

Evaluation of Technical Efficiency of Pabda (*Ompok-Pabda*)
Catfish Production in Pabna District, Bangladesh:
Stochastic Frontier Approach



M.S.S THESIS

A Thesis Submitted in Partial Fulfilment for the Requirement of the Degree of Master of
Social Science in Economics

Submitted

By

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Examination Roll No. 120846

Reg. No. 1087080

Session No:2015-16

M.S.S. Examination: 2016

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DEPARTMENT OF ECONOMICS
PABNA UNIVERSITY OF SCIENCE AND TECHNOLOGY
BANGLADESH

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**DEPARTMENT OF ECONOMICS
PABNA UNIVERSITY OF SCIENCE AND TECHNOLOGY
BANGLADESH**

MARCH,2019



Dedicated
To
My Beloved Parents

CERTIFICATE



This is to certify that this thesis contains the results of a research entitled “EVALUATION OF TECHNICAL EFFICIENCY OF PABDA (OMPOK-PABDA) CATFISH PRODUCTION IN PABNA DISTRICT, BANGLADESH: STOCHASTIC FRONTIER APPROACH” has been carried out by **Fatema Akter Nova** under my supervision.

This is to note that the work presented here is appropriate for submission in partial fulfillment for the degree of Masters of Social Science in Economics in the Department of Economics, Pabna University of Science and Technology, Bangladesh.

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Associate Professor
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Declaration

I, the undersigned, hereby declare that this thesis entitled “EVALUATION OF TECHNICAL EFFICIENCY OF PABDA (*OMPOK-PABDA*) CATFISH PRODUCTION IN PABNA DISTRICT: STOCHASTIC FRONTIER APPROACH “submitted to the examination committee, Department of Economics, Pabna University of Science & Technology in partial fulfillment for the degree of Master of Social Science in Economics, is my own work excepts for quotations and summaries, which have duly acknowledged. This research work has not been submitted previously, in part or full, for any degree to any university.

Signature

Date

ACKNOWLEDGEMENT

At first, my profound gratitude goes to the “Almighty Allah”, the creator of heaven and the earth and all that dwell there in, for His mercy, assistance, sustenance and perfections; especially for seeing me through this program successfully. I am ever grateful and I would like to express my profound gratefulness to the almighty Allah for good health and wellbeing that were necessary to complete this work and who enable me to prepare this thesis paper without whose desire I could not have materialized my dream to conclude this thesis.

I extremely convey my best complement, profound gratitude, indebtedness and deep appreciation to my honorable and beloved supervisor, Dr. Mir Khaled Iqbal Chowdhury, Associate Professor, Department of Economics, Pabna University of Science and Technology, for his sincere supervision, inspiring guidance, enthusiastic encouragement and wise advises through the entire period of research work. Despite heavy pressure of academic preoccupation, he made himself available whenever the author needed his help and suggestions. I am really grateful to him for giving me such a rare opportunity to work in close association with him.

I would like to express my gratefulness from the core of my heart to my preceptor Md. Al-Amin, Assistant Professor and Chairman Department of economics, Pabna University of Science and Technology, for his help, advice and cooperation during the period of my research analysis.

The author expresses his gratitude to Md. Enamul Haque Assistant professor, Department of Economics, Pabna University of Science and Technology.

I express my heartiest thanks to my honorable teachers Bikash Chandra Ghosh and Tawhidul Islam Assistant Professor, Pabna University of Science and Technology, by whom I am mostly influenced and encouraged in the research work. I salute to him for his unfathomable knowledge in research. I would like to express my gratefulness to him because at first, he encouraged and influenced me to dream be a researcher.

I would like to take the opportunity to thank my teachers Md. Redwan Ahmed, Md. Tahmidul Islam, Md. Nehal Hasnain and them who encouraged me a lot throughout my study in this department.

This study is based on primary data. So, I express my deep appreciation to the respondent households of sampling upazilas of Pabna district who were my respondents during the data

collection and helped me at the time of interview of my questionnaire and for supplying the valuable data. Without their cooperation this research would not have been possible.

Last but not the least, I would like to thank my family: my parents and to my brothers and sister for supporting me spiritually throughout writing this thesis and my life in general. I am really grateful to them.

March, 2019

Roll No. 120846

Session:2015-16

ABSTRACT

Although Bangladesh is considered one of the most suitable countries in the world for freshwater aquaculture, Pabda culture is not widespread. Culture of Pabda has not yet well established due to socioeconomic, technological, institutional and marketing constraints. However, while Pabda farming has huge potential, its production, commercial viability and sustainability depends on markets. The profitability of Pabda farming is largely determined by market conditions. Genetically improved farmed Pabda is increasingly getting popular in Bangladesh. It has high production potential. The study evaluated the technical efficiency of Pabda catfish production using stochastic frontier production function analysis. Primary data were collected using structured questionnaire from sixty farmers who were selected from three upazila such as Atgharia, Chatmohar, Bhangura the district of Pabna in Bangladesh using simple random techniques. Frequency tables, percentages and means were used to present the socioeconomic profile of the respondents, and to determine the production types and production technologies used by catfish farmers in Pabna district. Results show that majority of the Pabda catfish farmers were male (97%), with a mean age of 47 years, married (75.9%) with a household size of 6 persons on the average. Also, majority (70%) had tertiary education with a mean of about 9 years (± 7.3) experience in Pabda catfish farming. Most of the Pabda catfish farmers preferred to raise catfish to table size and used static renewal technology (62%). Also, feed inputs and pond size had positive relationship with output while fingerling had positive relationship with output. Increase in the number of fingerlings stocked in ponds will increase output of catfish. Also, about 65% of the Pabda catfish farmers had technical efficiency scores of 60% or less. Access to, household size, and the years of experience in Pabda catfish farming were factors that contribute significantly and positively to technical efficiency of catfish farms except education. The mean technical efficiency level of the Pabda catfish farmers is 85%. Government should introduce training workshops especially for fresh school leavers in order to encourage greater participation in the sector. Also, extension visits should be increased in order to improve the experience and efficiency of catfish farmers

Keywords: Bangladesh, stochastic Frontier Production Function, Pabda Catfish, Technical efficiency, Pabna district

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LIST OF ABBREVIATION

AE	:	Allocative Efficiency
AP	:	Average Production
APP	:	Average Physical Products
BBS	:	Bangladesh Bureau of Statistics
CD	:	Cobb-Douglas Production Function
CESL	:	Central Elasticity of Substitution
DEA	:	Data Envelopment Analysis
DOF	:	Department of Fisheries
EP	:	Elasticity of Production
EE	:	Economic Efficiency
FAO	:	Food and Agriculture Organization
GDP	:	Gross Domestic Product
MLE	:	Maximum-likelihood Estimation
MLE	:	Maximum-likelihood Method
MP		Marginal Production
MRS	:	Marginal rate of Substitution
MT	:	Metric Ton
MV	:	Modern Varieties
NGO	:	Non-government Organization
RTS	:	Returns to Scale
SD	:	Standard Deviation
TE	:	Technical Efficiency

Chapter One

Introduction

1.1 Background of the Study

The increase in human population and reports of large numbers of people, undernourished or starving (especially in the developing countries) has made the need for food production a major worldwide issue of concern. There are three major groups of activities that contribute to food production namely, agriculture, aquaculture and fisheries. Recent knowledge shows that the world's natural stocks of fish and shell fish, though renewable, have finite production limits, which cannot be exceeded even under the best management regimes. For most of our lakes, rivers and oceans, the maximum sustainable fishing limit has been exceeded. Therefore, fish production will depend on aquaculture to bridge the gap of fish supply (Oladejo, A.J. (2010). Aquaculture refers to the cultivation of aquatic organisms under controlled or semi controlled conditions for economic and social benefits. Aquaculture has been the world's fastest growing food production over the past decade (Fourier, 2006). The average growth rate has been 8.9% per year since 1970, compared to only 1.2% for capture fisheries and 2.8% for terrestrially meat production over the same period (Brink, 2001). Fisheries in Bangladesh have both prospects and challenges. Fisheries sector represents one of the most productive and dynamic sectors in Bangladesh. The fisheries sector of Bangladesh is playing an increasingly significant role in the economy for the last few decades. Bangladesh has achieved remarkable progress in the fisheries sector since its independence in 1971. Fisheries sector is contributing a very significant role in the socioeconomic development, and deserve potential for future development in the agrarian economy of Bangladesh. It contributes 3.61 percent to our national GDP and around one-fourth (24.41 percent) to the agricultural GDP (yearbook of FSB 2016-17). Bangladesh is blessed with vast and rich fisheries resources. The diversified fisheries resources of the country are divided into two groups as Inland and Marine fisheries. Inland fisheries have two sub sectors as Inland Capture and Inland Culture fisheries. Inland Capture fisheries comprise with river and estuaries, beels, floodplain, Sundarbans and Kaptai Lake. On the other hand, Inland Culture fisheries include pond, seasonal cultured waterbody, baor, shrimp/prawn farm, crab, pen culture, cage culture. Again, Marine fisheries include industrial (Trawl) and artisanal fisheries.

Fish farming contributes significantly to the economy, creating employment opportunities in rural and urban areas, serving as a viable source of protein nutrients in Bangladesh households and improving national food security. In 2009, fish accounted for 16.6 percent of the world population's intake of animal protein and 6.5 percent of all proteins consumed (FAO, 2012). Fish culture is an efficient means of animal protein production. It provides nutrition for over one billion people, including at least 50 percent of animal protein for about 400 million people from the poorest countries (The World Bank Group, 2011). Globally, fish provides about 3.0 billion people with almost 20 percent of their intake of animal protein, and 4.3 billion people with about 15 percent of such protein (FAO, 2012). Increasing demand for fish products has resulted in the growth of fish farms to meet a substantial part of the world's food requirement (Olasunkanmi, 2012)

Bangladesh is a land of water resources bestowed with rivers, beel, khal, floodplains, canals and thousands of small wetlands and ponds. Majority of those water bodies are suitable for the freshwater fish culture (M das 2018). Total fish production of Bangladesh in 2016-17 was 41.34 lakh MT where aquaculture contributes 56.44% (DoF, 2017). Bangladesh is now ranked 3rd in world aquaculture production (FAOSTAT, 2016). Fisheries sector contributes 3.65% of total GDP and 23.81% of the agricultural GDP (DoF, 2016). 18.5 million people have involved in this sector in which numbers of fish farmers are around 13.86 million. Total pond area of Bangladesh in 2016-17 was 1.83 million ha and annual production was 4.77 MT/ha (DoF, 2017). Freshwater fisheries play a significant role in the livelihoods of rural and poor people in Bangladesh (Mazid, 2002). Fish farming has been proved a profitable and attractive business comparing to the rice or other agricultural cultivations. Therefore, many rice farmers are converting their fields into fish culture ponds (Islam et al., 2002). A large number of people have improved their socioeconomic conditions through fish farming activities in Bangladesh (Ara, 2005). Aquaculture practice has the potentiality to achieve self-sufficiency in the food sector and to reduce poverty in Bangladesh (Al-Amin et al., 2012). Proper planning and development in any production sector need up to date information on available resources, prospect, current states, and problems. The implementation of the developmental program often turns to unsuccessful due to the lack of Catfish farming also plays a crucial role in driving the aquaculture sector in Bangladesh by creating employment directly and indirectly to millions of people, helping to diversify the nation's resources, earn foreign exchange through

potential export and help the country achieve the millennium development goals (MDGs). It also has the potential of contributing more to the gross domestic product (GDP) of the country. Evaluation of the technical efficiency exposed the need for catfish farmers to adopt new technologies and achieve sustainable production. This study is also important in determining the extent to which catfish farmers can raise productivity through improved efficiency with existing resource base and available technologies.

However, associated with the rapid development of catfish farming prices have decreased. The average export price of catfish decreased from USD 3.76 per kilogram in 2000 (VASEP, 2008) to USD 2.14 per kilogram in 2010 (VASEP, 2010). Falling prices were not only experienced in traditional markets, but also in new markets which have been growing fast, such as the Middle East, Mexico, Saudi Arabia and Australia (VASEP, 2010). On the other hand, the production cost of catfish has been increasing over time. In 2006 production costs were estimated to be 0.59 USD/kg (Phuong et al., 2007), but in 2008 costs had risen to 0.70 USD/kg (Hien, 2008). Catfish farming has been run at a loss in recent years, mainly due to reduction of product prices and increased production cost (de Silva, 2010). In 2009, the export value of catfish reached USD 1.3 billion and many researchers argued that the industry would still develop well, but actually the farmers lost the equivalent of 10-20 US cents for every kg they produced. In 2008, about 25% of catfish farmers went bankrupt, 30% lost household's own capital, and 40% of households could not pay the bank debt due to heavy losses (RFA, 2010).

Moreover, most of the people in Bangladesh depend on fish for their animal protein and fish provides 63.00 percent of animal protein consumption (Rahman, 2009). Bangladesh earns a significant amount of foreign currency, i.e., 4.90 percent of total export earnings from fisheries products (BBS, 2009). The export of fishery products such as frozen shrimp, live fish, dry fish, salted fish, fish maw, shark-fin, tortoise and turtles are increasingly emerging as a prominent economic activity. In our country, the natural annual fish production cannot meet the increasing demand of the human population which is resulting pressure on aquaculture to enhance the production. Continuous efforts are being made to increase fish production from locally available sources. Bangladesh has a great potentiality to increase inland fish production. To fulfill the deficit of animal protein, there is crying need to cultivate quick growing fish under scientific methods and management.

From 1998 to 2008, catfish farming areas increased 7 times, but at the same time these was a 36-fold increase in production and the export volume of fillets increased more than 40 times (AGROVIET, 2008). In 2010, the value of export reached a record of 1.5 billion USD, and catfish were exported to over 130 countries (VASEP, 2010).

Catfish farming is a subset of aquaculture which involves the rearing of catfish under controlled conditions for economic and social benefits. Catfish have many types now we include which are available in Bangladesh:

Table 1.1: Catfish in Bangladesh

Local Bengali name	Name in Bengali	status	Common English Name	Scientific Name
Artamim	আইড়/আরটামিম/আড়	Native	Long-whiskered catfish	<i>Sperata</i>
Arwari	আরওয়ারি	Native	Menoda catfish	<i>Hemibagrus-Medona</i>
Magur/Shing	মাগুর/শিঙি মাছ	Native	Indian torrent catfish	<i>Amblyceps - Mangois</i>
Gong Tenra	গং টেংরা	Native	Indian torrent Catfish	<i>Gagata-gagata</i>
Cheka	চেকা	Native	Squarehead catfish	<i>Chaca-Chaca</i>
Gagla	গাগলা	Native	Gagora catfish	<i>Arius-Gagora</i>
Gong Tengra	গং মাগুর	Native	Gray eel-catfish	<i>Plotosus-canius</i>
Kani pabda	কানি পাবদা	Native	Butter catfish	<i>Ompok-bimaculatus</i>
Kani tengra	কানি টেংরা	Native	Butter catfish	<i>Glyptothorax-cavia</i>
Kani tengra	কানি টেংরা	Native	Painted catfish	<i>Pseudolaguvia-ribeiroi</i>
Kani tengra	কানি টেংরা	Native	Painted catfish	<i>Pseudolaguvia-Shawi</i>

Magur	মাগুর	introduced	Walking-catfish	<i>Clarias - batrachus</i>
Nuna-Tengra	নুনা টেংরা	Native	Long whiskers Catfish	<i>Mystys -gulio</i>
Pabda	পাবদা	Native	Indian catfish	<i>Callichrus-Pabda</i>
Shillong	শিলঙ	Native	Silond catfish	<i>Silonia-silondia</i>
Shingi	শিঙি/শিঙঘি	Native	Stinging Catfish	<i>Heteropneustes- fossilis</i>
Modhu Pabda	মধু পাবদা	Native	Pabdah catfish	<i>Ompok -pabda</i>
Pangus	পাঙ্গাস / পাঙাশ	Native	Yellowtail catfish	<i>Pangasius- Hypothalmus</i>

Source: Wikipedia 2019

Fisheries together contribute about 3.57% of total GDP of the country's economy and 6% of the total annual export earnings. Contribution of aquaculture and fisheries for animal protein accounting for 63% of the total national intake is still dominating although considerable development was occurred in livestock and poultry sector [Department of Fisheries (DoF), 2018]. Bangladesh's total fish production for the year 2017-2018 was above 41.34 lakh MT achieving sixth rank among the major aquaculture producing countries in the world. Out of total fish production, aquaculture contributes 39% and remaining 42% and 19% was from inland capture fisheries and marine fisheries, respectively [Department of Fisheries (DoF), 2009] indicating aquaculture is the fastest growing food producing sector in Bangladesh.

The combined contribution of all sub-sector (crop, livestock, forestry and fisheries) to GDP is 15.35 percent where fisheries sector to the GDP are 3.65, 1.66 and 1.69, respectively (BER, 2016). Although the share of agriculture to GDP is decreasing day by day its contribution has always been very significant. Table 1.2 and Figure show the share of agriculture sector from 2001-16 in GDP of Bangladesh.

Table1.2: Share of Agriculture to GDP of Bangladesh

<u>Years</u>	<u>Contribution Of different Sub sector agriculture To GDP of Bangladesh</u>				
	<u>Agriculture (%)</u>	<u>Crops (%)</u>	<u>Forestry (%)</u>	<u>Livestock (%)</u>	<u>Fisheries (%)</u>
<u>2001-02</u>	<u>23.47</u>	<u>13.43</u>	<u>1.86</u>	<u>2.93</u>	<u>5.23</u>
<u>2003-04</u>	<u>22.30</u>	<u>12.51</u>	<u>1.82</u>	<u>2.95</u>	<u>5.00</u>
<u>2005-06</u>	<u>21.11</u>	<u>11.72</u>	<u>1.76</u>	<u>2.90</u>	<u>4.73</u>
<u>2007-08</u>	<u>19.01</u>	<u>11.52</u>	<u>1.43</u>	<u>2.30</u>	<u>3.76</u>
<u>2009-10</u>	<u>18.59</u>	<u>11.22</u>	<u>1.34</u>	<u>2.42</u>	<u>3.61</u>
<u>2011-12</u>	<u>17.38</u>	<u>10.01</u>	<u>1.78</u>	<u>1.90</u>	<u>3.68</u>
<u>2013-14</u>	<u>16.5</u>	<u>9.28</u>	<u>1.74</u>	<u>1.78</u>	<u>3.69</u>
<u>2015-16</u>	<u>16.01</u>	<u>8.78</u>	<u>1.72</u>	<u>1.73</u>	<u>3.69</u>
<u>2017-18</u>	<u>15.35</u>	<u>8.35</u>	<u>1.69</u>	<u>1.66</u>	<u>3.65</u>

Source: BBC (2008,2011,2014,2016), BER (2016)

Regionally, inland aquaculture production is dominated in the north region, i.e. the Pabna district, where Pabda catfish, (*Ompok-pabda*) farming was started commercially in 2015 by a private fish farming. Pabda is one of the best aquaculture species in Bangladesh due to its ease of culture, high market demand and well suited to the weather condition its propagation and culture. In recent years, Pabda has become one of the most popular commercial culturable species due to its high yield, higher response to external feeding, and availability of Pabda seeds to meet up the farmer's demand. Over the last 3 years, Pabda aquaculture evolved to a shape of commercial enterprise having long backward and forward linkages providing livelihoods for a wide range of stakeholders. Almost all of the produces are consumed domestically proving year-round supply of animal nutrition to low- and medium-income people in both rural and urban areas.

Over the last three decades, the fish production is increased more than five times (7.54 MT in 198384 to 41.34 lakh MT in 2016-17). The overall growth performance from inland aquaculture shows a moderate increased trend due to dissemination of improved technology packages and supportive/need-based extension services at farmer's level. During the last eight

years, the aquaculture production became more than double (10.63 lakh MT in 2008-09 to 23.33 lakh MT in 2016-17) [Department of Fisheries (DoF), 20018]. Such expansion has huge positive impacts as discussed above, however a large concern is that aquaculture has some negative environmental impacts. Expansion of aquaculture requires conversion of land related to crop fields, wetlands, seasonal waterbodies, mangrove forests, and other terrestrial and aquatic ecosystems. Land is the basic natural resource that provides habitat and sustenance for living organisms, as well as being a major focus of economic and livelihood activities. The population is increasing and the land is being converted from productive purposes, such as crop cultivation, to other uses such as housing, roads and urban development, and this trend is expected to continue. This is because there is no such a national policy for any systematic land use strategy that was already implemented by other Asian countries (e.g. Vietnam, Indonesia, etc.) consolidating and distributing the land resources to the appropriate users through the control of the government towards sustainable land use (Griffin et al., 2002). Collectively increasing pressure of aquaculture, agriculture and other non-agricultural activities on land use made the scientists and policy makers concerned about sustainability of food production for future generation.

In terms of inland aquaculture, particularly of Pabda aquaculture in Bangladesh, as there is no any legal aquaculture legislation in place for land use, consequences could be the same as the of shrimp farming in coastal areas. Therefore, the overall environmental impact due to land use for Pabda catfish farming became an important issue deserves to be addressed thoroughly. Considering the above fact, the present research work was carried out to assess the impacts of Pabda aquaculture on land use patterns in selected areas in Bangladesh.

1.2: Statement of the Problem

Fish production in Bangladesh is not only important as a source of rich protein, but it also can be used to bring about institutional changes. These changes can offer access to production assets and resources which can help to empower the poor and directly promote them livelihoods. The increase in fish consumption as a good source of protein and its cultural and religious acceptability are an indication that pabda catfish culturists must live up to expectation of meeting the local demand (Tsue, Lawal, and Ayuba, 2012). The current shortfall in fish

supply compared to local demand is putting pressure on the price of fish and its products. This can make fish unaffordable for many households in Bangladesh and further decreasing the per capita fish consumption rate (FAO, 2010). However, there is significant interest in the development of successful fish farming in Bangladesh. The fish industry remains the most virgin investment in Bangladesh compared with the importation of frozen fish in the domestic market (Ndu, 2006). A sure means of substantially solving the demand-supply gap is by embarking on widespread homestead/small scale fish production. Also, considerable efforts have been directed at examining productive efficiency of fish farmers in Bangladesh that is exclusively focused on technical efficiency of fish farmers in general and profitability of fish farming (Kudi et al., 2008). Consequent upon the increment in awareness of catfish farming and a substantial percentage of small-scale catfish farmers in Bangladesh, it has prompted the interest of researchers to study this firm, but most of the past studies in Bangladesh focused on large scale fish farming. There has been little information on economic analysis of pabda catfish production. It is on these bases that the following research questions were addressed by this study:

- i. What are the socio-economic characteristics of Pabda catfish producers in the study area;
- ii. What are the technical efficiencies of Pabda catfish production?
- iii. What are the determinants of technical efficiencies of Pabda catfish production?

To our knowledge, no study has been done on these issues in the context of Pabna District or any other district in Bangladesh. Therefore, this study tries to shed lights on the relationship on different aspects of fishing, and fish production efficiency with respect to the farming households of Pabna District

1.3: Objectives of The Study:

The general objective of this study is to determine the technical efficiency of catfish farms of Pabna district in Bangladesh. The specific objectives are:

1. To identify the production types and production technologies used in the pabda farms;
2. To determine the technical efficiency of Pabda farms;
3. To describe the socio-economic characteristics of Pabda producers in the study area;

This study tries to achieve the above objectives and answers the associated research questions by conducting a primary survey on a sample of the fish farming in Pabna district. To pursue this data were collected from fish farming from three upazila like Chatmohar Upazila, Atgharia upazila, Bhangura Upazila of Pabna district and analysis of data is performed by Stochastic frontier method and different econometric tools.

1.4 Justification of the Study:

Bangladesh is considered one of the most suitable regions for fisheries in the world, with the world's largest flooded wetland and the third largest aquatic biodiversity in Asia after China and India. The paper reviews the performance of fisheries in Bangladesh using data collected from the Bangladesh Department of fisheries. The findings within describe recent growth within Bangladesh inland fisheries, primarily in the inland aquaculture sector (2014-2015). The increase in the Aquaculture production has been made possible with the implementation of scientific and technological modernization.

There are an estimated 1.3 million fish ponds in the country, covering an area of 0.151 million ha, of which 55.30 percent is cultured, 28.52 percent is culturable and 16.18 percent is unused. In 2002 the percentage of production from the above three systems was 72.09, 20.01 and 7.90 respectively (BBS, 2002). In general, the size of fish ponds varies between 0.020 and 20 ha with an average of 0.30 ha. In Bangladesh, the highest number of ponds exists in the Barisal district (12.11 percent),

Currently, more than 600 000 people are engaged in shrimp farming activities (Fao, 2003), it is also estimated that around 14 000 fishermen (2.5 fishers per ha water body) are directly involved and 70 000 rural people are the direct beneficiaries of oxbow lake fisheries (Hasan,

2001a; Hasan and Talukdar, 2004). In both aquaculture and fisheries activities, it is the male members of the family who carry out almost all of the work in Bangladesh, very recently however a few women have been encouraged to participate through the motivation of NGOs and some private entrepreneurs. Thengamara Mahila Sabuj Sangha is a woman's NGO which is actively engaged in aquaculture development activities.

An estimated 9.5 million people (73 percent) are involved in subsistence fisheries on the country's flood plains (Azim et al., 2002), the number of fishermen increases dramatically to 11 million between June to October each year. There are 3.08 million fish farmers, 1.28 million inland fishermen and 0.45 million fry collectors (fish and shrimp) in Bangladesh (DOF, 2003) and it is estimated that fisheries and related activities support more than 7 percent of the country's population. According to figures revealed by the National Bureau of Statistics, the fisheries sector contributed 3.57% of total GDP in 2018, respectively. Evaluation of Pabda catfish farming will expose the need for catfish farmers to adopt new technologies and achieve sustainable production. This study will also be important in determining the two-extent which Pabda catfish farmers can raise productivity through improved efficiency with existing resource base and available technologies.

This thesis offers an improved understanding of technical efficiency of Pabda catfish farming; factors affecting fish farming. Its theoretical and academic contribution develops and operationalizes an integrated conceptual framework which incorporates socio-economic'. This investigation approach provides an improved understanding of the decision-making process of pabda catfish farming.

The results of this study are expected to give direction for policy makers in designing appropriate public policies to increase fisheries productivity. It will provide a useful guide to international and local donor agencies interested in fish production and resource management studies.

The results of this study will also help aquaculture planners in the Aquaculture Development Programs (ADPs) and Ministries of fisheries in Bangladesh. Researchers are going to have a good resource base to look at fish production where's farmers are going to benefit by knowing those adaption strategies, production efficiency and effect of adaptation strategies on the fish

production efficiency are more effective. Therefore, from the conducted discussion, the study is fully justified

1.5 Framework of the Study

The thesis on technical efficiency analysis of Pabda catfish production is presented in well-structure manner. The thesis contains eight chapters. Chapter one describes introduction of the study. Relevant review of literature and research finding by earlier researchers in the field of technical efficiency of Pabda production and profitability such as theoretical literature and empirical literature are presented in chapter two. The gaps in the previous research have also been mentioned here. Chapter three gives an account of the theoretical framework. It contains several concepts related with aquaculture production, Production function, Law of variable proportion, returns to scale, technical, allocative and factor efficiency. Chapter four focus the overview of Pabda production in Bangladesh as well as in Pabna district. It focuses the overall scenario of aquaculture, Pabda production and share of aquaculture production in GDP over the period. Chapter five highlights mainly research methodology. This chapter has two main sections. In first, empirical methodologies are presented. In section two, gives the description of the study area, method of sample selection and data collection. In chapter six, a description of the collected data is given by analyzing the simple descriptive statistics, i.e., the socioeconomic variables of the data in both tabular and graphical forms. Chapter seven shows estimation results and the interpretations of those results are provided. Finally, in chapter eight, summary, conclusion, policy recommendation is presented.

1.6 Limitation of the Study

The study mainly based on primary data. So, the major limitations are the collection of the data. The enumerators elicited information from the respondents using interview schedule as against the supposed structured questionnaire. The respondents were interviewed all through because of the importance of the information the questionnaire to elicit. It was not self-administered as it is supposed of questionnaire but rather enumerator and researcher administered (Ellis, 2007). This made the data collection process time consuming but the data were free of error due to omission of relevant information needed for the study.

This is a study of three Upazila under Pabna District like Chatmohar Upazila, Atgharia Upazila, Bhangura upazila. a small unit more over due to limited financial resources and time constraints the study has been conducted to on a small sample size of only 60 respondents from three upazila which may have limitations in generalizing the findings for elsewhere. In most cases fish production does not keep the actual record of the number of fingerlings, amount of feed used, amount of yield of production and other miscellaneous information. So, the researchers tried to get the answer that came out of their memories.

This study never attempted to include emission inventory of greenhouse gases, emission projections, and 'mitigation' issues. Having these limitations stated here, the present study helps us to understand the pabda catfish farming' adaption strategies and their impact on pabda catfish production efficiency for the areas of Pabna District which can be helpful to be used as a primary source for adopting appropriate policies and take programs to rises up fish production of mass.

CHAPTER TWO

Literature review

2.1. Introduction:

Literature review is a secondary source of scholar articles, books, dissertations, conference proceedings and other resources which are relevant to a particular issue, area of the study, or theory. It focuses on current knowledge including substantive findings as well as theoretical and methodological contributions to a particular topic. It gives a theoretical base for the particular study and helps to determine the nature of the study. Actually, research study tells a story and the existing literature helps us identify where we are in the story currently. It is up to those writing a dissertation to continue that story with new research and new perspectives but they must first be familiar with the story before they can move forward. A crucial element of all research study is the review of relevant literature. The key points of the literature review:

- ❖ What the study says i.e. theory of the study.
- ❖ How the study has carried out i.e. methodology of the study.
- ❖ What is missing, i.e. the gap that the study intends to fill.

And the literature review helps to motivate a researcher conduct a study by the following term:

- ❖ Help to avoid reinventing the wheel by discovering the research already conducted on a topic.
- ❖ Increases breadth of knowledge in the area of research.
- ❖ Help to identify seminal works in study area.
- ❖ Allows providing the intellectual context for work and position research with other, related research.
- ❖ Provides opposing viewpoints.

This chapter is a review of past and recent studies having relevance to the research problem. Some research reports on many types of fish farming and especially on catfish, marine fisheries, etc. Now, the available reports have been reviewed and briefly presented in the following paragraph.

This chapter is reviewing the present and past studies to the relevant study problem. Available studies on technical efficiency and economic efficiency of pabda catfish and its impact on total production of nation have been found. Now, the available report has reviewed and briefly presented in the following.

2.2 Theoretical Literature Review

Productivity and efficiency are both measure of production performance. However, there is slight difference between them. One can improve the state of technology by inventing new ploughs, pesticides, etc. This is commonly referred to as technological change and can be represented by an upward shift in the production frontier. Alternatively, one can improve farmer's education, extension service, etc. This in turn will improve production efficiency of farmers and will be represented by farmers operating closer to the existing frontier. Hence generally, productivity growth may be achieved through either technological progress or efficiency improvement (coelli,1995)

2.3 Literature related with the Technical efficiency of Pabda fish farming in Bangladesh

Rabbani et al., (2017) conducted a research on the technical efficiency for Setbag net fishing boats operated in the year 2014. A total of 100 samples of Setbag net fishing boats were selected, of which 40 were from Cox's Bazar, 40 were from Chittagong and 20 were from Bagerhat. Stochastic frontier (with technical inefficiency effect) model was specified and estimated. Results have shown that the estimated mean technical efficiency of Setbag net fishing boats is 84 percent. The efficiency of Setbag net fishing boat was positively associated with total cost, while the number of nets were negatively related to fishing day and crew size. Head maji's age had significant effect on inefficiency at 5% level. Although, the effect on boats' efficiency was positive, (though insignificant) for head maji's experience, head maji's education, engine horse power and boat age. The use of modern fishing boat and improved fishing technology should be promoted, through proper training and motivation program for fisher. At the same time old and unfit fishing boat and gears should be gradually removed and replaced by new and modern fishing boat.

Begum et al., (2016) conducted a study on technical efficiency of freshwater prawn farming in Bangladesh. Primary data has been collected using random sampling from 90 farmers of three

villages in southwestern Bangladesh. Prawn farming displayed much variability in technical efficiency ranging from 9.50 to 99.94% with mean technical efficiency of 65%, which suggested a substantial 35% of potential output can be recovered by removing inefficiency. For a land scarce country like Bangladesh this gain could help increase income and ensure better livelihood for the farmers. Based on the trans log production function specification, farmers could be made scale efficient by providing more input to produce more output. The results suggest that farmers' education and non-farm income significantly improve efficiency whilst farmers' training, farm distance from the water canal and involvement in fish farm associations reduces efficiency. Hence, the study proposes strategies such as less involvement in farming-related associations and raising the effective training facilities of the farmers as beneficial adjustments for reducing inefficiency. Moreover, the key policy implication of the analysis is that investment in primary education would greatly improve technical efficiency.

Adnan et al., (2016) conducted a study on the different aspects of marine fishery and examined whether its potential exists for further contribution to the whole fish production of the country. The objectives of the study are estimating the costs and returns of marine fishing under different fishing technologies and to determine the factors that are responsible for variations in catch and income from fishing. Two major production technologies are used in small-scale marine fishing: longline and setbag net fishing. Average per trip gross returns for longline and setbag net were Tk. 280540 and 446990 per boat and their subsequent net returns were Tk. 122550 and 220020 per boat, correspondingly. Therefore, providing higher level of efforts and better management, setbag fishermen earned higher level of income compared to other type of fishing gear. Considering the profitability and other economic aspects, setbag netters were more efficient than fishermen using other type of gear

Hasan. (2012) conducted a study on the sustainability of farmers' livelihood. The study used extensive field visits, interviews with the key informants of Regional Fisheries and Livestock Development Component (RFLDC) and farmers, personal communications and focus group discussion as the main procedures to collect data and information. The study also used the sustainable rural livelihood framework to show farmers' livelihood resources and transforming strategies to resilient livelihood outcome. The study found four common categories of aquaculture in the mainland, accreted and newly accreted lands of Noakhali and characterized

those with technology level, size, dependencies, markets, ownership, species mix, constraints and vulnerabilities to changing climate. Average net returns from the technology induced aquaculture in community-based ponds and waterlogged paddy lands were 905.33 and 362.78 USD/ha/year respectively.

Ferdous et al., (2011) conducted a study on the technical (TE), allocative (AE) and cost efficiency (CE) of pangas fish-producing farmers of Bangladesh. Data envelopment analysis is used to measure the efficiency while Tobit regression is applied to identify the factors affecting efficiencies. The estimated mean TE, AE and CEs are 86%, 62% and 54% respectively. Pangas production is characterized by considerable technical inefficiencies and substantial allocative and cost inefficiencies. Pond size, fingerling size, culture length and use of pelleted feed are important determinants of efficiencies. It is nevertheless profitable in terms of benefit–cost ratio, break-even yield and price criteria. Production of pangas can be made further profitable by eliminating inefficiencies. Proper mixing of inputs given their prices could make pangas producers profit maximizers. Efficiency improvement is expected to help to increase production and provide scopes for exporting the surplus production. More fisheries extension is suggested to expand pangas culture and improve efficiency.

Ali and Haque, (2011) conducted the study by using multiple methodological tools including participatory rural appraisal (PRA) tools and mainly questionnaire-based farm survey to assess the impacts of *Pangasius* farming on land use from February to September, 2009. The mean farm size (ha), water area (ha) and dyke area (ha) was 1.36 ± 1.25 , 1.06 ± 1.31 and 0.30 ± 0.27 , respectively. The *Pangasius* productivity was significantly and positively correlated with water area and dyke area. Around 10.1% area of the study area was converted to *Pangasius* farm which was previously used as rice-field. Farmers expanded their farm area by taking leased lands which contributed to 56.47% of total farm area and the lease value of *Pangasius* pond was doubled compared to agriculture land.

Akteruzzaman, (2011) a field survey was conducted to study on technical efficiency of tilapia farmers of Bangladesh using stochastic frontier production function involving a model for technical inefficiency effects. Data from fifty tilapia farmers of Jessore district are used in the analysis. The mean technical efficiency level of the tilapia farmers is 78%, and thus, the farmers operate 22% below the frontier production. Inefficiency effect is significant, and age,

education, income, culture length, pond age, pond depth, water color and pond tenure, as a group, are significant determinants of technical inefficiency. By operating at full technical efficiency levels, tilapia yield can be improved from the current level of 7.36–8.96 tons per hectare. The decision to add or not to add inputs is sometimes taken arbitrarily and not based on technology requirement. There is a lack of understanding of the technology practices. Fisheries extension efforts are required for proper understanding of the technology practices, further adoption and spread. For promotion of tilapia production, quality feed and seed at affordable price needs to be ensured.

Haque. et al., (2003) conducted a research entitled to determine the costs, returns and relative profitability of pond fish and nursery fish production. In order to attain this objective, a total of 70 producers: 35 producing pond fish and 35 producing nursery fish were selected on the basis of purposive random sampling technique from 6 villages under two Upazilas (Sujanagar and Santhia) of Pabna district. It was estimated that per hectare per year gross cost of pond fish production was Tk 65,918 while gross return and net return were Tk 91,707 and Tk 25,789 respectively. Per hectare per year gross cost of nursery fish production was Tk 87,489 while gross return and net return were Tk 1,39,272 and Tk 51,783 respectively. The findings revealed that nursery fish production was more profitable than pond fish production. Cobb-Douglas production function was applied to realize the specific effect of the factors on pond fish and nursery fish production.

Sayeed et al., (2014) conducted a study on the aquatic resources and fisheries status of the Chalan beel and to identify the opportunities for improvement of the existing fisheries management strategies, focusing on fish biodiversity conservation. Sampling for Catch Assessment Surevey (CAS), Fishing Effort Survey (FES) and water sediment was carried out at the Gumani, the Katagang and the Baral sites. Interview and Focus Group Discussions (FGDs) were conducted in ten upazilas in and around Chalan beel. The abundance of several species showed decreasing trend from 2007 to 2008. The number of professional fishers has declined by 58% between 1982 and 2008 and the fishers left the profession due to much decreased fish availability in the beel as a result of very low fish catch and falling income. A total of 34 different types of fishing gears including nets. The mean Catch Per Unit Effort (CPUE) of different fishing gears varied widely ranging from 2.04 to 48.99 kg unit⁻¹ day⁻¹.

The average total annual fish production of the beel was 12,566.57 MT having average fish production of 281.86 kg ha⁻¹ during the study period.

Flowra et al., (2012) a field survey was conducted to study the fish marketing system and socio-economic status of aratdars at Singra (Natore), Baneshwar and Puthia (Rajshahi). Four types of fishes were observed where maximum fishes (70%) were come from the local area and rest (30%) was come from outside of Bangladesh. Four types of marketing channel were identified and the commission agents usually earn about 3-4% commissions from the farmers. The highest landing was 388143.75 kg/yr (*Hypophthalmichthys molitrix* in Shingra) whereas the lowest landing was 701.75 kg/yr (*Xenentodon cancila* in Baneshwar). Price varied from 20.38±4.58 (Chanda ranga in Baneshwar) to 190.17±27.33 Tk/kg (*Clarias batrachus* in Baneshwar). The average marketing cost and marketing margin varied from 91 to 128 Tk/day and 17.75 to 28.25 Tk/kg in Baneshwar. Majority (53.76% in Puthia to 74.99% in Baneshwar) aratdars were found to class I-X. Major secondary occupation of the aratdars was fish farming (50% in Puthia to 75% in Baneshwar). Most of the aratdars (75% in Baneshwar and Shingra to 83% in Puthia) were found to earn Tk 100-500 per day. Infrastructure of wholesale and retail fish markets were not adequate with regarding to sales area, packaging, sanitation, water supply, drainage, cleaning, washing, maintenance and repairs except very few.

Uddin et al., (2012) conducted a study on the low-lying inland fish farming practices of Karimganj upazila under Kishoreganj districts. Field level data were collected through direct interview using semi-structured questionnaire. Eighty sample farmers were selected purposively from the study areas. Six types of farming practices were identified in the study area among which only two types were prominent i.e., pond fish farming and Beel fish farming. Tabular, statistical and mathematical analyses were done to achieve the major objectives. The benefit cost ratio in Beel fish farming was 2.86 and in case of pond fish farming it was 1.95. Multiple regression model was used to explain the variation of gross return of pond and Beel fish farming and it was found that coefficients of human labor, feed, cow dung and manure had significant impact on gross return, whereas coefficients of feed, harvesting and making sanctuary had significant impact on gross return of Beel fish farming. Resource use efficiency was calculated by the ratio of marginal value product and marginal factor cost. Finally, the

study identified some important problems of low-lying inland fish farming and suggested probable solutions relating to the problems.

Omar et al., (2015) conducted a study on the value chain, value addition, marketing cost & margin, marketing efficiency and market integration of rohu fish in selected areas of Bangladesh during the month of July-August 2012. The objectives of the study were to estimate costs and margins, seasonal price variation and to test market integration of rohu fish. Primary and secondary data were used for this study. The higher marketing cost was incurred by paiker and the lowest by retailer. On the other hand, retailers earned the highest net marketing margins. Chain II was found the most efficient chain. Analysis of market integration shows that rohu fish market in Bangladesh was well integrated. The findings of the study revealed that the marketing of rohu fish was a profitable business and some recommendations were provided for the improvement of rohu fish marketing in the country.

Chowdhury al., (2011) conducted a study on the development of fresh water pond fish culture through grassroots level organization in Bangladesh. The study was conducted in rural area of Bangladesh. The result of the study reveals that, management and cultural factors affect fish farming in ponds. The study also indicated that, higher production could be achieved by increasing the use of fertilizer and artificial feeding along with the improvement of other management practices. The grassroots level village organization had played a significant role in the process of technology transfer from the Thana level to the village level.

Das et al., (2018) conducted to reveal the present scenario, problems and the prospect of fish farming of Gazipur Sadar upazila Bangladesh. The primary data were collected through field survey, questionnaire interview and focus group discussion from the fish farmers of several villages and urban areas of the upazila. Secondary data were collected from the Department of Fisheries and aquaculture extension section. Gazipur Sadar upazila has 14462.42 ha potential fisheries resources of which floodplains, seasonal water bodies, and ponds comprise 71.01%, 13.04%, and 8.57%, respectively. The total fish production of the upazila in 2016-17 was 14492.7 MT, 27% of the Gazipur district. The highest fish production of 5436 MT and 4.39 MT/ha/year came from the pond sector. Among different pond culture systems, the semi-intensive system had the highest fish production output (2826 MT).

Mollah et al., (2009) conducted a study on the observed growth performance and survival of the larvae produced from the brood fish of *Ompok pabda* treated with 4 dietary levels of vitamin E for 90 days viz. 0 (served as control), 50, 100 and 150mg vitamin E/kg feed under 4 treatments i.e. treatment T1, T2, T3 and T4. After the feeding trials, the brood fish were induced to breed with equal dose of PG extract i.e. 12 and 18mg/kg body weight for male and female respectively and subsequently larvae were produced.

2.4 Literature related with the Technical efficiency of Pabda production in other countries.

This section presents a synthesis of the studies conducted on the fishery industry in different countries in previous years, regardless of the approach adopted. As briefly mentioned in the introduction, two alternative approaches have been used primarily to analyze productivity and efficiency in fisheries in the past: parametric SFA and the non-parametric DEA. It is worth noting that the literature on productive efficiency in the lobster fishing industry is quite scarce. However, the literature has a growing history and presents a large heterogeneity, not only in terms of the models used within each approach, whether it be parametric or non-parametric, but also in terms of the research subjects analyzed, and the hypotheses tested.

Francis and Xinhua et al., (2018) conducted a study on stochastic frontier production function was applied to estimate both the technical efficiency scores and determinants of inefficiency for 20 tilapia farms apiece in Malawi and China. The study used the Cobb-Douglas model in which efficiency estimates showed that tilapia farmers in Malawi were more technically inefficient than farmers in China, with mean efficiency scores of 47% and 91% respectively. With exception of aquaculture experience, all the inefficiency determinants were positive for Malawian farms even though none of the coefficients was significant. For Chinese tilapia farmers, age (significant), household size and education had negative signs except aquaculture experience. The Malawian tilapia industry need technology innovations in order to reduce the existing 53% yield gap, which can ideally be introduction or development of new strains of superior quality, enhanced use of all-male tilapia, improvement in both nursing and grow-out technologies as well as use of quality fish feed.

Nades. et al., (2017) conducted a study on Technical Efficiency of Catfish and Nile Tilapia Farming in Bangka Tengah Regency: A Stochastic Frontier Production Approach. the purpose

of this study was to analyze factors affecting catfish and Nile tilapia production and to measure the level of technical efficiency. The study was conducted in Bangka Tengah Regency, Bangka Belitung Islands Province, Indonesia, based on the cross-sectional primary data collected from 71 catfish and Nile tilapia farmers through stratified random and systematic sampling methods. Furthermore, methods of analysis using the stochastic frontier production approach to look at the effect of inputs on catfish and Nile tilapia production, followed by the analysis of technical efficiency (TE). Results showed that stochastic frontier Cobb-Douglas indicated that production input variables such as pond size, fingerlings, feed, labor, salt, lime and fuel pump statistically significant impacts on the catfish production, where the output elasticity associated with fingerlings is the highest (0.715), while, results of analysis showed that pond size, labor, salt, and fuel pump statistically significant impacts on the Nile tilapia production, where the output elasticity associated with labor is the highest (1.005). The TE of catfish farming ranges between 0.130 and 0.999 with a mean of 0.678, and the TE of Nile tilapia farming ranges between 0.047 and 0.999 with a mean of 0.221. The analysis of technical inefficiency aspect suggested that the length of formal education, and membership of fish farmer group in catfish farming were factors that contribute significantly and positively to technical efficiency of catfish farms.

GIREI. et al., (2013) conducted a study on efficiency of Fadama II beneficiary crop farmers in Adamawa state, Nigeria. Data were collected on a sample of 160 farmers and were analyzed using stochastic frontier production function. The maximum likelihood estimates (MLE) for the stochastic production function results shows that the coefficients of farm size, inorganic fertilizer, hired labor and expenses on ploughing, significantly affect food crop output of the respondents. The mean technical efficiency was 0.71 (or 71%), the mean allocative efficiency was 0.76 (or 76%) and the mean economic efficiency was 0.54 (or 54%). The study concludes that, the maximum likelihood estimates (MLE) for the stochastic production function of the coefficients of farm size (X1), inorganic fertilizer (X3), hired labor (X5) and expenses on ploughing (X6) were found to be positive and significantly affect food crop output of the respondents with the mean technical efficiency is 0.71 (or 71%).

Edward. et al., (2016) conducted a study on the productivity of hired and family labor and determinants of technical inefficiency of fish farms in Ghana. A modified Cobb-Douglas stochastic frontier production function which accounts for zero usage of family and hired labor

is employed on cross-sectional data of 150 farmers collected in 2007. The results reveal that family labor, hired labor, feed, seed, land, other costs and extension visit have a reasserting influence on fish farm production. Findings also show that family and hired labor used for fish farming production in Ghana may be equally productive. The combined effects of operational and farm specific factors (age, experience, land, gender, pond type and education) influence technical inefficiency although individual effects of some variables may not be significant. Mean technical efficiency is estimated to be 79 percent. given the present state of technology and input level, the possibility of enhancing production can be achieved by reducing technical inefficiency by 21 percent through adoption of practices of the best fish farm.

Shaowei et al., (2013) we consider empirical studies on fishery production efficiency of Zhoushan new district based on data envelope analysis (DEA) model of three-stage. The results show that environment variables and random factors do have an effect on fishery production of Zhoushan. The increase of urbanization level and the average year of population education are the favorable factors to improve fishery production; fishermen per capita income and fishery subsidies provided by the government are the adverse factors in the improvement of fishery production efficiency. After eliminating the influence of environment variables and random factors, we get a relatively real efficiency of fishery production in Zhoushan new district.

Gazi et al., (2016) conducted a study on a stochastic frontier analysis of technical efficiency of fish cage culture in Peninsular Malaysia. Cage culture plays an important role in achieving higher output and generating more export earnings in Malaysia. However, the cost of fingerlings, feed and labor have increased substantially for cage culture in the coastal areas in Peninsular Malaysia. This paper uses farm level data gathered from Manjung, Perak and Kota Tinggi, Johor to investigate the technical efficiency of brackish water fish cage culture using the stochastic frontier approach. The technical efficiency was estimated and specifically the factors affecting technical inefficiencies of fish cage culture system in Malaysia was investigated. On average, 37 percent of the sampled fish cage farms are technically efficient.

Edinam. et al., (2017) conducted a study on the profit efficiency of artisanal fishing in the Pru District of Ghana by explicitly computing profit efficiency level, identifying the sources of profit inefficiency, and examining the constraints of artisanal fisheries. Cross-sectional data

was obtained from 120 small-scale fishing households using semi structured questionnaire. The stochastic profit frontier model was used to compute profit efficiency level and identify the determinants of profit inefficiency while Garret tracing technique was use dot rank the constraints. The average profit efficiency level was 81.66% which implies that about 82% of the prospective maximum profit was gained due to production efficiency.

Jennifer et al, (2007) conducted to the effort to conserve fisheries resources and improve the welfare of small-scale fishing households is an important objective of poverty reduction strategies in Tanzania. The success of such strategies depends on both the diversity and the level of efficiency within small-scale fishing households. This paper examines the technical efficiency of Tanzanian small-scale fishing households, based on data from two coastal villages located near Bagamoyo and Zanzibar, using a stochastic frontier model with technical inefficiency. The estimated mean technical efficiency of small-scale fishing households was 52%, showing that they were operating far below optimum efficiency. The efficiency of individual fishing households was positively associated with fishing experience, size of farming land, distance to the fishing ground and potential market integration; it was negatively related to non-farm employment and bigger household sizes.

Yang and Xiaobo. (2016) conducted a study on technical efficiency study on Japanese marine fisheries applying stochastic frontier analysis and data envelopment analysis approaches. Technical efficiency analysis was carried out targeting Japanese marine fishery production in 2013, applying both Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA) approaches. Results showed the technical efficiency estimate of Japanese marine fishery production in 2013 was 0.783, 0.559 and 0.666 by means of SFA, DEA-CRS (constant returns to scale) and DEA-VRS (variable returns to scale), respectively. This indicates that a range of 22%-44% potential scope still exists for improving the current Japanese marine fishery production with the given inputs. Analysis of region-specific efficiencies showed Ehime Prefecture was the most efficient irrespective of estimation methods, while Osaka and Yamaguchi Prefectures were the least efficient using different analytical approaches. Comparison of the results between SFA and DEA shows that technical efficiency estimates applying SFA were closely associated with those by DEA, although the efficiency scores were higher by SFA approaches.

Hannesson et al., (1983) conducted a study on the first to study the production function of the Lofoten fishery using fishing effort (input) and fish biomass as independent variables. Since then, the literature of productivity efficiency in fisheries has steadily grown.

Donald et al., (2016) conducted a study on economic analysis of catfish production and its contribution to household food security in federal capital territory, Abuja, Nigeria. 32% of the variation in the total cost of production of catfish farmers were due to allocative efficiency. It was observed from the study that 15% of the farmers possess efficiency. Catfish farmers in the study area incurred output loss of about 33% due to technical inefficiency. In other words, there exist 33% potential for increasing output by the catfish farms. There is therefore room for improvement in catfish production in the study area given the available resources and available technology.

In similar efficiency studies, Alamode and Jihad (2014) study of catfish farmers in Oyo State revealed a technical efficiency of 52.9%. On average, economic efficiency of catfish farms can be improved by about 43% with existing resources.

The Data Envelopment Analysis (DEA) utilized by Obisesan O.O., Salmann K.K., and Akintayo O. (2017) to estimate the profit efficiency of processors. The result showed that Ekiti state processors had a profit efficiency of 88%, while those in Ebonyi state had 79%. In Ekiti state, processors were least profit efficient in transportation (14%), hiring of operating space (10%) and payment for duties and taxes (28%). In Ebonyi state, processors were least profit efficient in communication (13%), rice paddy (21%), maintenance and repairs (21%), transportation (28%) and fuel (35%).

Francis and Xinhua (2018) conducted a study on the technical Efficiency of tilapia Production in Malawi And China. The Cobb Douglas model in which efficiency estimates showed that tilapia farmers in Malawi were more technically inefficient than farmers in China, with mean efficiency scores of 47% and 91% respectively. With exception of aquaculture experience, all the inefficiency determinants were positive for Malawian farms even though none of the coefficients was significant. For Chinese tilapia farmers, age (significant), household size and education had negative signs except aquaculture experience. The Malawian tilapia industry need technology innovations in order to reduce the existing 53% yield gap.

Alawode and Jinad (2016) conducted a study on the investigated the evaluation of technical efficiency of catfish production in oyo state: a case study of ibadan metropolis. 72.3% of the respondents were involved in grow out operations, that is, raising of catfish to table size, while 8.4% were involved in the sole production of fingerlings. the majority of the catfish farmers (56.6%) used static renewal systems (earthen ponds) while 30.1% used flow through systems (tanks and troughs), and 13.3% used a combination of both systems. It was observed that technical efficiency indices were low, ranging between 11.3 and 83.7 with a mean efficiency score of 52.9. The study also found that farmers' cost efficiency scores were low, also ranging from 0.11 to 0.97 with a mean of 0.37, and that farmers' access to credit, level of education, culture system used, years of experience in catfish farming, and household size were factors which contributed significantly to catfish farming.

Nades (2012) conducted a study on the technical efficiency of catfish and nile tilapia farming in bangka tengah regency: a stochastic frontier production approach. the mean technical efficiency level of catfish and nile tilapia farming were 68% and 22% respectively implying that a substantial 32% and 78% of the potential for increasing output from the catfish and nile tilapia farming system by eliminating inefficiency.

2.5 Literature Gap

This review of the existing literature has outlined some gaps or weaknesses. The specific gaps were outlined in the chapter. The general gaps are summarized below:

- ❖ Production efficiency is an important factor of productivity growth in the aquaculture economy of a developing country like Bangladesh. Bangladesh increase the export earnings if productivity could be enhanced through increasing efficiency in production. Most of the earlier studies perform on only technical or economic efficiencies rather production efficiency studies.
- ❖ Earlier studies capture either Technical efficiency of Pabda (Catfish) Production. But Moreover, most of these early studies have focused merely on the likely others catfish production.
- ❖ Most of the past cross-sectional studies used county or district level data. But these studies do not allow for the detailed socio-economic and demographic characteristics of farmers that are likely to affect farm productivity, and its efficiency.

- ❖ Previous studies using time series data have not focused on Pabda. Moreover, the results from those studies were not robust because of insufficient statistical and diagnostic tests.
- ❖ In the case of Bangladesh, there are no empirical studies on pabda catfish production efficiency.
- ❖ In case of Pabna district, no research work has been conducted on the present issues.

2.6 Analytical Techniques

The type of analytical tools or techniques to be used in research studies depend to a considerable extent on the purpose for which the model is being estimated, nature of the study, available data, type of data (cross-sectional, time series and panel), convenience of the analysis, other econometric underpins and advantages derived from the tools. Since, to resolve the literature gap as possible as, the present study use the analytical tool. Selected fish farmers' coping strategies are going to be linked with some socio-economic variables as determinants (i.e. efficiency changing variables) of technical and profit efficiencies in rice production in northern Bangladesh. Hence the use of stochastic production and profit models to measure efficiency levels of the fish production farmers, which have been widely used in efficiency measurement.

This study evaluates individual strategies by distinguishing household and other socioeconomic factors affecting propensity of use of each of the main adaptation measures available to farmers. To simultaneously examine the relationships between each adaptation option and a common set of explanatory variables it uses a multivariate discrete choice econometric model (Nhemachena & Hassan 2007). The analytical approaches used in an adoption decision involving bivariate choices are logit, probit, and tobit models, among others but for those studies involving multiple choices are the multinomial logit (MNL): multinomial probit (MNP); ordered probit; and ordered logistic models, among others. Both the MNL and MNP are important for analyzing farmer adaptation decisions as these are usually made jointly. The present study conducted MNL logit model to analyze the determinants of farmers' decisions because it is widely used in adoption decision studies involving multiple choices and is easier to compute than MNP.

Another econometric model that was used in this study is factor analysis (FA) to seek answering the basic question of which constraints the technical efficiency of pabda catfish production.

2.7 Conclusion

This chapter focuses on the studies performed on examining the fish farmer's choice of technical efficiency of pabda catfish production and their effect on production efficiency from different perspectives. The factors influencing the pabda catfish production efficiency are discussed in the literature are identified. Various types of analytical, econometric methods, use of different functional forms, the study results and gaps of different literature are reported in the literature. This chapter helps to formulate a basis for the construction of a conceptual portrayal needed for this empirical study and also for the selector of a definite methodology with a view to conducting the econometric analysis in a perfect manner.

CHAPTER THREE

Conceptual Analysis of Production Function and Efficiency

3.1 Introduction

The main focus in this chapter is the conceptual framework that has close linked to the objective of this present study. That means, this chapter deals with such topics which are very important instrument to determine the technical efficiency of pabda catfish production in Pabna district. This chapter discusses production functions and some related concepts of technical, allocative and economic efficiency. The measurement of efficiency begins with Farrell (1957). The failure to produce the maximum output from a given input mix at minimum cost result in inefficiency. Inefficiency is explained by, *inter alia*, restricted access to technology, a lack of knowledge, restricted access extension services, an in appropriate scale of production and sub-optimal allocation of resources. The efficiency of a farm consists of two components: technical and allocative efficiency. Technical efficiency concerns the ability of a farm to produce maximum output from a given set of inputs using existing technology; allocative efficiency reflects the ability of a farm to choose the inputs in optimal proportions, given their inputs prices; and a combination of these two measures provides a measure of economic efficiency. Thus, economic efficiency concerns the ability of a farm to produce output at minimum cost, to obtain this minimum cost, the farm uses inputs in an efficient manner (technical efficiency) and chooses a cost-minimizing combination of input prices and marginal productivities.

The plan of this chapter is as follows: section 3.2 consider stochastic frontier production model; section 3.3 present production function and related concepts; section 3.4 discussion the laws of production and returns to scale; section 3.5 measures of efficiency and section 3.6 summarizes.

3.2 The stochastic frontier production model

The stochastic frontier model was used to achieve objectives of the study. The stochastic frontier as an economic method of efficiency measurement in production systems is built around the premise that a production system is bounded by a set of smooth and continuously differential concave production transformation functions for which the frontier offers the limit to the range of all production possibilities (sharma 72 et al,1999). It has the advantage of

allowing simultaneous estimation of individual farmers as determination of technical efficiency.

3.3 Production Function Analysis with Related Concepts

3.3.1 Definition and Classification of Production Function

In microeconomic theory, the production function explains then technical or physical relationship between output and inputs. Specifically, it shows the maximum output obtainable from a given set of inputs. Production is the process of combining and coordinating materials and forces (input, factors, resources, or productive service) in the creation of some good and services. The term input and output only have meaning in connection with a particular production process or it can be a final consumer good. The output of a farm depends upon the quantities of input used in production.

Generally, a function showing the maximum output possible with any given set of inputs, assuming these are used efficiently are called the production function. Let a production function is as follow:

$$Y=f(X, Z)$$

Here, Y is dependent variable and X & Z are the explanatory or independent variables.

So, the production function shows the relation between the dependent variable and the respective explanatory variables, more specifically it shows the relation between the production as dependent variable and its necessary inputs as the explanatory variables.

In shorts, the production function is mathematical relationship describing the way in which the quantity of particular product depends upon the quantities of particular input used.

The production function could be expressed in different functional forms such as Cobb-Douglas, linear, quadratic, polynomials and square root polynomials, semi log and exponential function. When time perspective is introduced into the production function, we have the short-run and long-run production function. However, only two types of production function namely Cobb-Douglas production function and CES production function will be discussed here.

3.3.2 Cobb-Douglas production function

In order to justify the effectiveness of various production laws, mathematician C.W. Cobb and economist D.H. Douglas investigate production scenario of various industries in U.S.A, Canada and Australia from the period of 1899 to 1922. After the investigation they found that labor and capital was the most important factor process. Then giving priority on labor and capital, the production function what they showed was known as Cobb-Douglas production function. Under the condition at returns to scale. This function can be expressed in general form as.

$$Q = AL^{\alpha}K^{\beta}$$

Q = Output

L = Labor

K = Capital

A = Efficiency parameter and

α, β = The factor shares or factor elasticity.

If L and K are infinity, then Q also will be infinity. If we write it as a logarithmic transformation we can write,

$$\ln Q = \ln A + \alpha \ln L + \beta \ln K$$

However, Cobb-Douglas production function holds several properties. Some of them are:

1. Cobb-Douglas production function is homogenous of degree $(\alpha+\beta)$;
2. its iso-quants are negatively slope and strictly convex;
3. the exponents of each input variable indicate partial elasticity of output with respect to the input;
4. the marginal productivities of factors of production are positive but declining;
5. the expansion path of Cobb-Douglas production function is straight line;
6. Cobb-Douglas production function satisfies the Euler's theorem;
7. the elasticity of substitution of Cobb-Douglas production function is one; and

8. the sum of α , β indicates the returns to scale in the long run.

If $\alpha+\beta>1$, the production function indicates the increasing returns to scale, if $\alpha+\beta <1$, the production function implies the decreasing returns to scale and if $\alpha+\beta=1$, the production function depicts the constant to scale.

3.3.3 constant elasticity of substitution (CES) Production Function

The production function characterized by a constant elasticity of substitution is known as CES Production function. Here, elasticity of substitution means to refer to the measurement of the extent of input substitution and that is supposed to be constant. The equation of this function can be expressed as follows:

$$Q = A [\delta K^{-p} + (1 - \delta)L^{-p}]^{-1/p}$$

Here Q = output; K=Capital input; L = Labor input; A= Efficiency parameter that indicate state of technology; δ = Distribution parameter that deals with the relative factor; p = substitution parameter that determines the value of the constant elasticity of substitution.

In case of CES production function, substitution happens between capital and labor. This production function is the desire output of the ACMS model development by KJ-Arrows, H.B. Chenery, B.S. Minhas and R.M. Solow. This model was published in the journal “Review of economics and statistics” volume 43 in 1961 August and the associated paper was “capital-labor substitution and economic efficiency”. The CES Production function has got a different and isolated due to its inherent properties.

Some major properties of CES production function are:

1. the CES production function is homogenous of degree one;
2. marginal productivities function of inputs in the CES production function are positive but declining although;
3. the iso-quants generated by the CES production function are negatively sloped and strictly convex to the origin;
4. elasticity of substitution of CES production function is $1/1+p$; and

5. Cobb-Douglas production function is a special case of CES production function.

However, the Cobb-Douglas functional form is commonly used for its simplicity and flexibility coupled with the empirical support. For this reason, the researcher confined himself with Cobb-Douglas production function.

Agriculture Productivity

Agriculture productivity is measure as the ratio of agriculture output to agriculture inputs., Conventionally, agricultural productivity is measured by an index of output divided by inputs. Two measure of productivity are frequently used: The partial factor productivity (PFP) and Total factor productivity (TFP).

Partial Factor Productivity (PFP)

PFP is simply the ratio of output and any one of the inputs, typically labor or land. In notation form this can be expressed as:

$$\text{PFP} = \frac{Y}{X_i}$$

Where Y is output and X is input i. Although it is commonly used, the partial productivity measure has one important weakness in that does not control for the level of other inputs employed.

Total Factor Productivity (TFP)

Total factor productivity measures the efficiency of all inputs to a productive process. Increase in TFP result usually form technological innovations or improvements. The factors, which fixed the level of production, are known as the determinants of agriculture productivity.

The basic concepts in production measurement are average production (AP), marginal production (MP), Elasticity of production (EP) and returns to scale (RTS). The knowledge of these concepts can be used to study the three stage of the production surface.

Total and Average Production (AP)

Total production (TP) is the amount obtained from various units of production. The average production of any input is defined as the total production divided by number or units of input used. For example, average production of labor,

$$AP_L = \frac{TP}{L}$$

Where,

TP = Total product and

L = Labor input.

The Marginal Production (MP)

The marginal production of any input is defined as the change in total production due to change in one unit of input. For example,

$$MP_L = \frac{\Delta TP}{\Delta L}$$

Where,

ΔTP = Change in total product and

ΔL = Change in labor input.

Elasticity of Production (E_p)

The elasticity of production refers to the percentage in output in relation to the percentage change in input. The concept of elasticity can be applied to the production function to determine the stage in which farmers are allocating their resources.

3.4 Laws of production

Laws of production describes the technically possible ways of increasing the level of production. Output may increase in various ways. Output can be increased by changing all factors of production. On the other hand, it may be increased by using more of variable factors

while at least one factor of production is kept constant. So, the law of production can be broadly classified by two categories

1. Laws of variable proportions: short-run analysis of production, and
2. Laws of returns to scale: Long-run analysis of production.

3.4.1 Laws of variable proportions: Short-run Analysis of Production

Law of variable proportions states that, as the quantity of one factor is increased, keeping the other factors fixed, the marginal product of that factor will eventually decline. This means that up to the use of certain amount of variable factor, marginal product of the factor may increase and after a certain stage its starts diminishing. When the variable factor becomes relatively abundant, the marginal product may become negative.

Marshall stated the law as: An increase in capital and labor applied in the cultivation of land causes in general less than proportionate increase in the amount of produced raised, unless it happens to coincide with an improvement in the arts of agriculture.

Illustration of the Law:

The law of variable proportion is illustrated in the following table and figure. Suppose there is a given amount of land in which more and more labor (variable factor) is used to produced pabda catfish:

Table 3.1: Laws of variable proportions

Units of labor	Total product	Marginal Product	Average Product
1	2	2	2
2	6	4	3
3	12	6	4
4	16	4	4
5	18	2	3.6
6	18	0	3
7	14	-4	2
8	8	-6	1

It can be seen from the table that up to the use of 3 units of labor, total product increases at an increase rate and beyond the third unit total product increase at a diminishing rate. This fact is shown by the marginal product which the addition is made to total product as a result of increasing the variable factor i.e. labor. It can be seen from the table the marginal product of labor initially rises and beyond the use of three units of labor, it starts diminishing. The use of six units of labor does not add anything to the total production of pabda catfish. Hence, total product diminishes and therefore marginal product of labor becomes negative. Regarding the average product of labor, it rises up to the use of third unit of labor and beyond that it is falling throughout.

Three Stages of the Law of Variable Proportions

These stages are illustrated in the following figure where labor is measured on the x-axis and output on the Y-axis.

Stage 1. Stage of Increasing Returns

In this stage, total product increase at an increase at an increasing rate up to a point. This is because the efficiency of the fixed factors increases as addition limits of the variable factors are added to it. In the figure, from the origin to the point Slope of the total product curve TP is increasing i.e. the curve TP is concave upwards up to the point F, which means that the marginal product MP of labor rises. The point F where the total product stops increasing at an increasing rate and starts increasing at diminishing rate is called the point of inflection. Corresponding vertically to this point of inflection marginal product of labor is maximum, after which it diminishes. this stage is called the stage of increasing returns because the average product of the variable factor increases throughout this stage. This stage ends at the point where the average product curve reaches its highest point.

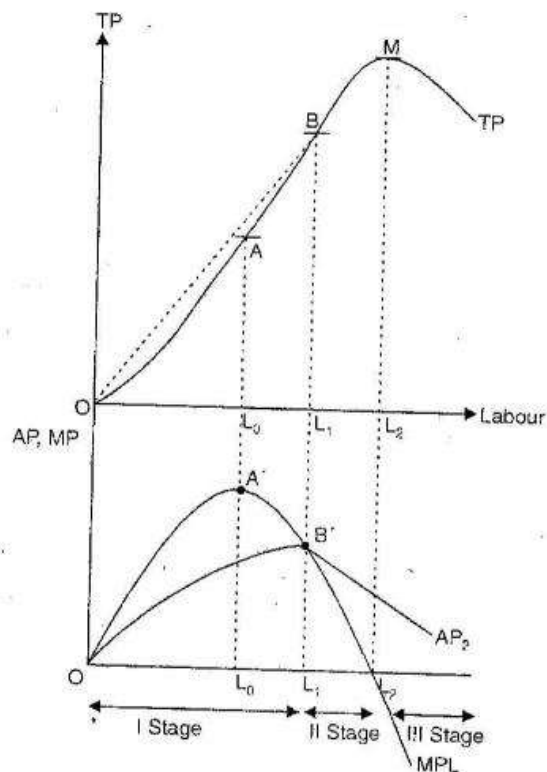


Figure 3.1: Three stages of the law of variable proportions.

Stage 2. Stage of Diminishing Returns:

In this stage, total product continues to increase but at a diminishing rate until it reaches its maximum point H where the second stage ends. In this stage both the marginal product and average product of labor are diminishing but are positive. This is because the fixed factor becomes inadequate relative to the quantity of the variable factor. At the end of the second stage, i.e., at point M, the marginal product of labor is zero, which corresponds to the maximum point H of the total product curve TP. This stage is important because the firm will seek to produce in this range.

Stage 3. Stage of Negative Returns:

In stage 3, total product declines and therefore the TP curve slopes downward. As a result, the marginal product of labor falls below the x-axis. In this stage, the variable factor (labor) is too much relative to the fixed factor.

For simplicity; we can summarize the above relation between total production (TP), Average production (AP) and marginal production (MP) as under:

1. when $MP > AP$, AP increasing;
2. when $MP < AP$, AP is decreasing and
3. when $MP = AP$ is at a maximum.

Importance and Applicability of the Law of variable proportion

The Law of variable proportion has universal applicability in any of production. It forms the basis of number of doctrines in economics. The Malthusian theory of population stems from the fact that food supply does not increase faster than growth in population because of the operation of the law of diminishing returns in agriculture. Ricardo also based his theory of rent on this principle. According to him rent arises because the operation of the law of diminishing return forces the application of additional doses of labor and capital on the piece of land. Similarly, the law of diminishing marginal utility and that of diminishing marginal physical productivity in the theory of distribution are also based on this theory. The law is of the fundamental importance for understanding the problems of underdeveloped countries. In such agriculture economics the pressure of population on land increase with the increase in population. This leads to declining or even zero or negative marginal productivity of workers. This explains the operation of the law of diminishing returns in LDCs in its intensive form. Ragnar Nurkse has suggested ways to make use of these disguisedly unemployed labor by withdrawing them and putting them in those occupations where the marginal productivity is positive.

3.4.2 Law of Returns to Scale: Long-run Analysis of Production

In the long run expansion of output may be achieved by varying all factors as all inputs are variable in the long run. Returns to scale refers to the response of output to an increase of all inputs. For example, what would happen to fish production if land, labor, capital, fingerlings, feed are changed by the same proportions. In Cobb-Douglas production function returns to scale are measured by sum of the factor elastration.

Mathematically we can express the returns to scale as follows:

Let us assume the following production function, $X_0 = f(L, K)$

And we increase all factors by same proportion t . we will clearly obtain a new level of output X^* , higher than the original level X_0 .

From the above expression we can say that, if X^* increase by the same proportion t as the inputs; we say that there exist constant returns to scale. If X^* increase less than proportionally with the increase in the factors, we have decreasing returns to scale. If X^* increase more than proportionally with the increase un the factors, we have increasing returns to scale. Thus, returns to scale are classified by three categories which are presented below:

Constant return to scale

It denotes a case where a change in all input needs to a proportional change in output. For example, if land and other input are doubled, then output would be doubled

Increasing Return to Scale

It is also called economics of scale. It arises when an increase in all input leads to a more than proportional increase the level of output.

Decreasing Return To scale

It occurs when an increase all inputs to less than proportional increase in the level of output.

3.5 Productivity and Efficiency Measure

Productivity and efficiency are both measure of production performance. However, there is slight difference between then. One can improve the state of technology by inventing new ploughs, pesticides, etc. This is commonly referred to as technological change and can be represented by an upward shift in the production frontier. Alternatively, one can improve farmers education, extension service, etc. This in turn will improve production efficiency of farmers and will be represented by farmers operating more closer to the existing frontier. Hence

Generally, productivity growth may be achieved through either technological progress or efficiency improvement (Coelli,1995)

3.5.1 Defining Efficiency

The concept 'efficiency' implies the success with which a farm best utilizes its available resources to produce maximum levels of potential outputs. A farm is efficient if and only if it is not possible to increase output (decrease inputs) without more inputs (without decreasing output) (Cooper et al., 1995). Failure to obtain this potential maximum output results in inefficiency. The neoclassical theory of production defines the production function based on the notion of efficiency that gives the maximum possible output for given amounts of input. It is not realistic to recognize this 'maximum' output simply by observing the actual amount of output unless the observed output is assumed to be a maximum: different farm produce different output among farmers can be explained through difference in efficiency.

The production process of a farm may reflect technical inefficiency, allocative inefficiency or both. The concept of technical inefficiency is due to Farrell (1957). A farm is technically efficient if it produced a maximum output, given the amount of inputs and technology. Thus, the production frontier is associated with the maximum obtainable level of output, given a level of inputs, or the minimum level of inputs required to produce a given output. In other words, it is the locus of maximum attainable output for each input mix. Technical inefficiency is attributed to a failure of the farm to produce the frontier level of output, given the quantities of input.

Allocative inefficiency arises if farms fail in allocating inputs which minimize the cost of production a given output, given relative input prices. This results from not allocating inputs in the most efficient manner, i.e., there exists resources misallocation or allocative inefficiency. Failure in allocating resources optimally results in increase cost and decreased profit. In particular, a farmer is said to be allocative inefficiency if the marginal rate of technical substitution between any two inputs is not equal to the corresponding minimizing inputs mixes. This can be attributed to sluggish adjustment to price changes and regulatory constraints. Thus, allocative efficiency is defined as the ability of farmer to adjust inputs and outputs to reflect relative prices, given the production technology. The distinction between technical and allocative efficiency provides four ways for explaining the relative performance of farms.

First, a farm might show both technical and allocative inefficiency;

Second, it may be technically efficient but allocative inefficient;

Third, it may display allocative efficiency but technical inefficiency; and

Fourth, it may be both technically and allocative efficient

Economic efficiency combines technical and allocative efficiency that reflects the ability of a farm to produce output at minimum cost. Thus, either one of the efficiencies may be necessary but not sufficient conditions to ensure economic efficiency for a farm. The simultaneous attainment of both efficiencies gives the sufficient condition to ensure economic efficiency.

Thus, production frontier characterizes the minimum input bundles required to produce a given level of output or the maximum possible level of production of output from a given level of inputs, commonly called technical efficiency.

Even though there is some similarity between terms production efficiency and technical efficiency however, they are not same. The simplest way to differentiate production and technical efficiency is to think of productive efficiency in terms of cost minimization by adjusting the mix of inputs, Whereas TE is output maximization from a given mix of inputs (Palmer and Torgerson, 1999). According to Coelli (1995) in analyzing efficiency, fitting a frontier model performs better than ordinary least square (OLS) regression. The two main benefits of estimating the frontier function, rather than average (e.g. OLS) functions, are that:

1. Estimation of an average function will provide a picture on the shape of technology of an average firm, while the estimation of the frontier function will be most heavily influenced by the best performing firm and hence reflect the technology they are using.
2. The frontier function represents a best practice technology against which the efficiency of firms within the industry can be measured. It is this second use of frontier, which leads to widely application of estimating frontier function.

3.5.2 Approaches of Measuring Efficiency

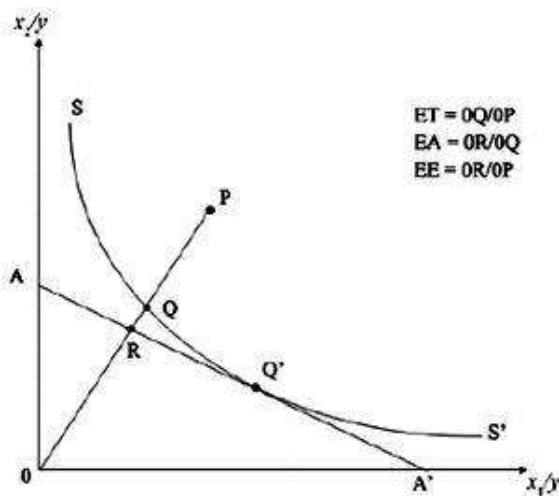
Basically, there are two approaches in measuring efficiency: input oriented and output oriented. The output-oriented Approach deals with the question “by how much output could be expanded from a given level of input?” Alternatively, one could ask “by how much can input of quantities be proportionally reduced without changing the output quantity produced?”

“This is an input-oriented measure of efficiency. However, both measures will coincide when the technology exhibits constant returns to scale, but are likely to vary otherwise (Coelli and Battese, 2005).

Input oriented Measure

In his first work on efficiency, Farrell (1957) illustration his idea about measuring efficiency with figure, as follow. The SS' is an isoquant, representing technically efficient combination of inputs, X_1 and X_2 , used in producing output Q . SS' is also known as the best practice production frontier. AA' is an isocost line, which shows all combination of inputs X_1 and X_2 to be used in such a way that the total cost of inputs is equal at all points. However, any firm intending to maximize profits has to produce at Q' , which is a point of tangency and representing the least cost combination of X_1 and X_2 in production of Q . At point Q' the producer is economically efficient.

Figure 3 2: Input oriented measure of technical, Allocative and Economic efficiency.



Source: Coelli (1995)

Given figure3.2 suppose a farmer is producing his output depicted by isoquant SS' with input combination level of (X_1 and X_2). If a given firm use quantities of input combination at point P to produce a unit of output, the technical inefficiency of that farm could proportionately reduce without a decline in output. In other words, the farmer can produce at any point on SS' with fewer inputs (X_1 and X_2), in this case at Q in an input-output space. The degree of TE of such a farm is measured as OQ/OP , which is proportional in all inputs that could theoretically

be achieved without reducing the output, hence all farmers that produce along the isoquant are 100 percent technically efficient

$$TE = OQ/OP \quad (1)$$

The value of TE ranges between 0 and 1, and represent the degree of technical efficiency. If TE is equal to 1, telling the farm produce with fully technical efficiency. For example, at point Q farm could gain full technical efficiency because point Q lies in the efficient isoquant curve.

If the input price ratio, represent by the slope of the isocost line, AA' is also known, allocative efficiency (AE) at P can be calculated and identified by the ratio:

$$AE = OR/OQ \quad (2)$$

The decrease in production cost with the distance from Q to R would happen if production is performed at the allocative and technically efficient point Q' instead at the technically efficient, but allocative inefficient point Q.

The total economic efficiency (EE) is defined to be the ratio:

$$EE = OR/OP \quad (3)$$

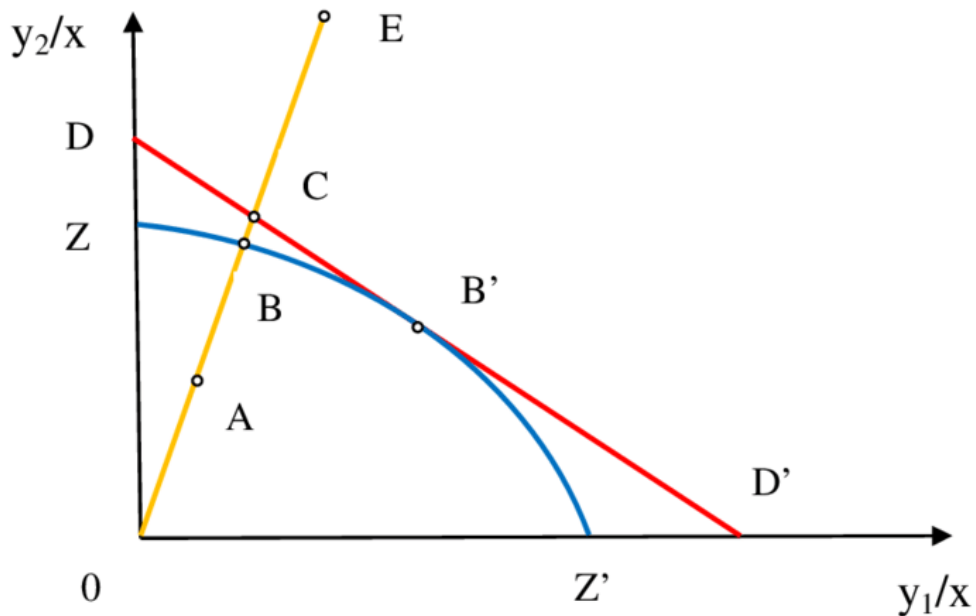
The distance from P to R also represent the cost cut in production if a farm produces at the point R with technical efficiency and allocative efficiency instead of at the point P with technical inefficiency and allocative inefficiency. Economic efficiency is to combine technically efficiency end allocative efficiency.

Output Oriented measure

In the output-oriented perspective, efficiency is evaluated keeping inputs constant. According to Farrell (1995), output oriented measures can be illustrated by considering the case where

Production involves two outputs (Y1 and Y2) and a single input (X). If the input quantity is held fixed at a particular level, the technology can be represented by a production possibility curve in two dimensions as follows:

Figure 3.3: output-oriented measurement of technical, allocative and economic efficiency



Source: Coelli, Rao, and Battese (1998)

The production possibility curve is represented by the ZZ' in figure 3.3 which represent technically efficient combination of production of output y_2/x and y_1/x . Given same level of input (X), it is not efficient to produce at point A. considering a firm situated at point A, TE can be calculated as OA/OB . Alternatively, all farmers producing along the production possibility curve are 100 percent efficiency.

3.5.3 Efficiency Model

Starting from the first empirical application of Farrell (1957) several different approaches of frontier estimation and efficiency score calculation have been developed. Efficiency measurements basically are carried out using frontier methodologies, which shift the average response function to the maximum output or to the efficient firm. Essentially there are two main methodologies for measuring TE: The econometric (parametric) approaches, and the mathematical (non- parametric) approaches. The parametric model are estimated based on econometrics model (Coelli, Rao, and Battese,1998) and the non- parametric methods are

measuring productive inefficiency are broadly speaking dependent upon classification of quantitative and qualitative variables under the well-known methodology of Data Envelopment Analysis (Burhan et al, 2009). Efficiency measure assume as production function of the daily efficient firm is known. But this is not possible in the reality; hence the efficient isoquant must be estimated from the sample data taking the relatively best performing firm as fully efficient (Coelli et al, 1998). Given parametric approaches is used in this study; I have reviewed the current literatures on parametric frontier models very briefly as follows.

Parametric frontier model can further be classified into deterministic and Stochastic Frontier Production (SFP) model. The very basic different between the two models is on their assumption about the error team. The deterministic model assumes that any deviation from the frontier is due to inefficiency, while the stochastic allows for statistical noise.

Non-stochastic/ deterministic

According to Coelli (1995), This model doesn't taka account the possible influences of measurement errors and other noise up on the shape and positioning of the estimated frontier. Alternatively, any deviation from the frontier can be estimated using linear programming econometric techniques such as Corrected Ordinary Least Square (COLS). Application of this model, especially in cases where there is high probability of measurement risk, will exaggerate the inefficiency estimate as compared to the models which decompose the error term into two components. Aigner and Chu (1968) specified a non-stochastic or deterministic frontier model of Cobb-Douglas production function for a sample of N firm as:

$$Y_i = F(X_i, \beta) - U_i \quad i = 1, 2, N$$

Where Y_i is the output of the i-th firm; X_i is the vector of the input quantities used by the i^{th} firm; β is the vector of unknown parameter to be estimated; $F(.)$ denotes an appropriate function (Cobb-Douglas); and U_i is the non-negative variable representing the inefficiency in production.

Stochastic frontier production function

To solve the limitation of deterministic approaches Aigner and chu (1968), Timmer (1971) designed a method that involves dropping a percentage of firm closest to the estimated frontier,

and re-estimating the frontier using the reduced sample. The arbitrary nature of the selection of some percentage of observation to omit has meant, however, the Timmer's probabilities approach has not been widely followed (Coelli,1995) In the process of meaning of managing the outliers, so that the inefficiency level would not be exaggerated, farmers who outperform will be considered as outliers.

According to Kumbhakar and Lovell (2000), SFP function oriented with two papers, published nearly simultaneously by two teams on two continents. Meeusen and van den Broeck (1977) appeared in June, and Aigner, Lovell and Schmidt (1977) appeared a month later. Unlike the deterministic model, SFP function has a disturbance term with two components; the error component (v) and the stochastic noise (u). the other merit of the SFP function over the former (deterministic) is that the estimation of standard error and test by hypothesis is possible, which the deterministic model fails to fulfil because of the violation of the maximum likelihood regularity conditions (Coelli,1995). Stochastic frontier production function can be estimated using Maximum likelihood (ML) or COLS method, unless one uses COLS for its simplicity, the ML method is asymptotically efficient and hence recommended to be used than COLS (Coelli, 1998).

3.6 Conclusion

This chapter examines the concept of the production function which is the technical relationship between output and inputs which describe the maximum output obtainable for a given set of inputs. We also discuss some concepts which are used in our empirical analysis; marginal productivities, output elasticity, marginal rate of technical substitution and returns to scale; the marginal productivity of an input explain the change elasticity is a unit- free measure of marginal productivity and it describes the percentage change in output resulting from a percentage change in an input, keeping all other input are substituted, holding output constant; the elasticity of substitution is unit free and measure the degree of substitution between input; returns to scale is the proportional change in output resulting from the proportional changes in all inputs and is shown as the sum of the output elasticity. We also explain that the farm obtains the least-cost combination of inputs at the point of ratio of input prices and the marginal rate of technical substitution is equal. We discuss the concepts of efficiency. The efficiency implies the success with which a farm produces maximum output utilizing its available resources with

minimum cost. In other words, a production function describes the maximum cost results in inefficiency. Efficiency consists of technical and allocative components; technical efficiency reflects the capability to produce maximum output with a given input mix utilizing the existing technologies; allocative efficiency reflects the capability to use cost-minimizing input proportions, given input prices; in other words, failure to produce with the least-cost input combination result in allocative inefficiency. The economic efficiency measure combines the two. Moreover, technical efficiency is the ratio of technical efficient cost to observed cost, economic efficiency is the ratio of frontier cost to observed cost, and allocative efficiency is the ratio of frontier cost to technically efficient cost.

CHAPTER FOUR

An overview of pabda catfish production in Bangladesh and Description of the study area

4.1 Introduction

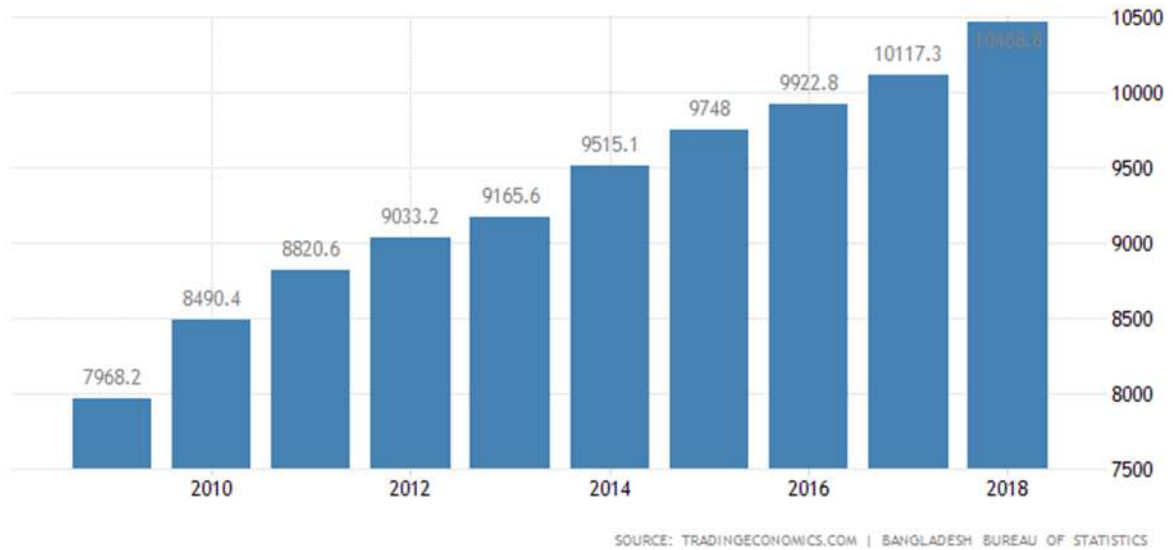
A brief description of the study area is given in this chapter to know the real situation (salient feature) of the area under study. Location, area, population, temperature and rainfall, aquaculture, occupation, communication and marketing facilities of the study area are discussed in this chapter. However, for the production of Pabda it is very essential to know the climate and topology of the study area. Therefore, the following description of the study area has been designed to focus mainly on the existing aquaculture status and support services available in the area.

4.2 Aquaculture

Aquaculture is one of the growing foods producing sector demonstrating continuous increase in total production throughout the last few decades in a number of developing countries. This significant expansion is due to growing demand for aquatic product and the development of new technologies for aquaculture. Aquaculture is diverse consisting of a board spectrum of different systems and practices ranging for simple backyard, small household pond systems to large scale, highly intensive and commercially oriented practices and operations. Aquaculture sector contribution to food security, poverty alleviation and social well-being in many counties of the world. Aquaculture is one of the means to supply protein to the people in a cost-efficient way (Jia et al, 2001).

The population of Bangladesh increase with 2.2 million people annually, with an increasing need for food. Bangladesh is fortunate in having extensive water resources in the form of ponds, natural depressions, lakes, canals, rivers and estuaries covering an area of 45600 km² (DoF, 2005). Although Bangladesh is predominantly an agro- based country, people are largely dependent on fish for animal protein. Fish consumption patterns change as price and income changes.

Figure 4.1: Total Aquaculture production in Bangladesh According to BBS statistics.



Source: BBS,2018

In 2009, total aquaculture production excluding aquatic plants was 1064285 tonnes in Bangladesh (FAO world fisheries production, by capture and aquaculture, by country, 2009). According to FSRFD (2003), pond aquaculture, inland capture fisheries and marine fisheries contributed 41, 32 and 26 percent respectively of the total fish production in Bangladesh. According to Akteruzzaman et al. (2006), inland fish capture production is decreasing due to heavy fishing and reduction of the flood plain area due to flood control and irrigation projects, indiscriminate use of insecticide in paddy fields and other factors. Aquaculture has therefore already become the major contributor of fish products though there is still a wide scope to increase fish production in Bangladesh by introducing more appropriate technology for aquaculture through focused extension services according to Akteruzzaman et al. (2006).

Proper management strategies to develop sustainable aquaculture practices are still in a developing stage in Bangladesh. Aquaculture activities have however been improved significantly in the recent years to increase production.

Small-scale pond aquaculture has taken off dramatically over the past thirty years especially under the influence of a number of major donor-funded aquaculture development and extension projects. The government of Bangladesh has by the support from these projects first

created a network of fish hatcheries which ensured reliable supply of good quality carp seed to the farmers. Managers then identified key parameters of successful pond aquaculture production: appropriate pond preparation, including preliminary fertilization, stocking with an appropriate mix of species to utilize the different ecological niches in the pond and at the right density, judicious feeding and fertilization during grow-out, maintenance of a good pond environment to ensure efficient utilization of pond fertility and feed.

The Department of Fisheries, Government of Bangladesh despite its limitations has been responsible for overseeing the rapid development of aquaculture in Bangladesh but it has an unclear perception on poverty focus (Demaine, 2011). Most of the aquaculture development took place in a project mode on the basis of resources offered by donors and in some cases these resources were channeled through large international NGOs such as CARE, CARITAS and BRAC, which have their own specific fisheries programs. Bangladesh has, partly as a result of significant donor support, adopted stocking and culture-based fisheries as national strategies to feed a rapidly growing population (Valbo-Jørgensen and Thompson, 2007). Elasha (2005) referred that climate change will affect socio-economic sectors which include water resources, agriculture, aquaculture, fisheries, human settlements, ecological systems and human health. The ecological systems which support aquaculture are already known to be sensitive to climate variability (FAO, 2008). Improved management and better aquaculture practices and diversification could be the best and most immediate form of adaptation to the effects of economic, climate change and socio-cultural factors providing a sound basis for production that could accommodate possible impacts and lead to the way of managing vulnerability context by helping people to become more resilient and better able capitalize on its positive parts.

4.3 An overview of Fish Farming in Bangladesh

The origin and development of aquaculture practices in Bangladesh are not well documented; historically the country's natural water bodies were stocked during the monsoon season through natural spawning. Fish farming had been a traditional practice dating back several centuries to when the country was ruled by Hindu kings. Many of the kings used to create ponds and tanks

for drinking, bathing and sometimes for small-scale irrigation, these ponds and tanks were also used for rearing fish although more from a recreation aspect than for any commercial purpose.

Bangladesh, with its rich inland waters and river systems, has significant capture fishery and aquaculture potential. The favorable geographic position of Bangladesh comes with a large number of aquatic species and provides plenty of resources to support fish-series potential. Fish is a popular complement to rice in the national diet, giving rise to the adage Maache-Bhate Bengali (“a Bengali is made of fish and rice”) (Ghose, 2014). The fisheries can broadly be classified into three categories: inland capture fisheries, inland aquaculture and marine fisheries, of which the inland aquaculture sector is contributing more than 55% of the total production (DoF,2016). The fisheries sector plays a very important role in the national economy, contributing 3.69% to the Gross Domestic Product (GDP) of the country and 22.60% to the agricultural GDP (FRSS,2016). Over the last 10 years (2004-2005 to 2013-2014 FY), the fisheries growth was fairly steady and at an average of 5.38% per year (FRSS, 2015). This sector experienced more or less consistent growth rate, ranging from 7.32% growth in 2009-2010 to 4.04% growth in 2013-2014 (Bangladesh Economic Review, 2014). More than 2% of Bangladeshi export value comes from the inland fisheries sector. Given proper government support, the fisheries sector has ample potential in creating various types of ancillary industries in rural areas that often have a high rate of economic return. These employment opportunities for poor rural citizens would also stem their migration to urban areas. Fish supplements about 60% of Bangladeshi people’s daily animal protein intake (DoF, 2016). More than 17 million people including about 1.4 million women depend on fisheries sector for their livelihoods through fishing, farming, fish handling, and processing (BFTI, 2016, p. 1215). A different survey revealed that more than 80% of laborers engaged in the fish processing industries were women (DoF, 2015).

Bangladeshi has one of the biggest and most active deltas, fed by three mighty rivers: the Padma, the Meghna and the Jamuna. This contributes to a high potential for fresh and brackish water capture and culture fisheries, in addition to the vast marine resources. Despite Bangladesh's long coastline and large freshwater and marine water bodies, fisheries are underdeveloped compared to other industry sectors. Inland fisheries production has escalated over the years, but the productivity per hectare water area is not yet attained at its optimum. In

recent years, the bulk of the production has been obtained from marine (16.78%) and freshwater (83.22%) wild capture fisheries. In 2015-2016, Bangladesh was the 5th in world aquaculture production, which accounted for half of the country's total fish production (55.15%) (DoF, 2016). In 2014e2015, total fishery production of Bangladesh was 3,684,245 metric tons, of which 1,023,991 metric tons was obtained from inland capture fisheries, 2,060,408 metric tons from inland aquaculture and 599,846 metric tons from marine water production (FRSS, 2016) (see Table 1). There have been few reviews of the development and potential of fisheries and aquaculture in many parts of Bangladesh published and no studies have been published on the present

status of fisheries in Bangladesh. table 4.1: fisheries resources of Bangladesh increasing

Types of water body	Water area
A) Closed water body (culture based)	6,78,724 hac.
1. Ponds	3,71,309 hac.
2. Oxbow Lakes	5,488 hac.
3. Shrimp Farm	2,76,492 hac.
4. Semi-closed flood plain	25,435 hac.
B) Open water body (capture based)	40,24,934 hac.
1. River and estuaries	8,53,863 hac.
2. Beel	1,14,161 hac.
3. Kaptai lake	68,000 hac.
4. Sundarbans	1,77,700 hac.
5. Flood plain	28,10,410 hac.
C) Marine Fisheries	
1. Teritorial water	2,680 sq. miles
2. Exclusive economic zone	41,040 sq. Miles
3. continental shelf	24,800 sq. miles
4. Coast line	710 km

Source: Fisheries and Aquaculture statistics of Bangladesh 2018

Table 4.1 show that culture-based farm is larger than other system of fish farming like capture based or Marine fisheries. where area of culture based is 6,78,724 hac but where capture based and marine fisheries area are 40,24,934 hac and 69,230 hac respectively.

Table 4.2: shows the trends of fish production from different sources of Bangladesh

Sector of fisheries	2016-17		2015-16		Growth Rate%
	Water area(ha)	Prod (MT)	Water area(ha)	Prod (MT)	
A) Inland water(capture)	3927142	116360	3918608	1048242	11.01
River	853863	271639	853863	178458	52.21
Beel	114161	98117	114161	95453	7.21
Floodplain	2712618	765782	2704084	747872	2.39
B) Inland water(culture)	833752	2333352	795831	2203554	5.89
pond	384700	1833118	372405	1719783	6.59
Seasonal culture	136273	215547	134876	207658	3.80
Baor	5488	8002	5488	7729	3.53
Shrimp prawn Farm	272717	246406	275509	239798	2.76
C) Marine Fisheries	-	637476	-	626528	1.75
Industrial	-	108479	-	105348	2.97
Artisanal	-	528997	-	521180	1.50
Total fish production		4134434		3878324	6.60

Source: yearbook of fisheries department 2017-18

4.4 Production

4.4.1 Inland Open Water (Capture) Fishery

The fisheries sector in Bangladesh is broadly divided into three sub-sectors: inland capture, inland culture and marine fisheries (DoF, 2016). The inland fishery is further divided into two sub-sectors: the inland capture fishery and inland culture fishery. The inland capture fishery has five types of habitat containing approximately 853,863 ha of river and estuary, 177,700 ha of Sundarbans, 114,161 ha of beel, 68,800 ha of Kaptai lake, and 2,695,529 ha floodplain (haor); and the inland culture fishery, which has six types of habitat containing an area of 371,309 ha of pond, seasonal 130,488 ha of cultured water body, 5,488 ha of baor, 275,274 ha of shrimp/prawn farm, pen culture 6,775 ha, and 7 ha of cage culture (FRSS, 2016). An analysis of time series data for 2003-2014 reveals the declining trend of capture fishery habitat area (a decrease of 0.16 million ha), while the trend of culture fishery habitat area is increasing (by 0.35 million ha). Fig. 1 shows the district-wise magnitude of capture fish production for 2015. Total fish production in Bangladesh in 2014-2015 was reported to be 3,684,245 t, of which 1,023,991 t (27.79%) were from inland open waters, 2,060,408 t (55.93%) from inland closed waters and 599,846 t (16.28%) from marine fisheries (Table 1 and Fig. 2). The early increasing rate of overall fish production increase in Bangladesh went from 7.20% to 3.84% during the years 2000-2001 to 2014-2015 which included a decreasing yearly increase since a peak in 2009-2010 at 7.32% (Table 2). As indicated in the Fig. 2, inland open water fisheries are still a major source of the total fish production, but their share has been declined, from 38.68% in 2000-2001 to only 27.79% in 2014-2015. Conversely, inland closed water fisheries contributions have been increasing, from 40.01% in 2000-2001 to 55.93% in 2014-2015. The contribution of marine fisheries over the same period has dropped from 21.30% to 16.28% (Fig. 3). The average yield (annual fish harvest per hectare in metric tons) in open inland waters declined throughout 2000-2001, but improved sharply afterward. Pen and cage culture are two new approaches to fish culture in Bangladesh and contributed 0.35% and 0.05% in the total fish production in 2014-2015, respectively (Table 2). These new methods have the potentiality to greatly increase fish production in Bangladesh.

4.4.2 Inland Closed Water (culture) Fishery

Aquaculture is the farming of fish and other aquatic organisms, with ‘farming’ implying some form of intervention to increase productions, and some form of private rights of the stock under intervention (Beveridge and Little, 2002). The entire area of inland closed (culture) water fisheries bodies is 0.29 million ha with littoral shrimp farms (National Fisheries Policy, 1998). In Bangladesh, the overall pond area is 1,46,890 ha and ox-bow lakes(baors) are 5,488 ha (DoF, 2015). Among various segments of the fisheries sub-sector, the inland aquaculture has generally experienced the fastest growth, with the establishment of new technologies, species, and intensification and improvement of farming, particularly in pond aquaculture, entirely over the country (Planning Commission, 2016) (Fig. 5). Aquaculture now provides around half the fish for direct human consumption in Bangladesh and is set to grow further. Aquaculture industry contributes to the economy with increasing production capacity and high export opportunities. Over the last 10 years, the average growth rate of fisheries is 5.4%, while aquaculture has grown 8.2%. This recent and rapid development has boosted Bangladesh to 5th in world aqua-culture production (DoF, 2015). Two types of aquaculture practices are going on in Bangladesh such as, freshwater and coastal aquaculture. There is no marine aquaculture currently practiced in the country and no marine or coastal finfishes are farmed. Freshwater aquaculture is mainly comprised of pond farming of carps (indigenous and exotic), Mekong pangasii catfish, tilapia, Mekong climbing perch, and a number of other domesticated fish, though in lesser scale (Table 3). Coastal aquaculture is mainly comprised of shrimp and prawn farming in gher (coastal pond or enclosures). In Bangladesh, aquaculture production systems are mainly extensive and improved extensive, with some semi-intensive, and intensive systems, in very few cases (Hossain, 2014). The present unit are an aquaculture production (MT/ha) are 3.60, 1.50, 0.95 and 0.71 for the pond, seasonal waterbody, baor (oxbow lake) and shrimp gher, respectively. Inland pond culture represents the mainstay of aquaculture in Bangladesh, accounting more than 80% of the total recorded aquaculture production, and is presently dominated by carps (indigenous and exotic), Mekong pangas and tilapia (Fig. 6). This sector contributed 55.93% of the total fish production in 2014e2015 (Fig. 2). Pond aquaculture is mostly practiced closed water fisheries in Bangladesh and contributed 43.79% (1,613,240MT) to the total fish production in 2014-15. The brackish water giant tiger prawn

(*Penaeus monodon*) and giant river prawn (*Macrobrachium rosenbergii*) are the main cultured species in coastal areas of Bangladesh (Azim, Wahab, & Verdegem, 2002).

4.4.3 Marine Fisheries

The coastal and marine environment of Bangladesh is blessed with a warm tropical climate and high rainfall, enriched with nutrients from the land, creating one of the world's richest ecosystems with high productivity (Hossain, 2001; Islam, 2003). Exploration, exploitation and management of living and non-living resources of the Bay of Bengal have potential to substantially contribute to the economy of Bangladesh. Particularly after the recent decision of the International Tribunal for Law of the Sea (ITLOS) regarding the Bangladesh-Myanmar maritime boundary, 2012 and the decision of the Arbitral Tribunal of the UNCLOS on India-Bangladesh maritime boundary, 2014 established sovereign rights on more than 118,813 km² area of territorial sea and 200 nautical miles (NM) of Exclusive Economic Zone (EEZ) and all kinds of living and non-living resources under the continental shelf up to 354 nautical miles from the Chittagong coast (MoFA, 2014). Currently, 32,440 km², starting from the coastline to 40 m depth, in the Bay, are open to around 67,669 unlicensed fishing boats, of which about 51% are non-motorized boats (Shamsuzzaman, Xiangmin, Ming, & Tania, 2017). In Bangladeshi marine waters, fish resources are extracted in three tiers: (1) up to 40 m in depth from the coastline where normal fishing boats operate; (2) from 40 m to 200 m in depth where mid-water trawlers operate; and (3) from 200 m in depth to the end of the EEZ where long-liner trawlers run (Islam et al., 2017). There are only 242 trawlers that are allowed for fishing in those regions by the government (MoFA, 2014). The Bay of Bengal is blessed with rich coastal and marine ecosystems, hosting a wide range of biodiversity, such as fishes, shrimps, mollusks, crabs, mammals, seaweeds, etc. Around 511 marine species, together with shrimps, exist within Bangladeshi waters (Murshed-E-Jahan, Belton, & Viswanathan, 2014). Marine fisheries production is only 16.28% of the national fish production (Fig. 2) (FRSS, 2016). The potential of the coastal fisheries sector has not been rationally harvested. Rather the resources have been over-exploited and as a result, the fish stocks declined. A number of surveys examined the status of marine fisheries resources between the 1970s and 1980s, but no recent or comprehensive knowledge is available on the fisheries stocks, systematics, biological and ecological aspects of the coastal and marine fisheries of Bangladesh. The main commercial

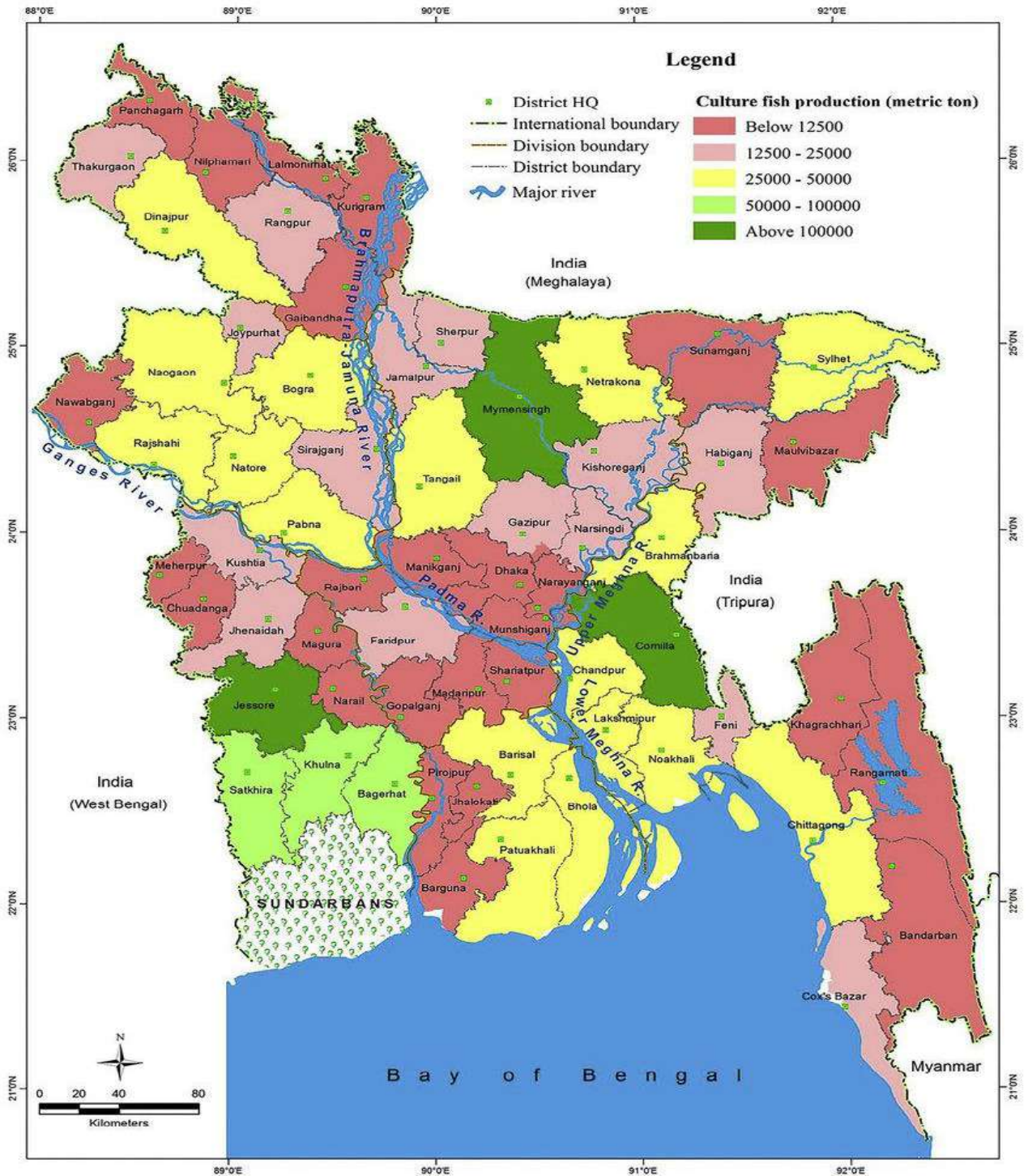
fishing zones in the Bay of Bengal are Swatch of no Ground, Middle Ground, South Patches and South of South Patches (Rahman, Islam, Roy, & Azad, 1994, pp. 1e124). Also, artisanal fishing is done in the near shore coastal area of Bangladesh. The fish species with greatest catch (MT) in the marine waters of Bangladesh from 2005e2015. Fig. 2. Sector wise marine and freshwater fish production (as a % of total) in 2014-15 of Bangladesh (Source:FRSS, 2016).Md. M. Shamsuzzaman et al. / Aquaculture and Fisheries 2 (2017) 145e156148

Table 4.3: Marine and Freshwater fish production and area in Bangladesh

Types of Fisheries	Fisheries sector	Water area (Ha)	Production (t)
Inland Fisheries	Inland open water (capture):	3,906,434	1,023,991
	Rivers, Sundarbans, beel, Kaptai lake, floodplain		
	Inland closed water (culture):	794,361	2,060,408
	Pond, seasonal cultured waterbody, Baor , Shrimp, Cage culture		
	Total	4,700,795	3,084,399
Marine fisheries	Industrial (Trawl) Fishing	12,111,000	84,846
	Artisanal fishing		515,000
	Total		599,846
Total production			3,684,245

Source: DOF 2016

Figure 4.2: Culture fish production in Bangladesh



District-wise inland closed water (culture)fisheries production (2015)

4.5 Fisheries Management System in Bangladesh

There are three Fisheries Management systems practiced in Bangladesh which are:

Type I. Traditional systems: These are classified as management systems operated by the administration of traditional authorities which enforce regulations to control fishing Practices such as ban on fishing at certain time of the year or during fish breeding period.

Type II. Mixed systems: The mixed systems involve the participation of both the traditional and the modern government administrations.

Type III. Modern systems: These include those operated by the administrations of the central government where fisheries regulations are enforced by officers of the fisheries departments.

Type II (mixed) is most common (56%), followed by the Type I (33%) and type III accounting for only 11%. However, the traditional management systems (Type 1), is the most effective at the local community level. The village heads that have responsibilities for enforcing the Type I management Systems are accepted and respected in their various domains. Although the Mixed System (Type II) is most prevalent, governments generally lack the logistic support (personnel, funds, field vehicles etc.) to enforce fisheries laws and regulations. In general, fisheries management systems in Bangladesh can be described as variable and hindered by poor financial support for policy implementation. Three keys issues confronting the management of the fisheries are:

- ✚ Environmental Change – climatic patterns and man's activities
- ✚ Exogenous Factors – human population, poverty and food demand
- ✚ Weak policies and policy implementations

4.6 Farming systems distribution and characteristics

There are an estimated 1.3 million fish ponds in the country, covering an area of 0.151 million ha, of which 55.30 percent is cultured, 28.52 percent is culturable and 16.18 percent is unused. In 2002 the percentage of production from the above three systems was 72.09, 20.01 and 7.90 respectively (BBS, 2002). In general, the size of fish ponds varies between 0.020 and 20 ha

with an average of 0.30 ha. In Bangladesh, the highest number of ponds exists in the Barisal district (12.11percent), followed by Comilla (9.36 percent), Sylhet (9.10 percent), Chittagong (8.02percent) and Noakhali (7.75 percent) (BBS, 2002).Historically people depended mainly on natural waters for supplies of fish; but as a result of declining catches of wild fish due to an increased fishing effort by the growing population as well as environmental degradation, people began to culture fish in enclosed waters. The polyculture of major and exotic cars and monoculture of striped catfish (*Pangasius hypophthalmus*), Nile tilapia and Java barb (*Barbonymus gonionotus*) and to some extent catfish (*Clarias batrachus*) are the most widely practiced culture system in Bangladesh. Three Indian major carps namely, *Labeo rohita* , *Catla catla* and *Cirrhinus mrigala* and one exotic carp, *Hypophthalmichthys molitrix* now account for more than 78 percent of total pond production (ICLARM, 2002). However, carp polyculture at the individual small holder level has the greatest potential for expansion since it can, through the implementation of more intensive culture systems including the application of fertilizers, use of supplemental feeding and improved management practices (Gupta et al ., 1999), provide a significant potential increase in income, by as much as 57 percent or US\$ 717/ha, this is more than the other culture practices in use (DoF, 2003). At present annual average fish production using pond culture is 2 609 kg/ha (DoF, 2005). Freshwater pond farming systems as defined in the context of Bangladesh

- a) Extensive Stocking mainly with the three Indian major carp species, no fertilization and feeding.
- b) Extended extensive Stocking mainly with the three Indian major and three exotic (silver, common and grass) carps, irregular use of fertilization (mostly cow dung) but without feeding. Silver barb is also occasionally stocked.
- c) Semi-intensive
- Stage 1: Stocking mainly with the three Indian major and three exotic carps. Regular use of fertilizer (both organic and inorganic) with occasional use of low-quality supplemental feed consisting of rice bran and oil cakes. Silver barb is generally stocked and also freshwater prawn and Nile tilapia.
 - Stage 2: Stocking mainly with the three Indian major and three exotic carps. Regular use of fertilizer (both organic and inorganic) and supplemental feed consisting of rice bran and oil cakes. Silver barb is

generally stocked and also freshwater prawn and Nile tilapia and striped catfish.

- Stage 3: Monoculture of striped catfish. Regular feeding with rice bran/wheat bran/oil cakes and/or commercially manufactured pelleted diet.

d) Intensive Monoculture of striped catfish. Regular feeding with commercially manufactured pelleted diet.

4.7 Food and Agricultural Organization (FAO) Sustainable Fisheries Development

Sustainable fisheries development is defined by FAO as fisheries development that integrates bio-ecological, technological, economic and social dimensions to sustainably improve the well-being of all the people engaged in the fisheries sector as well as the natural productive system (Serge, 1998). In other words, such development must integrate (Environment, Social and Economic) the triple bottom line framework captured in the Samuel Mann Venn diagram of sustainability (Mann, 2011). The Code of Conduct for Responsible Fisheries (FAO, 1995) has developed the FAO definition of sustainable development into a much more detailed and specific set of General Principles (Article 6) and a large number of specific provisions aiming at facilitating the implementation of the FAO definition in the various facets of the fisheries-related activities: The current policy thrust of the Federal Government is aimed at ensuring sustainable development of Bangladesh fisheries for national food security, optimum resource utilization and conservation. The policy focuses on employment generation, poverty alleviation and reduction in rural urban migration, among others. This in line with the National Economic and Empowerment Development Strategy (NEEDS) of the Federal Government and the New Partnership for Africa's Development (NEPAD) initiatives. Specific objectives which are expected to be private-sector driven include the following: achievement of self-sufficiency in fish production; modernization of the means of production, processing, marketing and resources conservation; ensuring total compliance with the FAO's Code of Conduct for Responsible Fisheries (CCRF), amongst others. Bangladesh is one of the world's leading inland fisheries producer with a production of 1 646 819 tonnes during 2003–4, with marine catch total of 455 601 tonnes and a total production from aquaculture of 914 752 tonnes during 2003–4. Bangladesh's total fish production for the year totaled above 2.1 million tonnes (DoF, 2005). FAO (2005) ranked Bangladesh as sixth largest aquaculture

producing country with its estimated production of 856 956 tonnes in 2003 (FAO, 2005). Aquaculture accounted for about 43.5 percent of the total fish production during 2003–4, with inland open water fisheries contributed 34.8 percent (DoF, 2005). In getting the third position, Bangladesh produced a total of 10,48,242 tonnes of fish from inland water bodies in 2016, about 2.4 percent higher than 2015, according to the FAO's fisheries and aquaculture report. China topped the list with 23,18,046 tonnes, while India was in second place with 14,62,063 tonnes, found the report which was made public on July 9. Myanmar and Cambodia secured fourth and fifth positions. In overall aquaculture production, Bangladesh was placed fifth by producing 22 lakh tonnes in 2016, said the report. China topped that list with a production of 4.92 crore tonnes. The report also said Bangladesh produced 1,13,200 tonnes of fish from marine and costal sources, and ranked 11th in the list.

4.8 Importance of Fish Farming in the Bangladesh economy

Fisheries occupy a unique position in the agricultural sector of the economy. In terms of Gross Domestic Product (GDP), the fishery sub-sector has recorded the fastest growth rate in agriculture to the GDP. The contribution of the fishery sub-sector to GDP at 2001 current factor cost rose from ₳76.76 billion to ₳162.61 billion in 2005 (CBN Report, 2005). Fish is an important source of protein to large teaming population of Bangladesh. Fish provides 40% of the dietary intake of animal protein of the average Bangladeshi (FDF, 1997). According to Adekoya (2004), fish and fish products constitute more than 60% of the total protein intake in adults especially in rural areas. Amienheme (2005) enumerated the importance of fish in Human Nutrition as follows:

- ✚ Food fish has a nutrient profile superior to all terrestrial meats (beef, pork and chicken, etc.) being an excellent source of high-quality animal protein and highly digestible energy.
- ✚ Fish is a good source of Sulphur and essential amino acids such as lysine, leucine, valine and arginine. It is therefore suitable for supplementing diets of high carbohydrates contents;
- ✚ Fish is also a good source of thiamine as well as an extremely rich source of Omega-3 polysaturated fatty acids, fat soluble vitamins (A, D and E) and water-soluble

vitamins (B complex) and minerals (Calcium, Phosphorus, Iron, Iodine and Selenium);

- ✚ It has a high content of Polyunsaturated (Omega III) fatty acids, which are important in lowering blood cholesterol level and high blood pressure. It is able to mitigate to alleviate platelet of (cholesterol) aggregation and various arteriosclerosis conditions in adult populations;
- ✚ It reduces the risk of sudden death from heart attacks and reduces rheumatoid arthritis
- ✚ Omega-3 fatty acids also lower the risk of age-related muscular degeneration and vision impairment; and
- ✚ It reduces the risk of bowel cancer and insulin resistance in skeletal muscles.

Bangladesh is one of the world's leading inland fisheries producer with a production of 1 646 819 tonnes during 2003–4, with marine catch total of 455 601 tonnes and a total production from aquaculture of 914 752 tonnes during 2003–4. Bangladesh's total fish production for the year totaled above 2.1 million tonnes (DoF, 2005). FAO (2005) ranked Bangladesh as sixth largest aquaculture producing country with its estimated production of 856 956 tonnes in 2003 (FAO, 2005). Aquaculture accounted for about 43.5 percent of the total fish production during 2003–4, with inland open water fisheries contributed 34.8 percent (DoF, 2005).

4.9 Exports and Imports

Fisheries and aquaculture sector have emerged as the second most important contributors to the export earnings of Bangladesh (Ghose, 2014). It is the second largest export industry in Bangladesh and produces 2.5% of the global production of shrimp. The value of aquatic products in international trade (export and import) in 2015 was US \$649.1056 million. Exports were 75,337.93t, worth about US\$605.878 million and imports reached 88,593.50tons, with a value of approximately US \$43.2276 million. The worth of export in 2010, 2011, 2012, 2013 and 2014 was approximately US \$443.1063, 598.4771, 611.5135, 560.6393 and 636.7686 million, respectively (Table 7). Bangladesh mainly exports ten categories of fishery products (Frozen fresh water fish, frozen marine water fish, frozen shrimp, chilled fish, livefish, dryfish, salted dehydrate, live kusia, live crab, and fish scale/shrimp scull) to more than 55 countries. In 2015, more than 45% of fishery exports, by quantity, were exported to European Union (EU), which has always been among the top markets. USA, Japan, Russia, China, Thailand,

Vietnam, India, Malaysia, Philippines, Saudi Arabia and others make up the other 55% (Table 8). The USA and EU together account for around 80% of the total shrimp export. The shrimp export for Bangladesh is primarily in the EU (Islam, 2008). The total imported fishery products in Bangladesh consisted of approximately 69.373% frozen marine fish followed by 25.353% chilled or iced fish (Fig. 8 and Table 9) (FRSS, 2016).

4.10 Environmental Impact of Fish Farming

Negative environmental impacts associated with aquaculture are of increasing concern due to the rapid growth and often unregulated aquaculture industry (Evans et al., 2007). The authors indicate that aquaculture has been associated with a range of issues including habitat degradation, contaminated water systems, increases in fish diseases, and the introduction of alien species. These adverse effects have to be addressed in order to develop sustainable, end-user level aquaculture systems.

This view is supported by (Piedrantha, 2003), who states that aquaculture effluents may contain a variety of constituents that could cause negative impacts when released into the environment. (Piedrantha, 2003) goes further to give suggestions on how this environmental degradation can be addressed by reducing potential environmental impacts by facilitating effluent treatments e.g. solids removal operations produce a stream with high concentration of solids (the sludge removed from the flow) that is also rich in nutrients and organic matter, while reducing the concentrations of these parameters in the culture water. The stream with a high concentration of solids could be treated prior to disposal using techniques appropriate for high strength waste and sludge. In a research conducted in China by (Ellis & Turner, 2007), it was found that China's waterways are highly polluted thus rendering food security a major concern for Chinese aquaculture. Besides municipal and industrial waste water contamination, mercury emissions from China's coal-fired power plants are another potential source of aquaculture contamination. International concern has cost China dearly since China supplies 70% of the tilapia imported into the United States and is also its fourth largest supplier of shrimp (Ellis & Turner, 2007). Further, countries have continued to ban species they discovered to be contaminated. The authors cite two major cases of the 2005 eel ban in Japan and the 2003 shrimp ban in the European Union. Chinese consumers are also increasingly concerned about water pollution, dangerous farming practices and poor processing in the aquaculture industry

that pose serious threats to human health. (Ellis and Turner, 2007) have identified the following environmental impacts causing concern worldwide in aquaculture:

1. Eutrophication and algae blooms-runoff of uneaten food and effluent from fish farm.
2. Antibiotics, pesticides and fungicides which are fed to fish and often misused to clear the water of other creatures, reduce parasites, control disease and boost weight gain on severely overcrowded animals. Antibiotics are not biodegradable and persist in the surrounding environment threatening wild fish stocks.
3. Habitat destruction – More natural bodies of fresh water are converted into fish farms with the rising demand for fish and therefore, diseases and pollution from overcrowded fish farms, are often pumped out into natural waterways, endangering native species.
- 4 Depleting wild fish stocks for feed – wild ocean fish are normally caught and pellets made to feed fish that are being farmed, especially shrimps. This can be very damaging to ocean habitats. It is estimated that it takes 2.8 pounds of wild fish to produce one pound of industrially-produced shrimp
5. Monoculture and invasive species – a major challenge for aquaculture is the need for fast-growing species that can withstand the conditions of farms. Monoculture of these fast-growing fish can lead to a reduction in genetic diversity and make farms susceptible to diseases.

4.11 Present situation of fish farming in Bangladesh:


After being self-sufficient in fish production for the first time this year, Bangladesh has started to get global recognition as one of the biggest fish producers. The country was ranked third in producing fish from inland water-bodies, behind China and India, according to a report of Food and Agriculture Organization (FAO). The country was the fifth on the list last year. Bangladesh is now also the fifth biggest aquaculture producer in the world, said the report titled “The State of World Fisheries and Aquaculture 2018”. Fisheries and Livestock Minister Narayon Chandra Chanda cited the report findings yesterday at a press conference, organized by the Department of Fisheries at Matsya Bhaban in Dhaka, marking National Fisheries Week, to be observed from July 22 to 28. “The continuous effort of the government for the country's fisheries sector

has resulted in such achievements,” said the minister. In the 2016-2017 fiscal, Bangladesh produced a total of 41,34,000 metric tonnes of fish, including a first-time surplus of 84,000 tonnes. It helped the country to achieve the rank, he said. The production of hilsa stood at around five lakh metric tonnes that year, twice the amount in 2008-09, he added. Citing a report of Bangladesh Bureau of Statistics (BBS), Narayon Chandra claimed that the country's per capita fish consumption -- about 63 grammes per day -- has exceeded the required daily demand. To ensure continuity of the success, the government will priorities conservation of jatka (small hilsa), protection of natural fish-breeding grounds, extension of shrimp cultivation, and collection of marine fish at a tolerant level, he said in a written statement. The government will also bring all fishing trawlers and vessels under license within 2030, and establish 20 marine surveillance check-posts in coastal areas within 2020. “Approximately 60 percent of animal protein that we consume every day comes from fish. And the fisheries sector contributes 3.57 percent to the country's GDP,” the minister said. The minister also said the fisheries week will be observed across the country through several programmes, like fair, seminar and rally. Prime Minister Sheikh Hasina will wrap up the observance of the week by releasing fish fry in Gono Bhaban lake, he said. Fisheries and Livestock Ministry Secretary Raisul Alam Mondal and Director General at the Department of Fisheries Goljar Hossain, among others, were also present at the press conference. In getting the third position, Bangladesh produced a total of 10,48,242 tonnes of fish from inland water bodies in 2016, about 2.4 percent higher than 2015, according to the FAO's fisheries and aquaculture report.

China topped the list with 23,18,046 tonnes, while India was in second place with 14,62,063 tonnes, found the report which was made public on July 9. Myanmar and Cambodia secured fourth and fifth positions. In overall aquaculture production, Bangladesh was placed fifth by producing 22 lakh tonnes in 2016, said the report. China topped that list with a production of 4.92 crore tonnes. The report also said Bangladesh produced 1,13,200 tonnes of fish from marine and costal sources, and ranked 11th in the list.

4.11.1 Remarkable achievements and future potentials

Some remarkable achievement

 in fish production and rural employment,

- ✚ fingerling release, establishment of beel nursery,
- ✚ extension of environment friendly shrimp culture,
- ✚ community based fisheries management establishment of fish sanctuary,
- ✚ implementation of fish act,
- ✚ registration of fishermen and distribution of identity card,
- ✚ conservation of breeding ground,
- ✚ protection of Hilsha fishery,
- ✚ technology transfer through e-extension service has been observed in last 5 years.

4.11.2 Issues and plans

- ✚ To increase the fish production and for the better management of fisheries resources Department of Fisheries has undertaken some short term (2008-09-2009-10) , mid-term (2010-11-201213) and some long term (2013-14-2020-2021) development strategy.
- ✚ Short term (production from 25.63mt to 28.97mt) and mid-term (production from 25.63mt to 34.87mt) target has already been achieved.
- ✚ Now department of fisheries is going to implement the long-term development plans.

4.12 Introduction of Catfish Farming

Catfish is hardly fish that can survive in kind of regions and they are easy to farm especially in warmer climatic conditions. Raising catfish in tanks and channels are considered to be safest method as their waste and disease do not spread to the wild. Catfish farming is very profitable with low cost set up and due to the fact that these fish gain weight in short period of time. There are many varieties of catfish across the globe. These catfish size varies depends on the Variety and can get from small size to very large size. However, In India, Bangladesh, African catfish is the one mainly cultivated species among all other varieties. Commercial and small-scale catfish farming business is becoming popular day by day. If you are interested in fish farming. These fish can be raised even in small tanks at home. Catfish are also good for our health like catfish is a source of omega-6 and omega-3 fatty acid, Catfish is an excellent source of protein, catfish is an excellent source of B-12 vitamin. Catfish is also good source of mineral like magnesium.



Figure 4.3: Catfish farming

In the following paper let us discuss about raising catfish and its management.

4.12.1 Catfish varieties in Bangladesh

There are various types of catfish available in Bangladesh like Artamim, Arwari, Magur/Shing, Tengra, Pabda, cheka, pangus. In the case study we select one catfish like Pabda. Now we will discuss the details about Pabda catfish in the perspective of Pabna district.

4.13 Pabda (*Ompok- Pabda*):

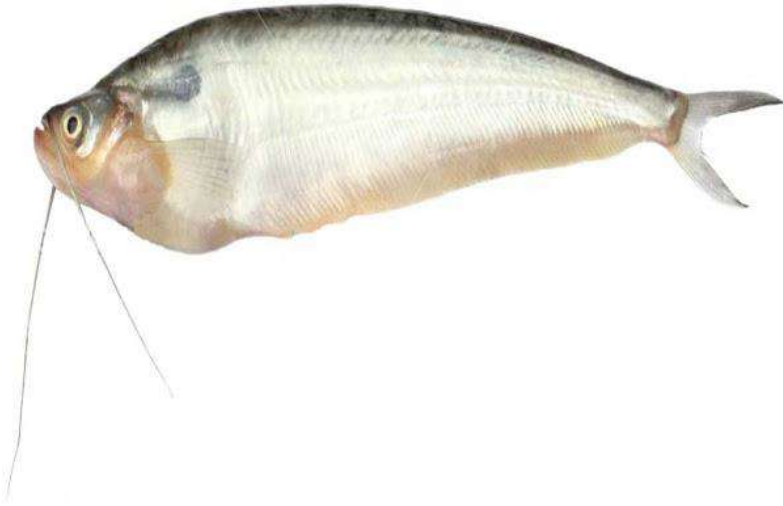
Among many indigenous fishes of Bangladesh, *O. pabda* locally known as pabda, a small freshwater catfish belonging to the family Siluridae of the order Siluriformes (Siddiqua et al., 2000) is a highly priced and one of the most sought-after fishes. It can thrive in all types of freshwater habitats, especially in rivers, canals, beels, swamps, floodplains and ponds. It is also geographically distributed in India, Pakistan, Afghanistan and Myanmar (Mukhopadhyay and Ghosh, 2007). Its total production from different water bodies of Bangladesh is only 150mt (FRSS, 2009). Its production can be increased through culture practice but sufficient number of fry and fingerlings of this catfish is, however, quite difficult to obtain from natural waters for stocking in the ponds. Added to this, the fry and juveniles of this species exhibit cannibalistic tendencies (Parameswaran et al., 1971) which creates management problem.

In spite of many advantages, very few attempts have been made to popularize its commercial culture and mass production of fry and fingerlings stands as one of the major impediments towards its aquaculture. Fry production and survival can be enhanced by feeding the broodstock with supplemental diets (Santiago et al., 1991). Vitamins are likewise needed for proper reproduction in fish; this has been documented for vitamin A, E and C (Sandnes et al., 1984; Watanabe, 1985; Soliman et al., 1986; Lie and MangorJensen, 1993; NRC, 1993). Dietary additives e.g. vitamin E have been found to have positive effects in the growth and reproduction of fishes (Gaylord et al., 1998; McDowell, 1989). A dietary requirement of vitamin E has been demonstrated in a number of fishes including salmon (Woodall et al., 1964), channel catfish (Wilson et al., 1984), bass (Kocabas and Gatlin, 1999), carp (Takeuchi et al., 1993), tilapia (Shiau and Shiau, 2001) and shing (Roy and Mollah, 2009). As a fat-soluble vitamin, it is the most effective chain-breaking, lipid-soluble antioxidant in biological membranes, where it contributes to membrane stability. A major function of vitamin E is to prevent peroxidation of polyunsaturated fatty acids of phospholipid and cholesterol in cellular and subcellular membranes. Aquatic animals have high levels of unsaturated fatty acids to maintain cell membrane fluidity especially at low temperatures; it is assumed that vitamin E plays an important role in this context (Blazer, 1992). Pabda fish is a freshwater fish species. It is very tasty and has high nutrition value. So, it has a great demand and high value in the market. Pabda fishes can be found mainly in the pond, swamp, paddy field etc. They are one type of catfish. They generally live in clean freshwater. Pabda fishes are available in the Asian countries, especially found largely in Bangladesh, India, Pakistan, Nepal and some other south Asian countries. Classification, physical characteristics, feed habit and breeding of this fish are described below.

Classification of Pabda Fish

- Kingdom : Animalia
- Phylum : Chordata
- Class : Actinopterygii
- Order : Siluriformes
- Family : Siluridae
- Genus : Ompok
- Species : O. pabda
- Scientific Name : Ompok pabda

Figure 4.4 Pabda catfish



Physical Characteristics: Pabda fishes are small sized freshwater fish species. The physical characteristics of the Pabda fishes are describe:

- The body of Pabda fishes is flat in both side.
- The caudal side is narrower than head side.
- Pabda has similarity in look with Boal fish.
- There are no scales in their body.
- Their chest is silver colored.
- There is a pair of mustache in their mouth.
- Has two pairs of fins.
- Pelvic fin lengths from belly to tail.
- Anal fin is divided into two parts.
- There is a fishbone in the pectoral fin of pabda fish.
- Pabda fish lengths between 12 to 30 cm.

Feeding and Breeding

Pabda fish usually live in the upper level of water. They are omnivorous. They generally eat protozoa, aquatic insects, crustasia, moss etc. But they also like to eat cake and fishmeal as a supplementary feed. Feed them supplementary feed containing 40% rice

bran, 30% mastered cake and 30% fishmeal before their breeding period. The breeding period of pabda fish is between May to July. Females lay eggs within this period.

Pabda Fish Farming Business

Commercial pabda fish farming is getting popularity gradually. Actually, pabda fish (which is also known as Butter Catfish or Ompok pabda) is an Indian freshwater catfish species with very good market demand, especially in the North-Eastern part of India, Bangladesh and some other South Asian countries. Pabda fish is very popular and has very high market value mainly for its fine flesh with soft meat texture, good taste and very high nutritional value and relatively low bones. Pabda fish is generally sold fresh locally or ice preserved.

The pabda fish is generally cultured in the ponds along with some other fishes pieces such as Rui, Catla and Mrigal (but rearing in shades and deserted ponds is not uncommon to be seen). Commercial pabda fish farming business is very profitable and can be a commercially viable enterprise for the rural unemployed educated youth. Although culture of pabda fish has not yet received due importance, despite its great potentiality. Commercial pabda fish farming business has not received much attention in recent aquaculture scenario mainly due to non-availability of information regarding its breeding and larval rearing technique. Although researchers are trying to change this situation. And we hope to have more insights and modern techniques for breeding and larval rearing methods of pabda fish commercially.

How to Start Pabda Fish Farming

Pabda fish farming business in freshwater pond is becoming popular gradually. We are learning and practicing more modern systems for commercial pabda fish farming. However, here we are trying to describe more about the systems for raising pabda fish in freshwater pond.

Site Selection

First of all, you have to select a good site for starting pabda fish farming business. It will be better if the selected site is free from all pollution and noises, and has full sun access. Although in small scale production, you can choose any site or location for raising pabda fish.

Pond Construction and Size

Size of the pond for pabda fish farming can be any depending on your available land type. You can even start raising pabda fish in smaller plastic or concrete tanks. But for commercial production, it will be better if the pond is around or up to one acre. You can use earthen/natural, plastic, fiber, glass or concrete pond for pabda fish farming.

Pond Preparation

After constructing the pond, you have to prepare it perfectly before stocking fingerlings into it. Applying lime and both organic and inorganic fertilizers into the pond is very important. Applying fertilizers into the pond helps in natural feed production. Exact amount of lime and fertilizers depends on the farming intensity and inherent productivity. Please contact any of your nearest aquaculture specialist or fisheries institution for having more information.

Seed Collection

Pabda fish is a naturally breeding catfish and you have to collect the seed from natural water bodies. There are some suppliers and they collect seed from the natural water bodies and sell to the interested farmers. You can contact such suppliers in your area. Or contact some people in your area who are already in this business.

Although, today there are some breeding hatcheries which are producing and rearing pabda fish fingerlings. You can contact any of your nearest hatcheries for having more information.

Stocking in the Pond

After preparing the pond perfectly, you can stock the fingerlings directly into the pond. As a catfish species, the pabda fish can do well in high stocking densities. But for proper growth, you should not stock more than 25,000 fingerlings per acre pond.

Feeding

The pabda fish live and consume food from the upper level of the pond. They are omnivorous and generally eat protozoa, aquatic insects, crustasia, moss etc. They also enjoy fishmeal or other supplementary fish feeds. Today, in some places commercial pabda fish feeds are also available.

Harvesting

You can expect to harvest the fish after 10-12 months of stocking them in the pond. Although, you can harvest the fish at any time when they reach your desired size. You can use fishing nets for harvesting the pabda fish.

Marketing

Pabda fish is generally sold live and fresh in the market. So, try to send the fish in the market immediately after harvesting. This will ensure higher price of the fish.

Pabda fish farming business requires relatively less investment, and profit from this business is very high. Feeding and other costs are less and you can start this business even if you are a beginner. The pabda fish farming business can create a great opportunity for the people, especially for the unemployed educated youth.

4.14 Prospect and potential of Pabda catfish production in Bangladesh

Economic considerations in the selection of an appropriate aquaculture production system by the private sector include its potential for economic returns, its economic efficiency and ultimately, the farmer's access to operating capital. According to Olasunkanmi (2012),

Ugwumba (2011), Emokaro et al. (2010), Oladejo (2010), Kareem and Williams (2008), Pabda catfish farming is a profitable business. However, increasing production costs demand that Pabda catfish farms should be run more efficiently, given the level of technology, in order to boost production. It has been estimated that Bangladesh has the potential to produce over 4 million metric tons annually (FGN, 2011). According to the people's republic of Bangladesh, current production stands at about 41.34 metric tons with an estimated domestic demand of about 68.31 thousand tons leaving an estimated shortfall of about 35.76 metric tons. This shortfall is supplemented by imports of frozen fish from Europe, Latin America and Eastern countries. According to the people's republic of Bangladesh, the country spent over N100 billion on the importation of over 780,000 metric tons of frozen fish in 2010. The shortfall of fish supply in the country has led to a low annual per capita fish consumption rate of only 7.5 kilograms as against 15 kilograms per annum as recommended by the Food and Agriculture Organization (FGN, 2011). It is therefore crucial to increase domestic production in order to meet the shortfall between demand and supply, and to diversify the country's resources. However, the current challenges of rising costs of production require a focus on technically efficient production systems. Profit maximization requires a firm to produce the maximum output given the level of inputs employed (that is, to be technically efficient), use the right mix of inputs in the light of the relative price of each input (that is, to be input allocative efficient) and produce the right mix of outputs given the set of prices (that is, to be output allocative efficient). The pabda Catfish farming also plays a crucial role in driving the aquaculture sector in Bangladesh by creating employment directly and indirectly to millions of people, helping to diversify the nation's resources, earn foreign exchange through potential export and help the country achieve the millennium development goals (MDGs). It also has the potential of contributing more to the gross domestic product (GDP) of the country.

4.15 Constraints to Sustainable Fisheries Development in Bangladesh:

In Bangladesh, there are a number of constraints that pose significant challenges to the sustainable development of fisheries, including the following:

- ✚ Inadequate knowledge of the resource and ecosystem: Insufficient and weak scientific data lead to incomplete information and knowledge, and policies based on such data will remain incomplete;

- ✚ Non-interaction between the government and the stakeholders: Another crucial gap in Bangladeshi fisheries policy is the complete absence of stakeholders' input during the policy formulation process (Godfray et al 2010). Experience shows that top-bottom approach to fisheries management does not yield the best results.
- ✚ Unavailability of financial resources to meet specific needs: According to Ajibefun (2002), Bangladesh governments do not have an adequate appreciation of the social and economic potential of sustainable fisheries development, and hence still invest minimum resources in fisheries development and management activities. Budgetary allocations to Fishery Departments and Research Institutes are too meager to meet vital requirements such as research to update the laws with national fishery statistics and other relevant information; or vessels for policing the coastal zone to enforce existing laws.
- ✚ Weak agricultural policy and implementation: Agricultural policies are not specific and most do not have strategy, targets, goals, or specific objectives and most importantly, do not include programs or projects geared towards accomplishment of the goals. Policy implementation also requires enforcement by laws which indicate lack of strong political commitment on the part of government (Adekoya 2004).
- ✚ Inconsistency in policies and programs: Agricultural programs have undergone changes that tend to reflect changes in government or administration.
- ✚ Inadequate technical advisory/extension services: Kareem and Williams (2008) suggested that technical advisory or extension services which are intended to provide, teach and convince farmers to adopt and diffuse innovation are lacking. The participants/beneficiaries are not adequately educated on the goals of these programs, which leads to their failure.
- ✚ Lack of monitoring and evaluation of programme/project: The philosophy of monitoring and evaluation of projects in Bangladesh is lacking.

4.16: Pabna district

The study area is the Pabna district in north-western Bangladesh, located between 23°48' and 24°21' north latitudes and between 89°00' and 89°44' east longitudes. It is the southernmost district of Rajshahi Division. Its administrative capital is eponymous Pabna town. Pabna forms the south-east boundary of Rajshahi Division. Sirajganj District is to the north-east, while the Padma River, main stream of the holy river Ganges, in the south separates it from Rajbari District and Kushtia District. The Jamuna River runs along its eastern border separating it from Manikgonj District; and on the north-west it has a common boundary with the Natore District. The Pabna district comprises nine upazilas: Asatkharia, Bera, Bhangura, Chatmohar, Faridpur, Ishwardi, Pabna Sadar, Sathia and Sujanager Upazila. Administration of Pabna District was formed in 1832. Of the nine upazila of the district Pabna Sadar is the largest (443.90.41 sq km, it occupies 18.72% of the total area of district) and Bhangura is the smallest (136 sq km). Average maximum temperature 36.8 °C, minimum 9.6 °C; annual rainfall 1872 mm. Characteristically the soil of the district is divided into four, viz flood plains of the Ganges, Karatoya, Jamuna and Barind Tract.

Of the 2.1 million inhabitants, 51.17% are male. 90.12% are Muslims, 9.50% Hindu, 0.22% Christian and others 0.16%. There are 2353 mosques, 420 Hindu temples, and 11 churches. There is no Buddhist pagoda in Pabna. Thakur Anukulchandra Aasrom (missionary) beside Mental Hospital, Pabna at Hemayetpur has the largest Hindu temple in Pabna. Most of the people in this district are related with agriculture activities. The distribution of their main occupations is as: Agriculture 34%, agriculture farm-hands 22.77%, wage laborer 4.46%, transport 2.18% weavers 2.85%, commerce 13.27%, service 7.26% and others 13.21%. About half of the population is educated. The current literacy rate is male 51.8% and female 31.5%. There is renowned science and technology University named Pabna University of Science and Technology. There are 34 colleges, a cadet college, a law college, a government polytechnic institute, a government vocational training institute, a textiles college, a government commerce college, a teacher training college, a primary teacher training institute, a nursing training institute, a homoeopathic college. 202 high schools, 29 junior high schools, a Madrassa Aliya, 261 qaomi madrassa (seminary), 667 government primary schools, 445 non-government primary schools, 8 community schools, 29 kindergartens, 32 satellite schools, 299 NGO-

operated school, and a music college. Pabna zilla School, Pabna Edward college and Banwarinagar C.B pilot high school these three institutions of this district is very old in these region. All these three institutions have already passed a hundred glorious years.

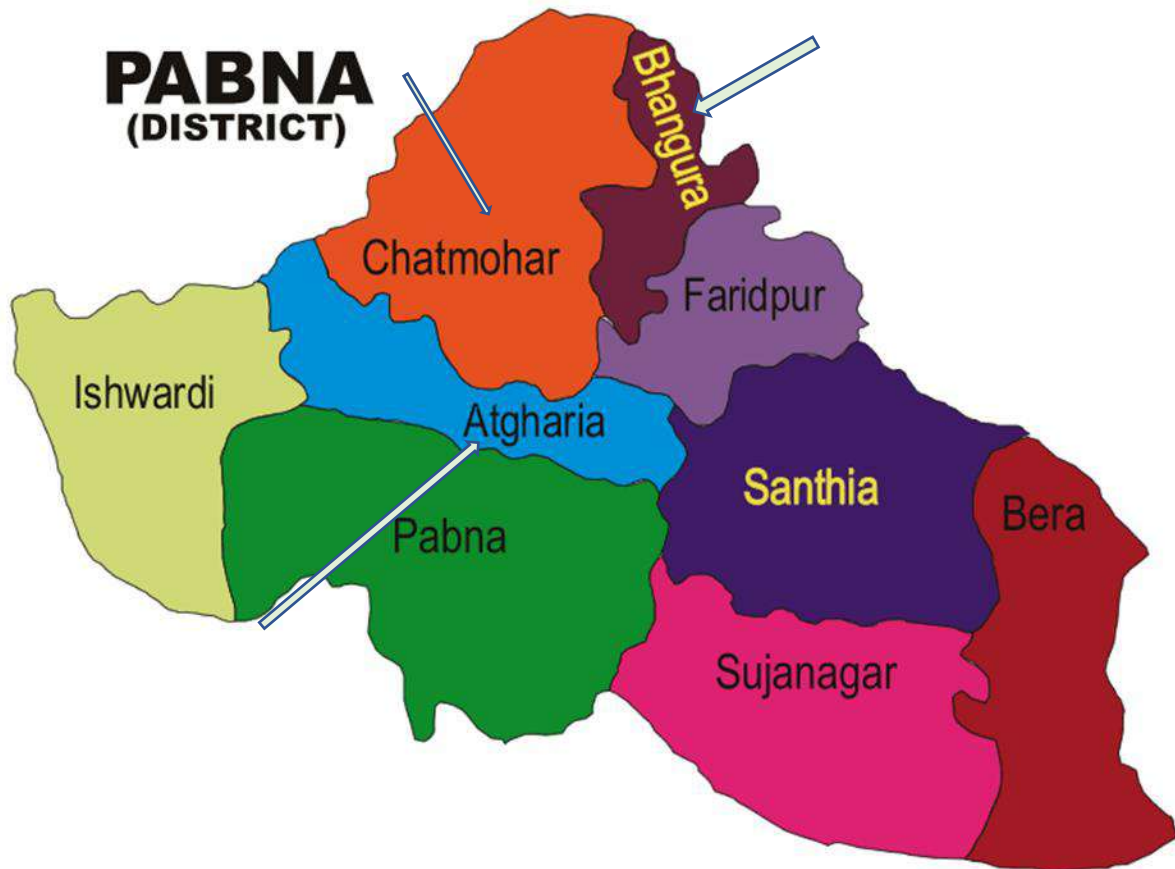
The Major crops of this district is Paddy (Rice), jute, sugarcane, turmeric, ground nut, oil seeds, pulses, maize etc main fruits are mango, blackberry, jackfruit, coconut.

Some prime historical events of this district are mentioned here. History of the War of Liberation an encounter was held between the freedom fighters and Pak army on 29 March 1971 at the telephone Exchange Compound of Pabna sadar upazila in which 22 Pak soldiers were killed. On the same day the Pak army killed 5 youths at the village Madhabdi under Ishwardi upazila. On 31 March 1971, the freedom fighters resisted the Pak army at the Nagarbari ferry Ghat in order to dislodge the freedom fighters when number of innocent civilians were killed. On 19 April, A battle was fought between the freedom fighters and the Pak army at Paikarhati (meeting place of Bera and sathia on the Nagarbari-Bogra highway) in which 25 freedom fighters and 150 Pak soldiers were killed. On 22 May 1971, the Pak army killed 156 innocent persons at village Handal of Faridpur Upazila.

Important installations Hardinge Bridge, Lalon shah Bridge, Ishwardi Railway Junction, Agriculture Research Centre (biggest in Asia), Sugarcane Research Center (only in Bangladesh and biggest in Asia) and ishwardi Airport.

The location and other information of the study area are presented in maps in below.

Figure 4.5: Pabna district map



4.16.1 Atgharia Upazila

Location

Atgharia Upazila of Pabna District with an area 186.15 sq. km, located in between 24⁰03' and 24⁰12' north latitudes and in between 89⁰10' and 89⁰25' east longitudes. It is bounded by Chatmohar and faridpur upazilas on the north, pabna sadar and Ishwardi upazilas on the south.

Santhia upazilas on the east and baraigram upazila of district on the west. The location and other information are presented in the map below

Table 4.4: Atgharia upazila

Upazila								
Municipality	union	Mouza	Village	population		Density (per sq. km)	Literacy rate %	
				Urban	Rural		Urban	Rural
-	5	111	132	8343	128137	733	46.4	44.5

Source: Banglapedia, 2017

Area and Population

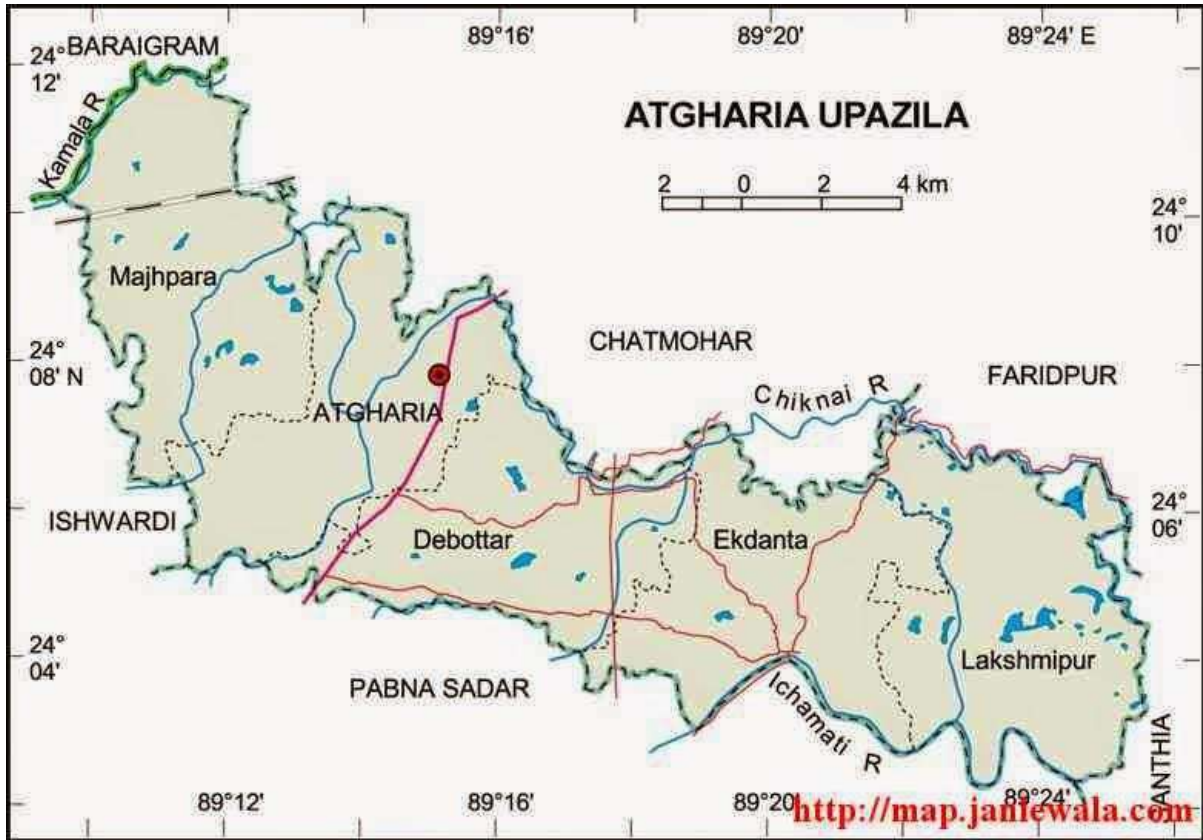
The total is of Atgharia Upazila is 186.15 sq. km. Total population was estimated 136480 at which the number of male and female stood at 70343 and 66137 respectively.

Table 4.5: Area and population of Atgharia upazila

Area (In km^2)	Total population	Male number	Female number	Population density (per sq km)
186.15	136480	70343	66137	733

Source: Banglapedia,2017

Figure 4.6: Atgharia upazila map



Research union: Atgharia Upazila

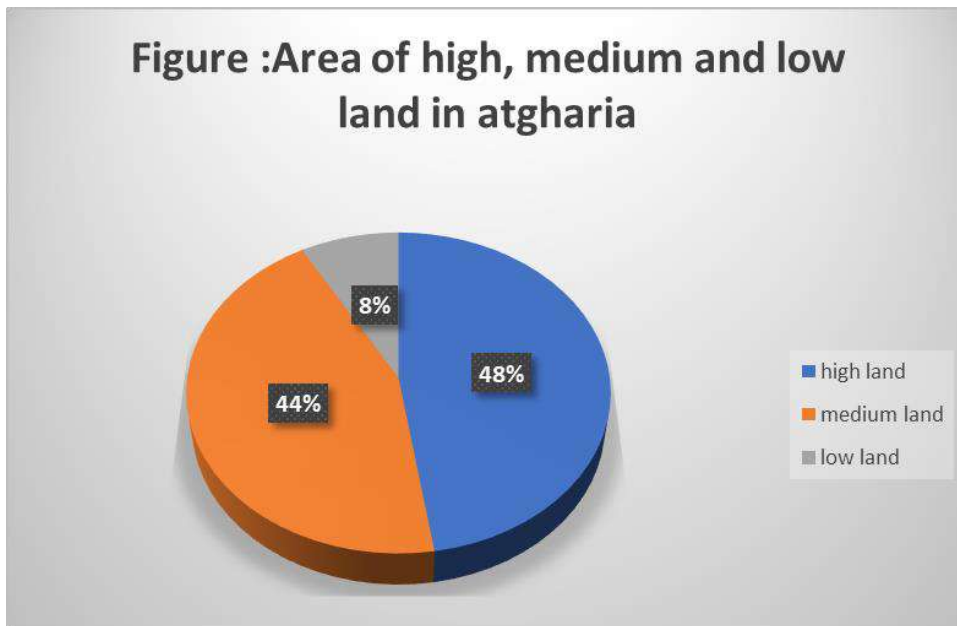
Soil Type and Land Topography

The land in the study area is mostly alluvial. The soil texture varies from sandy loam to clay loam. The area is fertile enough and a huge amount of food grain is produced in the area. Characteristically the soil of the district is divided into four, viz flood plains of the Ganges, Karatoya, Jamuna and Barind Tract. The area of high, medium and low land in the study area are high land 48 percent of total land while low and medium land are 8 and 44 percent, respectively.

Table 4.6: Area of high, medium and low land in Atgharia upazila.

Upazila	High land	Medium land	Low land	Total land
Atgharia	19100	17776	3307	40183

Figure 4.7: Area of high, medium and low land in Atgharia.



Climate, temperature and rainfall

In the study area there is no local meteorological center for recording temperature and rainfall. Thus, exact meteorological data could not be available. The district meteorological office records temperature, humidity and rainfall. The temperature of the study area varies from 36.8 °C to 9.6 °C; and annual rainfall is 1872 mm. (Banglapedia 2019)

Source of income and ownership of agriculture land

Main source of income in the study area at Atgharia Upazila are agriculture. Agriculture 73.76%, non-agriculture laborer 2.25%, commerce 8.33%, Transport and communication 2.09%, industry 0.26% and others 4.83%. Ownership of agricultural land in the study area is

found about landowner 61.18%, landless 38.82; agriculture landowner. Urban 44.57% and rural 62.27%. (Banglapedia, 2017)

Main crops

There are two main crop seasons in Bangladesh as well as the study area, namely Kharip (April to September) and Rabi (October to March). The main crop in the kharip season are Aus. rice, jute and the Rabi crops are wheat, boro, aman and various kind of vegetables like brinjal, lady's finger, cabbage, cauliflower potato, groundnut, tomato, mustard seed, brinjal, potato, green chili, onion, garlic, vegetables.

Occupation

Farming is the main occupation in the study area. Most of the male members work in the field. Some of them are engaged in business, petty trading and services while female members work mostly at home. The major agriculture activities are related to crop farming.

Education and religion

Religion institutions in the study area at Atgharia Upazila of Pabna District are about mosque 161, temple 17, church 1. Noted religious institution: Beruan mosque, Atgharia mosque. Debottar mosque, sreekantapur mosque, Ekdanta mosque, Radhakantapur mosque. Average literacy 44.6%; male 45.9%, female 43.2% educational institution: college 5, secondary school 29. Noted educational institutions: Atgharia pilot Model high school, Debattar pilot girls' high school, Sahid Abdul Khaleque high school, B.L.K high school, Khidirpur high school.

Transportation, communication and marketing facilities

The villages are well connected with the upazila headquarters and the district town. The north Bengal-Dhaka highway road passes by the side of the selected upazila of the villages. The transport facilities available in the area are bus, minibus, truck, van, rickshaw, trolley, tempo, etc. Pucca road 47.16 km, semi pucca road 20 km, mud road 320 km.

The marketing systems of the villages are also good. There is no problem to sale any agriculture crops. Generally, the farmers buy and sell their daily necessities in the village and upazila markets.

4.16.2 Chatmohar upazila

Area and location

Chatmohar Upazila of pabna district has an area of 305.63 sq. km, located between 24°06' and 24°21' north latitudes and in between 89°12' and 89°24' east longitudes. It is bounded by gurudaspur and tarash upazilas on the north, Atgharia upazila on the south, faridpur and bhangura upazilas on the east, baraigram and gurudashpur upazilas on the west. Main rivers: baral, chiknai. Atria: Failam beel, chalan beel, kural beel, diksal beel are notable. Chatmohar thana was formed in 1909 and it was turned into an upazila in 1982. The location and other information of these study areas are presented with appropriate map and table in this section.

The Chatmohar upazila is the larger upazila of pabna district has an area of 305.63 sq km Total population in this area is 239973; male 121265, female 118708; Muslim 227366, Hindu 10557, Buddhist 2046 and others 4.

Table 4.7: Chatmohar upazila

Chatmohar Upazila								
Municipality	Union	Mouza	village	Population		Density (per sq km)	Literacy rate%	
				Urban	rural		urban	Rural
1	11	170	132	22562	217411		56.7	36.7

Source: Banglapedia.2019

Soil type and land topography

The land in the study area is mostly alluvial. The soil texture varies from sandy loam to clay loam. The area is fertile enough and a huge amount of food grain is produced in the area. Characteristically the soil of the district is divided into four, viz flood plains of the ganges, Karatoya, Jamuna and Barind Tract

Table 4.8: area of land.

Upazila	High land	Medium land	Low land	Total land
Chatmohar	10700	29640	21785	62125

Source: Banglapedia 2019

Figure 4.8: Chatmohar upazila



4.16.3 Bhangura Upazila

Area and Location

Bhangura Upazila of Pabna district area 136 sq. km, located in between 24°09' and 24°21' north latitudes and in between 89°20' and 89°28' east longitudes. It is bounded by Tarash, Chatmohar and ullapara upazila on the north, Faridpur upazila on the south, Ullahpara and Faridpur upazila on the east, Chatmohar upazila on the west. *History of the War of Liberation* During the WAR OF LIBERATION in 1971 a battle was fought between the freedom fighters and the Pak army and rajakars near Baral Bridge in which the Pak army was defeated and a number of 'rajakars surrendered to the freedom fighters with their arms and ammunitions. Bhangura upazila was liberated on 15 December 1971. *Administration* Bhangura Thana, now an upazila, was formed in 1980.

Table 4.9: Bhangura upazila.

Bhangura upazila								
Municipality	union	mouza	village	Population		Density (per sq. km)	Literacy rate %	
				urban	rural		urban	rural
1	11	170	132	22562	21741	785	56.7	36.7

Source: Banglapedia 2019

Main sources of income Agriculture 70.49%, non-agricultural laborer 2.61%, industry 2.21%, commerce 11.51%, transport and communication 1.84%, service 5.70%, construction 0.98%, religious service 0.20%, rent and remittance 0.09% and others 6.58%.

Figure 4.9: Bhangura upazila



4.17 Conclusion

The land texture and weather of Atgharia, Chatmohar and Bhangura upazila of Pabna District is more suitable for fish farming. Therefore, there were no such study was undertaken in this area. For this reason, this area was selected for the present study. This reason study is mainly based on primary data. Primary data has been collected from the selected sample villages in February 2019 using a well- prepared questionnaire. However, for this research some secondary data have also been collected. These secondary data have been collected from various government and non-government organizations such as yearbook of fisheries department of Bangladesh economic review, Food and Agriculture organization (FAO), union parishad office, various website about aquaculture, Wikipedia the free encyclopedia, Bangladesh etc.

Chapter Five

Research Methodology

5.1 Introduction

Research methodology is a way to study the various steps that are generally adopted by a research in studying the research problems systematically along with the logic, Assumption and rational behind them. Farm management research depends on the proper methodology of the study. Proper methodology is a prerequisite of a good research. This chapter highlight the research methodology, which is followed throughout the research study, and the descriptive of data that are collected from primary sources for the purpose of analysis. A combination a analytical tools was employed in this study. It outlined technical efficiency of Pabda fish farming by using FRONTIER 4.1. This chapter also provides a description of the explanatory and dependent variables, used in the study and the relationship between them. The design of any survey is predominantly determined by the nature, aims, and objectives of the study. It is also depending on the availability of necessary resources, materials and time. There are several methods of collecting data for farm management research. A farm business study usually involves collection of information from individual farmers; collection of data for farm business analysis involves judgment of the analyst in the selection of data collection methods within the limits imposed by the resources available for the work (Dillon and Hardaker 1993). It I difficult to conduct research on Technical and efficiency of fish production in Pabna District due to lack of secondary data on these areas. Moreover, they do not understand the necessity of research and even sometimes they have wrong idea about the purpose of research. Again, respondents have lower level of education. All of these created problems during data collection. Therefore, this chapter also provides some key characteristics and features of the collected data.

In this study, “survey method “was employed mainly due to two reasons:

- i. Survey enables quick employed investigations of large number of cases; and
- ii. Its results have great applicability.

The major disadvantage of the survey method is that the investigator has to rely upon the memory of the farmers. To overcome this problem, repeated visits were made to collect data

in the study and in the case of any omission or contradiction the farmers were revisited to obtain the missing and correct information. Therefore, this chapter also provides some key characteristics and features of the collected data. The design of the survey for the present study in this chapter involved into mainly the following steps.

5.2 selection of fish

Among many indigenous fishes of Bangladesh, *O. pabda* locally known as pabda, a small freshwater catfish belonging to the family Siluridae of the order Siluriformes. Pabda is well known catfish in Bangladesh and it also very important to our nutrition's. The rationale behind this selection is that, Pabna district is important for aquaculture. And it is also predominantly aquaculture based, tilapia, Pabda are dominant fish produced simultaneously with other minor fish farming, such as Shing, tengra, pangush, and carp. Various development projects of Bangladesh are financed by the foreign exchange earnings from Pabda. It also holds an important position in the aquaculture sector in the economy of Bangladesh. In the study area Pabda is the single largest fish. The study areas are almost single and triple fish farming areas and Pabda are cultured extensively and there is a sufficient scope to improve yield frontier through aquaculture practices. Therefore, considering the significance and contribution of Pabda in the context of Bangladesh Economy as well as in the study area, Pabda has been selected for the present study.

5.3 Selection of Sample

5.3.1 Selection of the study areas and Rationale

In the present study the researcher selected the study areas with care so that real results would be representative. Selection of the study area is an important step for farm management study. The selection of an area fulfilled the particular purpose which was set for the study and also the possible cooperation from the farmer. In selecting the sample areas, the researcher has to consider the limitation of his intellectual and financial capabilities and his time limitations. Although Pabda fish are grown all over Bangladesh, the district Pabna is one of the important districts where it is grown quite extensively.

Thus, the present study has been based on primary data that are collected from pabna district of Bangladesh purposively. The selection of the respondent has been made using the multistage

simple random sampling procedure. At first stage, three out of nine upazila under pabna district has been selected using simple random sampling. These upazilas are Atgharia upazila, Chatmohar and Bhangura upazila. There are 5 and 11 unions under Atgharia upazila, Chatmohar and Bhangura upazila, respectively. At the second stage, using random sampling technique, from each upazila two union are chosen which are Debottar union and Majhpara union of Atgharia upazila, Haripur and mulgram union of Chatmohar upazila and Dil pasar and Bhangura union of Bhangura upazila. Finally, a list of farmers of the selected union are collected from the upazila fisheries office and chosen 60 respondents for data collection.

Table: 5.1 selection of data from Pabna district.

Upazila	Name of union	Num of respondent	Total respondent
Atgharia	Debottar	10	20
	Majhpara	10	
Chatmohar	Mulgram	10	20
	Haripur	10	
Bhangura	Dil pasar	10	20
	Bhangura	10	
Total respondent			= 60

Source: field survey 2019

The rationale behind this selection is that, Pabna district is predominantly aquaculture -based, Pabda are the dominant fish farming simultaneously with other minor fish farming. All these features confirm to the typical characteristics of Bangladesh aquaculture and these areas can be considered as area representative of the research objectives.

- i. Availability of large number of Pabda fish farm in the study area;

- ii. These union had some identical physical characteristics like topography, soil and climate conditions for producing Pabda fish;
- iii. No study of this type was conducted previously in these areas;
- iv. Easy accessibility and good communication facilities in these union; and
- v. Co-operation from the respondents was expected to be high so that reliable data would be obtained.

5.3.2 Sampling Technique and Sample Size

For obtaining the best outcome of the research study and therefore, in selecting samples for a study two factors need to be taken into consideration. The sample size should be as large as to allow for adequate degrees of freedom in the statistical analysis. On the other hand, administration of field research, processing and analysis of data should be manageable within the limitation imposed by physical, human and financial resources. However, because of diversity in the technical and human environment, it is necessary to sample several numbers of the population before any conclusion can be drawn. Therefore, the purpose of sampling is to select a sub set of the population that is representative of the population

It was not possible to include all the farmers of the study area due to limitation of time, money and personal. In total 60 farmers were randomly selected from Pabda fish farming. A multistage random sampling technique was followed in the present study for minimizing cost, time and to achieve the ultimate objectives of the study.

5.3.3 The questionnaire for data collection

For the collection of data, a well- organized questionnaire is needed to meet the required objective. A draft questionnaire was prepared for collecting information from the sample farmers. Keeping the objectives of the study in mind, the questionnaire was pre tested by interviewing some farmers who cultured Pabda, therefore necessary modifications, additions and alternations were made and then draft questionnaire was finalized. To meet the extreme needs of this study on the technical and allocative efficiency of Pabda production function, only primary data has been collected.

The final questionnaire contained three categories of information. The purpose of the first category was to obtain information about the socioeconomic condition of the selected farmers.

The second category contained information related to costs and returns of the two selected crops. The third category of information was related to constraints and problems faced by the farmers in producing Pabda fish.

5.3.4 Data collection method

The study was conducted for a period of 07 days from 07 February 2019 to 13 February 2019 on intermittent basis (Appendix 1). Field visits were carried out in the study areas for a period of 07 days. A combination of the participatory, qualitative and quantitative methods was used for gathering information through rapid appraisal. Rapid Rural Appraisal (RRA) is a group of methods to collect information on participatory basis from rural communities. The advantage of RRA over other methods is that it allows wider participation of the community, therefore the information collected is likely to be more accurate (Chambers, 1992; Chambers, 1994). Rapid appraisal methods are used to obtain accurate information through triangulation (USAID, 2010).

1. Secondary Information:

Secondary data were collected from several relevant organizations, including Bangladesh Fisheries Research Institute (BFRI), Department of Fisheries (DoF) and District Fisheries Offices. Fish production, culture areas, number of fish farmers involved and other related information were collected from various organizations. These data were also verified with data from other sources. Literature reviews were also performed with several reports published by BFRI and the World Fish Centre. Literature reviews were also performed with published articles and unpublished documents. Where information was found contradictory to that of secondary data, further assessment was carried out through field investigations and cross-check interviews with key informants.

2. Mapping Workshop:

After completion of the literature review, a Mapping Workshop was conducted in Pabna with the stakeholder of these species on February 9, 2019 the objective of the mapping workshop is

to identify the major clusters and to draw draft value chains of these three species from the stakeholder in a participatory approach. These stakeholders include district map of pabna zila.

3. Primary Study:

a) Questionnaire Interview:

Questionnaire interviews with farmers and associated groups were preceded by preparation and testing of the questionnaire and training of survey operators. The pre-survey activities included reconnaissance for the pilot survey, revision of survey instruments and preparation of sampling frame. For the preparation of the questionnaire, visits to fish farms, and markets were conducted. Primary interviews with fish farmers and associated groups including, and fish market actors were conducted. A total of 60 people was conducted for questionnaire interviews. Several visits were made to farming sites and markets for observation of farming and marketing practices. Interviews with farmers, lasting on average one hour, focused on production season, culture period, farming practices, using inputs (seed, feed, fertilizer and labor), productivities and the socioeconomic conditions of farming households

b) Key Informants Interviews:

A key information is someone with special knowledge on aquaculture development. Key informants are expected to be able to answer questions about the knowledge and behavior of others, and about the operations of the broader systems (Atkinson, 1992; Elmendorf and Luloff, 2006). For this study, key informants' interviews were conducted with government fisheries officers, progressive farmers, market actors, researchers, policymakers, relevant NGOs workers and project staffs. A list of questions was used for key informant interviews regarding the existing culture practices of pabda. Key informants were able to provide information on farming practices, productivities, production trends and future prospects, based on their knowledge, skills and experience. Key informants were also conducted for the validation of collected information and their opinions regarding the future production and consumption trends.

5.4 Method of analysis

Technical efficiency is the maximum possible output obtained from a given set of inputs. According to Farrell, M J. (1957), within a given level of inputs and technology the maximum possible output of a firm can be shown by the frontier production function. The present study uses stochastic frontier production function for measuring technical efficiency of Pabda fish farming in the study area. In order to arrive at a meaningful result, and so as to achieve the main objectives of the study, data has been analyzed in following analytical techniques.

5.4.1 Theoretical Model for estimation of Technical Efficiency

According to Farrell's (1957) model, technical efficiency (TE) is defined as the ability of farm to obtain the best production from a given set of inputs (output-increasing oriented), or alternatively as the measure of the ability to use the minimum feasible amount of inputs to produce a certain level of output (input-saving oriented) (Greene, 1980; Atkinson and Cornwell, 1994). Consequently, technical inefficiency is defined as the extent to which firm fail to reach the optimal production. Farrell (1957) proposed to measure TE of a farm by comparing its observed output to the output which could be produced by a fully efficient farm, given the same bundle of inputs. Aigner et al. (1977) and Meeusen and van den Broeck (1977) independently proposed the stochastic frontier (SF) production function to an account for the presence of measurement errors and other noise in the data, which are beyond the control of managers. Farmers in general operate under uncertainty and therefore, the present study employs a stochastic production frontier approach for measuring TE. Following Battese and Coelli (1995), the following stochastic frontier production function and inefficiency effects model are estimated simultaneously using single stage with the computer program, FRONTIER 4.1. developed by Coelli (1996).

Following their specification, we specify the general SF model defined as:

$$Y_i = f(X_i; \beta) + \varepsilon_i \quad i= 1, 2, \dots, N \text{ -----(1)}$$

Where, Y_i is the output value from Pabda for i^{th} farm, X_i is the vector of k inputs (or cost of inputs), β is a vector of unknown parameter to be estimated, f is the suitable functional form

for the frontier (Cobb- Douglas, translog or quadratic), ε_i is an error term, and N is the total number of observations. The stochastic frontier production is also called “composite error” model, because it postulates that the error term ε_i is decomposed into two components: a stochastic random error component (random shocks/ white noise) and a technical inefficiency component define as follows:

$$\varepsilon_i = V_i - U_i \text{ -----(2)}$$

Where

V_i is a symmetrical two sided normally distributed random error that capture the stochastic effects outside the farmers ‘control (for example, weather, natural disasters, omitted variables, luck, exogenous shocks, measurement errors, and other statistical noise). It is identically, independently and normally distributed, $N(0, \sigma^2 v)$ independent of the U_i . Thus, V_i , allows the production frontier to vary across farms, or over time for the same farms and therefore, the production frontier is stochastic in nature.

The term U_i (asymmetric non-negative error term) is a one-sided ($U_i > 0$) efficiency component that capture the technical inefficiency of the i th farmer. This may follow a half-normal, exponential, truncated-normal or gamma distribution (Stevenson, 1980; Aigner et al., 1977; Meeusen and Broeck, 1977). In the study we assumed that U_i follows the half-normal distribution symbolically $N(0, \sigma^2 u)$ as was done in various published studies in applied stochastic frontier literature. It is obtained by the truncation at zero of the normal distribution with mean μ , and variance $(\sigma^2 u)$. If μ is pre-assigned to be zero, then the distribution is half-normal. Besides, two error components (V and U) are also assumed to be independent of each other.

Other vital parameters estimated under this analysis include sigma square (σ^2 s), gamma (γ)

And log-likelihood ratio. σ^2 s indicates the goodness of fit of the model used, and gamma gives the proportions of the deviation of the Pabda output from the production frontier caused by technical inefficiency. For example, if $\gamma = 0$, it indicates that U_i is about in the model. If $\gamma = 1$, it mean all deviations from the frontier are due to technical inefficiency. The log -likelihood ratio is used to test for the significant presence of technical inefficiency effects in farmers ‘production. The variance parameters of the model are parameterized as:

The variance parameters of the model are parameterized as:

$$\sigma_s^2 = \sigma_v^2 + \sigma_u^2, \quad \gamma = \sigma_u^2 \div \sigma_s^2 \quad \text{so that } 0 \leq \gamma \leq 1 \text{-----}(3)$$

Where,

σ_s^2 = Variance parameters of sample statistic

σ_v^2 = Variance of the error term due to noise

σ_u^2 = Variance of the error term resulting from technical inefficiency

The parameter γ must lie between 0 and 1. Here, σ_s^2 denotes the total variation in the dependent variable due to technical inefficiency ($\sigma^2 u$) and random shocks ($\sigma^2 v$) together. The gamma (γ) parameter explains the impact of inefficiency on output. The maximum likelihood estimation (MLE) of equation (1) provides consistent estimators for β, γ and σ_s^2 parameter. Aigner et al. (1977) expressed the likelihood function in terms of the two variance parameters, $\sigma_s^2 = \sigma_u^2 + \sigma_v^2$ and $\gamma = \sigma_u / \sigma_v$. Battese and Coelli (1977) suggested that the parameter, $\gamma = \sigma_u^2 / \sigma_s^2$, be used because it has a value between 0 and 1. This property permits to obtain a suitable starting value for an iterative maximization process, Whereas the γ parameters could be any non – negative value. A value of γ closer to zero implies that much of the variation of the observed output from frontier output is due to random stochastic effects, whereas a value of γ closer to one implies proportion of the random variation in output explained by inefficiency effects or differences in technical efficiency.

The function determining the technical inefficiency effect is defined in its general form as a linear function of socio economic and management factors:

$$U_i = F(Z_i) \text{-----}(4)$$

The more detail about dependent and independent variables is given in empirical model.

According to Aigner et al, 1977, as cited by Ahmadu and Erhabor (2012), technical efficiency of the farmer is expressed below

$$TE = Y_i / Y_i^* \text{-----}(5)$$

Where, TE_i = technical efficiency of the ith farmer

Y_i = observed output of the ith farmer (tk)

Y_i^* = Potential output (tk)

This is technical efficiency (TE) which is defined as the ratio observed output to maximum feasible output which is called frontier output. When TE=1, it shows that a farmer obtains maximum feasible output, while if TE<1 means a shortfall of the observed output to the frontier output.

5.5 Selection of the Form of Production Function

Review of literature revealed that stochastic frontier production functions of Cobb-Douglas (CD) and translog (trans log) specifications of stochastic frontier production model is most commonly used in analyzing technical efficiency in crop sector. It is generally recommended that for technical efficiency analysis approaches in which more general model specification and assumptions are made should be used. (Battese and Broca, 1997). Few researchers have reported that choice of functional form does not affect mean technical efficiency levels and frequency distribution of the farmers into different ranges of scores; however, few other have depicted the opposite i.e. choice of functional form affects much the mean efficiency levels and frequency distributions of the farmers into different score ranges. Keeping all this in view, generalized likelihood ratio test was used to choose the form of the production function.

5.6 Model Specification and Estimation:

The technical efficiency of Pabda farmers was estimated using the stochastic frontier production function proposed by Aigner et al. (1977) and Meeusen and Van den Brock (1977). The general form of the stochastic frontier function is

$$\ln(Y_i) = \alpha_0 + \alpha_k \sum \ln X_{ki} + v_i - \mu_i \dots \dots \dots (2)$$

Where Y_i is per m^2 Pabda yield (kg) for the ith farmer X_{ki} s indicate input, variables used by the ith farmer. The α_0 and α_k are unknown parameters to be estimated, v_i is usual error term which may

result due to errors in the production of wheat, weather conditions, economic adversities or plain luck, or the aggregate effect of input variables not included in the production function. ε_i are assumed to be independent and identically distributed $N(0, \sigma_v^2)$ random variables. While, μ_i is non-negative (one-sided) error term that captures inefficiency, such as faults in management. For the inefficient farmer, the actual yield is less than (or equal to) the potential yield. Therefore, the ratio of actual and potential yield can be treated as a measure of technical efficiency. Using equation (2), technical efficiency (TE) of the i -th farm is derived as:

$$TE_i = e^{-\mu_i} = Y_i / Y_i^* \dots \dots \dots (3)$$

Where Y_i^* is the maximum possible yield and Y_i is the actual yield obtained by i -th farmer. To study the effect of socioeconomic factors on inefficiency, it was observed that it is better done in a single-step rather than in two-step procedures (Wilson and Hadley, 1998; Battese and Coelli, 1995). The error term associated with technical inefficiency of Pabda production of Pabda farmers is assumed to be independently distributed, such that the technical inefficiency effect for the i -th farmer; and is obtained by truncation (at zero) of the normal distribution with mean μ_i and variance σ_v^2 such

that:

$$\mu_i = \delta_0 + \delta_m \sum I_{mi} + \omega_i \dots \dots \dots 4$$

where I_{mi} are socioeconomic characteristics of the farmers. The δ s are unknown parameters to be estimated, and ω_i are unobservable random variables which are assumed to be independently distributed, obtained by truncation of the normal distribution with zero mean and constant variance (σ^2) Review of literature revealed that stochastic frontier production functions of CD and translog specifications of stochastic frontier production model is most commonly used in analyzing technical efficiency in crop sector. The CD form has advantage over the translog specification, as inclusion of square and interaction terms of the input variables in the production model results into multicollinearity problem, especially when the sample size is comparatively small. Furthermore, Cobb-Douglas functional form is preferred for the data about developing countries and there are many studies by different researchers relating to developing world in which CD form of production function was used to analyze

technical efficiency of crop farms viz. Ajibefin et al. (2002), Joshua (2005), Ogundari and Ojo (2007) etc. and in wheat technical efficiency studies international level viz. Croppenstedt, (2005), Ghaderzadeh and Rahimi (2008), Kamruzzaman and Islam (2008), Hasan and Islam (2010) and Kaur et al. (2010) etc., and in Pakistan viz. Ahmad et al. (2002), Hassan (2004), Abbass (2005) etc. Cobb-Douglas is a restricted form of production function i.e. rate of technical substitution (RTS) in inputs is fixed, with elasticity of substitution equal to one. However, this form of production function is easy to estimate and describe. While, trans log form is a flexible form of the production function and does not assume fixed RTS in inputs. However, it is sometimes difficult to estimate and interpret and ratios could be misleading on account of multicollinearity, arising due to inclusion of second order terms. If this is the case, the consideration of these individual t-ratios may lead to omission of some important coefficients, resulting in misspecification of the model (Coelli, 1996a). Generally, to obtain a simple and valid solution production elasticities of input variables are derived at sample means ($x^* = x_i - \bar{x}$) As, irrigation variable has been omitted for the rain-fed zone; thus, empirical models under CD specification is given separately in equations 5 and 7 for irrigated and rain-fed zones, respectively; and corresponding models under trans log specification are given in equation 6 and 8, respectively

$$\ln Y_i = \alpha_0 + \alpha_k \sum_{k=1}^5 \ln x_i + v_i + \mu_i \dots \dots \dots 5$$

$$\ln Y_i = \alpha_0 + \frac{1}{2} \sum_{i=1}^5 \sum_{j=1}^5 \alpha_{ij} (\ln x_i)(\ln x_j) + v_i - \mu_i \dots \dots \dots (6)$$

$$\ln Y_i = \alpha_0 + \alpha_k \sum_{k=1}^4 \ln x_i + v_i - \mu_i \dots \dots \dots (7)$$

$$\ln Y_i = \alpha_0 + \frac{1}{2} \sum_{i=1}^4 \sum_{j=1}^4 \alpha_{ij} (\ln x_i)(\ln x_j) + v_i - \mu_i \dots \dots (8)$$

The form of inefficiency model used for the study is as under

$$\mu_i = \delta_0 + \delta_m \sum_{k=1}^5 \ln I_{mi} + \sum_{d=1}^2 D_{ji} + \omega_i \dots \dots (9)$$

where,

I_{mi} = Socioeconomic characteristics of the i-th farmer.

D_{ji} = Dummy variables for farmer characteristics of the i-th farmer.

5.7 Choice of the Variables:

Choice of variables both for stochastic frontier production and technical inefficiency effect models has been made after extensive review of the past studies in general and recent studies of wheat crop in particular to make the findings of this study comparable with that of the earlier research. Variable used in the production function about total fertilizer nutrients applied per hectare has been developed keeping in view nutrients facts about fertilizers as given in Table 5. Labor variable was not included in the production model for some genuine reasons. One of these is highly mechanized crop farming in the country in general and study area in particular. Aurangzeb et al. (2007) reported that farm mechanization has reduced the labour requirements for wheat crop production over three times than traditional farming in Khyber Pakhtunkhwa province, which use machinery only for threshing purpose. Second reason for exclusion of labour use variable is non-intensive labour requirement nature of the wheat crop. Seed broadcasting, bund making, irrigation application, water course cleaning, fertilizer/ weedicide transportation and application, harvesting and threshing are operations which require human labour for the wheat crop production. About twenty-six and an half labour mandays are used in production of one hectare of wheat crop in Punjab province. Out of these, only about five and a half labour mandays are required for pre-harvest operations, and remaining twenty-one labour mandays are required for harvest and post-harvest operations. Thus, labour requirement for pre-harvest crop production operations is just 20.8 percent of the total labour requirement for the whole crop season (GOP, 2012b). Final reason of exclusion of labour use variable from the production function is somewhat ambiguous contribution of labour to wheat crop production i.e. there is disguised unemployment in this sector as reported by Anwar et al. (2004). Due to these reasons, many researchers excluded labour use variable from the production function in their studies about agricultural productivity, wheat crop and even rice crop technical efficiency analyses in the country viz. Ahmad and Qureshi (1999), Ahmad et al. (1999) and Ahmad et al. (2002), respectively. However, Hassan (2004) tried to solve the issue by using number of fulltime family members and permanent hired labour available on the farm as a proxy for labour use in wheat production, but it is thought that this not a good solution, as availability of labour and its use are two different things. Moreover, he found that availability of family and permanent hired labour was not a significant factor for wheat crop production. As far as crop farming is concerned, review of crop sector studies from the globe as well as

Pakistan revealed that labour contribute positively to crop production. However, review of both international and local literature of wheat crop showed that labour use may have a positive or negative impact the wheat crop production. Therefore, to keep the model simple and make the findings more reliable labour use was not considered in the production function in the technical inefficiency model, a dummy variable about incidence of technical and financial problems was incorporated. In the variable, farmers who were indebted to any financial institution, commission agents or NGO were considered as they were facing financial stress. Late sowing of crop, infestation of crop with weeds at maturity in spite of use of weedicides or otherwise, water shortage/missed irrigation at critical crop stage, were considered as technical problems. Another variable about percentage of wheat area as of total operational farm size in winter (Rabi) season has been added to see the impact of area allocation to the wheat crop at the farms on the technical efficiency of the farmers.

5.8 Stochastic Frontier Production Model

The linear and Cobb-Douglas forms are first order flexible i.e. they have enough parameters to provide first order differential approximation to an arbitrary function at a single point. Though second order flexible functional forms are preferred over first order forms however, estimation of more parameters may give rise to econometric difficulties (e.g. multicollinearity). Linearity in parameters makes a function amenable to estimate by using the linear regression techniques. Taking the logarithms of both sides of linear and Cobb-Douglas functional forms yields linearity in parameters. Most of functional forms including Cobb-Douglas function by-default satisfy the economic regularity properties (non-negativity, weak essentiality, monotonicity, concavity in inputs). Moreover, Cobb-Douglas function also fulfills the principle of parsimony (Coelli et al., 2005). Stochastic frontier production function assuming a Cobb-Douglas form for irrigated zones have been given in equation 10.

The stochastic frontier function used by Onu et al. (2000) and Parikh and Shah (1995) as derived from the error model of Aigner, Lovell and Schmidt (1977) was employed to achieve objectives iii and iv of this study. The Cobb-Douglas production function was fitted to the frontier model of catfish production. The result was estimated using the maximum likelihood method. The stochastic frontier production function is written as

$$Y_i = f(X; \beta) + e_i \dots\dots\dots (10)$$

$$e_i = v_i - \mu_i \dots\dots\dots (11)$$

Where,

Y_i = output of the i-th farm

X_i = vector of inputs used by the i-th farm

β = A vector of the Parameters estimated.

e_i = composite error term

U_i = Random error outside farmers control

μ_i = Technical inefficiency effect

The empirical stochastic frontier model that was employed is specified as follows:

$$\ln Y_i = \beta_0 + \beta_1 \ln(x_1) + \beta_2 \ln(x_2) + \beta_3 \ln(x_3) + \beta_4 \ln(x_4) + \beta_5 \ln(x_5) + \beta_6 \ln(x_6) + \beta_7 \ln(x_7) + v_i - \mu_i \dots\dots\dots (10)$$

Where;

Subscripts ij refer to the j-th observation of i-th farmer;

ln = logarithm to base e,

Y = output of pabda catfish(kg)

β_0 = constant

$\beta_1 - \beta_7$ = Parameter estimated

x_1 = Fingerlings(number)

x_2 = Fish feed (tk)

x_3 = Labor (tk)

$x_4 = \text{Drugs (tk)}$

$x_5 = \text{Pond size (m}^2\text{)}$

$x_6 = \text{Lime(tk)}$

$x_7 = \text{Salt(tk)}$

$U_i = \text{Random noise (white noise)}$

$\mu_i = \text{Inefficiency effect which are non-negative with half normal distribution. It is assumed that inefficiency effects are independently distributed and } \mu_i \text{ arises by truncation (at zero) of the normal distribution with mean } \mu_i \text{ and variance } \delta U^2, \text{ where } \mu_i \text{ is specified as;}$

$$\mu_i = \delta_0 + \delta_1 \ln z_{1i} + \delta_2 \ln z_{2i} + \delta_3 \ln z_{3i} + \delta_4 \ln z_{4i} + \varepsilon_i$$

$\mu_i = \text{Inefficiency effect of pabda catfish production}$

$\delta_0 = \text{constant}$

$\delta_1 - \delta_4 = \text{Parameters to be estimated}$

$z_1 = \text{Farmer's age (years)}$

$z_2 = \text{Household size of farmer (number)}$

$z_3 = \text{Years of formal education of the farmer (years)}$

$z_4 = \text{Years of farming experience of the farmer in Pabda catfish production (years)}$

$\varepsilon_i = \text{random disturbance term}$

The technical efficiency of an individual farm is defined in terms of the observed output (Y_i) to the corresponding frontier output (Y_i^*) given available technology, that is:

$$TE = Y_i/Y_i^* = f(x_i; \beta_i) \exp(v_i - \mu_i) / f(x_i; \beta_i) \exp(v_i)$$

$$TE_i = \exp(-\mu_i)$$

So that, $0 \leq TE \leq 1$. If $TE = 1$, the farm is said to be technically efficient and its output is on the frontier. Otherwise, that is, if $TE < 1$, the farm is technically inefficient because it could have produced more outputs with the given level of inputs irrespective of input prices.

The estimates for all the parameters of the stochastic frontier production function and the inefficiency model were simultaneously obtained using the computer programme Frontier 4.1 (Coelli, 1994).

The cost frontier for catfish farms is specified as:

$$\ln(c_{i/R_i}) = \beta_0 + \beta_1 \ln(Y_i) + \beta_2 \ln\left(\frac{W_i}{R_i}\right)$$

C_i = cost of the i-th farm

R_i = labor price

Y_i = output of the farm

W_i = capital price

β = is a vector of unknown parameters

V_i = is a vector of random variables which are assumed to be normally distributed with zero mean and constant variance and are independent of U_i which are non-negative random variables and are assumed to account for the cost of inefficiency in production. It defines how far the farm operates above the cost frontier. They are assumed to be normally distributed with zero mean and constant variance. The estimates of the stochastic cost function were also obtained using the FRONTIER 4.1 software

5.9 Explanation of the variables used in the Model

Definition of the variables used in the empirical model are presented in the below:

Fingerlings cost per bigha (X_1)

Efficient output and farm's high profitability largely depends on the quality fingerlings. Fingerlings is an important factor for Pabda production. Farmer in the study area, use mainly purchased fingerlings from the local market for the production Pabda. In the calculation of

fingerlings cost per bigha, the present study applies the following strategy: its amount is multiplied by their respective price to compute fingerlings cost per bigha.

Feed cost per Fingerlings (X_2)

Feed is another important factor for the production of Pabda. Mainly three types of feed that farmer purchased from the local market. In the calculation of feed cost per fingerlings. its amount multiplied by their respective price to compute feed cost.

Pond size (X_3)

Pond is the first factor for the production of Pabda. Farmer can achieve from inheritance or purchased on the other hand many farmers rent pond to produced Pabda. It has preparation cost. And production it depends on the size of pond.

Drug cost per bigha (X_4)

The respondents of the study area use both liquid and solid medication for obtaining higher production from the Pabda. These sample farmers in the study area purchase medication amount with their respective market prices.

Lime cost per bigha (X_5)

The respondents of the study area use both liquid lime for obtaining higher production from the Pabda. These sample farmers in the study area purchase lime. amount with their respective market prices. And it uses after three months in culture time.

Salt cost per bigha (X_6)

The respondents of the study area use both liquid salt for obtaining higher production from the Pabda. These sample farmers in the study area purchase salt. amount with their respective market prices. And it uses after three months in culture time.

Labor cost (X_7)

Labor hours include labor for feeding, pond preparation spreading medication and catch fish is not include because separate variable exists for these operations. Moreover, labor for harvesting is also not included because harvesting labor is not affecting the output. Labor

cost includes the total cost incurred by both family and hired labor employed in the production of Pabda in this study area.

5.10 Variables used in Estimation of the inefficiency effect model

There is no proper guideline in the literature as to which variables are to be included in the stochastic frontier production function and which in the technical inefficiency effects model. Coelli and Battese (1996) included land variable, among others, in the production function and pond size, among other, in the technical inefficiency effects model, Parikh and Shah (1994) and Parikh et al. (1995) included off- farm work, farm assets, nonfarm assets and credit in the technical inefficiency effects model. On the basis of this literature we include in the technical inefficiency effects model socioeconomic, infrastructure and environmental degradation variables which have not traditionally been included as input variables in the production function. It is also mentioned in different literature that there are some important factors that affect the technical inefficiency of Pabda farms in the study area. In order to identify those factors, the inefficiency effect model uses in the following variables which are shown in table

table 5.2: variable used in Estimation of the inefficiency effect model:

variables	Unit of Measurement
Age	Age in the farmer calculated in years
Education level	Formal education of the farmer measured in the year schooling
Experience	Length of growing Pabda activity by the framer measured in the number of years
Household size	Number of family members

5.11 Description Statistics

The descriptive statistics is a technique that is commonly used for the maximum, minimum, sum and average, percentage of costs, gross returns, net returns and profitability of Pabda growing farmers and stochastic frontier production function. It is also used for analyzing socioeconomic conditions and problems faced by Pabda growers.

5.12 Presentation of Result

Findings and estimated result of this study is presented in various ways. The descriptive statistics of the collected data are presented in both graphical and tabular forms. The estimation result has presented in Tabular form and appropriate explanations of the estimated coefficients are also given.

CHAPTER SIX

Socioeconomic characteristics of the sample farmer

6.1 Introduction

The socioeconomic characteristics of the selected farmers were not identical rather there was a wide variation in their socioeconomic position. The aim of this chapter is to present a brief description of the socioeconomic characteristics of the farmers producing Pabda. Socioeconomic aspects of the farmers can be looked upon from different points of view depending upon a number of variables related to their level of living, the socioeconomic environment in which they live and the nature and the extent of the farmers participation in national development activities. It was not possible to collect all the information regarding the socioeconomic characteristics of the sample farmers due to limitation of time and resources. Socioeconomic characteristics of the farmers affect their production pattern. The decision-making behavior is also determined to a large extent by it. It affects the adoption of innovations. The socioeconomic characteristics of the sample farmers considered in the study were composition of family size and age group, level of education, occupational status and land ownership pattern.

6.2 Distribution of the respondents in sample area

It was not possible to include all of the respondents and to collect the necessary information of the present study from the sample areas because of inadequate fund and time. For this reason, the author includes only 60 respondents or sample farmer that best represent the population of which 60 Pabda farmer from the six unions of the three upazilas, namely Atgharia, Chatmohar, and Bhangura under Pabna district. Distribution of the respondents in the study area are

Table 6.1: Distribution of the respondent in sample area

District	Upazila	Union		Respondents of Pabda farmers
Pabna	Atgharia	Debottar	10	20
		Majhpara	10	
	Chatmohar	Haripur	10	20
		Mulgram	10	
	Bhangura	Dil pasar	10	20
		Bhangura	10	
Total				= 60

Source: Field survey 2019

6.3 Distribution of the Respondent according to age group

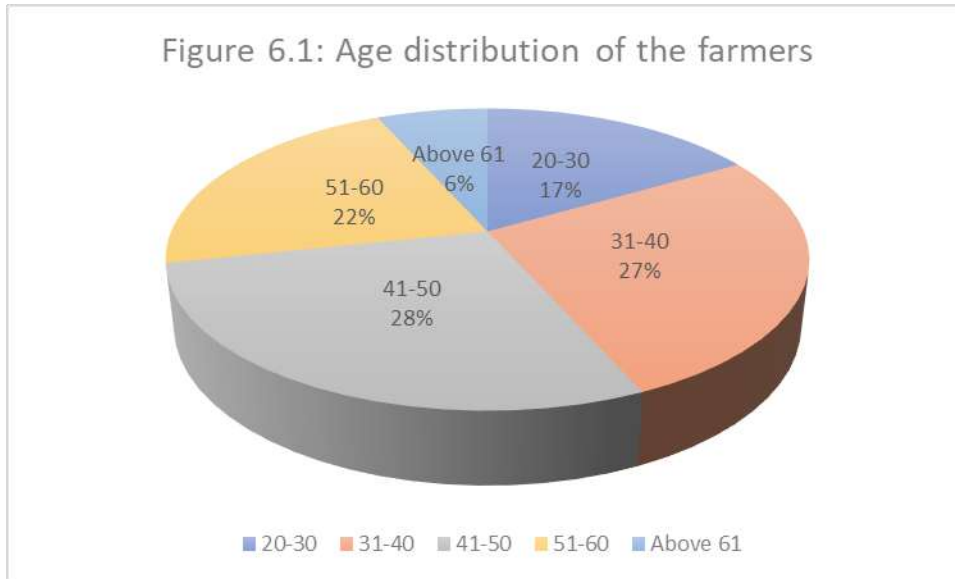
In the present study, all categories of Pabda grower in the study area were classified into different age group such as 20 to 30, 31 to 40 years, and 41 to 50 years, 51 to 60 years and above. The family members include wife, sons, unmarried daughter, parents, etc

Table: 6.2 Distribution of the sample farmer according to age group

Age group of the sample farmer (years)	Pabda farmers	
	Num of farmers	% of total
20-30	10	17
31-40	16	27
41-50	17	28
51-60	13	22
Above 61	4	6
Total	60	100

Source: field survey 2019

Table 6.2 reveals that out of the total Pabda grower about 16.7 percent of the Pabda farmers fell into the 20 to 30 years of the group, 26.7 percent fell into 31 to 40 years. 28.3 percent belongs to the age of group of 41 to 50 years, 21.7 percent fell into 51 to 60 years and 6.6 percent fell into above 60 years.



It appears from the figure 6.1 and table 6.2 that its obvious majority of the respondents in the study area are within 41-50 age group.

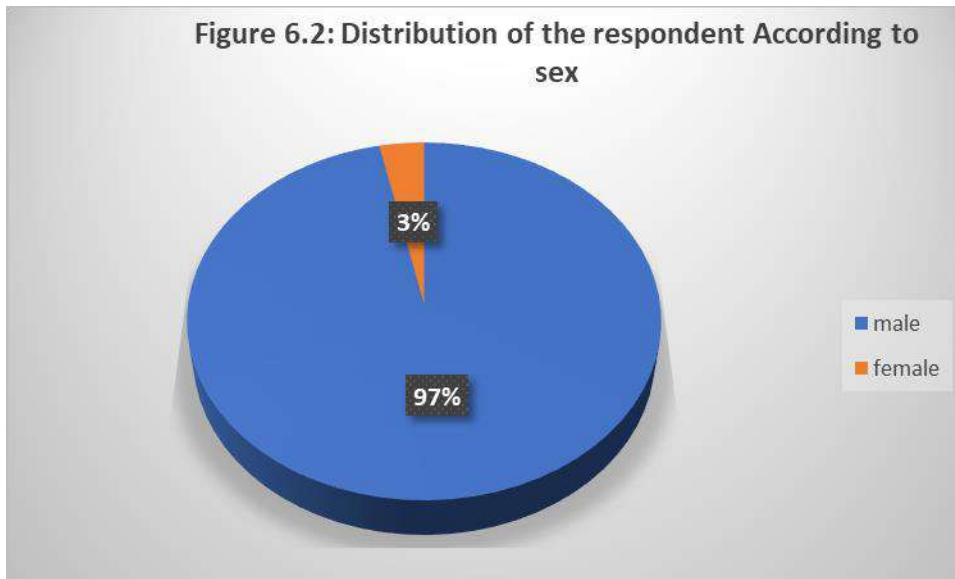
6.4 Distribution of the respondent according to sex

Aquaculture activities are mostly outdoor activities and in majority of the cases male member of the farmers family mainly engaged in these activities in the study area. So, due to more appropriate data collection and to get exact information males were often more involved rather than female. So, sex may be a crucial factor to determine whether respondent may be male or female.

However, the distribution of the respondent according to sex is represent in Table 6.3

Sex	Total Framers	
	Frequency	% of total
Male	58	97
Female	2	3
Total	60	100

From the collected data as shown in above table 6.3, it is found that 96.67 percent and 3.33 percent of the respondent were male and female, respectively. Tis result are shown in the following figure



6.5 Marital status of the Respondent

Married person is more likely to be active to the economic activities. Marital status of the respondent is an important factor that affects economic activities. Female are always less involved in economic activities while males are best fit.

Considering the marital status of the respondent, shown in Table 6.4

Sex	Total Farmers	
	Frequency	% of total
Married	53	88
Unmarried	6	10
Widow/widower	1	2
Total	60	100

Source: field survey,2019

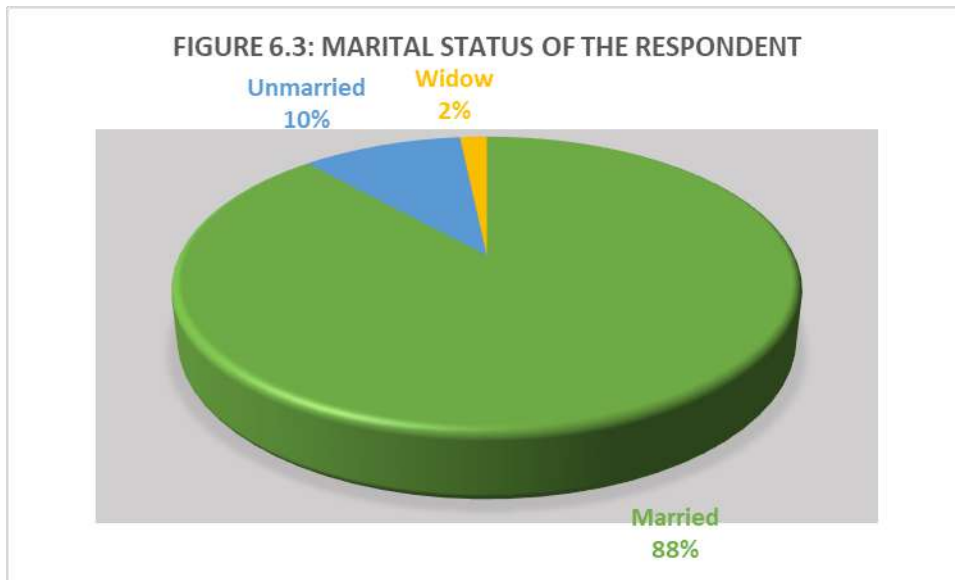


Table 6.4: it is found that 88 percent of the respondent were married while 2 percent in widow categories separately and 10 percent were unmarried.

6.6 Distribution of the Farmer According to Family size

In this study, Family size (members) has been define as total number of persons living together and taking meals from the same kitchen under the administration of the same head of the family. Family is a social institution where children, adult and economically active members are live together to get benefits from each other. The size of the family includes himself, his wife, sons, unmarried daughter, father, mother, unmarried brothers and sisters. Family size plays an important role in the economic and social life farmers. It has diversified effect on the

socioeconomic level of the farmers. A large family must have more labor to earn through different types of activities. On the hand large families require higher expenditure to fulfill the daily needs of the family members. For better understanding the present study, classified the whole respondent into broad family size based on family member viz, 2-5-member, 6-8 member and above 9 and above member. However, distribution of the respondents based on family size is shown in table 6.5

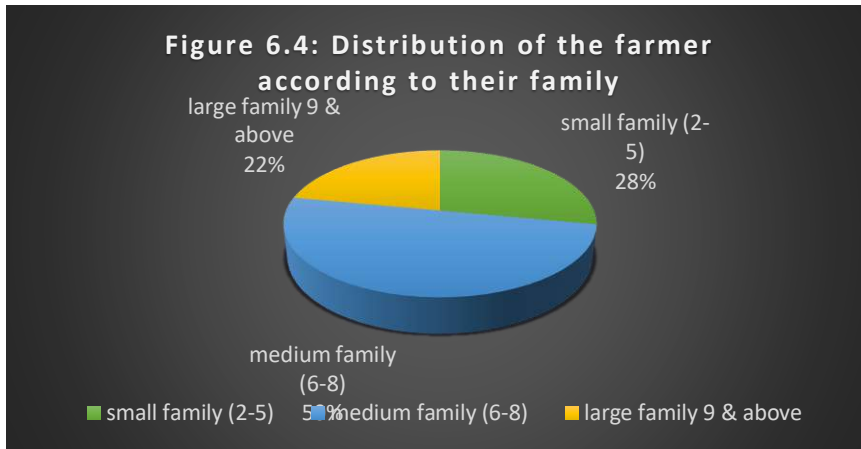
Table 6.5: Distribution of the Farmer according to Family size and composition

Number of family size	Pabda fish farmer	
	Frequency	% of total
Small family (2-5)	17	28
Medium family (6-8)	30	50
Large family (9 & above)	13	22
Total	60	100

Source: field survey 2019

Table 6.5 shows that, about 28 percent families of Pabda grower of the study area consisted 2-5 members, 50 percent respondent reported themselves that, they have 6-8 family members while respondent who had more 8 family members were 22 percent.

This is explained in following figure 6.4



From the above figure 6.4 it is clear that the majority of the respondent of both Pabda in the study area belongs to small family size category having 2-5 members.

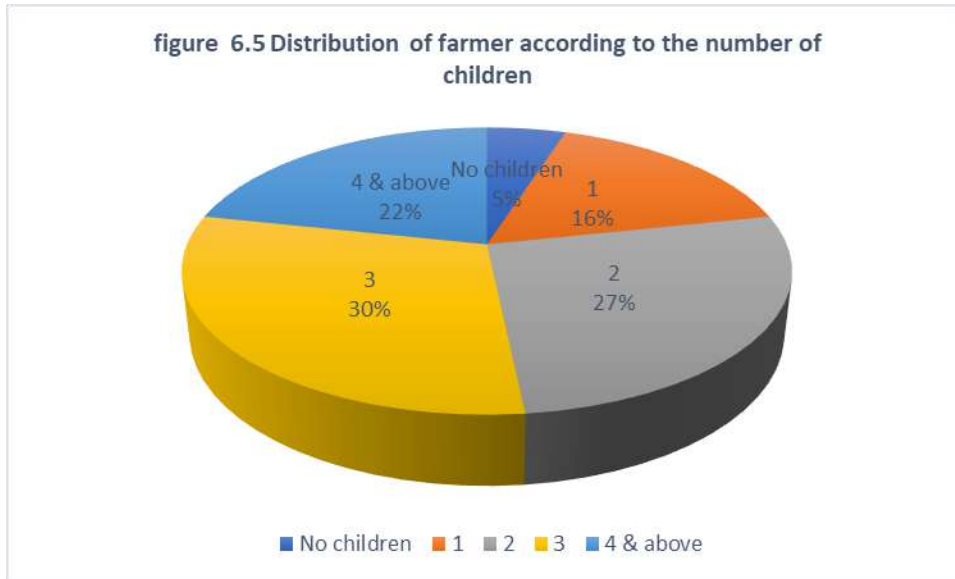
6.7 Distribution of the Farmer according to the Number of children

It is found that most of the Pabda farmers have three and four children. However, some families have 3 or four children also. In 5 cases we found that, the respondents have no children

Number of children	Pabda fish farmer	
	Frequency	% of total
No children	3	5
1	10	16
2	16	27
3	18	30
4 & above	13	22
Total	60	100

Source: Field survey, 2019

Table 6.6 shows that 5 percent respondent families among the Pabda farmers have only one child while 16 percent families have two children. It is also found that 30 percent, 22 percent families have 3, 4 & above more children, respectively. Whereas majority of the Pabda farmer have two children.



6.8 Educational status of the Farmers

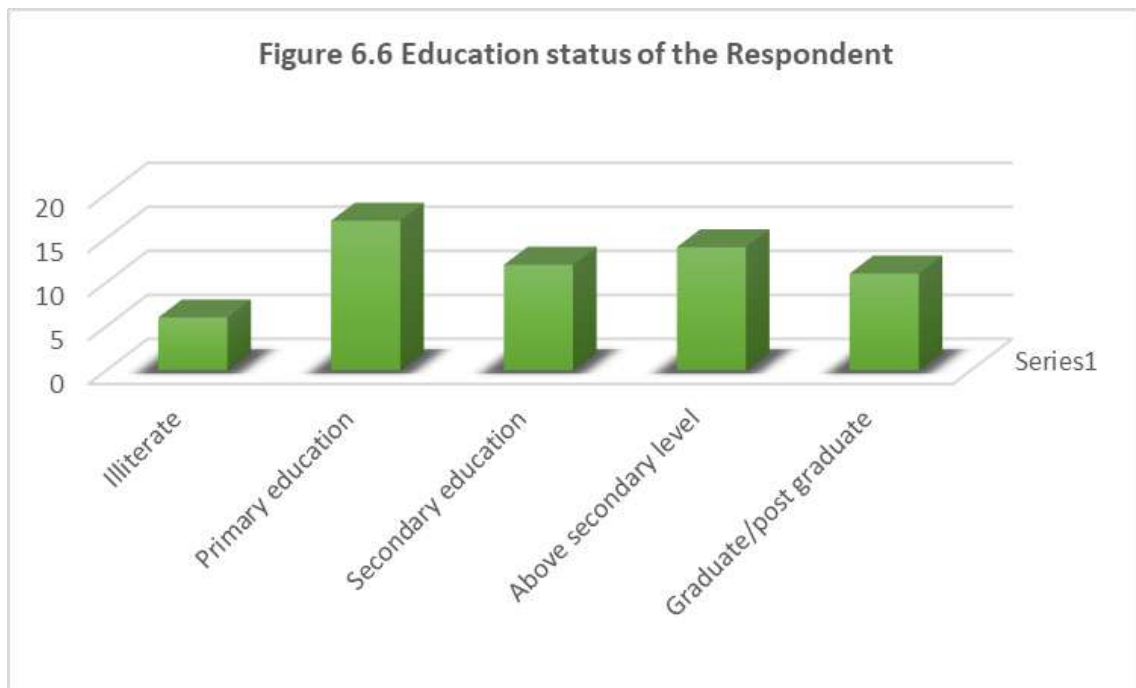
Education is defined as the ability of an individual aged above 7 years to read and write or formal education received up to certain standard. The government and various organization placed greater emphasis and extended special facilities for increasing the literacy rate in the study area. Education helps a person to have day to day information about the modern techniques, production costs and also production skills. To examine the educational status of Pabda growing farmers, the educational status of the sample farmers was divided into four categories. These were (1) illiterate, (2) primary level class (1-5), (3) secondary level class (6-10) or SSC, (4) above secondary level of education (HSC) (5) and graduate/post graduate. Those who cannot put signature, read and write were considered as illiterate

Table 6.7 display the education levels of the Pabda farmers.

Categories	All growers	
	Frequency	% of total
Illiterate	6	10
Primary education	17	29
Secondary education	12	20
Above secondary level	14	23
Graduate/post graduate	11	18
Total	60	100

Source: Field survey 2019

It is evident from Table 6.7 that 10 percent of Pabda farmers are illiterate, 29 percent had primary education, 23 percent had up to secondary education and 18 percent had graduate level



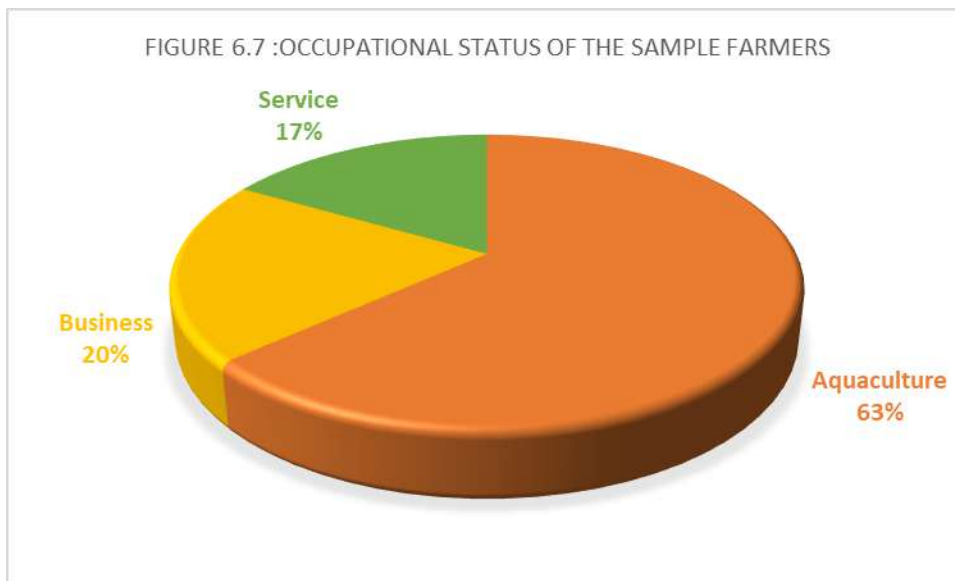
6.9 Main occupation of the respondent

Aquaculture was the main occupation and source of livelihood of the selected heads of the households in the study area. Besides Aquaculture, some farmers were engaged in petty trading and others were employed in government, semi-government or private services and other jobs.

Occupation	All growers	
	Frequency	% of Total
Aquaculture	38	63
Business	12	20
Service	10	17
Total	60	100

Source: field survey 2019

This Table 6.8 shows that in case of Pabda farmers 63 percent farmers had aquaculture, 20 percent had business, 17 percent had service as their main occupation.



Therefore, from the figure 6.7 it is outlined that aquaculture was the prime occupation of the majority of the respondent, 63 percent

6.10 Distribution of the farmers according to experience

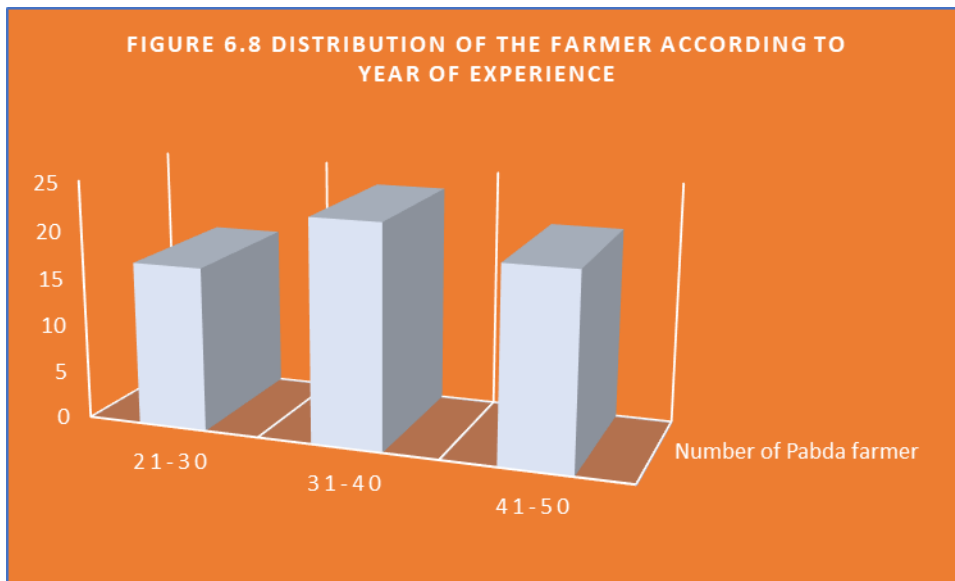
Experience is an important tool in order to operate aquaculture activities. An experienced farmer can handle easily how to till pond properly, Spread medication and lime, salt etc. than an inexperienced farmer.

Table 6.9: Distribution of the farmers according to year of experience

Years of experience	Number of Pabda farmer
21-30	17
31-40	23
41-50	20
total	60

Source: field survey 2019

Table 6.9 shows the years of experience of the Pabda farmer. It is clear from the table 6.9, that all farmers in the study area are experienced from 21-30 years. In the table most respondent have 31-40 years' experience who are related with aquaculture activities. This supposed to have positive impact on output, all things being equal



6.11 Distribution of the farmers by receiving aquaculture training

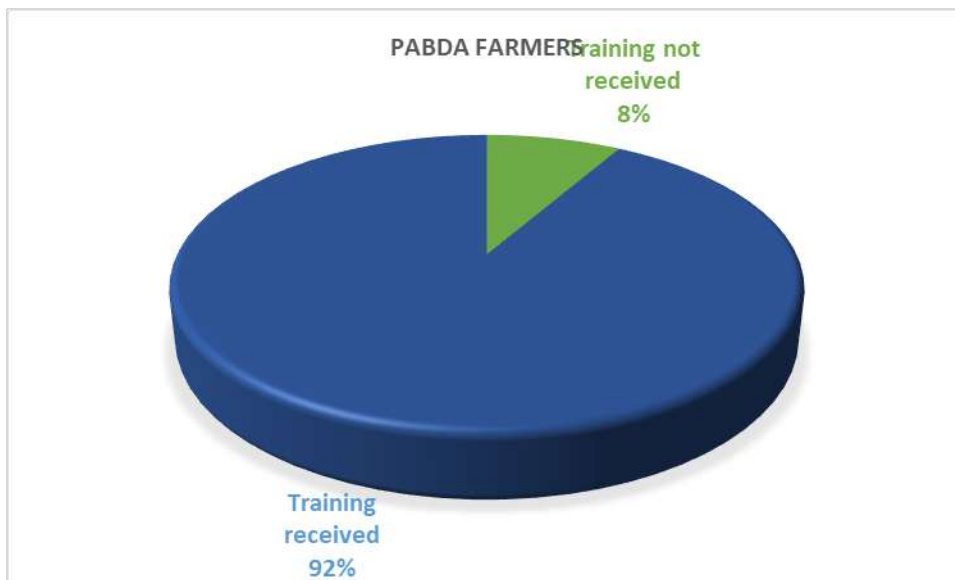
Training is the most important element for human resource development. In the other words, training is the important tool for development of skill and knowledge. It is found from the study area that, only 8 percent farmers had no aquaculture training in the study area. While 92 percent farmers had training in the study area.

Table 6.10 Distribution of the Farmers by Receiving Aquaculture Training.

Aquaculture training	Pabda farmer	
	Frequency	% of total
Training not received	5	8
Training received	95	92
total	60	100

Source: field survey 2019

Figure 6.9: Distribution of the Farmers by Receiving Aquaculture Training.



6.12 Farm Holding Size of the Respondent

Farm size is important in relation to production of adequate food grain and other necessities for the family. According to Yang (1965) “Farm size is measured by the entire pond area operated by the farm. However, farm size is the entire pond operated by the operator during the period under study whether it was owned by him as well as obtained from others by rented in or mortgaged in. It is computed by adding the area rented and mortgaged in from others and deducting the area rented and mortgaged out to and leased out to others. Therefore, farm size can be measured by using the following formula:

$$\text{Farm size} = \text{Homestead} + \text{own cultivated pond} + \text{rented in pond} + \text{mortgaged in} - (\text{rented out} + \text{mortgaged out})$$

Most farm families in the study area directly dependent on land for earning their livelihood. Farm holdings were broadly classified into following four categories as follows:

- ✚ **Marginal farmers:** The farm holding having an operated area of 0.15 to 1.49 bigha (0.05 to 0.49 acre) of land is known as marginal farm.
- ✚ **Small farmer:** The farm holding having an operated area of (1.50 bigha to 7.49 bigha (0.50 to 2.49 acre) of land is called as small farm.
- ✚ **Medium farmer:** The farm holding having an operated area of (7.50 to 22.49 bigha (2.50 to 7.49 acre) of land is termed as medium farm.
- ✚ **Large farmer:** The farmer holding having an operated area 22.50 and above (7.50 acre and above) of land is known as small farm.

Table 6.11: Farm holding size of the Respondent

Source: field survey 2019

outlined that, in the study area about 17 percent was small, 46 percent was medium and only 37 percent was large farmer.

6.13 Source of aquaculture information of the respondent

Transport and communication facilities in the study areas are well functioned and the respondents gets up to date agricultural information from various sources i. e. radio, television,

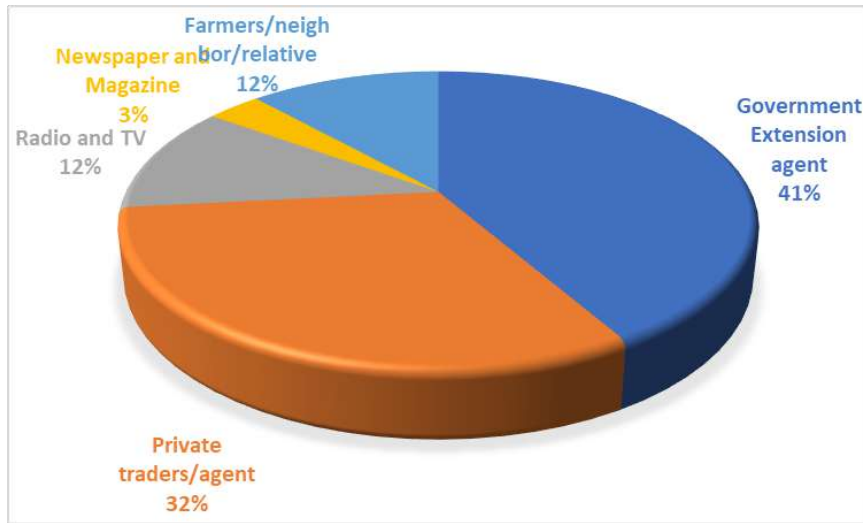
newspaper, local agricultural dealers, friend and neighbors. Therefore, the term “agricultural information”. However, the source of aquaculture information in the study area used by respondents is noted in table 6.12 From the field study it is seen that 41 percent farmer use government extension agent for collecting various aquaculture information. While 12 percent of the respondents collect aquaculture information from neighbors or other farmers or relatives. The study also revealed that 32 percent private traders/ agent in the study area.

Table 6.12: Source of aquaculture information of the Respondent.

Sources of information	All farmers	
	Frequency	% of total
Government Extension agent	25	41
Private traders/agent	19	32
Radio and TV	7	12
Newspaper and Magazine	2	3
Farmers/neighbor/relative	7	12
total	60	100

Source: field survey 2019

Figure 6.10: Source of aquaculture information of the respondent



6.14 Distribution of the farmers according to cultivation technique

In agriculture, cultivation is a technique of preparing land for sowing seeds. Cultivation in Bangladesh is mainly operated by two ways:

- 1) Traditional cultivation technique and
- 2) Mechanized cultivation technique

Cultivation operated by normal feed such as khol, wheat that is termed as traditional cultivation technique. and modern technique that is used for increasing the fish production.

6.15 Nature of problems of Pabda farmers in the study area

The Pabda farmers were faced with various types of problems with regard to their farming operations. The farmers in the study areas were facing several production and marketing problems during the study period. Some of them are cost of pond preparation is higher, middleman control on market, higher input price but lower output price: price fluctuates day by day and market to market; natural disaster (i.e., severe rain drought, flood etc.); lack of the supply of electricity in irrigation time; lack of capital; implementation problem of government policy; spread of artificial feed; unstable price of aquaculture product; marketing problem, lack of underground water and attack of many diseases. About 90 percent farmers have claimed that,

unstable price of aquaculture commodities is their major problem. Farmers in the study areas reported that they cannot get fair price of aquaculture commodities because of middleman control on market. Natural disasters are some harming their crops. Besides, Farmers cannot invest more and take proper action due to shortage of adequate fund. Another problem of Pabda fish production is diseases.

6.16 Conclusion

The objective of this chapter was to describe the socioeconomic characteristics of the present study. In this chapter, the ways by which the sample respondents are selected is described. The socioeconomic characteristics of the selected farmers were not identical rather there was a wide variation in their socioeconomic position. Socioeconomic characteristics of the farmers affect their production pattern. The decision-making behavior is also determined to a large extent by it. It affects the adoption of innovations. Thus, it is observed that the collection data have interesting feature that are presented in both tabular and graphical forms.

CHAPTER SEVEN

Discussion of the Result and Finding

7.1 Introduction

This chapter discusses the results of estimating the stochastic econometric frontier models. We focus on the estimation of technical efficiency of Pabda fish Production in Pabna district of Bangladesh using Cobb-Douglas stochastic production frontier model in a single-stage estimation procedure by maximum likelihood method (MLM), Given the specification of the technical inefficiency effects model. Technical inefficiency model as a function of socioeconomic characteristics and factors and thus this single-stage method simultaneously identifies the factors associated with technical inefficiency. We estimate the technical inefficiency effects model using both half-normal and truncated normal distributional assumptions. The collected data have been edited carefully for corrected any kind of bias and inconsistency in data so that data error is minimized. After editing the collected data, regression result is presented in tabular form comparing the coefficient values along with the significance level, the standard error and t-statistics. We also identify and quantify the factors affecting efficiency and provide some policy implications regarding the introduction of new technologies and in particular those policies which aim to increase the productivity of farmers.

7.2 Production types and technologies

From Table 7.1, 67% of the respondents were involved in grow out operations, that is, raising of Pabda catfish to table size, while 11% were involved in the sole production of fingerlings. Others combined feed production with fingerling production or grow out production. These made up 22% of the sampled farmers. Pabda Catfish farmers preferred grow out production because it is a profitable enterprise with high returns on investments. Fingerling production requires lower capital investment. However, fewer numbers of people were involved because it requires high technical knowledge and experience which these farmers did not have. There is also the issue of marketing; most fingerling producers complained of inadequate patronage for their products. This is because newcomers into the business have to build trust in the quality of the fingerlings and this takes time to accomplish

Table 7.1: Production types and technologies used by catfish farmers

Production type	Frequency	percentage
Grow out	40	67
Fingerlings	7	11
others	13	22
Production technology		
Static renewal	37	62
Flow through	15	25
Others	8	13
Culture system		
Monoculture	35	58
Polyculture	25	42
Total	60	100

Source: Field survey 2019

7.2.1 Production Technologies

Table 7.1 shows that the majority of the Pabda catfish farmers (62%) used static renewal systems (earthen ponds) while 25% used flow through systems (tanks and troughs), and 13% used a combination of both systems. The static renewal systems are cheaper to construct and are also available for hire. This makes it possible for people who cannot afford the cost of purchasing land and borehole construction to engage in Pabda catfish farming. Also, earthen ponds provide a natural environment for the growing Pabda catfish to perform well in terms of yield. Concrete tanks, on the other hand, can be constructed within living environments of the farmers where adequate supervision can be given. Others represent those who used a combination of static renewal systems and flow through systems on their farm for grow out operations. Some of them used flow through tanks for breeding operations and for raising fingerlings.

7.2.2 Culture System

Majority of the Pabda catfish farmers (58%) practiced monoculture, that is, the rearing of Pabda catfish alone without mixing it with another species of fish while 42% practiced polyculture, the rearing of Pabda catfish with another species of fish, mainly tilapia (Table 7.1)

7.3 Summary Statistics of the Variables Used in the Stochastic Frontier Model

In the present study, data on output and inputs are used to estimate farm level technical efficiency of Pabda fish production. Before estimation, some properties of data such as mean, minimum and maximum are calculated. Farm output is defined as the total market value of produced Pabda in 2018-2019 production years. Labor cost includes the total cost incurred by both family and hired labor employed in the production. Feed cost includes the cost of buying liquid and nonliquid feed. Fingerlings cost is calculated as the total cost of buying fingerlings. Pond size where production depends on the size of pond. Drug cost is calculated as the total cost of buying drug. Lime cost is calculated as the total cost of buying. And salt cost is calculated as the total salt buying cost. The measurement of variables and the summary statistics of the explanatory variables used in the stochastic frontier model are shown in table 7.2.

Table 7.2 Summary Statistics of the Variables Used in the Stochastic Frontier Model

Pabda Catfish					
Variables	Units	Max.	Min.	Mean.	Std. Deviation
Output	Taka/Bigha	970000	100000	53833.3333	216470.076
Fingerlings (Number)	Taka/Bigha	320000	75000	54134	50630.13941
Feed	Taka/Bigha	160000	10000	70516.67	39448.96
Pond (Size)	Taka/Bigha	100	13	33.34167	23.8634
Drug	Taka/Bigha	38000	10000	2916.67	5533.539
Lime	Taka/Bigha	9800	2200	598.333	2275.298
Salt	Taka/Bigha	13500	4300	844.283	2667.75
Labor	Taka/Bigha	99000	40000	69550	17537

Source: Field survey 2019

It is observed that the average farm output per bigha of Pabda is 53833.33 with SD value of 216470. There is wide variation in the yield rate across the farms and this leaves scope for further enhancing the productivity in the selected areas of Pabna district. The farmer produces an output of Pabda is 53833.33 per bigha by putting, in an average, 54134 Of fingerlings, 70516.67 of feed cost, 33.34167 of pond size. 2916.67 of drug cost, 598.33 of lime cost, 844 of salt cost, 69550 of labor cost.

7.4 Factors Determining/ Affecting Farm inefficiency

The literature indicates that a range of socio-economic and demographic factors determine the efficiency of farms (Seyoum et al., 1998; Coelli and Battese, 1996; Wilson et al., 1998). These include land use, credit availability, land tenure, and the educational level of farmer (Shapiro and Muller, 1977; Kumbhakar, 1994). Techniques of cultivation, share tenancy, farm holding size may also influence efficiency (Coelli and Battese, 1996; Kumbhakar, 1994). Some

environment factors and non-physical factors like farming experience and extension services may affect the capability of a producer to utilize the available technology efficiently (Parikh and Shah, 1995; Kumbhakar, 1994). We now consider the variables which may affect efficiency in aquaculture in Bangladesh.

There is no proper guideline in the literature as to which variables are to be included in the stochastic in the stochastic frontier production function and which in the technical inefficiency effects model. Wilson et al. (1998) included, among others, the cultivated potato area in the production function and the proportion of the cultivated potato area that is irrigated in the technical inefficiency effects model. Coelli and Battese (1996) included land variable, among others, in the production function and land size, among other, in the technical inefficiency effects model. Parikh and Shah (1994) and Parikh et al. (1995) included off-farm work, farm assets, nonfarm assets and credit in the technical inefficiency effects model. On the basis of this literature we include in the technical inefficiency effects model socioeconomic, infrastructure and environmental degradation variables which have not traditionally been included as input variables in the production.

In the context of farms within the Pabna district, the age of the farmer, the years of schooling, and plot size are considered relevant. The age of the farmer, a priori, may have a positive or negative effect or inefficiency. Farming experience can be achieved with increasing age but this may reduce inefficiency. However, some older farmers are less receptive to new technologies and practices. There is an interaction between age and education of farmers because younger farmers tend to be more educated than older farmers due to gradual improvements in the educational system in Pabna over recent years.

A priori, We expect that more years of formal education will increase efficiency because education enables farmers to acquire and process relevant information more effectively. Basic literacy enables farmers to use modern method and management and choose input combination. Farmers can be exposed to new technologies and improved techniques with education and extension services are related to the allocative efficiency of Indian farmers by Ram (1980).

Table 7.3 Technical efficiency index of the Pabda catfish producing farm in the study area

Efficiency interval	Number of farms	Percent
$0.100 < TE < 0.600$	1	1
$0.600 < TE < 0.700$	1	1
$0.700 < TE < 0.800$	11	18
$0.800 < TE < 0.900$	24	39
$0.900 < TE < 1.00$	24	39
Total	60	100
Minimum	0.10012	
Maximum	0.997703	
Average	0.854109	

Source: Author's own calculation.

The frequency distribution of the technical efficiency estimate from the stochastic frontier model is depicted in the table 7.3 given below.

Efficiency index in table 7.3 shows that the range of efficiency level varies from 0.00 to 1. The mean efficiency of Pabda catfish producing farms is 0.85. It indicates that there is still room for increasing efficiency in the production process. This implies that output of the farm can be increased by 8% under the given technology without increasing any additional inputs. In the study area about 24 percent farms are operating at efficiency level ranging from 0.90 to 1.00. However, the average level of technical efficiency of the sample farms indicates that there is a certain level of technical inefficiency in Pabda catfish production in the study area. This result suggests that in the short run it is possible to increase the amount of Pabda production in the study area by increasing the efficiency level. Farmers may increase the level of efficiency of their farms by controlling the use of inputs of production that have significant contribution to influence efficiency level of production. For this purpose, it is essential to identify the significant inputs of production which have positive or negative contribution to production. In section 7.6 significant factors of production are estimated using Cobb-Douglas production function. The table also displays that the minimum and maximum level of efficiency achieved by the sample farms are 0.100 and 0.99, respectively.

7.5 Results of the Cobb-Douglas Production Frontier for Pabda catfish production

The maximum likelihood estimates of the parameters of Cobb-Douglas frontier are estimated using frontier 4.1(Coelli, 1996). These are presented in table 7.3 for Pabda catfish production. We expect the signs of all of the coefficients are positive. We obtain positive coefficients for all seven parameters. In field level survey. We have observed some significant behavior for labor. It shows that there are already abundant supplies of labor in aquaculture sector of Bangladesh, particularly in the study area of northern part of Bangladesh. Table 7.4: Maximum-likelihood Estimates of the stochastic frontier model for Pabda catfish production.

Name of Variables	Parameters	Coefficients	Std. Error	T-ratios
Constant	β_0	7.681	0.448	7.205
Fingerlings	β_1	0.178**	0.011	2.186
Feed	β_2	0.06216**	0.136	2.037
Pond size	β_3	0.604***	0.009	6.383
Drug	β_4	0.1056	0.026	0.914
Lime	β_5	0.632	0.038	0.211
Salt	β_6	0.587*	0.026	1.907
Labor	β_7	0.102*	0.097	1.890
Inefficiency Model				
Constant	δ_0	-1.205	0.18	-1.276
Age of farmers	δ_1	-0.105***	0.018	-3.142
Year of schooling	δ_2	0.333***	0.039	3.68
experience	δ_3	-0.117***	0.0009	-3.07
Household size	δ_4	-0.277***	0.0095	-2.58
Sigma-squared	$\sigma_s^2 = \sigma_v^2 + \sigma_u^2$	0.3648	0.0004	5.4305
Gamma	$\gamma = [\sigma_u^2 \div \sigma_s^2]$	0.9999	0.397	2108.7726
Log likelihood value		36.398		
LR test one side error		91.177		
The mean efficiency		0.8541		

Source: Authors own calculation

Note: *= significance at 10%, **= significant at 5%, ***=significant at 1%

The estimates of the variance parameter σ_s^2 and the parameter of the γ are significantly different from Zero. This indicates that the inefficiency effects are significant in determining the level and variability of output of farm households in Bangladesh. This result is consistent with Sharma et al. (1997) and Coelli and Battese (1996). This shows that a conventional production function is not an adequate representation of the data.

7.6 Effects on Economic Factors on Production

From the maximum likelihood estimates of the stochastic frontier model we get the coefficients and respective t-ratio value for each of the variables. That is shown in table 7.3 These are explained in details in below:

Fingerlings (β_1)

The estimated coefficient for fingerlings was found 0.1782. That is other things remaining constant if 1% increase in fingerlings use then Pabda catfish production increase by 0.1782% and it is statistically significant at 5% level of significance.

Feed (β_2)

Estimated coefficient for feed is 0.06216 indicates that other thing being constant. If the farmers increased the feed 1% then Pabda catfish production increase by 0.06216. This means the positive relation between feed and production. It is statistically significant at 5% level of significance.

Pond Size (β_3)

Pond is an important component for Pabda catfish production. Estimated coefficient for pond size is 0.0621 indicates that other thing being constant. If the farmers increased the pond size 1% then the Pabda catfish production increase by 0.0621%. This means the positive relation between pond size and production. This is highly significant at 1% level of significance.

Drug (β_4)

To analyze coefficient for it is 0.1056 indicates positive relation with output. It is necessary for protecting the fish from disease.

Lime (β_5)

Estimated coefficient for lime is 0.632 and it shows the positive relation between the production.

Salt (β_6)

Estimated coefficient for salt is 0.587. that is other things remaining constant if 1% increase in salt use then Pabda catfish production increase by 0.587 and It is statistically significant at 10% level of significance.

Labor (β_7)

The coefficient for labor is 0.102 that means that the Pabda catfish production increased by 0.102% if the farmers used additional 1% labor in all situation of all other held constant. If the farmers use more labor then he/she can maintain all of his/her labor incentive activities properly that may help to increase the productivity. This result significantly significant at 10% level of significance in our study.

7.7 Impact of socio-economic factors on technical efficiency of Pabda catfish production

The inefficiency model was also presented jointly with efficiency in table 7.3. Some of the estimated coefficient for socio-economic factors are positive and some negative.

Age of the Farmers (δ_1)

The coefficient for age of the farmers is -0.105. The sign of the age is negative indicating that an increase in age of the farmers reduces technical inefficiency. This may be due to the fact that the higher the age level of farmer the more they become physically unfit to perform hard aquaculture work properly. It may be that the young farmer is more efficient and can use their labor in Pabda catfish production which increase farm productivity and decrease inefficiency.

Education (δ_2)

The educational attainment of the Pabda catfish farmers is expected to reduce inefficiency on the other farms. This is because it is easier for educated farmers to adopt new technology and properly prepare records in order to make informed managerial decisions. The estimated coefficient for education 0.333 was significant at 1% level. It was however positive, that the lower the level of education, the lower the level of technical efficiency of the Pabda catfish farm. Education with the positive coefficient will have a negative impact on technical efficiency.

Experience (δ_3)

The estimated coefficient -0.117 for Pabda catfish farming experience was negative and significant at the 1% level. This means that the more experienced the catfish farmers the more the output she/he is able to produce from the given inputs. His finding is similar to that reported by Kaliba and Engle (2004) that experienced catfish farmers were more efficient than new farmers.

Household size (δ_4)

The estimated coefficient -0.277 for household size was negative and significant at 1% level of significance. This implies that larger household size reduces inefficiency. This is so because large household sizes are a source of cheap labor on the farm. This agrees with the report of Ugwumba (2011) which found a negative relationship between household size and catfish farm inefficiency.

7.8 Conclusion

The chapter provides all estimated results if the present study. In case of technical efficiency significant variation is found among the farmers. The mean technical efficiency of Pabda catfish farmer in the study area is 0.85. Results of the determinants of technical inefficiency indicate that farmers “socio-economic variables should be considered as significant factors influencing inefficiency in Pabda production. Conclusion from these findings are that there is ample opportunity to increase the present level of efficiency of Pabda production in the study area.

Chapter Eight

Summary, conclusion and policy Recommendation

8.1 Introduction

Bangladesh, due to agroclimatic conditions, is one of the most suitable countries in the world for aquaculture. The demand for fish in Bangladesh is increasing rapidly because of increasing population. Aquaculture is a crucial sector for economic growth and development of Bangladesh. It provides food for the people as well as raw materials to the aquaculture-based industries that help forming capital. It is one of the largest sources of employment and income generation of the people in Bangladesh. Total population involved 11% in this sector. Bangladesh earned 2.46% foreign export earnings. And it also contributes the total agricultural GDP 22.76%. The country was ranked third in producing fish from inland water-bodies, behind China and India, according to a report of Food and Agriculture Organization (FAO). The country was the fifth on the list last year. Bangladesh is now also the fifth biggest aquaculture producer in the world, said the report titled “The State of World Fisheries and Aquaculture 2018”. In getting the third position, Bangladesh produced a total of 10,48,242 tonnes of fish from inland water bodies in 2016, about 2.4 percent higher than 2015, according to the FAO's fisheries and aquaculture report. China topped the list with 23,18,046 tonnes, while India was in second place with 14,62,063 tonnes, found the report which was made public on July 9. Myanmar and Cambodia secured fourth and fifth positions. In overall aquaculture production, Bangladesh was placed fifth by producing 22 lakh tonnes in 2016, said the report. China topped that list with a production of 4.92 crore tonnes. The report also said Bangladesh produced 1,13,200 tonnes of fish from marine and coastal sources, and ranked 11th in the list.

This study analyzes the technical efficiency of Pabda catfish farming in Pabna district of Bangladesh. It has also analyzed the key determinants of technical efficiency of Pabda production. The Cobb-Douglas stochastic frontier production function approach is applied to estimate the technical efficiency. Thus, the core point of this research is to study the technical efficiency of Pabda production in Pabna district Bangladesh.

8.2 Major Findings and Conclusion

In Bangladesh aquaculture sector has been recognized as the prominent sector of the economy and the fish sector has been regarded as the main strength of aquaculture. Sustainable development in aquaculture depends upon economic use of pond, labor, drug, lime and others factors. Again, this can be made possible through adoption of modern but appropriate technology with efficient management and cultural practices. However, the findings of this study obtained from the previous chapters are noted below.

This research starts with an introductory discussion in chapter one. In this chapter the researcher tries to find out the scope for the study in the context of Bangladesh and settled several research questions by identifying the fundamental problems related with technical efficiency of Pabda farming in Pabna district of Bangladesh. Backgrounds of the study, problem statement, rationality of the study, objectives of the study, structure of the thesis are discussed in this chapter.

Chapter two of the present study reviews the relevant literature on technical efficiency of aquaculture sector. By reviewing the literature comprehensively, it is found that there is a relationship between technical efficiency and key inputs of Pabda production. By investing the previous literature, it has become possible to portray o foundation for the undertakings of econometric techniques of the measurement of the technical efficiency. Moreover, reviewing the literature, it has become feasible to identify the gaps inherent in these studies.

In chapter three, conceptual issues related to the production function and brief descriptions of theoretical tools that are necessary for the present study are discussed. Chapter three provides definition used in production function analysis, types of production function such as Cobb-Douglas production function, and law of production, meaning of efficiency and the related concept of the measurement of the efficiency are analyzed. From this chapter it is observed that most of the researchers recommend using stochastic frontier production approach and Cobb-Douglas production function in measuring technical efficiency of Pabda production.

Chapter four mentioned the overall scenario of Pabda production in Bangladesh and Pabna district with special reference to several important issues like, role of fish in the economy of Bangladesh, current status of fish production in Bangladesh and Pabna district. Besides, fish

productivity scenario of Bangladesh and Pabna district over the past years had also been reviewed. By considering chapter four comprehensively, the first specific objective of this study has been achieved.

In chapter five, the methodology has been adopted for the present study and the data analysis has been depicted in order to measure the technical efficiency of Pabda production. This chapter also provides a description of the explanatory and dependent variables, used in the study and the relationship between them. It is difficult to conduct research on technical and efficiency of Pabda production in Pabna district due to lack of secondary data on these areas.

The result of the regression is presented and analyzed in chapter seven. In this chapter, the significant of the estimated result are also analyzed. In this chapter, it is observed that the average farm output per Pabda 53833.3333 with SD value of 216470.076. There is wide variation in the yield rate across the farms and this leaves scope for further enhancing the productivity in the selected areas of Pabna district. The farmer produces an output of Pabda is 53833.3333 per bigha by putting, in an average, 54134 of fingerlings number, 70516.67 of feed cost. 33.34167 of pond size. 2916.67 of drug cost. 598.333 of lime cost, 844.283 of salt cost, 69550 of labor cost.

From the econometrics analysis that are presented in chapter seven, it is clear that the key inputs of the production function have important contribution to the analysis of the technical efficiency of Pabda production. The chapter provides all estimated results of the present study. In case of technical efficiency significant variation is found among the farmers. The mean technical efficiency of Pabda farmer in the study area is 0.85. The main objective of this study is to estimate the level of technical efficiency and determine the factors affecting on technical inefficiency of Pabda production using Cobb-Douglas stochastic frontier approach. It is observed that the Pabda farms in the study area run their operation with less than full potentials as the mean technical efficiency of the farmers is found to be 85%. This implies that output of the farm can be increased 8% under the given technology without increasing any additional inputs. The estimation results clearly suggest that age, education, household size, experience are the crucial factors which can reduce the existing technical inefficiency in Pabda production.

Fish is the vital sector from economical, aquaculture and commercial point of view in Bangladesh. This sector has a good potential to earn a lot of foreign currencies for Bangladesh.

Because at present, people are very cautious about environment and Pabda fish is an environment friendly product. For this good number of researches are needed in this area. From this research, the policy maker will get some idea about how to improve this sector.

Based on the results, the study suggests that government should take necessary steps to increase the education level, training facilities and extension services of the farmers as well as improve the credit facility of the farmers. In general, some socio-economic factors contribute to farm level technical efficiency. Some of these have positive and some have negative impact on the level of technical efficiency of the farmers. In order to address this issue variables considered include, age of the farmer, family size, education level, farming experience. On the basis of the present study some policy suggestions and recommendation are as follows.

8.3 Policy suggestions and recommendation

The final objectives of this study were to put forward some policy suggestion towards increasing efficiency in Pabda production in Bangladesh. To this end, implications of the findings are interpreted and appropriate policies are drawn for the use of the policy makers. In the present thesis study the researcher studied the relationship between inputs cost and Pabda production. It argues that some variables impact on Pabda production significantly and some are insignificant which vary across the farmers group. The researcher has modified the Cobb-Douglas stochastic frontier production function to assess the impacts of variables such as pond feed, drug fingerlings on Pabda fish production. The study also estimates the determinants of technical inefficiency of Pabda catfish farming. Since there are opportunities to raise technical efficiency, it is important to design appropriate policies to improve technical efficiency at the farm level. Based on the findings of this research, the following recommendation are made:

1. There is need for Pabda catfish farmers to improve on the technical know-how of Pabda catfish production through seminars and workshops especially on the efficient use of resources in production of catfish.
2. The government should encourage financial institutions to give loans to active and registered Pabda fish farmers at considerable interest rates but with proper monitoring. This will help to increase farmers' production levels and profitability.

3. Pabda Catfish production has great potentials in the study area; Government should formulate policies that will create an enabling environment and attract more youths to invest in catfish production. This will create room for new ideas and increased level of productivity by the farmers towards achieving food security.
4. The Pabda catfish seed industry also needs to be standardized and regulated. Government needs to establish an agency to certify the quality of catfish seeds. This will go a long way in helping newly established hatcheries to secure market for their products as potential customers will have little fear in certified fingerlings.
5. The low and unstable price of Pabda catfish does not encourage most farmers to venture in production especially the most important cash of fish. This makes it number one constraint of Pabda production. Policy measures aimed at regulating price of Pabda are hereby recommended. Therefore, the coefficient of labor cost in the Pabda production is negatively significant in the inefficiency model that suggest, there needs a more careful study on labor employment.
6. Aquaculture credit should be more flexible and available to the farmers so that they can invest more in their field.
7. The role of the extension department needs to be strengthened in the study area which seems to be very poor in the present situation. The government should command Bangladesh fisheries institute, private companies and NGOs to develop their own hybrid fingerlings and provide them in time to the farmers as fingerlings plays a significant role on production.
8. On average Pabda catfish farmers are 85 percent technical efficient in the study area implying that little potential exists that can be explored to improve resource use efficiency in Pabda production. Therefore, in order to improve Pabda productivity in the long run, production function needs to be shifted upward with the help of new production technologies. It implies that research institute should focus for the development of high yielding and more qualitative varieties and this required more investment on research related activities.

8.4 Conclusion

The study suggests that government should take necessary steps to increase the education level, training facilities and extension services of the farmers as well as improve the credit facility of the farmer. In general, some socio-economic factors contribute to farm level technical efficiency. Some of these have positive and some have negative impact on the level of technical efficiency of the farmers. In order to address this issue variables considered include, age of the farmer, family size, education level, farming experience.

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21. cost and returns of pabda:

Variables	Per day num/amount	Per day cost	Monthly amount /num	Monthly cost	Yearly amount/num	Yearly cost
Fingerlings(num)						
Feeds(kg)						
Pond size(m2)						
Lime(kg)						
Salt(kg)						
Medication(kg)						
Area of land						
Other cost						
Fuel cost						
Transport cost						
Output of pabda						

22. What is the main source of labor? (a) Family labor (b) Hired labor

23. total water area in this firm?.....

24. water depth in this pond?.....

25. current year income?.....

26. current year production?.....

26. previous year income?.....

27. previous year production?.....

28. do you take any loan for fish farming?.....

29. if yes. Amount?.....

30. do you use any modern technology in fish farming?.....

31. what are the source of your fingerlings? () private () otherwise

32. do you take any training for fish farming? () yes () no

33. do you involve any member of farmer group? () yes () no

35. Would you say, your life has improved since you started your Pabda catfish farm? Please state reasons: I have been able to take care of my family's finances () I can employ people on my catfish farm () Our health has improved () We are no longer worried about food insecurity () Nothing has changed () I have not benefitted from catfish farming ()

36. How do you consider the future of catfish farming? Will decline () Is sustainable () Will grow ()

Module-3

(Constraints)

37. What are the extents of some of the challenges you face as a catfish farmer? (Please tick)

issue	Not a problem	Minor problem	Some problem	Major problem
Lack of finance				
Acquiring land on which to farm				
Farming inputs (water, fingerlings, equipment and machinery)				
Technical support from government/local authorities				
Pollution				
Environmental/Climate change				