2006). Rice statistics in Bangladesh. Bangladesh Rice Knowledge Bank, Bangladesh Rice Research Institute, Gazipur, Bangladesh.

2. DOF. (2007). Fishery statistical yearbook of Bangladesh 2005-2006. Fisheries Resources Survey System, Department of Fisheries, Dhaka, Bangladesh.
3. Dewan, S. (1992). Rice-fish farming systems in Bangladesh: past, present and future. In: Rice-Fish Research and Development in Asia (eds. C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao), ICLARM Conference Proceedings 24:11-17.
4. Wahab, M.A., Kunda, M., Azim, M.E., Dewan, S. and Thilsted, S.H. (2008). Evaluation of freshwater prawn-small fish culture concurrently with rice in Bangladesh. Aquaculture Research 39:1524-1532.
5. Frei, M. and Becker, K. (2005). Integrated rice-fish culture: coupled production saves resources. Natural Resources Forum 29:135-143.
6. Lightfoot C., dela Cruz, C.R. and Carangal, V.R. (1990). International research collaboration in rice-fish research. NAGA, the ICLARM Quarterly13:12-13.
7. Harun, A.K.Y and Pittman, K.A. (1997). Rice-fish culture: feeding, growth and yield of two size classes of *Puntius gonionotus* Bleeker and Oreochromis spp in Bangladesh. Aquaculture 154:261-281.
8. Nhan, D.K., Phong, L.T., Verdegem, M.J.C., Duong, L.T., Bosma, R.H. and Little, D.C. (2007). Integrated freshwater aquaculture, crop and livestock production in the Mekong delta, Vietnam: determinants and the role of the pond. Agricultural Systems 94:445-458.
9. Nabi, R. (2008). Constraints to the adoption of rice-fish farming by smallholders in Bangladesh: a farming systems analysis. Aquaculture Economics and Management 12:145-153.
10. Berg, H. (2002). Rice monoculture and integrated rice-fish farming in the Mekong delta, Vietnam - economic and ecological considerations. Ecological Economics 41:95-107.
11. Gupta, M.V., Sollows, J.D., Mazid, M.A., Rahman, A., Hussain, M.G. and Dey, M.M. (2002). Economics and adoption patterns of integrated rice-fish farming in Bangladesh. In: Rural Aquaculture (eds. P. Edwards, D.C. Little and H. Demaine), CABI Publishing, Oxford, UK, pp. 41-53.
12. Halwart, M. and Gupta, M.V. (2004). Culture of fish in rice fields. FAO and the WorldFish Center, 83 p.
13. FAO. (2000). Forest resources of Bangladesh - country report. Forest Resources Assessment Programme, Forestry Department, FAO Working Paper 15, Rome, Italy.
14. Mustow, S.E. (2002). The effects of shading on phytoplankton photosynthesis in rice-fish fields in Bangladesh. Agriculture, Ecosystems and Environment 90:89-96.
15. Kunda, M., Azim, M.E., Wahab, M.A., Dewan, S., Roos, N. and Thilsted, S.H. (2008). Potential of mixed culture of freshwater prawn (*Macrobrachium rosenbergii*) and self recruiting small species mola (*Amblypharyngodon mola*) in rotational rice-fish/prawn culture systems in Bangladesh. Aquaculture Research 39:506-517.
16. Lu, J. and Li, X. (2006). Review of rice-fish-farming systems in China - one of the globally important ingenious agricultural heritage systems (GIAHS). Aquaculture 260:106-113.
17. Mohanty, R.K., Verma, H.N. and Brahmanand, P.S. (2004). Performance evaluation of rice-fish integration system in rainfed medium and ecosystem. Aquaculture 23:125-135.

Nutritional and food security for rural poor through multi-commodity production from a lake of eastern Uttar Pradesh

Singh, S.K.

Central Institute of Freshwater Aquaculture, Kausalyagang, Bhubaneswar – 751 002, Orissa, India, email sharadsrinet@gmail.com

Introduction

India's population of more than 1 billion people may reach more than 1.4 billion by the end of 2020 AD, necessitating an intensive search for alternative and more efficient ways to produce food. In this search for new food supplies and their more equitable distribution, attention is naturally centred on the basic agricultural commodities. However, it is clearly recognised that these commodities should be supplemented by high quality protein food. In this context, aquatic food reserves can make an important contribution to supplies of protein. The natural water resources of Uttar Pradesh, India, consist of approximately 180,000 ha in the form of lakes, oxbow lakes, seasonal water logged areas, marshes and swamps[1]. Since time immemorial the flood plain lakes have provided man with many sources of livelihood. In eastern Uttar Pradesh, the lakes Bakhira, Ramgarh, Chilwa, Suraha, Reoti, Dah, Konar, Parvati and Leond Tal are some of the larger flood plains providing lucrative sources of multi commodity production.

Leond Tal is a perennial natural lake in the Siddharthnagar District, which forms a kind of no mans land. During the Mugal Empire period this lake and 80 others were awarded to the King of Bansi as 'Amir-UL-Bahar' by the Mugal Emperor Jahangir, and were know as 'Nankar' (the People's nourishment) during that period, in the area of Sarju River Basin and foot hills of Himalayas.

Topography and morphometry

The Leond Tal is surrounded by roads on eastern, western and south western sides, with its principal catchment area lying in the north and west. The tal lies in a clay-loamy soil region of the district and has a thick clayey mud deposition of 0.6-1.0 m depth at the bottom. The actual water surface area of the lake as per the Tahsil map is 327 ha. However, during flood conditions its surface area can increase 1.5 to 2.0 times. The lake is surrounded by the Sohna, Nathar-Deoria villages in the north; the Rajawapur, Burhoon and Duferia villages in the east; Kathautiaram, Mahua-Buzang villages in the south and Kataria, Babu and Leondi villages in the west. The main outlet of the lake is Ashadi Nullah, which receives water from