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Livelihood and Environmental Sustainability Analysis Using Aquaculture-based Indicators: A Study on Selected CD Blocks of Purba Medinipur District, West Bengal

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ABSTRACT

Aquaculture-based sustainability can be defined as a continuous and harmonic interaction with the aquaculture ecosystems to the local communities. The present study was based on empirical analysis of some environmental and socio-economic databases to accentuate the sustainability of aquaculture activity and quality of standard of living. Therefore, water samples from fresh and salt water were tested to analyse the physicochemical characteristics like pH, SO_4, F^-, AS, DO, BOD and soil samples were analysed for the measurement of soil quality through pH, NH_4+, HPO_4^{2-}, K+ as environmental parameters and 40 questionnaire survey hadbeen conducted for the analysis of livelihood scenario. All these environmental parameters were tested and socio-economic indicators were equated at the standard scale to describethe aquaculture sustainability and its significant effect on environment and local people. The results showed that the degree of aquaculture from fresh water and salt water had influenced on the local economical sustainability but environmentally salt water aquaculture had some risks. Therefore, it has urgently needed some governance on the water quality with proper management. Finally, the result recommends that this area have potential for aquaculture activity in an organic way and this will be really helpful for maintaining the aquaculture management system and social well-beings in study area at the upcoming days.

Introduction:

Aquaculture activity is now playing a pivotal role in socio-economic development of any region. In the developing countries, aquaculture is going on through the transformation of either arable land or wastelands. This aquaculture activity is divided into two categories - marine aquaculture or brackish water-based aquaculture and freshwater-based aquaculture.

Being one of the fastest growing food-producing sectors in the world and in India, now aquaculture has taken a significant place in respect of economic structure (FAO 2016). In India, inland aquaculture produces 60% of total production and 6.3% share in the world in 2014 (Handbook on Fisheries Statistics, 2014). Paul and Chakrabarty (2016) described that the fishing activity will be a companion of agriculture in a populated country like India. Moreover, it influences the local economy and creates scope of employment even for rural women and marginal farmers.

But, these activities have directly or indirectly created some impacts on the environment and raised the questions for its sustainability since the 1990s (Folke and Kautsky 1992; Naylor et al. 2000; Perdikaris et al. 2016). Moreover, these impacts may generate a problem for the society, farmers as well as the production (Neiland et al., 2001). As a consequence, local economy, livelihood and food securities to rural communities may hamper which breaks the prime principles of sustainable development (Costa Pierce 2010; Bene et al. 2016; Valenti et al. 2018). Aquaculture sustainability is measured with the help of various

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indicators like ecological and carbon footprint (Folke et al. 1998; Gyllenhammar and Håkanson 2005; Madin and Macreadie 2015),life cycle evaluation (Gronroos et al. 2006; Aubin et al. 2009; Santos et al. 2015; Medeiros et al. 2017), energy evaluation (Vassallo et al. 2007; Valenti et al. 2011; Lima et al. 2012; Shi et al. 2013; Wang et al. 2015; Williamson et al. 2015) etc. This is very difficult to overview all the indicators because of huge amount of data sets. In this context, various groups of organization have proposed the indicators for the evaluation of environmental sustainability (FAO 1999, 2011; EAS 2005; FOESA 2010) and some literature have been brought out in some specified scientific journals (Boyd et al. 2007; Pullin et al. 2007; Valenti et al. 2011; Fletcher 2012). Moreover, some indicators related to the aquaculture followed by Moura (2016) had given a concept of sustainable measure in terms of socio-economic and environmental conditions for further extent.

The recent sprout of aquaculture activities has converted the agriculture land to fisheries along a vast tract of coastal areas of Purba Medinipur district of West Bengal and raised the issue of measuring socio-economic as well as environmental sustainability.This area has been experienced a continuous saline water intrusion through the percolation process from the river track to paddy field. Consequently, paddy cultivation is becoming weaker with compare to the other human-induced activities. So that, thinking is shifting in their social behaviour as well as farming activities in the recent times. Ample number of local farmers has concentrated on fishery farming with the help of available saline water of Rasulpur River for better economy including low labour weighted productivity. Here, farmers are associated with both the freshwater farming and saline water farming. Moreover, most of the farmers still do not have any training or scientific bases for this kind of farming.Intensive commercial aquaculture farming has influenced on livelihood of the local people directly but, environmentally how much effective it is that is also our determination for this study. Therefore, we need to check out the livelihood and environmental risk factors for this study.

For that purpose,authors try to establishthe aquaculture-based indicators and find out the sustainability in the livelihood and environment depending on aquaculture activities over the study area.

Study Area

In this present study, four community development blocks (CD blocks) like Khejuri-I, Khejuri-II, Contai-II and Contai-III of Purba Medinipur district of West Bengal have been selected as study area, where the growing concern of land transformation from agricultural land to aquaculture land is detected. The extension of the study area is from 21°40’22.94"N to 22°02’47.24"N latitude and from 87°39’4.71"E to 87°58’38.45"E longitude with the elevation of 5-6 metres from the Mean Sea Level (MSL) covering an area of 74.72 km^2. Geographically study area is located on the bank of Rasulpur River and is a part of flood plain of river Hugli. In general, this region occupies a monotonous low-lying tract with alluvial deposits of river Hugli and Rasulpur. During winter season mean temperature is about 20^0C and in summer season it is 32^0C. The mean annual precipitation is 120-140 cm with maximum during the months of July and August. This suitable physical and climatic condition allows enough dynamicity in land transformation of the region.

2. Database and Methodology

2.1 Sample sites and data collection method

Aquaculture is expected to become an alternative income generatorfor the people of the study area especially for those who have altered their agricultural land or barren land to aquaculture farming. The present study was based on empirical analysis of some environmental and socio-economic databases to accentuate the sustainability of aquaculture activity and quality of standard of living (Fig. 3). Therefore, we have classified the study area into 4 different sample sites i.e., river site saline water fishery, subsistence household freshwater fishery, paddy-cum-fishery land and agriculture land. Among the selected sample sites, 24 water samples from fresh and salt water were tested to analyse the physicochemical characteristics like pH, SO_4, F^-, AS, DO, BOD and 20 soil samples were tested for the assessment of soil quality through pH, NH_4+, HPO_4^{2-}, K+ as environmental parameters and 40 questionnaire survey out of 3887 households (CD-Block wise Primary Census Abstract Data (PCA)- West Bengal, 2011) had been conducted from the selected CD-blocks for the analysis of livelihood scenario using quota sampling technique. Moreover, 45 questionnaire studies (10 samples from Khejuri-II and Contai-II; 12 samples Khejuri-I and 13 samples from Contai-III) were conducted to the directly aquaculture related families to understand the aquaculture environment and its activities over the land in a random basis. Selected samples of soil and water were collected using stratified random sampling techniques from the different lands(agriculture land, fishery land, river bank sites) in the study area (Fig. 2).We have used fourteen livelihood

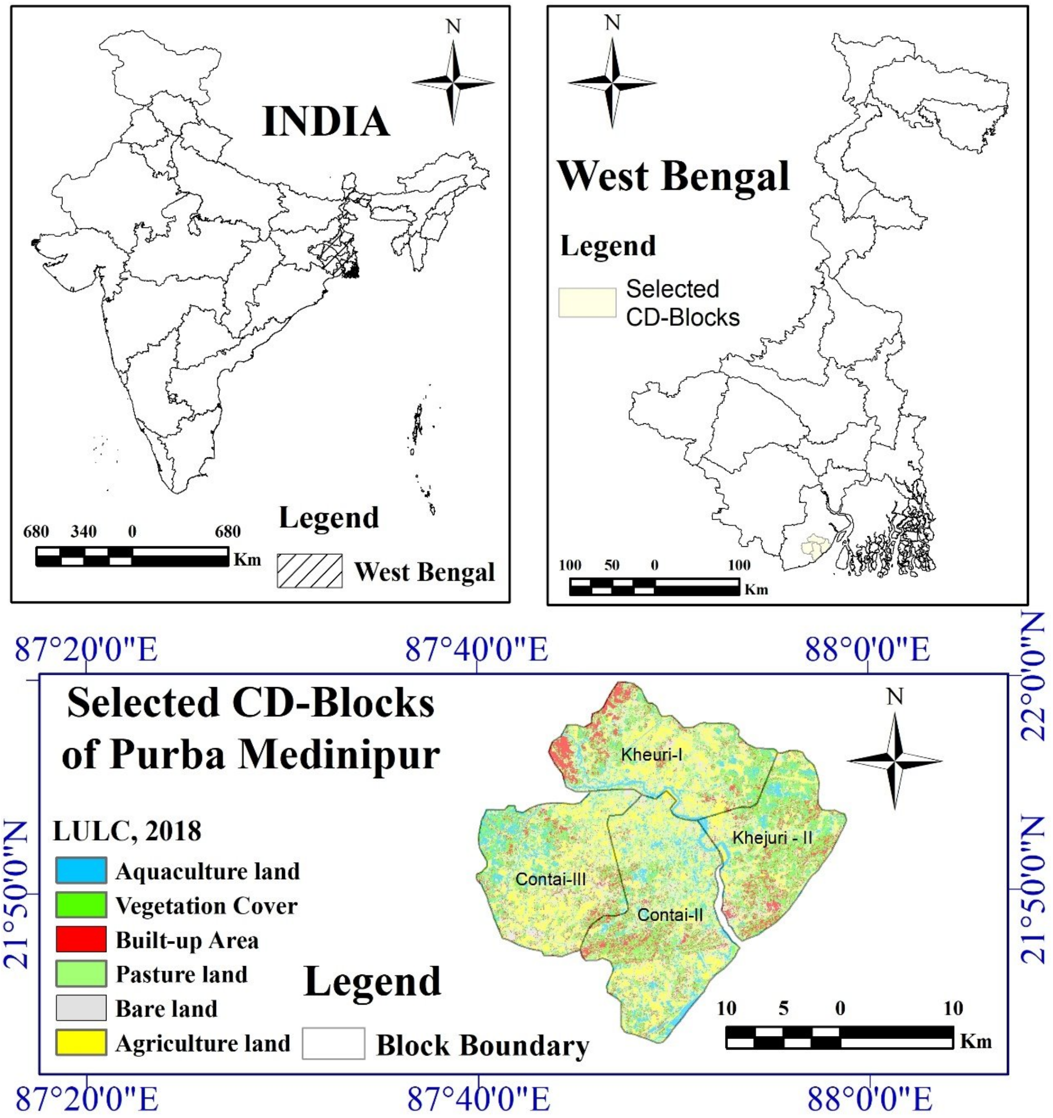

Fig. 1 : Location map of the study area with some important administrative boundaries

and nine environmental indicators to validate the results of primary field datawith proper justification (Table 1). Moreover, some experts or practitioners, previous literatures and district statistical handbooks wereused to validate the collected data and information regarding aquaculture activity.

2.2 Livelihood sustainability indicators

Livelihood sustainability indicators discuss the efficiency in using financial resources, the economic feasibility (net income, self-employment etc.), the standard of living, equal job opportunity to generate benefits to local people in the regional scale (R) and farming point of view (F).

Some important equations have been used to validate the actual cost-effective production and economic sustainability based on collected sample using field data.

Ratio between Net Income and Initial Investment (RII)

Net income relates to the sum of the profit and the

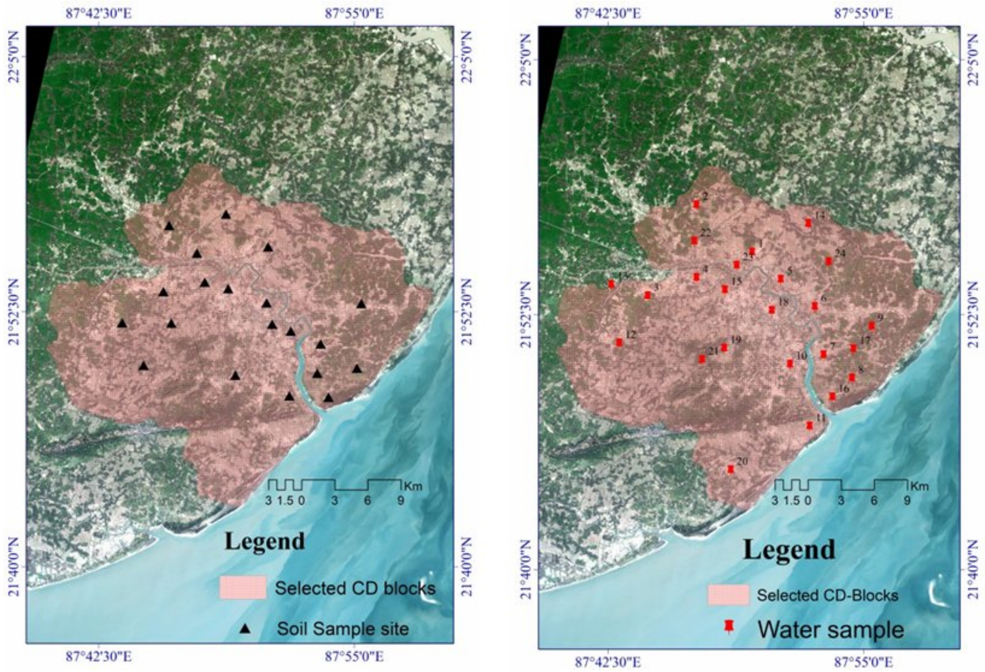

Fig. 2 : Water and soil sample sites in the study area

Table 1. Justification of selected Livelihood and Environmental Indicators

Dimension	Principles	Criteria	Indicators	Justification
Livelihood (Social and economic factors)	Effective use of capital and profitability	Level of capital efficiency and profitability	RII, CBR, NPe, AI	Livelihood sustainability indicators denote both social and economic factors and how much it will be profitable for society to reduce the negative impacts and create some opportunities in near future.
	Improvement of local economy, employment	Equity in job, proportion of payment to person	LE, GE, LW, SE, PCW	
	Introduction of productivity and labour economy	Level of production	DP, J, $Q_{n.o}$	
	Improvement of farm longevity	Level of performance at the aquaculture sector	PA, RR	
Environmental	Utilisation of sufficient energy and space	Level of space and energy	S, E	Environmental sustainability indicates the use of natural and renewable resources with efficiency and to minimise the environmental impacts on various ecosystem and control over quality of environmental health.
	Natural resources use and its efficiency	Use of natural resources	B	
	Improvement of water quality	Level of water quality	WQI (pH, SO_4, F^-, AS), DO, BOD	
	Improvement of soil health	Level of soil quality	SQ (pH, NH_4+, HPO_4^{2-} , K+)	
	Protection from biodiversity and environmental risk	Level of risk to biodiversity and environment	FRe, SEr	

opportunity cost. The opportunity cost includes farmer remuneration, interest over investment and operating capital and land hiring (Shang, 1990)

RII =Net income/initial investment

Cost Benefit Ratio:

A cost benefit ratio (CBR) indicator is used in cost benefit analysis that attempts to summarize the overall value for money of a proposal, expressed in monetary terms. A CBR can be a profitability index in the profit contexts. Higher the CBR means better the investment. General rule of thumb is that if the benefit is higher than the cost the project is good for investment. It can be equated as

$$CBR = B/C = \frac{\sum_{i=0}^{n} \frac{Y_i}{(1+r)i}}{\sum_{i=0}^{n} \frac{K_i}{(1+r)i}}$$

Where: Y_i=net annual benefit,B=total benefit, C= total cost, O= operating cost, r=discount rate,K_i= capital outlay for assets,n= no. of year.

Net profit (NPe)

Net profit refers to the bottom line or net earnings which is a measure of the profitability of a venture after accounting for all costs and taxes. It is the actual profit and includes the operating expenses that are excluded from gross income. It can be expressed as

NPe =GR – TPC+ Ep –En

Where, GR= Gross revenue, TPC=Total production cost, EP= Total positive externalities, En=Negative externalities.

Annual income (AI)

Annual income is defined as the sum of the profit to the opportunity cost. Taxes and fees vary among locally. Thus, these two variables should delete for comparisons between systems at different sites. For comparing farms of different sizes, AI should be divided by the farm areas. It can be expressed as

AI =GR –OC-D-T-F

Where, GR=Gross revenue, OC=Operating cost, D=Depreciation, T= taxes, F=Fees.

Development of local economy(LE)

This indicator measures the proportion of expenditure for goods and services that are acquired in local markets.

LE= Use of products and services from local markets / total products and services

Proportion of gender equity (Ge)

This indicator measures the gender composition of employment occupied in the activity from the local population.

Σ=GI min {a, b}

Where, min= minimum value, a= female population among the total employee, b= male population among the total employee.

Use of local worker (LW)

LW =number of jobs generated that permit recruitment among the local population /total number of jobs generated

Proportional Cost of Work (PCW)

Proportional Cost of Work shows whether the system is labour-intensive or machine-intensive reducing the number of jobs. In case of family-based aquaculture systems, the family work should be included.

PCW= Cost of work/cost of production

Products Diversity (DP)

It includes diversity of products and services exported, such as the number of ?sh species, other aquaculture products or services. It has been categorised into two class fresh water fishing (Major Indian carp, minor Indian carp) and salt water fishing (prawn, shrimp).

DP= {1,2,3,4,5, …,n}

Proportion of self-employment (SE)

SE = number of self-employed jobs generated /total number of jobs generated.

Total Productivity Index (J)

Productivity describes various measures of efficiency of production. This measure is expressed as the ratio of output to input used in production process and it is a crucial factor in production performance of the firms. Increasing national productivity can raise living standard because more real income improves people's ability to purchase good and service. It can be expressed as

$$J = \frac{\text{total output}}{\text{total input (labour+materials+capital+energy+other expenses)}}$$

Labour Weighted Production Index ($Q_{n.o}$)

Labour weighted production index is a new econometric formula by which we can easily measure a labour in unit of time to produce one unit of goods. It is calculated with the help of following parameters:

- Employer's social contribution including time, working days
- Total inputs cost in terms of energy, food, seeds, fertilizer (bio and chemical both), transport etc.
- Total outputs in terms of production and marketing (local and global scale)

$$Q_{n,0} = \frac{\Sigma m_0 q_n}{\Sigma m_0 q_0} * 100$$

Where, q_n = unit of work produced as input; q_0 = standard units of work expected; $\Sigma\, m_0$ = total output

Permanence in the activity (PA)

PA=average time spent by each worker in the aquaculture activity.

Risk Rate assessment (RR)

A risk assessment is the combined effort of identifying and analysing potential events that may negatively impact on individual or environment.

2.3 Environmental sustainability indicators

According to Wang, (2015) environmental sustainability indicators are defined to reflect the use of natural resources availability and the efficiency. Environmental indicator includes use of space for per unit production, water quality, quality of soil, use of bio-fertilizer, amount of species destruction, the amount of potential materials and energy used to produce each unit of production.

Use of space (S)

This indicator is measuring the area used in particular activity per unit of production and here the amount of land used for aqua-farming. It can be equated as

S=area (hectare, km^2, m^2) / production (Kg, tonnes, units)

Use of potential energy (E)

This indicator measures the total potential energy used to the system in its various forms, such as electricity, fuel and others per unit of production. It can be expressed as

E= total energy applied (MJ, KW)/production (kg, tonnes, units)

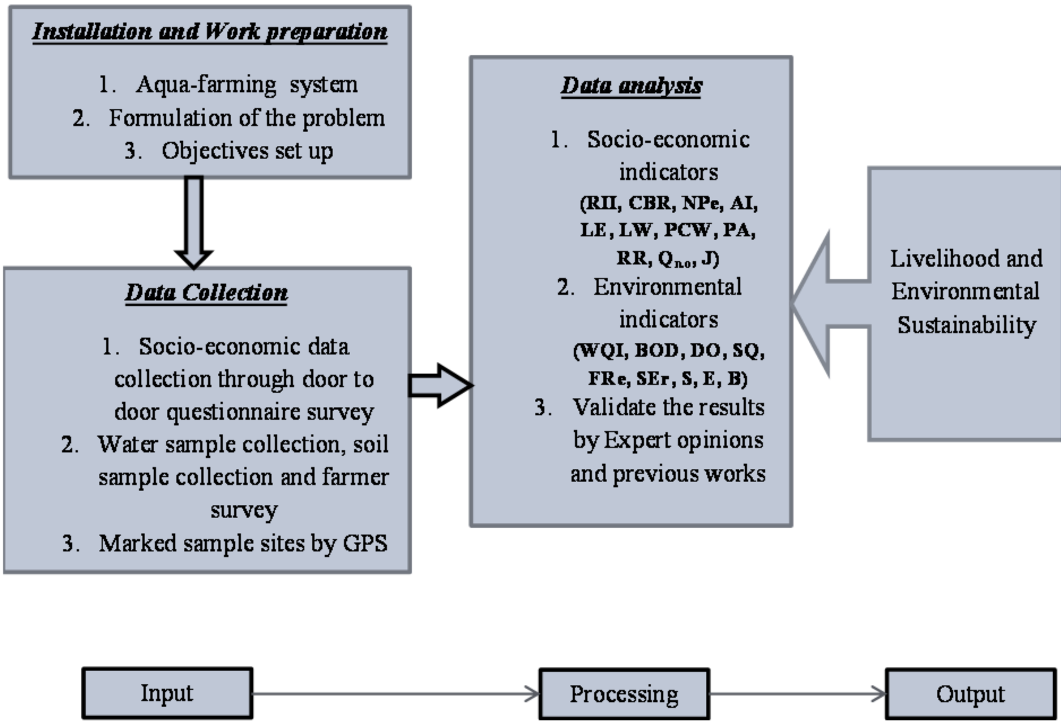

Fig. 3 : Methodological framework of the study

Use of bio-fertilizer (B)

To keep the sustainability of environment in aquaculture farming,bio- fertilizer is used more than chemical fertilizer to maintain the soil and water quality. Here authors have used ratio according to field information in the ratio scale of Nitrogen (N), Phosphorous (P), Potassium (K) and Organic Matter (OM) like lime.

Water quality index (WQI)

$$WQI = \Sigma q_n W_n \div \Sigma W_n$$

Where, q_n=water quality rating, W_n= unit weight of the selected parameter,

Water quality

Water quality has been analysed by testing pH, SO4, F, AS, DO and BOD. Here authors have tested these parameters for different water samples like salt water, fresh water and marine water.

Potential Dissolved Oxygen (DO)

It is used to measure the presence of dissolved oxygen in the water.

Potential Biological Oxygen Demand (BOD)

Potential BOD means there is plenty of organic matter present in the water. It reduces the supply of dissolved oxygen in the water.

Soil Quality:

Soil quality have been assessed by measuring the soil erosion rate (SEr), pH, NH_4^+, HPO_4^2 and K_2.

Risk of farm species (FRe)

It is measured bynumber of species destructedat the initial stage and during the time of nurturing.

3. Results

3.1 Livelihood sustainability

The livelihood sustainability of the aquaculture activities in the study area were developed by the major issues related to socio-economic sustainability.

The ratio between net income and initial investment indicates the efficient use of capital. Based on field survey it had cleared that subordinate initial investment, that produced the equal amount of net income,was more sustainable. The economic viability indicators (cost benefit ratio) wereused for both the commercial farmers and small farmers, usually who were interested to maintain a good standard of living for themselves. The average cost-benefit ratio was 5.65 per hectare of production. For small farmers, the annual income (AI) indicator was suitable because of pond ownership and freshwater aquaculture. Farm income for pond ownershipwas well enough in case of fresh water farming. Having and operating more units of ponds allow them to manage productivity and gain better farm income. Although it had been influenced by pond size, water quality, products diversity, proportional cost of work etc.,but the distribution of pond unit ownership amongst farmer was varied significantly from fresh water to the salt water farming. Consequently, the small farmerscould peruse the other activitiesrelated to aquaculture. In livelihood indicators, labour weighted production index ($Q_{n.o}$) measured the efficiency of production. The $Q_{n.o}$ for aquaculture farming was 0.03 hr/kg that means a labour could produce 1 unit of production by sparing only 0.03 hours (Table 2). Total productivity index (J) score was 2.5, which indicatesusing one unit of input farmers can get 2.5 units of production.This increasing rate of productivity raised the living standard of the local farmers. Actually,$Q_{n.o}$ and J both are complementary to each other and measure the duration and efficiency of a particular production over a particular area.

The economic success of any farm or aquaculture sector is evaluated by annual income, performance in the activity and the proportion of the investment. The aquaculture farming is labour intensive farming where the demandedlabours aresupplied purely by local area. The permanency of activity is cleared within 6 years and sometimes it is continued thereafter by the small subsistence farmers. The local people did not go anywhere for their work because the demand of labour was 100% in this field. But, the proportional cost of work (PCW) was 52% and thus theyoung generation did not show interest in this kind of labour-intensive work.In the present study, we had found 9 types of fishes in the fresh water farming such as *Rohu*, *Catla*, *Mrigel*, Silver carp and Catfish as major Indian carp and *Bata*, *Calibaush*, *Tilapia*, *Koi* as minor Indian carp and 2 types of salt water species like Shrimp and Prawn dominantly. Huge commercial production of salt water species created some risk over the livelihood of the small scale aquaculture farmer such as loss oflocal market demand, high rate of seeds, problem of getting loan and loss of agriculture land day by day.

3.2 Environmental sustainability

The environmental sustainabilityindicators were developed in the present study generally based on production value. In this perspective, authors compared extensive, semi intensive and intensive aquaculture

Table 2. Measurement ofLivelihood Sustainability Indicators

Socio-economic indicators	Value
Ratio between initial investment and net income	13
Cost benefit ratio	5.65
Net profit	Rs. 2,00,000.00 (per hectare)
Annual income	Rs. 3,90,000.00 (per hectare)
Use of local worker	100%
Permanency	6 years (each pond)
Self-employment	35%
Local economy development	65% (since 2011)
Proportional Cost of Work	52%
Labour weighted production index	0.03hr/ kg
Total productivity index	2.5
Products Diversity	9 (Fresh water); 2 (Salt water)
Participation and gender equity	100%
Risk rate assessment	5 (number of risk factors observed)

Note: Aquaculture sustainability data tables (livelihood and environmental indicators) have been prepared using Indian as well as international standard equations and scales (EAS, 2005; WHO, 2011).

survey. For sustainable analysis of environment, collected water samples (from both fresh and salt water) weretested for water quality analysis at the international standard scale. The water samples were found saline in nature with less amount of others physicochemical component (SO_4=230.12; F^-= 0.77; AS=0.0012). The DO value in salt water was found 9.65 ppm, BOD values was found 3.25 ppm and in case of fresh water, DO was 5.69ppm and BODwas 1.75ppm (Table 3). The calculated result of the samples showed that the presence of chemical components were suitable for fish farming (WHO, 2011). The other environmental indicators were soil quality (mostly saline and moderate quality in nature), use of bio-fertilizer per hectares, use of potential energy perunit of production which was 62.25 MJ/Kg for salt water fishing.

Table 3. Measurement of Environmental Sustainability Indicators

Environmental Indicators	Values
Use of space/ production	0.026 hectare /kg
Use of water	5.467 m^3/tonnes
Use of bio-fertilizer	N:P:K:OM=5:1:2:2
Use of natural resources	20%
Use of potential energy	62.25 MJ/kg
Water quality(pH) Water quality	Salt water=5-5.5; Fresh water=6, SO_4=230.12(mg/L); F^-= 0.77(mg/L); AS=0.0012 (mg/L)
Potential BOD	Saltwater=3.25(ppm); Fresh water=1.75(ppm)
Potential DO	Saltwater=9.65(ppm); Fresh water=5.69(ppm)
Soil quality (pH,NH_4+, HPO_4^{2-}, K+)	pH= 5-5.5; NH_4+, HPO_4^{2-}, K+= moderate
Soil erosion	Very low rate
Risk rate at farm species destruction	5(Number of risk factors observed)

Minimum soil erosion rate during the conversion of aquaculture land had made some changes over the surrounding agriculture area. Moreover 5 risk factors were found such as species destruction, species diseases, saline water intrusion into the ground water, water quality and soil erosion. If these factors are governed by practitioners then it will be a well-managed activity without hampering the environment.

4. Discussion

Over the recent decades, the landscape from agriculture to aquaculture had been transformed and consequently land use/land cover changed in coastal areas of selected CD-blocks at Purba Medinipur, West Bengal. Apart from its changes, the demand from large number of people was increased and created relatively complexities tothe small stakeholder's production behaviour. However, under growing human pressure, the local people are unable to give up the agriculture production for consumption, and thus theyadapted paddy farming inthe rotation system with the aquaculture and gradually converted their low productive agriculture land only into aquaculture land.

Some topics of the aquaculture process were not covered in this present study. Not all the indicators wereessential but,each of the indicators wasimportant to maintain the sustainability.Many consumers werewilling to pay thebest price for thesebrackish water fish or seafood (Valenti et al., 2018). Therefore, the degree of aquaculture based on salt water had influenced onlocal economical sustainability. Valenti et al. (2011) supported that the aquaculture production was well measurablesubject for sustainability oflivelihood and environmental indicators.

Results from the measurement of the indicators of sustainable livelihood and environment indicatedthat the area had a great potentiality for aqua-farming. Although, environmental sustainability indicators for aquaculture farming reflectedhigh risk on aquaculture (more resource was used and pollutants were generated) than other types of activity but, total amount of production value per unit was better than other farming. It was proved that production was higher enough to counter balance. Moreover, the results showed that the market demand, labour availability and suitable labour weighted production index still have great potential to continue the aquaculture activity in the study area for both commercial and small aquaculture farmers. Although, it helped to get employment andincreasestandard of living,resulting people more interested in this aquaculture activity. All these results were validated through international standard scale (EAS, 2005). Government had taken some initiativesthrough training programmes for the practitioners and the local labours like tree plantation, scientific fish breeding etc. Most important thing is that due tohigh local demand where half of the production was consumed by the local people, there is great potentiality for further economic expansion of this activity.

Nevertheless, the existing aquaculture type has enabled peoples to meet their immediate needs but it is not a sustainable nature of aquaculture in respect to future assurance. Commercial aquaculture system may have some possibilities to diminish the small scale subsistence aquaculture farmer. The aquaculture has potentiality to carry out the needs of present without exceeding the capacity of the resources(Ali, 2006). But,management or governance may be essential for the success of local production or any kind of production system (Fezzardi et al., 2013). Therefore, weak governance is harmful for the resolution of productive risks and therefore, sustainability becomes a question mark.

5. Conclusion

The overall results and findings have been established that still the area has enough potentiality to maintain the sustainable aquaculture activity. It has been explicated that aquaculture has great influence on livelihood with compared to environmental sustainability.So, more emphasis should be given to the selection of land for aquaculture that should be either on the less productive land or near to the saline water track. However, paddy-cum-fishery farming will be another way that may make their livelihood better and help to control over the land degradation. Even, agriculturally marginal lands can be solely used for year-round intensive shrimp farming.Consequently, the environmental degradation can be checked and created a balanced environment for the agriculture and aquaculture simultaneously. In this way the paddy fields should be saved and emphasis should be given on the opportunities for highly profitable aqua-farming to maintain the water quality, food security and economic well-being of the people and society in the study area.

Conflict of Interest

Authors have declared that there has no potential conflict of interest.

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