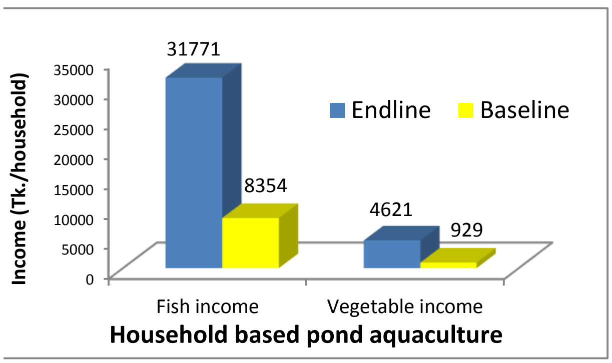
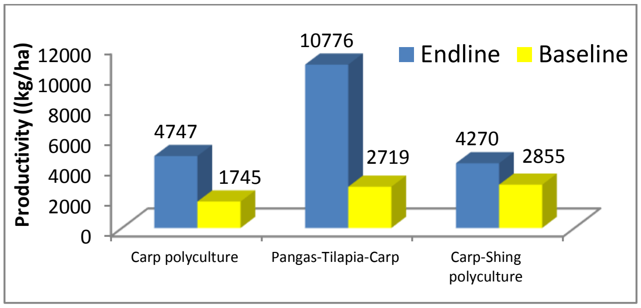
Cereal System Initiatives for South Asia (CSISA) in Bangladesh

AQUACULTURE FOR IMPROVED INCOME, FOOD SECURITY AND LIVELIHOOD: INITIATIVE AND SUCCESS





Performance Report
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Executive Summary

The *Cereal Systems Initiative for South Asia in Bangladesh* (CSISA-BD) was a USAID-funded five year project that began in October 2010 and ended in September, 2015 aiming to increase the household income, food security, and livelihoods of the small and marginal farming households. The project worked out of six hubs: four in Feed the Future influence zone the southwestern and two hubs in northwest and central impoverished and agriculturally dependent regions of Bangladesh. The project aimed to test and disseminate improved farming technologies and varieties in different agro-ecological context of the hubs. Considering the importance of income and nutrition potentials in Bangladesh, aquaculture was included in the cereal system in order to enhance income and diversified nutritious food availability of the farming households. The present study was undertaken to evaluate the performance of different aquaculture technologies along with horticulture activities on the pond and gher dyke and homestead area in six hubs *Khulna*, *Jessore*, *Barisal*, *Faridpur*, *Rangpur*, and *Mymensingh.*

The report aimed to evaluate aquaculture performance in CSISA-BD project covered 2,771 samples; but for Participatory Farmers Trial (Demonstration) and Direct farmers both baseline and endline information were collected applying multistage random sampling technique. Among 2,771 households, 700 were chosen from the project beneficiaries as Demo farmers who received training and critical inputs (fingerlings, feed, etc.) support from the project, and demonstrate the results of the technologies to fellow farmers for wider adoption. Also 1,381 project beneficiaries were selected as direct farmers who received only training from WorldFish and applied the same technology in their resources (Pond/ Gher). Another 690 farmers were selected as controls who didn't received any training from the project and did not participate in any events, and living adjacent the CSISA-BD village or para. In this study, baseline survey and performance data were available and samples were selected randomly; therefore, simple mean difference t-test was used to evaluate the project intervention on fish and vegetable production, per capita consumption, farm income and profit.

Socioeconomic profile indicated that all beneficiaries were within the age range from 35 to 40 years, implying that the beneficiaries were in the middle aged group and the majority of the respondents had completed their primary and secondary level of education. The average family size of the beneficiaries was estimated at 4.9 which is slightly higher than the national average, estimated at 4.49. The average farm size of the Demo and Direct beneficiaries was 186 and 175 decimal, which belonged to small farm group, respectively. Besides, in the case of selected

Demo and Direct farmers', the average pond and gher size was estimated at 40 and 43 decimal respectively.

Per hectare fish production was increased by about three times higher for Demo and Direct farmers in the endline situation due to project intervention for women-managed household based pond aquaculture. However, per household overall income has increased from BDT 9,283 (USD 119) to BDT 36,392 (USD 467) in case of Demo farmers and from BDT 9,508 (USD 122) to BDT 27,130 (USD 348) for the Direct farmers. In case of commercial aquaculture, per hectare fish production was increased in different aquaculture technologies at the endline situation as compared to the baseline situation. Productivity was increased by 2.72, 3.96 and 1.5 times in endline compared to baseline after project implementation for carp polyculture, pangas-tilapia-carp polyculture and carp-shing polyculture systems respectively. Like the productivity increasing trend in household and commercial aquaculture, integrated aquaculture-agriculture (rice-fish-veg in gher) technology provides 1.92, 4.59 and 3.38 times per hectare fish production at the endline scenario for freshwater prawn, tilapia in gher, and rice-fish culture respectively. Farmers were able to increase their earning because of higher productivity, and more income (BDT 106,054 per household) obtained from prawn aquaculture technology in the endline situation where the average gher size was 67 decimal (0.27 hectare) per household. Similar to household and commercial aquaculture, consumption was increased and the results were statistically significant. The project effect on brackish water shrimp aquaculture shows that per hectare shrimp production was accounted 905 kg and 598 kg for Demo and Direct farmers at the endline scenario which was 79% and 51% higher than the baseline scenario.

Enhancing livelihood status was one of the main objectives of CSISA-BD project. Livelihood status can be achieved through higher income and improved dietary option. The previous section showed that the project activities increase the income of the respondents. At the same time, fish and vegetable consumption were increased in different aquaculture technologies and the result was statistically significant, which in turn increased the nutritional dietary plan of households in the study area.

Remarkable progress was achieved in fish production along with vegetable production in the dyke area. As a consequence, small household income was also boosted up which contributed to food availability, reduced food insecurity, and vulnerability of resource-poor people. However, no initiatives proceeded without challenges, therefore, some remedial measures are needed for long term sustainability of the project initiatives.

Chapter 1

INTRODUCTION

1.1 Background

The *Cereal Systems Initiative for South Asia in Bangladesh* (CSISA-BD) is a five-year agricultural development project funded by the USAID. It is one of the USAID Feed the Future (FtF) projects in Bangladesh, which has been implemented through an innovative partnership with three CGIAR centers: International Rice Research Institute (IRRI), International Maize and Wheat Improvement Center (CIMMYT) and WorldFish. The five year project began in October 2010 and ended in September 2015 aimed to test and disseminate improved system based technologies and varieties to increase farming families income, food security, and livelihoods in impoverished and agriculturally dependent regions of Bangladesh. A total of 60,000 farming families (mostly marginal and poor) are targeted to be direct recipients of project interventions. As a consequence, the household income of a given period expected to increase by US $350 per year by the end of the project. An additional 300,000 farming households are anticipated to be benefited from project activities indirectly through participatory farmer's trial/demonstrations, linkage events, extension materials and dissemination of farmer-to-farmer information and technology transfer. Over the last five years of intervention a total of 27,495 Direct and 36,027 indirect participants have benefited, learning new knowledge and skills on improved varieties, newly-developed agronomic practices for cereals, and improved practices for aquaculture.

Aquaculture is expanding faster than any other area of agriculture in Bangladesh (Ali and Haque, 2011). Nevertheless, there is still huge untapped potential to make even greater contributions to food and nutrition security, and to increase and diversify the incomes of poor rural households. WorldFish endeavored under CSISA-BD, therefore pursued major outcomes that are also related to USAID intermediate results. The overall project goals are i) Increased household income and food security; and ii) Increased livelihood alternatives. To attain those outcomes, interventions are primarily aimed at the development and dissemination of improved appropriate varieties and technologies to improve on-farm productivity of freshwater prawn, brackish water shrimp and fish species in gher (an enclosed low-lying rice field with high dyke), low-lying rice field, commercial and homestead pond systems with integration of vegetables on the dikes. WorldFish also worked to test technology and promote culture of nutrient-rich small fish "*mola*" with polyculture of carp species in homestead pond by involving women. These small fish, such as *mola* and *darkina*, are rich in micronutrients- vitamin A, iron, calcium, and zinc, and can make important contributions in reducing malnutrition (Thilsted, 2012). Furthermore, a focus was maintained on targeting women in the promotion of household-based pond aquaculture and vegetables including vitamin 'A' rich orange sweet potato on pond dyke & homestead area for increased production, income and consumption of diversified nutritious food. In addition, capacity-building interventions with a range of stakeholders are aimed at addressing broader constraints in the potential uptake of technologies by the potential market actors.

1.2 CSISA-BD Approach: Dissemination of Improved Aquaculture Technologies and Varieties

In Bangladesh, several extension approaches have been practiced since long ago. Almost all of these approaches share common characteristics that tend to improve farmers capabilities through training and distribution of content-related extension materials. Based on past experience, project personnel have refined and developed a 02 year long comprehensive approach of technology dissemination as illustrated in the diagram below.

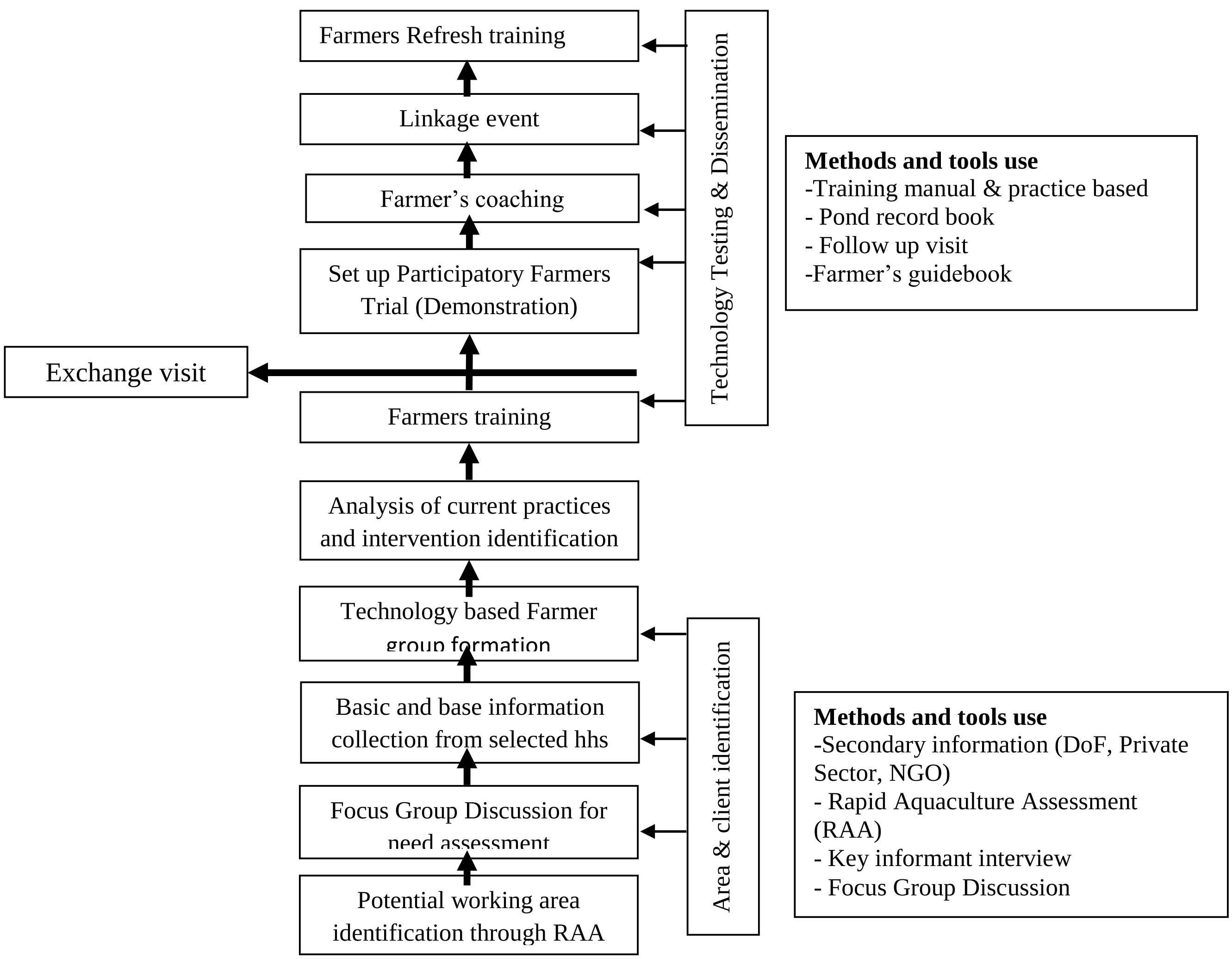


Figure 1.1: Technology dissemination steps and approach

Technology dissemination primarily starts with identification of appropriate location and program participants. Farm households having resources to involve aquaculture activities are selected for CSISA-BD support without consideration of sex, age, religion, caste and race. Despite that priority is given to some particular areas in participant selection for greater interest of program such as enhanced impact, transformation of gender equity, development of future farmers for long-time involvement, etc. Some preferential criteria for farmer selection include: marginal and small farm household mainly dependent on agriculture for their livelihoods, age between 21 to 40 or interested women of the family have ability to be involved in aquaculture, enthusiasm to receive, adopt and disseminate to fellow farming families. Primary selection of farmers is done by implementing partner NGOs staff through home and farm visit. Project staffs prepare the final list of a group of farmers (ideally around 25) following a Focus Group Discussion (FGD) to identify the issues and interventions related to aquaculture and collection of household basic information for baseline.

CSISA-Bangladesh works across four hubs in southwestern Bangladesh — *Khulna*, *Jessore*, *Barisal* and *Faridpur*, and one hub in the northwest *Rangpur* and one in central *Mymensingh* of Bangladesh. Each of these hubs represents an agro-ecological zone with distinct cereal system production problems. The selected districts in four hubs, which are also the focal area of USAID's Feed the Future program in the south, represent the poorest and most risk-prone areas of the country. The selected beneficiaries on the basis of technology are presented in Table 1.1.

Table 1.1: Technology wise beneficiaries household and women participation

Technology in Systems	Beneficiary HH	% of Women
Household based pond aquaculture	4,904	99
Commercial Aquaculture in Pond	13,989	52
Freshwater prawn aquaculture in gher	5,148	49
Rice-fish farming	1,340	10
Brackish water shrimp aquaculture in gher	2,114	30
Total	27,495	35

1.3 Objectives of the Report

Although the overall goal of CSISA-BD project was to increase the farming households income and wider adoption of crop and aquaculture improved technologies, and varieties in Bangladesh, this report deals with only production and income generation of poor farming households through aquaculture and horticulture improved technology dissemination in Bangladesh.

The specific objectives of the report are as follows:

I. To assess the socioeconomic characteristics of the CSISA-BD beneficiaries;

II. To estimate the productivity and profitability from aquaculture and dyke vegetable farming in different system of CSISA-BD beneficiaries households;

III. To evaluate the changes of productivity, profitability, consumption and income of the participating families due to project intervention;

Chapter 2

METHODOLOGY

Methodology is divided into two parts: the data collecting process and the data analysis technique. A short description of the methodology used for this study is presented below.

2.1 Study Area, Sample Size and Sampling Technique

CSISA-Bangladesh project was implemented in four hubs in southwestern Bangladesh — *Khulna*, *Jessore*, *Barisal* and *Faridpur*, and one hub in the northwest Bangladesh-Rangpur and one in central Bangladesh —*Mymensingh*. Each of these hubs represents an agro-ecological zone with distinct agricultural system production problems. The priority districts in the southern hubs are in USAID's Feed the Future focal area, a region that contains some of the poorest and most climate risk-prone areas of the country. The survey to assess the impact of improved aquaculture technologies was undertaken in CSISA-BD intervention from 2012 to 2014. The project implemented five aquaculture systems technologies i.e. household based pond aquaculture, commercial pond aquaculture, freshwater gher farming, brackish water farming and rice-fish farming. For this study, following samples were selected through stratified random sampling.

Table 2.1: Sample size for this study

Technology	Demo	Direct	Control	Total
Household based pond aquaculture	129	250	125	504
Commercial pond aquaculture	375	743	371	1489
Freshwater Gher farming	123	247	123	493
Brackish water shrimp farming	43	81	41	165
Rice-fish farming	30	60	30	120
Total	700	1381	690	2771

1. Demo Farmers: Farmers who received training, coaching, refreshers training etc. and received some portion (20-25%) of required critical input (fingerlings and/or feed, etc.) support from the project, and shared their resources (Pond/Rice field/Gher) and demonstrate their progress of activities, final results and experiences with interested farming families and stakeholders for wider adoption. In the report they will be referred as Demo farmer.

2. Direct Farmers: Farmers who received only training, coaching and refreshers training participated in events like linkage meeting from the project and replicated with the same technology in their resources (Pond/Rice field/Gher)
3. Control Farmers: Farmers who didn't receive any training or other exposure from the project and not participated any events and continued the similar type technology in their resources (Pond/Rice field/Gher) and living adjacent to the trained farmers and CSISA-BD village or *para*

Among a total sample of 2,771 farming families, both baseline and endline information was collected from Demo and direct farmers, but from control farmers only endline information was collected.

2.2 Analytical technique

Both tabular and statistical methods were used to analyze the data. Socioeconomic data were presented mostly in the tabular form. Fish and vegetable productivity were measured in kilogram (kg) per hectare. Farm performance was evaluated on the basis of gross return, gross margin, net return, and benefit cost ratio (undiscounted).

The main purpose of this report was performance evaluation of CSISA-BD aquaculture activities but there is no single statistical method to evaluate the performance of any program or project. In this study, baseline survey and performance data were available, and samples were selected randomly. Consequently, simple mean difference t-test was used to evaluate the project intervention on fish and vegetable production, *per capita* consumption, farm income and profit.

Chapter 3

SOCIOECONOMIC PROFILE OF THE BENEFICIARIES

3.1 Age distribution of the beneficiaries

Age is an important socioeconomic variable in case of agricultural farming; therefore, experience of the farmers has manifold effects on farming practices. Table 3.1 presents the age distribution of two different categories of beneficiaries (Demo and Direct) on the basis of technology adopted. It is found that all beneficiaries of all technologies were within the age range from 35 to 40 years, implying that the beneficiaries were in the middle aged group who had the capability of increasing the income level of the family as well as to make substantial contribution to the national economy. On an average, age of commercial pond aquaculture beneficiaries was relatively higher compared to other technologies (Table 3.1). On the other hand, average age of the household based pond aquaculture farmers was 36, and most of them were women. Considering all technology, average age of beneficiaries was 37 years. It was found that majority of the farmers belong to middle age group (31 to 60 years) followed by young group (less than 30 years).

Table 3.1: Average age of farmers in different aquaculture technologies (Years)

Technologies	Types of beneficiaries		Average
	Demo	Direct	
Household pond based aquaculture	36	36	36
Commercial pond aquaculture	40	39	39
Freshwater prawn in gher	36	37	37
Tilapia in freshwater gher	39	35	36
Rice-fish culture	37	36	36
Brackish water shrimp in gher	38	37	37
All	38	37	37

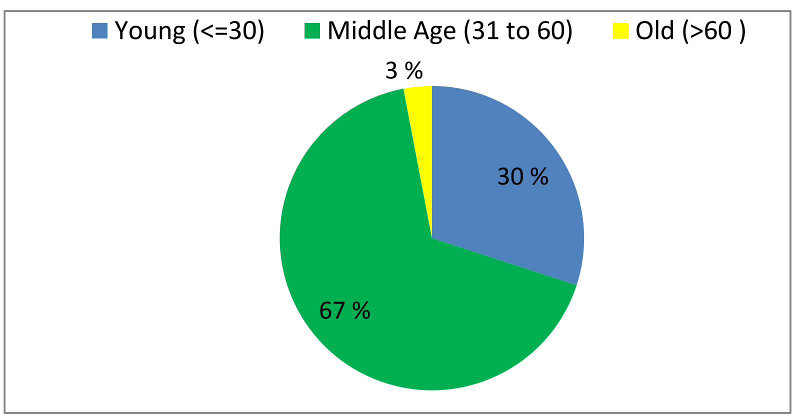


Figure 3.1: Age distribution of the selected farmers

3.2 Family size

Table 3.2 represents the average male-female ratio and average family size on the basis of technology. The average family size of the beneficiaries was estimated at 4.9 which was slightly higher than the national average estimated at 4.49 according to the last survey held by HIES (HIES, 2010). The average family size was higher for the Demo farmers (4.96) in compared to Direct farmers group (4.87). Gender distribution i.e. male-female ratio of the selected Demo and Direct farmers was 100:92, and 100:85 respectively. Therefore, the majority of farmers were male (65%) in the study areas.

Table 3.2: Average family size and male-female ratio of farmers in different aquaculture technologies

Technologies	Types of beneficiaries						Average		
	Demo			Direct					
	M	F	Ave.	M	F	Ave	M	F	Ave.
Household pond aquaculture	2.35	2.28	4.63	2.56	2.25	4.81	2.49	2.26	4.75
Commercial pond aquaculture	2.68	2.42	5.10	2.69	2.33	5.01	2.68	2.36	5.04
Freshwater prawn in gher	2.49	2.25	4.74	2.61	2.14	4.74	2.57	2.17	4.74
Tilapia in freshwater gher	2.64	2.50	5.14	2.07	1.50	3.57	2.26	1.83	4.10
Rice-fish culture	2.68	2.44	5.12	2.70	2.36	5.06	2.69	2.38	5.08
Brackish water shrimp in gher	2.29	2.24	4.54	2.27	2.17	4.44	2.28	2.20	4.47
All	2.58	2.38	4.96	2.62	2.24	4.87	2.61	2.29	4.9
Male-female ratio	100 : 92			100 : 85			100 : 88		

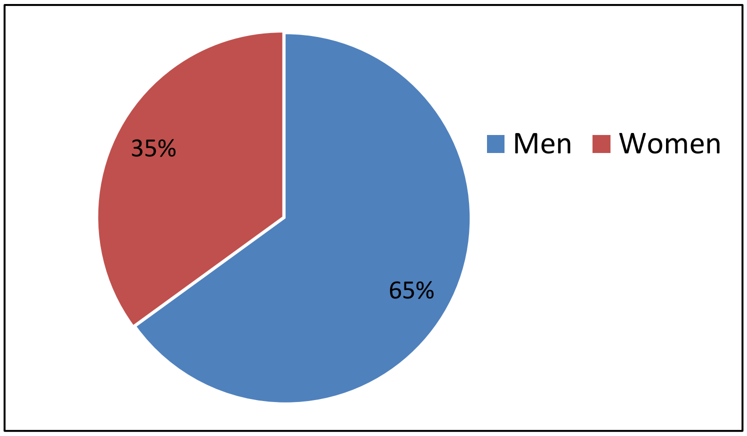


Figure 3.2: Male-female ratio of the selected farmers

3.3 Education status of the beneficiaries

In the case of socioeconomic analysis of any social research, knowing the education status of the respondents or beneficiaries plays a crucial role because education helps comprehension and improves the application of modern technologies in various production processes properly. Table 3.3 shows the average educational status of both groups of beneficiaries. Maximum average year of schooling was found to be 9 years for different production technologies. Generally, it is true that farmers are relatively less educated, and possesses lower socio-economic status. However, experienced and educated farmers judiciously use their farming resources, and capture the maximum benefits. Hence, besides formal education, the prime needs for the farmers are training, access to information on farming practices, and marketing that has been supported by CSISA-BD project. This development intervention could contribute significantly to enhance the capacity of the beneficiaries, and help to improve the socio-economic status. Figure 3.3 shows the selected farmers educational level as a whole. It was found that majority farmers had the primary education (70%) and a very small portion farmers had graduate or above educational capability.

Table 3.3: Average educational level of CSISA-BD selected fish farmers (year of schooling)

Technologies	Types of beneficiaries		Average
	Demo	Direct	
Household based pond aquaculture	7	7	7
Commercial pond aquaculture	9	9	9
Freshwater prawn	8	8	8
Tilapia in Gher	9	9	9
Rice-fish culture	9	9	9
Brackish water shrimp	7	8	7
All technologies	8	8	8

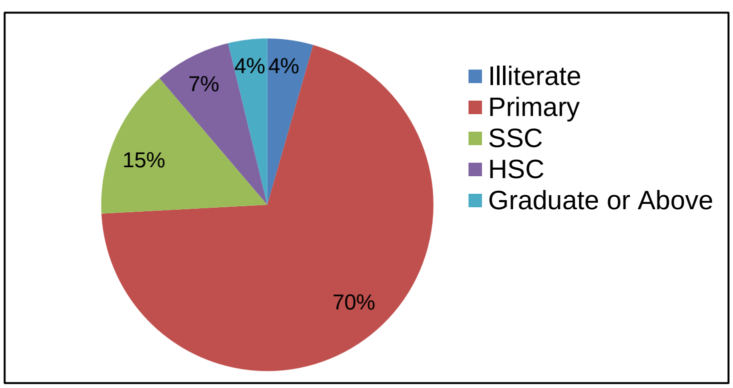


Figure 3.3: Educational status of the selected farmers

3.4 Farm size

Table 3.4 presents the average farm size of two different categories of respondents i.e. Demo and Direct beneficiaries. Here, farm size is estimated as: own land plus rented in/leased in minus rented/leased out (Palash, 2015). It is apparent from the table that the average farm size of the Demo beneficiaries was 186 decimal (0.75 hectare) in which the highest farm size was occupied by rice-fish culture technology 274 decimal (1.10 ha) and the lowest farm size was occupied by household based aquaculture technology 95 decimal (0.38 ha). Similarly, for the Direct beneficiaries, average farm size was 0.71 hectare, and the highest and lowest farm size was occupied by rice-fish culture and household based aquaculture technology respectively. The findings are logical that rice-fish culture technology should have more land area because only this technology is an integrated method of farming rice and fish together. Figure 3.4 shows that a majority of the CSISA-BD participants were small-scale farmers (50-149 decimal of land) and marginal farmers (less than 50 decimal of land), who played a meaningful role in adoption of different aquaculture technologies for boosting farm productivity and profitability.

Table 3.4: Average farm size of CSISA-BD selected fish farmers (in decimal)

Technologies	Types of beneficiaries		Average
	Demo	Direct	
Household based pond aquaculture	95	96	96
Carp polyculture in pond	198	189	192
Pangas-Tilapia-Carp polyculture in pond	221	187	199
Carp-Shing polyculture in pond	229	159	181
Freshwater prawn in gher	226	205	212
Tilapia in freshwater gher	192	155	167
Rice-fish culture	274	272	273
Brackish water shrimp in gher	143	176	165
All technologies	186	175	178

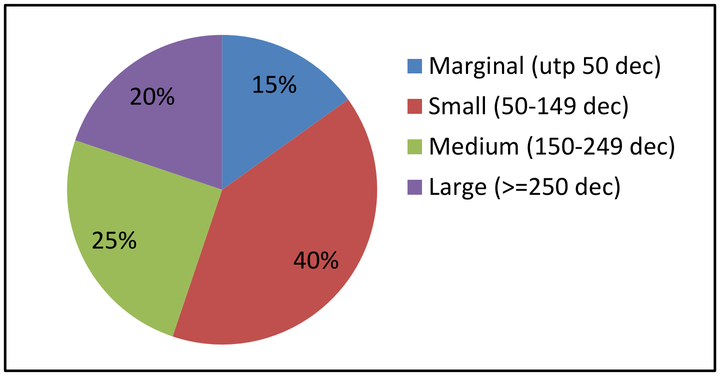


Figure 3.4: Average farm size of the selected farmers

3.5 Pond and gher size of the selected beneficiaries

Pond area is an important variable for applying different aquaculture technologies in the study area. The largest area was depicted for rice-fish culture 90 decimal (0.36 ha) in case of selected Demo farmers whereas the average pond size was estimated at 40 decimal (0.16 ha) for this group (Demo farmers) of beneficiaries (Table 3.5). The result is justifiable because rice field area is typically larger. In the case of Direct farmers, brackish water shrimp farmer had the largest farming area (83 decimal), whereas the average pond size of this group of beneficiaries was only 43 decimal (0.17 ha). It could be the reason that in the rice field area of Direct farmers group hold comparatively smaller land parcel size than that of Demo farmers group. Table 3.5 also shows the comparison of different technologies dyke area. Traditionally in rice-fish system dyke area is lesser than other aquaculture systems. Results show that the average dyke area in percentage form was about 20%, whereas dyke area of rice-fish system was around 12%. Widening the dyke for vegetable production was also the motivation of the CSISA-BD project intervention.

Table 3.5: Average pond / Gher size of CSISA-BD selected fish farmers (decimal)

Technologies	Types of beneficiaries						Average		
	Demo			Direct					
	Water body	Dyke	Total area	Water body	Dyke	Total area	Water body	Dyke	Total area
Household based aquaculture	15	4	19	16	4	20	16	4	20
Commercial pond aquaculture	30	7	37	29	6	35	29	7	36
Freshwater prawn in gher	48	9	57	60	12	72	56	11	67
Tilapia in freshwater gher	30	6	36	31	5	36	31	6	36
Rice-fish culture	80	10	90	55	7	62	63	8	71
Brackish water shrimp in gher	53	8	61	73	10	83	66	9	75
All	33	7	40	36	7	43	35	7	42

Chapter 4

IMPACT OF CSISA-BD INTERVENTION ON PRODUCTIVITY, INCOME AND CONSUMPTION

This section presents the impact of CSISA-BD project on productivity, profitability, household income, and consumption pattern on the basis of technology. It is important to note that CSISA-BD project implemented for the development of five different aquaculture systems namely; (i) household based pond aquaculture (Household based pond aquaculture has two species combination i.e. only carp polyculture and polyculture of carp with mola; in both cases many farmers also stocked tilapia), (ii) commercial pond aquaculture. Commercial pond based aquaculture has three different species combination i.e. carp polyculture, pangas-tilapia-carp and carp - shing polyculture, (iii) freshwater gher farming/aquaculture (freshwater prawn + carp polyculture, and two cycle tilapia culture in gher), (iv) brackish water gher aquaculture and (v) rice-fish farming.

Pond cultivation is the mainstay of aquaculture in Bangladesh which contributes about 86% of total aquaculture production, and 58% of culture area is being used as pond (DoF, 2012). In 1986, pond area was about 146 thousand hectare, increasing to 371 thousand hectare in 2011. At the same time, tremendous progress has occurred in pond fish productivity i.e. pond average productivity increased from 900 kg/hectare to 3,616 kg/hectare (DoF, 2012). Consequently, total production reached in 1,342 thousand metric tons in 2012 from 145 thousand metric tons in 1986 with annual growth rate about 7.5%. Traditionally, every household at village level has at least one pond in Bangladesh, and pond culture is commonly practiced in nearly every district of the country. Estimates suggest that about 4.27 million households in Bangladesh own a pond, and these account for 29.5% of aquaculture area of Bangladesh (Belton & Azad 2012). Although, pond culture was only homestead based until the mid-nineteen nineties, it became commercial due to technological innovation and increased fish demand. In addition, fish production is a more profitable practice than many other forms of agriculture. For example, the gross return of a hectare of land growing a combination of *Pajam* and BRRI *Dhan* 29 rice is BDT 81,098. In comparison a hectare of pond land devoted to carp polyculture returns BDT 194,231 (Mohsin *et al*., 2012). In order to meet the domestic fish demand for the growing population, governments of Bangladesh and different NGOs have taken different initiatives to increase the pond fish production. These initiatives contributed positively to the expansion of aquaculture area and the productivity. On the other hand, due to an overall high profitability in fish farming compared to rice, farmers are highly motivated to culture fish in many parts of Bangladesh. The process of converting rice areas into ponds started at least two decades ago for freshwater fish ponds and more than two decades for shrimp production. The main expansion has, however, taken place in the pond area. In 2010, WorldFish has taken an initiative for increasing pond fish productivity and increase income through USAID funded CSISA-BD project for both homestead based and commercial pond aquaculture. This section represents the cost-benefit analysis and impact of CSISA-BD project on productivity, profitability, income, and consumption of homestead based and commercial pond aquaculture.

4.1 HOUSEHOLD BASED POND AQUACULTURE AND HORTICULTURE

In rural Bangladesh, every household has a small or medium sized pond (Belton et al., 2011). When the household owner constructs a house, the basement of the house needs to be made higher than the surrounding area to protect the house from flooding in the rainy season. A large number of rural households have homestead area that includes ponds and ditches. These ponds may vary from 5 to 20 decimals in area and are traditionally farmed by the owners or sometimes remain fallow due to poor knowledge about improved aquaculture management. Homestead aquaculture means that these typically fallow ponds are brought under fish farming as enterprise. These ponds actually have potential to rear micro-nutrient dense small indigenous fish such as mola (*Amblypharyngodon mola*) along with carps and tilapia. As part of CSISA-BD objective, WorldFish has been working with “homestead pond aquaculture and horticulture technology” to improve the nutritional status and income of small and marginal farmers by increasing production of diversified nutritious food like fish and vegetables. The homestead based activities considered best suited for women of rural Bangladesh, most of whom have a lack of alternative livelihood options and productive activities. CSISA-BD WorldFish initiated homestead pond aquaculture and horticulture by engaging women of the participant families. The poor farmers use their limited homestead land and pond dykes to cultivate vegetables and produce fish for consumption and income by selling additional produce. These farmers require mainly appropriate culture technology, quality inputs (seed, feed etc.), linkage with the stakeholders and market to boost their production and income. From 2010 to 2015, CSISA-BD WorldFish trained 9,672 women farmers and established 1,107 participatory farmers trial Demo for increasing productivity, consumption and income.

4.1.1 Maximum potential possibilities from household based pond aquaculture system

In Bangladesh household based pond aquaculture is traditional, but has the potential to increase productivity through the active participation of women. Figure 4.1 shows the changes of per hectare fish production of household based pond aquaculture during the development interventions. Development interventions were initiated through CSISA-BD project to increase productivity of fish farming in the selected areas. Understandably, there is a direct linkage of increasing household income with the increase of fish productivity of the farmers. Two technologies were practiced in the study area; specifically these were carp polyculture system and polyculture of carp with *mola*.

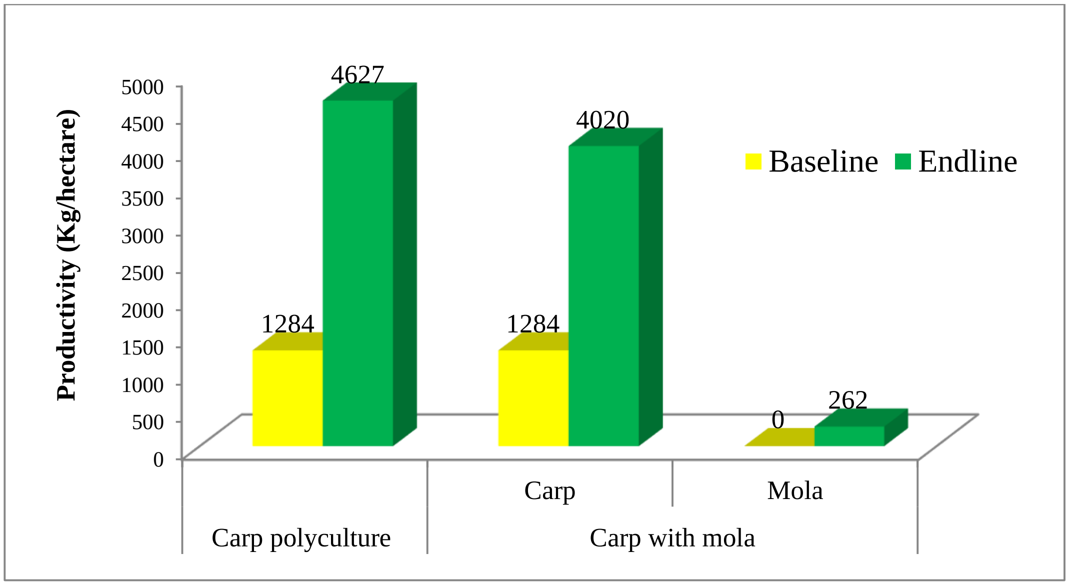


Figure 4.1: Productivity changes due to intervention

After project interventions, per hectare fish production was increased by about three times (Figure 4.1). The Demo farmers produced the highest amount of fish per hectare, since they received some portion of critical inputs like fingerlings and/or feed along with regular technical supports like training and coaching from the project. It is worth noting that the value both in terms of retail cost per kg and the nutritional benefits of the carplet *mola* are relatively greater than those of carp. Profitability issues are discussed below, in section 4.1.3. Besides, the fish productivity of the Direct beneficiary group was also increased significantly which implies that access to service, information, input, and appropriate technical support had a positive impact on fish productivity.

4.1.2 Effects of intervention level on productivity

This section describes the effects of intervention on productivity on the basis of extent of intervention where species combination is not considered. Every Demo farmer was under regular supervision of CSISA-BD project, and received some portion (around 20-25%) of required critical inputs support. Figure 4.2 reveals that productivity was increased with the extent of intervention. Demo farmers were able to increase per hectare fish production by 29% (4,723 kg per hectare) in comparison to Direct farmers (3,676 kg per hectare). This implies that if poor fish farmers get some critical input supports, then they can significantly increase fish production. On the other hand, Direct farmers were able to increase productivity by 60% compared to Control farmers, implying that when farmers get technical services like training and supervision or extension service, these can result in significantly enhanced fish productivity. Figure 4.2 also reveals that if farmers get training, extension service, and better access to market, then they can increase fish production by 2 times than the present situation.

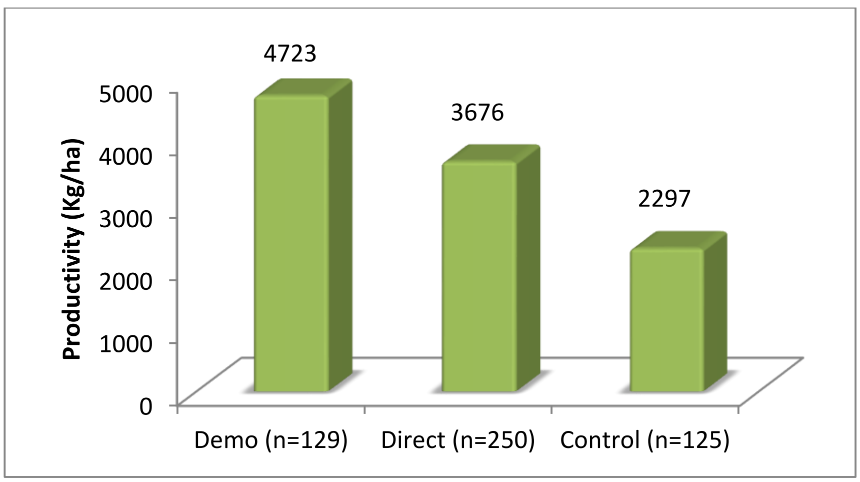


Figure 4.2: Fish productivity on the basis of extent of intervention

4.1.3 Cost-Benefit and profitability analysis of household based pond aquaculture

Cost-benefit and profitability of household based pond fish farming was estimated on the basis of level of intervention of CSISA-BD project. In case of household based pond aquaculture, Demo and Direct beneficiaries adopted two types of species combination such as carp polyculture and carp with *mola* polyculture; in many cases farmers also stocked tilapia within those polyculture systems. *Mola* is a small fish species, but it has higher market price and better nutrition value compared to many other fishes. *Amblypharyngodon mola* is herbivorous fish and phytoplankton is the basic food group for this fish species (Gupta and Banerjee, 2013). Results reveal that fingerling and feed were the major cost items in different fish production technologies (Figures 4.3 and 4.4). Labor cost was found to be the third most important cost item for household based pond aquaculture practices. On an average, fingerling cost was the major cost of all types of fish farming except carp polyculture of Demo farmers where feed was the major cost item. In fact all those farming practices were based on improved extensive culture practices whereas Demo farmers received some local agro byproduct as feed from the project. Total cost was higher for carp polyculture of Demo beneficiaries and lower in the Control group. If we consider the Benefit Cost Ratio (BCR) level of each fish farming technologies of different beneficiaries, the BCR was higher for carp with *mola* farming (Direct beneficiaries) because of higher revenue with minimum production costs. Overall, farmers who cultured *mola* got the higher total revenue as well as earned higher profit in case of both Demo and Direct farmers (Table 4.1). Therefore, it can be concluded from cost-benefit analysis that low cost agriculture byproduct based carp polyculture with *mola* fish species was more beneficial for the small-scale pond fish farmers in Bangladesh.

Table 4.1: Cost-benefit Analysis of Fish (BDT/ hectare)

Item	Demo		Direct		Control
	Carp polyculture	Carp with *mola*	Carp polyculture	Carp with *mola*	
Labor cost	14,461	12,036	8,815	6,584	4,739
Fingerling cost	115,872	123,722	81,990	92,132	60,832
Feed cost	155,375	118,794	66,908	86,144	44,412
Fertilizer cost	8,708	11,848	5,740	10,098	4,180
Other cost	10,002	9,387	10,220	7,311	3,361
Cost of fish production	304,418	275,787	173,673	202,269	116,693
Cost of vegetable production	9,385	8,993	8,530	8,577	5,256
Total cost of farming	**313,803**	**284,780**	**182,203**	**210,846**	**121,949**
Revenue from fish	560,564	567,310	352,644	434,579	235,406
Revenue from vegetable	48,161	46,750	44,376	45,155	12,852
Total revenue from farming	**608,725**	**614,060**	**397,020**	**479,734**	**248,258**
Profit	294,922	329,280	214,817	268,888	126,309
BCR	1.93	2.16	2.18	2.27	2.03

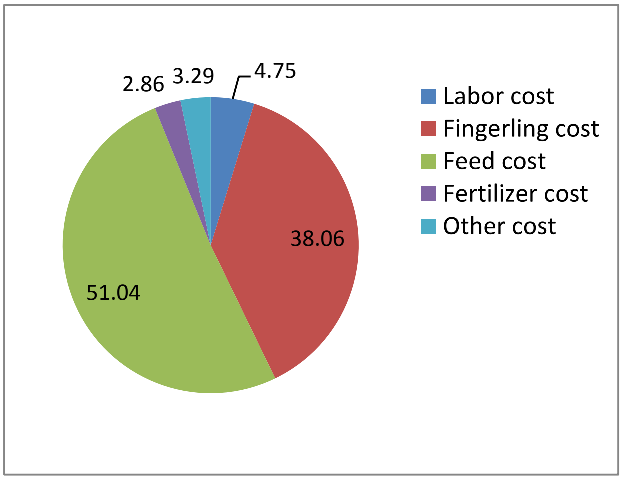


Figure 4.3: Percentage contribution of different cost item for carp polyculture system

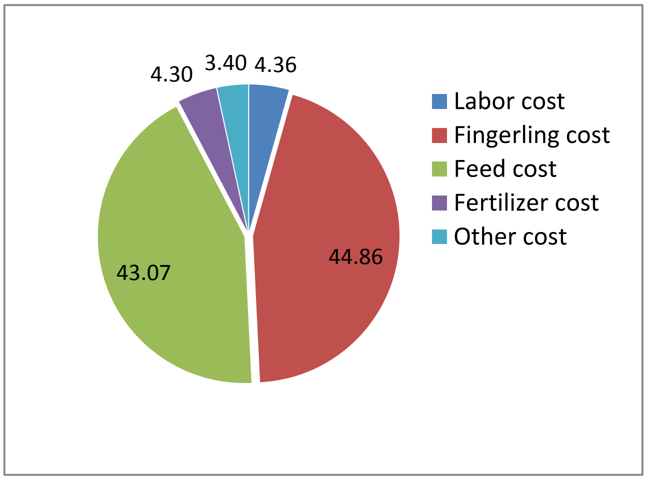


Figure 4.4: Percentage contribution of different cost item in carp with *mola* culture system

Farmers also produced different types of vegetable in the dyke of ponds. It is worthwhile to note that about four times higher profit was estimated for Demo and Direct farmers in comparison with Control farmers in the case of vegetable production (Table 4.1). The results were in line with fish production revenue, so both forms of farming can be considered as profitable enterprises if proper technical assistance is available. Finally, a simple intervention like technical support and linking market can enable rural poor and marginal families enhancing household based pond aquaculture systems productivity, which might bring greater benefits to those families.

4.1.4 Household level financial gain

In this study, income means the monetary value of produced fish and vegetable which was calculated by multiplying the total amount of production (sold plus consumed) by the average market price of that product. Accordingly, income was calculated per household basis (only considering per household pond area which was 19 and 20 decimal for Demo and Direct farmers respectively) instead of per hectare basis to see the changes of overall household income strength during project interventions.

Table 4.2: Effects on household income (BDT/pond size/household)

Situation	Fish		Vegetable		Overall income	
	Demo {n=129}	Direct {n=250}	Demo {n=129}	Direct {n=250}	Demo {n=129}	Direct {n=250}
Endline	31,771	24,176	4,621	2,954	36,392	27,130
Baseline	8,354	8,563	929	945	9,283	9,508
Change	23,417 (20.55)	15,613 (14.11)	3,692 (5.99)	2,009 (5.19)	27,109 (19.47)	17,602 (14.86)
Control	12943		420		13362	

Figures in the { } indicate the number of samples and figures in the ( ) indicate t-value

Table 4.2 reveals that income from fish was increased by about four and three times for Demo and Direct farmers respectively after the project interventions. On the other hand, beneficiaries were trained for vegetable production, and a notable change was achieved in vegetable income. After project interventions, beneficiaries were able to earn manifold income from the dyke and homestead area of the pond. The overall endline income of the Demo household was BDT 36,392 (USD 467) whereas baseline income was BDT 9,283 (USD 119) (income from 19 decimal of pond area consisting of 15 decimal for water body and 4 decimal for dyke area), and the income change (BDT 27,109 or USD 348) was statistically significant. Accordingly, overall endline income for the Direct farmers was BDT 27,130 (USD 348), compared to baseline income of BDT 9,508 (USD 122) and the change of income of the family was BDT 17,602 (USD 226). In both cases the change was significant at the $p<1\%$ level. Moreover, Direct farmers income derived from 20 decimal of pond area in which 16 decimal for water body and 4 decimal for dyke area. On the contrary, per household income of the Control group farmers were more than the income at the baseline situation of Demo and Direct beneficiaries, but less than the income of the endline situation of those beneficiaries. Therefore, it can be regarded that the project intervention has significant positive effect to increase the household income in the study area. It is noted that, all household based pond aquaculture project beneficiaries were the women participants; therefore, women family members made the contribution to increase household income which in turn increased their empowerment in the family.

4.1.5 Utilization pattern of fish and vegetable of CSISA-BD beneficiaries

Figure 4.5 shows the changes in fish and vegetable sales and consumption per household before and after project intervention. Fish consumption was slightly increased (14%) after project intervention. However, per household vegetable consumption was increased dramatically (150%) which in turn improved the nutritional dietary plan of the household in the study area.

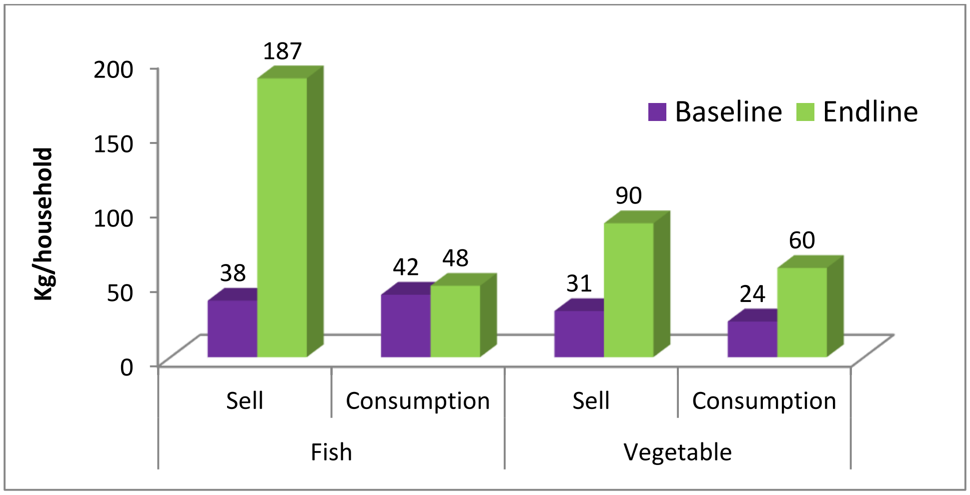


Figure 4.5: Changes in fish and vegetable utilization pattern

Likely, in case of selling to the market, positive changes were estimated which was 392 % and 194 % higher for fish and vegetable selling after project intervention respectively. It can be concluded that project intervention certainly contributes to increase the selling and consumption of fish and vegetable of the farmer's household.

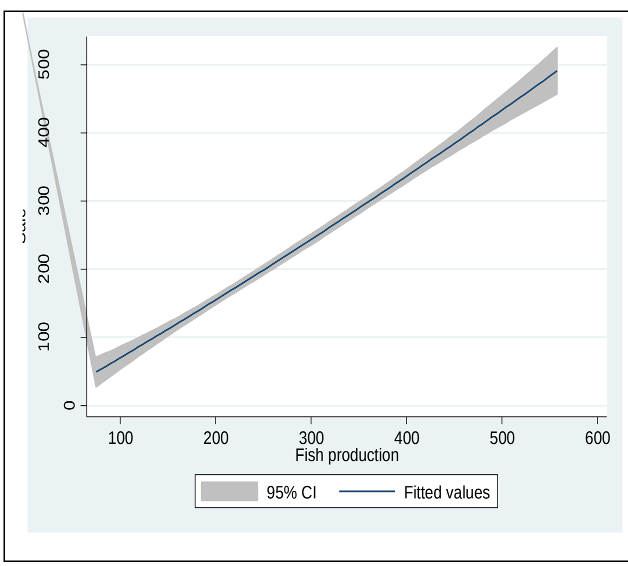


Figure 4.6: Relationship between fish production and sale

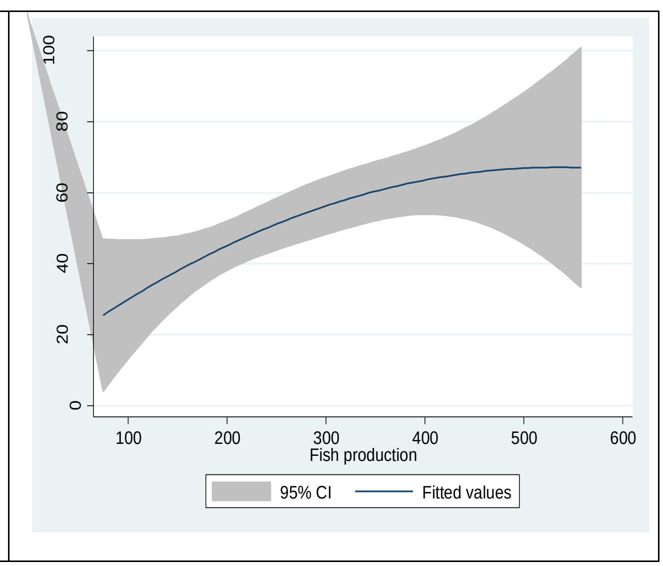


Figure 4.7: Relationship between fish production and consumption

This section discusses the relationship of fish production with fish selling and consumption. Figure 4.6 and 4.7 presents the relationship of fish production with selling and consumption at 95 % confidence interval level. Generally, fish selling and household fish consumption were increased with the increase of fish production. Despite the fact that household based pond aquaculture was mainly aimed to increase family consumption, participants showed greater interest in selling fish with increased production. Fish consumption of the family increased some extent with increased production, but the rate of consumption change was not increased proportionately with production increase trend. In reality, household has also certain level of consumption requirement based on economic status, and probably nutrition awareness. This implies that after project implementation, farmers showed the tendency of taking aquaculture as an income-generating activity with value that is dependent on productivity.

4.2 COMMERCIAL POND AQUACULTURE

Commercial aquaculture has been started few decades ago in Bangladesh. It has two main characteristics: first, use of semi-intensive to intensive technologies and quality inputs (seed, feed etc). Enterprising farmers adopted stocking more fingerling per unit area, feeding with commercially produced pelleted feed, and use of other inputs in appropriate and scientific ways. The second characteristic is that the famer’s main purpose of commercial aquaculture is to sell the product in the market with highest possible margin. Generally, a pond or gher is used for commercial aquaculture. Aquaculture in Bangladesh is dominated by polyculture system in which more than one species of fish are raised at the same time in a grow-out system like pond. Carp fish polyculture is the oldest and still widely practiced in Bangladesh. In carp polyculture system, farmers commonly use 6 – 7 carp species including Indian major carp such as Catla (*Catla catla*), Ruhu (*Labeo rohita*), Mrigal (*Cirrhina mrigala*) etc. with some exotic especially Chinese carp species such as Silver carp (*Hypophthalmichthys molitrix*), Grass carp (*Ctenopharyngodon idella*), Common carp (*Cyprinus carpio*) etc. and other minor carp species that include Silver barb (*Barbonymus gonionotus*), Bata (*Labeo bata*) etc. Traditional carp polyculture takes at least seven months to get return which is somewhat longer than most other forms of aquaculture practices. Farmers were struggling to harness full production potential due to the seasonal nature of the ponds hence the lower water depth and low temperature during some part of culture period from December to March. As a result, fish production does not reach up to the full potential due to lack of suitable species combination especially with fast growing species. Considering the context, CSISA-BD, WorldFish has standardized fast growing Genetically Improved Farmed Tilapia (GIFT), Shingi (*Heteropneustes fossilis*) and Thai pangas (*Pangasius sutchi*) into the carp polyculture system aiming to diversify, and achieve reasonable returns within short duration.

4.2.1 Effects of CSISA-BD intervention on commercial pond productivity

Overall impact of the project intervention on fish productivity is presented in Table 4.3. Particularly, results show the changes of fish production using different aquaculture technologies, contrasting the baseline and endline situations.

Table 4.3: Overall impact on fish productivity on the basis of aquaculture system (Kg/hectare)

Types of commercial farming	Fish production		
	Endline	Baseline	Change
Carp polyculture {n=275}	4,747	1,745	2,714 (21.68)
Pangas-Tilapia-Carp polyculture{n=82}	10,776	2,719	8,059 (8.15)
Carp-Shing polyculture {n=46}	4,270	2,855	1,415 (3.52)

Figures in the { } indicate the number of samples and figures in the ( ) indicate t-value

Per hectare fish production was increased in different aquaculture technologies at the endline situation compared to baseline situation. Productivity was increased by 2.72, 3.96 and 1.5 times in endline compared to baseline for carp polyculture, pangas-tilapia-carp polyculture and carp-shing polyculture system respectively. Accordingly, maximum fish productivity was depicted under pangas-tilapia-carp polyculture (10,776 kg/hectare) in the endline situation. It is apparent from data presented in Table 4.3 that changes of fish production were found to be statistically significant at 1% level for all three commercial aquaculture technologies.

Figure 4.8 describes the effects of CSISA-BD intervention on productivity on the basis of extent of intervention. Although different types of species combination were considered in the project, we have discussed these in general terms. Demo farmers were able to increase fish production by 39% compared to Direct farmers. This result implies that if pond fish farmers get some critical inputs supports, and access to market for technical information, then they can increase fish production significantly. On the other hand, Direct farmers were able to increase productivity by

78% as compared to Control farmers, implying that when farmers get minimal technical services like training and supervision or extension service, they can also enhance the fish productivity significantly.

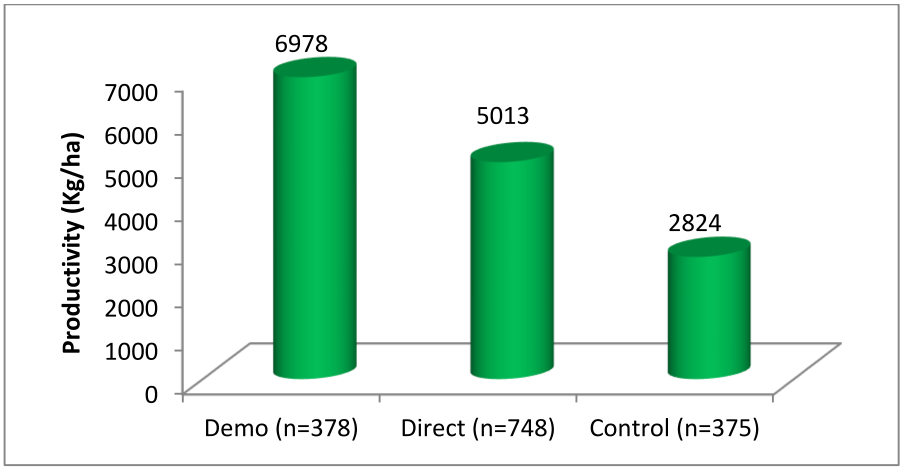


Figure 4.8: Impact of extent of intervention on commercial pond productivity

4.2.2 Cost and Return of Commercial Pond Aquaculture

The main objective of the project was to increase the farming household income through fish production; therefore, cost and return and BCR of fish were calculated of different beneficiaries groups. Generally, many species are cultured simultaneously in Bangladesh for commercial aquaculture but CSISA-BD project considered three species combinations of aquaculture practices such as carp polyculture, pangas-tilapia-carp polyculture and carp-shing polyculture in pond system. Table 4.4 shows the profitability analysis of fish production which was standardized in BDT per hectare. The major cost items of fish farming were fingerlings and feed in commercial aquaculture in pond for all type of species combination during different project intervention level; specifically in the case Demo farmers group, feed cost was 41%, 74%, and 50%; and fingerling cost was 42%, 22%, and 38% of total variable cost for carp, pangas-tilapia-carp, and carp-shing polyculture respectively (Figure 4.9). Feed cost was 5.3 times higher for pangas-tilapia-carp polyculture system compared to carp polyculture system for Demo farmers, and it was 2.6 times higher for carp-shing system. Total production cost was so high for pangas fish farming because it requires huge amount of commercial feed which incurred the higher feed cost as well as increase the production cost. Per hectare production cost was estimated BDT 202,711 (USD 2599); BDT 595,287 (USD 7632) and BDT 429,235 (5503) for carp polyculture, pangas-tilapia-carp polyculture and carp-shing polyculture system respectively for the Demo farmers.

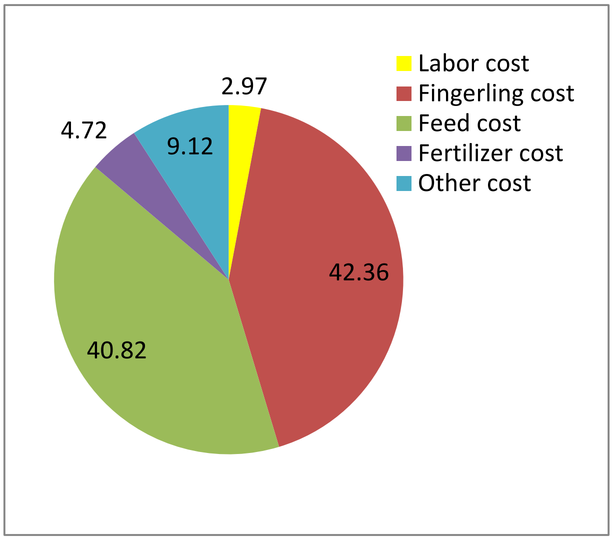
Like production cost, total revenue of Demo farmers was also higher for pangas-tilapia-carp polyculture under all beneficiaries group. Total revenue was 2.2 and 1.12 times higher in pangas-tilapia-carp polyculture system compared to carp polyculture and carp-shing polyculture system respectively (Table 4.4).

A similar pattern of changes was observed in case of Direct and Control group farmers for fingerling and feed cost ratio with total production cost as well as total revenue comparison of pangas-tilapia-carp polyculture with carp and sarp-shing polyculture. In all levels of project intervention, pangas-tilapia-carp required higher input cost and provide more revenue; but the BCR was low in compare with other species farming practices.

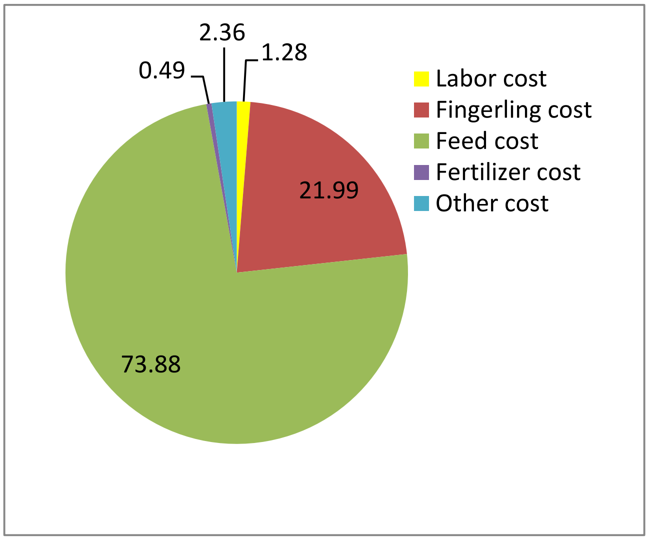
Now, the question is about the feasibility of pangas-tilapia-carp fish farming which requires more investment, but also gives more return? The question can be addressed by looking at the BCR value in Table 4.4. The results show that BCR was not higher (1.64) for pangas-tilapia-carp farming of Demo farmers indicates comparative efficiency may not be better even though total volume of production and profit may higher. In contrast, BCR was higher for improved extensive to semi-intensive carp polyculture of Demo beneficiaries (2.19) implying better efficiency of the used resources compared to intensified aquaculture like pangas-tilapia-carp farming practices. However, selecting commercial aquaculture technologies might be a challenge for the subsistence and small-scale farmers. As a consequence, it can be concluded that small scale farming households who do not have sufficient capital or ability to invest more money can still practice improved extensive to semi-intensive type of carp polyculture to maximize the return from limited resources, but the farmers who have the capacity to invest more money can be involved in intensified aquaculture such as high density of pangas-tilapia-carp species combination.

Table 4.4: Cost-Benefit analysis of different types of commercial pond fish polyculture (BDT/ hectare)

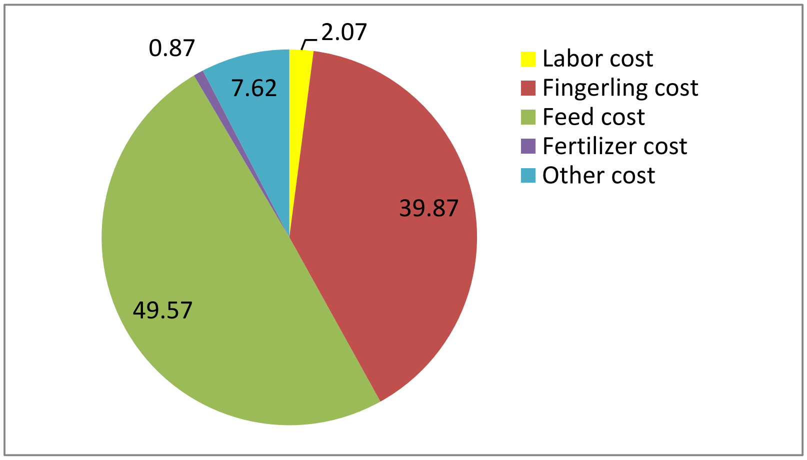
Item	Demo **{n=378}**			**Direct {n= 748}**			**Control {n=375}**		
	Carp polyculture	Pangas-Tilapia-carp polycultu re	Carp-shing polycultu re	Carp polyculture	Pangas-Tilapia-carp	Carp-shing polyculture	Carp polyculture	Pangas-Tilapia-carp	Carp-shing polyculture
Labor cost	6,027	7,628	8,865	5,278	5,236	3,605	3,727	4,133	4,885
Fingerling cost	85,875	130,875	171,153	65,177	93,899	122,008	46,364	86,432	103,473
Feed cost	82,753	439,816	212,785	56,982	273,734	140,961	29,158	147,846	82,700
Fertilizer cost	9,565	2,911	3,715	8,491	3,783	3,018	4,633	3,199	2,140
Other cost	18,491	14,057	32,717	16,182	15,712	24,111	11,048	13,633	25,208
Total cost	**202,711**	**595,287**	**429,235**	**160,935**	**396,588**	**309,906**	**100,638**	**261,648**	**239,927**
Total revenue	**444,202**	**974,334**	**866,727**	**341,957**	**683,885**	**498,533**	**184,483**	**389,952**	**356,731**
Profit	241,491	37,9047	437,492	181,022	287,297	188,627	83,845	128,304	116,804
BCR	2.19	1.64	2.02	2.12	1.72	1.61	1.83	1.49	1.49



(a) Carp polyculture



(b) Pangas-tilapia-carp polyculture



(c) Carp-shing polyculture

Figure 4.9: Percentage of different cost items in different species combinations

4.2.3 Household level financial welfare of commercial pond farming

One of the major objectives was to estimate the household income effect in different aquaculture practices. Hence, income was calculated per household basis instead of per hectare basis to evaluate the changes of overall household income strength during project intervention. The different beneficiary farmers were moving from subsistence level farming to commercial level farming by selling their product along with their daily consumption.

Table 4.5: Impact on fish income on the basis of aquaculture system (BDT/pond size/household)

Types of commercial farming	Fish production		
	Endline	Baseline	Change
Carp polyculture {n=275}	55,142	20,829	34,313 (21.57)
Pangas-Tilapia-Carp polyculture {n=82}	142,323	38,791	103,532 (8.02)
Carp-Shing polyculture {n=46}	95,198	38,616	56,582 (7.02)

Figures in the { } indicate the number of samples and figures in the ( ) indicate t-value

Table 4.5 shows that fish income was changed significantly due to project intervention. Changes of fish income from fish culture were statistically significant at 1% level for all three commercial aquaculture technologies. Results justified the importance of project intervention in the study area. Accordingly, more fish income obtained from pangas-tilapia-carp polyculture technology in the endline situation that means 36 decimals of pond area of a household provide BDT 142,323 (US$ 1825) per year. At the same time, the income was BDT 55,142 (US$ 707) and BDT 95,198 (US$ 1220) for carp and carp-shing polyculture from the same amount of land respectively.

4.2.4 Changes in fish utilization of commercial farmer

Table 4.6 shows the changes of fish sale and consumption pattern per household before and after project intervention. Fish consumption was increased in different aquaculture technologies, and the result was statistically significant. It indicates nutritional status or food security has enhanced in the study area after project implementation. On contrary, fish selling was increased significantly at 1% level. The major amount of fish sold to the market from pangas-tilapia-carp polyculture adopted farmers group, and it was 1,368 kg/household. Alongside, consumption change was highly noticeable in three group of aquaculture practices. Increased productivity influenced increased consumption in intensified commercial form of aquaculture; consumption was changed 43% and 111% for pangas-tilapia-carp and carp-shing polyculture respectively. However, in the case of carp polyculture system change of consumption was only 18%.

Table 4.6: Impact on fish utilization pattern (kg/household)

	Sell			Consumption		
	Baseline	Endline	Changes	Baseline	Endline	Changes
Carp Polyculture {n=275}	131	449	317 (24.56)	55	65	10 (3.15)
Pangas-Tilapia-Carp polyculture {n=82}	270	1368	1098 (8.56)	63	90	27 (2.76)
Carp-Shing polyculture {n=21}	235	451	216 (5.97)	47	99	51 (3.24)

Figures in the { } indicate the number of samples and figures in the ( ) indicate t-value

4.3 INTEGRATED AQUACULTURE-AGRICULTURE (Freshwater Gher*) SYSTEM

In the early 1960s, the Bangladesh Government constructed a large number of embankments in the coastal area to protect agricultural land from tidal waves and saline water intrusion (Yasmin *et al.* 2010). This initiative made vast saline areas suitable for rice cultivation. Later on, thousands of rice farmers converted their paddy fields to brackish water shrimp (*Pennaeous monodon*) culture due to its strong demand in the international markets and its high price, as in as gher shrimp culture. During 1978, a few well-off local farmers in the Bagerhat area began to experiment with stocking freshwater prawn juveniles into the carp ponds (Kendrick 1994). Later on, some pioneer farmers developed the first prawn farms in low-lying agricultural land and rice field, which is locally named gher, in the Fakirhat area (Rutherford 1994). Integrated farming system required less input which in turn emitted less $C0_2$ in the atmosphere. This mechanism makes the gher system climate resilient and has the ability of producing diversified food from same land.

Integrated aquaculture – agriculture (IAA) farming system technology is developed by the farmers to overcome severe food shortages due to climate change effect occurring from different development initiatives including degradation of farm land caused by polder development in 1960's. Farmers of the coastal districts grow black tiger shrimp (*Penaeus monodon*) during

* A *gher* (comes from 'gherao') is an enclosed low-lying field with high and broad dykes, typically used to raise tiger shrimp (locally called bagda). There are two types of *ghers*, developed in response to climate change effects like salinization in the coastal region of Bangladesh. Saline water *ghers* mainly produce bagda, some fish integrated with rice. Innovative farmers have also developed freshwater *gher* systems where golda and some fish are produced with rice. Farmers produce boro rice from December to April, freshwater prawn (locally called golda) and fish during the remaining months and vegetables all year round. *Gher* farming is mostly concentrated in southwest Bangladesh, but there is potential for freshwater *ghers* to expand and be adopted widely across the country.

February-July after Aman rice cultivation. In some areas especially in the deep low gher shrimp farming is characterized by only a single crop. On the other hand, in freshwater gher, giant freshwater prawn (*Macrobrachium rosenbergii*) is grown together with fish and vegetables during April to December following *Boro* rice production. It has emerged as a unique source of income, food security and livelihood for the people living in the coastal region. Lack of farmers technical knowledge, access to extension services and financial support, opportunity of research and technology development, policy support and market linkages are considered as the most important constraints that restrict the expected improvement of the sector. Helping farmers to utilize the full potentials of gher system, CSISA-BD has undertaken various interventions centering the focus on research in development: a) test and fine tune technologies suitable for existing farm situation and to address climate change effect b) widespread dissemination of improved aquaculture technologies for increasing production and income, and c) reduced risk of investment through the addition of extra crop and minimize disease occurrences. Major intervention to improve farming practices and productivity includes culture of disease free and quality Post Larvae (PL) of shrimp and prawn, fish fingerlings, shrimp and prawn nursery establishment in a corner of the gher, two cycle tilapia as alternative to prawn in response to export market challenge, double cycle shrimp production, shrimp-fish mix culture and efficient utilization of dykes with vegetables and adaptive production calendar. A total of 27,495 farmers, nearly 35% women directly participated in the project with training during last 5 years in fresh water gher system.

Twenty-four species of freshwater prawn are found in Bangladesh. However, only giant freshwater prawn (*Macrobrachium rosenbergii*) locally called "Golda Chingri" has aquaculture potential and is commercially cultured in Bangladesh (DOF, 2012). In response to export market demand, local farmers also initiated tilapia and carp culture in gher besides freshwater prawn farming.

4.3.1 Effects of CSISA-BD project on IAA (Freshwater Gher system) productivity

Table 4.7 shows the productivity of prawn, different types of fish and rice in three different scenarios to evaluate the project interventions on freshwater gher systems. Freshwater gher aquaculture is divided into three categories: i) freshwater prawn with carp polyculture and rice, ii) 02 cycle tilapia culture with rice, and iii) carp polyculture with rice farming (in the northwest of Bangladesh). All three technologies consisted of combinations of rice and different types of fishes, so freshwater gher system becomes more popular to the farmers. Farmers can produce at least one-season rice (mainly *boro* rice which is the major contributing rice variety in Bangladesh) in the gher.

Table 4.7: Changes in fish productivity on the basis of Freshwater Gher system (Kg/ha)

Species	Freshwater Prawn in Gher*{n=325}*			02 cycle Tilapia in Gher *{n=42}*			Rice-fish farming {*n*=90}		
	Baseline	Endline	Change	Baseline	Endline	Change	Baseline	Endline	Change
Prawn	300	640	340	-	-	-	-	-	-
Tilapia	-	-	-	1839	7241	5402	-	-	-
Carp	902	1665	763	-	1193	1193	755	2549	1794
Total fish & prawn	1,202	2,305	1,103 (7.41)	1,839	8,434	6,595 (8.59)	755	2549	1794 (7.29)
Rice	4,024	7,985	3,961 (6.17)	4,327	5,414	1,087 (1.67)	4,575	5,532	957 (1.84)

Figures in the { } indicate the number of samples and figures in the ( ) indicate t-value

Per hectare fish production was 2,305, 8,434, and 2,549 kg at the endline scenario for freshwater prawn, two cycle tilapia in gher, and rice-fish farming respectively. Although the productivity was four and half times higher for tilapia in gher technology but the investment was profitable for freshwater prawn in gher technology because of higher market price of prawn and lower production cost. Accordingly, per hectare rice production was 7,985, 5,414 and 5,532 kg at the endline scenario for all aquaculture technologies respectively. Changes of fish and rice production from different farming systems in gher were found to be statistically significant. These significant changes of fish and rice production might contribute in respect to the fulfillment of nutritional requirements as well as additional earning for the household.

Figure 4.10, 4.11, and 4.12 show the effects of CSISA-BD intervention on productivity on the basis of extent of intervention. Results reveal that the productivity has increased with the extent of intervention. Firstly, Demo farmers were able to increase per hectare fish production by 35% compared to Direct farmers, which implies that if fish farmers receive critical input supports as well as easy access to technical assistance and input market, then they can increase fish production significantly. Secondly, Direct farmers were able to increase fish productivity by 53% compared to Control farmers in case of freshwater prawn system, implying that if farmers get only technical assistance like training and supervision or extension service, they can enhance fish production significantly (Figure 4.10).

Similarly, in case of two cycle tilapia in gher system, Demo farmers were able to increase per hectare fish production by 50% compared to Direct farmers (Figure 4.11). Figures 4.12 also reveals that if rice-fish farmers get training, extension service and better access to input market, then they can also increase fish production by twofold.

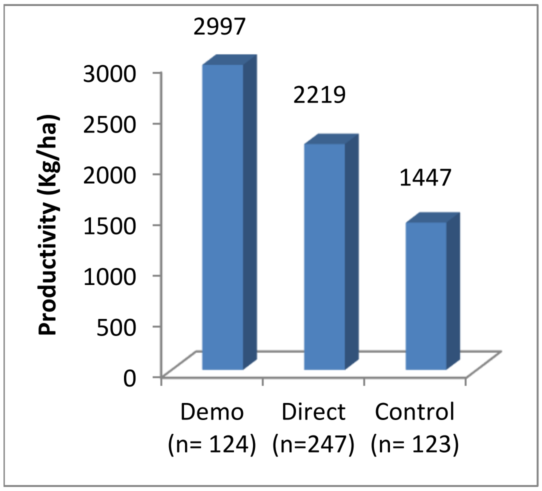


Figure 4.11: Effects of intervention on fish productivity in freshwater prawn

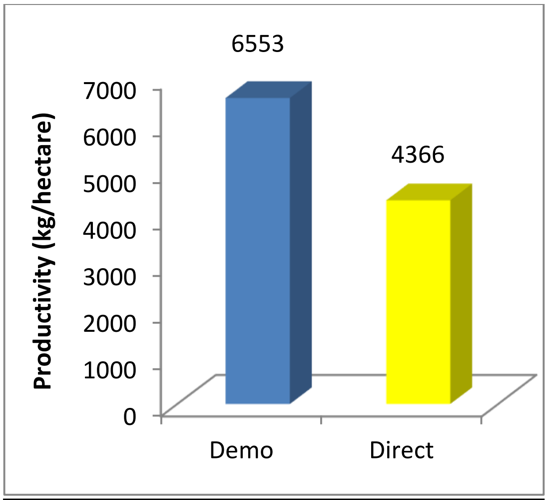


Figure 4.10: Effects of intervention on fish productivity in Tilapia in *gher*

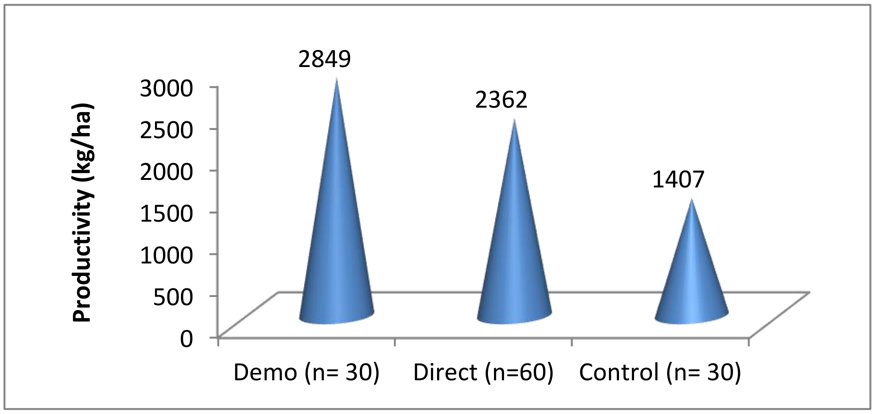


Figure 4.12: Effects of intervention of fish productivity in rice-fish farming system

In order to assess whether growing fish in the rice field is really worthwhile, productivity per hectare of rice, and fish is determined. Figure 4.12 shows the fish productivity per hectare of land according to project intervention level. The average rice field/pond size was 90 decimal (0.36 hectare), 62 decimal (0.25 hectare), and 71 decimal (0.31 hectare), (0.29 hectare) of the selected beneficiaries (Demo, Direct and Control respectively), but results were estimated per hectare of land for better understanding. Results reveal that fish productivity was increased by 21% (from Direct to Demo farmers) and 68% (from Control to Direct farmers) during project implementation. Overall, fish production was boosted by 102%, if we consider the change from Control to Demo farmer group. The combined rice-fish option also conserves the traditional and culturally significant production of rice, as opposed to the practice of converting rice fields into fishponds.

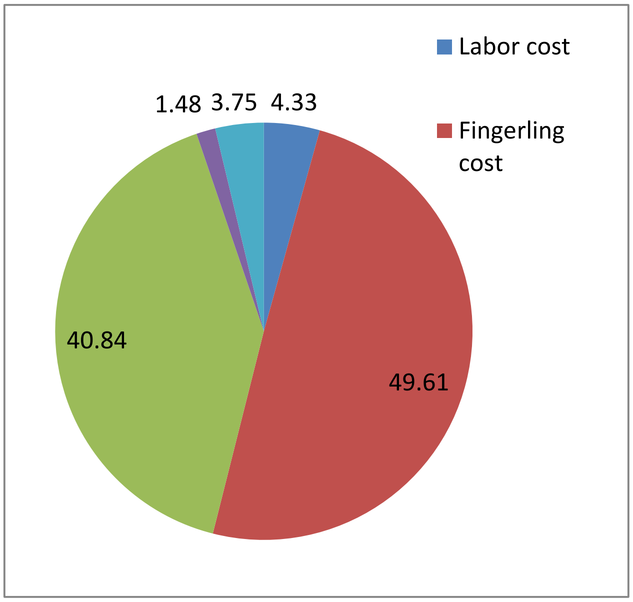
4.3.2 Cost-Benefit and profitability analysis of Freshwater Gher system

Table 4.8 shows the cost-benefit analysis of integrated aquaculture-agriculture (freshwater prawn, tilapia farming in freshwater gher, and rice-fish farming) in case of different project interventions. It is important to note that CSISA-BD promoted tilapia farmer produces tilapia in two production cycles per year. As a consequence, two cycle tilapia in gher farming was more profitable compared to freshwater prawn-carp polyculture and rice-fish farming for Demo and Direct beneficiaries group, but in case of control group, freshwater prawn-carp farming was more profitable. Although freshwater prawn is a high valued commodity in local and international market, per hectare productivity of tilapia farming exceeded the freshwater prawn farming revenue in gher system for Demo and Direct farmers.

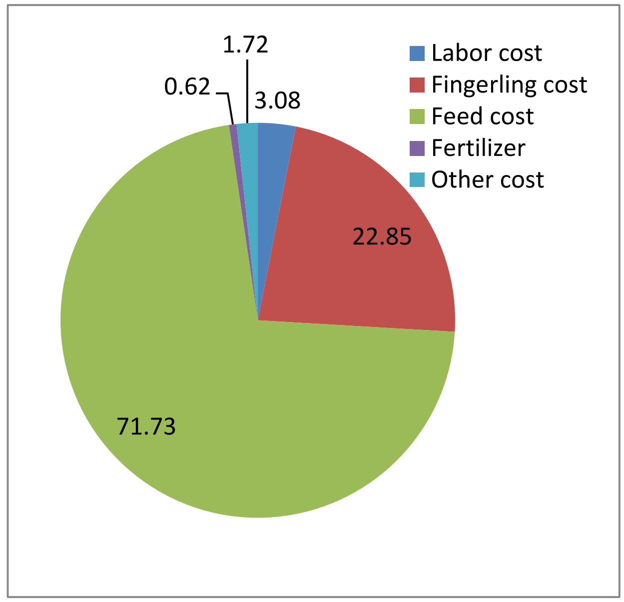
However, if we consider tilapia production cost items of Demo farmers, fingerling (23%) and feed (70%) were the major production costs of farming (Figure 4.13). In the case of freshwater prawn farming, juvenile (young prawn) cost (47%) was higher than feed cost (38%) to all types of beneficiaries group, but the finding was opposite in the case of tilapia farming in gher where feed cost was more than two times higher. The reasons behind the lower feed cost of freshwater farmers were to maintain moderate stocking density, mostly homemade feed along with some supplemental commercial feed, and also that these fish and prawns rely upon natural productivity including benthic organisms grown on paddy straw leftover. On the other hand, semi-intensive tilapia farming used comparatively high stocking density and high priced pellet feed. Similar to the Demo farmers three types of fish farming, Direct and Control farmers' fingerling cost was higher for freshwater prawn and rice-fish farming, but in the case of tilapia farming in gher, feed cost was higher than fingerling cost.

Table 4.8: Cost-Benefit and profitability analysis of Freshwater Gher system (BDT/ ha)

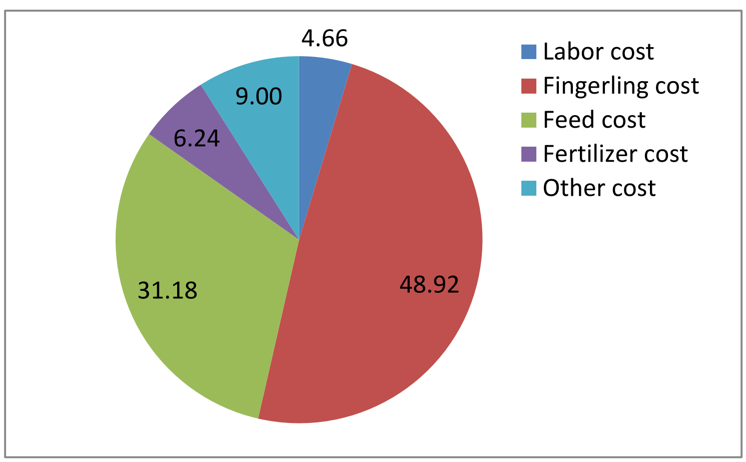
Item	Demo			Direct			Control		
	Freshwater Prawn	Tilapia in gher	Rice-fish	Freshwater Prawn	Tilapia in gher	Rice-fish	Freshwater Prawn	Tilapia in gher	Rice-fish
Labor cost	5,905	9,428	5,577	5,929	10,098	2,538	4,430	5,407	1,141
Fingerling cost	67,723	69,951	58,552	64,902	54,423	48,003	62,000	49,866	21,463
Feed cost	55,753	219,578	37,312	51,384	126,643	32,208	37,661	55,919	11,898
Fertilizer	2,024	1,904	74,72	1,934	2,603	62,61	2,146	6,852	2,585
Other cost	5,116	5,267	107,67	5,258	3,652	128,04	10,265	8,588	6,924
Cost of fish production	136,521	306,128	119,681	128,338	197,419	101,814	115,574	126,631	44,011
Cost of vegetable production	8,754	9,381	5,880	9,087	10,463	7,581	4,260	1,309	471
Total Cost (TC)	**145,275**	**315,509**	**125,561**	**137,425**	**207,882**	**109,395**	**119,834**	**127,940**	**44,482**
Revenue from fish	413,914	630,964	264,924	326,062	417,132	216,171	226,421	197,945	85,852
Revenue from vegetable	70,969	43,320	24,923	52,333	54,934	23,218	29,333	5,827	3,866
Total Revenue (TR)	**484,883**	**674,284**	**289,847**	**378,395**	**472,066**	**239,389**	**255,754**	**203,772**	**89,718**
Profit	339,608	358,775	164,286	240,970	264,184	129,994	135,920	75,832	45,236
BCR	3.34	2.14	2.31	2.75	2.27	2.19	2.13	1.59	2.02



(a) Freshwater prawn farming



(b) Tilapia farming in *gher*



(c) Rice-fish farming

Figure 4.13: Percentage of different cost items in different IAA

Although table 4.8 shows tilapia in gher farming was more profitable but the BCR results was not higher for tilapia farming because of higher production cost. The results show that BCR was higher for Demo farmers of freshwater prawn farming (3.34) due to the lower production cost. Among three IAA technologies BCR was always higher for freshwater prawn based farming through different project intervention level. The freshwater prawn-carp farming BCR level was also higher in comparison with recent research conducted by Yasmin et al. (2010). She found the freshwater prawn farming BCR of 2.69 which clearly suggests the potential benefits of CSISA-BD project intervention in development and extension of IAA technologies. It is documented from Benefit-cost ratio that project interventions played an important role in all kind of IAA technologies to increase the total return as well as the profit of the beneficiaries group.

4.3.3 Can intervention enhance household welfare?

Table 4.9 depicts that changes of fish and vegetable income were highly significant in the study area. Farmers were able to increase their earning which was estimated at BDT 84,369 (USD 1082) BDT 59,244 (USD 760) and BDT 56,331 (USD 522) per household in freshwater prawn-carp in gher, tilapia in gher, and rice-fish farming system respectively. These changes were statistically significant at 1% level. However, more fish and vegetable income obtained from prawn aquaculture technology [BDT 106,054 (USD 1360) from prawn, BDT 38240 (USD 490) from carp fish and BDT 17,597 (USD 226) from vegetable per household (farm size 67 decimal or 0.27 hectare) respectively] in the endline situation. So, it can be concluded that all IAA systems were profitable enterprises but prawn aquaculture technology generated more income, which suggests a need for further study and support. But as market resilient strategy and volume of animal protein biomass production, tilapia also demonstrated good alternative strategy and may be recommended as feasible in response to special situation like export market, availability of critical inputs etc. Alongside, rice-fish farming also could be an alternative strategy for diversifying and increasing household income in different suitable parts of Bangladesh.

Table 4.9: Changes in fish and vegetable income on the basis of technology (BDT/gher size/household)

Technology	Freshwater Prawn and carp in Gher			Tilapia in Gher			Rice-fish		
	Baseline	Endline	Change	Baseline	Endline	Change	Baseline	Endline	Change
Prawn	48,411	106,054	57,643 (13.14)	-	-	-	-	-	-
Fish	26896	38240	11524 (4.12)	24,905	78,707	52,462 (6.12)	20,981	71,238	50,257 (9.37)
Vegetables	2,395	17,597	15,202 (10.24)	1,475	8,258	6,782 (4.02)	1,115	7,189	6,074 (7.69)
Total	77702	162071	84369	26,380	86,965	59,244	22,096	78,427	56,331

Value in the parentheses indicates t-value

4.3.4 Effects on fish and vegetable utilization pattern of Freshwater Gher system household

Table 4.10 shows the changes in fish selling and consumption of per household in three different situations. It is apparent from the table that per household fish selling amount was increased in the endline situation for all IAA systems. Household fish selling was increased by 85, 333, and 309% after CSISA-BD intervention for freshwater prawn, tilapia in gher and rice-fish farming respectively and the increases were statistically significant at 1% level.

On the other hand, household fish consumption was also statistically increased by 49 and 79% in the case of freshwater prawn-carp polyculture and rice-fish farming respectively. In contrast, a trend favoring increased consumption was also seen in the case of tilapia aquaculture (11%), but it was not statistically significant. Non-significant consumption change in tilapia farming might be the result of less consumption of tilapia in comparison with carp and different types of small indigenous fishes produced and consumed form freshwater prawn and rice-fish farming integrated aquaculture system. The result implies that farmers are moving towards commercial production, and interested in selling fish in the market. As a consequence, fish selling was increased at a 1% level of significance for all technologies.

Table 4.10: Changes in fish utilization pattern (Kg/household)

Technology	Sell			Consumption		
	Baseline	Endline	Changes	Baseline	Endline	Changes
Freshwater Prawn in Gher	203	374	172 (8.89)	33	49	16 (4.65)
Tilapia in Gher	180	779	599 (6.54)	46	51	5 (0.59)
Rice-fish farming	205	839	634 (6.81)	38	68	30 (3.27)

Value in the parentheses indicates t-value

Like fish consumption, vegetable consumption was changed positively, and the change was statistically significant. Certainly, more vegetable consumption improves the nutrition and food security of the respondent household. Per household average vegetable selling amount was increased by 353, 779, and 1007% in the endline situation for freshwater prawn, tilapia in gher and rice-fish farming system respectively. The changing figure was surprising, but the fact was project interventions increased the vegetable production dramatically in the study areas. On contrary, the average consumption was also increased dramatically by 130, 250, and 667% respectively for three IAA technologies.

Table 4.11: Changes in vegetable utilization pattern (kg/household)

Technology	Sell			Consumption		
	Baseline	Endline	Changes	Baseline	Endline	Changes
Freshwater Prawn in Gher	114	516	402 (8.13)	30	69	39 (5.46)
Tilapia in Gher	56	491	436 (2.50)	28	98	70 (2.93)
Rice-fish farming	43	476	433 (2.77)	15	115	100 (5.02)

Value in the parentheses indicates t-value

To summarize, CSISA-BD project intervention has significant effect on consuming fish and vegetable in the study areas. It is important to mention that, the figure of changes in consumption does not represent entire consumption of fish and vegetable of a person in a year rather consumption changed only from selected IAA farming areas. Table 4.10 shows that, fish consumption from own production per household per year was reached from 49 to 68 kg varies with farming system, implies that due to project implementation fish consumption was increased which was statistically significant at $p < 1\%$ level. The national level fish consumption is about 82.3 kg per household (HIES, 2010) considering all types of fish consumption. In addition, notable vegetable consumption changes were achieved, reaching 115 kg per household per year from only 69 kg per household.

4.4 BRACKISHWATER SHRIMP AQUACULTURE

In Bangladesh, a rapid expansion of brackish water shrimp farming has taken place since the early nineteen seventies (Karim, 1986) because of increasing demand in the world market. At that time, the government policy was also in favor of the expansion of brackish water area rather than by aquaculture intensification. Brackish water shrimp farming is mostly practiced in low-lying tidal flood plains within Water Development Board (WDB) polders that were originally constructed to reclaim land with potential suitability for agriculture. Brackish water shrimp locally called “Bagda” (*Pennaeous monodon*) is the main species of brackish water aquaculture. Shrimp farming acknowledged as an industry and adopted essential measures for increased production by the government of Bangladesh under the Second Five-Year Plan (1980–85) (Haque, 1994). Shrimp farming was introduced in the coastal areas particularly in the Southwestern part of Bangladesh initially. At present, shrimps are cultivated throughout coastal region, and Bangladesh produces more than 2.5% of the global production of shrimp and has become the 7th largest exporter of shrimp to the Japanese and USA markets (Rahman et al., 2013).

Under this technology the step-wise activities of shrimp culture management are followed- shrimp nursery management; preparation of gher; pre stocking lime & fertilizer management; stocking management; post stocking management includes feeding, water quality management, shrimp health management, shrimp harvesting and post harvesting management and shrimp marketing. WorldFish, through Cereal Systems Initiative for South Asia in Bangladesh (CSISA-Bangladesh) project, was given the priority of training the shrimp farmers of the south on the use of virus free post larvae (PCR tested) and improved culture management considering the problems and prospects of shrimp farming with utmost priority.

4.4.1 Effects of CSISA-BD project on brackish water shrimp farming productivity

Table 4.12 shows the productivity of shrimp in two different scenarios for two types of beneficiaries to see the impact of project intervention. Demo farmers have some privileges over Direct farmers in shrimp production. This section makes a comparison of project interventions between PFT and Direct beneficiaries on fish productivity.

Table 4.12: Changes in shrimp productivity (Kg/hectare)

Situation	Shrimp Productivity	
	Demo (kg/hectare)	Direct (kg/hectare)
Baseline	506	395
Endline	905	598
Change	399 (3.92)	203 (3.34)

Value in the parentheses indicates t-value

Shrimp production amounted to 905 and 598 kg/hectare at the endline scenario that was almost two times higher than the baseline scenario. Demo farmers cross the national level shrimp productivity which is 786 kg per hectare (DoF, 2015); therefore the necessity of CSISA-BD project development activities were proved in case of brackish water shrimp farming in the study areas. Shrimp production changes were found to be statistically significant at 1% level for both types of beneficiaries. However, without development intervention, the potential of shrimp production will be unexplored. Another aspect of harnessing better production potential would discourage horizontal expansion of brackish water gher rather farmer will be able to increase production and income.

Figure 4.14 describes the CSISA-BD project intervention on productivity on the basis of intervention level. Productivity was shown in general, irrespective of species. Figure 4.14 reveals that productivity was increased with the extent of intervention. Demo farmers were able to increase production by 56% compared to Direct farmers from per hectare of water body. It implies that if farmers get some critical input support and easy access to technical services and input market, then they can significantly enhance shrimp productivity. On the other hand, Direct farmers were able to increase productivity by 28% compare to Control farmers, implying that when farmers get training and supervision or extension service, they can also enhance shrimp productivity significantly.

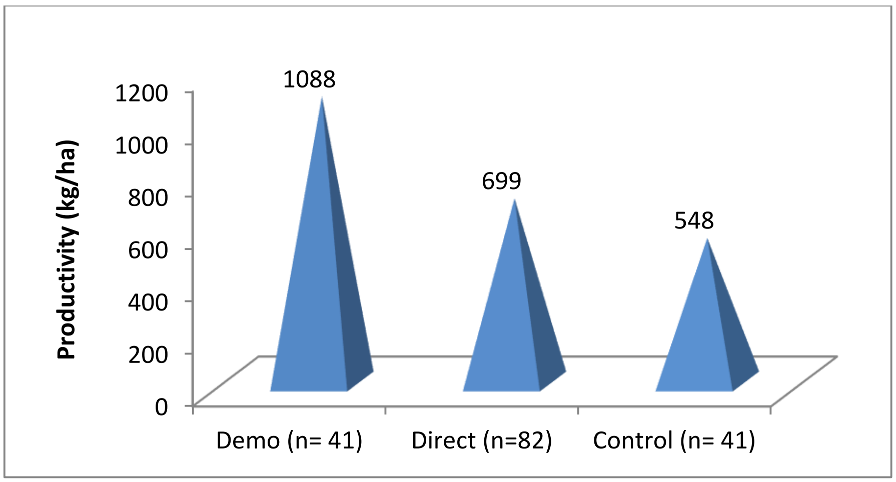


Figure 4.14: Effects of CSISA-BD intervention on shrimp productivity

4.4.2 Cost-Benefit analysis of brackish water shrimp aquaculture

Because of higher market price in the local and international market, brackish water shrimp farming was found to be profitable among the respondent households. Table 4.13 shows the cost-benefit analysis of brackish water shrimp farming of different types of farmers group (Demo, Direct and Control). Among these three types of beneficiaries, Demo farmers got some portion of required critical input supports from the development project; as a consequence Demo farmers were in an advantageous position as compared with the other two types of farmers.

Table 4.13: Cost-Benefit Analysis of brackish water shrimp (BDT/ hectare)

Item	Demo	Direct	Control

Labor cost	9,000	5,419	6,335
Juveniles cost	58,682	55,767	48,515
Feed cost	48,902	29,660	27,598
Fertilizer cost	1,381	1,862	1,243
Other cost	17,779	10,700	10,917
Total Cost (TC)	135,743	103,407	94608
Total revenue (TR)	339,834	221,585	182,512
Profit	204,091	118,178	87,904
BCR	2.50	2.14	1.92

Table 4.13 shows brackish water production cost and return in the study area. It is apparent that among different cost items, shrimp juvenile (43% for Demo) and feed (36% for Demo) were the major production cost items to all types of beneficiaries (Fig. 4.15). More precisely, juvenile cost was always higher than that of feed cost in shrimp farming. Accordingly, juvenile cost was the highest for Demo farmers (BDT 58,682/hectare) and lowest for Control farmers (BDT 48,515). Demo farmers relied upon continuous stocking leads high stocking density, increasing the juveniles cost proportionately. Alongside, Control farmers followed traditional farming practices that added less cost in feeding procedure than that of Direct farmers' shrimp farming feeding cost in the study areas. If we look at the BCR of different beneficiaries group, Demo farmer's BCR was 2.50 followed by Direct farmer (2.14) and Control farmer (1.92). It implies that brackish water shrimp farming has the potential of increasing profitability if technical services and market linkages are available.

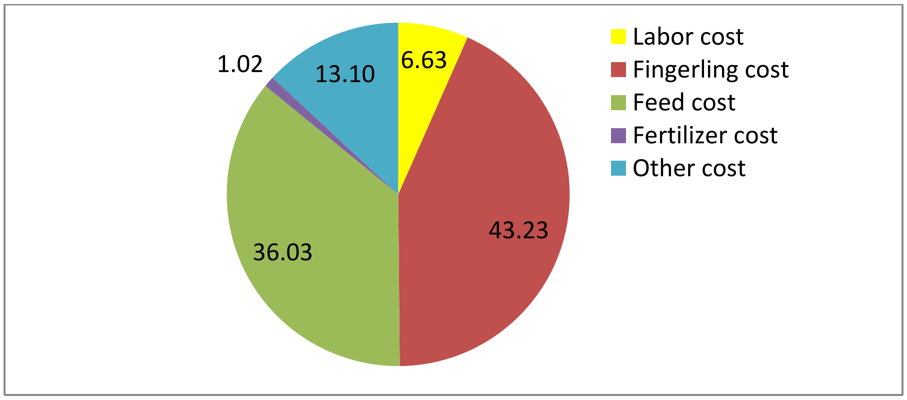


Figure 4.15: Percentage of different cost item in brackish water shrimp aquaculture

4.4.3 Changes in household income through CSISA-BD project

As in the case of other aquaculture technologies, project intervention has a positive effect on household income of brackish water shrimp farmer as well. After running the project, per hectare income from brackish water aquaculture was increased by about two times for Demo and Direct farmers. However, the overall per household shrimp income has increased (average household pond size was 75 decimal or 0.30 hectare), by BDT 43,744 and BDT 34,032 for the Demo and Direct farmers respectively. Higher financial gain was obtained by the Demo farmers who obtained critical input supports. The result was statistically significant at 1% level for Demo and Direct beneficiaries.

Table 4.14: Changes in shrimp income (BDT/pond size/household)

Situation	Shrimp	
	Demo (BDT /household)	Direct (BDT /household)
Baseline	38,833	41,185
Endline	82,577	75,217
Change	43,744 (6.18)	34,032 (6.60)

Value in the parentheses indicates t-value

4.4.4 Effects on shrimp utilization pattern

Table 4.15 shows the changes of shrimp selling and consumption pattern per household before and after project intervention. CSISA-BD project development activities had a significant effect on the per hectare productivity of shrimp income in different intervened aquaculture technologies which in turn increased the household level income, as well as household level consumption also. Like other aquaculture technologies, shrimp consumption was increased, and the result was statistically significant at 1% level in brackish water shrimp farming.

Table 4.15: Changes in shrimp utilization pattern (kg/household)

	Sell			Consumption		
	Baseline	Endline	Changes	Baseline	Endline	Changes
Shrimp	113	197	83 (5.72)	12	19	7 (2.10)

Value in the parentheses indicates t-value

At the same time, change of shrimp selling was reported statistically significantly at 1% level. It is noted that per household (0.30 hectare of land) amount of shrimp selling was increased by 73% respectively after project intervention. These findings can be regarded as a step forward for brackish water shrimp production in the study areas.

Chapter 5

CONCLUDING REMARKS

The Bangladesh government is trying to develop a 'model household' considering the concept of integrated farming. The project vision was also in line with the government initiatives such as the way small households can use their land in different ways and household resources to enhance their livelihood status. Persistent population growth and gradual agricultural land shrinkage force the rural household to diversify in their farming practices. In a consequence, the small households are looking for more profitable enterprises considering the limitation of the capital. Aquaculture and vegetable farming are the two most profitable farming ideas where farmer can culture fish in their pond or rice field, at the same time they can cultivate vegetable on the dyke of the pond. As we know, vegetables are a source of many nutrients, including different minerals and vitamins. Therefore, increased vegetable production could improve food security as well as offer income opportunities to small farmers, including women.

The project was implemented to see the impact of different aquaculture technologies (household based pond aquaculture, commercial pond aquaculture, integrated aquaculture-agriculture (IAA), and brackish water aquaculture) on productivity, return, household income, and consumption pattern. Per hectare fish production was increased by about two times higher in the endline situation due to project intervention for household based pond aquaculture. Results reveal that fingerling and feed were the major cost items in different fish production technologies which stand 51 and 43% for fingerling, and 38 and 45% for feed respectively for carp and carp with *mola* polyculture. However, per household income from aquaculture has increased to BDT 36,392 (US$ 466) from BDT 9,283 (US$ 119). If we look at the project effect on consumption pattern of the household based farmers, the results show that fish consumption was slightly increased (14%) and vegetable consumption was increased dramatically (150%).

In the case of commercial pond aquaculture, productivity was increased by 2.72, 3.96 and 1.5 times in endline compared to baseline after project implementation for carp polyculture, pangas-tilapia-carp polyculture and carp-shing polyculture system respectively. Similar to household based pond aquaculture, fish consumption was increased by 1.18 (carp), 1.43 (pangas-tilapia-carp) and 2.10 (carp-shing) times in endline for three commercial pond aquaculture technologies, and the results were statistically significant. In pond based aquaculture, polyculture of different fish species adopted by the farmers in order to maximize the effect of the used inputs, natural productivity potential of the ponds, diversify the income source hence reduce the risk of disease and market shock in case monoculture. Polyculture of Indian and Chinese carp is still the most widely popular practice by the small farmers, probably due to its comparative advantage of growing fish based on natural productivity and low-cost agro byproduct and better benefit cost ratio.

Per hectare fish production was 2,305; 8,434 and 2,549 kg at the endline scenario for freshwater prawn-carp polyculture in gher, two cycle tilapia in gher, and rice-fish culture respectively. Freshwater gher aquaculture farmers were able to increase their earning (BDT 106,054 per household) because of higher productivity; in the endline situation. Similar to household and commercial based aquaculture, consumption was increased and the results were statistically significant in the case IAA (freshwater gher) systems.

The project effect on brackish water shrimp aquaculture shows that per hectare shrimp production reached up to 905 kg at the endline scenario that was almost two times higher than the baseline scenario. Because of higher shrimp productivity, the overall per household shrimp income (average gher size per household was 75 decimal or 0.30 hectare) has increased about BDT 43,744 in the study area.

The study findings highlighted the impact and importance of technical support for the poor, small and medium farmers. Only due to appropriate technical support like trainings and time to time technical advice increase productivity significantly in different form of aquaculture. However, when farmers were linked with quality input supply further productivity has increased significantly in the study area. These findings indicated if the poor and small farmers receive technical assistance and by linking with quality inputs, national fish production will be increased substantially.

We found improved extensive and semi-intensive type of Aquaculture system has the potential to increase sustainable productivity and income, if the following

I. Low input based and efficient improved aquaculture and horticulture technologies and varieties appropriate to the context should be disseminated among the poor households in both freshwater and brackish water aquaculture.

II. Regular technical support including training, refreshers training, coaching, linking with market should be offered by respective public and private stakeholders for increasing knowledge and skill of the poor and small farming household.

III. Poor households required start-up support with critical inputs for production activities through inputs like high quality fish fingerlings, horticulture seed & seedlings, lime, fertilizer and basic feed through price support or subsidy by linking them with input market.

IV. Based on agro-ecological context, resource availability and socio-economic condition of beneficiaries, technology needs to be tested, fine-tuned and developed regularly for promotion.

V. Intensive initial effort is needed in developing leadership, effective linkage with market actors and other stakeholders including GoB departments DAE, DoF.

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