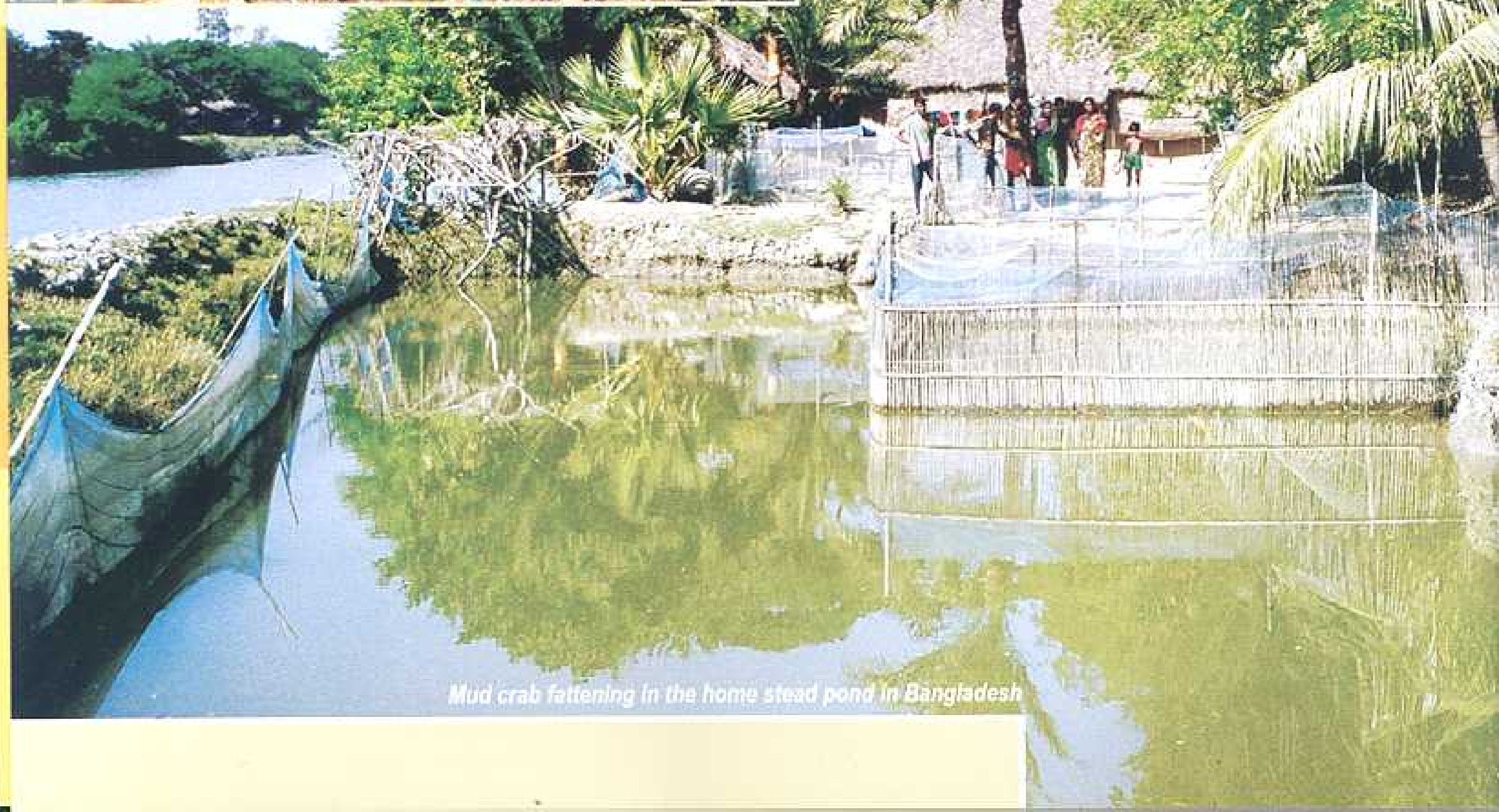
 

New Advances in Rice-aquaculture Production Systems for Deltaic Plains

– key findings from a project funded by the CGIAR Challenge Program on Water and Food

Pond design in Bangladesh-Trench dredging and dike strenghtening

Integrated rice-fresh water prawn in Bangladesh



Mud crab fattening in the home stead pond in Bangladesh

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A. Historical background

Forty per cent of the world population is settled in coastal zones, where much of industrial needs and world's food are produced. The influence of the sea on the environment and human livelihood is not restricted to the coastline and mangrove belt. Indeed, its influence can be found up to 50 km further inland. Brackish water creates an environment in which continuous and dynamic flux impinges upon the stability of agricultural production systems and concomitant livelihood strategies. Most common management interventions fail to recognize the diversity of rural livelihoods in the coastal zones, and the environmental consequences for water quality and aquatic biodiversity. To address the diverse stakeholder interests and complex multi-scale upstream-downstream interactions, the Challenge Program on Water and Food Number 10 (CPWF #10) project started in 2004 with the aim of developing appropriate rice-aquaculture production systems to increase land and water productivity for improved food security and livelihoods suited to the different environments across the land water interface of two deltaic plains; the Mekong River Delta (Vietnam) and Indus-Gangetic Delta (Bangladesh).

B. Project goals and partners

To achieve the specific objectives, the project approach included a close relationship and collaboration between several international research centers, including: International Rice Research Institute (IRRI), International Water Management Institute (IWMI) and the WorldFish Center, and a diverse group of local partners both in Bangladesh and Vietnam involved in various fields of research, policy development, public administration and development agencies. The key implementing agencies were Bangladesh Fisheries Research Institute (BFRI) in Bangladesh, Can Tho University (CTU) and Research Institute of Aquaculture n°2 (RIA2) in Vietnam. Within this institutional research framework, the project implemented a series of on-farm experiments over a three year period (2004-2007) to achieve two specifics goals: *"to develop ecologically friendly and socially acceptable techniques for rice and rice-aquaculture production systems" and "to enhance human resource capacity and develop recommendations for resource management at the farm and regional level".*


Fish harvest in rice-integrated aquaculture system in Bangladesh

C. Study sites: similarities and differences between Mekong and Ganges deltas

The Ganges and the Mekong deltas show similar development patterns in terms of land use. However, the deltas do differ in some areas of water management infrastructure and agro-ecological environment.

Bac Lieu Province-Mekong Delta-Vietnam

The Mekong Delta has a long history of water infrastructure development, with a complex canal network developed during the 19th and 20th centuries to colonize the area and later improve irrigated rice culture. The study area is located in Bac Lieu Province, on the Ca Mau Peninsula (figure n°1). Since 2002, a network of sluice gates along the coast and further inland regulate salinity intrusion in Bac Lieu to promote different farming systems in the province. This specific characteristic allows a wide diversity of water salinity within the province and throughout the year. The duration and range of salinity during the year directly influences farmers' strategies and the evolution of farming systems.

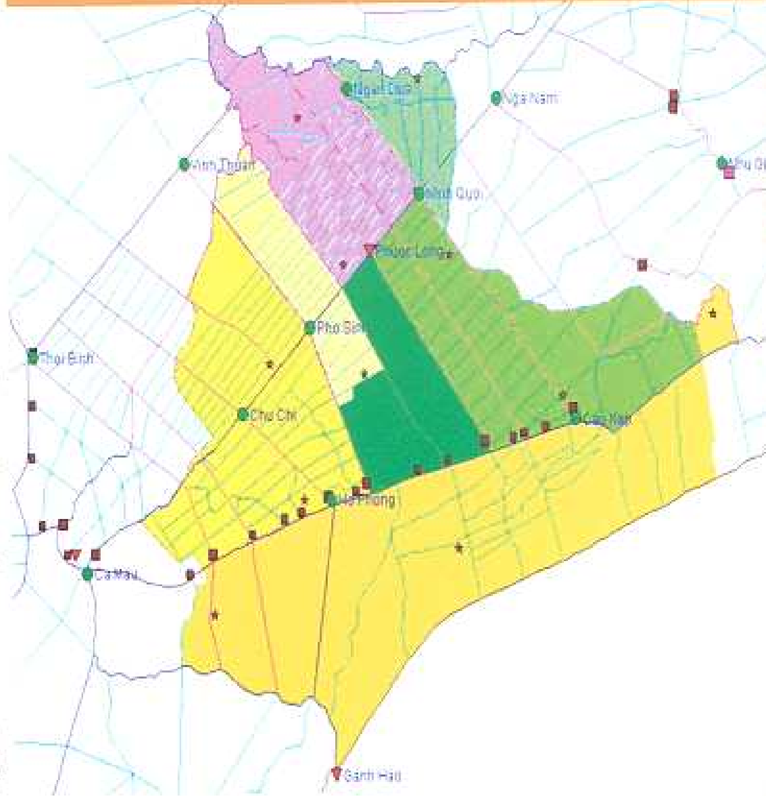


Figure n°1: Bac Lieu province (Mekong Delta, Vietnam)

In recent years, with the improvement in water quality and the control of saline intrusion, farmers have been able to grow two rice crops per year in the eastern part of the province. The fresh water period gradually decreases towards the western part of the province and farmers have adopted a rice shrimp farming system in areas where fresh water is available during the rainy season. In the western part of the province, rice cultivation may be further constrained by acid sulfate soils and therefore farmers adopt only shrimp culture.

In consideration of these specific hydrological characteristics, we chose seven study sites (inside and outside the protected area) with various levels of saline water influence (from fresh water all year round to saline water influence all year) to test different models of aquaculture and integrated rice-aquaculture systems.

Rice fish culture in Vietnam

Paikgacha Upazila-Khulna District-Bangladesh

In Bangladesh (figure n°2), such canal networks to control salinity intrusion are not found. Polders (embankments) have been developed in the late 20th century to increase rice production, but most of these have since been converted into shrimp ponds. The duration of the fresh water period does not vary within the study area occurring annually from July to December/January.

Both rice and shrimp culture is constrained by the absence of a dense canal network which prevents easy access to and discharge of water. Compared to the Mekong Delta, shallow acid sulfate soils are absent in this area and do not constrain agriculture production. The main farming systems in this area are extensive shrimp monoculture and rice/shrimp rotational culture.

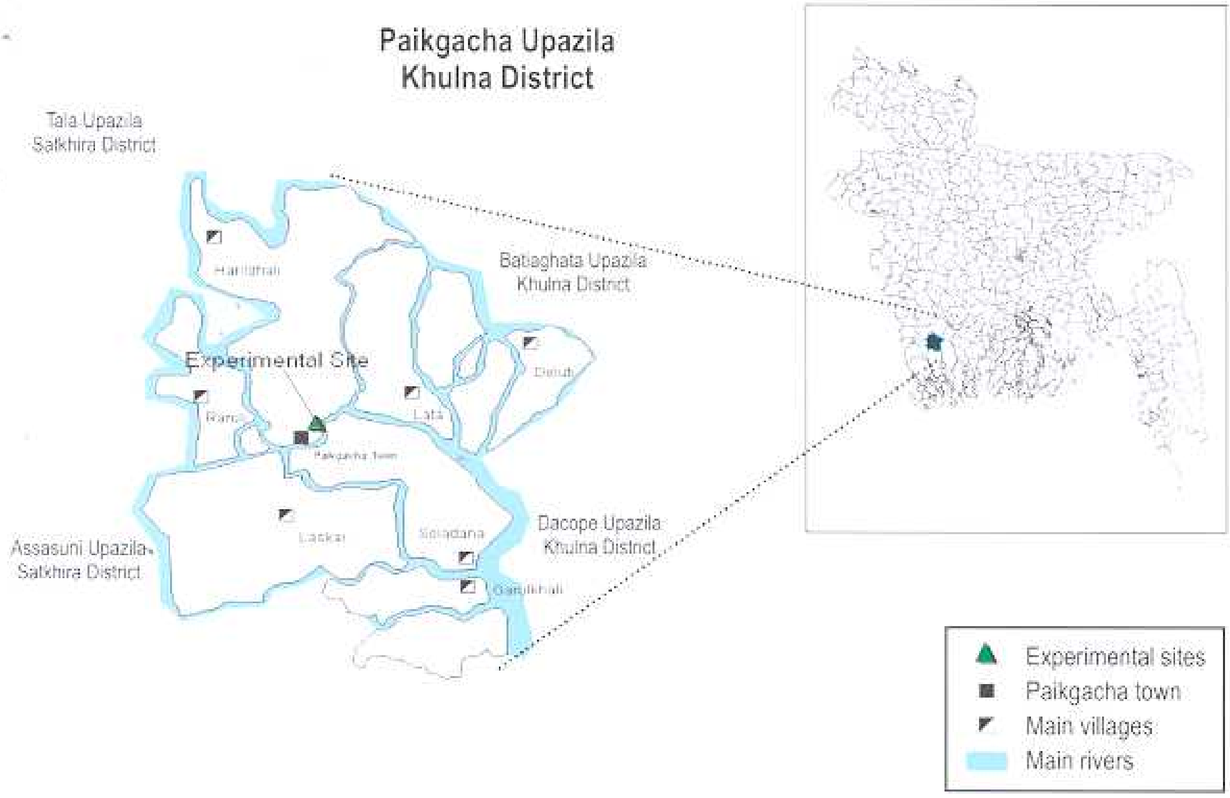
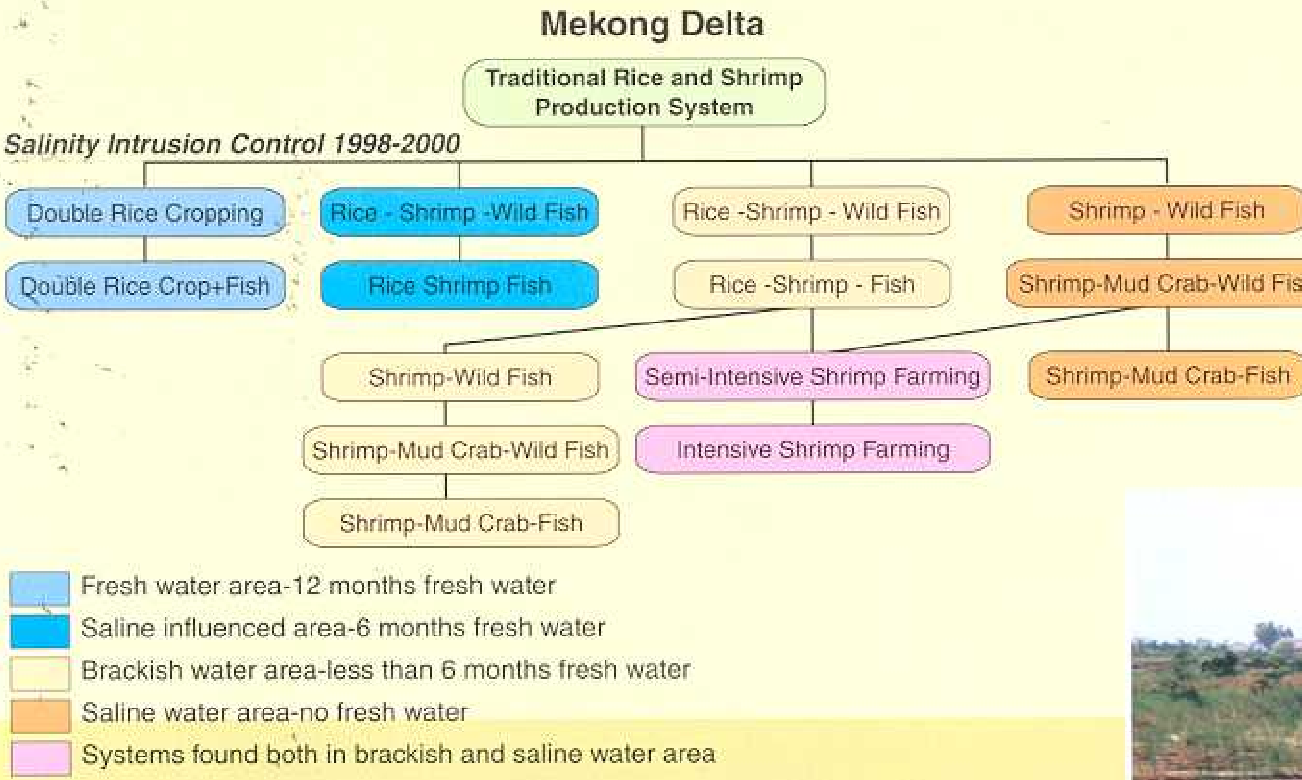


Figure n°2: Paikgacha Upazila (Ganges Delta, Bangladesh)

D. Evolution of farming systems in the Mekong and Ganges deltas

At about the same time as the experimental trials, surveys were implemented in 2005 and 2006 to investigate the evolution pattern of the farming systems in both coastal areas in Bangladesh and Vietnam so that researchers may gain a greater understanding of the temporal interdependencies between farmers and the environment, the factors that influence decisions, and the cause-effect relationships in the area.

From a rice-based agriculture system, deltas gradually evolved towards an agro-economy based on shrimp aquaculture, rendering these lowland coastal areas lucrative for enterprise and export generation. Initially, a constraint for livelihood improvement through agriculture, saline intrusion became an opportunity for the economic development of these regions. The canal network developed in the aim to improve rice culture allowed saline water to be conveyed further inland and facilitate the spread of shrimp farming in the deltas. After several years of profit, in the late 80's and the beginning of 90's, shrimp production was affected by the spread of virus (White Spot Shrimp Virus, WSSV) and in many cases crop failure. Faced with this threat, resourceful farmers began to adapt their farming systems to maintain profitability and reduce their exposure to risk of total loss (figure n°3).



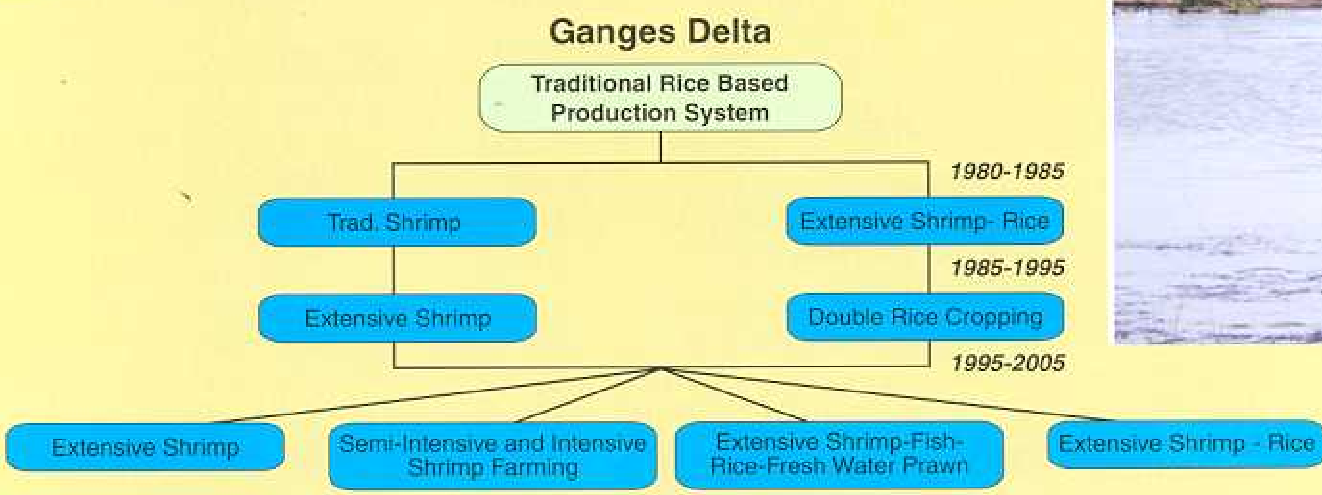


Figure n°3: Evolutionary stages of coastal aquaculture in the Mekong and Ganges deltas

The results of informal surveys conducted during the project period show a number of differences between the two study areas due to several environmental factors and socio-economic factors. Due to the development of salinity intrusion control tools (sluice gates) in the Mekong Delta, Bac Lieu Province has evolved with a wide range of agro-ecological areas characterized by the duration of the fresh water period. The development of salinity control tools protected some areas from saline intrusion and allowed farmers in these areas to develop two rice crops per year. The next evolutionary stage was the adoption by some farmers of integrated rice-fish farming.

The fresh water period is the main determinant for rice culture and areas with less than 6 months of fresh water cannot develop a rice based production system without a high risk of crop failure. The rice-shrimp rotational system gradually improved by a few innovative farmers, adopting an integrated rice-fish culture in the rainy season with the culture of climbing perch, common carp or tilapia instead of relying on wild fish trapped in the pond. These two systems were also found in areas with a shorter period of fresh water; however, due to the dependence of the rice crop on rainfall occurrence, most farmers modified their production systems through diversification into brackish water polyculture, or through specialization and intensification of shrimp culture with semi-intensive or intensive shrimp culture. The same evolution pattern was found outside the protected area, where brackish water is present all year long. The main characteristics of the evolution of farming systems in the Mekong Delta are as follows:

- Diversification of production is driven by market forces, with the development of high value species production, such as mud crab (for the international market) and high value fish (for the national market), to cope with the risks associated with shrimp farming due to virus outbreaks. This evolution was allowed by the diversity of knowledge sources for farmers and the development of a competitive and reactive value chain for aquaculture production and input
- The intensification of production in some areas was permitted not only through available access to credit, but also by the presence of a well-established private sector which provides farmers with knowledge and technology

Evolution of farming systems in the Ganges Delta followed the same steps, beginning with a traditional shrimp culture based on wild species trapped in ponds, with or without a rotational rice crop in the rainy season depending on drainage capacity of the field. After the widespread adoption of *Panaeus monodon* farming, the next evolutionary step was driven by the spread of virus along the south-western coastal belt in the nineties.

Fish harvest in shrimp-mud carb fish culture Vietnam

Farmers developed four main coping strategies, all related to an overall "risk reduction" strategy, in the aim to maintain the economic sustainability of the farm, specifically through:

- Diversification of aquaculture production with fish, prawn concurrently with rice or a mixed combination with rice or shrimp and mud crab fattening;
- Return to rice culture in the rainy season for household food security instead of shrimp monoculture all year;
- Different stocking patterns, with multiple stocking and harvesting of shrimps to reduce the economic risk related to virus outbreak; and
- Intensification of production toward a semi-intensive shrimp production system

Although the strategies are evident they are not widespread across the Ganges and the Mekong deltas. Only one third of 21-farm survey in the Ganges delta were diversifying or intensifying their aquaculture production system and these farmers were located near the city within the influence area of the extension services. From a previous survey in 2004, (sample size: 60 farms), a typology based on multivariate statistics distinguish four farm types in Paikgacha Upazila based on a rice-shrimp rotational system or on shrimp monoculture within a sample of 60 farms.

- The two first types are small land owners (1-1.4 ha) who practice rice shrimp rotation using inorganic inputs (lime and fertilizer) for the shrimp crop. Type 1 represents farmers who prioritize their investment toward shrimp culture, using higher shrimp stocking density and improving the pond water quality with lime and fertilizer. Type 2 farms, on the other hand, use lower stocking density and inorganic inputs

- Farm types 3 and 4 lease the land on which they operate. Type 3 farms practice extensive shrimp monoculture, operate over a large area (6 ha), and do not use inorganic inputs or grow rice in conjunction. Type 4 farms are large-medium sized leased farms (3 ha), which use a low rate of inorganic input for the shrimp culture and prioritize their investment toward HYV rice culture

These surveys carried out in both deltas highlight the similarities and differences between the two study areas. For example, in Bangladesh, water management infrastructures such as irrigation canal or sluice gates to prevent saline intrusion are not well developed, and the agro-ecological situation is less diverse, with homogenous duration of fresh water and no strong soil constraint. Compared to the Mekong Delta, evolution of farming systems in Bangladesh, whether through improved extensive shrimp culture or integrated rice-fish culture, largely depends on land tenure. Only the farmers who own the land have the possibility to transform their fields and ponds to enhance water management, such as the addition of discharge canals or strengthening dikes. We found that small land owners achieve higher shrimp production (268 kg//ha) than farmers who rent land (between 73-142 kg/ha over 3.4 to 6.7 ha of land) due to higher investment in water quality management (such as lime and fertilizers) and more easily managed smaller and deeper ponds.

Additionally, it was found that the level of diversification and innovation of new technical patterns is less developed in the Ganges Delta compared to the Mekong Delta. This is due to a lower involvement of extension services and lower diversity of knowledge sources such as radio, television and private companies selling shrimp inputs (feeding pellets, pro-biotics, etc.).

We found that even with a less favorable environment, with acid sulfate soil and a large variation in fresh and saline water periods, aquaculture in the Mekong Delta is much more innovative and dynamic than in Bangladesh, where socio-economic factors (land tenure, less developed value chain, limited information and knowledge) do not enable the development of diversified farming systems.

E. Improving existing diversified farming systems

New aquaculture technologies were tested using two different approaches. In Vietnam, we tested three different models in seven farms, according to the duration of the fresh water period in the canals. In Bangladesh, on farm experiments were conducted in the same area with different treatments of integrated rice-aquaculture and different shrimp stocking patterns.

Integrated rice aquaculture in Bangladesh

Table n°1: On-farm experiments in the Mekong and Ganges deltas from 2004 to 2006

Bangladesh - Ganges Delta		Vietnam - Mekong Delta
2004 wet season-3 replicates of each treatment Genetically Improved Farmed Tilapia (GIFT) + Rice (1 ind/m^2) Rice+GIFT+Microbrachium rosenbergii (0.5+0.5 ind/m^2) Rice+M. rosenbergii (1 ind/m^2)		**2004 wet season** 1- Rice-Rice + fish polyculture (GIFT+climbing perch+common carp)-1 farm (Fresh water area) 2- Rice+fish (GIFT)-3 farms 3- Fish (GIFT)-3 farms
2005-3 replicates of each treatment		**2005**
Shrimp Single stocking (5 PL/m^2) Double stocking (3+2 PL/m^2) Double stocking (2+3 PL/m^2)	Rice + GIFT (0.5 ind/m^2) Rice + GIFT + M. rosenbergii (0.25+0.25 ind/m^2) Rice + M. rosenbergii (0.5 ind/m^2)	1- Rice - Rice + fish polyculture - 1 farm 2- Rice + fish polyculture (GIFT + climbing perch + common carp) and shrimp - 3 farms 3- Shrimp + mud crab and fish (elongated goby) in rainy season - 3 farms
2006-4 replicates of each treatment		**2006**
Shrimp same as above	Rice + GIFT + M. rosenbergii (0.25+0.25 ind/m^2) 7 months grow out Same as above-6 months grow out Same as above-5 months grow out	Same as above

E.1. Mekong Delta

In the Mekong delta, the diversity of salinity throughout the year gives the opportunity to test different production systems (Table n°1)

- In the fresh water area protected from saline intrusion, the model tested was based on the introduction of fish polyculture during the second rice crop
- The second model, based on rice and fish polyculture in the rainy season followed by a shrimp crop during the dry season was tested in two different agro-ecological areas, one with a fresh water duration exceeding 6 months and one with a fresh water duration shorter than 6 months

Mud carb fish culture in shrimp mud carb fish model in Vietnam

- The third and last model tested relied on a brackish water polyculture with a shrimp and mud crab concurrent culture in the dry season, followed by a high value fish crop in the rainy season. This model was experimented inside the protected area, where fresh water duration is shorter than 6 months and outside the protected area

The technologies tested in on-farm experiments were designed to improve land and water productivity from currently practiced production system. The level of technology used in these models was chosen to be accessible to farmers, with a low investment required and to promote a diversification of the farm incomes. Three models were tested during 3 years, with diverse results, reflecting the complexity of the situation. In each experimental site, we compared production and economic results with the most common production systems.

E.1.2. Double rice cropping and fish culture model

In the fresh water area, protected from saline intrusion, the model tested with concurrent rice and freshwater fish polyculture (GIFT+*Anabas testudineus*-climbing perch+*Cyprinus carpio*-common carp) was successful, diversifying the farm production and increasing the farm revenue compared to double rice cropping (Table n°2).

Table n°2: Results of double rice cropping and fish culture model (Mvnd: Million Vietnam Dong)

Farming system	Net return (Mvnd/ha/year)	Aquaculture Yield (Kg/ha)	Rice Yield (ton/ha)	Water quality conditions
Rice - Rice + fish model	23 ± 9	343 - 553	11.9 ± 1.2	12 months fresh water
Rice - Rice Survey farms (n=7)	19 ± 3	0	11 ± 1.51	

- The fish yield recorded was between 343 kg/ha and 553 kg/ha depending on the stocking density (0.30 to 0.69 ind/m2) and the rice yield was higher than in the surveyed farms in the same areas
- The farm net return improved by 21% compared to the double rice culture system
- However there are a number of important constraints to consider;

i. The investment (1.5 to 3.3 Mvnd)/ha) and the allocation of 10 to 15 per cent of the paddy field for the trench needed for fish culture;

ii. Fish production in rice field faces security problems (theft) and the labor costs for watching the rice-fish field will constrain fish production for most of the farmers who own land far from their home;

iii. The current very low market value of fish species available for polyculture system discourages widespread uptake

E.1.3. Rice + fish culture followed by a shrimp crop

The model of rice-fish culture followed by a shrimp crop was found to be successful when the duration of fresh water ***exceeded 6 months*** (Table n°3).

Table n°3: Result of Rice+fish culture followed by a shrimp crop model (Fresh water period longer than 6 months)

Farming system	Net return (Mvnd/ha/year)	Aquaculture Yield (Kg/ha)	Rice Yield (ton/ha)	Water quality conditions
Rice+fish-shrimp model	**39 ± 1**	**Shrimp:324 ± 80 Fish : 250 -500**	**5.6 ± 0.5**	6 months of fresh water and good water flow
Rice-wild fish-shrimp Survey farms (n=25)	14.7 ± 8	Shrimp: 127 ± 74 Wild Fish: 75 ± 54	3.8 ± 1	

- The use of HY rice varieties saline tolerant increased rice yield compared to local variety
- The fish production was also successful, with a GIFT yield of 500 kg/ha (stocking density of 0.19 ind/m2) or 250-345 kg/ha with a GIFT+Climbing perch+Common carp polyculture (stocking density of 0.14-0.26 ind/m2) compared to local practice based on wild fish trapped in the field
- During the dry season, the shrimp culture model using improved extensive techniques (2.55 post larvae/m2) can achieve a yield of 324±80kg/ha with no outbreak of disease during the two years, compared to 23 per cent of disease outbreak recorded in the survey farms
- The total farm net return was improved by 165 per cent

Fish harvest in

Areas with a fresh water period ***shorter than 6 months*** saw unsatisfactory results due to the dependency of rice culture on climate, and several crop failures occurred due to saline water intrusion (Table n°4).

Table n°4: Result of Rice+fish culture followed by a shrimp crop model (Fresh water period shorter than 6 months)

Farming system	Net return (Mvnd/ha/year)	Aquaculture Yield (Kg/ha)	Rice Yield (ton/ha)	Water quality conditions
Rice+fish-shrimp model	**14 ± 10**	**Shrimp: 302 ± 220 Fish: 150 ± 117**	**Failed**	Less than 6 months of fresh water and low water flow
Rice - wild fish-shrimp Survey farms (n= 27)	11 ± 18	Shrimp: 301± 380 Wild Fish: 111 ± 24	1.6 ± 1.2	

Pond Design for rice fish-shrimp culture in Vietnam

- Rice culture failed due to saline water intrusion and the shorter growing period for the fish, September to December instead of July to December in the previous agro-ecological area resulted in a reduced yield (54 to 187 kg/ha of GIFT or GIFT+Climbing perch)
- Shrimp production was found to be variable (94 -576 kg/ha) and dependant on the water quality of the area, which presented high level of salinity (>35 ppt), limiting shrimp growth
- Compared to local farming system, the farm net return improved by 27 percent

...p, mud carb-fish model in Vietnam

This model was found dependant on the duration of fresh water to enable the integrated rice + fish culture. The alternate system (rice+fish-shrimp) can be expanded in areas with more than 6 months of fresh water to increase and diversify farm income.

The same model, applied in areas where the fresh water period was less than 6 months does not provide a stable shrimp and fish production, and rice crops failed within the two years period. In addition, the low market value of the targeted species for integrating with rice also discourages farmers although some were pleased with high value wild fish returns (e.g. snakehead fish *Channus striatus*).

E.1.4. Brackish water polyculture (shrimp, mud crab and fish)

This model, based on polyculture of shrimp (*P. monodon*) and mud crab (*Scylla paramamosain*) in the dry season and a high value fish (elongated goby-*Pseudoapocryptes elongates*) in the rainy season was found successful outside the protected area and presented mixed results inside the protected area (Table n°5).

Table n°5: Result of brackish water polyculture model

Farming system	Net return (Mvnd/ha/year)	Aquaculture Yield (Kg/ha)	Water quality conditions
Inside protected area Shrimp+mud crab-fish	**12.3±5**	**Shrimp: 115± 63 Mud crab: 62 ± 36 Fish : 117 ± 102**	High salinity (over 30 ppt) in dry season and low water flow
Shrimp+mud crab+wild fish Survey farms (n=15)	10±19	Shrimp: 141 ± 136 Mud crab: 34 ± 35 Wild Fish : 168 ± 172	
Outside protected area Shrimp+mud crab-fish	**22.7±11**	**Shrimp: 322± 21 Mud crab: 92 ± 81 Fish : 158 ± 94**	Outside the protected area. Good water flow and salinity lower han 30 ppt in dry season
Shrimp+mud crab+wild fish Survey farms (n=19)	7.8±17	Shrimp: 95 ± 81 Mud crab: 33 ± 40 Wild Fish :93 ± 119	

In the protected area, the water quality in the canals, with high salinity (>35 ppt) and alkalinity (>150 mg/l) in the dry season, did not allow a suitable environment for shrimp production (59-206 kg/ha), while fish production fluctuated widely between years (12 to 250 kg/ha). Shrimp and fish production were found lower than in the currently practiced farming system but the farm net return improved by 23 per cent compared to the local farming systems, due to lower operational cost.

Outside the protected area where salinity is between 8 ppt and 30 ppt, the model was successful. Shrimp yield was over 300 kg/ha/yr, with no outbreak of disease during the three years, compared to 66 per cent of disease outbreak recorded in the survey farms. Fish production was found satisfactory (73-180 kg/ha), as for mud crab production (92 kg/ha). The farm net return improved by 191 per cent and mud crab and fish production contributed to 40 percent of the farm income.

This model presents a significant improvement of the farm income and a diversified production outside the protected area when the natural water flow was not constrained by sluice gates. The results of this model show its dependency to water quality, with fluctuation of fish and shrimp production in the farms located within the protected area.


Mr. Ben's House (Before)

The story of Mr. Ben is a clear demonstration of the benefits generated by this kind of brackish water polyculture (shrimp with mud crab then fish). Mr. Ben, living in the outside the protected area, joined the CPWF 10 project in 2004. Before 2004, he stocked shrimp every month and faced several disease outbreaks. Restocking post larvae after each crop failure, he entered a cycle of stocking, failure and restocking. Since the project started, Mr. Ben reduced the frequency and density of stocking and started to stock fish in the rainy season and mud crab in the dry season. In addition, he received training on water quality monitoring and management, allowing him to understand better the importance of pond water quality. Over the last three years he has not failed a shrimp crop. He also improved the household income with a diversified production. After three years of positive economic results, the results are clearly evident from Mr Ben's investment in a new house.


Mr. Ben's House (After)

E.2. Ganges Delta - Bangladesh coastal area

In Bangladesh, the experimental sites were all located in the same area (Paikgacha Upazila). With a brackish water period from January to June/July, shrimp are raised in the ponds during the dry season and rice is cultivated during the wet season from August to December.

E.2.1. Wet season - Integrated rice-aquaculture system

Between 2004 and 2007, on-farm experiments on rice-fish and shrimp culture were conducted in Paikgacha Upazila to find suitable high yielding rice varieties (HYV) acclimatized to the brackish water environment and to investigate the economic and technical suitability of various integrated aquaculture production to be farmed concomitantly with rice.

Three HYV rice varieties, BR23, BR40 and BR41, responded positively with significantly higher yield ($p<0.05$) compared to the local variety and also provide a higher yield than HYV cultivated in monoculture. However low rice yield recorded in 2005 reflects the need for discharge and drainage infrastructure after abundant rainfall resulting in water logging. GIFT production was satisfactory at a total density of 0.5 ind/m2 (258 kg/ha). The low production level for *M. rosenbergii* in 2005 was due to the short growth periods during the rainy season and the absence of feeding. It appears that stocking juvenile fresh water prawn concurrently with rice is not an economically suitable solution for farmers in this area. However, *M. rosenbergii* culture in association with rice and GIFT was found to be highly profitable when post larvae are stocked earlier in the season, in June (7 months grow period) instead of August, when the salinity in the pond is still high (10-15 ppt). The yield was found to be significantly higher ($p<0.05$) in this case, compared to a shorter grow out period (5 and 6 months compared to 7 months in the first year) and the net return of this production system in the rainy season was found to be more profitable compared to other systems tested. In this case aquaculture production represents more than 50 per cent of the farm net return during the rainy season.

Table n°6: Aquaculture yield (kg/ha), rice yields (kg/ha) of BR23, BR40 and BR41 HYV and net return ('000 Tk/ha: Thousand Taka per hectare) of the entire system (rice and aquaculture) in 2005 and 2006.

Species combination		Stocking Density (ind/m^2)	Grow period (month)	Aquaculture Yield (kg/ha)	Rice Yield (tons/ha)	Rice-aquaculture net return ('000 Tk/ha)
2005						
T1	GIFT	0.5	5	258 ± 65.39	2.88 - 3.16	24.64 ± 14 (43%)
T2	GIFT	0.25	5	211 ± 12.7		22.30 ± 3.29 (37%)
	M.r	0.25	5	28.83 ± 10.36		
T3	M.r	0.5	5	70.91 ± 16.47		13.29 ± 4.61 (0%)
2006						
T1	GIFT	0.25	5	193.57 ± 2.85	4.22-4.54	64.19 ±8.4 (59%)
	M.r	0.25	7	72.53 ± 4.70		
T2	GIFT	0.25	5	192.11 ± 26.19		50.70 ± 6.6 (37%)
	M.r	0.25	6	38.02 ± 4.01		
T3	GIFT	0.25	5	179.69 ± 23.82		51.90 ± 5.8 (25%)
	M.r	0.25	5	27.88 ± 1.53		

Numbers in parenthesis represent the proportion of aquaculture in the net return of the entire system.

E.2.2. Shrimp production and stocking patterns

During the dry season, three different shrimp stocking patterns were tested in 2005 and 2006: single stocking (5 PL/m2), and two different double stocking methods (3+2 PL/m2 and 2+3 PL/m2) with 30 to 35 day intervals between stockings.

The results of the experiment show that that the stocking pattern does not have any effect on shrimp production, survival rate, or water quality. At this stocking density, the average yield over the two years was 300 kg/ha. In 2005, a correlation was found between the water depth of the pond and the shrimp yield, regardless of stocking pattern ($r=0.855$; $p<0.01$), with a higher yield corresponding to a deeper water depth. This result highlights that shallow water depth (30-50 cm) is one of the key causal factors limiting shrimp production in Bangladesh.

F. Lessons learned and recommendations

F.1.1 Mekong Delta

The models tested were successful in areas where the duration of fresh water and brackish water was stable and when the water flow was not constrained by sluice gate management. In these areas, the tested models revealed improved land and water productivity, higher economic returns, lower variability and a more diversified income than typical production systems. Diversification of production, with rice-integrated aquaculture or with brackish water polyculture (shrimp, mud crab and high value fish) can improve land and water efficiency compared to typical farming systems.

Aquaculture production in Bac Lieu Province can be improved with some minor changes to local farming practices. We have already seen the dynamic nature of aquaculture in the Mekong Delta where new techniques spreading quickly through self-replication by farmers. The successful technical patterns developed by the project can be widely adopted by farmers according to their agro-ecological area. However, the main constraints for aquaculture improvement include water salinity and water management at the provincial level:

- Water management needs to be improved at the regional level to allow a stable fresh water period in areas where farmer follow a rice-shrimp system;
- Sluice gate management has to be adjusted to improve water quality inside the protected area during the dry season to allow a more sustainable shrimp production

F.1.2. Ganges delta

The comparison of the different farm types described in the surveys and the production systems tested in 2006 during our experiments show that it is possible to enhance aquaculture and rice production and diversify farm

Household shrimp harvest in Vietnam

income through fish and fresh water prawn production. The tested systems, which utilize a more diversified production including rice, shrimp, fish and freshwater prawn, can provide farm net returns 30 to 811 per cent higher than four farming systems currently practiced (Table n°7).

Table n°7: Rice and aquaculture productivity and economic results of the one production system tested (Rice-GIFT and Macrobrachium rosenbergii followed by a shrimp crop) compare with the main farming system observed in the area.

	Shrimp (kg/ha/yr)	Fresh water aquaculture (kg/ha/yr)	Rice (tons/ha/yr)	Total Farm Net return ('000Tk/ha/yr)
Rice GIFT M. rosenbergii and Shrimp	**300**	**GIFT: 193 M.r: 72**	**4.22 - 4.54**	**64.1 (59%)**
Farm Type 1* (Rice - shrimp system)	268	-	1.83	49.0 (82%)
Farm Type 2 (Rice - shrimp system)	161	-	2.59	43.4 (66%)
Farm Type 3 (Shrimp monoculture)	142	-	0	7.9 (100%)
Farm Type 4 (Rice - shrimp system)	73.67	-	3.41	26.9 (31%)

**The farm types are based on 60 on-farm interviews, description of these farm types is presented in section D. Numbers in parenthesis represent the proportion of aquaculture in the net return of the entire system.*

The synthesis of three years of on-farm experiments and surveys provides some important findings and recommendations for the improvement of these types of farming systems:

- Shrimp yield can be enhanced with higher stocking density (5 PL/m^2 compared to 1 to 2.5 PL/m^2) and additional feeding. The stocking pattern does not have any significant effect on the shrimp production; single or multiple stocking patterns could be recommended, according to the household economy. Trench construction around ponds to improve water depth, which increases shrimp yield, should be promoted among local farmers
- Rice production can be increased using high yield rice saline tolerant varieties, and farm income can be improved with integrated aquaculture production during the rice crop

- The natural physiological requirements of *M. rosenbergii* post-larvae and juveniles to grow in brackish water and later in their life cycle as adults in fresh water can be an opportunity for farmers to harness such variable environments. Fresh water prawn culture in tandem with rice and fish was found economically profitable when the growth period was longer than 6 months and when post larvae instead of juveniles were stocked to reduce the cost of the initial stock
- The development of rice-integrated aquaculture requires the transformation of the rice field, which can be a constraint for farmers who lease their land or cannot afford the investment to build a trench. However, after three years of observing the successful implementation of rice-integrated aquaculture in the project sites, neighboring farmers independently started to improve their water management infrastructure with higher dikes and trenches to develop such integrated production systems of their own
- In addition, farmer training is required to improve water management techniques for rice-aquaculture and rice pest management

F.1.3 - Interactions between the research sites

Three years of on-farm research and surveys in the Mekong and Ganges deltas has provided a number of lessons with regard to aquaculture and its development in these areas.

We have seen that the water management issues are different in each delta. We highlighted that in Bangladesh, farmers should improve water management infrastructure at the pond level, whereas Vietnam requires more effort in water management at the provincial level to improve water quality.

Interactions between the two research sites have increased our knowledge on the types of rice-integrated aquaculture currently practiced in each delta and opened new avenues of research. Further experiments on the potential of rice with freshwater prawn have to be tested in the Mekong delta. Brackish water polyculture with shrimp and mud crab could also be further tested in Bangladesh, and Vietnamese techniques for water management at the pond level can be a source of knowledge for improving farming techniques in Bangladesh.

The commonly held belief that coastal areas are lagging behind inland areas is no longer true. The example of the Mekong Delta demonstrates the potential for farmers to react positively and proactively, with innovation and development of new production systems, to national and international markets. Farmers here have changed their point of view; brackish water and seasonal salinity fluctuations is no longer perceived as a constraint but as an opportunity to enhance annual returns by adapting to local environmental conditions through innovative approaches to diversified farming systems.

Experimental Site at Paikgacha Upazila in Rice Aquaculture and Shrimp production Seasons

November 2006

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Key implementing agencies:

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Text:

Olivier Joffre

Edited by:

Alan Brooks

Photo credit:

Olivier Joffre, Mark Prein, Chu Thai Hoanh, Alan Brooks

Coordination:

Md. Mamunur Rahman

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WorldFish
CENTER

The WorldFish Center - Bangladesh and South Asia Office
House-22B, Road-7, Block-F, Banani, Dhaka-1213, Bangladesh
Phone: (+880-2) 8813250, 8814624, 8817300, Fax: (+880-2) 8811151
E-mail: worldfish-bangladesh@cgiar.org

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