ECONOMIC ANALYSIS OF JHORA FISHERIES IN WEST BENGAL

Dissertation submitted in partial fulfillment
of the requirements
for the degree of

M. F. Sc. (Fisheries Economics)

By

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AUGUST, 2020

Abhilash Thapa., (2020). Economic Analysis of Jhora Fisheries in West Bengal. M.F.Sc. Dissertation, I.C.A.R-Central Institute of Fisheries Education (University established Under Sec 3 of UGC Act 1956), Panch Marg, Off Yari Road, Versova, Mumbai- 400061.

Dedicated to my dearest

APPA & AMMA

FAMILY, FRIENDS

&

my GUIDE

Dated: 30th August, 2020

CERTIFICATE

Certified that the dissertation entitled "**ECONOMIC ANALYSIS OF JHORA FISHERIES IN WEST BENGAL**" is a bonafide record of independent research work carried out by **MR. ABHILASH THAPA** during the period of study from August, 2019 to August, 2020 under our supervision and guidance for the degree of **Master of Fisheries Science (Fisheries Economics)** and that the dissertation has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or any other similar title.

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I hereby declare that the dissertation entitled **"Economic Analysis of Jhora Fisheries in West Bengal"** is an authentic record of the work done by me and that no part thereof has been presented for the award of any degree, diploma, associateship, fellowship or any other similar title.

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ACKNOWLEDGEMENTS

First and above all, I praise the almighty ***Devi Dewta,*** *for providing me this opportunity and granting me the capability to proceed successfully.*

I want to express my deepest gratitude to my major advisor ***Dr. Rama Sharma****, Senior Scientist, Associate Dean (Academics), CIFE, Mumbai, for her generosity, care, continuous support, excellent advice and belief in my master`s study and research. Her valuable guidance helped me a lot in all the time of framing, analysing the research and especially in thesis writing. I could not have imagined having completed my master's study successfully without her and no words can describe my heartfelt thanks to her.*

I want to express my sincere thanks to ***Dr. Arpita Sharma,*** *member of my advisory committee, for her never-ending suggestions, beautiful corrections and encouragement, which holds an immense contribution to this study.*

I express my heartfelt thanks to ***Shri R. F. Lepcha,*** *member of my advisory committee, for his valuable suggestions, support, considerate assistance and help during the data collection.*

I am grateful to ***Dr. Gopal Krishna,*** *our respectful director, for providing me with the opportunity to do my research work in this prestigious institution.*

I would also like to thank ***Dr. S. N. Ojha,*** *our head of the department, whose friendly support and motivations have always been a boon for me.*

I thank ***Dr. P. S. Ananthan****,* ***Dr. Shivaji D. Argade****,* ***Dr. Neha Qureshi****,* ***Dr. Vinod Kumar Yadav, Dr. Swadesh Prakash*** *and* ***Dr. S.K. Pandey****, Faculty, FEESD, for their co-operation, kind support, timely help and advice during the course work as well as research.*

I am incredibly thankful to ***Dr. Anuja A. R****. and* ***Dr. Kanchan Sinha*** *for their help during my data analysis.*

I am thankful to all the hardworking Fisheries Extension Officers, especially ***Mr. Sarthak Pradhan, Mrs. Barnika Gurung, Mrs. Nelishma Gurung, Mrs. Pratistha Yonzone, Mrs. Sharda Saha, Mr. Sandip Roy, Mrs. Megha Bhutia, Mr. Ankit Sharma****, AFO* ***Mr. Sonam Bhutia*** *and technical staff* ***Mr. Prem Gurung*** *for the sincere help and support during the study.*

Thank you is such a small word to express my gratitude to my dear Appa, ***Mr. Saran Thapa****, my brothers* ***Mr. Sushant, Mr. Avideep****,* ***Mr. Sailesh*** *and my sister* ***Ms. Vishaka****, for their immense help and company during data collection.*

I am indebted towards my senior/brother **Mr. Saral Gurung** for his constant help throughout my research. Thank you for always responding to my queries and making things easier.

My special thanks to all the Jhora fish farmers for sharing their valuable time and knowledge with me. Especially **Mr. Hem Kumar, Mr. Daniel, Mr. Arun, Mr. Sandup** and **Bunkulung uncle** for their help during data collection.

I am also very much thankful to my seniors, especially **Mr. Stanzin, Ms. Tenji, Mr. Rinchen, Mr. Nitesh, Mr. Umesh and Mr. Kesavan,** who always helped me, encouraged me and made me feel like home in CIFE.

I would also express my gratitude towards my seniors **Ms. Gomati V, Ms. Keyho, Mr. Velumuni, Mr. Suman, Mr. Sandip, Mr. Pasang, Mr. Ankit, Mr. Rajiv, Mr. Rajesh, Mr. Krishna, Ms. Fracia, Ms. Hoilenting, Mr. Pawan, Mr. Sambit, Mr. Rajpal, Mr. Khemraj, Mr. Chinmaya, Mr. Pritam** for their support.

I express my heartfelt thanks and appreciation for my batch mates, **Bethsy (Partner), Naila, Akilendeswari (Aki), Arthi, Nidhi, Camelia, Lukas (luku), Sanjay (Stephu) and Shyam (Bhau)**, for being there as a team supporting and helping each other.

My hearty thanks to my friends, **Monalisa, Udipto, Tanmoy** and especially my roomie **Shiva**, for being such a wonderful and caring friend.

Special thanks to my beloved juniors, **Deepa, Rohan, Rolen, Sashank, Shravan, Mandeep, Dhiraj, Shubham, Talib** and also **Ms.Vidhi** for their cooperation throughout my research.

I thank my beautiful sisters; **Ms. Anandita, Ms. Subarna, Ms. Nivedita, Mrs. Banira, Ms. Swarna, Ms. Akriti, Ms. Afsaini** and handsome brothers; little **Pema, Mr. Sagar, Mr. Gaurav, Mr.Viraj, Mr. Saurav, Mr. Amol, Mr. Anmol. Devraj** mama, **Arthi** maiju and other lovely relatives who have always been a source of love and strength.

Finally, yet importantly, I would like to thank my parents, as no words can describe the support that I have received from my father **Mr. Saran Thapa** and mother **Mrs. Chandana Thapa**, who have both done tremendous hard work and dedicated their lives to make me the person I am today.

Dated: 30th August 2020

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सारांश

पश्चिम-बंगाल में एक विशेष प्रकार की मछली पालन है, जिसे "झोरा फिशरीज" के रूप में जाना जाता है, जो १९८१ वर्ष से शुरू किया गया था । पहाड़ी ठंडे पानी की धाराओं में झोरा मछली पालन एक पारंपरिक मछली पालन तरीका है और अगर ठीक से इसका प्रबंधन किया जाए तो यह दार्जिलिंग पहाड़ियों में मत्स्य पालन के विकास का एक बड़ा साधन हो सकता है। वैज्ञानिक प्रबंधन पद्धतियों के माध्यम से झोरा मछली पालन को लोकप्रिय बनाने की शुरुआत १९८१ -८२ के दौरान मत्स्य विभाग, पश्चिम बंगाल द्वारा की गई थी और यह दार्जिलिंग पहाड़ियों की आबादी के लिए आजीविका का साधन बनकर उभरा है। वर्तमान अध्ययन तीन अलग-अलग प्रकार के तालाबों में विकसित झोरा मछली पालन के अर्थशास्त्र का विश्लेषण करने के लिए किया गया है, यानी सीमेंट का तालाब, सीमेंट का तालाब जिसमें मिट्टी का आधार होता है तथा कीचड़ से बना तालाब जो पश्चिम बंगाल के दार्जिलिंग हिमालयन पहाड़ी क्षेत्र में मिलता है। प्री-टेस्टेड स्ट्रक्चर्ड इंटरव्यू शेड्यूल का उपयोग करके १२० झोरा मछली किसानों से प्राथमिक डेटा एकत्र किया गया था। डेटा का विश्लेषण करने के लिए प्रतिशत, कृषि व्यवसाय विश्लेषण, बी-सी अनुपात, स्टोचस्टिक फ्रंटियर मॉडल और अधिकतम संभावना अनुमान जैसे विभिन्न उपकरणों का उपयोग किया गया है। परिणाम बताते हैं कि सभी प्रतिवादी किसानों ने प्राथमिक व्यवसाय, कृषि के अलावा झोरा मछली पालन को माध्यमिक व्यवसाय के रूप में लिया था। उनमें से अधिकांश हिंदू पुरुष हैं, माध्यमिक स्तर तक शिक्षित, ४0-६0 वर्ष आयु वर्ग के हैं, सीमांत और छोटी भूमि जोत है और आय समूह में हैं (₹ ३-६ लाख)। किसानों ने छोटे पैमाने पर अर्ध-गहन मछली पालन और पाली-मछली पालन प्रथाओं का पालन किया तथा ४४. ३७ किलोग्राम / ५00 वर्ग फीट (९५५१ किलोग्राम / हेक्टेयर) का औसत उत्पादन मिला, जो राज्य के अन्य मीठे पानी के किसानों की तुलना में काफी अधिक है । तीनों प्रकार के झोरा तालाबों में बी-सी अनुपात एक से अधिक पाया गया है तथा कीचड़ तालाब के लिए यह उच्चतम (१.५८) रहा है, यह दर्शाता है कि किसी भी प्रकार के तालाब में झोरा मछली पालन एक आर्थिक रूप से व्यवहार्य व्यवसाय है । अधिकतम संभावना पैरामीटर अनुमानों से पता चलता है कि झोरा मछली उत्पादन घनत्व, तालाब के आकार, फ्लोटिंग फीड, अन्य फ़ीड, घास और श्रम से सकारात्मक और महत्वपूर्ण रूप से प्रभावित हुआ है। झोरा मछली किसानों की अनुमानित तकनीकी दक्षता स्तर ९0% था, यह दर्शाता है कि औसतन, झोरा मछली के उत्पादन में अभी भी मौजूदा तकनीक और संसाधनों के साथ उत्पादन में १0% की वृद्धि की गुंजाइश है। यह पाया गया कि शिक्षा का तकनीकी दक्षता पर सकारात्मक और महत्वपूर्ण प्रभाव पड़ा है। इसके विपरीत, अनुभव, घरेलू आकार और मिट्टी के तालाब के लिए एक डमी, तकनीकी दक्षता पर नकारात्मक और महत्वपूर्ण प्रभाव डालती है। रैंक आधारित भागफल पद्धति का उपयोग तकनीकी, बुनियादी ढांचे, पर्यावरण और आर्थिक बाधाओं का विश्लेषण करने के लिए किया गया है तथा परिणामों ने संकेत दिया कि क्षेत्र में झोरा मछली किसानों द्वारा सामना किए जाने वाले गुणवत्ता फ़ीड, हैचरी, फीड मिल्स, शिकार और स्व-वित्त की गैर-उपलब्धता सबसे महत्वपूर्ण बाधाएं हैं। इस प्रकार, दार्जिलिंग पहाड़ियों में झोरा मछली उत्पादन को बढ़ाने के लिए, मत्स्य पालन विभाग, पश्चिम बंगाल को स्थानीय युवाओं के बीच प्रशिक्षण और प्रबंधन प्रथाओं को लोकप्रिय बनाने के द्वारा अपने सहयोग को और बढ़ाना है। इसके अलावा, स्थानीय गुणवत्ता फ़ीड, बीज और विपणन बुनियादी ढांचे की उपलब्धता किसानों को इस लाभदायक व्यवसाय में शामिल होने के लिए प्रोत्साहित करेगी।

प्रमुख शब्द: झोरा मछली पालन, स्टोचैस्टिक फ्रंटियर विश्लेषण, अधिकतम संभावना अनुमान और तकनीकी दक्षता।

Abstract

West-Bengal has a special type of fish culture, known as "Jhora Fisheries" which dates back to the period 1981. Jhora fishery is the traditional way of fish culture in hilly cold water streams and if properly managed, it could be a great resource for fisheries development in Darjeeling hills. Popularization of Jhora fisheries through scientific management practices was initiated by DoF, West Bengal during 1981-82 and it has emerged as a means of livelihood for Darjeeling hills population. Current study has been carried out to analyze the economics of Jhora fisheries developed in three different types of ponds, viz.; cement ponds, cement with mud bottom ponds and mud ponds in Darjeeling Himalayan hill region of West Bengal. Primary data was collected from 120 Jhora fish farmers by using pre-tested structured interview schedule. Various tools like percentages, farm business analysis, B-C ratio, stochastic frontier model and maximum likelihood estimation have been used to analyse the data. Results reveal that all the respondent farmers had taken up Jhora fisheries as secondary occupation in addition to the primary occupation, agriculture. Majority of them are Hindu males, educated up to secondary level, belong to age group 40-60 years, have marginal and small land holdings and are in the income group (₹3-6 Lakhs). Farmers followed small scale semi-intensive and poly-culture practices and got an average production of 44.37 kg/500sq. ft. (9551 kg/ha) which is quite high as compared to other freshwater farmers in the state. B-C ratio in all the three types of Jhora ponds have been found to be more than unity and for mud pond it has been highest (1.58), indicating that Jhora fisheries in any type of pond is an economically viable business. Maximum likelihood parameter estimates reveals that Jhora fish production has been positively and significantly influenced by stocking density, pond size, floating feed, other feed, grass and labour. The estimated mean technical efficiency level of Jhora fish farmers was 90%, indicating that on average, Jhora fish production still have scope to increase the production by 10 % with the existing technology and resources. The estimated stochastic production frontier model together with inefficiency parameters shows that education has been found to have positive and significant effect on technical efficiency. In contrast, experience, household size and a dummy for mud pond were found to have a negative and significant effect on technical efficiency. Rank based quotient method has been used to analyse the technical, infrastructure, environment, and economic constraints and results indicated that non availability of quality feed, hatchery, feed mills, predation and self-finance are the most important constraints faced by Jhora fish farmers in the region. Thus, in order to enhance Jhora fish production in the Darjeeling hills, Department of Fisheries, West Bengal has to further extend their co-operation by providing trainings and popularizing management practices among local youths. Further, availability of local quality feed, seed and marketing infrastructure will encourage farmers to get involved in this profitable business.

Key words: Jhora Fisheries, Stochastic Frontier Analysis, Maximum Likelihood Estimate and Technical efficiency.

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INTRODUCTION

1 INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Globally, India is the 2nd largest producer of aquatic animals and nearly 12.8 percent of total animal protein consumed comes from freshwater fish only. Presently, the country is on the threshold of massive development in fisheries and aquaculture and the sector is contributing incredibly to improve food security and nutrition for Indians (DAHDF, 2018-19). Majority of aquaculture growth has taken place during 21st century, but still the potential of this sector has not been harvested completely.

Fishery being one of the promising sectors of agriculture and allied activities in India, Govt. of India, has come out with a scheme on Blue Revolution. It aims to focus on tapping the full production potential and enhance productivity substantially from aquaculture and fisheries resources with an anticipated growth rate of 6 to 8% per annum. With high potentials for diversification of farming practices, the possibilities extend from vast seas to high mountains with valued cold-water species.

Cold water fisheries occupy an important place amongst the freshwater fishes of India. It deals with fisheries activity in water where temperature of water ranges from 5^{o} to 25^{o} C. Such conditions in India occur in Himalayan and peninsular regions. India has significant resources in the form of upland streams, rivers, lakes, reservoirs and ponds that are located at medium to high altitudes of Himalayan corridors of Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, West Bengal and all North-Eastern States.

National Research Centre on Cold Water Fisheries (NRCCWF) has played a significant role in the improvement and conservation of indigenous species as well as in the establishment of exotic species in this region. Important cold water species, having potential for farming, are Mahseer, Snow Trout, Barilius, Labeo, Garra and exotic fishes like Trouts and Cyprinus Carpio. At present, total fish production from upland areas constitutes about 3% of inland fish production, which is a very small share of the country’s overall production. Commercial farming of high value cold water species like exotic rainbow trout has been taken up successfully and estimable progress has been made in the region (DAHDF, 2018-19). It will ensure doubling the income of the fishers and fish farmers with inclusive participation of the socio-economically weaker sections and ensure sustainability with environment and biosecurity.

The state of West Bengal is one of the leading states in fish production and unique in harbouring all type of resources (marine, brackish water, fresh water and cold water). Such rich resource potential provides ample scope for development in the sector through different fisheries economic activities (Handbook of Fisheries Statistics, 2017-18).

In West Bengal, there is a special type of fish culture, known as "Jhora Fisheries" practiced in the hills, which has emerged as a means of livelihood for the people of Darjeeling hills.

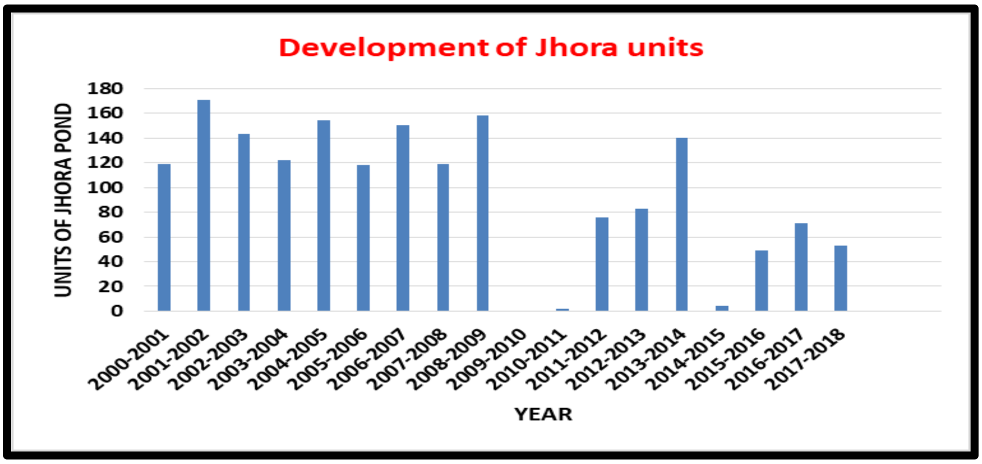
1.2 About Jhora Fisheries

Jhora fisheries date back to the period 1981. Jhora denotes 'spring water' in Nepali and 'Jharna' in Bengali language. The fish culture pond that is fed by the perennial spring water or Jhora is commonly known as "Jhora fisheries." Generally, an area having 1,500 sq. ft. is called one unit of Jhora pond with dimension of 50 ft. length and 30 ft. breadth. Depth of the Jhora pond varies between 9.8 to 1.0 m. and slope of the bottom outlet at about 0.2 per cent. Usually, there should not be any trees around embankments as the roots can cause water seepage. The ideal Jhora ponds should have a gentle continuous flow of water (Mukherjee *et al.*, 2013).

Fish culture in the hilly areas has been reported since time immemorial though not on a commercial scale. In earlier times, people used to collect fingerlings from rivers, streams and keep them in their backyard or kitchen pond. This type of culture has been practiced more as a hobby and decorative purpose rather than financial gains (Mukherjee *et al.*, 2013).

However, to fulfill the annual demand for fish for hilly population, Dept. of Fisheries, Govt. of West Bengal initiated popularizing Jhora fisheries by using scientific management practices. Jhora fishery was introduced under the Fish Farmers Development Agency (FFDA) Programme in the Darjeeling district during 1981-82. Under this programme, nine demonstration units (1,500 sq. ft. = 1 unit) were set up at different altitudes to study the growth of fish in running water system. Initially, scientific fish culture was started in small excavated ponds fed by perennial Jhora water at Kalimpong (Foning, 1987). Government provided 50% subsidy to the beneficiaries on the total cost of fish culture.

Since 2000, year after year, numbers of Jhora fisheries units have been developed in the hills, but no units were reported to be constructed during the year 2010 due to indefinite shut down because of the Gorkhaland movement. Under FFDA programmes, total of 4,713 Jhora fisheries units have been constructed in Darjeelling district till 2017-18 and are given below in figure 1:



(Source: Handbook of Fisheries Statistics, 2017-2018)

Figure 1: Development of Jhora units

Generally, cold tolerant fish species are stocked and cultured by accruing the benefit of continuous flow of the feeder Jhora and this facilitates culture throughout the year or part of the year with high stocked biomass. The main concept of these units lies in storing Jhora (stream) water in a small ditch of any size by constructing barricade with the help of earth, sand and stone so that dissolved oxygen content of the water remains high (6-9 ppm). These water bodies are subjected to a wide range of cold temperatures.

The Jhora fishery in the hilly region of Darjeeling is the first of its kind in India, being a traditional way of fish culture in hilly cold water streams, which are also used for irrigation (Sarma *et al.*2015). Since in Jhora ponds, water is continuously flowing, problem of pollution and oxygen depletion never happened and only feed is required. ICAR-Directorate of Cold water Fisheries (DCFR), Bhimtal provides technical supports for Jhora fish culture in the subdivision of Kalimpong, Siliguri and Kurseong of West Bengal State. Mahseer species, both chocolate and golden mahseer, have been attempted to grow and thrive well in pond conditions with the artificial feed developed by ICAR-DCFR. These species are also being propagated in “Jhora Fisheries Pond” at Kalimpong, West Bengal along with grass carp for aquaculture production (Singh, 2015).

Three types of Jhora ponds used for fish culture are:

1) Cement Pond: where the whole pond, both bottom and walls (embankments) are constructed with rods, stones/gravel/ bricks, etc.
2) Cement pond with mud bottom: where the bottom is muddy and embankments in all the four sides are made up of concrete.
3) Mud pond: where the whole pond, both bottom and embankments are made up of mud.

According to Foning (1987) and Mukherjee *et al.* (2013), following culture practices have to be adopted in Jhora fisheries ponds:

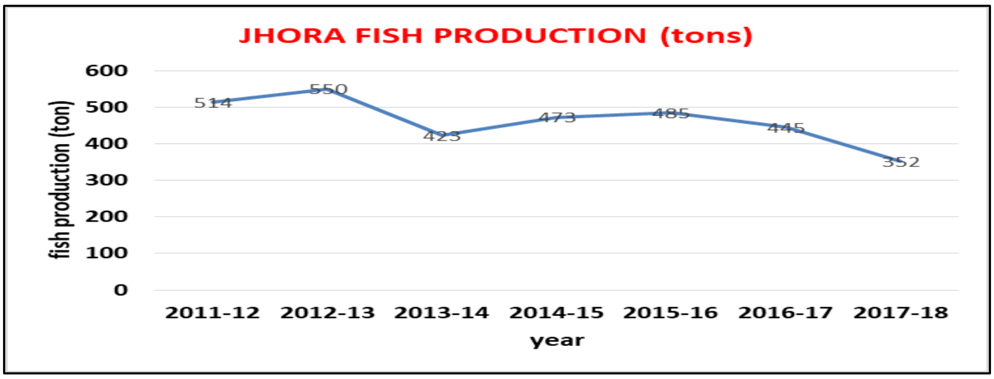
Stocking rate: Fingerlings of about 7-8cm at the rate of 2240 numbers/unit of 1500 sq. ft. (140 M^2) or 1,60,000 numbers/ha (10000 M^2)

Mortality rate: Mortality rate on an average is 20%

Culture period: March to October, a culture period of 8 months

Harvesting: End of October

If proper culture practices are followed for about 8 to 9 months, then yield received from each unit of 1500 sq ft is approx. 100 to 120 kg., (i.e., 7.5 to 9.0 tons/ha) which is quite high as compared to the yield received in plain areas as per Handbook of GIS-Based Mapping, Govt. of West Bengal (2015). During the decade, trend of year wise Jhora fish production (in tonnes) is depicted in figure 2:



(Source: Handbook of Fisheries Statistics, 2017-2018)

Figure 2: Trend of Jhora fish production from 2011 to 2018

In most of the Jhora ponds, fishes are cultured without proper scientific management protocols, which have resulted in poor production thereby meagre gain. This may be due to number of constraints faced by the Jhora fish farmers (Foning, 1987), which are not known till now. As per Nur (2010) due to lack of research, extension support and ignorance of beneficiaries about different aspects of cold-water aquaculture management, Jhora fisheries has not been flourished.

Most of the previous studies have focused on the economics of fish culture for both inland and brackish water in West Bengal. Studies carried out on Jhora fisheries, so far, had focused on productivity, limno-chemistry, development, efficacy of feed mahseer, etc. As Jhora ponds could be a great resource for fisheries development in the hills of Darjeeling, if properly managed, therefore, a study entitled "Economic Analysis of Jhora Fisheries in West Bengal" has been carried out with the following research objectives:

1.3 OBJECTIVES OF THE STUDY

1) To assess the socio-economic profile of Jhora fish farmers and culture practices followed by them.
2) To evaluate cost and returns, and technical efficiency of Jhora fisheries.
3) To analyse constraints faced by Jhora fish farmers and suggest suitable measures.

1.4 SIGNIFICANCE OF THE STUDY

This study is expected to generate adequate knowledge related to actual culture practices adopted by the Jhora fish farmers in different type of ponds, their socio-economic status, benefit-cost ratio and profitability. Main focus of the study has been on to determine the level of technical efficiencies of Jhora fish farmers using three types of Jhora ponds and identifying the factors influencing their technical efficiencies. This study has also provided useful information related to the constraints faced by Jhora fish farmers. Current study will help professionals and policy makers to improve upon its efficiency so that higher productivity can be achieved in the hills of Darjeeling. Listed constraints will help the Department of Fisheries, West Bengal in planning the training needs and the required technology extension for Jhora fish farmers in the hills of Darjeeling.

REVIEW OF LITERATURE

2 REVIEW OF LITERATURE

A review of literature is an evaluative report of studies found in the literature related to the selected area. The review describes, summarize, evaluate and clarify the literature. It gives a theoretical basis for the research and help in determining the nature of research. It is required to select a limited number of works that are interior to an area rather than to collect a large number of works that are not as closely connected to the topic area. Hence, an effort has been made to review studies under the following heads.

2.1 Existing Literature on Jhora fisheries

2.2 Socio-economic Profile of Farmers

2.3 Culture Practices

2.4 Economic Analysis

2.5 Technical Efficiency

2.6 Constraint Analysis

2.1 Existing Literature on Jhora fisheries

Foning (1987) performed research on the development of mahseer and Jhora fisheries in Darjeeling district. He reported that the status of Jhora fishery research and extension in the Darjeeling uplands was far from satisfactory. He suggested that with sincere efforts on the part of researchers and extension officials, the culture technologies for mahseer could be standardized and made available to Jhora beneficiaries in the next couple of years.

Kar *et al.* (2000) studied the productive potentiality of locally available organic manures in the Jhora fed carp culture of Darjeeling hills. They revealed that poultry is relatively superior to that of gobar-gas slurry. The percentage of NPK, as well as that of organic matter, had been relatively higher in the pond treated with poultry manure. They concluded that poultry manure is efficient in boosting up growth and production of the Indian major carps and exotic carps in the 'Jhora' fed fish ponds of Darjeeling hills.

Lepcha *et al.* (2003) studied the efficacy of fishmeal as supplementary feed for the fingerlings of chocolate mahseer, *Neolissocheilus hexagonolepis* (McClelland), cultured in artificial Jhora ponds in Darjeeling hills. They reported that low fish meal and no fish meal in the feed achieved better growth than feed with a higher percentage of fish meal.

Barat *et al.* (2005) conducted a study on bionomics and culture prospects of katli (*Neolissocheilus hexagonolepis*, McClelland) in Darjeeling district of West Bengal, where they have discussed the distribution, morphometry, present status and cultural aspects of Chocolate mahseer in Jhora ponds.

Nur *et al.* (2010) discussed the potentials of an integrated culture of coldwater fish, *Neolissocheilus hexagonolepis* (McClelland), with livestock in Jhora ponds of Darjeeling hills in West Bengal. A six-month trial was conducted; they reported that the growth rate of fish and pig was found quite significant in terms of body mass and the system of integrating farming seems to be benefitting in the Jhora ponds.

Jha *et al.* (2013) performed a comparative study on limno-chemistry and primary productivity of some fish ponds located in the northern districts of West Bengal, India. They reported a marked difference between the water temperature of ponds from different areas. The average dissolved oxygen was found to be high in the pond in Pudung in Darjeeling district. Whereas, the nutrient level was high in the pond in Gajole in Malda district. However, the average gross primary productivity was least for the ponds of Darjeeling.

2.2 Socio-economic Profile of Farmers

Goswami *et al*. (2002) conducted a study on the socio-economic dimension of fish farmers in two districts of Assam, viz., Darrang and Nagaon, and found that majority of the respondents, i.e., 80.00% of Darrang and 92.00% of Nagaon, had a family size of more than four members. Caste pattern of both Darrang and Nagaon showed that majority of the respondents were from general castes, i.e., 48.00 % and 43.33%, respectively. Most of the respondents of both Darrang and Nagaon resided in kutcha houses, i.e., 58.33 and 45.83%, respectively.

Kumaran *et al.* (2003) studied the socio-economic consequences in the East Godavari District of Andhra Pradesh. It was evident from their study that 53.3%

of shrimp farmers had higher education, a majority of 73.3% of farmers had agriculture and business as other occupations along with shrimp farming. Most of the farmers were small, with a farm size of less than 5 ha.

Ekka *et al.* (2012) conducted a rapid assessment of socio-economic status of reservoir fishers in seven states of India with the main focus on income, illiteracy and health. A total of 415 respondent households from seven states, viz. Andhra Pradesh, Himachal Pradesh, Jharkhand, Kerala, Madhya Pradesh, Tamil Nadu and Uttar Pradesh, were taken. Their result showcased a literacy rate of 63.32% among the sampled fishers, which was less than the Indian average literacy rate of 74.52% and the average monthly expenditure of the households were found out to be ₹ 3148.3 only, which was very low.

Pandey and Upadhayay (2012) conducted a study on the socio-economic profile of fish farmers of an Adopted Model Aquaculture Village, Kulubari, West Tripura. This study emphasised on education, employment, income levels from aquaculture and other farm and non-farm activities in Tripura. They concluded that majority of fish farmers are in middle age group, i.e., 57.5%, many had undergone education up to middle school, most of them had large family size and they had sufficient experience in aquaculture. Their social participation was of medium level, had a smaller pond area with single ownership and very low family income.

Roy *et al.* (2013) conducted an explorative study on the socio-economic status of hill farmers in Almora District of Uttarakhand. Variables like category, age, education, occupation, social participation, land holding, herd size, farming experience, annual income and material possession were selected to assess the socio-economic status. They used simple statistical tools like frequency, percentage, mean and standard deviation to analyse and interpret their data.

Biswas *et al.* (2014) studied the socio-economic dimensions of fish farmers towards composite fish farming and their impact upon the productivity status in North 24 Parganas District, West Bengal. They revealed that 88.33 % of fish farmers were in middle age group (31 to 60 years) and 63.33% of them were from nuclear families. It was highlighted that middle age group farmers achieved higher productivity (>5 tons hectare^{-1} year^{-1}).

Gupta and Dey (2014) conducted a study on the socio-economic status of fish farmers in Assam. They reported that 54.5% of farmers belonged to scheduled caste had large family size and 51% of elderly farmers were engaged in fish farming. Majority of fish farmers had their own land and practiced fish farming as a primary occupation for decades. Their study revealed that farmers could earn meager income from fish farming, i.e., 60% earned ₹ 20,000-30,000/year, which was spent on basic needs like food and children's education. Most of the farmers reported to borrow money from their friends and relatives and took financial help. It was also found that farmers had low institutional participation, lack of technical training and lack of marketing facilities in their area.

Ghosh *et al.* (2015) evaluated the livelihood and social status of fishermen in Teknaf by conducting a study on the socio-economic conditions of the fishermen. Data on income generation, age distribution, housing, literacy rate, health and sanitation facilities of the fishermen were collected. Their primary source of income was fishing. Among 105 fishermen interviewed, 59.25% were below 30 years, 29.62% were between 30 and 39 years, and the remaining 11.11% were more than 40 years old. Their literacy level was 62.96% illiterate, 18.51% could write their names, 14.81% had received education up to primary level and 3.70% had received a secondary level of education.

Sen and Roy (2015) in their study on the socio-economics of fish farmers in Tripura found that demographic and socio-economic indicators of the fish farmer households need improvement. Their study showcased that fish farmers in Tripura were economically poor, with an average annual per capita income of Rs. 24,940. They mentioned that although the literacy rate among farmers and their spouses was higher, i.e., 90%, but majority of them had education up to secondary level. 55% of the farmers were found to be residing in kutcha houses but were having basic amenities like drinking water, electricity, sanitation facility, etc. Considering the involvement in different social and political activities, farmer households were categorised into three groups. ‘Category A’ includes those farming households with a member of Panchayat. ‘Category B’ consists of those farming households with active involvement in any Non-Government Organisation (NGO), Self Help Group (SHG), Co-operative Society or any such social organisation excluding Category A.

‘Category C’ includes those farming households where none of the family members is a member of Panchayat or NGO/SHG/Co-operative society or any such social or political organisation.

Sancley *et al.* (2017) found that majority of the respondent had medium level of socio-economic status after conducting a study to assess the adoption of improved fish farming practices in Ri-Bhoi district of Meghalaya. To achieve their objective socio-economic variables like fish farmer`s age, education, occupation, annual income were studied, which showed a positive significant relationship with the adoption behaviour of the respondents.

Devi *et al.* (2018) carried out a study to understand the domestic fish marketing system and socio-economic status of the key market functionaries in three important fish markets located in three different districts, Viz., Kabirdham, Bemetara and Rajnandgaon of the Chhattisgarh state. It was found that fish marketing was mainly male dominant (more than 80%). 60 to 85% of the respondent had nuclear family. It was evident that adult age group of market functionaries had the highest proportions in all the markets with more than 70 percent of respondents and 90 percent of them were found to be married.

Sharma *et al.* (2018) conducted a study on socio-economic status of fishermen of Amethi district, Uttar Pradesh, India. This study revealed that majority of farmers were from age group of 45-50 years old, majority of fishermen had primary education followed by secondary educations and some old farmers have good experiences in fisheries activities for 15-20 years.

Baruah *et al.* (2019) evaluated the socio-economic status of fishermen in three districts of Assam viz., Nagaon, Sibsagar and Cachar district; their total sample size was 415 fishermen. Their study showcased that most of the fishermen were illiterate and had no proper training on modern fishing techniques. Socio-economics status parameters like education, income level, savings and expenditure, etc. were also not satisfactory.

Rishan *et al.* (2019) assessed information about the socio-economic & livelihood status of fishermen in the Habiganj Sadar Upazila, Bangladesh. They found that majority of the fishermen belonged to the age groups of 31-40 years, 97%of the respondent were Muslim, 85% of them were married & 15% were unmarried. They found that 61% of them lived in nuclear families and 39% live in joint families, about 72.5 % of fishermen were illiterate and only 22% of the respondent had a bank account.

2.2 Culture Practices

Kumaran *et al.* (2003) presented a case study on shrimp farming practices in the East Godavari District of Andhra Pradesh. This detailed study was conducted in 30 shrimp farms concerning the cultural practices, water, feed and health management. Shrimp (P. monodon) seed (PL-20) was purchased at the rate of Rs.400-500 per thousand pieces and stocked at a density of 4-7/m^2 in ponds. The farmers used two types of feeding strategies - ‘extensive’ (35% c.p) for the first 60 days and ‘intensive’ (32% c.p) for the remaining period. For aeration, most of the farmers used paddle wheel aerators (2/ha) for 4-6 hours/day. On average, two laborers per hectare were employed permanently for the routine culture operation.

Abraham *et al.* (2010) performed a comparative study of the aquaculture practices adopted by fish farmers in Andhra Pradesh and West Bengal. They compared the socio-economic profile of the fish farmers and the aquaculture practices of the two leading fish producing states of India. They found that farmers of both states cultured carps; however differences in farm holdings, size of the pond/farm, species cultured, stocking and stocking density and many other cultural aspects were reported.

Singh *et al.* (2015) conducted a study on the profitability and technical efficiency of aquaculture in Punjab and discussed some of the cultural aspects followed by the fish farmers. They reported that small farmers stocked highest number of fingerlings, i.e., 37035 nos. per ha, 37% of the selected farmers obtained fingerlings from both private and government hatcheries, polyculture was practiced and Indian major carps (IMC) were the most preferred species. Only 16% of the farmers use branded feed and the use of diammonium phosphate and urea was reported by 56 and 23% of the fish farmers.

Chidambaram *et al.* (2016) conducted a techno-economic analysis of carp farming practices in Krishnagiri district, Tamil Nadu, India. In their study, technical details on carp farming practices were discussed, like 61.3% of the farmers commonly cultivated Catla, Rohu and Mrigal, followed by Catla and Rohu species by 9.7%. Mainly extensive type of fish culture was practiced with an average culture period of seven months and a survival rate of 60%. This study revealed the most profitable enterprise, which was also the most extensively used farming system as integrated pig-fish farming with 6 species composition of fish viz, catla, rohu, mrigal, silver carp, common carp and grass carp, followed by horti-pigfish, poultry-fish and horti-fish farming.

Mavuti *et al.* (2017) evaluated management practices undertaken by fish farmers in Nyeri County. Data from 117 fish farmers was collected to assess fish pond types, fish species kept, fish culture practices, fish pond water sources, fish pond drainage and harvesting. They found that tilapia monoculture was the most popular fish culture, 84.6% of farmers used manure to fertilize their ponds and 80.3% were using commercial fish feeds, for 63.2% rivers were the primary source of pond water and 76.9% of farmers did not drain their ponds after harvesting.

2.3 Economic Analysis

Islam *et al.* (2005) estimated BCR in small, medium and large Ghers of Bangladesh as 2.1 and 1.8 and 0.9, respectively. They reported that shrimp farming is highly profitable in small and medium Ghers, but profitability decreases in large Ghers.

Uddin and Takeya (2005) examined the low lying inland fish farming practices of karimganjupazilla. Tabular, statistical and mathematical analysis was performed to achieve the objectives. The benefit-cost ratio in beel fish farming was estimated to be 2.86 and in pond fish farming it was 1.95.

Singh *et al.* (2008) conducted a study on economic analysis of fish ponds in Himachal Pradesh. The input-output ratio was worked on different fish ponds based on the size viz., marginal, small, medium, large, extra-large. Amongst all the categories of pond the highest input-output ratio was found on medium category of fish ponds (1:2.59) and the average ratio for all the samples farms was found to be 1:1.93, which was very profitable.

Olajedo (2010) studied the economic analysis of small scale catfish farming in Ido, Nigeria. Per harvest return and cost analysis revealed the gross margin as N 428,917.78, net revenue as N 370,154.40 and BCR 2.173. This result shows that catfish farming is a profitable enterprise.

Bhattacharya *et al.* (2011) conducted a comparative study on economics of Traditional Vs. Scientific Shrimp Farming in West Bengal and reported that estimates of BCR as 1.25 for those adopting scientific shrimp farming which was lower than those adopting traditional shrimp farming i.e., 2.1.

Kumar *et al.* (2012) studied the economics of fish production in Bharatpur district, Rajasthan, India. Benefit-cost ratio (BCR) was found to be 2.19 for owned ponds and 2.28 for leased ponds, respectively. They further found that BCR was higher in small owned ponds (2.34) when compared to small leased ponds (2.12). Similarly, in the case of large sized ponds, it was higher in leased ponds (2.71) against owned ponds (2.00).

Goswami *et al.* (2013) attempted economic evaluation of pond fish farming in Gondia district of Maharashtra and their results indicated that pond fish culture was an economically feasible enterprise with a benefit-cost ratio ranging from 2.22 to 4.44.

Sahu (2013) conducted a study on impact assessment of better management practices (BMP‟s) in shrimp farming in Balasore and Puri districts of Odisha. Their results indicated that total cost of production was ₹ 59,5991.41/ha and ₹ 34,3371.39/ha with B-C ratio varies between 1.24 and 1.12 in the selected districts, respectively.

Tunde *et al.* (2015) conducted a study on fish farming in Saki-East Local Government Area of Oyo State, Nigeria. Results of a cost and return analysis concluded that the total revenue was N244364.30 per cycle, whereas total cost was N129379.52 per cycle. Implying that fish farming was profitable and was expected to continue in the study area. Even the Benefit-Cost Ratio (BCR) of 1.9 also revealed profitability of the venture.

Gawa and Kumar (2017) estimated the economics of rainbow trout farming in Kashmir. They found that construction of raceway accounted for 67.60 percent of total investment on sample farms, with the major share of investment. The total variable and fixed cost had a share of 75.32 percent and 24.68 percent, respectively to the total cost. The major cost component accounting for about 45.35 percent of the total cost was feed. The B-C ratio was reckoned to be 1.80, indicating trout farming in the Kashmir valley to be economically feasible.

Islam *et al.* (2017) found that commercial fish culture in Northern Bangladesh was economically feasible, with a cost-benefit ratio of 1.5. Total cost of fish culture per hectare was found as BDT 158,930 and net returns of same per hectare as BDT 244,075.

2.4 Technical Efficiency

Sharma and Leung (2000) examined the levels and determinants of technical efficiency in carp pond culture in India. The stochastic production frontier technique involving the model for technical inefficiency effects was applied separately to samples of semi-intensive/intensive and extensive carp producers. The mean technical efficiencies for semi-intensive/intensive and extensive sample farms were reckoned to be 0.805 and 0.658, respectively. Hence extensive farms showed significant technical inefficiency in carp production.

Irz *et al.* (2003) evaluated the technical efficiency of aquaculture in the Philippines. A comparative study between freshwater ponds and brackish water aquaculture was conducted. Stochastic frontier production functions revealed that TE was low in brackish water aquaculture, with a mean of 53 percent and in case of freshwater aquaculture, the farms achieved a mean TE of 83 percent.

Dey *et al.* (2005) used stochastic frontier production function analysis to estimate the levels and determinants of farm-level technical efficiencies in freshwater pond polyculture systems in China, India, Thailand, and Vietnam. TE estimates ranged from 42 percent among extensive farms in Vietnam to 93 percent among intensive farms in China. They found that yield, input levels, and TE increases in line with intensity levels.

Ekunwe *et al.* (2009) used stochastic frontier production function analysis to examine the technical efficiency of catfish farmers in Kaduna metropolis Kaduna State, Nigeria. The estimated farm level TE ranged from 47.0 percent to 97.1 percent, with a mean of 85.4 percent. Almost 90 percent of the farmers had technical efficiency exceeding 0.71. Experience and age were found to be positively related to TE, whereas gender, household size and education were found to be negatively affecting TE.

Singh *et al.* (2009) used stochastic production frontier approach to study the technical efficiency of freshwater aquaculture and its determinants in Tripura. Both one-stage and two-stage procedures have been followed. The TE of freshwater aquaculture ranged between 0.21 and 0.96 with mean of 0.66. Quality of seed was found out to be an important determinant of TE. This study also revealed that one-stage procedure with technical inefficiency model gives reliable estimates of coefficients for Cobb-Douglas form of stochastic frontier production function than that of two-stage procedure.

Misra and Misra (2014) in their study on the technical efficiency of fish farms in West Bengal and reported an overall TE of 62.8%, farm experience and ownership were the most important determinants of TE.

Singh *et al.* (2015) used stochastic frontier production function analysis to examine technical efficiency of aquaculture in Punjab. The average technical efficiency of the aquaculture farms was 78 percent. Factors that significantly affected the TE were the use of nursery, high proportion of rohu and training received by fish farmers.

Roy and Mazumder (2016) used stochastic production frontier with inefficiency effects to measure technical efficiency of fish catch among traditional fishermen of the Sone Beel in Karimganj district of Assam. The mean technical efficiency was around 68 percent. Non-input socio-economic variable experience in fishing was found to have a positive influence on technical efficiency. In contrast, formal education and income from other sources are found to have negative effects on TE.

Baruwa *et al.* (2018) used a single-stage procedure of stochastic production frontier approach to evaluate level of technical efficiency and its determinants on catfish farms in Oyo State. TE of catfish farmers ranged between 0.41 and 0.90 with mean of 0.74. They found that years of fishing experience was significant ($P<0.01$) and was the only socio-economic variable contributing significantly to inefficiencies in aquaculture systems in Oyo State.

2.5 Constraints Analysis

Singh (2005) evaluated the constraints of fish farming in Bihar, India. Major constraints in fish production were observed in this study, viz., economic constraints, institutional constraints, social constraints and technology constraints. He further stated that despite having a huge demand for fish consumption and existing vast resources, fish farming has failed to attract the younger generation of farmers as a result of the constraints mentioned above.

Mohanty *et al.* (2011) conducted a study to identify the major constraints in adopting/developing participatory agri-aquaculture and to make technological interventions with low input-based scientific aquaculture practices. Constraint analysis through preferential ranking technique delineated as many as nine constraints with Rank Based Quotient values ranging between 19.05 for priority to domestic use to 100.0 for lack of awareness and technical knowledge in all the three study locations.

Das *et al.* (2013) used simple descriptive statistics and conducted a study to identify the constraints in the adoption of improved fish culture practices under the aqua-model village scheme in Tripura. Analysis was done separately for the adopted and non-adopted village. Six major constraints were reported in the adopted villages, constraints in stocking was followed by feeding (78.54%), management (55.41%), pond preparation (51.66%), pond construction (48.75%) and others (31.66%) whereas, in non-adopted villages, constraints in stocking was followed by pond preparation (64.58%), feeding (61.66%), pond construction (60.00%), management (55.41%) and others (29.58%).

Rahaman *et al.* (2013) conducted a study on the problems and constraints in production and marketing of fish in West Bengal. They reported that major constraints faced are theft and pilferages, non availability of quality fish seeds, lack of government support both technically and financially.

Debnath *et al.* (2014) studied the major constraints in fish consumption for different fish group in Tripura. RBQ analysis revealed that high price and price fluctuation were the two major constraints, followed by irregular supply and freshness of fish. Lack of hygiene and nearness to source were two least important constraints

Kumar *et al.* (2014) analysed constraints faced by fish farmers in adoption of scientific aquaculture practices in East and West Champaran districts of Bihar. The constraints were reported under five-category viz., extension, financial, production, marketing and social constraints. They found that majority of the fish farmers were facing extension related constraints.

Phukan *et al*. (2015) conducted a study on challenges faced by progressive fish farmers in Cachar district of Assam and reported 29 such problems. Out of these problems, some of the major were lacks of funds, availability of skilled labour for pond preparation, lack of facilities for soil and water testing and availability of quality fish seed.

Karki *et al.* (2016) analysed the constraints faced by fish farmers in Nepal. The major constraints faced by the sample fish farmers were shortage in fingerlings supply, lack of marketing infrastructure, disease problems and lack of skilled human resources in the fishery sector.

Vinay *et al.* (2016) used Rank Based Quotient method to conduct a study in four major tuna landing islands of Lakshadweep and reported three core constraints such as production, marketing and government policy. The most important constraint in production was escalating fuel cost (RBQ: 98.32), lack of cold storage facilities (RBQ: 94.61) in marketing and lack of cooperation/support from fisheries officers (RBQ: 97.64) from the government side.

Lytan (2017) identified the constraints faced by fish farmers of Ri-Bhoi district of Meghalaya and reported that lack of fish seeds, non-availability of inputs, fish mortality during transportation, lack of technical knowledge on scientific fish farming practices and use of ponds for dual purpose were the problems faced by the farmers of the district.

Munish (2017) conducted a study on constraints faced by fish farmers of Kashmir valley and reported that lack of awareness regarding fisheries schemes, non-availability of quality seed & feed, lack of water, misuse of subsidy, lack of proper exposure visits including institution credit, non-availability of insurance cover and discrimination in allocation of ponds were the main constraints faced by fish farmers in the Valley.

Tank *et al*. (2019) analysed constraints of shrimp farming in Saurashtra, Gujarat, India. Descriptive statistical tools were used. This study revealed that lack of experience (86.51%) was the most important socio-personal constraint, 61.86% were facing a problem of lack of technical guidance under technical constraints, problem of price fluctuation during harvest (88.84%) was the major economic constraints, lack of disease diagnose lab (97.21%) was the top most infrastructural constraint faced by the shrimp farmers.

This literature review draws our attention to the fact that studies on economic analysis of different fisheries sub-sectors have been done in different states. Still, not much work has been reported for hilly regions. In West Bengal, several studies had been reported on cost and returns and technical efficiency of fish farming. Still, such type of study has not been carried out so far on Jhora fisheries and the studies conducted on Jhora fisheries so far had focused on productivity, limno-chemistry, development, efficacy of fish meal for mahseer, etc.

RESEARCH METHODOLOGY

3 RESEARCH METHODOLOGY

This chapter presents a comprehensive view of all the methods used in an organized manner. Details regarding locale of study area, sampling design, selection of respondents, collection of data and analytical tools used are presented in the following sections:

3.1 Locale of Study and Description of the Study Area

Geographically, Jhora fisheries are practiced only in the Darjeeling Himalayan hill region of West Bengal. This region is a mountainous area on the north-western side of the West Bengal and belongs to the Eastern Himalayan Range. Among the twenty-three districts of West Bengal, only Darjeeling district, except for the Siliguri Subdivision of Darjeeling and the entire Kalimpong district, constitute this region.

Darjeeling Himalayan region is often referred to as the *Queen of the Hills* and is located at an elevation of 6,700 ft. (2,042.2 m), from 27^{o} 13` N to 26$^{o}$ 27` N Latitude 88^{o} 53` E to 87$^{o}$ 59` E Longitude. Kurseong, Siliguri, and Mirik, three other major towns in the district, are the sub-divisional headquarters of the district. The district is bound on the north by Sikkim, the south by Kishanganj district of Bihar, the east by Kalimpong district and the west by Nepal. Darjeeling district has a length from north to south of 18 miles (29 km) and a breadth from east to west of 16 miles (26 km). It was reported as the second least populous district of West Bengal, after Dakshin Dinajpur (Census, 2011).

Darjeeling has a temperate climate with wet summers caused by monsoon rains. The annual mean maximum temperature is 14.9 °C (58.8 °F) while the mean minimum temperature is 8.9 °C (48.0 °F), with monthly mean temperatures ranging from 6 to 18 °C (43 to 64 °F). The district receives rains on an average of 126 days in a year and highest rainfall occurs in July month. Darjeeling also receives snow at least once during winter months of December and January.

Kalimpong is a district in the state of West Bengal and came into existence on 14th February 2017, after splitting from the Darjeeling district. The district has its headquarters at Kalimpong with an area of 1,053.60 km^2 (406.80 sq. metres) with population of 251,642 (census, 2011). This district has five distinct seasons: spring, summer, autumn, winter and the monsoons. The annual temperature ranges from a high of 30 °C to a low of 9 °C. With an average maximum temperature of 30 °C in August, summers are mild and follow rains, which lash the town between June and September. The monsoons are severe, often causing landslides that isolate the town from rest of India. Winter lasts from December to February, with the maximum temperature being around 15 °C. During the monsoon and winter seasons, Kalimpong is often enveloped by fog.

Thus, the existing cold climatic condition has expedited a culture of cold-tolerant exotic carps in Jhora ponds of the Darjeeling Himalayan hill region of West Bengal.

Figure 3(a): India Map

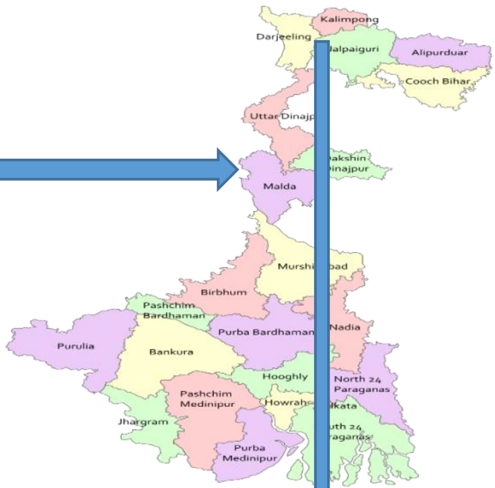


Figure 3(b): West Bengal Map

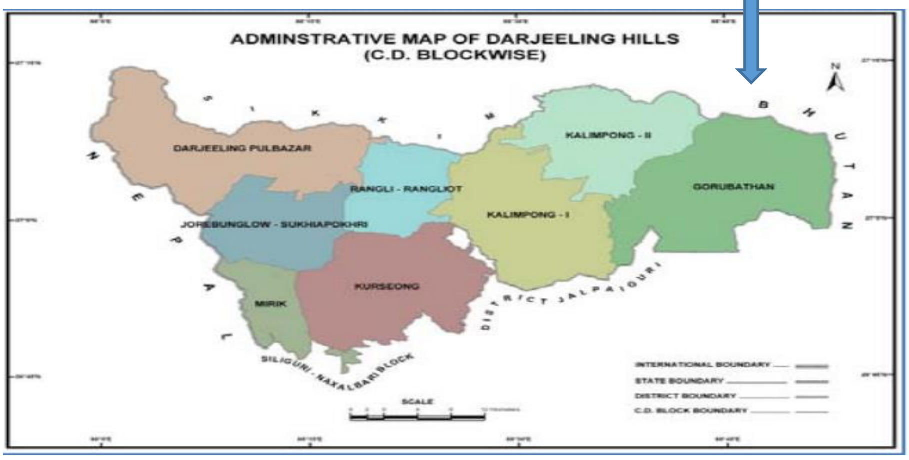


Figure 3(c): Darjeeling Himalayan hilly region Map

3.2 Sampling Design

Three-stage sampling technique was used to select the region, ponds, and sample households. Out of seven geographical regions in West Bengal, Darjeeling Himalayan hilly region was purposively selected as a first stage unit, where farmers have been practicing Jhora fisheries. Different types of Jhora ponds, namely cement, mud, and cement with a mud bottom, were purposively selected as the second stage unit. Later 40 respondent Jhora fish farmers were randomly selected from each of the three ponds as the third stage unit given as under in figure 4.

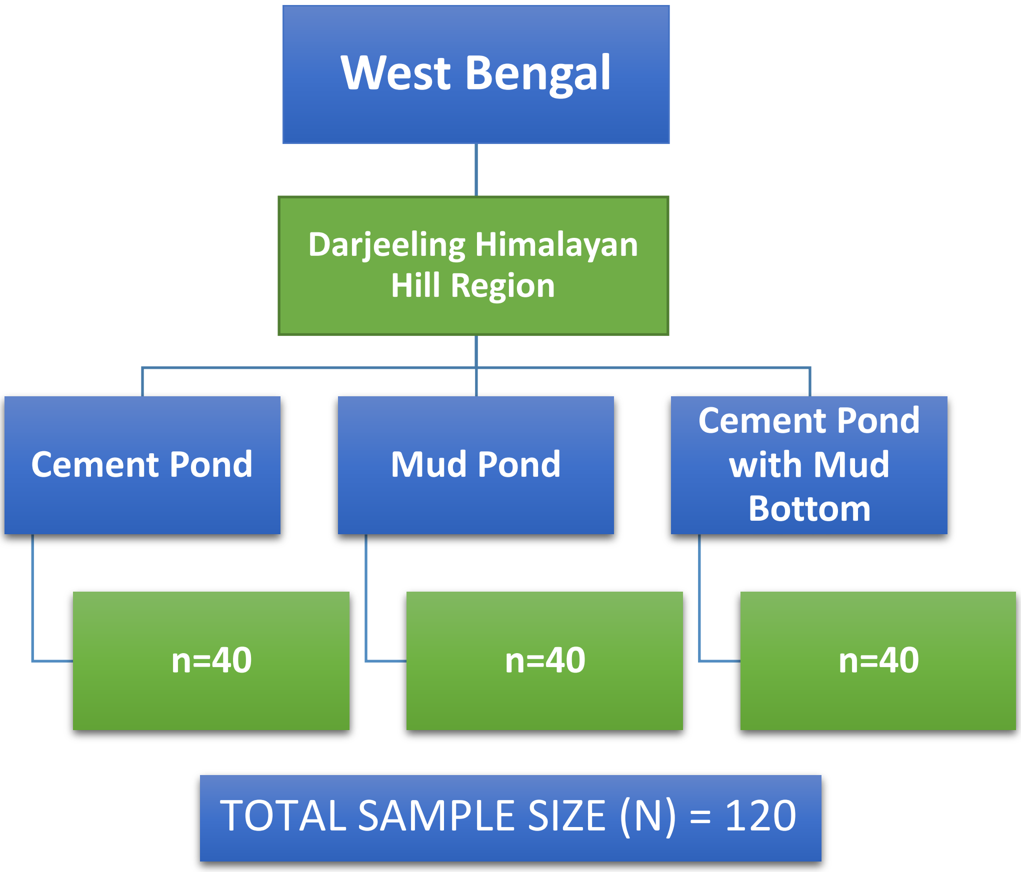


Figure 4: Systematic representation of sampling design

3.3 Selection of Respondents

Total of 120 respondents were selected practicing Jhora fisheries in three types of ponds of Darjeeling Himalayan hilly region.

3.4 Collection of Data

Primary data was collected by using a structured interview schedule from 120 selected Jhora fish farmers using three types of Jhora ponds, viz; cement, mud, and cement with a mud bottom. Secondary data was collected from published/unpublished records/documents of state fisheries department, Govt. of West Bengal, websites and other relevant sources.

3.5 Survey Period

Field survey was conducted during October 2019 to December 2019 to collect the data.

3.6 Price of Inputs and Output

The prices of inputs purchased from markets were taken as it is and home grown inputs were priced on prevailing market price. Fish harvested were evaluated at the prevailing market price at the time of harvest.

3.7 Analytical Framework

Suitable statistical tools have been used to analyse the collected data. To achieve the first objective, descriptive statistics, percentage analysis and one way ANOVA have been used. For the first half of second objective, percentage analysis, farm business analysis and benefit-cost ratio has been used. For the second half, the data was checked for regression model assumptions like multicollinearity, heteroscedasticity, and model specification test. Finally, the data were analysed using and stochastic frontier model with a single-stage estimation approach have been used. And for the third objective, rank-based quotient method has been used for constraints analysis.

3.7.1 Percentage analysis

Percentage analysis was used to describe socio-economic variables such as gender, age, family type, family size, education, occupation, house type, etc. and the cultural practices followed by Jhora fish farmers.

3.7.2 One Way Analysis of Variance (ANOVA)

One-way ANOVA has been used to test the significant difference between the annual average incomes of Jhora fish farmers using three different types of ponds.

3.7.3 Farm Business Analysis

Farm business analysis has been used to evaluate the cost and returns from Jhora fisheries based on the following components:

Fixed cost:

Fixed cost is a cost that does not change with an increase or decrease in the level of production and has to be incurred by Jhora fish farmers. It has been calculated by considering the following items:

I. Depreciation on fixed assets has been calculated by using the straight-line method.

II. Interest in fixed capital has been calculated @ 12 percent per annum on fixed capital.

III. Expenses on repair and maintenance of fixed assets had been estimated based on the information given by Jhora fish farmers.

Variable cost:

Variable/operation cost is the cost which varies with changes in output level and accounts for daily expenses on the following items:

I. Seed cost

II. Floating feed cost

III. Other feed cost

IV. Transportation cost

V. Casual labour cost

VI. Lime cost

VII. Miscellaneous cost

VIII. Interest on working capital is calculated @ 11.3 percent for eight months (Interest rate on working capital loan, SBI, 2019)

Farm Business Income Measures:

Farm business income has been calculated by the product of quantity produced and their respective prices.

$$\textbf{Gross Income}: Q * P \tag{1}$$

Where,

Q= quantity of fish produce (Kg)

P= selling price of fish (Rs/Kg)

Net Income:

Net income is the balance amount after deducting expenditure on fixed cost and variable cost from gross income.

$$\text{Net income} = GI - TC \tag{2}$$

Where,

GI = Gross income

TC = Total cost

$$TC = TFC + TVC \tag{3}$$

Where, TFC is the total fixed cost and TVC is the total variable cost.

Benefit-Cost Ratio (B:C Ratio):

B:C ratio estimates the ratio of benefits and costs incurred in the business. Hence determine the profitability. Mathematically, it can be expressed as

$$B{:}C\ Ratio = \frac{Gross\ Income}{Total\ Cost} \quad (4)$$

Depreciation:

It is the reduction in the value of assets over a period of time due to wear and tear. In the present study, the straight-line method of depreciation has been used and can be calculated by the formula

$$Annual\ Depreciation = \frac{(cost\ of\ asset - salvage\ value\ of\ asset)}{economic\ life\ period\ of\ asset} \quad (5)$$

3.7.4 Technical Efficiency:

It relates the physical input with the optimum level of output that can be produced at a given level of technology. In other words, TE reflects the ability of a farm to obtain maximum outputs from a given set of inputs (Farell, 1957).

The most basic method of TE estimation is to map a production frontier (statistically or non-statistically, parametrically or non-parametrically), find the locus of maximum output levels associated with given input levels, and estimate farm-specific TE as a deviation from the fitted frontier. Among different major approaches, the stochastic frontier production function approach involving econometric estimation of parametric function (Aigner *et al*., 1976 and 1977; Meeusen and Broeck, 1977) and nonparametric programming, also known as data envelopment analysis (DEA) (Charnes *et al*., 1978), are the most popular one.

However, Coelli *et al*. (1998) recommended that stochastic frontier analysis is more appropriate than Data Envelopment Analysis and deterministic models in agricultural applications, especially in developing countries, where measurement errors heavily influence the data, and the effect of weather, disease etc. plays a significant role.

3.7.5 Stochastic Frontier Analysis

For estimating technical efficiency of Jhora fisheries, the stochastic frontier approach, which was introduced by Meeusen and van den Broeck (1977) and Aigner et al. (1977), has been used.

3.7.5.1 Specification of the Empirical Model

Stochastic production frontier technique is most appropriate for efficiency studies that have a probability of being affected by factors beyond the control of decision making unit. As a result, this technique accounts for measuring inefficiency of these factors and technical errors occurring during measurement and observation, also measurement and observational errors which could occur during data collection. To capture effects of these errors, stochastic frontier model is most used.

Stochastic frontier analysis was introduced simultaneously by Aigner *et al.* (1977) and Meeusen and Van der Broeck (1977). This approach splits the error term into two parts to accommodate factors that are purely random and are out of the control of the firm. One component is the technical inefficiency of a firm and the other component is random shocks (white noise) such as bad weather, measurement error, and omission of variables and so on.

The model is given as under:

$$lnY_i = \beta_0 + \sum \beta_1 \, lnX_{ik} + exp^{ei} \quad (6)$$

Where;

ln = denotes the natural logarithm;

i = represent the i^{th} Jhora fish farmer in the sample,

Y_i = represents yield of fish production of the i^{th} Jhora fish farmer (kg),

X_{ik} = refers to the farm inputs of the i^{th} Jhora fish farmer,

$e_i = v_i - u_i$, is the residual random term composed of two elements v_i and u_i.

The v_i is a symmetric component and permits a random variation in output due to factors such as weather, omitted variables and other exogenous shocks.

A maximum likelihood estimation technique has been employed, since OLS yields inconsistent estimate of β_0 and it is impossible to decompose the technical inefficiency from the white noise with OLS.

3.7.5.2 Single Stage Maximum Likelihood

Coelli (1996) stated that the two-stage MLE method leads to estimates that are less efficient than single-stage estimates, followed by Wang *et al.* (2002), who theoretically explained that the two-step procedure are biased. Therefore, in the current study, a single-stage maximum likelihood estimation procedure has been used to obtain the parameter coefficients of β_i and the parameter coefficients of the in/efficiency effects.

3.7.5.3 Variance parameters

Variance parameters (σ_u^2 and σ_v^2) are expressed in terms of following parameterization:

$$\sigma_s^2 = \sigma_u^2 + \sigma_v^2 \tag{7}$$

$$\gamma = \sigma_u^2 / \sigma_s^2 \tag{8}$$

Where, γ = variance ratio and takes value between 0 to 1. A value close to 1 indicates that the random component of inefficiency effects makes a significant contribution to the analysis of the production system [Battese and Corra (1977)].

3.7.5.4 Distribution

MLE for estimation of β_i and u_i requires a prior imposition of distributional assumptions about v_i and u_i. The MLE techniques generally assume a normal distribution with mean zero and constant variance for v_i, whereas, the distribution of u_i follows different assumptions. This one-sided term can follow distribution such as exponential distribution (Aigner *et al*., 1977; Meeusen and van den Broeck, 1977), half normal as indicated by (Aigner *et al*., 1977, and Jondrow *et al*., 1982) and truncated normal (Stevenson, 1980) amongst the most frequently assumed distributions for u_i. Here, a truncated normal distribution has been assumed for the single-stage MLE procedure.

3.7.5.4 Selection of the Functional Form

To estimate the level of technical in/efficiency of Jhora fish production in the study area, Cobb-Douglas production frontier function has been used (Battese and Coelli, 1992). Logarithmic nature of the production function makes the econometric estimation of parameters simple, both in terms of analysis and interpreting elasticity of production with parsimonious degrees of freedom. Thus, Hazarika and Subramanian, (1999) stated that this is a widely used approach.

3.7.5.5 Cobb-Douglas form of stochastic production frontier

The technical efficiency of Jhora fish production in the Darjeeling Himalayan hill region has been reckoned by considering the output obtained per household as the dependent variable. (The output of fish produced in kilograms from the production year 2018/19). The independent variables are the inputs (factors) of production used in the same production year. Accordingly, the relevant inputs considered are given as under:

Y_i= total amount of fish produced in kg by the i^{th} farmer. (i =1,2,3,…n)

X_1= total number of fingerlings stocked by the i^{th} farmer.

X_2= total size of pond used for fish culture by the i^{th} farmer.

X_3= total labour in man-days used for fish production by the i[th] farmer.

X_4= total amount of floating feed in kg used for fish production by the i[th] farmer.

X_5= total amount of other feed in kg used for fish production by the i[th] farmer.

X_6= total amount of grass in kg used for fish production by the i[th] farmer.

X_7= lime in kg used the i[th] farmer.

X_8= manure in kg used by the i[th] farmer.

D_1= floating feed dummy. (Value 1 if floating feed used, otherwise 0)

D_2= other feed dummy. (Value 1 if other feed used, otherwise 0)

D_3= grass dummy. (Value 1 if grass used, otherwise 0)

D_4= lime dummy. (Value 1 if lime used, otherwise 0)

D_5= manure dummy. (Value 1 if manure used, otherwise 0)

The Cobb-Douglas form of stochastic production frontier for sample Jhora fish farmers can be given as:

$$lnY_i = \beta_0 + \sum_{k=1}^{8} \beta_k \, ln\, X_{ki} + \beta_9 D_{1i} + \beta_{10} D_{2i} + \beta_{11} D_{3i} + \beta_{12} D_{4i} + \beta_{13} D_{5i} + V_i - U_i \quad (9)$$

Where, subscript i refers to the i[th] Jhora fish farmer in the study area; ln represents the natural logarithm; Y is output variable and X and D are input and related variables; β's are the parameters to be estimated; V_i is the two-sided error term and U_i is the one-sided error term (technical inefficiency effects).

Since all fish farmers do not apply a particular type of input (X), therefore, value of ''0'' will be reflected in the data matrix for that particular variable input. Battese (1997) mentioned that corresponding parameter estimates of variables such as floating feed, other feed, grass lime and manure obtained from C-D production function will be biased if the corresponding dummy variable will not be included in the estimation.

3.7.5.6 Technical inefficiency distribution parameter

According to Battese & Coelli (1995), the technical inefficiency distribution parameter, U_i, is defined as:

$$\mu_i = \delta_0 + \sum_{k=1}^{8} \delta_k Z_{ik} \qquad (10)$$

Where,

μ_i is the technical inefficiency effect,

δ_k is the coefficient of explanatory variables and is to be estimated. As the dependent variable in equation (10) is defined in terms of technical inefficiency, a farm-specific variable associated with the negative (positive) coefficient will have a positive (negative) impact on technical efficiency.

The Z_k variables represent the socio-economic characteristics of the farmer, explaining inefficiency of the i^{th} fish farmer.

As a result, for technical inefficiency following determinants have been used:

Z_{i1}= Age of the sample Jhora fish farmer (years);

Z_{i2}= Education (number of years of schooling of the fish farmer);

Z_{i3}= Household size (total numbers of family member who lives in one roof);

Z_{i4}= Experience (number of years of Jhora fish farming);

Z_{i5}= Gender (a dummy variable. It takes a value of 1 if male, 0 otherwise);

Z_{i6}= Training (a dummy variable. It takes a value of 1 if training attended, 0 otherwise);

Z_{i7}= Cement pond (a dummy variable. It takes a value of 1 if the pond is cement, 0 otherwise);

Z_{i8}= Mud pond (a dummy variable. It takes a value of 1 if the pond is Mud, 0 otherwise);

Technical efficiency of the ith selected Jhora fish farm (TE_i) can be given as:

$$TE_i = \exp(-U_i) \tag{11}$$

3.7.5.7 Generalized Likelihood ratio

Validity of the models used for the analysis and hypothesis test has been investigated by using the general Likelihood ratio test by using the formula,

$$LR = -2[lnLH_0 - lnLH_1] \tag{12}$$

Where,

LR = Log-likelihood ratio

LH_0 =Value of log-likelihood function of a restricted model specified by H_0

LH_1= Value of log-likelihood function of an alternative hypothesis H_1

m*=degree of freedom= number of restrictions= number of estimated inputs and inefficiency variables in the current model (alternate hypothesis) minus number of estimated inputs and inefficiency variables in the preceding model (null hypothesis).

H_0 will be rejected when LR (calculated χ^2 m*) > tabulated χ^2m* and if H_0 is true, the test statistic will approximately follow a χ^2distribution or mixed χ^2distributions with 8 degrees of freedom.

Moreover, the actual output from the stochastic model used in equation (6) can be given by:

$$Y_i: \exp(X_i\beta + V_i - U_i) \tag{13}$$

From this equation, technical efficiency (exp-u_i) can be calculated as:

$$TE_i = \frac{Y_i}{Y_i^*} \tag{14}$$

Where,

TE_i=technical efficiency of the ith Jhora fish pond

Y_i^*= the frontier output of the i_{th} Jhora fish pond

Y_i = the actual output of the i_{th} Jhora fish pond

3.7.6 Rank Based Quotient

Rank-based quotient given by Sabarathnam (1988) has been used to quantify the technical, infrastructural, economic, and environmental constraints faced by the Jhora fish farmers. The problems faced by Jhora fish farmers were first identified and then they were asked to rank them accordingly.

The result shows four different constraints category with 27 sub-heads. Farmers were asked to rank these constraints according to their preference from 1 to n in such a way that rank 1 has been given for major constraint and rank (n) for minor constraint.

The formula used for RBQ is as follows:

$$RBQ = \frac{\sum f_i(n+1-i)}{(N*n)} * 100 \quad (15)$$

Where,

f_i = Number of Jhora fish farmers reporting a particular problem under i^{th} rank.

N = number of Jhora fish farmers.

n = number of problems identified.

RESULTS AND DISCUSSION

4 RESULTS AND DISCUSSION

The results and discussions related to the objectives of the study are presented under the following headings.

4.1 Socio-economic Profile of Jhora Fish Farmers.

4.2 Culture Practices Followed by Jhora Fish Farmers.

4.3 Economics of Jhora Fisheries.

4.4 Technical Efficiency of Jhora Fisheries and its Determinants.

4.5 Constraints Faced by Jhora Fish Farmers and to Suggest Suitable Measures.

4.1 Socio-economic Profile of Jhora Fish Farmers

The social profile of selected Jhora fish farmers in Darjeeling Himalayan hill region have been studied by using variables such as gender, age, education, marital status, religion, caste category, family type, family size, house type and social participation (Table 4.1.1) and discussed below:

Gender: It has been found that overall majority of respondent Jhora fish farmers were males (86.67%) and only 13.33% were females. In case of three types of ponds, majority of them (85%) were males culturing in mud ponds, whereas in the other two cases of cement ponds and cement ponds with mud bottom, 87.5% were males and rest of them (12.5%) were females.

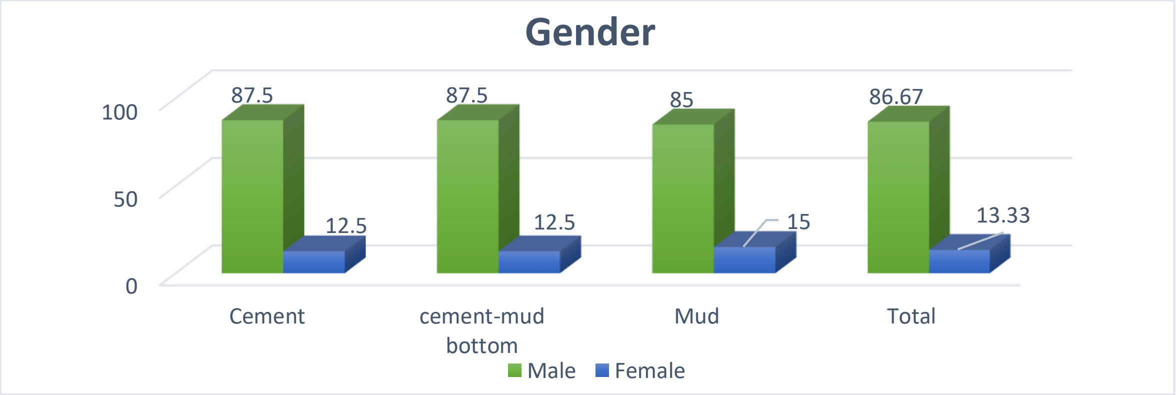


Figure 5: Gender of the respondent Jhora fish farmers

Age: Age of the respondent farmers have been categorized into three categories viz., less than 40 years (younger group); between 40-60 years (middle age group) and more than 60 years (old age group) [Sen &Roy, (2015)]. Out of selected fish farmers, majority of them have been found to be in middle age group using three types of ponds, viz, cement ponds, cement pond with mud bottom and mud ponds with 75%, 67.5% and 52.5% respectively. This is followed by younger and older age groups farmers except in case of mud ponds. Overall, majority of the respondent farmers (65%) belonged to middle age group, followed by younger age group indicating that younger generation is not attracted to Jhora fisheries. Similar findings were reported by *Biswas et al.* (2018), stating that majority of the fish farmers (88.33 %) from North 24 Parganas district of West Bengal were middle-aged.

Education: Educational status of the selected Jhora fish farmers in Darjeeling hills revealed that among the selected fish farmers, nearly 42.5%, 37.5% and 45% of them respectively had secondary level of education for fish farmers using three types of ponds, viz., cement ponds, cement ponds with mud bottom and mud ponds. This is followed by higher secondary and primary educated farmers, except in case of farmers using cement ponds. It has also been found that Jhora fish farmers using cement ponds with mud bottom were more educated than the other two type of ponds. Overall, 93.33% of the respondent farmers were found to be literate, while only 6.67% were illiterate. Similar findings were reported by Abraham *et al.* (2010), stating that majority of farmers (41.67%) were educated up to secondary level which is better than other fish farmers in different districts of WB, who could have education up to class eight only.

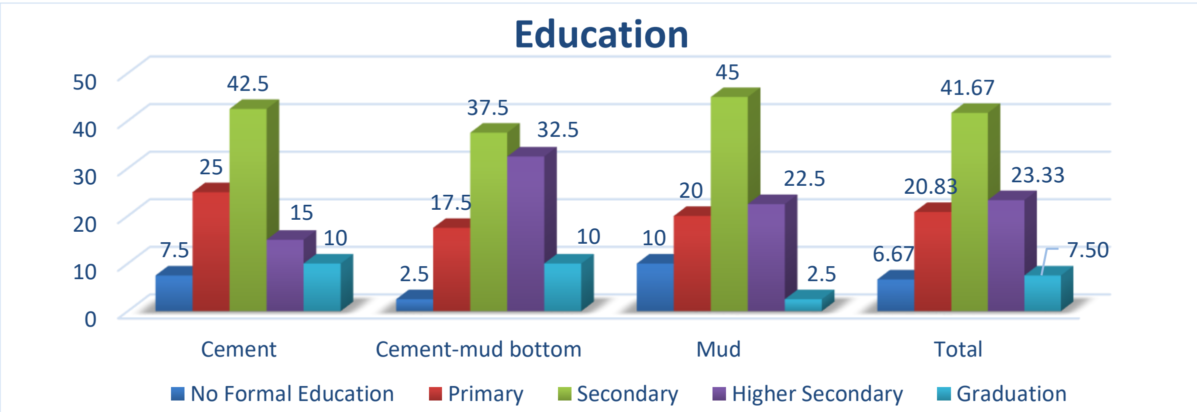


Figure 6: Diagrammatic representation of education status of Jhora fish farmers

Marital status: It has been found that among the selected fish farmers using three types of ponds, viz., cement ponds, cement ponds with mud bottom and mud ponds, majority of them with 92.5%, 95% and 75% respectively, were reported to be married. Overall, 87.5% of Jhora fish farmer respondents were married while 5% of them were unmarried and 7.5% were widow/widower also.

Religion: Among the selected Jhora fish farmers using cement and mud ponds, majority of them were found to follow Hinduism with 60% and 57.5%, respectively, followed by Buddhism and Christianity. While most of the fish farmers using cement ponds with mud bottom follow Buddhism (42.5%) followed by Hinduism and Christianity. Overall, most of Jhora fish farmers (52.5%) were reported to follow Hinduism, followed by Buddhism (30%) and Christianity (17.5%). These results are found to be similar to the 2011 census, where majority (74%) follow Hindu religion followed by Buddhists (11.3%), Christian (7.7%) and Muslim (5.7%). However, none of the respondents reported to follow Muslim religion.

Caste Category: Among the selected fish farmers using three types of ponds, viz., cement ponds, cement ponds with mud bottom and mud ponds, majority of them with 75%, 62.5% and 57.5% respectively, belongs to Schedule Tribe caste. This is followed by Other Backward Class, General and Schedule Cast for all three types of ponds. Overall, 65% of the selected Jhora fish farmers belong to Scheduled Tribe community.

Family type: Among the selected fish farmers using mud ponds and cement ponds with mud bottom, majority of them have reported to be living in a joint family with 87.5% and 55%, respectively, followed by nuclear family. In contrast, most of the respondents using cement ponds have reported to be living in nuclear family (52.4%) and remaining (47.5%) in joint families. Overall, majority of them (63.3%) reported to be living in joint family and rest of them (36.7%) in a nuclear family. These findings contradict the results reported by Biswas *et al*. (2018), where farmers living in nuclear and joint family in North 24 Parganas district of West Bengal were 63.3% and 36.75%, respectively.

Family size: Selected farmers have been categorised into three groups viz., small family (<4 members), medium family (4-6 members) and large family (>6 members) [Sen & Roy, (2015)]. Among the selected fish farmers using three types of ponds, viz., cement ponds, cement ponds with mud bottom and mud ponds, majority of them with 72.5%, 52.5% and 61.67% respectively are having medium family size. This is followed by farmers having large and small family except for those using cement ponds. Overall, majority of the respondent farmers (61.67%) have medium family size, followed by 27.5% of them having large family size and 20 % having small family size. The average household size of the selected respondents has been found to be 5.4, which is higher as compared to the state average of 4.5 persons in a family (India National Family Health Survey, 2005-06).

House type: Among the selected respondent farmers using three types of ponds, viz., cement ponds, cement ponds with mud bottom and mud ponds, majority of them with 75%, 90% and 67.5% respectively, resides in pucca houses followed by those residing in semi-kachcha houses. However, none of the respondents reported to be residing in kachcha houses. Overall, majority of fish farmers (77.5%) have been residing in pucca houses followed by 22.5% of them residing in semi-kachcha houses, indicating that Jhora fish farmers are staying in better housing structures as compared to other fishers of Sundarban, WB, where majority of them reported to be residing in kachcha huts as reported by Bhattacharya (2011).

Table 4.1.1: Social profile of selected Jhora fish farmers

Category		Cement pond		Cement pond with mud bottom		Mud pond		Total	
		No.	Share (%)	No.	Share (%)	No.	Share (%)	No.	Share (%)
Sample size		40		40		40		120	
Gender	Male	35	87.5	35	87.5	34	85	104	86.67
	Female	5	12.5	5	12.5	6	15	16	13.33
Age	Young (<40)	8	20	9	22.5	8	20	25	20.83
	Middle (40-60)	30	75	27	67.5	21	52.5	78	65
	0ld (>60)	2	5	4	10	11	27.5	17	14.17
Education	No Formal Education	3	7.5	1	2.5	4	10	8	6.67
	Primary	10	25	7	17.5	8	20	25	20.83
	Secondary	17	42.5	15	37.5	18	45	50	41.67

	Higher Secondary	6	15	13	32.5	9	22.5	28	23.33
	Graduation	4	10	4	10	1	2.5	9	7.50
Marital status	Married	37	92.5	38	95	30	75	105	87.5
	Unmarried	0	0	1	2.5	5	12.5	6	5
	Widow/er	3	7.5	1	2.5	5	12.5	9	7.5
Religion	Hindu	24	60	16	40	23	57.5	63	52.5
	Buddhist	8	20	17	42.5	11	27.5	36	30
	Christian	8	20	7	17.5	6	15	21	17.5
Category	ST	30	75	25	62.5	23	57.5	78	65
	OBC	7	17.5	7	17.5	13	32.5	27	22.5
	SC	1	2.5	2	5	2	5	5	4.17
	General	2	5	6	15	2	5	10	8.3
Family Type	Nuclear	21	52.5	18	45	5	12.5	44	36.7
	Joint	19	47.5	22	55	35	87.5	76	63.3
Family Size	Small (<4)	7	17.5	8	20	2	5	17	14.17
	Medium (4-6)	29	72.5	21	52.5	24	60	74	61.67
	Large (>6)	4	10	11	27.5	14	35	29	24.17
House Type	Kachcha	0	0	0	0	0	0	0	0
	Semi-kachcha	10	25	4	10	13	32.5	27	22.5
	Pucca	30	75	36	90	27	67.5	93	77.5
Social Participation	Category A	0	0	0	0	0	0	0	0
	Category B	16	40	6	15	10	25	32	26.7
	Category C	24	60	34	85	30	75	88	73.3

Social participation: Selected farmer households have been categorised into three groups in terms of their involvement in different social and political activities. ‘Category A’ includes those farmers’ households, where either the respondent farmer or at least anyone of his/her family members is a member of Panchayat. ‘Category B’ includes those farming households, where either respondent farmer or at least anyone of his/her family members is actively involved in any Non-Government Organisation (NGO)/Self Help Group (SHG)/Co-operative Society/any such social organisation excluding those who falls under Category A. ‘Category C’ includes those farming households, where none of the family members is a member of Panchayat or NGO/SHG/Co-operative society/any such social or political organisation [Sen and Roy, (2015)]. It has been found that among the selected fish farmers using cement ponds, cement ponds with mud bottom and mud ponds majority of them with 60%, 85% and 75% respectively fall under ‘Category C’ followed by those falls under ‘Category B’ with 40%, 15% and 25% respectively. Overall, it has been found that majority of the respondents have not been involved in any social participation and they also reported that Panchayat election had not been held in the Darjeeling hilly region since May 2000. Only 26.7 % of the respondents were found to be members of SHGs, Cooperatives and NGOs and fall under Category B.

Economic profile of the selected Jhora fish farmers in Darjeeling Himalayan hill region have been studied by using variables such as primary/secondary occupation, land holdings, savings, debt, annual income/expenditure (Table 4.1.2) and are discussed below:

Primary occupation: Among the selected respondent farmers using cement ponds, cement ponds with mud bottom and mud ponds, majority of them with 77.5%, 57.5% and 85%, respectively had reported agriculture as their primary occupation. This is followed by service, except for those using mud ponds. Overall, 73.3% of them had reported agriculture as the primary occupation. It has been found that none of the Jhora fish farmers had fisheries as their primary occupation. However, all of them had registered as ‘Fish farmers’ in the records of the Department of Fisheries, Government of West Bengal.

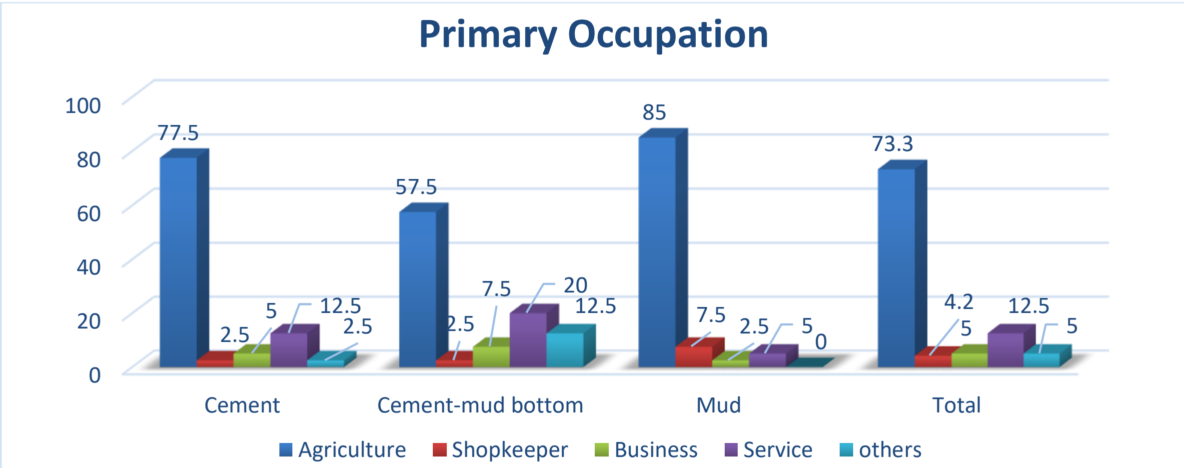


Figure 7: Primary occupation of the respondent Jhora fish farmers

Table 4.1.3: Economic profile of selected Jhora fish farmer

Category		Cement pond		Cement pond with mud bottom		Mud pond		Total	
		No.	Share (%)	No.	Share (%)	No.	Share (%)	No.	Share (%)
Selected size		40		40		40		120	
Primary occupation	Agriculture	31	77.5	23	57.5	34	85	88	73.3
	Shopkeeper	1	2.5	1	2.5	3	7.5	5	4.2
	Business	2	5	3	7.5	1	2.5	6	5
	Service	5	12.5	8	20	2	5	15	12.5
	Others	1	2.5	5	12.5	0	0	6	5
Secondary occupation	Fisheries	32	80	31	77.5	32	80	95	79.17
	Agriculture	2	5	7	17.5	5	12.5	14	11.67
	Others	6	15	2	5	3	7.5	11	9.17
Land Holding	Marginal	19	47.5	21	52.5	20	50	60	50
	Small	15	37.5	16	40	13	32.5	44	36.7
	Semi-small	6	15	3	7.5	7	17.5	16	13.3
Savings	Commercial bank	37	92.5	35	87.5	36	90	108	90
	Post office	5	12.5	4	10	7	17.5	16	13.3
	LIC	3	7.5	6	15	6	15	15	12.5
Debt	Yes	3	7.5	2	5	2	5	7	5.83
	No	37	92.5	38	95	38	95	113	94.17
Annual Income	EWS (< ₹3 lakh)	14	35	18	45	17	42.5	49	40.8
	LIG (>₹3 lakh to ₹6 lakh)	26	65	22	55	23	57.5	71	59.2
Annual Expenditure Pattern	Food		50.6		49.4		46.8		48.9
	Clothing		14.3		15.1		15		14.8
	Festivals		10.5		9		10.9		10.1
	Education		9.2		9.8		8.25		9.1
	Medical		6		5.2		7.75		6.3
	Transportation		5		6.4		6.1		5.8
	others		4.4		5.1		5.2		4.9

Secondary occupation: Among the selected respondent farmers using cement ponds, cement ponds with mud bottom and mud ponds, majority of them with 80%, 77.5% and 80% respectively had reported fisheries as their secondary occupation followed by agriculture except for those using cement ponds. Overall, 79.17% of them had reported “Jhora fisheries” as their secondary occupation.

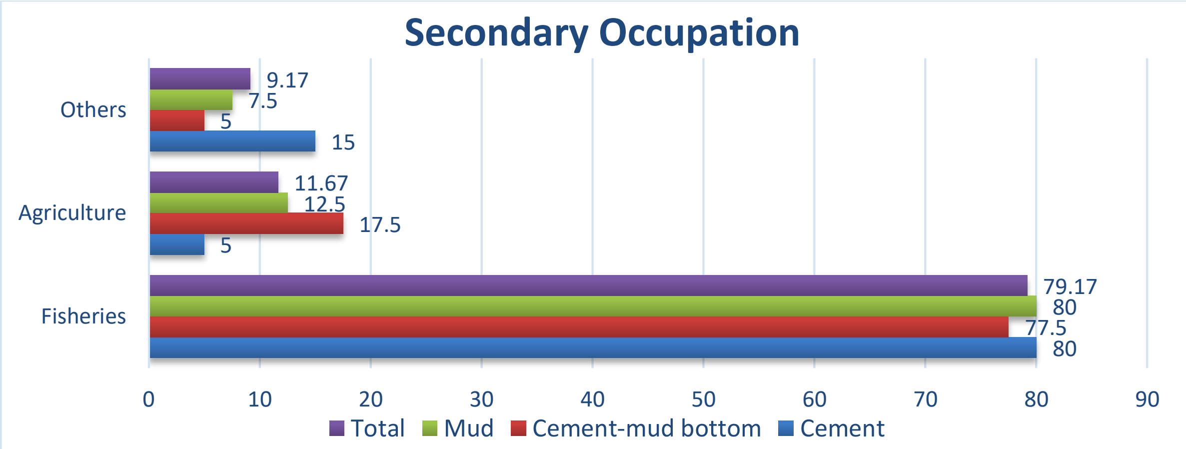


Figure 8: Secondary occupation of the respondent Jhora fish farmers

Land holding: Land holding of the Jhora fish farmers household have been categorised into marginal, small and semi-medium (Census of India, 2011). Among the selected respondent farmers using cement ponds, cement ponds with mud bottom and mud ponds, nearly 47.5%, 52.5% and 50% of them respectively had belonged to be in marginal category followed by small and semi-medium categories. Overall, 50% of them were found to have marginal land holding followed by small (36.7%) and semi-medium ones (13.3%) in the similar pattern of the census 2011, where majority of the land holding in the Darjeeling district falls under marginal category (83.00 %). Bijalwan (2011) had also reported that maximum farmers of Garwal Himalayan region were found to have marginal land holding (83.3%) followed by small (14.3%).

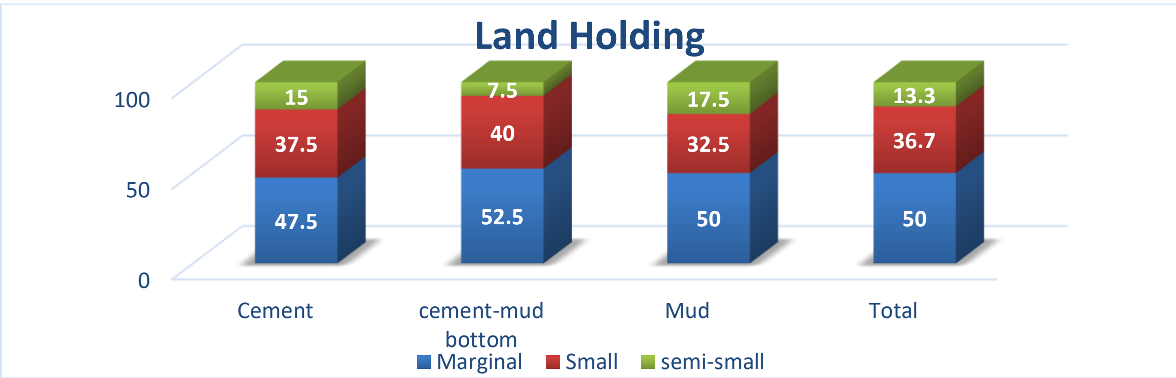


Figure 9: Land holding of the respondent Jhora fish farmer household

Savings: Among the selected respondent farmers using cement ponds, cement ponds with mud bottom and mud ponds, majority of them with 92.5%, 87.5% and 90%, respectively hold a savings account in a commercial bank whereas 12.5%, 15% and 17.5% of them respectively hold savings in the post office and 7.5%, 15% and 15% of them respectively had invested in LIC also. Overall, 90% of the respondent farmers had a savings account in commercial banks, 13.5% of them had savings in the post office and 12.5% had invested in LIC also, indicating that Jhora fish farmers in the Darjeeling hills have better savings as compared to other fish farmers of Assam, where 91 % were not in a position to save as reported by Baruha *et al.* (2019).

Debt: It was reported that only 7.5% of fish farmers using cement pond were under debt and 5 % of them belong to mud ponds and cement ponds with mud bottom were under debt. Overall, majority of them (94.17%) had reported that they are managing their household from their income only, whereas 5.83% had availed credit from small microfinance institutions like Asirvad and Bandhan and are under debt.

Annual Income: Annual income of the Jhora fish farmer households have been grouped into two categories, viz., Low Income Group (>₹3 lakh to ₹6 lakh) and Economically Weaker Section (< ₹3 lakh) [Ministry of Housing and Urban Affairs, Govt. of India (2017)]. Among the selected respondent farmers using cement ponds, cement ponds with mud bottom and mud ponds, majority of them with 65%, 55% and 57.5%, respectively were found to be low income group (LIG) whereas remaining 35%, 45% and 42.5% of them were to economically weaker section (EWS). Overall, nearly 59.2% of respondents belong to LIG and rest of them (40.8%) to EWS. The average per capita annual income during 2018-19 of the Jhora fish farmer households has been found to be ₹ 66,612/- which was less than as compared to the per capita net state domestic product at current prices for West Bengal, i.e., ₹ 1,09,491 /-.

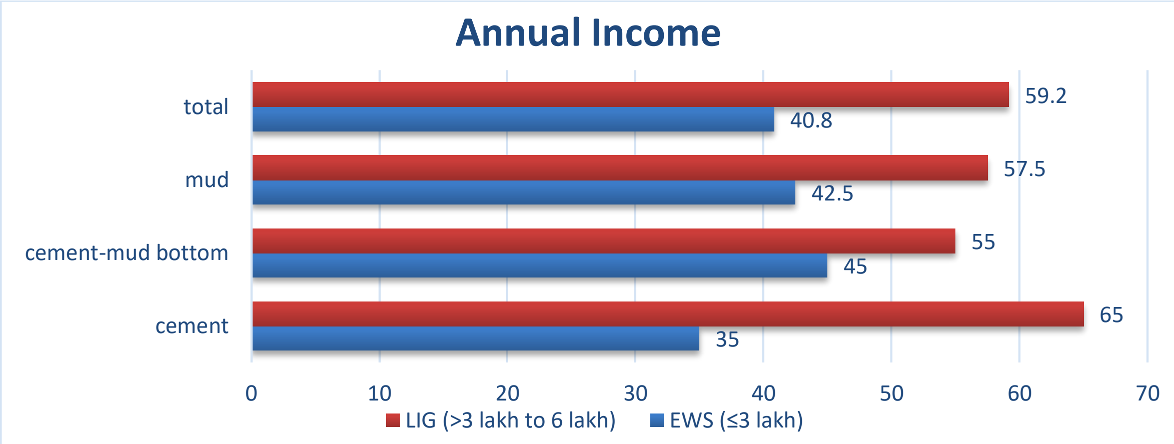


Figure 10: Annual Income of respondent Jhora fish farmer household

One way ANOVA has been used to test the difference between the annual household incomes of Jhora fish farmers using three types of Jhora ponds, with the following null hypothesis:

H_0: There is no significant difference among the average incomes of Jhora fish farmers using three types of Jhora fisheries ponds in the Darjeeling Himalayan hill region.

Table 4.1.2: One way ANOVA

Source	SS	df	MS	F	Prob > F
Between groups	$6.9770*10^{09}$	2	$3.4885*10^{09}$	0.14	0.8713
Within groups	$2.9590*10^{12}$	117	$2.5291*10^{10}$		
total	$2.9660*10^{12}$	119			

Since F = 0.14 with $p > 0.05$, therefore the average incomes of Jhora fish farmers are not significantly different using three types of ponds in Darjeeling hill region.

Annual Expenditure Pattern: Annual expenditure pattern of the Jhora fish farmer household have been analysed by taking the average amount of income spent on various items like food, clothing, festivals, education, medical and transportation and others. Among the selected respondent farmers using cement ponds, cement ponds with mud bottom and mud ponds, majority of them spend 50.6%, 49.4% and 46.8%, respectively, of their annual income on food, followed by clothing, festival, education, medical, transportation and others. Overall, 48.9% of them had reported to spent of their annual income on food, followed by other items.

4.2 Culture Practices Followed by Jhora Fish Farmers

Selected Jhora fish farmers in Darjeeling hill region had reported to follow various culture-practices (Table 4.2.1) and are discussed below:

Access to Schemes: From the advent of Jhora fisheries, various kinds of schemes and subsidies had been provided to the farmers through World Bank, pond construction under FFDA, Blue Revolution and MGNREGA, cultural subsidy, free seed/feed from the DoF and poly-lining. Among the selected respondent farmers using cement ponds, cement ponds with mud bottom and mud ponds, majority of them with 67.5%, 67.5% and 75% respectively, had access to free feed/seed. These farmers had access to several schemes, as depicted in table 4.2.1. Overall, 70% of them had access to free feed/seed from the DoF, WB and these farmers got their farms constructed under various schemes like Blue revolution, FFDA and MGNREGA while only 2.5% of them had received poly-lining and 0.83% had received cultural subsidy also.

Training attended: It was reported that among the selected respondent farmers using cement ponds, cement ponds with mud bottom and mud ponds, majority of them with 85%, 87.5% and 95% respectively, had participated in a formal training program. Overall, majority of them (89.17%) had reported to attend training program organized by DoF, which is relatively higher than other fish farmers (67.9%) of West Bengal who had attended training as reported by Abraham *et al.* (2010). 67.9%

Experience: Years of experience of the selected farmers have been categorized into four groups, viz.; (i) <5 years, (ii) 6-10 years, (iii) 11-15 years and (iv) >15 years. Among the selected respondent farmers using cement ponds, cement ponds with mud bottom and mud ponds, nearly 47%, 50% and 35% of them respectively had an experience of more than fifteen years, followed by those having

6-10 years, 11-15 years and <5 years except for those using cement ponds. Overall, nearly 44.17% of the respondent farmers reported to have more than 15 years of experience, followed by having experience falls in other groups.

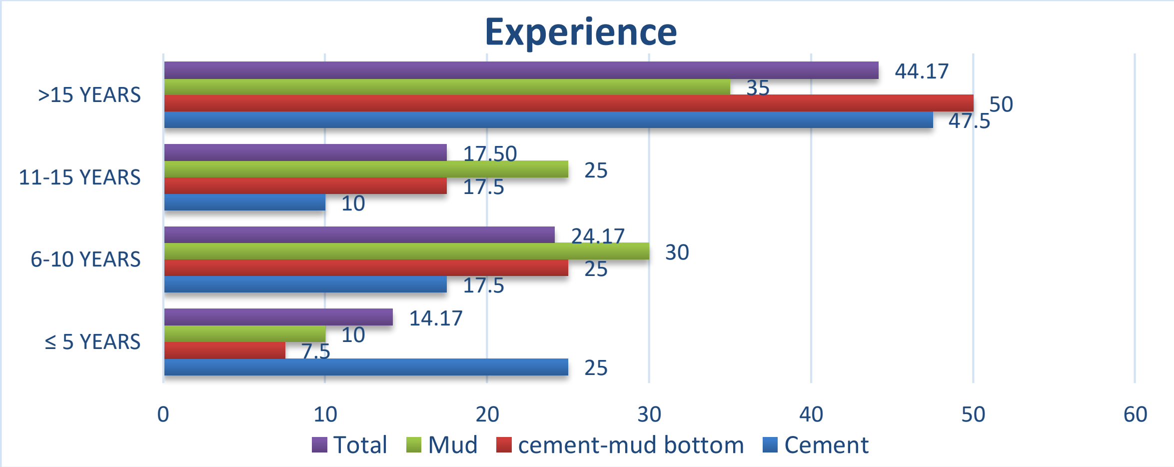


Figure 11: Experience of the respondent Jhora fish farmers

Learned fish culture: Among the selected respondent farmers using cement ponds, cement ponds with mud bottom and mud ponds, majority of them with 67.5%, 77.5% and 70% respectively, had reported that they learned fish farming on their own and some of them from fellow farmers and Fisheries Extension Officers (FEO). Overall, majority of them (71.67%) were reported to have learned farming on their own as since generations their family had been involved in fish farming, while 18.33% of them had learned from fellow farmers also and only 10% had learned from the FEO.

Pond area: Total pond area of individual Jhora fish farmer household have also been grouped into four categories viz., <500 sq ft., 501-1000 sq ft., 1001-1500 sq ft. and >1500 sq ft. Those farmers who were using cement ponds and cement ponds with mud bottom, nearly 35% and 50% of them respectively reported to have pond area of less than 500 sq ft. whereas those who were using mud ponds, nearly 57.5% of them reported having pond area between 501-1000 sq ft. Overall, as many as 39.17% of each of the respondent farmers hold pond areas of <500 sq ft. and 501-1000 sq ft., followed by 15% of those farmers who hold pond area of 1001-1500 sq ft. and only 6.67% of them hold more than 1500 sq ft.

Number of Jhora units: Among the selected respondent farmers using cement ponds, cement ponds with mud bottom and mud ponds, majority of them with 87.5%, 90% and 80% respectively, reported to have only one unit of Jhora pond and some of them with two or three units also. Overall, majority of them (85.83%) had only one Jhora unit, followed by those (13.33%) having two units and only one farmer had three units also (units ranges from 250 sq ft. – 4000 sq ft.).

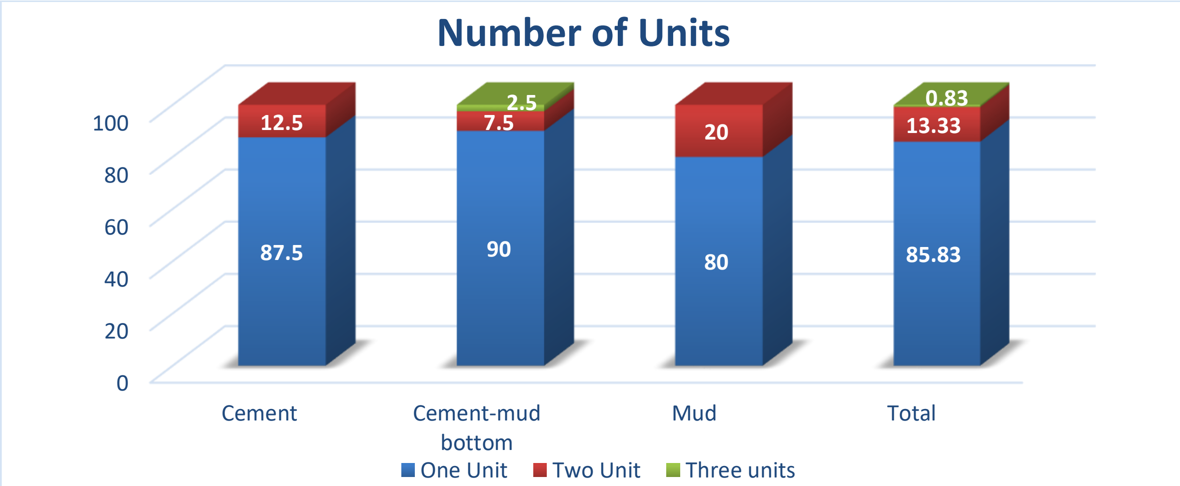


Figure 12: Number of Jhora pond units with the respondent fish farmers

Source of water: Among the selected respondent farmers using cement ponds, cement ponds with mud bottom and mud ponds, majority of them with 82.5%, 75% and 80% respectively, reported to receive water from Jhora, followed by spring and both the sources. Overall, for 79.17% of the respondents, Jhora was the source of water followed by spring (14.17%) and rest of the 6.67% uses both the sources.

Distance of water source: Total distance from the water source to the farm have been categorised into three groups, viz., short (<0.5km), medium (0.5-1km) and long (>1km). Among the selected respondent farmers using cement ponds, cement ponds with mud bottom and mud ponds, nearly 52.5%, 57.5% and 60% of them respectively reported that source of water is available to their culture ponds within the close proximity (<0.5 km.), while rest of them have at medium and long distance. Overall, nearly 56.67% of the farmers were reported to have water source available within close proximity, while 40.83% of them have at medium distance and for a few of them (2.5%), it is quite far away.

Table 4.2.1: Culture practices followed by selected Jhora fish farmers

Category		Cement pond		Cement pond with mud bottom		Mud pond		Total	
		No.	Share (%)	No.	Share (%)	No.	Share (%)	No.	Share (%)
Sample size		40		40		40		120	
Access to Schemes	Feed/Seed	27	67.5	27	67.5	30	75	84	70.00
	Blue Revolution	7	17.5	8	20	10	25	25	20.83
	FFDA	13	32.5	2	5	1	2.5	16	13.33
	MGNREGA	1	2.5	3	7.5	0	0	4	3.33
	Poly-lining	0	0	2	5	1	2.5	3	2.50
	Cultural Subsidy	1	2.5	0	0	0	0	1	0.83
Training Attended	Yes	34	85	35	87.5	38	95	107	89.17
	No	6	15	5	12.5	2	5	13	10.83
Experience	≤ 5 years	10	25	3	7.5	4	10	17	14.17
	6-10 years	7	17.5	10	25	12	30	29	24.17
	11-15 years	4	10	7	17.5	10	25	21	17.50
	>15 years	19	47.5	20	50	14	35	53	44.17
Learned fish Framing	Self	27	67.5	31	77.5	28	70	86	71.67
	Farmers	6	15	6	15	10	25	22	18.33
	FEO	7	17.5	3	7.5	2	5	12	10.00
Pond Size	<500 sq ft.	14	35	20	50	13	32.5	47	39.17
	500-1000 sq ft.	10	25	14	35	23	57.5	47	39.17
	1001-1500 sq ft.	13	32.5	3	7.5	2	5	18	15.00
	>1500 sq ft.	3	7.5	3	7.5	2	5	8	6.67
Number of Jhora Units	One unit	35	87.5	36	90	32	80	103	85.83
	Two units	5	12.5	3	7.5	8	20	16	13.33
	Three units	0	0	1	2.5	0	0	1	0.83
Source of Water	Jhora	33	82.5	30	75	32	80	95	79.17
	Spring	4	10	6	15	7	17.5	17	14.17
	Both	3	7.5	4	10	1	2.5	8	6.67
Distance of Water Source	< 0.5 km	21	52.5	23	57.5	24	60	68	56.67
	0.5-1 km	18	45	17	42.5	14	35	49	40.83
	> 1 km	1	2.5	0	0	2	5	3	2.50
Bio-integration	Yes	16	40	12	30	12	30	40	33.33
	No	24	60	28	70	28	70	80	66.67
Stocking Density	≤ 500	17	42.5	10	25	18	45	45	37.5
	501-1000	20	50	22	55	18	45	60	50
	≥1001	3	7.5	8	20	4	10	15	12.5
Fertilization	Yes	8	20	22	55	29	72.5	59	49.17
	No	32	80	18	45	11	27.5	61	50.83
Liming	Yes	17	42.5	14	35	19	47.5	50	41.67
	No	23	57.5	26	65	21	52.5	70	58.33

Source of Seed	DoF	15	37.5	18	45	15	37.5	48	40.00
	Vendor	4	10	3	7.5	0	0	7	5.83
	DoF & vendor	19	47.5	14	35	19	47.5	52	43.33
	DoF & river	1	2.5	3	7.5	2	5	6	5.00
	Vendor & river	1	2.5	0	0	3	7.5	4	3.33
	All	0	0	2	5	1	2.5	3	2.50
Species Cultured	Grass carp	40	100	39	97.5	40	100	119	99.17
	Common carp	34	85	36	90	38	95	108	90.00
	Silver carp	7	17.5	7	17.5	3	7.5	17	14.17
	Chocolate mahseer	6	15	6	15	10	25	22	18.33
	Tilipia	3	7.5	1	2.5	8	20	12	10.00
	Mrigal	7	17.5	2	5	2	5	11	9.17
Feed used	Floating feed	29	72.5	27	67.5	33	82.5	89	74.17
	Atta	36	90	35	87.5	30	75	101	84.17
	MOC	7	17.5	7	17.5	1	2.5	15	12.50
	Rice	12	30	11	27.5	17	42.5	40	33.33
	Grass	40	100	39	97.5	40	100	119	99.17
	Rice husk	3	7.5	4	10	0	0	7	5.83
	Meat/eggs	3	7.5	3	7.5	0	0	6	5.00
	kitchen waste	3	7.5	1	2.5	0	0	4	3.33
Harvesting Method	Netting	33	82.5	39	97.5	36	90	108	90.00
	Doko	1	2.5	1	2.5	3	7.5	5	4.17
	Total drainage	6	15	0	0	1	2.5	7	5.83
Culture Period	< 12 months	8	20	10	25	3	7.5	21	17.50
	12 months	29	72.5	30	75	37	92.5	96	80.00
	> 12 months	3	7.5	0	0	0	0	3	2.50
Harvesting Month	August	2	5	1	2.5	3	7.5	6	5.00
	September	1	2.5	10	25	11	27.5	22	18.33
	October	28	70	19	47.5	20	50	67	55.83
	November	4	10	8	20	3	7.5	15	12.50
	December	5	12.5	2	5	3	7.5	10	8.33
Survival Rate	<60%	8	20	6	15	2	5	16	13.33
	60-80%	14	35	23	57.5	23	57.5	60	50.00
	>80%	18	45	11	27.5	15	37.5	44	36.67
Cause of Mortality	Disease	8	20	8	20	2	5	18	15.00
	Water stop	23	57.5	13	32.5	15	37.5	51	42.50
	Lack of Food	0	0	1	2.5	3	7.5	4	3.33
	Weather change	1	2.5	4	10	3	7.5	8	6.67
	Transport stress	8	20	12	30	16	40	36	30.00

	Others	0	0	2	5	1	2.5	3	2.50

Bio-integration: Nutritious water that flows out of the Jhora ponds was reported to be directed towards the field to grow crops leading to bio-integrating of Jhora fisheries with crop culture. It was observed that 40%, 30% and 30% of the selected Jhora farmers respectively have been using bio-integration in their cement ponds, cement ponds with mud bottom and mud ponds. Overall, 33% of the respondent farmers had practiced bio-integration, while 67% of them did not follow this practices.

Stocking density per 500 sq ft.: Number of fingerlings stocked in the ponds by the Jhora fish farmers have been grouped into three categories viz., <500, 500-1000 and >1000. Among the selected respondent farmers using cement ponds, cement ponds with mud bottom and mud ponds, nearly 50%, 50% and 45% respectively had reported to stock fingerlings between 500-1000, followed by less than 500 and more than1,000 per 500 sq ft. of pond area. Overall, 50% of the respondent farmers were reported to stock fingerlings in the range of 501 to 1001 followed by 37.5% of them to stock ≤500 fingerlings and 12.5% of them to stock ≥1001 fingerlings per 500 sq ft. of pond area. An average stocking density of Jhora fish pond has been found to be 691.4 fingerlings per 500 sq ft. (1,48,843.4 /ha) which is comparatively less than as reported by Mukherjee *et al.* (2013), i.e., 746.66/ 500 sq ft. However, it is very high as compared to the usual stocking density in ponds with normal productivity status, i.e., 5000 fingerlings/ha (Jhingran, 1991).

Fertilization: Only 20% of the Jhora fish farmers having cement ponds used manure to fertilize their ponds. However, in case of cement ponds with mud bottom and mud ponds, 55% and 72.5% of them had reported that they had used manure to fertilize their ponds. It has been noticed that manure is not very useful, especially in cement pond, as Jhora fisheries mainly depend on artificial feeding. Overall, 49.17% of the respondent farmers applied manure, while none of the farmers reported to be using inorganic fertilizers. These figures are relatively higher than other fish farmers in West Bengal, where nearly 64% of them did not apply manure (Abraham *et al.* 2010).

Liming: Among the selected respondent farmers using cement ponds, cement ponds with mud bottom and mud ponds, it has been found that 42.5%, 35% and 47.5% of the respondents respectively applied liming in their ponds. Overall also 41.67% of the respondent farmers used lime.

Source of seed: Most of the respondents culturing in cement ponds brought fingerlings from DoF/vendors (47.5%), followed by DoF (37.5%) only, vendors (10%) only and 2.5% of them from either DoF/river or vendors/river. Whereas, in case of culturing in cement ponds with mud bottom, they had received fingerlings from DoF only (45%), followed by DoF/vendors (35%), DoF/river (7.5%), only vender (7.5%) and remaining 5% have used all the sources. Those, who are culturing in mud ponds, 47.5% of them brought from DoF/vendors followed by DoF (37.5%) only, vendors/river (7.5%), DoF/river (5%) and remaining 2.5% have used all the sources to obtain fingerlings. Overall, for seed collection, nearly 40% of the farmers had reported to rely only on DoF while 51% of them have brought from DoF & other sources, 6% from vendors and rest 3% from rivers/vendors. However, during field survey, it has been noticed that none of the Jhora fish farmers were engaged in producing their own seeds, whereas Abraham *et al.* (2010) reported that 10.26% of fish farmers from other parts West Bengal produced their own seeds.

Species cultured: All the respondent farmers using three types of Jhora ponds were practicing for poly-culture, with similar types of species. Overall, 99.17% cultured grass carp, 90% cultured common carp, 18.33% cultured chocolate mahseer, 14.17% cultured silver carp, 10% cultured tilapia and 9.17% cultured mrigal.

Feed used: All the selected framers had reported using similar kinds of feed. However, those using mud pond did not report the use of rice husk, meat/eggs and kitchen waste. Overall, feed used by the respondent farmers were mainly grass (91.17%), wheat flour (84.17%) and floating feed (74.17%), whereas *Abraham et al.* (2010) reported that mainly mustard oil cake was used by 84% of WB fish farmers and no one had used floating/pelleted feed.

Source of feed: 94.38% of the respondent Jhora fish farmers using floating feed are dependent on DoF, West Bengal, whereas 2.25% of them brought feed from Jalpaiguri and 3.37% got from both the sources. For all the Jhora fish farmers, grass was readily available at their farm itself. Other types of feeding materials, majority of them (96.36%) reported to be buying from the nearby ration shops, and some of them were using kitchen waste also.

Harvesting method: Majority of the fish farmers (82.5%) having cement ponds used netting for harvesting followed by total drainage (15%) and use of bamboo doko (2.5%). Those who are having cement ponds with mud bottom, 97.5% of them had reported netting followed by the use of bamboo doko (2.5%) for harvesting. And farmers, who are having mud ponds, 90% of them had reported netting followed by bamboo doko (7.5%) and total drainage (2.5%) for harvesting. Overall, 90% of the respondent farmers had reported the use of netting as the most preferred option for harvesting.

Culture period: Three categories of culture period have been considered for Jhora fisheries, viz, <12 months, 12 months, > 12 months. It had been noticed that among the selected respondent farmers using cement ponds, cement ponds with mud bottom and mud ponds, majority of them with 72.5%, 75% and 92.55 respectively, cultured fish for 12 months. Usually, the culture period ranged from 8 months to 14 months, but 80% of them had reported that it lasts for 12 months, while Mukherjee *et al.* (2013) reported that culture period of Jhora fisheries lasts for eight months only.

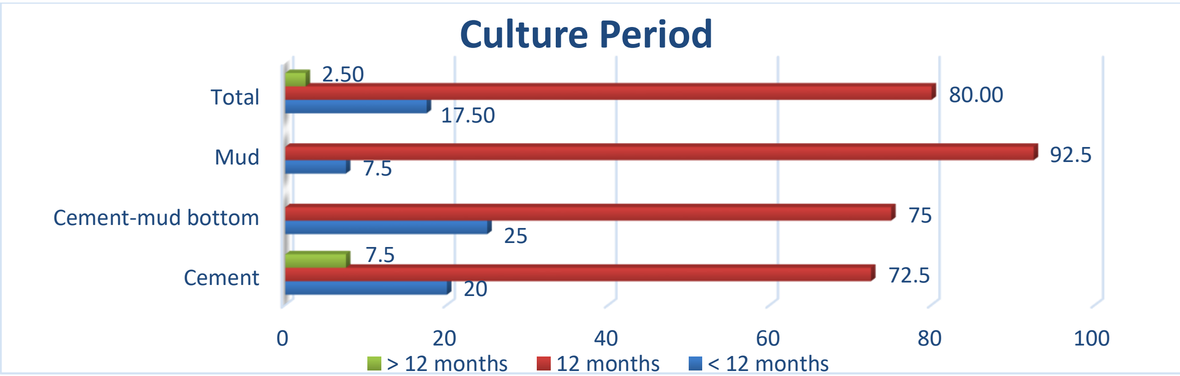


Figure 13: Culture period of Jhora Fisheries

Harvesting month: It had been observed that among the selected respondent farmers using cement ponds, cement ponds with mud bottom and mud ponds, nearly 70%, 47.5% and 50% of them respectively harvested fish in October month. Overall, nearly 55.83% of them had reported that harvesting is done in the month of October, 18.33% of them do in September, 12.50% in November, 8.33% in August and 5% in December.

Survival rate: Survival rate of fish stocked in Jhora ponds has been categorised as <60%, 60-80%, >80%. Most of the respondents (45%) using cement ponds had reported that more than 80% of the fish stocked survived, followed by 60-80% and less than 60% survival. Whereas, majority of fish farmers (57.5%) using cement ponds with mud bottom and mud ponds had reported survival of 60-80% in both the cases, followed by more than 80% and less than 60% survival. Overall, 50 % of them had reported getting survival rate between 60-80%, which was found to be comparatively better than other fish farmers of West Bengal, where only 41% had a survival rate between 60-80%, as reported by *Abraham et al.* (2010).

Cause of mortality: Nearly, 57.5% of the selected fish farmers having cement ponds and 32.5% having cement ponds with mud bottom had reported that water stoppage is the main cause of mortality, whereas 40% of the selected farmers having mud ponds reported that stress due to transportation is the main cause of mortality. Overall, 42.5% of the respondent Jhora fish farmers had reported water stoppage is the main reason for mortality in all the three types of ponds because when water stops, the D.O. falls, which results in mortality. This is followed by stress due to transportation (30%) as they expressed that fingerlings distributed by DoF, West Bengal are in a moribund condition till the time it reaches to the ponds.

Average production per 500 sq ft.: Average production reported by Jhora fishers having three types of ponds, viz., cement ponds, cement ponds with mud bottom and mud ponds had been 43.40 kg, 44.90 kg and 44.80 kg per 500 sq ft., respectively. Overall average production of Jhora ponds has been found 44.37 kg/500sq ft. (9551 kg/ha) which is very high, compared to average freshwater fish production in West Bengal [4000-4750 kg/ha/year (Handbook of Fisheries Statistics, 2017-2018)].

Marketing: All the Jhora fish farmers had reported selling fish directly at farm itself to the locals in Darjeeling hill region.

4.3 Economics of Jhora Fisheries.

4.3.1 Fixed capital investment pattern on selected Jhora fish ponds

An ideal Jhora ponds unit is of size 500 sq ft. (DoF, Govt. of West Bengal) and the three types of ponds were constructed under various schemes like FFDA, Blue Revolution and MGNREGA, and also self-financed by the farmer. The fixed capital investment pattern of Jhora fisheries ponds has been estimated per 500 sq ft. (Table 4.3.1), since the size of Jhora ponds in the study area ranges from 250 sq ft. to 4000 sq ft.

Among the selected respondent farmers using cement ponds, cement ponds with mud bottom and mud ponds, table 4.3.1 reveals that the total investment made on the selected ponds have found out to be ₹32,033.16, ₹22,469.57 and ₹8,821.27 per 500 sq ft., respectively. The major investment for all three types of ponds was for pond construction, which accounted 84.36% for cement ponds, 85.60% for cement ponds with mud bottom and 73.67% for mud ponds. Gawa *et al.* (2017) had reported similar findings that the construction of cement raceways accounts for 67.60% of the total fixed investment in Kashmir.

Table 4.3.1: Fixed Capital Investment pattern on the different type of Jhora ponds

(Investment in ₹)

	Cement Pond (n=40)		Cement Pond with mud bottom (n=40)		Mud Pond (n=40)	
Particulars	₹/500 ft^2	%	₹/500 ft^2	%	₹/500 ft^2	%
Pond Construction	27,054.99	84.46	19,234.38	85.60	6,498.75	73.67
Fencing	3066.40	9.57	672.6948	2.99	315.47	3.58
Pipeline	847.99	2.65	1079.44	4.80	868.18	9.84
Nylon net	498.45	1.56	747.79	3.33	526.21	5.97
Buckets	204.43	0.64	262.04	1.17	197.49	2.24
Weigh balance	360.90	1.13	473.23	2.11	415.16	4.71
Total	32033.16		22469.57		8821.27	

For cement ponds, fencing has 9.57% of the share of cost incurred, followed by pipeline (2.65%), nylon net (1.56%), weigh balance (1.13%) and buckets

(0.64%). In case of cement ponds with mud bottom, pipeline has 4.80% share in other investments followed by nylon net (3.33%), fencing (2.99%), weigh balance (2.11%) and buckets (1.17%). For mud ponds, pipeline has 9.84 % of share of other cost followed by nylon net (5.97%), weigh balance (4.71%), fencing (3.58) and buckets (2.24%).

From these findings, it can be concluded that cement pond followed by cement ponds with mud bottom requires higher initial investment as compared to mud ponds due to high cost of construction material and labour charges. Olaoye (2013) also reported a substantial difference between initial fixed cost in earthen and concrete pond, which was lower for earthen pond.

4.3.2 Input use pattern on selected Jhora ponds

The input pattern on three types of Jhora ponds have been evaluated and presented in table 4.3.2. This table shows that fingerlings stocked in three types of ponds have been found to be 586.81, 845.2 and 642.19 per 500 sq ft., respectively. Floating feed had been used @ 42.27 kg/500 sq ft. in cement ponds, 52.41 kg/500 sq ft. in cement ponds with mud bottom and 67.23 kg/500 sq ft. for mud ponds. In addition to this, other feeds used had reported to be made of locally available materials. Other feed in three types of ponds have been reported @ 235.44 kg, 300.94 kg and 187.01 kg per 500 sq ft.

Table 4.3.2: Input use pattern in selected Jhora fish ponds

(Input use in kg per 500 sq ft.)

Inputs	Cement Pond (n=40)	Cement Pond with mud bottom (n=40)	Mud Pond (n=40)
Fingerlings (no.)	586.81	845.2	642.19
Floating feed	42.27	52.41	67.23
Other feed	235.44	300.94	187.01
Grass	1300.27	1515.91	1455.30
lime	0.74	1.03	1.31
Manure	0.64	4.66	5.78

As Jhora fisheries include culture of grass carp, grass has been one of the major inputs in terms of quantity. Grass has been used by Jhora fish farmers @ 1300.27 kg, 115.91 kg and 1455.30 kg per 500 sq ft. in three types of ponds. Other inputs used for fish culture has been found to be lime and cattle manure used for fish culture. These findings indicate that the farmers having cement ponds uses lesser inputs as compared to the farmers having other two types of ponds.

4.3.3 Costs and return in selected Jhora ponds

The cost and returns of Jhora fisheries in the Darjeeling Himalayan hill region have been obtained for three types of Jhora ponds separately and are presented in the table 4.3.3.

Table 4.3.3: Cost and Returns for three types of Jhora ponds

(values in ₹/500 ft.^{2})

	Cement pond (n=40)		Cement pond with mud bottom (n=40)		Mud pond (n=40)	
PARTICULARS	₹/500 ft.^{2}	%	₹/500 ft.^{2}	%	₹/500 ft.^{2}	%
Seed cost	1,131.92	11.58	1,637.93	16.15	1,487.64	20.76
Floating feed cost	1,479.57	15.14	1,834.27	18.09	2,353.11	32.84
Other feed cost	726.24	7.43	1,418.35	13.99	420.54	5.87
Transportation cost	82.40	0.84	86.20	0.85	209.75	2.93
Casual labour cost	217.68	2.23	339.48	3.35	281.64	3.93
lime cost	10.04	0.10	14.31	0.14	20.13	0.28
Miscellaneous	146.38	1.50	359.03	3.54	275.42	3.84
Total working capital	3,794.24		5,689.57		5,048.22	
Interest on Working Capital	214.37	2.19	321.46	3.17	285.22	3.98
TOTAL VARIABLE COST	**4,008.61**	**41.03**	**6,011.04**	**59.27**	**5,333.44**	**74.43**
Depreciation	1441.49	14.75	1011.13	9.97	444.31	6.20
Interest on Fixed Cost	3,843.98	39.34	2,696.35	26.59	1,184.83	16.53
Annual repair & maintenance	477.00	4.88	423.17	4.17	203.39	2.84
TOTAL FIXED COST	**5,762.47**	**58.97**	**4,130.65**	**40.73**	**1,832.53**	**25.57**
TOTAL COST	**9,771.08**		**1,0141.69**		**7,165.98**	
TOTAL PRODUCTION(KG)	43.40		44.90		44.80	
COST OF PRODUCTION (₹/KG)	225.16		225.88		159.95	
SELLING PRICE (₹/KG)	238.50		263.75		252.25	
FARMERS MAGGINE (₹/KG)	13.34		37.87		92.30	
GROSS REVENUE	**10,350.07**		**11,841.97**		**11,301.37**	
NET REVENUE	578.99		1,700.28		4,135.39	
B:C RATIO	**1.06**		**1.17**		**1.58**	

4.3.3.1 Cost and returns for cement pond:

Table 4.3.3 shows that total cost of fish culture in cement pond has been found out to be ₹ 9,771.08 per 500 sq ft. having 41.03% share of total variable cost and 58.97% share of total fixed cost. Interest on fixed cost holds the highest share to the total cost (39.34%) whereas, Singh *et al.* (2008) had reported that major cost component was feed cost, accounting 52.45% share of the total cost for pond fish farmers in Himachal Pradesh. Other components of total fixed cost like depreciation, annual repair and maintenance contributed 14.75% and 4.88 % respectively to the total cost. Among total variable cost, cost of floating feed has 15.14% share to the total cost, followed by seed cost (11.58%), other feed cost (7.43%), including the share of cost incurred on casual labour, transportation, lime, interest on working capital and miscellaneous.

By using cement ponds, the average cost of producing 1 kg of fish has come out as ₹ 225.16 and the average selling price of fish is ₹ 238.50 per kg with a margin of ₹ 13.34 per kg. Gross revenue from cement pond is ₹ 10,350.07 per 500 sq ft., while the total cost is ₹ 9,771.08 per 500 sq ft. with the benefit-cost ratio of 1.06, indicating economic viability of Jhora fisheries in cement ponds.

4.3.3.2 Cost and returns for cement pond with mud bottom:

Total cost for Jhora fish culture using cement ponds with mud bottom has been found out to be ₹ 22,469.57 per 500 sq ft., having 59.27% share of total variable cost and 40.73% share of total fixed cost. Similar to cement pond, interest on fixed cost holds the next highest share (26.59%) to the total cost along with other components such as depreciation, annual repair and maintenance contributed to the total cost. As far as total variable cost is concerned, cost of floating feed has maximum share (18.09 %) to the total cost, followed by cost of seed, other feed, transportation, casual labour, lime, interest on working capital and miscellaneous to the total cost.

By using cement ponds with mud bottom, average cost of producing 1 kg of fish has come out as ₹ 225.88 per 500 sq ft. and is similar to cement ponds. The average selling price of fish is ₹ 263.75 per kg with a margin of ₹37.87 per kg. Gross revenue from these ponds has been found to be ₹ 11,841.97 per 500 sq ft.

while the total cost of ₹ 22,469.57 per 500 sq ft. with benefit-cost ratio of 1.17, indicating economic viability of Jhora fisheries even in cement ponds with mud bottom.

4.3.3.3 Cost and returns for mud pond:

Total cost for Jhora fish culture using mud ponds has been found out to be ₹ 7165.98 per 500 sq ft., having 74.43 % share of total variable cost and 25.57 % share of total fixed cost due to low initial fixed investment in mud ponds. Singh *et al.* (2008) had also reported that fixed cost and variable cost constituted 21.77% & 78.23% share of total cost incurred by the pond fish farmers in Himachal Pradesh. In mud ponds, cost of floating feed holds the highest share (32.84%) to the total cost and is different than the other two types of ponds. Singh *et al.* (2015) had also reported feed cost contributes maximum to the total cost in Punjab. Total variable cost also includes the cost of other components such as seed, other feed, transportation, lime, casual labour, interest on working capital, and miscellaneous cost. As far as total fixed cost is concerned, interest on fixed cost has been found to hold the highest share (16.53 %) to total cost, followed by depreciation, annual repair and maintenance to the total cost.

By using mud ponds, average cost of producing 1 kg of fish has come out to be ₹ 159.95 and the average selling price is ₹ 252.25 per kg with a margin of ₹ 92.30 per kg. Gross revenue from mud ponds has been found to be ₹ 11,301.37 per 500 sq ft., while the total cost is ₹ 7165.98 per 500 sq ft. with benefit-cost ratio 1.58, indicating economic viability of Jhora fisheries even in mud ponds also.

Thus, as B-C ratio for Jhora fisheries in all three types of ponds resulted more than unity; therefore, Jhora fisheries is an economically viable business in the Darjeeling Himalayan hill region. However, Jhora fish farmers using mud ponds are found to receive higher benefits due to low cost of production as compared to other two types of ponds.

4.4 Technical Efficiency of Jhora Fisheries and its Determinants.

4.4.1 Econometric Assumptions

To estimate the technical efficiency (TE) of Jhora fisheries and factors affecting the technical efficiency of Jhora fisheries by using econometric tools, data set has been checked for econometric assumptions of heteroskedasticity and multicollinearity. Breusch Pagan test has been used to test heteroskedasticity and the problem of heteroskedasticity was not found (Appendix table 4). To check the multicollinearity problem among the explanatory variables, Variance Inflation Factor (VIF) has been used and if VIF > 10, problem of multicollinearity is indicated in the model, Gujarati (2004). However, VIF tests for multicollinearity confirmed the absence of multicollinearity among explanatory variables used in the model (Appendix Table 1, 2 and 3).

4.4.2 Hypothesis Testing

Hypothesis testing has been done by using generalized Likelihood-Ratio (LR) by using (Eq. No. 12, given in methodology) and results are presented in the following table 4.4.1.

Table 4.4.1: General likelihood ratio for hypothesis testing (n=120)

Null hypothesis	Log-likelihood function under		Likelihood ratio (λ)	df	5% critical value (χ^2)	Decision
$H_0: \delta_1 = \cdots = \delta_8 = 0$	H_0	H_1				
(no technical inefficiency or no inefficiency effect)	16.21	33.12	33.8	8	14.853	Rejected
The correct critical value for the H_0 is obtained from Table 1 in Kodde & Palm (1986, p.1246) with 8 dof.						

As the null hypothesis, which states that there is no technical efficiency, has been rejected at 5 % level of significance (LR. Statistics 33.8 ≥ critical Chi-square 14.85), therefore, the observed inefficiency among the Jhora fish farmers in the Darjeeling Himalayan hill region could be attributed to the farm-specific variables described in the model. These variables contributed a significant role in explaining the observed inefficiency and indicates the appropriateness of stochastic frontier model.

4.4.3 Stochastic Production Frontier Model and Estimation of Parameters by using Maximum Likelihood method

A stochastic production frontier model with Cobb-Douglas production function (equation no. 9 given in methodology) has been used to estimate the technical efficiency of Jhora fish farmers and to identify factors determining the inefficiencies (equation no.10, given in methodology) in Jhora fish production. Under the assumption of the truncated-normal distribution of error terms, one-stage procedure has been used to estimate the parameters. Maximum-likelihood estimates of the parameters for the stochastic production frontier model and those for the technical inefficiency model for Jhora fish production in the Darjeeling Himalayan hill region are presented in the following table 4.4.2.

Table 4.4.2: Maximum-likelihood estimates of Stochastic Production Frontier and Technical Inefficiency models for Jhora fisheries.

Variables	Parameters	Coefficient	Standard error	Z
Production Frontier model				
Constant	β_0	-.4828	.3951	-1.22
Ln(Stocking Density)	B_1	.1467 ***	.0408	3.59
Ln(Pond size)	B_2	.3838 ***	.0435	8.82
Ln(labour)	B_3	.0898 **	.0395	2.27
Ln(Floating feed)	B_4	.3956 ***	.0336	11.77
Ln(Other feed)	B_5	.1840 ***	.0385	4.77
Ln(Grass)	B_6	.1539 ***	.0304	5.06
Ln(Lime)	B_7	.0002	.0705	0.00
Ln(Manure)	B_8	-.0272	.0533	-0.51
Floating feed dummy	B_9	-1.3918 ***	.1573	-8.85
Other feed dummy	B_{10}	-.9121 ***	.2255	-4.04
Grass dummy	B_{10}	-.6893 **	.3142	-2.19
Lime dummy	B_{11}	-.0339	.1021	-0.33
Manure dummy	B_{12}	.1420	.1183	1.20
Technical Inefficiency Model				
Constant	δ_0	-7.6788 ***	2.7337	-2.81
Age	δ_1	.0108	.0330	0.33

Education	δ_2	-.2801 **	.1422	-1.97
Experience	δ_3	.3129 ***	.1085	2.89
Gender Dummy	δ_4	.9084	1.8776	0.48
Training Dummy	δ_5	-7.0574		
Household size	δ_6	.8563 ***	.2474	3.46
Cement pond Dummy	δ_7	-14.9319	16.5605	-0.90
Mud pond Dummy	δ_8	2.7719 *	1.4326	1.93
Variance parameters				
	$\sigma_s^2 = \sigma_u^2 + \sigma_v^2$	0.512 ***		
	$\gamma = \sigma_u^2/\sigma_s^2$	0.95 ***		
Log likelihood = 33.1230				

***, **, * represents significance at 1%, 5% and 10% probability levels, respectively

Results of maximum likelihood estimation mentioned in the above table indicate that all slope coefficients of inputs for Jhora fish farmers had the expected significant signs. Except for lime and manure, all slope coefficients for stocking density, pond size, floating feed, other feed and grass are highly significant (p≤0.01) and for labour, slope coefficient is significant (p≤0.05). Thus, there is a potential of increasing fish production through raising the levels of these inputs. With low levels of lime and manure used, insignificant coefficients for these inputs were expected.

4.4.4 Determinant of Technical Efficiency

Current study investigated farm and fish farmer-specific attributes that had an impact on Jhora fish farmer's technical efficiency. Results of technical inefficiency model are presented in terms of inefficiency in the above table 4.4.2. Negative sign of the coefficient shows that the variable has negatively contributed to inefficiency level and reduced the inefficiency. This implies its positive effect in increasing or improving the efficiency of the Jhora fish farmer and vice versa.

Education is the most common factor affecting Jhora fish farmer's efficiency (P≤0.05). Results indicate that higher educated farmers are more technically efficient as compared to less educated ones. These findings are similar as reported by Schultz (1964), which states that education increases the ability to perceive, interpret and respond to new events and enhances farmer's managerial skills, including efficient use of agricultural inputs. Dey *et al.* (2005) also reported that education was the most important factor influencing TE of semi-intensive fish farms in India.

Experience showed a negative effect on technical efficiency and found significant at 1% level of significance, indicating that TE decreases if older farmers with more experience are involved in Jhora fisheries. Onu *et al.* (2000), Fasasi (2007), Raphael (2008) and Singh *et al.* (2009) had also found similar results. Experience has a negative effect, mainly because young and educated Jhora fish farmers are willing to implement new technologies with better management practices. Therefore, they are technically efficient and more progressive than other farmers having more experience.

Household size also showed a negative effect on technical efficiency and found significant at 1% level of significance. The negative effect of household size, maybe as mentioned by Bekata *et al.* (2013) that a larger family with more dependents decreases efficiency in farming due to low supply of farming labor.

Training and dummy for cement pond showed a positive effect on technical efficiency but are not significant.

Dummy for mud pond showed a negative effect on technical efficiency and found significant at 10 % level of significance, indicating farmers using mud pond as less technically efficient.

4.4.5 Variability of output due to Technical Efficiency differentials

Maximum Likelihood estimation of the stochastic frontier model mentioned in table 4.4.2 gives value for the variance parameter (γ), i.e., the variance ratio,$\gamma = \sigma_u^2/\sigma_s^2$, where $\sigma_s^2 = \sigma_u^2 + \sigma_v^2$. This value of γ indicates the relative variability of one-sided error term to total error-term. The estimated value of variance parameter (γ) has been found close to 1 (0.95) and highly significant at 1% level of significance. This implies that 95% variation in the output is due to the differences in technical efficiencies of Jhora fisheries household, while the remaining 5% is due to the effect of disturbance term or random factors, which are beyond the control of Jhora fish farmers.

4.4.6 Technical Efficiency of Jhora fisheries

Technical Efficiency of Jhora fisheries has been estimated by using (Eq. No. 11, given in methodology) and the summary results mentioned in the following Table 4.4.3

Table 4.4.3: Summary of Technical Efficiency of Jhora fisheries

Variable	Observations	Mean	Std. Dev.	Minimum	Maximum
Technical Efficiency	120	.90	.114	.46	.98

Results mentioned above indicate that the mean efficiency level of Jhora fish farmers is 90% with minimum efficiency level 46 % and maximum efficiency level 98%. Sharma and Leung (2000) and Dey *et al.* (2005) also reported similar findings stating that mean TE of semi-intensive fish farms in India was 0.805 and 0.86. Figure 14 depicts the technical efficiency of selected Jhora fish farmer's households, indicating more than 70% of selected Jhora fish farmers fall above the mean TE score, while only 30% of them fall below the mean TE score.

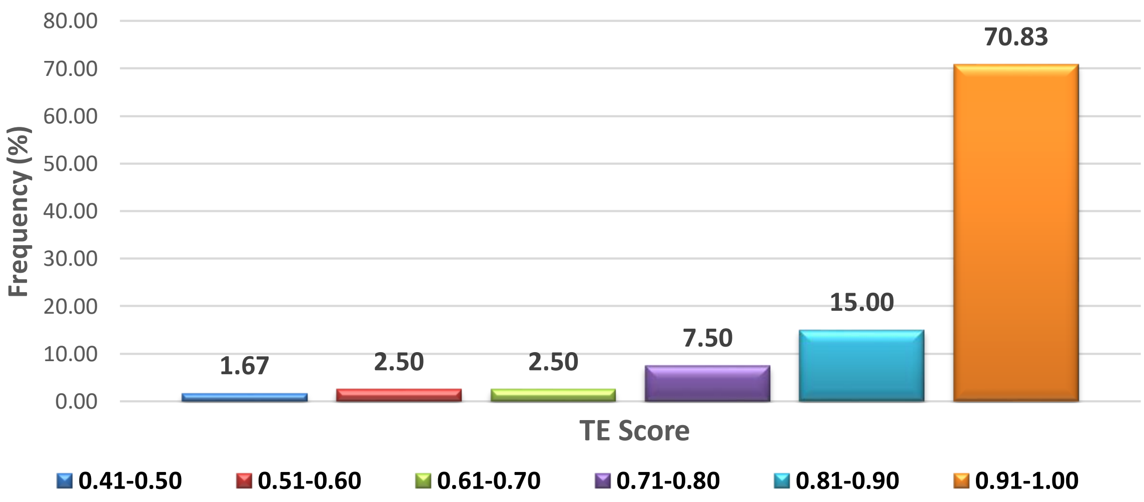


Figure 14: Technical efficiency of selected Jhora fish farmers

Current study indicates that there is little disparity in technical efficiency level of Jhora fish farmers. However, on average, the Jhora fish production can be raised by 10 % in the Darjeeling Himalayan hill region with the existing technology and resources.

4.5 Constraints Faced by Jhora Fish Farmers and to Suggest Suitable Measures

Rank-based quotient has been calculated by using (Eq. No. 15, given in methodology) to quantify the constraints faced by Jhora fish farmers. Farmers were asked to rank four different constraints category with 27 sub-heads according to their preference from 1 to n in such a way that smaller rank, i.e., 1 for major constraint and larger rank, i.e., n for minor constraint. The technical, environmental, infrastructure and economic constraints faced by the respondent Jhora fish farmers have been discussed below:

4.5.1 Technical Constraints

Table 4.5.1 describes the technical constraints faced by Jhora fish farmers in the Darjeeling Himalayan hill region. Results indicate that the respondents had ranked non availability of quality feed and less availability of quality seed as the major constraints with an RBQ score of 84.91 and 79.44, respectively. As floating feed was not available locally, farmers had to buy that from Jalpaiguri district. It was also reported that seed from the vendors was not of good quality and showed a slower growth rate. Almost all the respondent farmers believed that they have less knowledge of modern and scientific fish farming, with an overall RBQ score of 60.65 (Rank III). However, Mohanthy *et al.* (2011) had reported lack of awareness and technical knowledge as the most important constraint (RBQ:100) faced in aquaculture practices. The fourth major constraint was seepage of water with an overall RBQ score of 58.33 as to a greater extent, this problem was faced by fish farmers with cement ponds and they could overcome by using poly-lining. Maintenance of water line was ranked fifth with an overall RBQ of 48.61 as the farmers had to wait for hours, if there has been any interruption in the water supply. However, transportation of feed/seed, mortality rate and technical guidance were not reported as that important constraint by the Jhora fish farmers as these issues received comparatively lower RBQ.

Table 4.5.1: Technical Constraints faced by the Jhora fish farmers

Technical Constraints								
	Cement Pond (n=40)		Cement-Mud bottom pond (n=40)		Mud Pond (n=40)		Over all (n=120)	
Constraints	RBQ Score	Rank	RBQ Score	Rank	RBQ Score	Rank	RBQ Score	Rank
Non availability of quality feed	83.89	I	85.00	I	85.83	I	84.91	I
Less availability of Quality Seed	79.44	II	82.22	II	76.67	II	79.44	II
Less knowledge on Modern & scientific fish farming	59.72	IV	62.78	III	59.44	III	60.65	III
water seepage	62.22	III	55.00	IV	57.78	IV	58.33	IV
Maintenance of Water line	44.72	VIII	50.83	V	50.28	VI	48.61	V
Difficulties in Transportation of feed	47.22	VII	41.94	VII	54.72	V	47.96	VI
High rate of Mortality	49.17	VI	48.61	VI	35.46	IX	44.44	VII
Difficulties in Transportation of seed	49.44	V	39.44	VIII	40.28	VII	43.06	VIII
Less Technical Guidance	26.39	IX	37.78	IX	39.44	VIII	34.54	IX

4.5.2 Environmental Constraints

Table 4.5.2 describes the environmental constraints faced by Jhora fish farmers in the Darjeeling Himalayan hill region. Results indicate that the respondents had ranked predation as the most important environmental constraint with an overall RBQ score of 71.46, since birds eat the fish when the size is small which can be checked by using leaf netting to cover the ponds. Even fish farmers also get affected by snakes, animals and crabs also and this can be checked by using of small mesh fencing. Natural disaster has been found as a second constraint with an overall RBQ of 67.71, as landslides during monsoon resulted in breakage of water pipes and hindered transportation also. Third constraint has been found pollution in Jhora with an overall RBQ score of 56.66 due to dumping of waste in the nearby Jhora and in that situation, some farmers had to change the water source to get fresh water for fish farming. Disease outbreak has been found as the least faced environmental constraint with an overall RBQ of 55.41, as majority of farmers get fresh water but some of them had experienced fungal disease also. Whereas Abraham *et al.* (2010)

reported disease as the most important constraint faced by 82% of the fish farmers from different parts of West Bengal.

Table 4.5.2: Environmental Constraints faced by Jhora fish farmers

Environmental Constraints								
	Cement Pond (n=40)		Cement-Mud bottom pond (n=40)		Mud Pond (n=40)		Over all (n=120)	
Constraints	RBQ Score	Rank	RBQ Score	Rank	RBQ Score	Rank	RBQ Score	Rank
Predation	71.25	I	74.38	I	68.75	II	71.46	I
Natural Disaster	58.13	IV	72.5	II	72.50	I	67.71	II
Pollution in Jhora	61.25	II	50.63	IV	58.13	III	56.66	III
Disease outbreak	58.75	III	56.25	III	51.25	IV	55.41	IV

4.5.3 Infrastructural Constraints

Table 4.5.3 describes the infrastructural constraints faced by Jhora fish farmers in the Darjeeling Himalayan hill region. Results indicate that the respondents had reported non availability of hatchery as the major infrastructure constraint with an overall RBQ score of 83.2. This is mainly because of the availability of only one hatchery (Reyang Hatchery) in the hills, which has not been operational since long and farmers have to buy fish seeds from the neighbouring Jalpaiguri district. Non availability feed mill has been found as the second major constraint with an overall RBQ score of 82.74, as no feed manufacturing facility is available in the hilly regions and floating feed used to be brought from Jalpaiguri district. Poor development of road and transportation has been found as the third constraint with an overall RBQ of 71.07. It has been observed that proper roads are yet to be developed and most of the farmers had to walk a long way from their places. Inadequate marketing facility has been found as the fourth constraint with overall RBQ score of 70.12, as the region does not have any established hygienic fish market for local fish produce. However, communication facility, power supply, drinking water and daily needs with lower RBQ score of 41.31, 33.81 and 17.74, respectively are not found as the important constraints for the respondent farmers.

Table 4.5.3: Infrastructure Constraints faced by Jhora fish farmers

Infrastructure Constraints								
	Cement Pond (n=40)		Cement-Mud bottom pond (n=40)		Mud Pond (n=40)		Over all (n=120)	
Constraints	RBQ Score	Rank	RBQ Score	Rank	RBQ Score	Rank	RBQ Score	Rank
Non availability of Hatchery	86.43	I	85.00	I	78.21	II	83.21	I
Non availability of Feed Mills	81.43	II	81.79	II	85.00	I	82.74	II
Poor Development of Roads & Transport Facility	64.64	IV	71.07	IV	77.50	III	71.07	III
Inadequate Marketing Facility	71.79	III	73.21	III	65.36	IV	70.12	IV
Less Communication Facility	49.64	V	39.29	V	35.00	VI	41.31	V
Irregular Power Supply	27.50	VI	33.57	VI	40.36	V	33.81	VI
Shortage of Drinking Water & Daily needs	18.57	VII	16.07	VII	18.57	VII	17.74	VII

4.5.4 Economic Constraints

Table 4.5.3 describes the economic constraints faced by Jhora fish farmers in the Darjeeling Himalayan hill region. Results indicate that mostly farmers with cement and cement-mud bottom ponds ranked self-finance and high initial investment as the top two economic constraints with an overall RBQ score of 79.17 & 71.07, respectively. Initial fixed investment in these two types of ponds are relatively higher, i.e., ₹32,033.16 /500 sq ft. & ₹24,469.57 /500 sq ft., respectively as compared to mud pond (₹8,821.27 /500 sq ft.). Lack of financial support in the form of subsidy has been found the third major constraint with an overall RBQ score of 68.10. Since subsidies are mainly provided under TSP and could be availed by the ST & SC category farmers only, hence other farmers are deprived of subsidies. Fourth constraint has been found as the high price of feed with an overall RBQ score of 67.38. Since feed was brought from Jalpaiguri district, its price increases from ₹35/kg to almost ₹50/kg due to additional transportation costs. Non availability of credit, problem of theft and high price of seed was not an important constraint for the respondents with lower RBQ score. In contrast, Rahaman *et al.* (2013) had reported theft and pilferages as the most important constraint of fish production in West Bengal.

Table 4.5.4: Economic Constraints faced by Jhora fish farmers

Economic Constraints								
Constraints	RBQ Score	Rank	RBQ Score	Rank	RBQ Score	Rank	RBQ Score	Rank
Self-finance	86.43	I	81.07	I	70.00	III	79.17	I
High Initial Investment	73.21	II	74.29	II	65.71	IV	71.07	II
Lack of Financial Support / Subsidies	61.43	IV	68.93	III	73.93	II	68.10	III
High Price of Feed	65.36	III	62.50	IV	74.29	I	67.38	IV
Availability of Credit	53.21	V	56.07	V	50.00	V	53.09	V
Problem of Theft	30.71	VI	28.57	VI	32.50	VI	30.59	VI
High Price of Seed	28.93	VII	28.21	VII	31.79	VII	29.64	VII

4.5.5 SUGGESTIONS

The Darjeeling Himalayan hill region of West Bengal, also known as "the Queen of the Hills," has ample of Jhoras, springs, streams and rivers. It could be understandable that many people have started Jhora fisheries from a long time, knowing the easiness and profitability of fish culture including the nutrition benefits. Keeping in mind the supply gap of fish in the hills and its dependency on neighboring states like Andhra Pradesh, scientific fish farming and the use of modern technology in Jhora fish farming is required to fulfil the demand for growing population in the hills. In order to make the Jhora fish culture more remunerative to attract younger generation following suggestions have been proposed based on the observation and findings of the study, which will help policy makers in increasing production and developing marketing facilities in the hills.

1. It was observed that Department of Fisheries, Government of West Bengal assisted most of the Jhora fish farmers in the hills for inputs like floating feed, seed, etc., which have limited supplies and lead to inadequate use of inputs in Jhora fish farming. Thus resulting in low yield and low return from fish farming. Thus, Department of Fisheries, West Bengal can help the farmers as well as other locals to avail different schemes of PRADHAN MANTRI MATSYA SAMPADA YOJANA (PMMSY), which was approved by the Government of India in May, 2020, such as:

- Local youths, business people, cooperatives, farmers, etc., can take the initiative in the construction of mini, medium and large feed mills to remove the biggest problem of feed scarcity.

- Private hatcheries can be started locally, thus making quality seed readily available.
- Farmers can be encouraged to take up modern techniques like bio-flocks to counter the unavailability of feed, as bio-flocks technique reduced feed intake by almost fifty percent.
- It was observed that Jhora fisheries were practiced only by farmers having a regular and continuous supply of fresh water. So, techniques like Recirculating Aquaculture System can be adopted by youths and farmers with low water supply also.

All of these can be availed by the local farmers under PMMSY, with some technical help from the Department of Fisheries for framing the detailed project report (DRP).

2. The Department of Fisheries, West Bengal, should arrange advanced training programs for the block FEOs and send them to different training institutes in the country, to learn more about better management and new techniques.
3. Department of Fisheries, West Bengal, can run its Reyang Hatchery, which has been non-functional for a long time. Once it starts operating, the problem of quality seed scarcity will no longer exist.
4. Very little social participation of the respondent farmers was observed. Formation of social groups like cooperatives and SHG should be encouraged so that farmers in groups can efficiently deal with problems of various inputs marketing.
5. As the production was less, marketing was smooth for most of the farmers and the produce were being sold directly at the farm. To motivate the farmers and boost production, better marketing infrastructure is the need of the hour. It was noticed that a new fish market for the local Jhora fish was under construction in block 1 of Kalimpong District. However, similar fish market should be developed in all the blocks of the hills, where exclusively local fish could be sold and purchased.
6. Farmers believed to have less knowledge of modern & scientific fish farming and almost half of the farmers lacked basic knowledge on fish farming like liming and manure. So, there is a need of their skill development with modern

farming practices, including input use and there benefits. The Department of Fisheries, West Bengal, could come up with exciting demonstration programs to help the farmers more about fish culture.

7. Fish farming was found to be a supplementary business with the main focus on agriculture. So, there is a need to educate youth and local farmers about the ease and profitability of Jhora fisheries.

8. The price of fish in the hills is relatively high as the majority of supply comes from the plains. With better production, fish could be sold at a lesser price compared to that from the plains, fill the supply gap and will be available as a cheaper and better source of protein. Therefore there is a need to popularise fish farming as a profitable enterprise among the rural youth. Thus, it can help generate livelihood and employment opportunities with low investment.

9. Both the seeds that were provided by the Department of Fisheries and those brought from the vendors were found to be of variable sizes. Hence, seeds of advanced fingerling size should be provided, so that the mortality rates will reduce, survival rates will be increase and better production can be achieved.

10. Department of Fisheries should take necessary steps to ensure local availability of inputs, as they are available in other districts either through own retail units or through private participation. It will reduce transportation cost also.

11. Construction of mud ponds should be given more preference as Jhora fish culture in mud pond was more profitable.

12. Department of Fisheries, along with the Gorkhaland Territorial Administration (GTA), should arrange for issuing an angling license and thus integrating fisheries with tourism, earning revenue and boosting local tourism.

SUMMARY & CONCLUSION

5 SUMMARY & CONCLUSION

The state of West Bengal is one of the leading states in fish production and has a special type of fish culture, known as “Jhora Fisheries”, which dates back to the period 1981. Jhora fishery is the traditional way of fish culture in hilly cold water streams and if properly managed, it could be an excellent resource for fisheries development in the Darjeeling hill region. Department of Fisheries, West Bengal initiated popularization of Jhora fisheries through scientific management practices during 1981-82 and it has emerged as a means of livelihood for the Darjeeling hills population.

Keeping in view the importance of fish in providing nutrition and livelihood to people of Darjeeling hills, a systematic study has been carried out to analyse the economics of Jhora fisheries developed in three different types of ponds, viz., cement ponds, cement with mud bottom ponds and mud ponds in Darjeeling Himalayan hill region of West Bengal. Till date, no such studies had been carried out in hills, therefore to address the economic importance of Jhora fisheries, the present study entitled “Economic Analysis of Jhora Fisheries in West Bengal” has been undertaken as Master’s research with the following objectives:

- To assess the socio-economic profile of Jhora fish farmers and culture practices followed by them.
- To evaluate cost and returns, and technical efficiency of Jhora fisheries.
- To analyse constraints faced by Jhora fish farmers and suggest suitable measures.

Primary data was collected from 120 Jhora fish farmers using three different types of ponds in Darjeeling Himalayan hill region by using a pre-tested structured interview schedule. Various economic tools like percentages, farm business analysis, B-C ratio, stochastic frontier model, maximum likelihood estimation and technical efficiency have been used to analyze the data.

Analysis of socio-economic profile of selected Jhora fish farmers in the in Darjeeling Himalayan hill region revealed that 86.67% of the respondent Jhora fish farmers are males, 87.5% are married, 65% belonged to middle age group (40-60 years) and 75% of them belongs to Schedule Tribe caste. Nearly half of them follow Hindu religion, 93.33% are literate with nearly 41.67% of them educated up to secondary level. Majority of them (63.3%) are residing in a joint family with an average household size of 5.4. Majority of them (79.19%) had taken up Jhora fisheries as secondary occupation in addition to the primary occupation, agriculture (73.3%). Nearly, 77.5% are residing in pucca houses and half of them are marginal land holders. Among all, only 26.7 % are found to be members of SHGs/Cooperatives/NGOs. As reported, 90% had a savings account in commercial banks and some of them had also invested in post office and LIC. They spent nearly 48.9% of their annual income on food and rest on clothing, festival, education, medical, transportation, etc. Average per capita annual income during 2018-19 for these households has been found out ₹ 66,612.09/- and 59.2% of them belonged to LIG, followed by EWS. Statistical test ANOVA reveals that average incomes of Jhora fish farmers are not significantly different using three types of ponds, indicating that Jhora fish farmers have a medium level of Socio-economic status in Darjeeling hill region.

Assessment of cultural practices revealed that almost 70% of the Jhora fish farmers had access to seed and feed from DoF, WB and these farmers got their farms constructed under various schemes like Blue revolution, FFDA and MGNREGA. Nearly 44.17% had more than 15 years of experience and majority of them (89.17%) had attended a training program organized by DoF. Overall, as many as 39.17% of each of them holds pond area of <500 sq ft. and 501-1000 sq ft. followed by others. Overall, majority of them (85.83%) had only one Jhora unit, and only one farmer had three units also (units ranges from 250 sq ft. – 4000 sq ft.). All of them are practicing semi-intensive aquaculture, polyculture of exotic carps with chocolate mahseer, mrigal and tilapia. Majority of them (71.67%) had learned farming on their own as since generations their family had been involved in fish farming. Nearly 56.67% of them have water source within close proximity and the main source as Jhora (79.17%). Overall, 33% of the respondent farmers had practiced bio-integration and 50% of them had stocked 501 to 1001 fingerlings / 500 sq ft., with the average stocking density of 691.4 fingerlings per 500 sq ft. (1,48,843.4 /ha). Nearly 40% of the farmers had to rely only on DoF for getting seed, while 51% of them had brought from DoF and other sources also. However, none of them were engaged in producing their own seed. Less than half had applied lime and manure, while no one used inorganic fertilizers. Grass, wheat flour and floating feed were mainly used and for floating feed they are dependent on DoF. Overall, 90% of them preferred netting for harvesting in the month of October. Culture period of Jhora fisheries lasts for 12 months and they are getting a survival rate between 60-80%. Overall, 42.5% of them had reported that water stoppage is the main reason for fish mortality. Average production of Jhora ponds was 44.37 kg/500sq ft. (9,551 kg/ha) which is quite high compared to average freshwater fish production in West Bengal and harvest was being sold directly at farm to the locals. Thus, even though Jhora fish farmers are practicing small scale semi-intensive, poly-culture, but still there is a scope for improvement.

The total investment made on the sample ponds is ₹ 32,033.16 per 500 sq ft., ₹ 22,469.57 per 500 sq ft. and ₹ 8,821.27 per 500 sq ft. for cement ponds, cement ponds with mud bottom and mud ponds, respectively. The major investment for all three types of ponds was for pond construction accounted 84.36%, 85.60 %, and 73.67%, respectively, resulting in higher fixed investment (58.97 %) in cement ponds, whereas for cement pond with mud bottom, it was 40.73% and for mud pond only 25.57%. The total cost of fish culture in cement pond was ₹ 9,771.08 per 500 sq ft., for cement pond with mud bottom was ₹ 10,141.69 per 500 sq ft. and for mud pond was ₹ 7,165.98 per 500 sq ft., with the gross revenue of ₹ 10,350.07, ₹ 11,841.97 and ₹ 11,301.37 per 500 sq ft., respectively. Benefit-Cost Ratio for cement ponds, cement-mud bottom ponds & mud ponds has been found 1.06, 1.17 & 1.58, respectively, indicating economic feasibility of Jhora fisheries in all three types of ponds. However, farmers are receiving higher profits in mud ponds.

Technical efficiency (TE) of Jhora fisheries has been obtained by using Cobb-Douglas function with eight input variables and five dummy variables. Likelihood ratio test with the hypothesis of no technical inefficiency was rejected. Estimation of parameters has been attempted by using a single-stage maximum-likelihood method. Its results reveal that except lime and manure, all the slope coefficients of stocking density, pond size, floating feed, other feed and grass are highly significant ($p \leq 0.01$), whereas for labour, slope coefficient is significant at 5%

level of significance. Thus, there is a potential of increasing fish production through raising the levels of these inputs. The estimated value of variance ratio ‘γ’ has been found close to 1 (0.95) and highly significant at 1% level of significance. This implies that 95% variation in the output is due to the differences in technical efficiencies of Jhora fisheries household, while the remaining 5% is due to the effect of disturbance term or random factors, which are beyond the control of Jhora fish farmers. The mean efficiency of Jhora fish farmers is 90% with minimum efficiency level 46 % and maximum efficiency level 98%. Therefore, on average, the fish production can be raised by 10 % in the Darjeeling Himalayan hill region with the existing technology and resources.

Among all the socio-economic variables in the inefficiency model, negative sign of the slope coefficient of education indicated that education is the most common factor affecting Jhora fish farmer’s efficiency ($P \leq 0.05$) and concludes that higher educated farmers are more technically efficient as compared to less educated ones. Whereas, positive signs of the slope coefficients of experience, household size and dummy for mud pond indicated negative effect on technical efficiency.

Rank-based quotient has been used to quantify the technical, environment, infrastructure and economic constraints faced by Jhora fish farmers in the Darjeeling Himalayan hill region. Results indicated that non availability of quality feed or less availability of quality seed have been found the most important technical constraints, whereas predation was found as environmental constraint, non-availability of hatchery found as the infrastructure constraint and self-finance found as the economic constraint.

Thus, though Jhora fish farming in Darjeeling Himalayan hill region is a profitable venture in all the three types of ponds but highest profit has been found in mud ponds. However, profit through this venture can further be enhanced if the Department of Fisheries, West Bengal, extends their co-operation in providing more training among local youths and popularizing scientific management practices. Further, the availability of local quality feed, seed and marketing infrastructure will encourage more farmers to get involved in this profitable business.

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PLATES

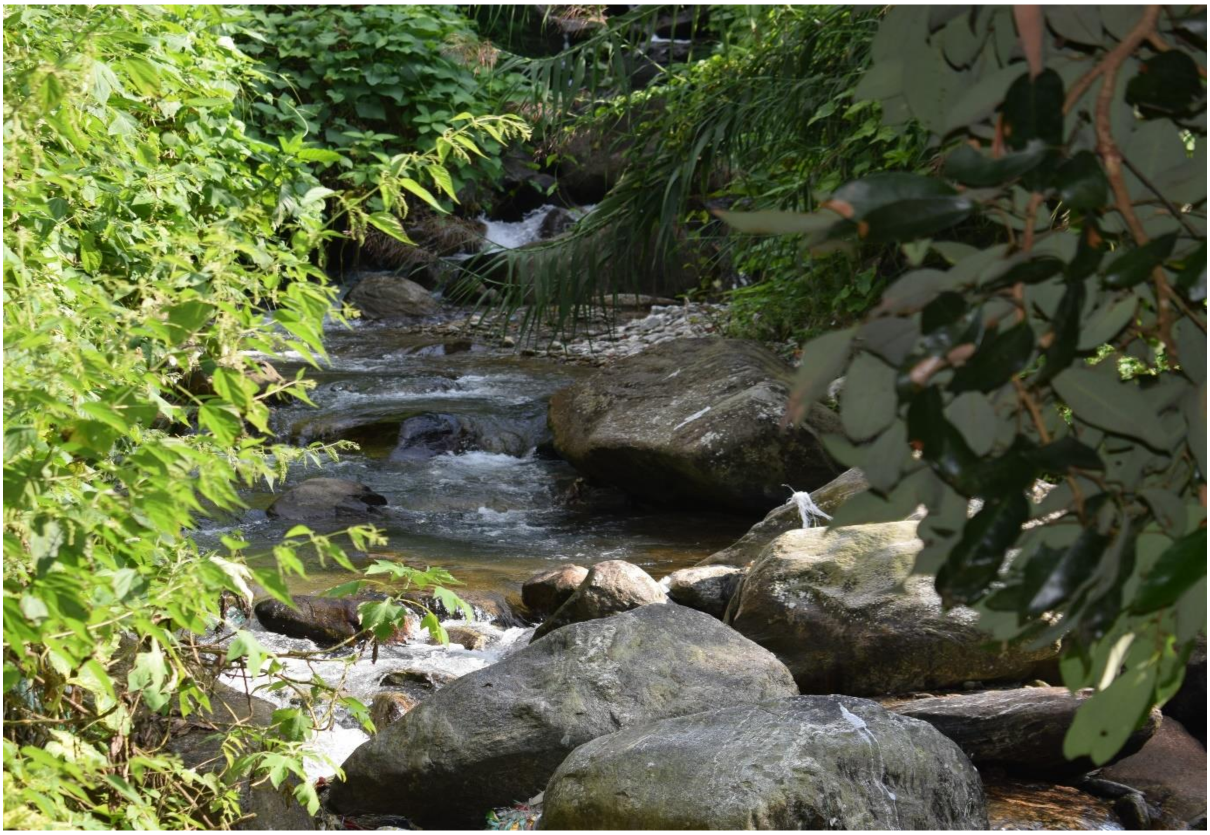

Plate 1: The main source of water "Jhora"

Plate 2: Cement pond

Plate 3: Cement pond with mud bottom

Plate 4: Mud pond

Plate 5: Netting of fish from Jhora pond

Plate 6: Bamboo doko used for harvesting fish

Plate 7: Interview with Jhora fish farmer (a)

Plate 8: Interview with Jhora fish farmer (b)

APPENDICES

APPENDICES

Appendix I. List of Tables in the Appendices

Appendix Table 1: Variance inflation factor for the input variables entered into the SPF model

Variable	VIF	1/VIF
ln(pond area)	2.55	0.393
ln(Man days)	2.08	0.481
ln(Stocking density)	1.93	0.517
ln(Lime)	1.52	0.657
ln(Other feed)	1.30	0.768
ln(Manure)	1.29	0.77
ln(Grass)	1.20	0.832
ln(Floating feed)	1.18	0.842
Mean VIF	1.63	

Appendix Table 2: Variance inflation factor for the dummy of input variables entered into the SPF model.

Variable	VIF	1/VIF
Dummy lime	1.14	0.88
Dummy manure	1.12	0.895
Dummy floating feed	1.08	0.922
Dummy grass	1.03	0.971
Dummy other feed	1.01	0.985
Mean VIF	1.08	

Appendix Table 3: Variance inflation factor for the inefficiency variables

Variable	VIF	1/VIF
Dummy mud pond	2.48	0.403
Household size	1.77	0.655
Dummy cement pond	1.70	0.589
Experience	1.22	0.820
Age	1.21	0.825
Education	1.21	0.829
Dummy training	1.13	0.883
Dummy gender	1.13	0.886
Mean VIF	1.48	

Appendix Table 4**:** Heteroskedasticity test

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
Ho: Constant variance
Variables: fitted values of ln(fish-production)
chi2(1) = 2.15
Prob > chi2 = 0.1426
Decision is to Accept Ho.

Appendix II: Interview Schedule

ICAR-CENTRAL INSTITUTE OF FISHERIES EDUCATION

(Deemed to- be University Established under Sec. 3 of UGC Act 1956)

Panch Marg, Off Yari Road, Versova, Andheri (W), Mumbai - 400061

ECONOMIC ANALYSIS OF JHORA FISHERIES IN WEST BENGAL

A) GENERAL PROFILE:

1) Name of the respondent:__________________________ Phone No:____________
2) Head of the family: Age____ sex______
3) Name of district:_______________ Block: ______ Village name: ____________
4) Languages known: Nepali ☐ Hindi ☐ English ☐ others ☐

B) SOCIAL PROFILE

1. Age: ___ Sex: M ☐ F ☐
2. Religion : _____________
3. Category: General/ST/SC/OBC/other
4. Education: Illiterate ☐ Primary(1-6) ☐ Secondary(7-10) ☐ Higher Secondary(11-12) ☐ Graduate ☐
5. Marital status: (married/unmarried/divorce/widow)
6. No. of family member:
7. Adults: M___ F____; Children: M____F____; Infants: ______
8. Family Type: Joint /Nuclear
9. House : Owned/ Rented
10. House type: Pucca / semi kachcha / kachcha
11. Transportation facility: own car/ own bike/ public transport/ shared tax
12. Social participation:

SL. NO.	STATEMENT	OPTION	DETAILS
1	Membership	Cooperative society/Gram Panchayat /NGO /SHG / Political Party/ Fisheries-agri organisation/ any other	

2	Degree of participation	Daily/Weekly/Fortnightly/Monthly/Occasional/Yearly /Never	
3	Leadership	YES/NO	

C) ECONOMIC PROFILE:

1. Total Land Holdings: Owned: ______________Leased:___________
   Lease rent_____________ leasing period_____________
2. No. of earning members in the family: ___ ; no. of dependent: ____
3. Family Income(annual): ________
4. Primary occupation: fish farming/ Agriculture/ Business/ Daily labours/ Service/other
5. Secondary occupation: fish farming/ Agriculture/ Business/ Daily labours /Service/others
6. How do you meet you expenses: Income/savings/loan from bank/loan from money lender/others
7. Are you in depth? Yes/ No
8. Source:

Sl.no.	Credit source	Amount (₹)	Interest(%)	Repayment(₹)	Purpose
1					
2					
3					
4					

9. How do you pay your loan? . . . .
10. Do you save money? Yes/No
11. Where do you save? Commercial bank / cooperative bank / SHG / LIC / post office / chit fund / No savings / others.

Food & other expenditure: (Last 30 days)

Sl. No.	Particulars	Total expenditure	
		Amount(₹)	% expenditure
1	Food		
2	Education		
3	Clothing		

4	Medicine		
5	Festival		
6	Transport		
7	Others		

D) CULTURE ASPECTS:

1. No. of years of experience in fish culture. . . . .
2. Whom did you learn fish culture from? . . . .
3. Training attended: Yes/No ; If yes, Number of days: . . . .
4. Conducted by: Govt./ DOF/ Pvt org/ Others /Self-financed/ sponsored
5. Total area of jhora ponds: . . . . (ft^2); owned ☐ leased ☐
6. No. of jhora units: . . . .
7. Types of jhora pond: . . . .
8. Depth of each units: . . . .
9. Source of water: . . . . ; Distance. . . . , availability: Seasonal/Perennial
10. Liming: . . . . .kg/unit, price. . . . . /kg
11. Manure . . . . kg/unit
12. Chemical fertilizers . . . . kg/unit
13. Health care used . . . . ₹/unit
14. Labour (man-hours or days) . . . .
15. Hired labour, wage if any: . . . .
16. Any other expenses: . . . .
17. Access to different schemes, subsidy and programs of dof:

Sl. No.	Name of scheme	Year	Benefits (₹)

b) Type of Aqua farming:

1) Extensive / semi-intensive / intensive
2) Mono-culture/ poly-culture
3) Integrated, if yes then with what? . . . .
4) Species cultured: . . . .

c) STOCKING:

Species	Seed stage	SD	Area (m^2)	Source of seed	Seed Cost (₹)	Distance (km)	Materials used for transport	Transportation cost (₹)

d) FEEDING:

Feed	Source of feed	Method of feeding	Frequency of feeding (No./day)	FCR	Total quantity of feed used (Kg/U/crop)	Cost (₹)	Trans port. cost (₹)

e) HARVESTING AND DISPOSSAL PATTERN:

1) Reason for harvesting schedule:

Need of money- optimize production- scarcity of water-

Get highest price- demand specific- others-

2) Method of harvesting:

Total drainage- netting- doko- other-

3) No of harvest per crop-

Month	species	Eaten (kg)	Giveaway (kg)	Others (kg)	Price per kg	Local market in kg

4) SURVIVAL RATE: <60% . . . . ; 60-80% . . . .; >80% . . . .

5) Possible cause of mortality:

Disease- water stoppage- transportation stress-

Lack of food- weather change- others-

6) Where do you sell your fish? Place . . . . , price . . . . per kg.

E) FIXED INVESTMENT ON JHORA FISHERIES:

Particulars	No.	Year of construction / purchase	Cost of purchase or construction /PV(Rs.)	Expected life (Yr)	Present value	Annual repair/ maintenance Cost (Rs)
Pond construction						
Fencing						
Poly pipe						
Nylon nets						
Weigh balance						
Tubs & buckets						

F) CONSTRAINTS:

1) Technological constraints:

Sl. No	Problem	Rank	Remarks
1	Non availability of quality seed		
2	Difficulty in transportation of seeds		
3	Less availability of quality feed		
4	Difficulty in transportation of feed		

5	Maintenance of water line		
6	Water seepage		
7	High rate of mortality		
8	Less knowledge of modern & scientific fish farming		
9	Less technical guidance		

2) Environmental constraints:

Sl. No	Problem	Rank	Remarks
1	Pollution in Jhora		
2	Natural disaster		
3	Disease outbreak		
4	Predation		

3) Infrastructure constraints:

Sl. No	Problem	Rank	Remarks
1	Poor development of road and transport facility		
2	Less communication facility		
3	Irregular power supply		
4	Shortage of drinking water and daily needs		
5	Inadequate marketing facility		
6	Non availability hatchery		
7	Non availability feed mills		

4) Economic constraints:

Sl. No.	Problem	Rank	Remarks
1	High initial investment		
2	High price of feed		
3	High price of seed		
4	Lack of financial support/subsidy		
5	Self-finance		
6	Availability of credit		
7	Problem of theft		

Thank you for sharing your experience!!