WATER MANAGEMENT OF INTEGRATED RICE-FISH FARMING IN INUNDATED FLOODPLAINS OF BALAJTALA-KALMADANGA SUBPROJECT

A Thesis by

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June, 2008

INSTITUTE OF WATER AND FLOOD MANAGEMENT

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The thesis titled '**Water Management of Integrated Rice-Fish Farming in Inundated Floodplains of Balajtala-Kalmadaga Subproject**' submitted by Md. Sydur Rahman, Roll No. MF 10062847, Session: October 2006, has been accepted as satisfactory in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE IN WATER RESOURCES DEVELOPMENT on June 25, 2008.

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Dedicated to my

BELOVED MOTHER AND FATHER

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ABBREVIATIONS

BAU	Bangladesh Agricultural University
B. Aus	Broadcast Aus
BBS	Bangladesh Bureau of Statistics
BFRI	Bangladesh Fisheries Research Institute
BRAC	Bangladesh Rural Advancement Committee
BRRI	Rice Research Institute
BWDB	Bangladesh Water Development Board
CARE	Co-operation for American Relief Everywhere
CEGIS	Center for Environmental and Geographical Information Services
CB	Crossing Boundaries
DAE	Department of Agricultural Extension
DWR	Deep Water Rice
DW	Deep Water
FCDI	Flood Control, Drainage and Irrigation
HYV	High Yielding Variety
ICLARM	International Center for Living Aquatic Resources Management
IPM	Integrated Pest Management
SWAIWRP	Sonth-West Area Integrated Water Resources Plan Project
SWIWRMP	South West Integrated Water Resources Management Project
LGED	Local Government Engineering Department
LLP	Low Lift Pump
LV	Local Variety
NGO	Non-Government Organization
PWD	Public Works Department
SRDI	Soil Resources Development Institute
T. Aman	Transplanted Aman
WMCA	Water Management Co-operative Association

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ABSTRACT

The burning issues that currently surround the countries in South Asia are food security and ecosystem security. While food security is of paramount importance, protein requirement is also an important issue, since many of the rural children and older people suffer from severe protein malnutrition. In Bangladesh, fish is the only source of free animal protein for the poorer section of the community. One of the potential scopes for improving fish production in Bangladesh is to integrate aquaculture with rice farming, and considerable scopes are there to exercise such practice in inundated rice fields during the monsoon season through local community based water management.

In this study, the potential of integrated rice-fish farming was explored in inundated areas of a small water management project, namely, Balajtala-Kalmadanga Subproject in Gopalganj district of the Southwest region of Bangladesh. The study followed an interdisciplinary approach through technical assessments as well as application of participatory tools to address different dimensions of integrated rice-fish farming in the study area, including physical, socio-economic, institutional and environmental aspects. Using a set of criteria and indicators, the system was evaluated from a sustainability point of view; for example, whether the existing physical systems are suitable for integrated farming practice, whether the new system is able or have the potential to have a positive impact on the socio-economic condition, whether the system will be environmentally sound, and what kind of management infrastructure and water management system are required for the integrated farming system to be sustainable over long periods.

The water management infrastructures in the project area were found to be conducive to the adoption of the new farming system. Desired water levels required for minimization of rice yield reduction and increasing favorable condition for fish culture were analyzed, which can be met from the available water in the study area. Results indicate that standing water depth up to 50% of plant height is recommended during the different growing stages of rice that maximizes yield and increases the favorable condition for fish culture. Benefits obtained by the community were more than that they obtained in previous years from rice monoculture. However, potential of further enhancement of benefits are there in the study area. Since introduction of fish culture is still in an experiment stage in the study area, the existing fish yield is relatively on the lower side at 0.10 ton/ha. However, there are immense potentials to increase the yield many folds by increasing the stocking of fish fingerlings feasible for the study area. With increased stocking of fish fingerlings, the simulated fish yield was 6.20 ton/ha, which is much higher than the present yield. Full implementation of the project by Local Government Engineering Department (LGED) will allow more area to be brought under cultivation during Kharif-II season. The existing benefit-cost ratio (BCR) for rice-only is 1.61 compared to 1.78 in the projected post-project condition. Integration of fish with rice will increase the BCR manifolds; the simulated BCR for rice plus fish cultivation system is 5.11 compared to the existing ratio of 2.18.

The integrated farming system was found to be socially acceptable. The quality of soils was enhanced with the introduction of fish in inundated rice field, which is favorable for Boro crops to be followed in the field in the dry season. Organic carbon, organic matter and nitrogen content in soil after fish cultivation in rice field recorded about 2, 3 and 19 times higher, respectively than that of only rice cultivation system. However, no remarkable impacts on soil quality were found in P^{H}, phosphorous and potassium content between with and without rice-fish cultivation system. The integrated farming system improved pest management and weed control, and did not negatively impact water quality, indigenous capture fisheries and biodiversity.

There are some shortcomings in the management process with the integrated system, including community-based fish farming through Water Management Co-operative Association with fair distribution of shares and benefits among landowner, landless, traditional fisher men and women. The study suggests some management processes, and anticipates that these will pave the way for more motivation and social acceptability among the community members with disparate socio-economic status, which in turn will help sustain the system.

The results conclude that community-based fish culture approach in the study area has the potential of being technically feasible, economically profitable, environmentally sound, and socially acceptable.

Chapter One
INTRODUCTION

1.1 Background

The burning issues that surround the countries in South Asia are food security and ecosystem security. These two can not be isolated from another; rather they are closely related. While food security in general refers to security with cereals, protein requirement is also an important issue, since many of the rural children and older people suffer from severe protein malnutrition.

In Bangladesh, fish is second only to rice as a source of food, representing 50% of caloric intake and 80% of protein intake (ISPAN, 1993). Fish is virtually the only source of free animal protein for the poorer section of the community, who catches fish from open water bodies including inundated floodplain, rivers and swamps. Fisheries sector provides full-time jobs to 1.2 million people and part-time and other jobs to another 12 million people (DOF, 2001).

In Bangladesh, the conflicts between agriculture and fisheries are well-known; many of the flood management projects have led to substantial decrease in inland capture fisheries production and fish biodiversity (summarized in Chowdhury et al., 1997). Although not able to match the fish bio-diversity and richer dietary nutrients of capture fisheries, culture fisheries are increasingly compensating the production loss of capture fisheries; the production from capture and culture (ponds, baors, coastal shrimp and fish) fisheries were 0.71 and 0.86 million metric tons, respectively, in 2002-03 compared to 0.57 and 0.26 million metric tons in 1993-94 (BBS, 2004). The demand for fish has increased due to the increase in the population of the country. Annually 18 kg fish is needed per capita, while the availability is only 8.81 kg (DOF, 1995). For the poor people who live in the rural areas, the intake is even less than 8.81kg. This has had a negative impact on the health condition of the people. So care should be taken for the best use of the fisheries sector of the country. There are further scopes for improving the situation through improved integration between the agriculture sector and the fisheries sector. This can be potentially achieved by integrated rice-fish cultivation in seasonal inundated paddy fields or flood-prone areas.

Rice-fish farming is practiced in many countries in the world, particularly in Asia. While each country has evolved its own unique approach and procedures, there are also similarities, common practices and common problems. Global recognition of, and interest in, the potential of rice-fish farming in helping combat malnutrition and poverty has been well known for a long time. The FAO Rice Committee recognized the importance of fish culture in rice field back in 1948 (FAO, 1957). Subsequently it has been the subject of discussions by the Indo-Pacific Fisheries Council (IPFC), the General Fisheries Council of the Mediterranean (GFCM), the FAO Rice Meeting and the International Rice Commission (IRC). IPFC and the IRC took a joint program for promoting investigations to evaluate the utility of fish culture in rice fields.

Integrated fish farming is generally considered particularly relevant to benefit the rural small holder farmers (FAO/IPT, 1992). A major socioeconomic benefit of integrated farming is that inputs to the various subsystems that comprise the farming systems tend to be intra-farm, with a diminished reliance on inter-farm or agro-industrial inputs. Integrated farming systems lead to a more balanced diet for the farming family that chooses to eat some of its own produce (Edwards et al., 1988). Apart from the additional production of fish and the resulting enhanced nutrition level and income (Gupta et al., 1998), other benefits of such practice include improved yield of rice (Halwart, 1993), increased nutrient concentration in rice and straw (Uddin et al., 2000), an incentive to implement integrated pest management (IPM) (as fish reduces pest populations and hence provides opportunities to reduce misuse and overuse of pesticides, a common problem in developing countries (Halwart, 1998; Gupta et al., 1998, 1999), and lower rice production cost (Sarker et al., 2000).

Halwart (1998) described that from the point of view of IPM, fish culture and rice farming are complementary activities because it has been shown that fish reduce pest populations. In Indonesia, evidence from the inter- country program for integrated Pest Control in Rice in South and Southeast Asia shows that the number of pesticide applications in rice-fields can be drastically reduced through IPM. Such a reduction not only lowers costs but also eliminates an important constraint to the adoption of fish farming. With savings on pesticides and additional earnings from fish sales, increases in net income on rice-fish farms are reported to be significantly higher than on rice monoculture farms by widely varying margins of 7 to 65 percent.

1.2 Rice-fish farming practices

Rice with capture (wild) fish farming

Farming practices in the flood-prone ecosystem are governed by a number of interacting physical factors, of which the chief ones are the flooding regime (onset, depth, recession, and variability), topography, rainfall pattern, soil texture, and the water management regime. Traditionally, farmers used to grow deepwater rice and capture fish during the flood season and subsequently cultivate a wide range of crops, such as pulses, oil seeds, and vegetables, during the post-flood dry season (Fig. 1.1a).

Over the last few decades, the flood-prone ecosystems in Asia have undergone some dramatic changes due to the establishment of deep wells (for example, in Bangladesh and eastern India) and construction of the Flood Control, Drainage and Irrigation (FCDI) systems (Dey and Prein, 2006). With the availability of irrigation facilities, farmers grow high yielding varieties (HYV) of rice in the dry season under irrigated conditions. In the Gangetic floodplains, the dominant farming pattern in shallow flooded areas is irrigated HYV rice during the dry season, followed by transplanted deepwater rice varieties during the rainy seasons (Fig. 1.1b); while the dominant pattern in deep flooded areas is single crop irrigated HYV rice (Fig. 1.1c). Late harvest of HYV dry season (winter) rice does not usually allow timely establishment of a deepwater rice crop in the deep-flooded areas during the rainy season.

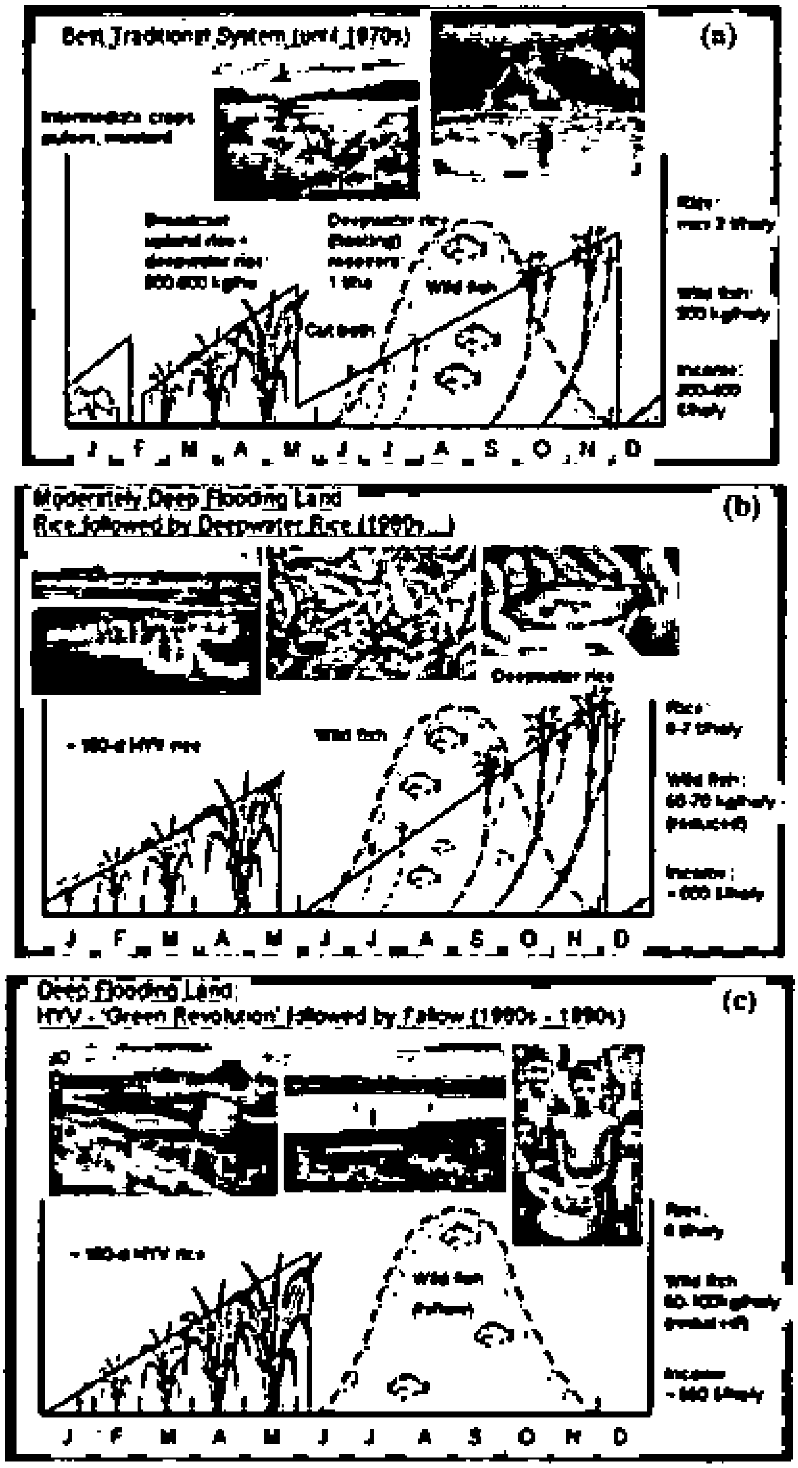

Fig. 1.1 Farming systems with rice and wild fish
[Source: Dey and Prein, 2006]

Integrated rice-fish (wild plus culture) farming

An opportunity for further increasing production in the flood-prone ecosystem is in the integration of fish culture with rice farming. The flood-prone areas are seasonally flooded during the monsoon and remain submerged from four to six months. In these flood-prone areas, land ownership is fixed according to tenure arrangements during the dry season. However, during monsoon season, individual land holdings are not visible and waters are community property granting all members access to fish in all areas of the community. Consequently, as it is essential that the rice-fish culture activity in the flood-prone ecosystem is undertaken by the rural community under a group approach. The group should include the landless, who have traditionally accessed the flooded areas for fishing, but would lose this key resource if they were denied access to areas stocked with fish.

Generally three types of rice-fish culture systems can be established in flood-prone areas: (i) concurrent culture of deepwater rice (with submergence tolerance) with stocked fish during the flood season followed by dry season rice in shallow flooded areas; (ii) concurrent culture of deepwater rice (with elongation ability) with stocked fish during the flood season, followed by dry season none-rice crops in deep flooded areas; and (iii) alternating culture of dry season rice followed by stocked fish only during the flood season (that is, without rice) in the enclosed area (for example, in a fish pen) in deep flooded areas. The World Fish Center and its national partners recently tested the concurrent rice-fish culture given as in option (i) above (Fig. 1.2a) in shallower flooded areas, and the alternating rice and fish culture option (iii) (Fig. 1.2b) in deep-flooded areas of Bangladesh and Viet Nam through a community-based management system. These (Fig.1.2) and other potential technical options need to be tested and validated in various floodplains of Asia and Africa under varying institutional arrangements suitable for locally prevailing socio-cultural economic and political conditions.

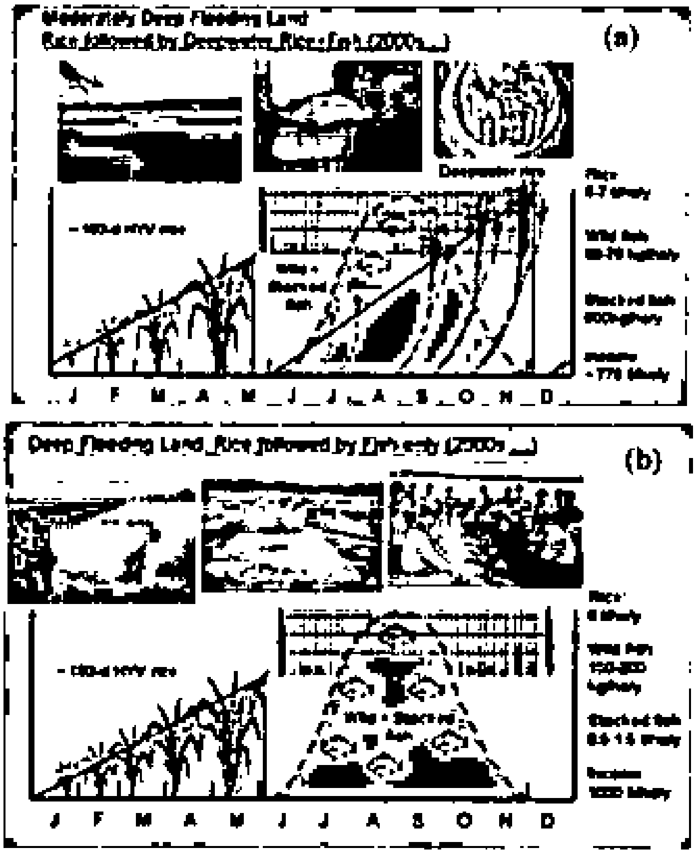

Fig. 1.2 Farming systems with rice and wild fish
[Source: Dey and Prein, 2006]

1.3 Why integrated rice-fish farming?

Integrated rice-fish farming approach helps to mitigate the trend of declining production from inland capture fisheries accompanied by increasing price of fish (which makes it less affordable to the poor). For example, Dey and Prein (2005) reported that there are 3 million ha of medium and deep flooded areas, out of which about 1.5 million ha are estimated to be suitable for community-based fish culture in Bangladesh. If this approach is adopted in only 50 per cent of these areas, annual fish production will increase by 450,000 tons (additional to the presently produced 60,000 tons of wild fish caught in these areas) with an approximate value of US$340 million, and will be of benefit to an estimated 6.7 million people (2.7 million of which are landless and/or functionally landless). Similar opportunities are seen for floodplain and deltaic systems in other countries in Asia and Africa. In the Mekong river basin, there are 0.8 million ha of medium and deep flooded areas that could be utilized by the local communities for joint fish culture activities during the flood season, which is otherwise a fallow season with very low economic and agricultural activity. Of the 5.2 million ha of medium and deep flooded areas in the Indo-Gangetic basin, 3 million ha are in Bangladesh, wherein an estimated 27 million potential direct beneficiaries live. If only 25 per cent of these adopt the approach, 6.7 million would benefit, of which 2.7 million persons are landless

The combination of rice and fish is a good and reasonable option for both the agronomists and aquaculturists meeting the challenge to feed the increasing human population and ecologists trying to keep habitats in balance (Halwart, 1993). Integration of fish with crops is the most efficient way of increasing production per unit area of land. Integration within the farm has been a practical necessity, where farmed fish have been economically and nutritionally most important. Integrated aquaculture compliments and improves the overall yield in terms of labour input and efficiency in terms of resource use (Little and Muir, 1987). The ecological benefit of fish growing in the rice fields could make integrated rice-fish farming a type of ecological farming (Eco-farming) that leads to sustainability of rice fields (Cagauan et al., 1993).

1.4 Rationale of the study

In Bangladesh, integrated freshwater rice cum prawn and fish farming is practiced by more than 100,000 households, especially in the southwest region, in modified rice fields locally known as ghers (Williams and Khan, 2001). A study of 256 farms integrating aquaculture with agriculture reported increased rice yields and decreased infestations of both pests and weeds (Gupta et al., 1999, 1998). Farming systems and Environmental Studies (FSES) of Bangladesh Agricultural University (BAU) Mymensingh, Bangladesh Fisheries Research Institute (BFRI), Co-operative of American Relief Everywhere (CARE) and some other local Non-Government Organization (NGOs) have currently been promoting the rice-fish culture technology through massive extension and conducting on station and field based trial for the last ten years.

In Bangladesh, the potential for integrated rice-fish cultivation in inundated deepwater rice fields has been mostly unexplored. There have been a few studies which investigated the usefulness of this technology on experimental basis. Dey and Prein (2003, 2004) demonstrated the usefulness of integrated rice-fish farming in shallow flooded areas in three upazilas (Kuripara, Sadhukhali, Maizpara). Ali et al. (1998) examined increase of farm income by introducing fish culture in deepwater rice environment using net pen and polder systems. A number of rice-fish culture experiments were undertaken by BRRI, one example of which is fish culture in transplanted aman fields in Mymensingh district by Haroon et al. (1992).

The total area of rice fields in Bangladesh is about 10.14 million hectares of which 2.83 million hectares are seasonal paddy field where water stands for 4-6 months, and hence can play an important role in increasing fish production (DOF, 2002 and Rahman, 1995). There exists considerable scope for increasing fish production by integrating aquaculture in those types of inundated rice fields. In floodplain ecosystem, opportunity exists to fence- in large areas by creating enclosed water bodies and stocking these with fish, and community management groups can play a significant role in jointly deciding on management and share of benefits based on agreed rules (Dugan et al., 2005). However, sustainability of such project is a question, which will largely depend on a good understanding of the feasibility of such practice in the context of physical suitability and socio-economic and environmental impacts and water management requirements including a sound institutional arrangement.

This study is an attempt to investigate different aspects of a recently started integrated rice-fish farming practice in rice fields inundated during the monsoon which is managed by local water management association in a small water management project, namely, Balajtala-Kalmadanga Subproject in Gopalganj district of the southwest region of Bangladesh. The central research question of the study is: 'what are the potentials of the integrated rice-fish farming system and what would be the water management requirement in the study area?' This question is interdisciplinary in nature, as it touches upon several important aspects of water management from the sustainability point of view, for example, whether the existing physical systems are suitable for such practice or what they should be, whether the new system is able or have the potential to have a positive impact on the socio-economic condition, whether the system will be environmentally sound, and what kind of management infrastructure and system is required for the integrated farming system to be sustainable over long periods.

1.5 Objectives of the study

Specific objectives of the study were as follows:

(i) To assess the physical suitability, including water requirements, of integrated rice-fish farming in the study area;

(ii) To analyze the favorable institutional arrangement required for sustainable rice-fish farming;

(iii) To analyze the socio-economic and environmental impact of integrated rice-fish farming; and

(iv) To suggest water management practices.

The study was expected to provide significant insight on how to translate the existing rice-fish farming system into a sustainable practice.

1.6 Organization of the thesis

Chapter two provides a review of literature on integrated rice-fish cultivation system. It includes a description of the traditional rice-fish cultivation practices in Bangladesh, and a rather thorough review of results of both field level and on-station experiments with integrated farming with concurrent, rotational, rice and fish mono- and polyculture within Bangladesh and abroad. Chapter three presents the methodology followed in the thesis. It outlines the criteria and indicators used for evaluating different aspects of the integrated farming practice in the study area and the participatory methodology and primary sampling of data used in the study. The study area is introduced in Chapter four. The description includes the physical water management infrastructures, land type and topography, and the existing socio-economic conditions in the project area. Results are presented in Chapter Five. Results include examination and discussion of physical, socio-economical, environmental and institutional aspects of the new farming system. Conclusions are presented in Chapter six along with some recommendations.

Chapter Two

LITERATURE REVIEW

2.1 Introduction

The Asian countries like China, Bangladesh, India, Malaysia, Indonesia, Thailand and Vietnam have a long history of integrated agro- aquaculture systems, but the extent of the traditional practices have not been wide. Lately, this farming system is becoming a favorite option among the resource-poor fish farmers in the developing world, mainly because of its ability to remove many risks associated with the stand-alone pond aquaculture of both intensive and extensive scale (Prein and Dey, 2002). Potential, existing areas and yield data of integrated rice-fish farming from a number of studies are summarized in Table 2.1. To maximize the output from the rice field, a lot of on station and on farm research works have been done in many countries, specially in the rice growing countries in Asia, such as China, Indonesia, Thailand, Philippines, India, Malaysia etc. Rice and fish prodnctivity in integrated systems in some countries are summarized in Table 2.2. In Bangladesh farming fish in the inundated rice field is a recent innovation compared to other countries.

There is an estimated 81 million ha of irrigated rice worldwide, with an additional 11 million ha of flood-prone land under rice cultivation (Halwart, 1988), rice-fish production is possible in both of these systems under either capture systems where wild fish enter, reproduce and are harvested from the flooded fields, or culture systems where the rice fields are stocked with fish either simultaneously or alternately with the rice crop. One and sometimes both of these systems are practiced in many countries.

Table 2.1 Potential and existing areas of rice-cum-fish farming in different countries

Country	Rice field area ('000 ha)			Potential area ('000 ha)	Existing area ('000 ha)
	Irrigated	Rainfed	Total		
Bangladesh	1227	9002	10229	615	Unknown
China	30902	2296	32798	5000	985.5 (1986)
India	14349	26644	40991	2000	Unknown
Indonesia	6230	3659	9889	1570	94.3 (1985)
Malaysia	427	220	647	120	Unknown
Thailand	1313	8065	9378	254	Unknown

Source: Lighfoot et al. (1992); cited in Uddin (2002)

Table 2.2 Rice and fish productivity in integrated systems as reported from various Asian countries

Country	Type of study	Rice yield (tons /ha)	Fish yield (kg/ha)	Fish species	References
Vietnam	Field experiment	1.8–7.3	291–474	*C. carpio* *B. gonionotus* *O. niloticus*	Rothuis *et al.*, 1998 Vromant *et al.*, 2002
Vietnam	Socio-economic	4.2–4.5	326–459	*C. carpio* *B. gonionotus* *O. niloticus*	Berg,2002
Bangladesh	Field experiment	1.5–3.7	226–271	*B. gonionotus* *O. niloticus*	Haroon and Pitman, 1997
Bangladesh	Socio-economic	3.8–5.0	118–616	*C. carpio* *B. gonionotus* *O. niloticus*	Gupta *et al.,1996*
Indonesia	Socio-economic	7.8	0.8–625	*C. carpio* *O. niloticus*	Purba,1998
Thailand	Review	n.d.	70–363	*C. carpio* *B. gonionotus* *O. niloticus*	Little *et al.,1996*
India	Field experiment	3.0–3.6	906–1282	*C. catla* *C. carpio* *C. mrigala* *L. rohita*	Mohanty *et al.,2004*
China	Review	n.d.	225–2250	*C. carpio* *O. niloticus* *B. gonionotus*	Li,1988

Source: Frei and Becker (2005)

A thorough review is made in the following sections of both field level studies and on station experiments on integrated rice-fish farming systems conducted in Bangladesh and abroad.

2.2 Rice-fish culture in Bangladesh

Dewan (1992) describes the traditional rice-fish culture practices in Bangladesh. Farmers in Bangladesh have been harvesting fish from their rice fields for a very long time. Farmers construct ponds of different sizes in low-lying areas of the field and when the ponds and rice fields are full of water during the monsoon, carp fry are released, following no specific stocking density. The small ponds can be provided with brush shelters, but no fertilizers or feed are applied. The fish are harvested over a period extending from the time the rice is harvested in November-December up to March. In the coastal areas, marine shrimps such as the various penaeids including *P. monodon* may also be cultured. The traditional 'bheri' system is used wherein the rice fields are enclosed by small embankments complete with inlet channels and sluice gates. Fields vary in size from 3 to 50 ha. Both rotational and concurrent systems are practiced. Occasionally, the freshwater prawn (*M. rosenbergii*) may also be cultured. Prawn fry gathered from nearby rivers are stocked after the monsoon rains have washed out the salinity from the rice fields.

Agro-ecological conditions are particularly favorable for the cultivation of integrated rice-field in many parts of Bangladesh and more than 100,000 households now practice integrated freshwater rice cum prawn and fish farming, mainly in southwest Bangladesh. Farmers grow prawn with rice fin-fish and vegetables in modified rice- fields known locally as Ghers. Gher-farming provides land management alternative well adapted to the conditions of southwest Bangladesh. It uses scarce land and abundant labour in the proportions that exists locally and has created economic opportunity for smallholder households that would otherwise be very poor (Finan, 2001). Gher farming generates an average income that is four times higher than any other typical agriculture practice in Bangladesh (Abedin and Kabir, 1999).

Field level studies

NGOs in Bangladesh are showing increasing interest in rice-fish farming. Among the more successful NGO efforts was the Noakhali Rural Development Program in 1989 which used the rotational system to produce from 223 to 700 kg/ha of mixed species of fish in 50 fields planted with local rice varieties (Haroon et al., 1992). Dey and Prein (2003, 2004) reported that the World Fish Center and its national partners tested the concurrent rice-fish culture in the shallower flooded areas and the alternating rice and fish culture in the deep flooded areas of Bangladesh (Kuripara, Sadhukhali, Maizpara thana) through a community based management system over three years (1998-2000). Under this approach, fish was cultured communally during the flood season while the same land was cultivated with rice during the dry season by individual farmers in their separately owned plots. The average rice yield was about 7 ton/ha/year. The resnlts show that the adoption of Community Based Fish Culture (CBFC) can substantially increase fish production by about 600 kg/ha/year in shallow flooded areas and up to 1.5 tone/ha/year in deep-flooded areas, without reduction in rice yield and wild fish catch. For the overall system, an additional income ranging from US$ 135 per hectare in southern Vietnam to US$ 437 per hectare in Bangladesh was achieved, which is an increase of 20-85% over the previous profitability. The arrangements involved landholders and landless, who received shares of the returns based on their contributions to management and upkeep. The landless which were seasonal fishers in the area, had income gains from their labor and additionally were able to conduct fishing for indigenous non-stocked fish and thereby meet their family nutritional and income requirements during this period.

Gupta (1999) undertook studies to assess the impact of the integration of aquaculture with rice-fish farming in medium high land during the irrigated and rainfed seasons and the introduction of low-input pond aquaculture in flood-prone ecosystems in Bangladesh. Baseline surveys were undertaken in the project areas prior to the introduction of new technologies as well as two years after the completion of the projects to assess the adoption of technologies by the farmers and impact if any, on household income and nutrition. These studies indicated that in both cases the farmers had adopted the technologies and some had even improved/intensified the technologies in the case of integrated rice-fish farming. Farm income increased by 65 percent, while there was a tripling of household consumption of fish in the case of farmers adopting low-input aquaculture practices introduced in the flood prone ecosystem. In both cases, the studies revealed that relatively well-off farmers took advantage of the new technologies, indicating the need for institutional support for poor farmers to benefit from the technologies. Gupta et al. (1996) studied the economics of more than 250 rice and rice-fish farms in Bangladesh. The studies concluded that the adoption of integrated culture had brought about an increase in net benefits by more than 60% in irrigated areas and by more than 80% in rainfed areas. In the same example, the increase in production costs by 14 to 18% was more than compensated for by the increase in revenues.

Many of the on field experiments showed increase in rice yield when integrated with fish cultivation. For example, Ali et al. (1998) conducted a study on fish culture in deep water rice (DWR) environment using net, pen and polder system. A 5 species combination (rohu, mrigal, and common carp, grass carp and Thai silver bard) were cultured with BR 3 rice variety and DWR. Boro rich-fish production system produced 2.8 ton/ha of fish and 7.33 ton/ha of rice in polder system with 5 species combinations. Mazid et al. (1993) studied fifty farmers' plots under rice fish culture system from four thanas of Mymensingh district during Aman season. *P. gonionotus* and *C. carpio* were stocked at the rate of 3000/ha and the average yield of fish recorded were 76 kg/ha for *P. gonionotus* and 157 kg/ha for *C. carpio* and rice yields recorded were 4.4 ton/ha with fish and 4.2 ton/ha without fish.

Intensive studies and surveys undertaken from 1992 to 1995 in Bangladesh showed improvement in income and food availability for most of the respondents to the extent that 89% of the farmers involved planned to continue with the practice. The net returns from rice-fish were over 50% greater than that from rice monoculture. The higher net returns were probably due to the lower mean costs of rice cultivation and higher rice yields in addition to the fish yield from integrated farms (Gupta et al., 1998).

Significant improvements in yields were also found by Kohinoor et al. (1993) in their experiments with two rice-fish culture systems, one conducted in 1988 and another in 1989 during the Aman season, in six plots with the size of 1360-2880 m^2 in Mymensingh district. Each plot was provided with ditch covering 3% of the plot area. *P. gonionotus* was stocked at a density of 2000/ha in 3 plots each year. The experimental plots were fertilized with nitrogen-phosphorus-potassium and gypsum at the rate of 150, 225, 75 and 75 kg/ha, respectively as per normal practice followed in transplanted Aman in the area. Rice seedlings of variety BR-11 were transplanted in the plots. The fish culture period continued for 85-90 days in 1988 and 70-75 days in 1989. The yield of fish recorded was 98.4 kg/ha and 73.6 kg/ha in 1988 and 1989, respectively and rice yield varied between 4.8-5 ton/ha.

Fisheries Research Institute (FRI) undertook studies on rice-fish culture in 68 farmers' plots during the boro season in collaboration with Department of Agricultural Extension (DAE) and International Center for Living Aquatic Resources Management (ICLARM) in 1992 (Gupta and Mazid, 1993). The experimental plots were selected from 12 thanas of Mymensingh and Jamalpur district. The rice plots were stocked with *P. gonionotus* and *C. Carpio* at a stocking density of 3000/ha. These two species of fishes were stocked in the plots either singly or in combination in the ratio of 1:1. Some farmers used rice-bran and oil cake while others used duck weeds as supplementary feeds for fish. Average fish production obtained was 229.4 kg/ha and rice yields were recorded as 4.4 ton/ha with fish and 4.2 ton/ha without fish. Similar results were found from a study by the FRI (Rahman et al., 1995) in 85 irrigated boro rice fields, with size varying from 0.08 ha to 1.2 ha during the year 1994. The study also found that fish polyculture integrated with rice produced more yields than fish monoculture integrated with rice. The rice fields were provided with ditch covering about 2.8% of the total area. The farmers were suggested to stock fish at a density of 3000/ha. The fish species viz. *C. carpio*, *P. gonionotus* and *O. niloticus* were stocked either singly or in combination, with a stocking period of 71 days. The average fish production recorded under different species combination stood at 145-577 kg/ha with the highest yield in multi species plots. Higher yield of rice (6.4% by average) was recorded in 88% rice fields with fish compared to those without fish. Average fish recovery recorded was 52.4% for *C. carpio*, 65.6% for *P. goniontus* and 68.4% for *O. niloticus*.

A somewhat lower yield of rice was found in the rice-fish culture experiment undertaken by Bangladesh Rice Research Institute (BRRI) in collaboration with Department of Agricultural Extension (DAE) in 6 transplanted Aman fields of the village Kismat at Mymensingh district (Haroon et al., 1992). Fish fingerlings of *O. niloticus* were stocked in the field at the rate of 6250/ha after one month of transplanting BR11 seedlings. The rice fields were fertilized with nitrogen-phosphorus-potassium (N-P_2O_5-K_2O) at the rate of 60-40-40 kg/ha. Low cost supplemental feed and insecticide were used during the culture period. Average yield of fish was 416.7 kg/ha and that of the rice was 3.97 ton/ha with fish and 4.0 ton/ha without fish.

CARE Bangládesh (CARE, 1992) initiated studies for evaluating the use of rice fields as nurseries. The stocking rates used for hatchlings and fry were 315,000-600,000 and 50,000-100,000/ha, respectively. Fingerlings were harvested two months after stocking.

The rate for hatchings was 3-5% and in the case of fry it was 31-45%. Under both stocking regimes, more than 75% of the farmers were able to make a profit. Net benefit averaged 8,038 Tk./ha and 11,689 Tk./ha at high stocking densities of sperm and fry, respectively.

Whitton et al. (1988) worked in deep water rice fields in Bangladesh. They reported physical, chemical and biological features of Bangladesh deep-water rice fields. Temperature showed a narrow range with values for the upper part of the water column during July-October seldom outside the range 29-35^{0}C. Measurement of conductivity ranged from 60.7-288 µS/cm, NH_3-N ranged from 0.006-0.05 and pH 6.53-7.08.

On station experiments

Mondal (2001) conducted an experiment on the culture of *Rohtee cotio* in combination with mola *(Amblypharyngodon mola)* and common carp *(Cyprinus carpio)* in rice fields and he found that the yield of rice grain and straw were found to increase by 9.02-17.29% and 9.80-18.85%, respectively in treatments with fish than without fish. Das (2002) conducted two sets of experiments, in the field of Bangladesh Agricultural University. *A. mola* in different stocking densities and *R. cotio* in combination with silver burb *(Barbodes gonionotus)* and *C. carpio* were used. He stated that yield of rice grain and straw increased by about 5.90-13.24% and 5.61-14.05%, respectively rice fish culture over rice culture alone. Haque et al. (1998) conducted a study in Mymensingh to examine the relative profitability of rice fish culture and rice monocrop production. The results of the study showed that the rice fish farming was economically more rewarding than the rice monocrop farming, although both the farming activities were found to be profitable over cash as well as full costs. In addition to extra-earning, there was very minimum extra cost for fish.

Ahmed et al. (1995) suggested *P. goniontus*, *C. carpio* and *O. niloticus* as suitable fish species for simultaneous method of rice-fish culture. The stocking densities recommended by them were 2500-3000/ha in monoculture and 5000/ha in mix culture and the suggested species ratios were 1:1 for two species combination and 2:2.1 for 3 species combination. The fertilizers such as urea, TSP, MP and gypsum were suggested to be applied at the rate of 200, 153, 77 and 128 kg/ha respectively. The suggested stocking density for monoculture was found to be low especially for *P. gonionotus and O. niloticus.*

An experiment carried out in Bangladesh (Haroon and Pittman, 1997) demonstrated maximum fish yields (silver barb) of 271 kg/ha in each rice growing season without fertilizer or extra feed. In contrast, Mohanty et al. (2004) observed fish yields (advanced fingerlings) of up to 1,245 kg/ha with the application of mineral fertilizer and manure (cow dung), at a stocking density of 35,000 fingerlings per ha.

Das and Dewan (1982) conducted experiments on fish growth in rice-fish concurrent systems. Rui (*Labeo rohita*), mrigal (*Cirrhinus mrigala)*, common carp (*C. carpio*) and tilapia (*O. niloticus*) were stocked both in monoculture and polyculture. All the species showed better growth in monoculture than in polyculture. Tilapia performed highest average growth, closely followed by common carp. Mrigal had the lowest growth rate. Similar results were found by Haroon et al. (1992), who conducted experiments with *P. gonionotus* and *O. niloticus* polyculture and monoculture. With a constant stocking rate of 7000/ha, the highest yield was observed from *P. gonionotus* monoculture (508 kg/ha).

Chowdhury et al. (2001) condncted an experiment on rich fish culture by stocking *A. mola* alone (T_1) and in combination with *B. gonionotus* (T_2) and *C. carpio* (T_3). He recorded total fish production 125.0 kg/ha, 175.21 kg/ha and 261.88 kg/ha, respectively in T_1, T_2 and T_3. Rice yield was increased by about 12.10% in T_1, 13.30% in T_2 and 16.33% in T_3 in context to T_4, rice alone culture. Uddin et al. (2001) obtained higher fish production (244.9 kg/ha) and income (Tk. 6,399/ha) by stocking *P. gonionotus* than that of *O. niloticus* (142.8 kg/ha and Tk. 2137/ha) in rice fish culture. They also obtained significant differences ($p<0.01$) in the yield of rice grain and straw between the treatments with fish and without fish.

Trials carried out by GOLDA project implemented by CARE in southwest region of Bangladesh found that yields of fish were 18% higher in rice-prawn plots compared with prawn only plots (Nabi et al., 1999). Overall, house incomes increased by 46-104%

following these interventions in southwest Bangladesh (Finan et al., 2001). The GOLDA project also promoted Integrated Pest Management (IPM) of rice and vegetable crops. Introduction of IPM in southwest Bangladesh significantly increased productivity by reducing the use of pesticides and chemicals as well as enabling farmers to select good rice varieties and controlling pests with non-chemical measures. Not only were the annual costs of cultivation using IPM much cheaper than conventional practices (14,964 Tk/ha compared to 20,490 Tk/ha), but rice yields were also higher, 5.4 ton/ha in IPM plots compared to 4.7 ton/ha in non-IPM plots (Sarker et al., 2000)

Enrichment of quality (nutrients) of rice and soil were found in a number of studies. The higher concentration and uptake of nutrients by grain and straw in rice fields with fish might be associated with the accumulation of fish feces and increased bioperturbation of the soil by fish movements which resulted in nutrients being more available for plant use and accumulation of fish excreta leading to higher organic load in the soil. For example, nutrients uptake by rice and straw in rice field culture system was reported by Uddin et al. (2000). They obtained significantly higher concentrations ($p<0.05$) of N, P, K, Na and Mg in rice grain and straw in treatments with fish than without fish. And such differences were also recorded in the amount of Ca and Fe between the treatments with and without fish in the case of straw only. Soil quality was also reported to have improved with the introduction of integrated farming system by Chowdhury (1999). While no significant differences in initial values of pH, organic matter, N, P and K were observed among the different treatments, there were significant differences in the final values (after harvest of rice and fish) of these nutrients between the treatments with fish and without fish in most of the cases.

A number of studies revealed the state of water quality in integrated rice-fish farming system. Das (2002) studied the water quality parameters in rice fields. The values of temperature, dissolved oxygen, p^H, nitrate-nitrogen, phosphate-phosphorous and chlorophyll-a that he recorded were found to range from 25.40-32.46^0 C, 3.29-4.53 mg/1, 6.57-8.45, 1.60-2.77 mg/1, 0.38-1.23 mg/1 and 26.21-33.31 µg/1, respectively. Uddin et al. (2001) reported that in rice fields, the water temperature, dissolved oxygen, pH and chlorophil-a concentration ranged from 21.9 to 33.60^0 C, 3.7 to 6.6 mg/1, 6.7 to 7.8 and

14.7 to 55.1 μg/1, respectively. Islam et al. (1998) studied the physico-chemical parameters of water in the rice fields and the values of water depth, temperature, dissolved oxygen, p^H, salinity, nitrate and phosphate were found to range from 14.4-14.6 cm, 29.3-29.5^0 C, 5.3-5.6 mg/1, 7.7-7.8, 0.83-0.90 ppm, 0.12-0.20 mg/1 and 1.0-1.0 mg/1, respectively. Witton et al. (1987) recorded a pH value range of 6.53-7.08 in deep water rice fields in Bangladesh. Rahman (1990) conducted an experiment on rich fish culture and the average pH recorded was 7.6.

2.3 Rice-fish culture practice abroad

India

An efficient rice-fish system adapted to rainfed conditions has been developed at the Central Rice Research Institute (CRRI) in India (Sinhababu and Das, 2004). During the monsoon season, when water is abundant, rice and fish are produced concurrently. During the dry season, when the rice fields run dry, the fish remain in a refuge pond, which retains water until the next flood season. After the rice harvest, the now dry fields can be used to grow vegetables under irrigation, using the water remaining in the refuge ponds. Shortly before the following monsoon season, rice is planted and fish are again allowed to enter the rice fields as water levels rise.

A good number of experiments were conducted by scientists to study a variety of aspects associated with integrated rice-fish farming, including production rate. The production of fish (common carp) was found to have ranged from 17.5-152.5 kg/ha with the mortality rate varying from 15-60% in the experiment by Muddan et al. (1970). Sinhababu et al. (1983) observed an increase in rice yield in the range of four to six percent in the presence of fish (common carp), while Panda et al. (1987) found significantly enhanced uptake of nitrogen by rice plants in the presence of native carp species. Baruah et al. (1999) conducted rice cum fish culture trial and found the yield of rice to increase by 15% as compared to rice grown in nearby areas. Fish culture in rice fields stimulates the activities of micro-organisms, increases availability of organic matters, have positive impact on mineralization as a consequence of lower P^H of water and increases the release of nutrients for better rice growth.

Victor et al. (1994) observed that composite culture of edible fishes (common carp, silver carp, grass carp, catla, rohu, and mrigal) in rice fields in the Cauvery delta of Tamil Nadu, India, resulted in 81% reduction in the immature mosquito population of anophelines and 83.5% of cultivines.

Spacing of rice plants was also found to have an impact on yields of rice and fish. Singh et al. (1980) conducted an experiment in which planting pattern of paddy was found to affect the growth and yield of rice and fish. Rice was grown in single rows 20 cm apart, paired triple or quadruple rows 10 cm apart with an interspaces of 30 cm. The authors recorded the highest yields, in triple rows 20 cm apart with interspaces of 30 cm.

Ghosh (1992) observed that physico-chemical condition in rice plot is favored for fish culture. In this experiments, water temperature ranged from 27.2^0 C to 29.0^0 C, p^H ranged from 7.1-8.0, dissolved oxygen ranged from 3.2-4.5 ppm andconductivity ranged from 229-489 µs/cm.

Indonesia

Rice-fish farming is believed to have been practiced in the Ciamis area of West Java, Indonesia, even before 1860 although its popularization apparently started only in the 1870s. By the 1950s some 50,000 ha of rice land were already producing fish. The development of irrigation systems also contributed to the expansion of the area used for rice-fish farming. Recent reports indicate that rice-fish farming is on the upswing. The 1995 figures from the Directorate General of Fisheries indicate a total area of over 138,000 ha (World Fish Center, 2004).

An empirical survey of 42 farms in Sumatra, Indonesia, conducted by Purba (1998) demonstrated that the average gross margin was $1,052 per year in rice fish farms, while it was merely $618 in farms growing only rice. Enhanced liquidity and efficient allocation of excess family labour were found to be additional advantages of the adoption of concurrent rice-fish culture. He concluded that the rice-fish system is a profitable technology and that its adoption is likely to increase farm household income, labor absorption, and liquidity.

Philippines

In the Philippines, fish are traditionally allowed to enter the rice fields with the irrigation water and are later harvested with the rice. In addition, it has been demonstrated that it is possible to achieve a three-fold increase in profitability of rice farming by culturing fish as well as rice (Fermin, 1992; Israel et al., 1994). Israel and Sevilleja (1994) found that rice-fish culture leads to a higher rice production compared to rice monoculture.

Apart from economic benefits, Horstkotte-Wesseler (1999) observed improved household food supply in rice-fish farms in the Philippines. A positive ecological side-effect is that the economic threshold level for pesticides application is shifted to a higher level (Waibel, 1992; Waibel *et al.*, 1993). In other words, less or no pesticides are applied if the potential income from fish and the potential loss of fish due to pesticide application are considered.

Sollows (1992) in his study stressed that having a satisfactory water situation in the field is a key factor in the technology. This can not be achieved if the plot preparation is poor. In field preparation, there are four main things to consider: (i) field size and shape, (ii) dikes (iii) refuge and (iv) drains.

Vietnam

A recent work in Vietnam has shown that community-based fish culture (CBFC) in flood - prone rice fields is technically feasible, economically profitable, environmentally non-destructive and socially acceptable (Dey and Prein, 2003, 2004). The results show that the adoption of CBFC in flooded rice fields increase water productivity per ha per year substantially; it can increase fish production by about 600 kg/ ha/ year in shallow flooded areas and up to 1.5 ton/ha/year in deeply flooded areas, without reduction in rice yield and wild fish catch. For the overall system, an additional income of US $135 per hectare in southern Vietnam was achieved, which is an increase of 20-85% over the previous profitability.

A survey of 76 farms in the Mekong Delta of Vietnam (Rothuis et al., 1998a) showed a 16% lower rice yield and a 20% lower overall net return in farms that allocated part of their area to rice-fish culture. Mai et al. (1992) reported that from three farms in the Mekong Delta, the net returns from the rice fields with unfed shrimps was 52% higher than that of rice monoculture and 176% higher in the rice fields where shrimps were fed with rice bran and decomposing animals.

Long et al. (2002) conducted an experiment on integrated rice fish polyculture system at two stocking densities (1 and 2 fish/m^2). The water quality such as temperature (29.1-29.0^0 C), pH (6.6-6.7), transparency (18.0-20.8 cm) and dissolved O_2 (4.6-4.7 ppm) were similar at both densities and acceptable for the 6 tropical fish species. The fish yield (808 kg/ha) with 2 fish/m^2 stocking density was higher than that obtained with 1 fish/m^2 stocking density (482 kg/ha). The benefit cost ratio (1.84) for farm households at 1 fish/m^2 were lower than that at 2 fish/m^2 (2.1).

Fish polycnlture appeared to stimulate increased yields of fish, due to the complementary utilization of trophic niches in the rice field. A successful combination is, for instance, Nile tilapia, a micro-herbivorous column feeder, coupled with common carp, an omnivorous bottom feeder (Frei and Becker, 2005). Rothuis et al. (1998b) also found the highest fish yield (474.1 kg/ha) in a polycnlture including silver barb, nile tilapia and common carp. The 'polyculture effect' may be somewhat attenuated when natural feed is scarce and no supplementary feed is provided. This was demonstrated by Chapman and Fernando (1994), who found that the diets of nile tilapia and common carp in rice fields were largely similar. Vromant et al. (2002b) similarly reported competition over feed between common carp and silver barb in a field experiment in Vietnam.

A socio-economic study covering aronnd 120 farms in Vietnam (Berg, 2002) found that farmers who attained increased income through rice- fish farming also had a high level of education. In farms combining rice-fish production and integrated pest management, the average net income was roughly 20% higher than in rice monoculture farms.

China

In China the rice-fish system today is practiced over almost 4% of total rice cultivating area, and this proportion has been on the increase since the 1980s. Chinese fish production in rice fields was estimated at 377,000 tons in 1996 (Halwart, 1998) and rose to 849,055 tons in 2001 (Xiuzhen, 2003). Growing fish was almost three times more profitable than rice alone (Yan et al., 1995). Lin et al. (1995) related the economic benefits of rice-fish farming to an increase in rice yields and savings in labor and material inputs. Rice yields in rice–fish culture were 8% higher, labor inputs were 19% lower, and material costs were 7% lower (savings in the cost of controlling diseases and pests). Additionally, fish production increased the net income.

Thailand

Thailand, in contrast to previously mentioned countries, showed lower net returns in the rice fish fields than in the rice-only fields. The Thai figures indicate that profitability in the rice-fish in rice fields was only 80% that of rice monoculture. Thongpan et al. (1992) attributed this to the high initial investment in rice-fish culture.

However, rice-fish farming did not completely vanish and in recent years it has recovered, particularly in the Central Plains, North and Northeast Regions (Little et al., 1996). The high expectations of farming communities is thought to be a major constraint to the wider adoption of rice-fish systems where off-farm employment was the norm as the major means of livelihood until the economic crisis in mid-1997. The increasing frequency of directly broadcasting rice seeds and using machines for field preparation are signs of the growing labor shortage. The shortage may favor the development of more easily managed pond culture rather than the more laborious rice-fish system.

Malaysia

Ali (1990) conducted a study in Kerian, North Perak in Malaysia for three growing seasons September 1985 to January. He studied water quality parameters affecting fertility and productivity of rich fish farming system. Parameters were studied in both sump (ditch) ponds and rice field. Dissolved oxygen were higher 5.5±0.3 mg/l in the more exposed rice field than in the sump ponds (1.70± 0.2 mg/l) and both environment had slightly acidic p^H (6.3±0.2 and 6.0± 0.2 respectively).

2.4 Discussion

The literature review revealed comparison of yield and productivity between rice monoculture and integrated system, comparison of concurrent systems with rotational systems, and comparison of fish monoculture (i.e. single fish stocking) with fish polyculture (more than one type fish stocking). The review also revealed the status of environment (e.g. pest control, weed control, soil quality and water quality parameters) associated with integrated rice-fish farming system.

Most of the studies showed increase in rice yield and productivity with integrated systems. Majority of the studies showed positive results with multiple fish stocking, while a few showed better results with single fish stocking. Reviews of a number of studies also emphasized the need for proper institutional structure to sustain the system and to ensure equitable distribution of benefits of the system.

Chapter 3
METHODOLOGY

3.1 Introduction

The study followed an interdisciplinary approach; it addressed different aspects of the integrated rice-fish farming system, including technical (physical suitability), socio-economic, institutional and environmental aspects in an integrated way. The study was techno-social in nature, as it involved some technical assessments of the physical system together with application of participatory tools (PRA) to address some fairly diverse aspects. This chapter provides a description of the methodology used in the study, which includes selection of criteria and/or indicators for evaluating the existing system of integrated rice-fish farming and its future potential, collection of both primary and secondary data, and primary soil sampling for quality analysis.

3.2 Selection of the study area

To show the potential for integrated rice-fish cultivation in seasonally inundated deep water rice field, a small water management project, namely, Balajtala-kalmadanga subproject in Gopalgonj district of the southwest region was chosen as the study area. This area falls within the South-West Area Integrated Water Resources Plan Project (SWAIWRP) of Bangladesh Water Development Board (BWDB) and Local Government Engineering Department (LGED) (ADB, BWDB and WARPO, 2004), which is the study area selected for the Crossing Boundaries (CB) project of IWFM, BUET. The districts of Narail, Gopalgonj and Faridpur of SWAIWRP primarily constitute the study area of the CB project.

Recently the local people in Balajtala-Kalmadanga subproject have started an integrated rice-fish farming practice in inundated floodplains through a community initiative. In floodplain ecosystem of this project, opportunity exists to fence a larger area (i.e. enclosed by natural elevated lands, raised homesteads, embankment and dams for roads etc) by creating enclosed water bodies and stocking these with fish, and community groups can play a significant role in jointly deciding on management and share of benefits based on agreed rule.

3.3 Indicators for evaluating integrated system

As stated in chapter one, the objective of the study was to assess the physical system (i.e. whether the physical system is conducive to such practice), analyze favorable institutional arrangement, and socio-economic and environmental impact of the system. A number of criteria or indicators were selected for analyzing the above mentioned aspects, as presented in Table 3.1.

Table 3.1 Impact indicators/criteria for integrated rice-fish farming system

Type of impact		Criteria/ Indicators
Physical suitability		• Water retention and drainage system • Seasonal availability of water
Socio-economic	Efficiencies	• Crop yield (t/ha) • Fish yield (t/ha) • Total production (tons) • Benefit-cost ratio (BCR)
	Social acceptability	• Resource endowment
Environmental		• Soil quality • Pest management • Weed control • Water quality • Risk to indigenous species • Biodiversity
Institutional		• Institutional structure • Distribution of shares and benefits

Physical suitability were assessed in the context of water conveyance, retention and drainage systems, functions of water control structures, and seasonal availability of water in the tidal environment. Socio-economic assessment was based on analyzing the efficiency (yield, production) and social acceptability of the system. The institutional arrangement was analyzed in the context of water management decision making in the rice-fish culture system, and distribution of shares and benefits. Environmental impacts were assessed in the context of soil quality, pest management, weed control, risk to indigenous capture fisheries and water quality. Conduciveness of the system to integrated rice-fish culture was analyzed by sampling soils (following standard protocols) in the field at different times (before and after rice-fish cultivation) and analyzing them for different parameters, e.g. soil type, pH, organic carbon, organic matter, total nitrogen, phosphorous etc. Other environmental parameters, e.g. water quality was analyzed qualitatively from people's perceptions.

3.4 Data collection

3.4.1 Primary data collection

Primary data collection was done mainly through the application of Participatory Rural Appraisal (PRA) tools and technique. Participatory Rural Appraisal is an intensive, systematic but semi-structured learning experiences carried out in a community by a multi-disciplinary team, which includes community members. The PRA has different types of tools such as resource mapping, social mapping, focus group discussion (FGD); key informants, transect walk, timeline and seasonality. The PRA is relatively a new method, fast becoming a very popular one because of its participatory, rapid, flexible, iterative, cost-effective and interdisciplinary nature. PRA tools are extensively used in socio-economic survey studies. Their application in bio- resource assessment is emerging in recent times. One example is the study by Metillo et al. (2004) who used PRA approach to address the crucial global issue of environmental degradation and loss of biodiversity in Mindanao, Philippines.

The primary data collections were conducted during the period from September 2007 to April 2008. Use of PRA tools in the study included Focus Group Discussion (FGD) and key informants' interview. Besides, a number of semi-structured interviews were also conducted. The focus groups comprised of members of the Water Management Co-operative association (WMCA), fishermen, agricultural farmers with land and landless, and women. In total, five FGDs were conducted with the personnel of WMCA (12 persons), fishermen (12 persons), agricultural farmers with land (10 persons), landless agricultural farmers (10 persons) and women (10 persons). A semi-structured questionnaire was prepared to collect the primary data like fish and rice yield data from within the members of the focus group, and the person who took lease of the inundated rice field for fish culture. Photographs of FGD and samples of questionnaires are attached in Appendix-A and B

The primary data included:

- Fish production: data on weight, size and number of stocked fingerlings and harvested fish according to fish types in rice field, cost and return, were collected from personnel of WMCA and the person who took lease of the flooded rice field for fish culture.
- Rice production: data on cropping pattern, cultivation system, rice yields, and plant height during growing stages were collected through FGD with farmers.
- Water management: Data on water depths and rice plant heights on the different land types during monsoon season.
- Institutional arrangement: Data on structure and activity of the WMCA, levels of stake holder involvement and beneficiaries group in the community based integrated rice-fish cultivation were collected through FGD with personnel of WMCA, fishermen, agricultural farmers with land and land less, and women.
- Environmental parameter: Data on environment including soil quality, weed control, pest control, effect of pesticide, any loss of capture fisheries and biodiversity, degradation of water quality and public health were collected through field observations and FGD with different groups.

3.4.2 Soil quality

Soil qualities were analyzed by direct sampling of soil in the study area. Soil samples were collected from 0.5 ha of land within study area. Soil samples were also collected from 0.25 ha of land of another nearby project area (Kaikubunia-Chinguri subproject), where only rice cultivation is practiced. This area would serve as a control area in that the comparison between the soil qualities in the study area and the control area would help isolate the effect of integrating fish with rice cultivation.

Soil samples were collected in two installments: after rice-fish harvest in the month of December and before broadcasting of rice seeds in the month of April. It is noted here that soil sampling should have ideally followed the reverse sequence, i.e., the first sampling after the harvest of Boro and before broadcasting of rice seeds followed by the second sampling after the rice-fish harvest. This could not be done because of time constraint. However, the reverse sequence of soil sampling and analysis is not expected to cause any significant deviation in the interpretation of the results, as the temporal changes in soil properties likely to repeat a similar pattern with the existing farming system.

Collection and preparation and of soil samples

Soil samples were collected at a depth of 0-15 cm from the surface. A number of 50 soil samples were collected from 10 different locations (5 samples in each) of the study area. Composite samples were prepared from each location. Similarly, a number of 25 soil samples were collected from 5 different locations (5 samples in each) in the control site, and composite samples were subsequently prepared following the same procedure.

After removing weeds, plant roots, stubbles etc, all the samples were air dried and ground to pass through a 2 mm mesh size sieve. These ground samples were stored in a clean plastic container for subsequent chemical analysis.

Chemical analysis of soil

The soil samples were analyzed in BRAC Soil Analytical Lab, Joydebpur to determine pH, organic matter, organic carbon, total nitrogen, available phosphorus, available potassium, and sulpher, following the methods recommended by SRDI (2005).

3.4.3 Secondary data collection

Secondary data on the location and area of the study area, household size, number and occupation, distribution of farmers' categories, hydro-meteorology (such as river water level, rainfall etc.) land types, water conveyance and drainage system, and agricultural and fisheries practices were collected from the appraisal reports of the project (LGED, 2004a,b), but were cross checked during field survey and FGD. Other important secondary information were also collected from different published and unpublished reports from the LGED, BWDB, FRI, BBS, BUET, BRRI, BARI, BAU, SRDI and other government non-government organizations.

There is no water gauge station within and around the sub-project. The water level data from 1981 to 2002 were collected of the river Gorai-Madhumati at station SW105 (off take at Athrabanka) and SW 107A (Nazirpur). Water level at the project was estimated from interpolation of the water levels at the two available stations using the water surface slope. Rainfall data of 1980 to 2002 were collected from nearby station at Mollahat (station 511). The hydro-meteorological stations are shown in Fig. 3.1.

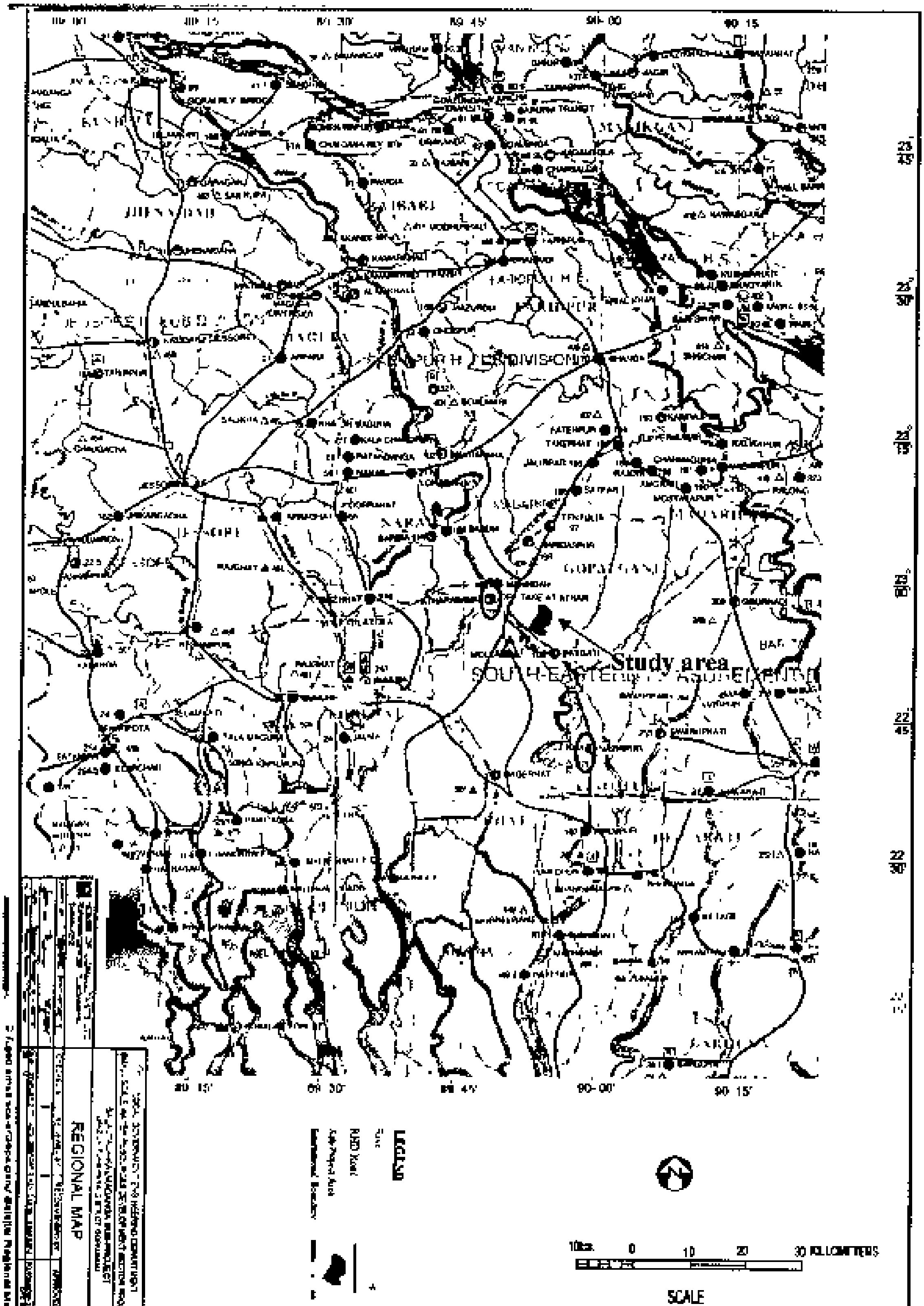

Fig. 3.1 Location of relevant hydrometric stations

Chapter Four

OVERVIEW OF STUDY AREA

4.1 Introduction

The study area named Balajtala-Kalmadanga subject is a Flood Management, Drainage and Water Conservation (FMDWC) subproject of the ADB-funded LGED Second Small-Scale Water Resources Development Sector Project-2 (SSWRDSP-2) (LGED, 2004a). The early flooding, drainage congestion at the end of monsoon and shortage of irrigation water in dry season are the predominant features of the subproject area. Local people used to construct earthen cross-dams at different locations of khals (namely Swanirvar khal, Hazir khal and Balajtala khal) to conserve water for irrigation of Boro crop and to protect young B. Aman (and HYV Boro occasionally) from early flood. People could not continue the practice due to fund constraint. As such local people demanded construction of two regulators over Swanirvar khal and Balajtala khal along with re-sectioning of the embankment that crosses these khals in order to protect young B. Aman from early flood. Local people also demanded construction of one water retention structure over Hazir khal to conserve water by allowing tidal flow for irrigation of Boro.

The feasibility study of the project observed that while agricultural production will be increased with the implementation of the project, there may be some adverse impact on natural fish production. The embankment (re-sectioning) and the regulators will obstruct the ways of natural movement of fishes, thus reducing the natural fish; but at the same time culture-based fisheries will be increased if it is organized by the Water Management Co-operative Association (WMCA). WMCA is fonned with villagers to participate in or to maintain the subproject. The project is meant for partial flood management (i.e. to protect B. Aman from early floods); during the peak monsoon, the whole subproject area will be under water that can be a suitable place for fish culture, as envisioned in the feasibility study. The expected impacts of the subproject are summarized below (LGED, 2004a):

(i) Improvement of irrigation.

(ii) Control of monsoon flood.

(iii) Increase of cropping intensity (double to triple)

(iv) Increase of cultivable land.

(v) Improvement of communication facility.

(vi) Improvement of facilities for women so that they can do their household works easily.

(vii) Enhancement of fish production if planned fish culture is done.

(viii) Create green environment.

4.2 Physical environment

The study area named Balajtala-Kalmadanga subproject is located on the west bank of the Singair river in Barni Union of Tungipara upazila under Gopalgonj district in between latitudes 22^0 54' 30" N and 22^0 56' 26" N and the longitudes 89^0 51' 38" E and 89^0 52' 48" E. It is situated at about 4 km north-west of Tungipara upazila Head Quarter and spread over Gimadanga and Uttara Basuria mojuas of Barnai union. Detail map of the study area showing subproject boundaries, structural works, hydrologic network and relevant hydrometric stations are provided in Figs. 4.1-4.2.

The sub-project is bounded by rural road and embankment (fixed at 4.10 mPWD and length 2.34 km) on the north and north-east along the Singair river and Hazir Khal respectively, and south-east by Hazir Khal and east by the Gimadaga khal. On the south the study area is bounded by Gopalgang-Patgati-Pirojpur Regional Highway. The western side of the study area is bounded by metal road that connects the Gopalganj-Patgati Highway on the south.

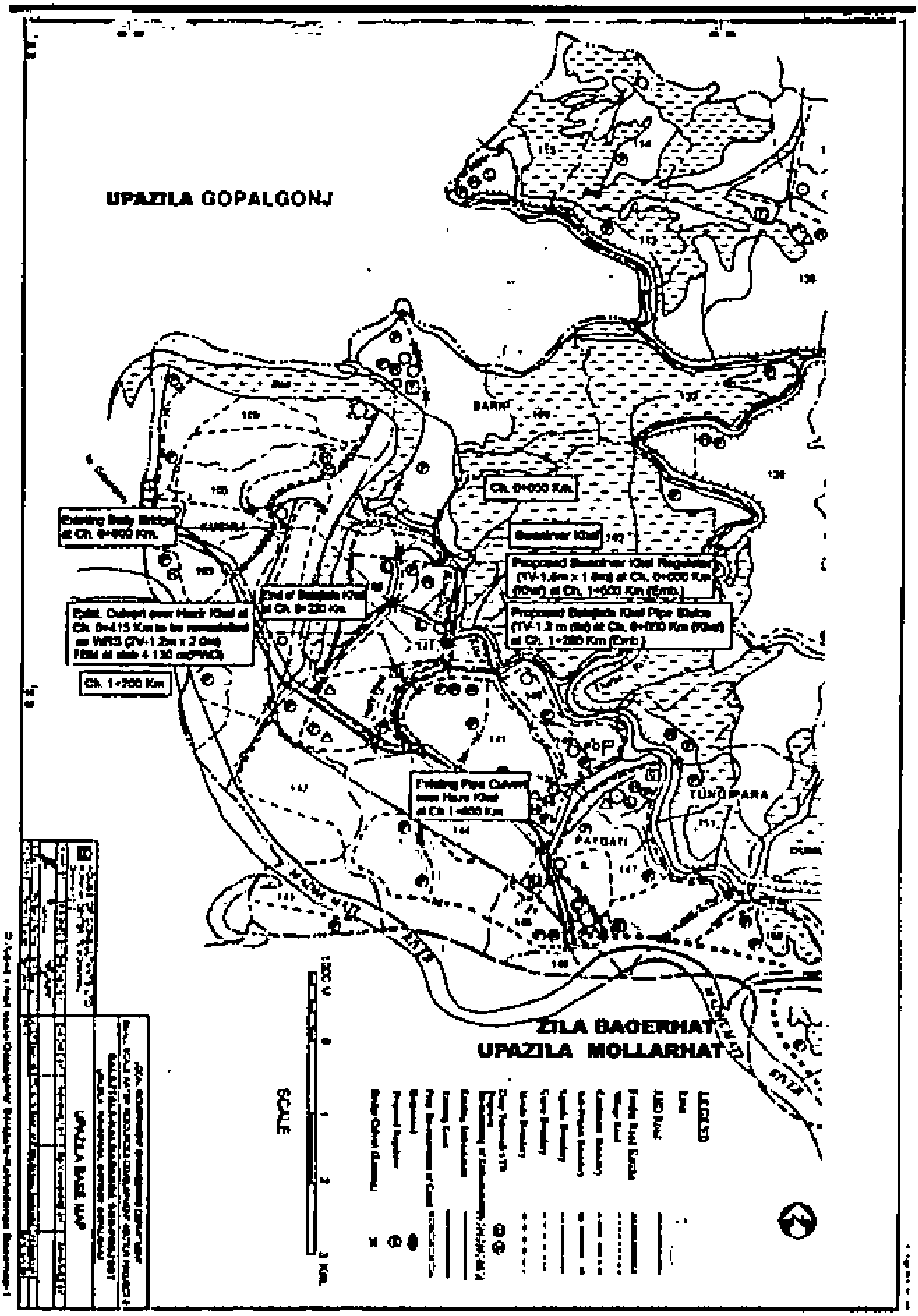

Fig. 4.1 Study area with access roads and main hydrologic network.

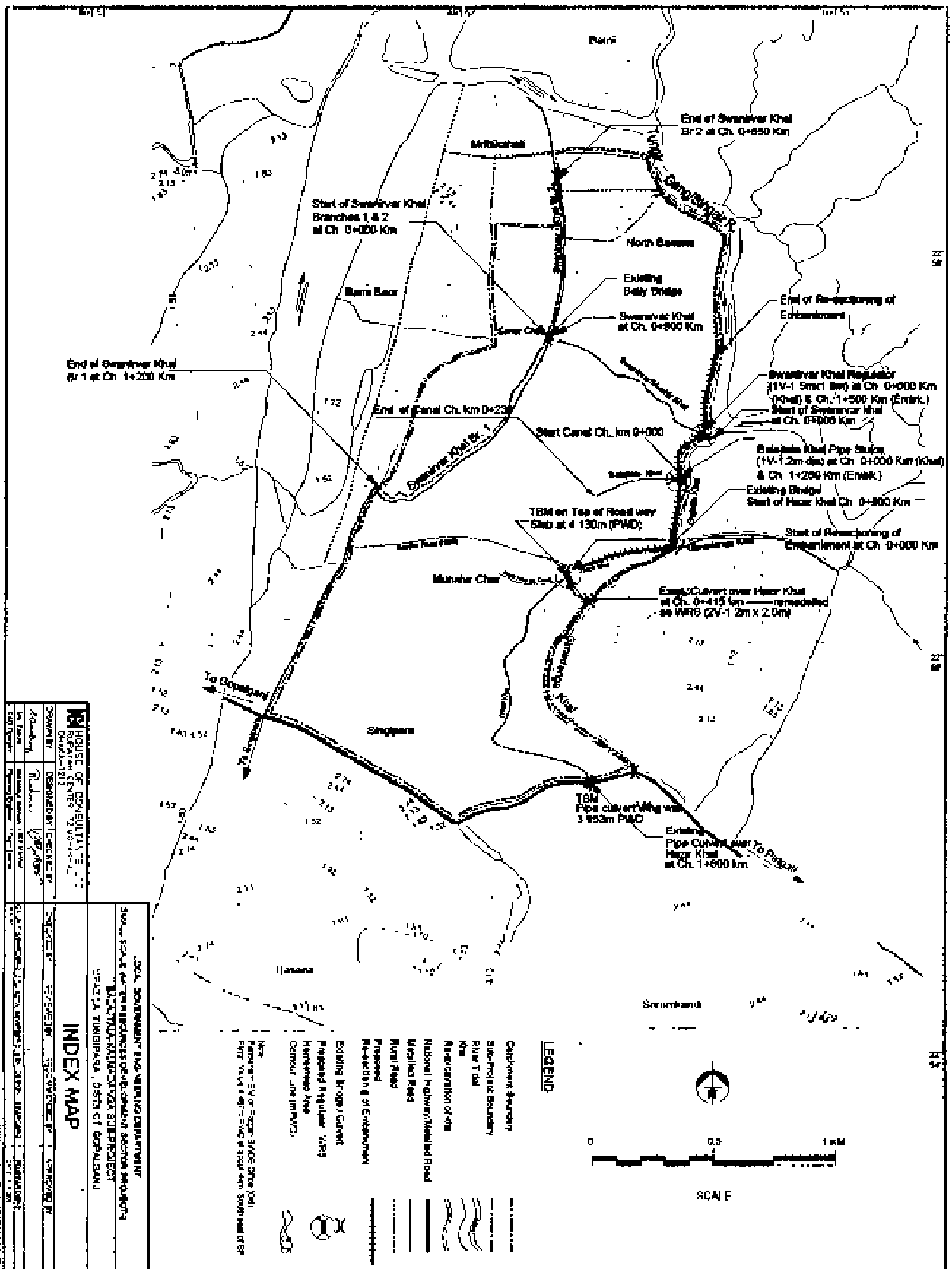

Fig. 4.2 Detailed map of study area (sub-project)

4.3 Water retention and drainage systems

There is one main khal namely Swanirvar khal within the study area, which originates in two branches from Barni Baor located at the west side of the study area and passes through the study area, finally falling into the Singair river to the east of the Subproject. There are two other khals, namely Hazir khal and Balajtala khal within the Subproject, which are connected to the Gagalia khal, which finally falls into Singair river. The branch of Hazir Khal, along the south side of Sardar road is almost blocked and silted upto the existing bridge near the Gimadanga khal. Local people use water from this khal for irrigation of boro/rabi crops, and also in Kharif-I season. The beneficiaries irrigate mainly local and HYV boro and B. Aus by lifting water from Singair river and the khals within the study area by low lift pump (LLP) during high tide.

The tidal water from Singair River on the east of study area enters into study area through Swanirver khal and Balajtala khal. Tidal water from the Singair River also enters into the subproject through Gimadanga khal and Gazalia khal on the east of study area, which are connected to the Hazir Khal. The main problem in the area, thus, is early floods from the Singair River, which damages mainly young B. Aman, standing vegetables and matured boro crops occasionally. Drainage congestion at the end of monsoon also occurs.

Water management in the project area has so far been managed by constructing earthen cross dams in the three khals as and when necessary. Regulators have recently been completed in the three canals, which will hopefully eliminate the need for yearly construction of rather costly earthen dams. Construction of regulator on Swanirvar khal will protect cropping land from pre-monsoon flood that causes damage to tender Aman on the norther part of the subproject (Basurea & Senerchar Village). Construction of pipe sluice on Balajitala khal will protect tender B.Aman from pre-monsoon flood. These help proper drainage of rainfall-runoff as and when needed. Construction of water retention structure over Hazir khal by remodelling of existing culvert will protect B.Aman and Aus from monsoon flood. These structures will also conserve water in the khals during boro season to supply irrigation water to fields by gravity flow or LLPs. The banks of these re-excavated khals are raised by spoil earth to protect the land from damage at normal flood and high tide. Details of the khals are summarized in Table 4.1

Table 4.1 Description of khals in the study area

<table>
<tr><th colspan="2">Name of khal</th><th>Length, Km</th><th>Catchment's area, ha</th><th>Drainage rate, mm/day</th><th>Discharge, cumec</th></tr>
<tr><td colspan="2">Balajtala khal</td><td>0.25</td><td>75</td><td>121</td><td>2.09</td></tr>
<tr><td colspan="2">Hazir khal</td><td>2.00</td><td>184</td><td>121</td><td>5.13</td></tr>
<tr><td rowspan="3">Swanirvar khal</td><td>Main</td><td>0.90</td><td rowspan="3">201</td><td rowspan="3">121</td><td rowspan="3">5.61</td></tr>
<tr><td>Branch 1</td><td>0.65</td></tr>
<tr><td>Branch 2</td><td>1.20</td></tr>
</table>

Source: LGED (2004b)

4.4 Settlement

The settlements of the study area are described in Tables 4.2 and 4.3. Total population of the subproject is 7110 of which household number and size are 1165 and six, respectively. Out of the total population, the landless farmers are about 37.43% followed by marginal farmers (25.13%), small farmers (21%), medium farmers (11.84%) and large farmers (4.60%).

Table 4.2: Inventory of study area

Sl. No.	Name of village inside sub-project	No. of Household	Population	Household Size
1	Munshir char	225	1350	6.0
2	Shingi para	250	1700	6.8
3	Uttar bashuria	250	1500	6.0
4	Ghimadanga	170	940	5.5
5	Gajali	200	1200	6.0
6	Mittika Bari	70	420	6.0
	Total	1165	7110	6.0
	Outside village			
1	Mittika bari	95	570	6
2	Shriram kandi	80	480	6
	Total	175	1050	6

Source: LGED (2004b)

The survey data shows that about 61.25% arable lands are operated by the landless, small and marginal farmers. About 11% farmers lease full and 19.4% some of their lands from the large and medium farmers for their livelihood.

Table 4.3: Distribution of farmer's category (According to farmers)

Farmer Categories	Number	%
Landless <0-0.2 ha	335	37.43
Marginal 0.21-0.61 ha	225	25.13
Small 0.62-1.0 ha	188	21.00
Medium 1.01-2.0 ha	106	11.84
Large> 2.01	41	4.60
Total:	895	100

Source: LGED (2004b)

The survey (Table 4.4) shows that agriculture is the main sources of income of the household. About 34% depend on agriculture, followed by agriculture labour 25.9%. Traditional fisher and others are 2.90% and 37.2%, respectively.

Table 4.4: Primary occupation of the households (according to farmers)

Type of occupation	Numbers	%
Agricultural farming	305	34
Daily paid agri. labour	232	25.9
Traditional fishermen	26	2.9
Other occupations	332	37.2
Total	895	100

Source: LGED (2004b)

4.5 Land and soil

Land types and soil types within the study area are described in Table 4.5. The study area is divided into highland, medium high land, medium low land and lowland. Medium high land and medium low land occupy major portion of the study area. Non-cultivated high land, high land, medium high land, medium low land and low land occupy 8.26%, 6.25%, 27.9%, 48.44% and, 8.48% of total area respectively in the project area. Non-cultivated lowland and permanent water bodies constitute a very small percentage (0.67%) of the total area. Gross area is 488 ha of which net benefited area is 355 ha. Soil texture of these lands varies from silty clay loam to silty clay. Average elevation of the area varies from 2.40 m PWD to 0.91 mPWD.

Table 4.5: Land and soil types in the study area

Land types	Nature of flooding	Covered area (ha)	Soil yype	Elevation, mPWD (average)
Non-cultivated highland	Not flooded	37	Sandy Loam	
F0 (d<0.3 m) Highland	Intermittent	28		2.40
F1 (0.3<d<0.9 m) Medium high land	Seasonal	125	Clay Loam	1.98
F2 (0.9<d<1.8 m) Medium low land	Seasonal	217		1.52
F3 (d>1.8 m) Lowland	Seasonal<9months	38	Silty Clay	0.91
Non-cultivated lowland andpermanent water bodies	Perennial	3		< 0.91
Net benefited area		408		
Gross Area		448		

Source: LGED (2004b)

4.6 Topography

The land elevation varies from 0.91 m PWD to 2.96 m PWD within the study area. Details of topography are described in Table 4.3. A topographic map is provided in Fig. 4.4.

Table 4.6 Area –elevation in the study area.

Elevation mPWD	Area (ha)	Cum. Area (ha)	Cum. Storage volume (ha-m)
0.91	41.48	41.48	0.00
1.22	62.22	103.70	43.56
1.52	70.52	174.22	126.93
1.83	87.11	261.33	257.60
2.13	45.63	306.96	428.09
2.44	78.82	385.78	635.91
2.74	49.78	435.56	882.31
2.96	12.44	448.00	1147.38

Source: LGED (2004b)

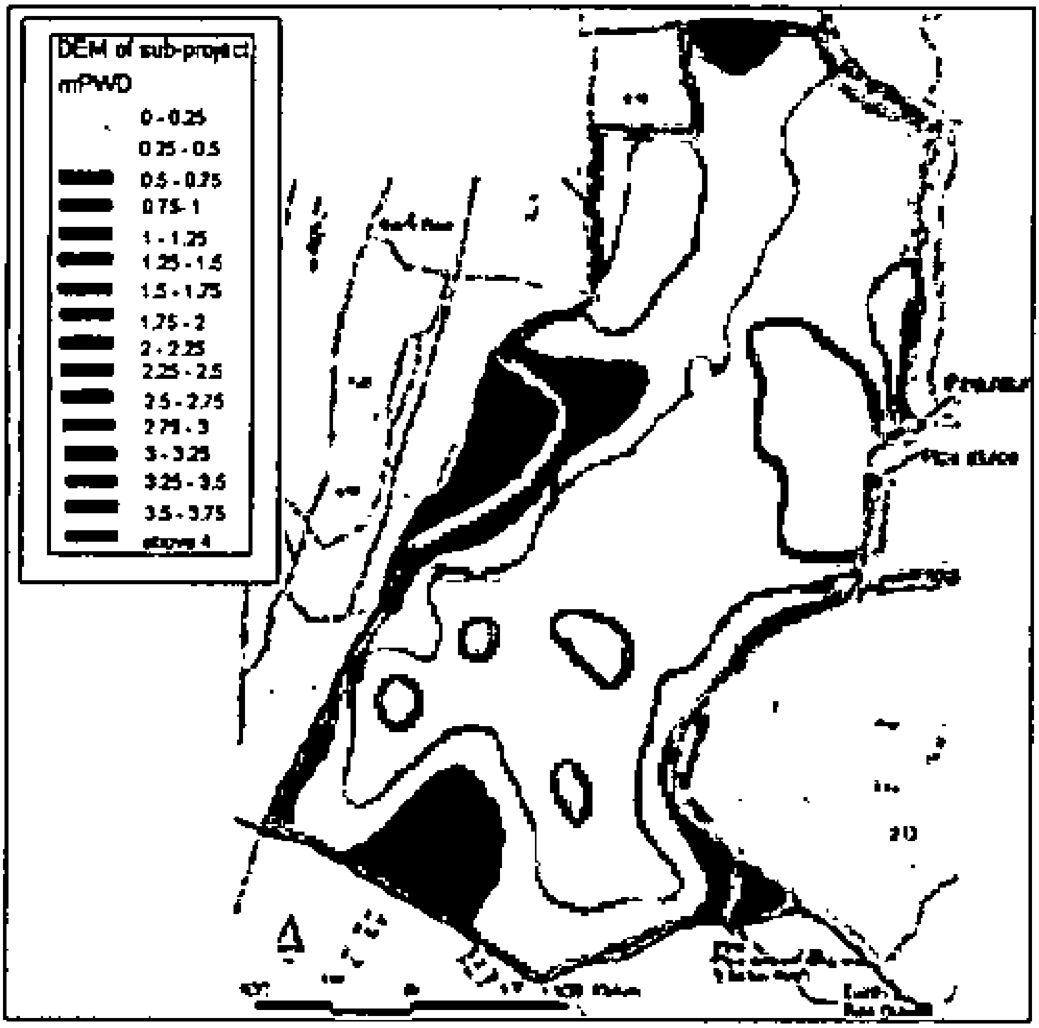

Fig. 4.3 Topography of the study area

4.7 Cropping pattern

Different crops cultivated under Kharif-I, Kharif-II, and Rabi seasons are summarized in Table 4.7. Cropping intensity is 150%. Most of the lands are single cropped and some are double cropped. The major crops of the area are rice (B. Aus, B. Aman, T. Aman and Boro), rabi crops and vegetables. There are huge lands in the area that remain fallow due to flood and drought.

Table 4.7 Existing cropping pattern

Name of cultivated crops			Percent of total cultivated area in each land types			
Kharif-I (March/April-June)	Kharif-II (July-October)	Rabi (Nov.- March)	F0 (28 ha)	F1 (125ha)	F2 (217 ha)	F3 (38 ha)
Jute	Fallow	Wheat	20			
Jute	T.Aman (HYV)	Mustard	20			
B.Aus	T.Aman (HYV)	Pulses, Vegetables	40			
Fallow	T.Aman (HYV)	Pulses, Vegetables	20			
B.Aus (LV)	+ B.Aman (LV)	Boro (HYV)		30		
B.Aus (LV)	+ B.Aman (LV)	Fallow		50*		
Fallow	Fallow	Fallow		20**		
Fallow	Fallow	Boro (HYV)			90***	
Fallow	Fallow	Fallow			10****	
Fallow	Fallow	Boro (HYV)				100*****
Total			100	100	100	100

Source, LGED (2004b)

*Fallow land in Rabi season will be brought under Boro (HYV) cultivation in post-project condition

** Fallow land in Kharif-I and Kharif-II seasons will be brought under cultivation with B Aus and B.Aman in post project condition

***Fallow lands will be brought under cultivation in Kharif season in post-project condition having cropping pattern of B Aman-Boro(HYV)

**** fallow lands will be brought under cultivation in Boro season in post-project condition

*****80% of land will be brought under B.Aman cultivation in Kharif season in post-project condition

All lands under F0 category are under cultivation; however the cropping pattern is not the same everywhere. Major part of the area (40%) has a cropping pattern of B.Aus-T-Aman-Pulses/Vegetables. In 80% of the F0 land, T.Aman is cultivated in the Khariff-II season. About 80% of F1 land is under cultivation, while 20% remains fallow. A combination of local variety B.Aus and B. Aman is broadcast, with the B.Aus being harvested at the end of Kharif-I season. Most of the land (50%) remains fallow during the rabi season, while 30% of land is Boro cultivated. All the lands under F2 category remain fallow, except Boro cultivation in 90% of land in the Boro season. All the lands under F3 category are Boro cultivated.

As indicated in Table 4.7, the implementation of the project by LGED aims at increasing the agricultural production to almost its maximum potential, by bringing most of the lands under cultivation in different growing seasons. Only 20% of F0 land, 10% of F2 land and 20% of F3 land will remain fallow in Kharif seasons as per the project objective.

4.8 Natural capture fisheries

Natural fish migration process from river to khal or rice field are partially hampered by construction of earthen cross dams in khals during the flood season. Total natural captures fisheries production in 2004 were 15 tons from the rice field. Details are summarized in Table 4.8.

Table 4.8 Natural fisheries production from different types of water body.

Type of water body	Fish species (local name)	Production, ton (2004)
Seasonal flood land	Rui, Katla, Mrigel, Koi, Shing, Magur, Shol, Boal, Taki, Puti, Mola	17.75
Perennial water body		0.66

Source: LGED (2004a)

Chapter Five

RESULTS AND DISCUSSION

5.1 Introduction

Data and information gathered from the application of participatory tools and secondary sources are summarized to elucidate the existing integrated rice-fish cultivation system, including rice cultivation, and fish stocks and fishing pattern, water management practiced by the farmers and existing institutional arrangement. This is followed by the evaluation of the system for physical suitability, socio-economic impact, environmental impact and institutional arrangement. Along with the evaluation of the system that exists now, the future potential of the system is also analyzed, and some future water management practices are suggested.

5.2 Integrated cultivation system in Balajtala-Kalmadanga subproject

5.2.1 Rice cultivation system

Existing system

Local deep water B. Aman (such as Jabra, Kalamona, Digha) which has fast elongation ability and submergence tolerance to 1-2 weeks with floating capacity, and local B. Aus varieties (such as Nunsaratul, Gararshor) which has moderate elongation ability with gradual increasing depth of water up to certain plant height (i.e. about 100 cm) are broadcast together in equal ratio at a rate of 100 kg/ha in moist or saturated soil usually in the 2nd week of April in medium high land. In 1st and 2nd week of May, only local Aus is broadcast in high land. After establishment of seedlings the flood water or rainfall storage in the field are allowed by the construction of (temporary) earthen cross dams on the three khals. Only urea fertilizer is used, and it was applied at a rate of 120 kg/ha in the field before stocking of fish fingerlings. No pesticides were applied in rice field. Also no pesticides were applied in rice field during the previous years.

B. Aus rice (only panicles) is normally harvested during 3rd and 4th week of August. After harvesting of B. Aus, T. Aman (HYV) such as BR33 or BR11 is transplanted in high land and B. Aman remains in medium high land. Flood water is again allowed in the field and stored up to end of November. As the deep water B. Aman has fast elongation ability, it can tolerate greater depths of water, which is essentially needed for fish cultivation. Draining of water from the field is allowed to the last week of November up to the top level of khals. Aman is harvested at the month of December when most of the water came in khals. Rice cultivation practices during monsoon are summarized in Table 5.1.

Table 5.1 Existing rice cultivation during monsoon season.

Rice varieties	Sowing/Transplanting	Harvesting	Land Covered (ha)				Yield, Kg/ha
			F0	F1	F2	F3	
B. Aus (LV)	1st -2nd week, May	2nd -3rd Week, August	11				2400
T. Aman (HYV)	3rd -4th Week, August	1st -2nd week, December	22				4000
B.Aus(LV) + B.Aman (LV, DW)	2nd -3rd week, April	Aus: 2nd -3rd Week, August Aman: 1st -2nd week, December		100	-	-	*2050

* 900 Kg/0.5 ha (B. Aus) + 1150 Kg/0.5 ha (B. Aman) = 2050 kg/ha

Suitability of the system

(i) Varietals selection:

Rice, the only crop grown in low lying areas during wet season, often suffers due to water logging or flooding in rainfed lowland and flood prone area. It is established in previous literatures that the extent of damage generally depends upon varieties grown and the stages at which the plants are subjected to different depths and duration of submergence (e.g. Alim et al., 1982; Palada, 1970; Chowdhury and Zaman, 1970; Ghosh, 1979 Reddy, 1982). In order to overcome the losses and to get significant return, varietals selection is an important issue. A plant type for these ecosystems should possess good seedling vigor, submergence tolerance, kneeing and elongation ability, and photoperiod sensitivity should assure flowering when plants are least vulnerable to submergence. In this context, the types of rice varieties selected in the project area are suitable. As the deep water Aman has fast elongation ability, it can tolerate greater depth of water which is essentially needed for fish cultivation.

(ii) Planting: Unlike some other floodplain ecosystem where transplanted varieties are used, in the Balajtala-Kolmadanga sub-project, local Aman and Aus are broadcast together in moist or saturated soil and after establishment of seedlings the flood water or rainfall storage in the field is allowed. This has been possible by the farmers so far by controlling the water environment through the construction of earthen dams in the three khals. This will be better achieved after the full implementation of the project with all regulators and water retention structures in place.

(iii) Fertilization: As mentioned earlier, only urea fertilizer was sprayed in the field at a rate of 120kg/ha in the early vegetative stage of rice. However, the efficiency of chemical fertilizer in general and nitrogen in particular is very poor in water logged, low land situation because they are subjected to various types of losses (because of high volatilizing rate and washout). Such losses in the project area can be minimized by application of N fertilizer through deeper placement of modified urea materials like Urea Super Granules, Sulphur Coated Urea, Lac Coated Urea, and Neem Coated Urea, etc.

5.2.2 Fish cultivation system

Existing practice

(i) Fish species: Fish species like thai sarputi (*Puntius gonionotus*), rohu (*Labeo rohita*), catla (*Catla catla*), common carp/mirror carp (*Cyprinus carpio*) were selected for stocking by the farmers. Other species being considered by farmers were silver barb (*Barbodes gonionotus*) , grass carp (*Ctenopharyngodon idella*), and mrigal (*Cirrhina mrigala*).

(ii) Fingerling supply and stocking

Fingerlings were collected from hatcheries in Jessore district. After the flood water entered into the rice field, fish fingerlings of thai sarputi, rohu, catla, and common carp were preliminary stocked in the khals during the 4^{th} week of June, and later on reared in the inundated rice field up to December. Details of stocking fingerlings are summarized in Table 5.2

Table 5.2 Existing fish cultivation practices in rice field during monsoon season.

Fish species	Fingerlings stocking time	Fingerling stocking size(ave.), gm	Fingerling stocked, kg	*Stocking area, ha	Stocking density, kg/ha	**Loss of Fingerling, kg.	Harvest time
Thai sarputi	June (4th week)	25	120	380	3.16	12	December
Rui		65	200				
Katla		60	160				
common carp		50	720				
Total			1200				

*Fish is stored in the seasonal flooded land of 380 ha (F1+F2+F3) ** Loss of Fingerlings is 1% of total stocked fingerlings

(iii) Feeding and harvesting

Fish can feed on natural food and by-product available in rice field. So no supplementary feeding was supplied in the field for fingerlings. Draining of water from the rice field was allowed from the last week of November up to the top level of khals. When maximum water came in khals, fishes were harvested gradually from the khals as well as in the low lands of rice field during December.

Suitability of the fish cultivation

(i) Fish species: In related literature, fast growth of fish species is mentioned as a desirable characteristic so that fish can attain marketable size when the rice is ready for harvest. The species used in the study area are comparatively fast growing. If compared with previous practices of integrated farming system in Bangladesh and abroad (as described in Chapter Two), it is seen that the species selected are expected to give better yields. Commonly used species have been common carp/mirror carp, nile tilapia, silver barb, thai sarputi, rohu, catla, mrigal and grass carp (Gonzal, 2001; Haroon and Pitman, 1997; Little, 1996; Halwart, 1994; Ali, 1990).

(ii) Fingerling supply and stocking:

The availability of fingerlings to stock the rice fields is a determining factor for the choice of culture species in many areas. It is also a critical part of any type of aquaculture development. Hatchery and nursery technologies for most, if not all, of the freshwater fish species that are currently being cultured in rice-fish systems are well established. However, getting the required number of fingerlings of the desired species at a particular time remains a problem in many areas. However, this was not found to be a problem in the study area.

Stocking density of fingerling was very low in the study area because the integrated rice-fish farming in that area is still in an experimental state and the full potential has yet to be realized. On the one hand, lower stocking density would mean a lower fish yield compared to potential; on the other hand, a very high stocking rate may negatively affect the survival rate of fingerlings (e.g. grass carp) and average body weight. Literature shows that fish stocking density may range from population of 2000 to 35000 individuals per ha depending on the size of fingerlings. Different suggested stocking pattern and densities are presented in Table 5.3, which could be helpful in future in selecting the appropriate density in accordance with the fish species selected and the type of stocking system (e.g. concurrent or rotational).

Table 5.3 Stocking densities for rearing fish in rice fields

Stocking pattern		Stocking density(fish/ha)	
		Concurrent	Rotational
Monoculture	*Oreochromis niloticus*	3 156 to 5 000	10000
	Cyprinus carpio	3 000 to 3 400	
	Barbodes gonionotus	3 017	
Polyculture	*O. niloticus* + *C. carpio*	3 000 + 2 000 (3 070 total)	(6 000 to 10 000) + (4 500 to 5 000)
	C. carpio + *B. gonionotus*	4 667 total	
	Multispecies (carp+barb+ tilapia)	9 323 total	
	C. carpio + *C. auratus* + *C. idella*	(1 500 to 2 250) + (750 to 1 200) + (300 to 450)	
	O. niloticus + *C. carpio* + *C idella*	(6-10 cm: 6 000 to 9 000 or 3 cm: 12 000 to 18 000) + (300 to 600) + (150 to 300)	
	B. gonionotus + *M. rosenbergii*	26 000 + (5 000 to 20 000)	
Fingerling production	13 cm *C. carpio* (30 days)	------------------------------	70 000 – 100 000
	3-5 cm *C. carpio* (50 days)		10 000 – 15 000
	5-8 cm *C. carpio* (50 days)		6 000 – 10 000
	5-8 cm *C. carpio* (50-90 days)		1500-3000
	8-11 cm *C. carpio* (30 days)		1 000 – 2 000

Source. World Fish Center (2004)

(iii) Feeding and harvesting

No supplementary feeding was supplied for the fingerlings in the project. This is feasible in the context of physical system of the project. Deep water rice (DWR) ecosystem is highly fertile due to silt deposition and decomposition of organic matter which favors the growth of flora (phytoplankton) and fauna (zooplankton). The phytoplankton provides fish feed which is enough for fish rearing for a period of 4-5 months (Ali et al., 1993; Das et al., 1990).

5.2.3 Water Management

Existing practice

Water management including the standing water depths that were maintained by the farmers in order to culture rice-fish in the field through existing embankment and (seasonal) construction of earthen cross dam in the khals during the flood season are described in Table 5.4. Operation schedule of earthen cross dams roughly maintained by the farmers are presented in Table 5.5. Farmers maintained different standing water depths corresponding to the plant heights during different stages of rice growing season in the high land and medium high land.

Table 5.4 Water depths and plant height maintained in the farmers' rice field

Rice variety	Rice growing stage	Duration (months)	Average plant height (cm)		Standing water depth ,cm (approximately)	
B. Aus + B. Aman, and T. Aman			High land (F0)	Medium high land (F1)	High land (F0)	Medium high land (F1)
	Broadcasting to seedling establishment stage	April (2nd week) - May	15	30	Saturation	Saturation
	Seedling establishment to tillering stage	June	35	50	Saturation	Saturation
		July(1st week)	45	60	Saturation	30
B.Aus	Tillering to flowering stage	July(3rd week)	60	85	5	45
		August (1st week)	65	90	15	55
	Flowering to grain formationstage	August (3rd week)	70	100	20	60
	Grain formation to ripening and harvesting stage	August (4th week)	*70	**100	24	64
	Vegetative stage on going	September	55	110	26	66
B.Aman	Vegetative to flowering stage	October	70	115	22	62
	Flowering to grain formation and ripening stage.	November	75	115	15	55
T.Aman	Harvesting stage	December (1st week)	Harvesting starts		Water starts to drain out	

*B. Aus was harvested and T. Aman was transplanted
**B. Aus was harvested and B. Aman remained

Table 5.5 Operational schedule of earthen cross dam constructed on khals.

Month	Status of earthen dam	Reasons
December-January	Open	Drain out water from the field for rice-fish harvest
February-May	Closed	To prevent saltwater
June – July	Generally open (and closed as required)	Storage of rain or tidal water (prevention of flooding)
August- November	Closed	Storage of water for rice-fish cultivation

Constructing earthen dams and removing the dams in the three khals has been a practice by the local people to manage water in the project area round the year. The khals are closed during February-May to prevent crop damage in the low land by early floods and to prevent salt water from entering the study area. The salinity of water is usually at the highest from towards the last week of March to end of April. Rainfall is the major source of water for cultivation during April and May in the medium high land. From June, tidal water is allowed to enter the khals to meet the water requirement for the rice plants (towards the end of June). When there is enough water for the floodplain lands, the khals are closed by earthen dams again, usually in July. During this time, the source of water for cultivation is both rainfall and tidal water from river. From August to November, the khals are closed to store the required water for rice (and the recent practice of fish cultivation) and prevent the rice field from excessive flooding. The dams are cut in late November or December to drain out water from the rice field, and harvest rice (and fish). The khals remain open till January.

Evaluation of water management practice

Rice being a semi-aquatic plant, its height increases with increasing depth of water, but tillering is affected adversely. Further, culm strength and lodging resistance decrease as plant height increases. For lodging resistant, semi-dwarf varieties, high water level poses problem during and immediately after transplanting. They also have limited capacity to elongate. So to avoid the adverse effect on rice crop under flood prone water logged lands, water management practice should be considered as one of the important measures.

From the farmer's practice as illustrated in Table 5.4, it is observed that standing water depths which were maintained in the rice field were more or less 25% and roughly 20% to 50% of plant height during B. Aus and T. Aman season, respectively in high land (F0) and roughly 50% to 65% of plant height in medium high land during different growth stages of B. Aus and B. Aman season. Higher rice yield (for B. Aus) was obtained in the high land than that from the medium high land (Table 5.1). Similar type of observation was found by Swain et al. (2005) and he reported that under flood-prone ecosystem the minimum rice yield reductions were obtained from submergence up to 25%, 50% and 50% of plant height at seedling establishment to tillering stage, tillering to flowering stage and flowering to maturity stage, respectively. Also Pande et al. (1978) indicated that high stagnation of water at early tillering stages is considered to be more detrimental than at other growth stages of rice and submergence less than 50% plant height at any growth stage resulted minimum yield reduction.

From the above discussion, the favorable standing water depth up to the maximum tolerant level by rice without affecting it's production (considering minimum yield reduction) is recommended which will also increase the favorable condition for fish culture. Rice yield reduction for B. Aus was observed in medium high land for high water depth (about 50% - 65% of plant height) compared to B. Aus of high land. So standing water depth up to roughly 25% of plant height at tillering stage and 50% of plant height from tillering to ripening stage of B. Aus should be maintained in medium high land for yield maximization. Also, after harvest of B. Aus, standing water depth up to 50% of plant height of B. Aman should be maintained in medium high land. This water depth in medium high land will also minimize the water depth in high land with increase of yield because ideal water depth condition for rice is continuous flooding starting at 3 cm depth gradually increasing to a maximum of 20 cm as reported by Singh et al. (1980), and DAE and FAO (1990). Again, as high stagnation of water at early tillering stages is considered to be more detrimental than at other growth stages of rice, the water depth should remain not more than 25% of plant during tillering stage for yield maximization.

As mentioned before (Table 5.1), the medium low land and low land remain fallow in the monsoon season. Water management in medium low land and low land which will be under cultivation by deep water B. Aman during flood season are not essential. Because deep water Aman has quick growing (fast culm elongation) ability with increasing floodwater and floating or complete submergence capacity for few weeks at different growth stages. Besides water management in medium low land and low land will be partially fulfilled if water management in high and medium high land is done.

In principle, as long as there is enough water in a rice field, it can serve as a fish culturing system. Pillay (1990) reported that suitable standing water depth for fish culture in rice field was 0.4-1.5 m for nursery and 0.8-3.0 m for grow-out. Gupta (1998) observed in his study that fish culture can be suitable in deepwater rice field where flood waters over 50 cm might persist for four months or longer. So, water depth for maintaining maximum submergence up to 50 % of plant height at seedling establishment to tillering stage, tillering to flowering stage, and flowering to maturity stage available in the field are sufficient or suitable for fish culture.

Recommended water depths

In view of the above discussions, the water depths that should be maintained in the field through existing water management infrastructure for rice-fish cultivation during flood season are summarized in the Table 5.6. The depths in F2 and F3 land corresponding to the depth suggested for F1 land will be generally suitable for fish culture because of sufficient water depth available. During the flowering and ripening stage of B. Aman in the month of October and November, however, because of less availability of water (Table 5.4) from inadequate rainfall and low tidal water level, the standing water depth may be maintained below 50% of plant height.

Table 5.6 Recommended maximum standing water depth with respect to rice plant height in the field.

Duration (months)	Average plant height in medium high land (F1), cm	Maximum standing water depth in medium high land (F1)		Standing water depth in other land types corresponding to maximum water depth in medium high land (F1), cm		
		% of plant height	cm	High land (F0)	Medium lowland (F2)	Low land (F3)
April (2nd week) - May	30	-	Saturation	Saturation	Saturation to 10	Saturation to 30
June	50	-	Saturation	Saturation	46	107
July (1st week)	60	25	15	Saturation	61	122
July (3rd week)	85	50	43	1	89	150
August(1st week)	90	50	45	3	91	152
August(3rd week)	100	50	50	8	96	157
August(4th week)	100	50	50	8	96	157
September	110	50	55	13	101	162
October	115	40	46	4	92	153
November	115	27	31	-	77	138
December (1st week)	Harvesting starts	Water starts to drain out				

5.3 Physical suitability of the integrated farming system

5.3.1 Water availability

Desired water levels

Water levels are fixed during different growing stages of rice on the basis of corresponding water depths estimated for different growing stages in medium high land (F1) with the help of water level vs water depth relationship in the field, which are described in Table 5.7. It is to be mentioned here that water depth required in the Medium High Land in May is met through rainfall, and flooding does not take place during this time. From June, the water depths required in different land types are met through both rainfall and tidal water allowed in the study area. The desired water levels required for different time periods are summarized in Table 5.7. The levels are considered as critical levels for rice cultivation as well as fish cultivation in the different types of land in the study area. As explained earlier, this is due to minimization of yield reduction for rice and maximization of water depth for fish. Some illustrative examples of the extent of flooding and inundation depths in different parts of the study area are given in Figs. 5.1-5.4. These figures were obtained by digitizing the elevation contours of the area followed by GIS analysis.

Table 5.7 Estimated desired water levels in the field during monsoon season.

Months	Water level (m PWD)	Average (monthly) water level (m PWD)	Average flooding depth (cm)			
			High land (F0)	Medium high land (F1)	Medium low land (F2)	Low land (F3)
April (2nd week)-May	-	-	Saturation	Saturation	Saturation to 10	Saturation to 30
June	1.98	1.98	Saturation	Saturation	46	107
July (1st week)	2.13	2.27	Saturation	15	61	122
July (3rd week)	2.41		1	43	89	150
August (1st week)	2.43	2.46	3	45	91	152
August (3rd week)	2.48		8	50	96	157
August (4th week)	2.48		8	50	96	157
September	2.53	2.53	13	55	101	162
October	2.44	2.44	4	46	92	153
November	2.29	2.29	-	31	77	138

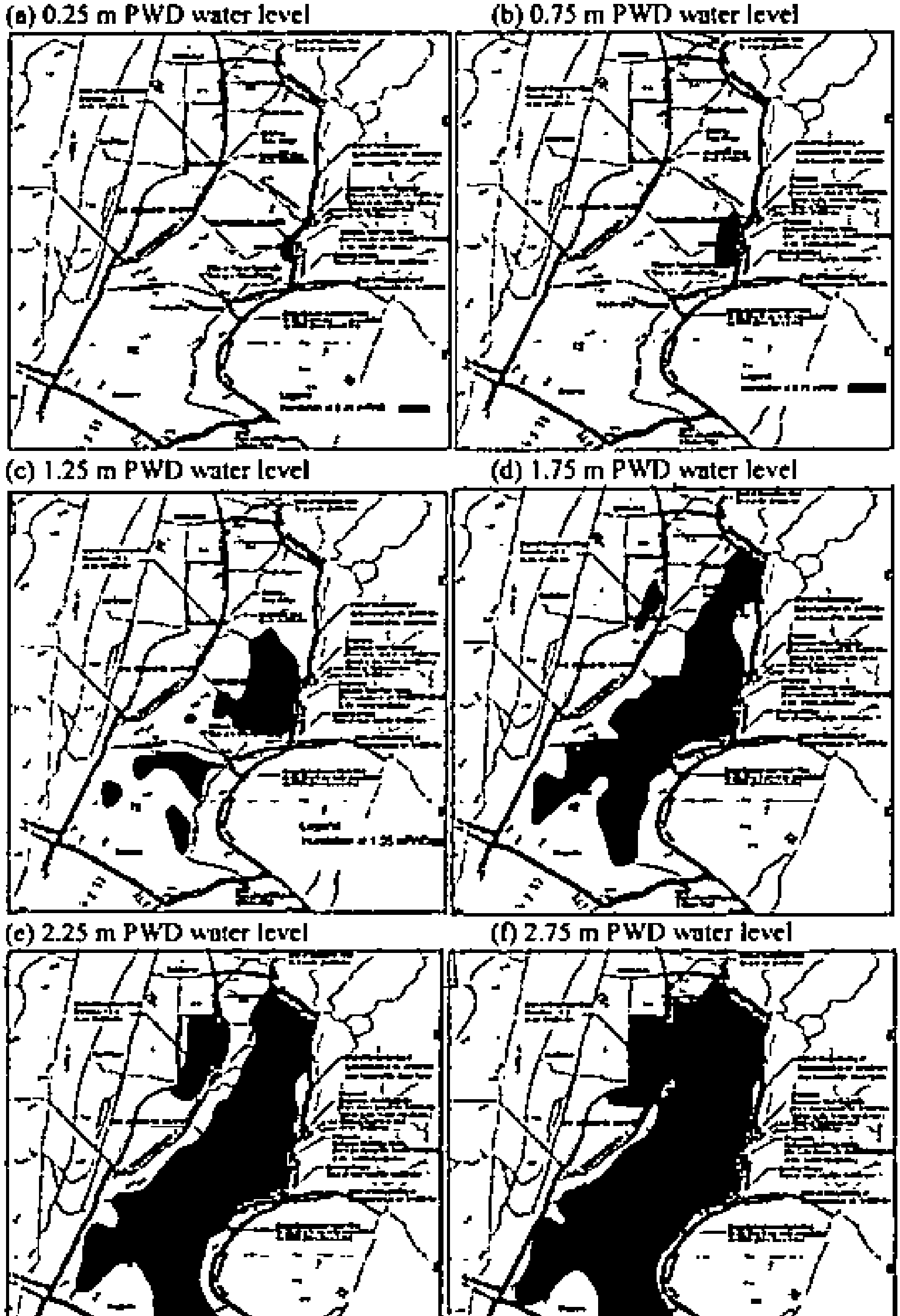

Fig. 5.1 Inundation area at different water levels

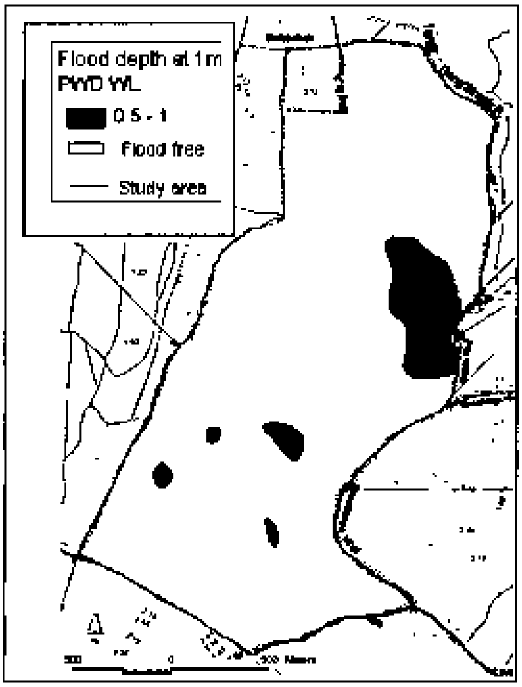

Fig. 5.2 Flooding depth at 1 m PWD water levels.

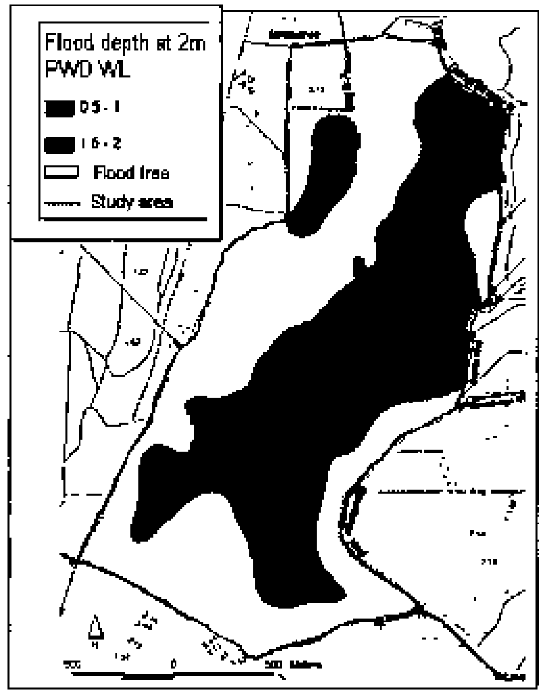

Fig 5.3 Flooding depth at 2 m PWD water levels.

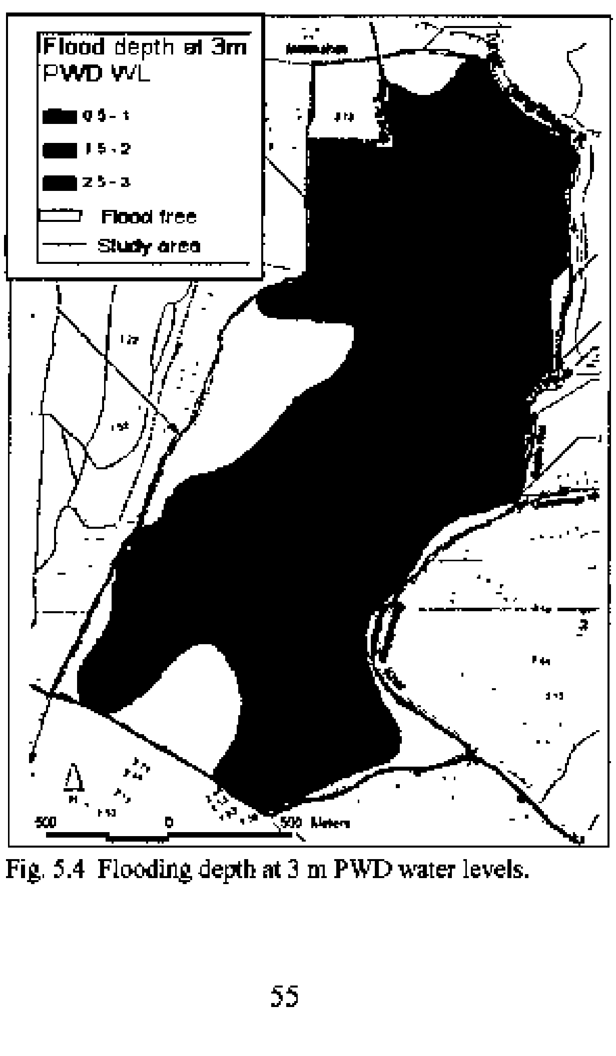

Fig. 5.4 Flooding depth at 3 m PWD water levels.

Source of water to meet requirement

Water requirement for B. Aus and B. Aman in medium highland in May is met from rainfall. The required water depths from June to November can be maintained from a combination of rainfall and tidal water allowed through the khals. Figure 5.5 shows the average monthly High Water Level (HWL) and Low Water Level (LWL) (22-year average), and Table 5.8 shows desired water levels to be maintained along with amount of total monthly rainfalls (22-year average), and monthly average HWL in the river. It can be achieved through the combination of storing the tidal water by opening the water control structure and rainfall. The maximum water level that can be maintained in June by allowing entry of tidal water level is equal to the HWL (1.94 m PWD). The remaining water depth required to elevate the level to the desired 2.03 m PWD could be met by rainfall. Additional water available from rainfall after deducting an approximate seepage/percolation and evapotranspiration loss of 7 mm/day (considered reasonable for the existing cropping pattern and clay soil texture in the study area) contribute a storage volume of 52 ha-m (calculated from elevation-storage volume relationship). This is equivalent to more than 10 cm of water depth, enough to maintain the desired water depth. For the months from July to September, the desired water levels can be maintained from the tidal water levels. In October and November, the water level retained in previous months, after accounting for rainfall and losses will help maintaining the desired levels. So, the regulators and water retention structures would generally be closed from July to November.

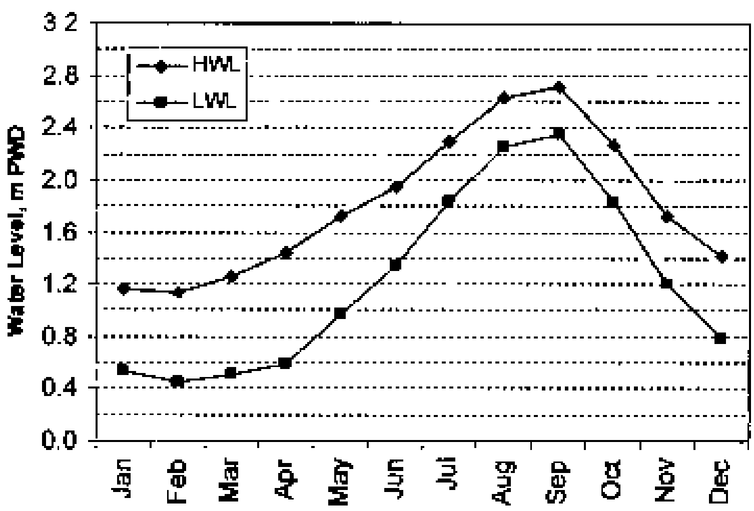

Fig. 5.5 Average monthly high and low water levels in the study area (data: 1981-2002)

Table 5.8 Source of water to maintain desired water levels

Month	Desired water level (m PWD)	Rainfall (mm)	High water level (HWL), m PWD
June	1.98	337	1.94
July	2.27	315	2.30
August	2.46	321	2.62
September	2.53	279	2.72
October	2.44	124	2.26
November	2.29	40	1.72

5.3.2 Functions of water retention and drainage system

Several physical environment or modifications (if required environment is not there) are needed in the inundated floodplains in order to make the rice fields better suited for fish culture. All physical modifications have the basic goals of providing enclosed deeper area for the fish to grow with provision of passage of flood water in or out. Halwart and Gupta (2004) suggested in their studies about physical environment or modifications of rice fields to culture of fish in that fields. Generally, there are four physical environments that are commonly needed for fish culture in rice field:

- The first is the making of enclosed area to allow deeper water inside the field and/or to minimize the risk of it being flooded. This is achieved either by making there provision embankment, dike, and/or bund within the area or by using natural elevated lands, raised homesteads and rural roads as a barrier.

- The second is the provision of water control structure or gate (such as sluice gate, regulator, pipe sluice etc) with fish net to manage flood water and to prevent the fish from escaping as well as keeping predatory fish from coming in with the flood water.

- The third is the provision of proper drains or canals within the area for the passage of flood water in or out.

- The fourth is the provision of deeper areas (such as small pond, trench, pit etc) as a refuge for the fish within area

Provision of enclosed area

Embankments, rural/highway roads, raised homesteads, bamboo fence etc may be used as barriers to make the enclosed area for growing fish in rice field in inundated flood plains. The sub-project is bounded by rural road and embankment on the north and north-east along the Singair river and Hazir khal, respectively. On the south the study area is bounded by Gopalgang-Patgati-Pirojpur regional highway. The western side of the study area is bounded by metalled road that connects the Gopalganj-Patgati highway on the south. The embankment and rural road elevation is fixed about 4.10 m PWD. Details are shown in Fig 5.6

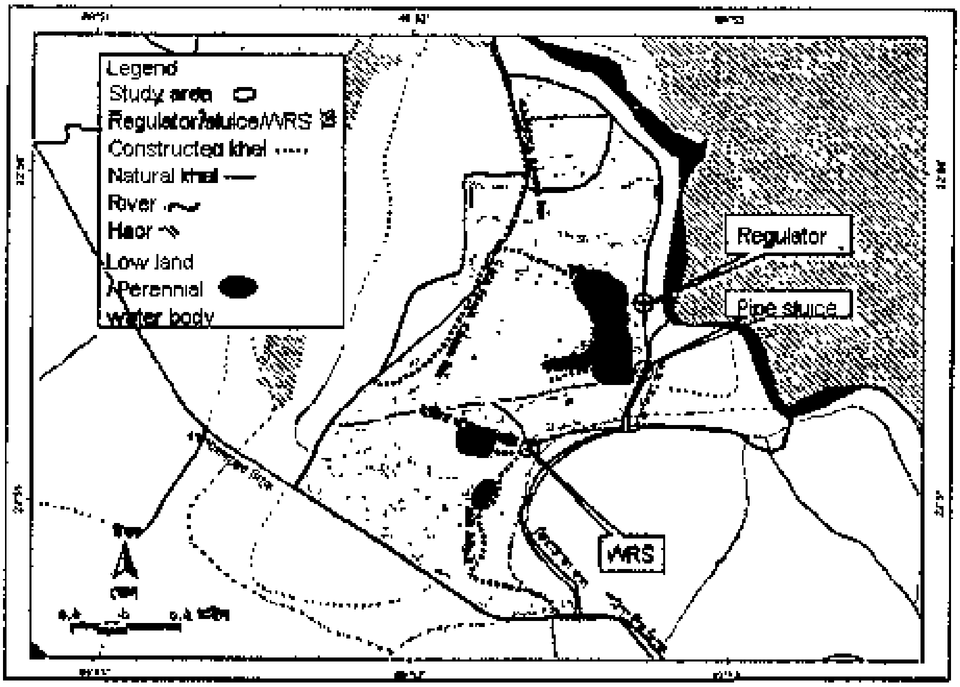

Fig. 5.6 Physical environment of project

So the study area is considered as an enclosed area. From the river water level analysis it is observed that average peak flood level (2.71 mPWD) is less than the level of the embankment and rural road level (4.10 mPWD) which are used as barriers. The top of embankment and rural road are fixed with sufficient level to minimize the risk of being flooded or to prevent most fish from jumping over. As the study area is enclosed with barrier without over flooding, the rice-fish culture in that area is suitable or preferable.

Provision of water control structures/gates with fish net

Water control structures/gates are needed to maintain proper water depth within the enclosed areas of inundated flood plains in order to maximize the rice-fish yield. Fish net is also important to prevent fish from escaping with the water, regardless of whether it is flowing in or out.

In the sub-project there are two regulators one at the outfall of Swanirvar khal, one at the outfall of Balajtala khal and one water retention structure over Hazir khal. Construction of structures will be completed soon. Three fish nets are also attached with three structures. Details are shown in Fig. 5.6. These interventions will facilitate storage of flood water with sufficient or proper depth for rice-fish culture and to remove extra runoff water from the field. These interventions will also be helpful to remove water from the field at the time fish harvesting.

So managing flood water level and preventing fish from escaping as well as keeping wild fish from coming in with the flood water within the study area are possible through gate operation. Thus rice-fish culture may be considered as suitable in that field.

Provision of canals

Provision of drains or canals in the area is important as a passage or route through which entry and draining of flood water will allowed. Canals are also used to drain out excess rainfall runoff from the rice field. These may be used for stocking fish fingerlings at early stage of seedlings when the water depth in rice field is not sufficient. Harvesting of fish is convenient from the canals. The presence of the three khals (Swanirvar khal, Hazir khal and Balajtala khal) in the study area make all these operations possible.

Provision of deeper areas as fish refuges

A fish refuge is a deeper area provided for the fish within a rice field. This can be in the form of a pond or a pit in inundated flood plains. The purpose of the refuge is to provide a place for the fish in case water in the field dries up or is not deep enough. It also serves to facilitate fish harvest at the end of the rice season, or to contain fish for further culture whilst the rice is harvested. Halwart (1998) suggested in his study to provide fish refuges within rice field for creating deeper areas to safely accommodate all fish during weeding and harvesting. In conjunction with the refuge, provisions are often made to provide the fish with better access to the rice field for feeding.

In Balajtala-Kolmadanga sub-project, there are about 38 ha of lowlands (seasonal flooding >9 months) and about 3 ha of permanent perennial water bodies within the study areas. These lowlands and permanent perennial water bodies as shown in Fig. 5.6 can be used as refuge for the fish in the rice field. In sum, the fish culture in rice field in the study area is also feasible in the context of presence of fish refuge. However, it may be noted that fish refuges are not mandatory within deep flooded environment for fish culture in the rice field.

5.4 Socio-economic impact analysis

5.4.1 Rice and fish yield

Existing potential yield of rice and fish

From Table 5.9, it is found that 11 ha and 22 ha land were cultivated under B. Aus and T. Aman, respectively in high land (F0) and 100 ha in the medium high land (F1) were cultivated under B. Aus + B. Aman during the monsoon season. Rice yields were 2.4 ton/ha for B. Aus (LV), 4 ton/ha for T. Aman (HYV) and 2.05 ton/ha for B. Aus (LV) +B. Aman (DW) varities. The average rice yield was 2.4 ton/ha. On the other hand, total rice production was 320 tons. Medium low land (F2) and low land (F3) land will be under cultivation during monsoon season through water management in post project condition in the study area.

Table 5.9 Existing yield of rice during flood season within study area.

Crops	Land Covered (ha)				Yield (ton/ha)	Total rice production (ton)
	F0	F1	F2	F3		
B. Aus (LV)	11				2.4	26.4
T. Aman (HYV)	22				4.0	88
B.Aus (LV) + B. Aman (DW)		100	-	-	2.05	205
Total					*2.4 (average)	319.40 ≈ 320

* Average yield is calculated for the total cultivated area

The rice yield in the project is compared with rice yields reported in other studies in integrated rice-fish system. For example, Haroon and Pitman (1997), Gupta (1996), Dey and Prein (2003, 2004), and Ali (1998) reported for Bangladesh that rice yields under rice-fish cultivation system are 1.5-3.7 ton/ha, 3.8-5.0 ton/ha, 7 ton/ha (in single and double cropped system) and 7.33 ton/ha (BR3-Fish production in polder system) respectively.

From Table 5.10, it is seen that total 1200 kg fingerlings were stocked in about 380 ha of seasonal flooded land and stocking density was about 3.16 kg/ha. The harvested fish size was about 888 gm/fish, and yield and total production were 0.10 ton/ha, and 27.35 ton respectively. Yield of fish depends on the stocking density as well as the size of fingerlings. While the size of stocking was comparatively large (about 50 gm), the stocking density was very low that caused the low yield.

Data on fish yield vary widely and comparisons are difficult in view of variations in environment, species of fish, fingerlings size, stocking density, duration of culture period, inputs provided, rice spacing, and productive objective- whether marketable, full size fish is intended, or fingerlings for aquaculture. Some examples are provided here, however to show the importance of fingerling size and stocking density in regards to fish yield. Different fish yields have been reported in previous studies. Mohanty (2004) found relatively high fish yield of 1245 kg/ha at a stocking density of 3000 no/ha, but using advanced (bigger size) fingerlings. Ali (1998) also found high yield (2800 kg/ha) with small size of fingerlings (average 8.92 gm), but at a high stocking density of 10,000 no/ha. Uddin (1998), on the other hand, found relatively small yield with fingerling size (average 5.65 gm) at a 6250 no/ha stocking density. Haroon and Pitman (1997), Gupta (1996), and Dey and Prein (2003, 2004) reported that fish yields under rice-fish cultivation system were 226-221 kg/ha, 118-616 kg/ha, 1500 kg/ha respectively with stocking of small sized fingerlings (called fry). Fish yields under rice-fish system for different country are also summarized in Chapter 2 (Table 2.2)

Table 5.10 Existing yield of different varieties of fish cultured in rice field

Fish species	Fingerling stocked, kg	Stocking area, ha	Harvested fish size, gm (ave.)	Harvested fish production (ton)	Loss of fish due to uncontrolled flooding, ton	Total fish production, ton	Fish yield, ton/ha
Thai sarputi	120	380	350	1.08	0.27	1.35	0.10
Rui	200		900	2.15	0.50	2.65	
Katla	160		800	1.76	0.44	2.20	
Common carp	720		1500	16.95	4.20	21.15	
Total	1200	-	888 (ave.)	21.94	5.40	27.35	

Projected potential yield of rice and fish

Projected rice yield as well as production is shown in Table 5.11. Projected production of rice and fish were calculated considering the whole potential land in the study area under cultivation through flood water management after post project. Also, projected production was estimated using existing rice yield, and considering that additional 25 ha of medium high land, and 195 ha of medium low land and 30 ha of low land within the study area will be cultivated under B. Aus (LV) plus B. Aman (DW), and deep water B. Aman (with yield of 1.9 ton/ha), respectively through water management. Existing rice yield which may be increased due to proper water management was ignored in the calculation.

Table 5.11 Projected yield of rice during monsoon season within study area.

Rice varieties	Land Covered (ha)				Yield (ton/ha)	Total rice production (ton)
	F0	F1	F2	F3		
B. Aus (LV)	11				2.4	26.40
T. Aman (HYV)	22				4.0	88.00
B.Aus (LV) + B. Aman (DW)		125			2.05	256.25
B. Aman (DW)			195	30	1.9	427.5
Total						798.15 ≈ 798

From Table 5.11, it is observed that the projected total rice production is 798 tons which is much higher than the existing total rice production of 320 tons (Table 5.9). This is due to inclusion of additional 250 ha of land considered under cultivation through water management practice. Comparison between existing and projected rice production is also shown in Fig. 5.7 and Fig. 5.8.

It can be noted here that existing average rice yield is 2.4 ton/ha (from F0 and F1). In the projection for post-project situation, F2 and F3 lands will also be brought under cultivation, and since yield (from DW Aman) for these land types are comparatively lower (see Table 5.11) the average yield for the entire cultivated area will be less. However, in the post project situation, some more F1 land (25 ha) will also be brought under cultivation, and the yields of rice from F0 and F1 land are expected to increase substantially (20% - 50%) with proper water management, which was also anticipated in appraisal report (LGED, 2004a). Considering an average 30% increase in yield for B. Aus and B. Aman, the average yield for the entire cultivated area in post-project condition becomes 2.42 ton/ha. In view of this, the yield of rice from the cultivated area has kept as the same (2.4 ton/ha) in economic analysis of projected return in subsequence section.

Projected yield as well as production of fish was calculated on the basis of maximum stocking density of 1 fingerling/m^2 and fish recovery rate of 54%, 74%, 74% and 63% for common carp, rohu, katla and thai sarputi, respectively that were reported by Ali (1998) for deep water rice environment in Bangladesh. Secondary recovery rate of fingerlings are used because data regarding fish recovery rate was not found from the farmers of study area. From Table 5.6, it is observed that high land (F0) and medium high land (F1) are not suitable for fish cultivation due to lower water depth compared to the required depths as suggested by Pillay (1990) and Gupta (1998). So the stocked area of fish is considered to be 255 ha land comprising of F2 and F3 land categories within the project area.

Data on existing fish species, fingerlings size and harvested fish weight were used in the calculation of projected fish yield that are presented in Table 5.2 and Table 5.10. Fish species such as common carp, rohu, thai sarputi and katla was considered to be stocked at the ratio of 2:1:1:1. Common carps are stocked at higher rate than the other species because these species are fast growing compared to rohu, thai sarputi, and katla. Projection of fish yield is presented in Table 5.12 and comparison between the existing and the projected fish production is shown in Fig. 5.7 and Fig. 5.8

Table 5.12 Projected yields of different varieties of fish cultured in rice field

Fish species	No of fingerling stocked	Fingerlings' recovery rate, %	No of survived fingerlings	Harvested fish weight (ave.), gm/fish	Total fish production, Kg	Total fish production, ton	Fish yield ton/ha
Thai sarputi	510,000	63%	321,300	350	112,455	112	6.20
Rui	510,000	74%	377,400	900	339,660	340	
Katla	510,000	74%	377,400	800	301,920	302	
Common carp	1,020,000	54%	550,800	1500	826,200	826	
Total	2,550,000					1580	

Stocking area=255 ha (2,550,000 m²), Stocking density = 1 fingerling/m²

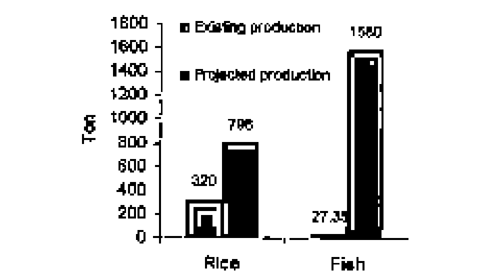

Fig. 5.7 Comparison between existing and projected production.

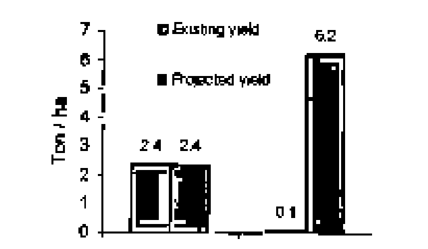

Fig. 5.8 Comparison between existing and projected yeld.

From Table 5.12, it is shown that the projected total fish production are 1580 tons (6.20 ton/ha) which are very much higher than the existing total fish production of 27.35 tons (0.10 ton/ha).

5.4.2 Economic analysis

Economic analysis of existing rice-fish production.

Different items of cost and return of rice-fish cultivation are summarized in Table 5.13 and Table 5.14. Values of costs and returns which are used in this analysis were collected from the study area. Cost items which are used for rice-only cultivation were land preparation, labour for broadcasting, weeding, harvesting and threshing, making earthen cross dam on khals (existing condition), fertilizes, pesticides etc whereas income items were selling of rice grain and straw. On the other hand, cost and return items for rice cultivation when fish is cultured in rice field were the same as rice-only cultivation without application of fertilizer (TSP and MP) and pesticide, since fertilizers (except urea) and pesticides applications are not needed for rice cultivation with fish. Besides, labour requirement for weeding was less with rice+fish cultivation system compared to only rice cultivation system. Because fishes used weed biomass and by-products available in rice fields as their feed. Cost items for fish culture included fingerlings, salary of guards, making of bamboo fence, fish harvesting, transport cost for selling fish and sale commission, whereas return item was only fish selling.

From the economic analysis (Table 5.15), it is seen that costs of rice-only cultivation, cost of rice cultivation when fish is cultured in rice field, cost of fish cultivation and cost of rice+fish cultivation are 23,570 Tk/ha, 18,410 Tk/ha, 780 Tk/ha, and 19,190 Tk/ha, respectively. On the other hand, the net return from rice-only cultivation is 14,430 Tk/ha while the net return from rice cultivation when fish is cultured in rice field is 19,590 Tk/ha, which is 5160 Tk/ha higher. Again, the net return from fish cultivation is 3,050 Tk/ha, while the net return from rice +fish cultivation is 22,640 Tk/ha. The higher net return from rice-fish production system is mainly derived by the contribution of fish yield.

Benefit cost ratio (BCR) for rice only cultivation is 1.61 where as for rice+fish cultivation is 2.18, which is about two times that for rice-only cultivation. BCR for fish cultivation is 4.90, where as for rice+fish cultivation is 2.18 which is smaller than fish cultivation. BCR for rice+fish is comparatively less in this study area because very low amount of fingerlings are stocked in a large area (about 380 ha) of flooded land as an experiment by the farmers. As BCR for only fish cultivation are about three times of rice+fish cultivation, farmers are inclined towards only fish cultivation. But this is not suggested due to national food security.

Table 5.13 Existing unit cost and return for rice cultivation during monsoon

1	2	3	4
	Items	Rice-only cultivation(Tk/ha)	Rice cultivation when fish is cultured in rice field (Tk/ha)
Cost Items	Land preparation by power tiller, Tk/ha	2800	2800
	Seed for broad casting, 100 kg /ha @ 22 Tk/Kg.	2200	2200
	Labour for broadcasting, 2 person /ha @ 100Tk/person	200	200
	Labour for weeding, 50 person/ha for column3 and 30 person/ha for column4 @ 100Tk/person	5000	2000
	Fertilizes: -Urea-120 kg/ha @ 8 Tk/kg, TSP - 50kg/ha @ 30 Tk/kg, MP-10kg/ha @ 30 Tk/kg for column 3 -Only Urea-120 kg/ha @ 8 Tk/kg, is used for column. 4	2760	960
	Pesticides: -Basudin 2.5 kg/ha @ 90 Tk/kg, sabicron 1.5 kg/ha @ 90 Tk/kg for column 3 -No pesticides is used for column 4	360	-------
	Labour for harvesting and threshing, Tk/ha (If 6 unit rice grains are harvested and threshed, 1 unit is taken by labour as a charge.)	8000	8000
	Labour for making earthen cross dam on Khals, 15 person /3 dam @ 150Tk/person	2250	2250
Total cost		23570	18410
Return Items	Income from average rice yield, 2400 kg/ha @ 15 Tk/ Kg	36,000	36,000
	Income from rice straw yield, 500kg/ha @ 4Tk/ kg	2000	2000
Gross return		38,000	38,000
Net return	Total Cost - Gross return	14,430	19,590

Table 5.14 Existing cost and return for fish cultivation in rice field during monsoon

Cost Items	Total fingerling cost (with transport), Tk	Thai sarputi - 120 kg @ 135Tk/kg	16,200
		Rui - 200 kg @ 110 Tk/ kg	22,000
		Katla - 160 kg @ 110 Tk/kg	17,600
		Common carp - 720 kg @ 135 Tk/ kg	97,200
	Salary of guard/security man (during 4 month), Tk	6 person/month @ 1500Tk /person/month	36,000
	Making of bamboo fence on 3 khals to protect fish from flooding, Tk	66 no bamboo and 10 no labour @ 80 Tk/bamboo and 150 Tk / labor	67,80
	Fish harvest cost (during 30 days),Tk	12labour/day@ 60Tk/person/day	21,600
	Transport cost for selling,	Total 21,940 kg - 600Tk/ 800 Kg capacity Vehicle	16,455
	Sale commission (3% of total sell), Tk	About 3% of total sell of fish	58,000
Total cost (Tk)			296,530
Return items	Total Fish selling, Tk	Thai sarputi- 1080 kg @ 80 Tk/ kg	86,400
		Rui- 2150 kg @ 90 Tk/ kg	193,500
		Katla- 1760 kg @ 90 Tk/ kg	158,400
		Common carp - 16.950 kg @ 60 Tk/ kg	1,017,000
Gross return (Tk)			1,455,300
Net Return (Tk)		(Gross return -Total Cost)	1,158,770

Table 5.15 Existing cost and return analysis for rice-fish production

Items	Rice-only cultivation	Rice when fish in rice field	Cultured fish	Rice +fish
Total cost (Tk/ha)	23570	18,410	780	19,190
Gross return (Tk/ha)	38,000	38,000	3,830	41,830
Net return (Tk/ha)	14,430	19,590	3,050	22,640
Benefit/Cost ratio (BCR)	1.61	2.10	4.90	2.18

Economic analysis of projected rice-fish production.

Projected economic performance of rice production during the monsoon season is analyzed on the basis of projected yield and considering that the whole potential land are brought under cultivation as per project objective by flood water management. Cost of construction of earthen cross dams on three khals are excluded from this analysis because of the new water control structures that would serve the purpose of earthen dams. Different items of cost and return, and analysis of rice production are summarized in Table 5.16 and Table 5.18. Comparison between the existing and the projected economic performance for rice-fish is shown in Fig 5.9.

Table 5.16 Projected unit cost and return for rice cultivation during monsoon

1	2	3	4
	Items	Rice-only cultivation (Tk/ha)	Rice cultivation when fish is cultivated in rice field (Tk/ha)
Cost Items	Land preparation by power tiler, Tk/ha	2800	2800
	Seed for broad casting or planting, 100 kg /ha @ 22 Tk/Kg.	2200	2200
	Labour for broadcasting, 2 person /ha @ 100Tk/person	200	200
	Labour for weeding, 50 person/ha for column 3 and 30 person/ha for column 4 @ 100Tk/person	5000	2000
	Fertilizes -Urea-120 kg/ha @ 8 Tk/kg, TSP -50kg/ha @ 30 Tk/kg, MP-10kg/ha @ 30 Tk/kg for column 3 -Only Urea-120 kg/ha @ 8 Tk/kg, is used for column. 4	2760	960
	Pesticides -Basudin 2.5 kg/ha @ 90 Tk/kg, sabicron 1.5 kg/ha @ 90 Tk/kg for column 3 -No pesticides is used for column 4	360	-------
	Labour for harvesting and threshing, Tk /ha(If 6 unit rice grains are harvested and threshed, 1 unit is taken by labour as a charge.)	8000	8000
Total cost		21320	16160
Return Items	Income from average rice yield, 2400 kg/ha @ 15 Tk/ Kg	36,000	36,000
	Income from rice straw yield, 500kg/ha @ 4 Tk/ kg	2000	2000
Gross return		38,000	38,000
Net return	(Gross return -Total Cost)	16,680	21,840

Projected economic performance for fish cultivated in rice field is analyzed on the basis of projected fish yield and considering that unit value of cost and return items are same as the existing unit value. This analysis is summarized in Table 5.17

Table 5.17 Projected cost and return for fish cultivation in rice field during monsoon

Cost Items	*Total fingerling cost (with transport), Tk	Thai sarputi – 12.75 ton @ 135Tk/ kg	1,721,250
		Rui -33.15 ton @ 110 Tk/ kg	3,646,500
		Katla -30.60 ton @ 110Tk/kg	3,366,000
		Common carp-51 ton @ 135 Tk/kg	6,885,000
	Salary of guard/security man (during 4 month), Tk	20person/month @ 1500Tk /person/month	120,000
	Fish harvest cost (during 30 days),Tk	50 labor/day@ 60Tk/person/day	90,000
	Transport cost for fish selling	Total 1580 ton @ 600Tk/ 800 Kg capacity Vehicle	1,185,000
	Sale commission (3% of total sell of fish), Tk	About 3% of total sell of fish	3,489,000
Total cost (Tk)			20,502,750
Return Items	Total Fish selling, Tk	Thai sarputi - 112 ton @ 80 Tk/ kg	8,960,000
		Rui- 340 ton @ 90 Tk/ kg	30,600,000
		Katla - 302 ton @ 90 Tk/ kg	27,180,000
		Common carp- 826 ton @ 60 Tk/ kg	49,560,000
Gross return (Tk)			116,300,000
Net Return, (Tk)	(Gross return -Total Cost)		95,797,250

* Fingerlings, no/ha is converted to fingerling, ton /ha

Table 5.18 Projected cost and returns analysis for rice-fish production

Items	Rice-only cultivation	Rice when fish in rice field	Cultured fish	Rice + fish
Total cost (Tk/ha)	21,320	16,160	80,473	96,633
Gross return (Tk/ha)	38,000	38,000	456,078	494,078
Net return (Tk/ha)	16,680	21,840	375,675	397,515
Benefit/Cost ratio (BCR)	1.78	2.35	5.66	5.11

Fingerlings are considered to be stocked in 255 ha of flooded rice field in post-project condition.

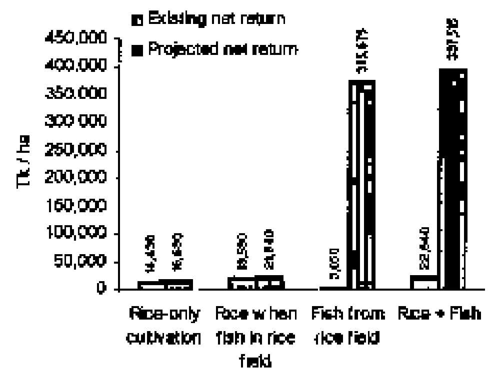

Fig. 5.9 Comparison between existing and projected net return.

From Table 5.16, it is observed that costs of rice-only cultivation and rice cultivation when fish is in rice field are 21320 Tk/ha, 16160 Tk/ha respectively where as the net returns are 16,680 Tk/ha, 21,840 Tk/ha respectively. From Table 5.18, it is shown that projected cost and net return of fish cultivation are 80,473 Tk/ha and 375,675 Tk/ha, respectively. From Table 5.18, it is also shown that benefit cost ratio (BCR) for rice-only cultivation is 1.78 where as benefit cost ratio for rice cultivation when fish is in field and rice+fish are 2.35 and 5.11, respectively and both of these are higher than that of rice-only cultivation.

5.4.3 Social acceptability

It seems far-fetched that stocking fish in rice fields has a significant impact on the society as a whole, particularly so with isolated cases of technology adoption by one or a few farmers widely dispersed. However, when there is a large scale adoption involving an entire community the social impact is quite profound. In the study area, the integrated farming system has been a large scale practice in the sense that the entire community area has been brought under the new cultivation system. However, it is still too early see a profound socio-economic impact, since fish stocking has been far below the full potential, and the exiting institutional arrangement lacks appropriate structure for which satisfaction of the local community has not reached its fullest extent. Nevertheless, from the perceptions of the local people, it was clear that the new system is in general acceptable to them because of its huge potentials, and social acceptability will not be at all an issue if the full potentials of the system are achieved, both in terms of improvements of production and distribution of shares and benefits to be ensured through a proper institutional arrangement.

There have already been evidences (from people's perceptions) of increased farm income and job opportunity (such as making fish culture accessories, guarding, harvesting, and sorting, packing and transport of fingerlings), and household's nutrition level. Regarding social acceptability Halwart (1999) reported that nutritional benefits and lowered risk of production may provide strong motivation for rice farmers to diversify and that rice+fish farming can be "profitable" in many ways including from social, environmental, or ecological point of views. Improvements of a farming household's nutrition as a result of culturing fish in the rice fields may just be an incidental and perhaps even indirect effect, such as being able to buy meat or chicken as a result of the extra cash earned from fish. With greater availability of fish, the local population of a rice farming community will have easy access to fish at affordable prices. Gupta et al. (1998) found that in Bangladesh, extra income was the most appreciated benefit from growing fish (70%) followed by "increased food for the family" (59%).

Instead of the leasing system that was used before, the community expressed their willingness to undertake a group approach within landowners, fishers of the community and landless laborers (with customary access rights for fishing in the flood season), and determine for themselves the management criteria and institutional arrangements which they consider suitable to their local conditions and social context, with shares allowed to everybody, and net returns distributed among the shareholders depending on their contributions.

Women in the study area find the new farming system attractive. Being members (1/3rd of the total) of the WMCA, they will have the opportunity of buying shares, and this will directly add to their economic capital. Also they do not see the conflict regarding feeds between fish and ducks (reared by the women).

Overall, the results show that the community-based fish culture approach in seasonally flooded rice ecosystems will benefit landowners as well as landless participants, women, and hence will be socially acceptable.

5.5 Environmental impact

5.5.1 Soil quality

The nutrients status of the soil before and after rice-fish cultivation were measured to investigate if there have been any variations in the availability of nutrients in soil. Soil quality was also investigated in a nearby project (Kaikubunia-Chinguri) area where only rice is cultivated. This would help to understand the impacts coming from only the rice-fish farming system. The results are presented in Table 5.19.

Table 5.19 Availability of nutrients in soil of rice field with and without fish

Location	Soil sampling time	Concentration of different nutrients in soil (average)						
		pH	Organic C (%)	Organic Matter (%)	N (%)	P (ppm)	K (ppm)	S (ppm)
Study area	Initial (Before rice-fish cultivation)	6.54	1.15	2.45	0.082	10.84	49.1	7.57
	Final (After rice-fish cultivation)	6.53	1.41	2.78	0.101	11.56	51.1	7.61
	Average increase/ decrease	-0.01	0.26	0.32	0.019	0.72	2	0.04
Another project (control)	Initial (Before rice cultivation)	6.61	1.19	2.10	0.073	9.93	44	6.45
	Initial (After rice cultivation)	6.59	1.31	2.23	0.074	10.13	43.6	6.26
	Average increase/ decrease	-0.02	0.12	0.13	0.001	0.19	-0.4	-0.19

p^H

From Fig.5.10, Fig.5.11 and Table 5.19, it is observed that the initial values of soil P^H obtained were 6.54 and 6.61 in rice-fish and rice-only cultivation system, respectively and the final values obtained were 6.53 and 6.59 in rice-fish and rice-only cultivation system, respectively. The average initial and final P^H values both in rice-fish and rice-only cultivation system were more or less similar and did not show any remarkable difference between them. While pH values obtained in the study area before and after cultivation followed a similar pattern, it was sort of erratic for the control site.

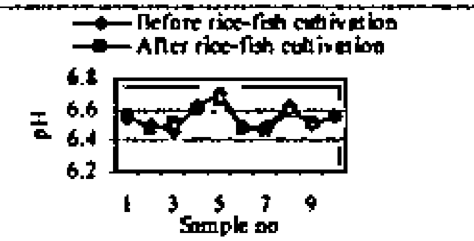

Fig. 5.10 Change in pH of soil for rice-fish cultivation

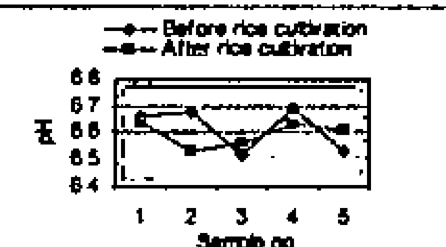

Fig. 5.11 Change in pH of soil for only rice cultivation

Organic C (%)

From Fig.5.12, Fig.5.13 and Table 5.19, it is observed that the initial values of organic carbon (C) in soil obtained were 1.15% and 1.19% in rice-fish and rice-only cultivation system, respectively and the final values obtained were 1.41% and 1.31% in rice-fish and rice-only cultivation system, respectively. While the organic carbon increased in both rice-fish and rice-only (control) system, the increase in the former system was more than twice than that in the latter system. While the increase in organic carbon was consistent spatially in the study area, it did not follow the same pattern in the control site.

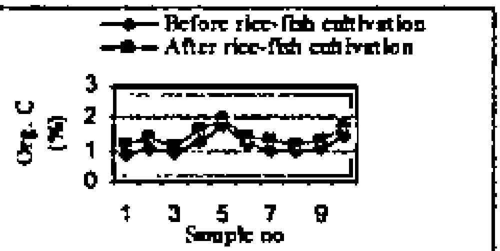

Fig. 5.12 Change in organic Carbon (C) of soil for rice-fish cultivation

Fig.5.13 Change inf organic carbon of soil for only rice cultivation

Organic matter (%)

Similar results were found for organic matter. It is seen that the initial values of organic matter in soil obtained were 2.45 % and 2.10 % in rice-fish and rice-only cultivation system, respectively and the final values obtained were 2.78 % and 2.23 % in rice-fish and rice-only cultivation system, respectively. The final values of organic matter were higher than initial values both in rice-fish and only rice cultivation system. But the average increase of organic matter in rice-fish system was about 3 times higher than that of organic matter in rice-only cultivation system. The increase in organic matter also showed a more consistent pattern than that in the control site.

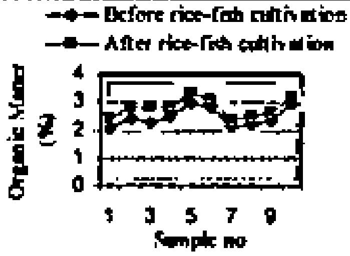

Fig. 5.14 Change in organic matter of soil for rice-fish cultivation

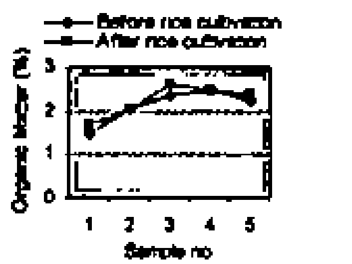

Fig. 5.15 Change in organic matter of soil for only rice cultivation.

Total nitrogen (%)

There was improvement in total nitrogen because of integrating farming. It is observed from Fig. 5.16, Fig. 5.17 and Table 5.19 that the initial values of nitrogen in soil obtained were 0.082 % and 0.073 % in rice-fish and only rice cultivation system, respectively and the final values obtained were 0.101% and 0.074 % in rice-fish and rice-only cultivation system, respectively. The final value of nitrogen was higher than that of initial value in rice-fish system, whereas no remarkable difference was found between initial and final values of nitrogen in only rice cultivation system. On the other hand, the average increase of nitrogen in rice-fish system was about 19 times higher than that of nitrogen in rice-only cultivation system. The spatial pattern of increase in total nitrogen was consistent in the study area and erratic in the control site.

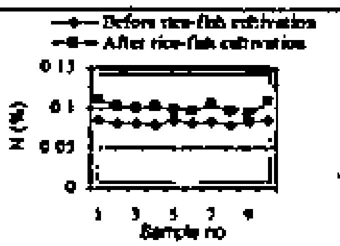

Fig.5.16 Change in nitrogen of soil for rice-fish cultivation

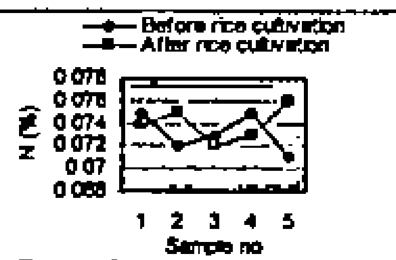

Fig. 5.17 Change in nitrogen of soil for only rice cultivation

Phosphorus (ppm)

Change in phosphorus in soil followed a similar pattern; however, the change (or increase) is not as strong as in the other cases mentioned above. From Fig.5.18, Fig.5.19

and Table 5.19, it is seen that the initial values of phosphorus in soil obtained were 10.84 ppm and 9.93 ppm in rice-fish and rice-only cultivation system, respectively and the final values obtained were 11.56 ppm and 10.13 ppm in rice-fish and rice-only cultivation system, respectively. The initial and final values of phosphorus both in rice-fish and rice-only cultivation system were more or less similar and did not show any remarkable difference between them.

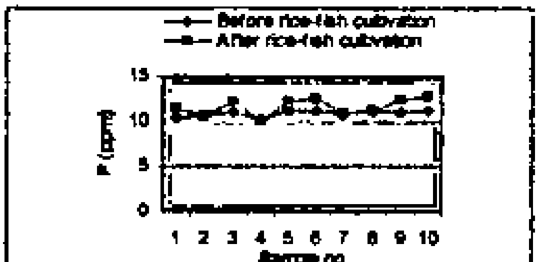

Fig.5.18 Change in phosphorus of soil for rice-fish cultivation

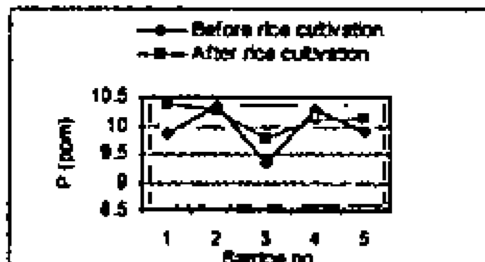

Fig.5.19 Change in phosphorus of soil for only rice cultivation

Potassium (ppm)

From Fig. 5.20, Fig. 5.21 and Table 5.19, it is observed that the initial values of phosphorus in soil obtained were 49.1 ppm and 44 ppm in rice-fish and only rice cultivation system, respectively, and that of the final values obtained were 51.1 ppm and 43.6 ppm in rice-fish and only rice cultivation system, respectively. The initial and final values of phosphorus both in rice-fish and rice-only cultivation system were more or less similar and did not show any remarkable difference between them.

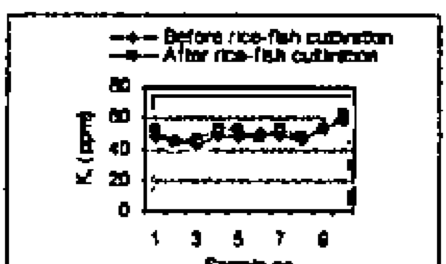

Fig. 5.20 Change in potassium of soil for rice-fish cultivation

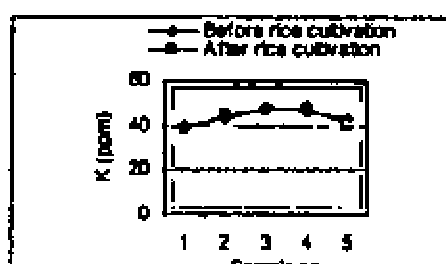

Fig. 5.21 Change in potassium of soil for only rice cultivation

Sulpher (ppm)

From Fig. 5.22, Fig. 5.23 and Table 5.19, it is shown that the initial values of sulpher in soil obtained were 7.57 ppm and 6.45 ppm in rice-fish and only rice cultivation system, respectively and that of the final values obtained were 7.61 and 6.26 ppm in rice-fish and rice-only cultivation system, respectively. The initial and final values of phosphorus both in rice-fish and only rice cultivation system were more or less similar and did not show any remarkable difference between them.

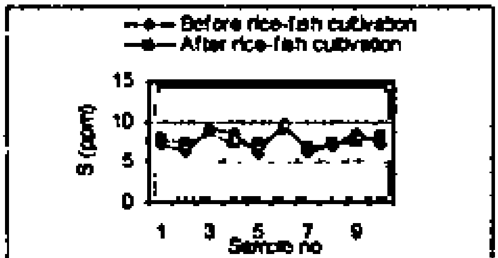

Fig. 5.22 Change in sulpher of soil for rice-fish cultivation

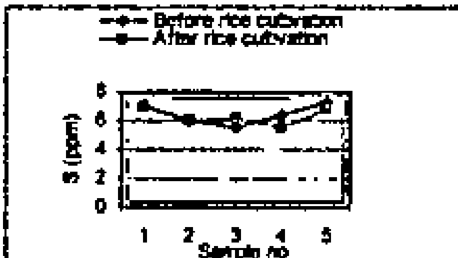

Fig. 5.23 Change in sulpher of soil for only rice cultivation.

From the above findings, it is seen that there has been an increase in a number of soil quality parameters (e.g. organic carbon, organic matter and nitrogen). This increase may be attributed to the enrichment of these nutrients by the culture fish as well as the capture (wild) fish existing in the system. Similar findings were also reported by Lipton (1983), Middendrop (1985), Xu and Guo (1992), and Gaunt et al. (1993) and they stated that fish culture in rice fields stimulates the activities of micro-organisms, increases availability of organic matters, have positive impact on mineralization as a consequence of lower P^H of water and increases the release of nutrients for better rice growth.

Similarly, Panda et al. (1987) recorded that the higher concentration and uptake of nutrients by grain and straw in rice fields with fish might be associated with the accumulation of fish feces and increased bioperturbation of the soil by fish movements which resulted in nutrients being more available for plant use and accumulation of fish excreta leading to higher organic load in the soil favouring the uptake of iron by rice. On the other hand, Cagauan et al. (1983) stated that fish growing with rice could influence the nitrogen flows in low land irrigated rice fields. Bioperturbation of the soil by fish increases the thickness of aerobic zone that make nutrients more available for plant use. Also Roger (1988) reported that fish grazing on the aquatic biomass contributes to nitrogen accumulation at the soil surface through their feces and the reduction algal biomass by fish grazing on them helps keep the P^H near neutral which in turn reduces ammonia losses by volatilization.

However, the increase in these nutrients could have manifolds, which was not possible because of low amount of fish fingerlings stocked by the farmer in the rice field as a trial. For example, the increase in concentration of organic matter (0.32%) after rice+fish farming recorded in the soil of the present study is much lower than that (0.86% -0.90%) obtained by Uddin (1998).

5.5.2 Pest control

From the Focus Group Discussion (FGD) in the different groups of people, there was a clear indication that integrated rice-fish farming in the study area had a positive impact on pest control. Pest (such as lady beetle, leaf-hoppors, stem-borers, aphids, spider, damsel fly etc) population or insect population was lower during the season in rice-fish system compared to rice-only system without pesticides in the previous year. It may be mentioned that no pesticides were used in the previous year. Since many fish species feed partly on the aquatic fauna, they can act as biological control agent in rice fields. The pest controlling capacity of fish may allow the application of chemical plant protecting agents to be reduced. Literature (Vromant et al., 2002a, b; Halwart, 1994; Ichinose et al., 2002) shows that inducing common carp, being an omnivorous feeder, is the most promising species in controlling pest, insects and snails in the rice field. This was one major fish species used by the farmers in the study area.

Stocking fish in rice fields was not only effective in protecting rice plant from pests, it has also reduced propagation of mosquito in the study area, because fishes feed mosquito larva as their feeding. Such an effect was also reported by Lee and Lee (2003) from a field study involving muddy loach (*Misgurnus mizolepsis*), a small freshwater fish, in Korea. Neng et al. (1995) stated similar experiences with the introduction of different carp species in a rice growing area in China.

Pest control is a very important issue in Bangladesh. Aquatic organisms like frogs, shrimp, crabs, snails, mussels, and even some insects are potentially more important sources of animal protein for rural populations than fish. They too can be enhanced through the elimination of pesticides. However, very little is known about the effects of pesticides on various aquatic organisms. Snails and mussels are known to build up a concentration of pesticides in them. All water organisms are subjected to granular pesticides when they are applied. In most South East Asian countries, these organisms are eaten by farmers. In Bangladesh, they are usually fed to poultry. Ducks, important in Bangladesh, normally feed in the rice paddies on snails and other aquatic plants and animals themselves. Pesticide residues could potentially affect the health and egg-laying ability of the ducks.

5.5.3 Weed control

Rice-fish farming has had a positive effect in weed control in the study area. Labour requirement for weed (such chocha, jolshechi, abali, joldurba, jai gass, colbon, baspata, bagjhar etc) control in previous years was roughly 50 persons/ha with only rice cultivation compared 20 persons/ha in the integrated rice-fish cultivation system. Fishes use weed biomass and by-products available in rice fields as their feed. So the partial control of weeds by fish is possible in rice field. Reduction of weed biomass can help reduce competition for nutrients and raise availability to the rice plants. These are explained in details in Chapter Two drawing references of previous studies and experiments.

The control of aquatic weeds by fish has been demonstrated in a number of studies. Reduction of weed biomass can help reduce competition for nutrients and thereby raise availability to the rice plants (Lightfoot et al., 1992). A reduction of the weed biomass by 39% due to the presence of common carp fry was confirmed by a field trial by Patra and Sinhababu (1995) in India. Rothuis et al. (1999) reported a reduction of submerged and floating weeds, which are readily available as fish feed by up to 100%. Frei and Becker (2005) noted a complete elimination of filamentous algae in rice plots due to the feeding by Nile tilapia and common carp. At low stocking densities, the weed controlling effect of fish may be less, as reported from a field experiment by Piepho and Alkämper (1991). In that study, however, only 60 to 200 fish per ha were present.

The weed controlling effect appears to depend on the feeding characteristics of the specific species of fish stocked. A study on the feeding ecology of fish in rice-fields (Chapman and Fernando, 1994) detected the seeds of grassy weeds in the diets of Nile tilapia and common carp. Macroherbivorous fish species, such as silver barb, may cause damage to rice plants, as this fish feeds not only on grassy weeds, but also on the leafy parts of the rice plant (Rothuis et al., 1998b). This type of detrimental effect is more likely to occur under high fish densities.

5.5.4 Water quality

Direct measurement of water quality parameters was not done. However, indirect qualitative information was obtained from the local people related to water quality. The villagers use water from khals for their domestic purposes. Any odd flavour, bad colour and taste were not observed by them compared to previous years with rice only system. As no pesticide was used for rice-fish cultivation system, there was less possibility for the water to be polluted in the field or khals. With fish removing the weeds and reducing the insect pest population to tolerant level, the possibility of the water quality degradation is further reduced.

5.5.5 Risk to indigenous species

Fish is cultivated in the rice field under controlled environment. So, natural fish migration process from river to khal or rice field are partially hampered during flood the season. The published data of 2004 were compared with the data obtained from FGD in 2007. The field level data summarized in Table 5.20 indicate the reduction of natural fisheries.

Table 5.20 Natural fisheries production

Type of water body	Fish species (local name)	Production (ton), 2004		*Production (ton), 2007
Seasonal flood land	Rui, Katla, Mrigel, Koi, Shing, Magur, Shol, Boal, Taki, Puti, Mola	17.75	18.41	12
Perennial water body		0.66		

Source LGED, 2004a. *Production about 2/3 of previous production which was estimated through FGD.

However, reduced pesticide use will have positive effects on the natural stocks of wild fish which are considered a critical resource for populating the flood plains at the beginning of the monsoon season. The immediate effects of reduced pesticides on capture fisheries as well as its possible effects on the reproductive potential of these stocks, while difficult to measure may be significant.

5.5.6 Biodiversity

The extent of vegetables such as Kolmi, Malancha, Salok, Sapla which are grown in rice field were the same as previous years, as observed by the local people. So, fish did not have any significant negative impact on them.

The farmers also informed that movement of fish in rice field is helpful for pollination of rice. A rice field is known to be the habitat of a diverse assemblage of species (Heckman, 1979; Balzer et al., 2002). Intensification of rice cultivation with an associated increase in chemical pesticide use is reducing this diversity (Fernando et al., 1979). Since rice-fish farming often reduces the need to use chemicals for pest control, this assists in preserving a diverse rice field biota. Utilizing the existing native species for rice-fish culture serves to actively preserve the biodiversity.

5.6 Institutional set up for rice- fish cultivation

5.6.1 Existing arrangement

Institutional arrangement for rice-fish

The flood-prone areas are seasonally flooded during the monsoon and remain submerged from four to six months. Land ownership is fixed according to tenure arrangements during the dry season. However, during wet season floods, individual land holdings are not visible and waters are community property granting all members access to fish in all areas of the community. Consequently, it is seen that the rice-fish culture activity in the flood-prone ecosystem is undertaken by the rural community under a group approach. The villagers of the study area are practicing integrated rice-fish cultivation in seasonally flooded land through Water Management Co-operative Association (WMCA).

The authority of the WMCA gave lease of the seasonally flooded land for a year (from May to December, 2007) to a person for fish cultivation in rice field. The person invested all his money for fish cultivation in the rice field and provided 30% of total profit to the WMCA. WMCA did not supervise and monitor the fish cultivation in the rice field. Profits that were obtained from the leasing system were not equally and fairly distributed among the members of the WMCA; members were partially benefited. All landowners of the flooded rice field were not included as members of the WMCA. Also, landowners who are not members of the WMCA did not get any profit due to fish cultivation in the rice field. But they have a right to get a share of the benefit due to landownership in that flooded land. So conflicts did arise among the members of WMCA and the non-members, and non-members tried to catch or poach fish in their rice field during flood season.

A minimum of 10% (according to constitutions of WMCA) of total general members will be always constituted by landless including traditional fishermen. Landless and traditional fishermen who are not members of the WMCA are also deprived from the benefits of fish culture and natural fish catch. So conflict arises between landless (including traditional fishermen) and WMCA. These kinds of conflicts are potential threats to the sustainability of integration of fish in rice field in the flooded areas.

Arrangement of Water Management Co-operative Association

In the study area, the name of water management association is Balajtala-Kalmadanga Water Management Co-operative Association and it's registration number and the total general members are 00011/05 (registered with Co-operative Department) and 454 (300 men and 154 women), respectively. Constitutions and structures of the WMCA include:

- Minimum numbers of general members of WMCA must be 200 of which 2/3 and1/3 will be men and women respectively. All landowners within the subproject may or may not be included as member of WMCA and there is no restriction for membership.

- There are four committees, viz. executive committee, agricultural sub committee, fisheries sub committee, ward sub committee, and operation and maintenance sub Committee in the WMCA. An organogram of WMCA is given in Figure 5.24
- All committee and sub- committee consist of 12 members (such as Chairman, vice-chairman, Secretary, accountant, member-4 men & 4 women) and 1/3 member will always be women.
- Executive committee is formed within members of the WMCA through election in the present of local government administration and other Committees formed by the Executive Committee.
- Chairman of the Executive Committee is also the chairman of the Operation and Maintenance Committee.
- 1/3rd and 10% of total general members will be always women and landless as well as traditional fishermen, respectively.
- Sup-project area is divided into 9 Ward (not government ward) by the WMCA and 9 ward committees are formed.
- There is monthly fees system and all cash from any income and fees are deposited in a joint account of Chairman and secretary of the executive committee.
- Shares may be offered due to fund collection for special activity.
- All members are collected within the study area, but there is a provision of membership (20%) outside of the study area.
- 33% of any profits are deposited as a fund of the WMCA.
- The WMCA provides loan facility (Tk 500- 50,000 Tk) with 10% interest among the members.
- Fund of deposits is used for small scale repair and maintenance work, and loan purposes.

- Yearly audit are conducted by government authority (Department of Co-operative)

Function of Committees:

(1) Executive Committee: All types of decisions are made through meetings, and financial matters are maintained by this committee. This committee is also responsible for arrangement of meeting, trainings (about agricultural technology, fisheries technology, problems and solution related to rice and fish culture) etc.

(2) Operation and Maintenance sub Committee: Responsible for operation and small scale maintenance of sluice gate, regulator, embankment etc. Fund is used for such type of work from deposit money of WMCA.

(3) Agricultural sub Committee- Responsible for advising the members about modern agricultural practices and solution of problems.

(4) Fisheries sub Committee: Responsible for advising the members about fisheries related technology and problem solution.

(5) Ward sub Committee: Responsible for collection of monthly fees, forecasting of decisions of Executive Committee to the members, making awareness among villagers to be members of the WMCA. Accountant of ward sub committee collects monthly fees and finally all money is deposited in a joint account of chairman and secretary of the Executive Committee.

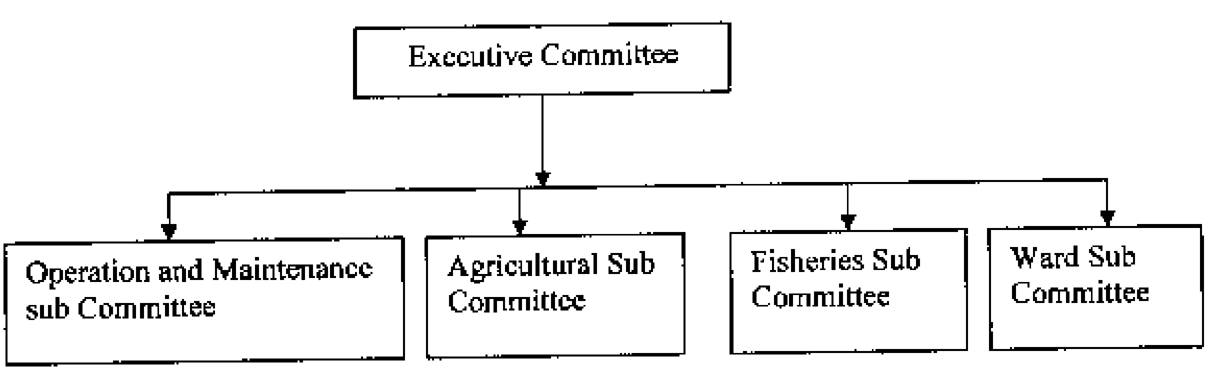

Fig.5.24 Organogram of WMCA

5.6.2 Required arrangement

Institutional arrangement for rice-fish

Arrangements between stakeholders are necessary because of individual land holdings are not visible during flood season floods, and waters are community property granting all members access to fish in all areas of the community. This approach is needed to exploit the resource. The following recommendations that are identified from the villagers are needed for sustainable fish culture in rice field:

- Fish culture in the rice field should be arranged directly by the WMCA, not by any leasing system.
- The WMCA should collect fund for fish culture in rice field by offering shares. Amount of each share should be fixed by the meeting of the Executive Committee. One-third of net profit of fish cultivation should be deposited as a fund of the WMCA. This can be helpful to increase the deposit. Rest of the net profit with share money should be distributed among the share holders
- Share should be made open to both the members of the WMCA and landowners who are not member of WMCA. Many landowners are not members of WMCA although there is no restriction for membership. If a member is not capable to take a share, then another member can take that share. The WMCA should try to motivate them to take share or to be included as members of the WMCA. If those landowners do not want to take share, they should be subsidized with certain amount of money to use their rice fields for cultivation of fish during the flood season. So these systems eliminate conflicts between landowners (who are not members of WMCA) and the members of the WMCA.
- The landless and traditional fishermen are important groups since these people have generally been using such areas either for fishing or other activities to derive their livelihood. The inclusion of these people to meet the labour requirement of the activity in fish cultivation like guarding, harvesting and other related activities can helped them in getting a share of the profit or a job opportunity. One benefit from the inclusion of such people is the elimination of poaching and group conflicts. Likewise, it will increase community bondage.

- In some instances, natural fish should be given to traditional fishermen to sell and make a living. They should also be allowed to catch natural fish that are not cultivated by the WMCA using special type of fishing gears during the flood season. It is also helpful for reduction of predator type natural fish which attack fish fingerlings.

Function of Water Management Co-operative Association

Required organogram of WMCA should be same as the existing organogram of WMCA but rice-fish cultivation system through this organogram should be different. The following additional activity should be done by different committees of the WMCA for sustainable integrated rice-fish farming:

(1) Executive Committee: This committee should be responsible for overall monitoring and supervision, and coordination among different sub committees. This committee should also be responsible for positive awareness growing of rice-fish cultivation.

(2) Operation and maintenance sub committee: This committee also be responsible for operation and maintaining of sluice gate, regulator, embankment, earthen cross dam, fish net (bamboo fence) which are essential for water management in rice field for culturing of fish.

(3) Agricultural sub committee: This snb committee should be responsible for monitoring of any problem related to rice cultivation due to fish cultivation in that field.

(4) Fisheries Sub Committee: This committee should be directly responsible for the fish cultivation activity in the rice field such as fingerlings collection, stocking, rearing, harvesting and marketing etc.

(5) Ward sub committee: This sub committee should be responsible for guarding fish from poaching within their respective areas without any payment, although there must be provision to provide guards with salary for guarding fish.

5.7 Impact on SAIWRPMP

This thesis work has been conducted under the aegis of the South Asian Water Fellowship (SAWA) program of the Crossing Boundaries (CB) Project of IWFM, BUET. The research program of the CB project is being carried out in collaboration with an on-going project of BWDB and LGED so that the research findings have useful contributions to the project, and help enhance sustainable water management in the area. The project is the "Southwest Area Integrated Water Resources Planning and Management Project" (SAIWRPMP), which is co-funded by the Asian Development Bank, the Government of the Netherlands, and the Government of Bangladesh, and implemented by BWDB and LGED (ADB, BWDB and WARPO, 2004). The selected districts in the southwest areas for the project are Faridpur, Gopalganj, Jessore, Magura, Narail, and Rajbari. The selected study region for the research program of the CB project covers the districts of Narail, Gopalganj and Faridpur.

SAIWRPMP

The overall goal of the project is to enhance economic growth and reduce poverty in the project area (ADB, BWDB and WARPO, 2004). It aims at enhancing the livelihood of the rural population by improving the productivity and sustainability of the existing flood control and drainage/irrigation (FCD/I) schemes. This will be achieved through holistic and participatory planning, development, and management of water and strengthening the institutions for delivering the agricultural and fishery services (to the poor population) to address locally identified constraints on agriculture, fishery, and livelihood development. The scope of the project comprises a number of components: (A) preparing participatory integrated water management plans (IWMP); (B) establishing productive and sustainable water management systems through IWMP implementation comprising WMA formation and strengthening with participatory preparation of program implementation plans, water management infrastructure, support services for developing agriculture, fishery, and livelihood enhancement of the poor, and support for establishing sustainable O&M mechanisms; (C) strengthening institutions (including policy and institutional framework and organizational capacities) for effective provision of services to achieve this ends and project management.

Contribution of current research to SAIWRPMP

This thesis work is related to the component B of the SAIWRPMP objectives as outlined above. One potential area identified is the enhancement of livelihood for the poor through integrated rice-fish farming in subprojects backed by proper water management infrastructures and strong and proper water management associations in place. The project acknowledges that fishery yields per hectare in the south west area are relatively low. Capture fishing communities are in decline and families are slipping into ever-increasing poverty. The project emphasizes that that there is considerable scope for improving fishery production as both as economic growth and poverty reduction strategy. To provide benefit to fisheries households, and for development of fisheries in the southwest project area, a fisheries development plan is to be prepared to include a community-based floodplain stocking in the sub-project area. The objective of this component would be to promote improved fisheries management in floodplains by supporting stocking interventions which are managed by and affordable by local people. One of the key means of increasing culture fisheries has been envisioned to be through the adoption of paddy cum fish culture where feasible. The project recognizes that during rainy season, sufficient water is available in all paddy fields for 4-6 months, when fish can be released in inundated paddy fields, which will grow naturally and can be harvested after 4-6 months in the post monsoon.

The thesis work analyzed a recently started integrated rice-fish farming system in the Balajtala-Kalmadanga Sub-project. Using a set of criteria and indicators, the system was evaluated from a sustainability point of view; for example, whether the existing physical systems are suitable for integrated farming practice, whether the new system is able or have the potential to have a positive impact on the socio-economic condition, whether the system will be environmentally sound, and what kind of management infrastructure and water management system are required for the integrated farming system to be sustainable over long periods. The study provides significant insight into the required water management infrastructure (e.g. regulators, water retention structure) and their functions, and how the water flows and levels are to be controlled to provide a favorable condition for integrated rice-fish farming. The study also analyzed the socio-economic benefits that can be achieved through the implementation of the new farming system at its full potential. At present, there are some shortcomings in the management process with the integrated system, including fair distribution of shares and benefits. The benefits are distributed among the members of the WMCA, while the non-members including a large number of land owners, landless poor, traditional fishermen and women do not receive any benefits. This leads to conflicts and discontent among different groups of the community. The study suggests a community based rice-fish farming management system through the WMCA, which would be socially acceptable, and will ensure a fair distribution of shares and benefits among the community members with disparate socio-economic conditions. In sum, the study provides ample information that would help the SAIWRPMP planners to replicate this integrated rice-fish farming and water management systems at other places of the project area, which is one of the key objectives of the project.

Chapter Six

CONCLUSIONS AND RECOMMEMDATIONS

6.1 Conclusions

The conclusions of the study are as follows:

- The water management infrastructures in the project area are conducive to the adoption of the new farming system; hence the integrated rice-fish technology in inundated rice field is technically feasible.
- Critical water levels required for minimization of rice yield reduction and increasing favorable condition for fish culture can be met from the available water in the study area. Standing water depth up to 50% of plant height is recommended during the different growing stages of rice that maximizes yield and increases the favorable condition for fish culture.
- Economic benefits obtained by the community from rice-fish cultivation were more than that they obtained in previous years from rice monoculture. Existing and simulated benefit cost ratio (BCR) for rice +fish cultivation system were 2.18 and 5.11, respectively which was higher than that of ratio (1.78) of only rice cultivation system.
- However, there are immense potentials to increase the yield and production many folds by increasing the stocking of fish fingerlings that is feasible in the study area. The simulated fish yield is 6.20 ton/ha which are very much higher than the existing fish yield, 0.10 ton/ha.
- The integrated farming system is socially acceptable.
- The quality of soils (e.g. organic carbon, organic matter and nitrogen) was enhanced with the introduction of fish in inundated rice field, which is favorable for Boro crops to be followed in the field in the dry season. With increased stocking of fish in future, it is anticipated that soil quality would be enhanced further.

- The integrated farming system improved pest management and weed control, and did not seem to have negatively impacted water quality, indigenous capture fisheries and biodiversity.
- There are some shortcomings in the management process with the integrated system, including community-based fish farming through Water Management Co-operative Association with fair distribution of shares and benefits among land owner, land less, traditional fisher men and women, and if the management processes suggested in the thesis are followed, it will pave the way for more motivation and social acceptability among the community members with disparate socio-economic status, which in turn will help sustain the system.

6.2 Recommendations

Although integrated rice-fish farming is found to be a considerably profitable activity for the farmers, adoption of the technology to date remains far off from the full potential. Further expansion of rice-fish culture is hampered by a number of constraints. Some recommendations are listed below:

- The study was undertaken in an area where integrated rice-fish farming has been only a recent practice, with fish farming being far less than the full potential. Future studies can be undertaken to see different impacts, including that on environmental, in details in a fully developed system.

- Low educational level of the farmers and lack of extension services is a constraint. This is crucial since rice-fish farming requires skills in both rice cultivation and fish-culture management.

- Increased labour and capital requirement, as well as farmers' reluctance to adopt unfamiliar and risky innovations is a constraint. External financial supports are thus needed. NGOs can play a significant role in this regards.

- Technological and infrastructural constraints, such as lack of water control facilities, water retention capacity, loss of fish due to escape, invasion of predatory fish, and unavailability of fingerlings are some of the deterrents in expansion of the farming practice. These constraints can only be overcome if policy makers actively support the integrated rice-fish farming, e.g., through education and extension programmes, or by providing the required infrastructure.

- To ensure availability of quality fish fingerlings/fry in the locality, small pond/khals in the project area can be used as nursery ponds. The fishermen, particularly the women, can earn extra money by rearing fish fry/fingerlings in ponds.

- Locally adapted methodologies need to be developed for specific conditions, such as inundated, irrigated or rainfed environments, as well as for the rotational mode of rice-fish systems, depending on the local economic and environmental setting. If these conditions are met, rice-fish culture can indeed help to save resources, especially water and land, in Bangladesh.

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APPENDIX- A

FGD with agricultural farmer (land own[illegible]

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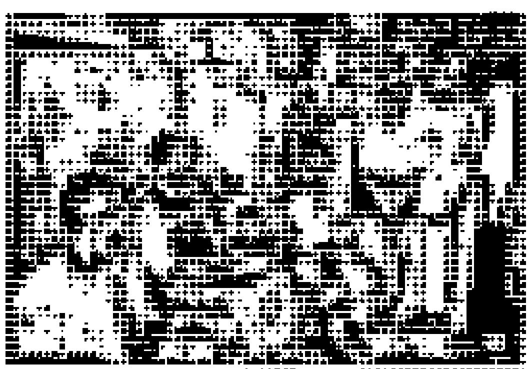

FGD with fishermen

FGD with members of WMCA

FGD with women

APPENDIX- B

A sample of questionnaire (for the leasee):

1. Identification of respondent:

Name of the respondent:	
Occupation	
Age	
Education	
village	

2. How long experience do you have in fish culture in rice field?

3. Have you taken the inundated rice field for fish cultivation through what system?

4. Who is the leasing authority?

5. What is the condition for leasing system?

6. What are the fish cultivation systems that you follow?

Fish species	Fingerlings stocking time	Fingerling stocking size	Fingerling stocked	Loss of Fingerling	Harvest time

7. What is the source of fingerlings?

8. Do you feel any problem to collect fingerlings?
If yes then problems and suggestions

9. What are the sources of feed for fishes in the rice field?

10. What are the yields of fish?

Fish species	Harvested fish size	Harvested fish production

11. What is the harvested fish marketing system?

12. What are different cost items and costs for fish cultivation?

13. What are the different return items and returns for fish cultivation?

14. Do you observe any changes/benefits for fish cultivation in the rice field?
    If yes, then what are the changes?

15. What are the overall problems that you found during fish cultivation?

16. Do you face any problem during flood season for fish cultivation?
    If yes, then what are the problems?

17. Do you think leasing system is good for such type of fish cultivation?

18. Do you have any suggestion to long term sustainability of this type of fish cultivation?

    If yes then what are your suggestions?

Date: Signature of the enumerator

A sample of questionnaire (for the agricultural farmers):

1. Identification of respondent:

Name of the respondent:	
Occupation	
Age	
Education	
village	

2. How long experience do you have in agriculture?

3. What kind of cropping pattern does you practicing in the project area?

Name of cultivated crops		
Kharif-I (March/April- June)	Kharif-II (July-October)	Rabi (Nov.- March)

4. What are the land categories in the project area?

5. What kind of rice varieties are you practicing in different land during monsoon season?

Rice varieties	Sowing/Transplanting	Harvesting	Land categories

6. What are the inputs/cost items and costs for rice cultivation?

Inputs/cost items	Cost (Tk/ha)

7. What are the yields of different varieties of rice?

8. How do you maintain the water in the rice field during monsoon season?

9. What are the operational schedule for earthen dam on khals to manage the water in the field?

Month	Status of earthen dam (open or close)	Reasons

10. What are the water depths that you maintained in your rice field during different growing stages during monsoon season?

Rice variety	Rice growing stage	Duration (months)	Plant height,		Standing water depth	
			High land (F0)	Medium high land (F1)	High land (F0)	Medium high land (F1)

11. Do you observe any benefit/changes occured in the rice field when fish was cultivated in rice field?
If yes, then what are the benefits/changes?

12. Do you think what should be the institutional arrangement/ cultivation system (except leasing system) for fish cultivation in inundated rice field?

14. Why should be such institutional arrangement/ cultivation system?

Date:

Signature of the enumerator

A sample of questionnaire (for the fishermen):

1. Identification of respondent:

Name of the respondent:	
Occupation	
Age	
Education	
village	

2. How long experience do you have in fisheries?

3. What are the types and sources of natural fish in the project area?

Types	Sources

4. What is the natural fish production during this year?

Type of water body	Fish species (local name)	Production

5. Do you observe the amount of natural fish is decreasing day by day in your area? If yes, then what are the reason/factors ?

6. Do you know that the inundated rice fields have given lease to someone for fish culture?

6. Why did you not practice rice-fish culture before?

7. Do you satisfied with this system (leasing system)?
If no/yes, then what are the reasons?

8. Do you agree to culture fish in rice field in future?

9. What should be the fish species for culturing in rice field?

10. What should be functions of water retention structures and regulators regarding fish culture?

9. What should be the institutional arrangement/ cultivation system for fish cultivation in inundated rice field?

10. Why should be such institutional arrangement/ cultivation system?

11. Do you observe any benefit/changes occurred in the rice field when fish was cultivated in rice field?
If yes, then what are the benefits/changes?

Date: Signature of the enumerator