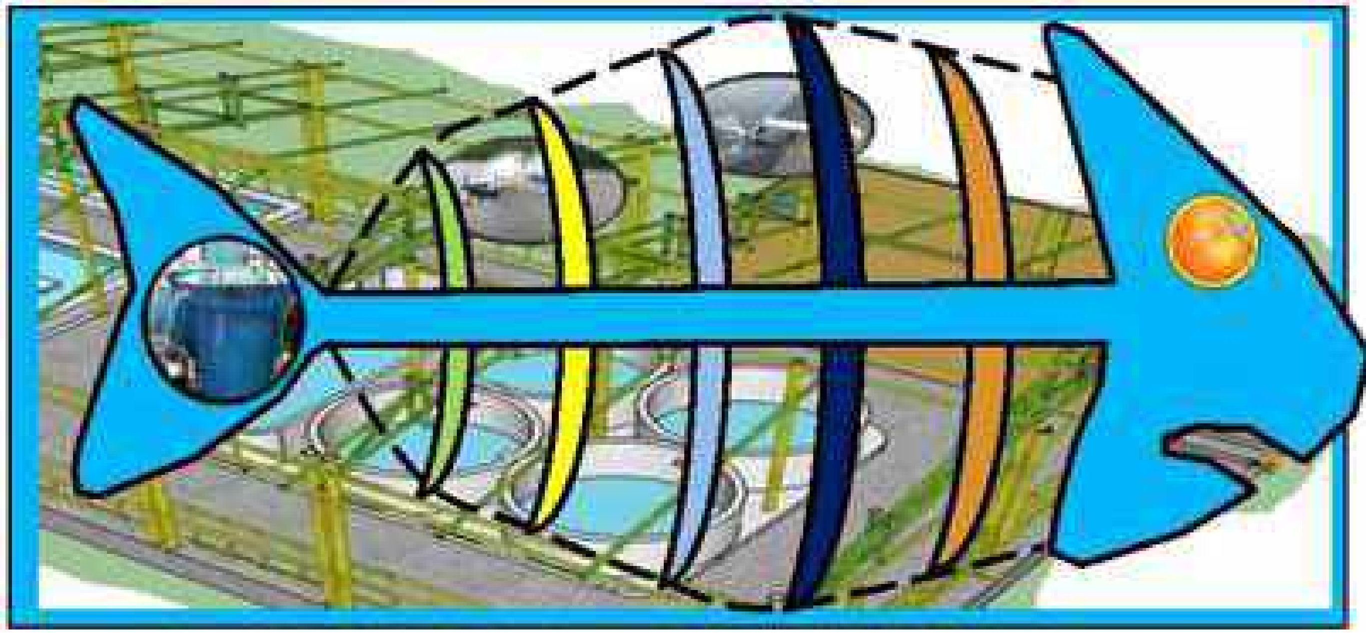
Precision Fish Farming: Automation Principles and Technological Solutions for Sustainable Aquaculture Production and Productivity



A.K. Verma
Chandrakant M.H.
Madhuri S. Pathak

ICAR-Central Institute of Fisheries Education
(University under Sec.3 of UGC Act, 1956)
Mumbai-400061
www.cife.edu.in

ASSESSING ECONOMIC EFFICIENCY IN PRECISION FARMING: TOOLS AND TECHNIQUES

Shyam S Salim

Principal Scientist, Socio Economic Evaluation and Technology Transfer Division, Central Marine Fisheries Research Institute, Cochin-682 018

Fisheries sector is an integral part of the Indian economy. Over the years, the sector has emerged and plays a strategic role in food security; international trade and employment generation. The sector constitutes about 6.3 percent of the global fish production and contributes to 1.1percent of the GDP and 5.15percent of the agricultural GDP. The total fish production of 10.07 million metric tonnes presently has nearly 65percent contribution from the inland sector and rest by the marine sector. The marine fisheries sector is a labour-intensive sector, with multiple craft and gear combinations, each of these combinations provides employment ranging from two to three people per craft to thirty people per craft. Over the years the scale of production increase and the sector faces emerging biological, economic and social challenges that may influence the ability to maintain ethically sound, productive and environmentally friendly production of fish. It is therefore important that the industry aspires to monitor and control the effects of these challenges to avoid also upscaling potential problems when upscaling production.

The Precision Fish Farming (PFF) is one of the concept which aims control-engineering principles to fish production, thereby improving the farmer's ability to monitor, control and document biological processes in fish farms. By adopting several core principles from Precision Farming (PF), and accounting for the boundary conditions and possibilities that are particular to farming operations in the fisheries environment , PFF will contribute to moving commercial fishery from the traditional experience-based to a knowledge-based production regime. This can only be achieved through increased use of emerging technologies and automated systems. Review of the existing technological solutions that could represent important components in future PFF applications are hence very important which solves the challenges related to fish production. Precision farming is not a single technology, but rather a set of many components from which farmers can select to form a system that meets their unique needs and operation size.

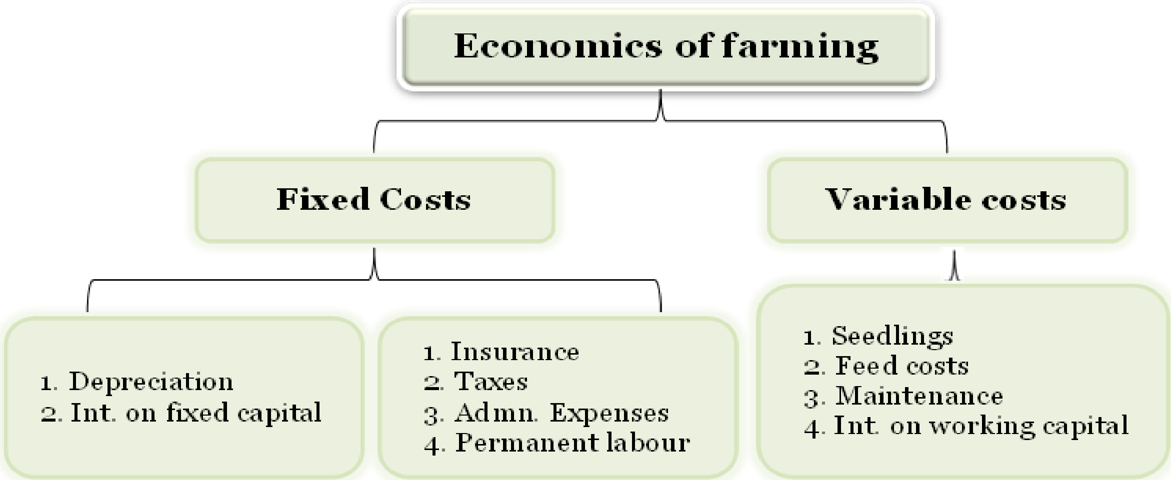
Evidences show that precision farming has the potential for improving the fisher s income and thereby enhancing the livelihood security. The impacts of precision farming in terms of increased fish production and generating high revenue were impressive. However the extent of spread of precision farming technology beyond the fishermen were found to be limited due to the high initial cost. The assessment of economic efficiency and viability of precision farming highly essential to understand the prospectus of the precision farming in the current of the fisheries sector. It is therefore, in need of the hour to study the tools and techniques for analysing the precision farming technology.

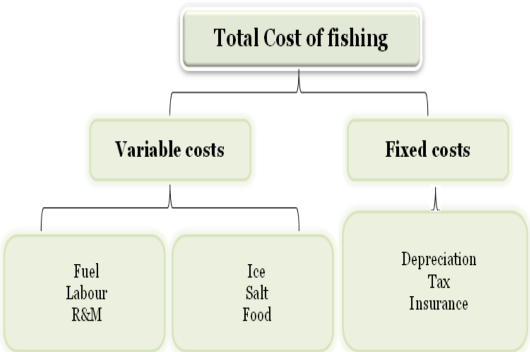
Why Economic Evaluation

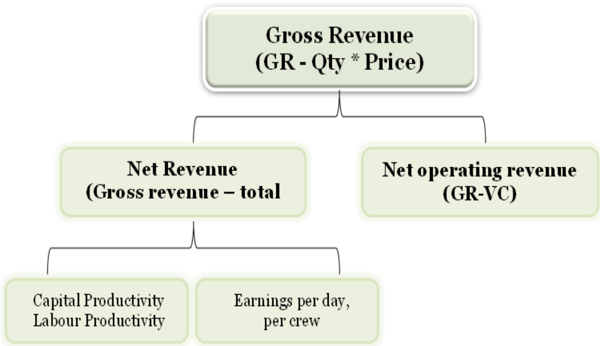
The success of the adoption of any innovation or new technology lies in its economic performance. The rate of return per rupee invested is the economic indicator that guides the investor to choose a particular enterprise or practice. Besides, the analysis of the economic performance serves as an indicator for the investor to allocate his resources in the enterprises. This becomes very much essential, since the resources are scarce and the investor is interested to invest his scarce capital resource in that enterprise that gives the maximum return for his investment. This will also serve as the guidelines to the institutional agencies for extending financial support to the enterprise. The success of the adoption of any innovation or new technology lies in its economic performance. The rate of return per rupee invested is the economic indicator that guides the investor to choose a particular enterprise or practice. Besides, the analysis of the economic performance serves as an indicator for the investor to allocate his resources in the enterprises. This becomes very much essential, since the resources are scarce and the investor is interested to invest his scarce capital resource in that enterprise that gives the maximum return for his investment. This will also serve as the guidelines to the institutional agencies for extending financial support to the enterprise.

Components of ecnomic evaluation

The economic evaluation mainly comprises cost and returns of farming,







Indicators of Economic performance

The economic performance of any aquaculture/ mariculture activity can be assessed by working out the following cost and return indicators and financial feasibility indicators.

Table 1. Indicators of economic performance of a fishery enterprise

Sl.No.	Economic Indicators
I.	**Initial investment** a)Fixed installations b)Land (if any) c) Major accessories d) Minor Accessories d) Others
II.	**Total Investment**
III.	**Fixed cost (For crop duration of six months)** a)Depreciation b)Insurance (2% on investment) c) Interest on Fixed capital (12%) d) Administrative expenses
IV.	**Total Annual Fixed cost (A)**
V.	**Operating costs** a) Cost of seeds b) Cost of feeding and other labour charges c) Interest on working capital (6%)
VI.	**Total Operating or Variable cost (B)**
VII.	**Total cost of production [Row(IV)+Row(VI)]**
VIII.	**Yield of the fish variety (in kg)**
IX.	**Gross revenue [(VIII) * Price per kg]**
X.	**Net income [(IX)-(VIII)]**
XI.	**Net operating income [(IX)-(VI)]**
XII.	**Cost of production (₹/kg)[(VII)/(VIII)]**
XIII.	**Price realized (₹/kg) (IX)/(VIII)**
XIV.	**Capital Productivity (Operating ratio) (VI)/(IX)**
XV.	**Rate of return over investment (IX)/(II)**

Precision farm budgeting

The basic concepts of precision farm budgeting includes the method of analyzing plans for the use of resources at the command of decision maker and the process of estimating costs, returns and net profit of a farm or a particular enterprise. There are two types of farm budgeting

- Complete budgeting (whole farm budgeting) - plan for the farm as a whole.
- Partial budgeting (enterprise budgeting) - partial change in the farm operation.

Partial Budgeting Format

S.No.	Debit (cost)	Credit (Benefit)
I	Added cost (A_1)	Reduced cost (B_1)
II.	Reduced Return (A_2)	Added Return (B_2)
Total	$A = A_1 + A_2$	$B = B_1 + B_2$
Partial budgeting = $(B_1 + B_2) - (A_1 + A_2) = B – A$		

where, added cost (A_1) - additional expenses associated with the proposed change, reduced return (A_2) - listing of all receipts that would no longer be obtainable under the alternative plan, reduced cost (B_1) - listing of all input and their values, which will no longer be incurred if the change is made and added return (B_2) - estimate of additional receipts that will occur from the proposed change. The results could be summarised by the value of B-A, if B – A is positive, profit - change is advisable, if B – A is negative, then loss - change is not advisable and if B – A is zero, no profit - no loss.

Example:

A fish farmer cultivating local varieties of carp wants to replace it with the composite fish culture technology. The per hectare costs and returns from the two methods are given below. The duration of both the varieties are four months. Interest on working capital is 14 per cent. Suggest whether the fish farmer could adopt the composite fish culture technology to enhance farm profit.

Price of fish	- Rs. 300 per kg	Working capital	- Rs. 8, 75000
Local carp	- 1200 kg	Working capital	- Rs. 20, 55000
Composite fish culture	- 2015 kg		

Solution:

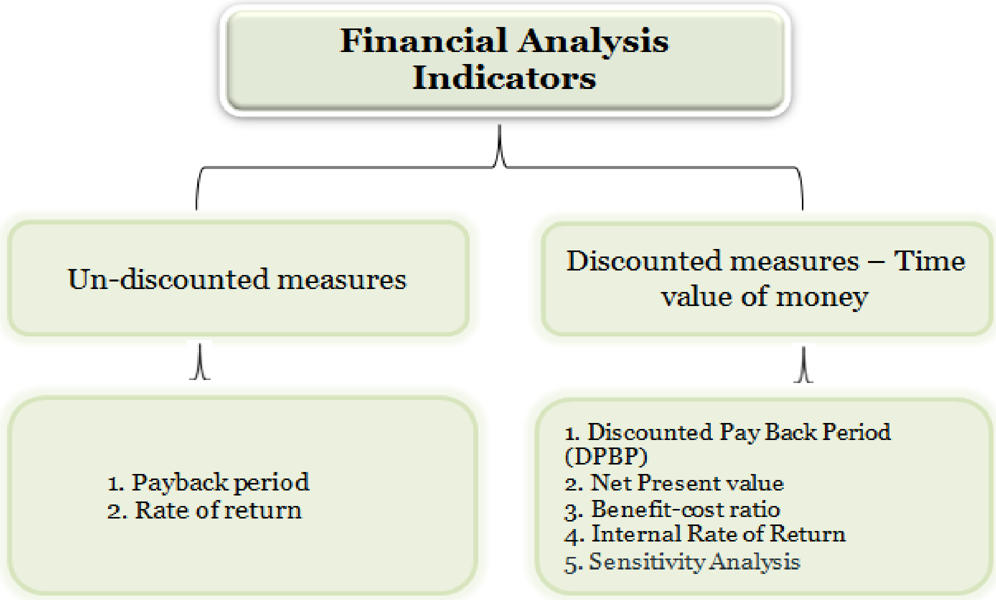
Sl. No.	Debit (Cost) (A)	Credit (Benefit) (B)
1.	Added cost (A_1) $A_1 = 1180 + \frac{(20,500-8,750)\times 14\times 14}{100\times 12}$ A_1 =12,350.75	Reduced cost (B_1) Nil B_1
2.	Reduced Return (A_2) Nil A_2	Added Return (B_2) B_2=(2015-1200) x 30=24,450 B_2=24,450
Total	**12350.75**	**24,450**

Partial budgeting = B – A = 24450 - 12350.75 = 12099.25

The result indicates that the partial budgeting is feasible and profitable .Hence the enterprise may be considered

Financial performance

The profitability of a farming system influences its value and the amount of income it generates for its producers. The financial performance of an enterprise is analysed by working out various types of indicators as given below. These measures compute either in terms of undiscounted or discounted – mainly taking into consideration of the time value of money.



The financial feasibility analysis is done using the following capital budgeting techniques with appropriate assumptions on the duration of the farming, annual days of operation, inflation of costs and returns and related parameters. Three indicators will be estimated namely, Net Present Value (NPV), Benefit Cost Ratio (BCR) and Internal Rate of Return (IRR).

There are 4 discounted measures:

(i) Discounted Pay Back Period (DPBP)

Number of years required to return the capital investment, which is computed by the cumulative sum of discounted cash inflows.

(ii) Net Present Value / Net Present Worth (NPV)

NPV is the difference between the discounted benefit and discounted cost where present value of the expected future net cash flows discounted at a specified discounted rate.

$$NPV = \sum_{t=1}^{n} \frac{CF_t}{(1+r)^t}$$

$$= \left[\frac{CF_1}{(1+r)^1} + \frac{CF_2}{(1+r)^2} \dots\dots\dots\dots\dots\dots\dots.. + \frac{CF_t}{(1+r)^t}\right] - C,$$

Where, C is the Capital investment, (CF_1 ….CF_t) is the Cash inflow and t is the time in years

(iii) Benefit Cost Ratio (BCR)

Ratio of the discounted benefit of cash inflows to the discounted investment outlay.

$$B/C \text{ ratio} = \frac{\text{Total Discounted Benefit}}{\text{Total Discounted Cost}}$$

$BCR = \frac{\sum_{t=1}^{n} \frac{B_t}{(1+r)}}{\sum_{t=1}^{n} \frac{C_t}{(1+r)^t}}$, where B_t is the Cash inflow and C_t is the Cash outflow

(iv) Internal Rate of Return (IRR)

IRR is the discount rate at which Net Present Value (NPV) is equal to zero and benefit cost ratio is equal to one where discount rate is that equates the present value of the expected future cash flows or receipts to the initial cost of the project.

IRR= NPV = 0

For working out IRR two discount rates, one of which gives positive NPV and the other gives negative NPV are generally used. The formula used is as follows

$$IRR = r_L + \left[\frac{P_v - C}{\Delta P_v}\right] \times \Delta r ,$$

Where, IRR is the Internal Rate of Return, r_L is the lower rate of discount, P_V is the present value at lower value of discounting, C is the capital investment,ΔP_V is the Difference in the present values at the two discount rate,Δr is the Change in discount rate.

(v) Sensitivity analysis

A simple technique to assess the effects of adverse changes on a project. It involves changing the value of one or more selected variables and calculating the resulting change in the NPV or IRR. The extent of change in the selected variable to test can be derived from post evaluation and other studies of similar projects. Changes in variables can be assessed one at a time to identify the key variables. Possible combinations can also be assessed. Sensitivity analysis should be applied to project items that are numerically large or for which there is considerable uncertainty. The results can be presented together with recommendations on what actions to take or which variables to monitor during implementation and operation. The merits includes forces management to identify the underlying variables and their relationships., shows how robust or vulnerable a project is to change in underlying variables and indicates the need for further work in terms of gathering information in NPV or IRR is highly sensitive to changes in some variables. The demerits includes inability to provide leads - if sensitivity analysis merely presents complicated set of switching values it may not shed light on the characteristics of the project and the fact that the impact of variation in one factor at a time, holds other factors constant, may not be very meaningful when underlying factors are likely to be inter-related.

Methodology:

Sensitivity analysis can be done to ascertain the project feasibility at three different stages.

(i) Increasing cost of capital or interest rate increases

The increasing cost of capital or the interest rate increases can be accounted in the sensitivity analysis by computing the NPV and BCR at different discount rates and thereafter checking the profitability of the changes.

(ii) Escalation of cost of the project due to different risks involved

The cost of the projects gets escalated due to the various risk factors involved in the business which include the prophylactic measures needed to control and prevent the disease outcome, application of more fertilizers than the expected, more number of irrigations, more number of man days increase due to the inefficiency of human labour, etc. These increases in the cost of the project can be accounted by the exante approach of increasing the project cost by 10 percent and 20 percent and later working the NPV and BCR with the benefit stream keeping unchanged.

(iii) Uncertainties resulting due to differences in the price receivables

The uncertainties in the project benefit stream arise due to the uncertain nature of the prices that are expected in the market after the harvests. The uncertainties are basically due to the reason that the factors determining prices itself are subjected to changes. The other uncertainties include the yield uncertainty, technological uncertainty and institutional uncertainty. In countering the uncertainties, the anticipated benefit stream in the project can be reduced by 10,20,30 percentages and the NPV and BCR are computed accordingly, keeping the project cost unchanged.

Example: Financial Performance

Compute the discounted payback period, net present worth, benefit-cost ratio and internal rate of return for the aquaculture project. The discount rate is 12 percent.

Year	Cash outflow	Cash inflow	Discounting factor	Discounted cash outflow	Discounted cash inflow
1.	250,000	-	1	250,000	-
2.	-	120,000	0.8929	-	10,7150
3.	-	100,000	0.7972	-	7,9720
4	-	80,000	0.7118	-	5,6940
5	-	5,4000	0.6355	-	3,4320
Total	250,000	35,4000		250,000	27,8130

Solution:

1. Discounted Pay Back Period = 4.5 years.
2. Net Present Value = 27,8130 - 25,0000 = 2,8130
3. Benefit Cost Ratio = 27,8130 ÷ 25,0000 = 1.112
4. Internal Rate of Return

Year	Cash outflow	Cash inflow	Discount-ing factor at 12%	Discount ed cash outflow	Discounted cash inflow at 12%	Discount-ing factor at 20%	Discounted cash outflow
1.	25,0000	-	1	25,0000	-	1	-
2.	-	12,0000	0.8929	-	10,7150	0.83300	10,0000
3.	-	10,0000	0.7972	-	7,9720	0.6944	6,9440
4.	-	8,0000	0.7118	-	5,6940	0.5787	4,6300
250000					27,8130		24,1780
Net Present Value =					+ 2,8130		- 8220

There are discount rates which gives a positive and negative net present worth.

$$IRR = rL + \left[\frac{P_V - C}{\Delta P_V} \right] \times \Delta r$$

$$IRR = 12 + \left[\frac{(27{,}8130 - 25{,}0000)}{(27{,}8130 - 24{,}1780)} \right] \times (20 - 12)$$

$$IRR = 12 + \left[\frac{2813}{3635} \right] \times 8$$

$$IRR = 18.19$$

Conclusion:

The project is feasible because the NPV is greater than zero, BCR is greater than one and IRR is greater than the opportunity cost of capital.

Example on Sensitivity Analysis

For the following fisheries project perform the sensitivity analysis for the three different cases

(i) Increasing cost of capital.

(ii) Increased cost of project due to risks involved at 10 and 20 percent cost like.

(iii) Uncertainties due to the differences in the price receivables at 10, 20 and 30 percent reduction for the yield.

Example: Sensitivity Analysis

CASE I: Increasing Cost of Capital

Year	Cost	Benefit	d.f.at 12%	d.c.at12 %	d.b.at12%	d.f.at 20%	d.c.at20 %	d.b.at 20%	d.f.at 25%	d.c. at 25%	db. at 25%
1	25000	0	1	25000	0	1	25000	0	1	25000	0
2	5000	20000	0.893	4465	17860	0.833	4165	16660	0.8	4000	16000
3	5000	20000	0.797	3985	15940	0.694	3470	13880	0.64	3200	12800
4	5000	20000	0.712	3560	14240	0.579	2895	11580	0.512	2560	10240
5	5000	20000	0.636	3180	12720	0.482	2410	9640	0.41	2050	8200
6	5000	25000	0.567	2835	14175	0.402	2010	10050	0.328	1640	8200
				43025	74935		39950	61810		38450	55440
				NPV	31910		NPV	21860		NPV	16990
				BCR	1714		BCR	1.5471		BCR	1.4418

Remarks:

The computation of the NPV and BCR at different cost of capital indicates that the project is feasible and profitable even at 25 percent discount rate. At 25 percentage discount rate also there exists a positive NPV and BCR of more than one. The exercise indicates the high yielding capacity of the project even at higher discount rates.

CASE II: Escalation of the cost of the project due to the different risks involved

Year	Cost	Benefit	d.b. at 12%	d.c. at 12%	d.b. at 12%	Cost increase by 10%	d.c. at 12%	d.b. at 12%	Cost increase by 20%	d.c. at 12%	db. at 12%
1	2500000	0	1	25000	0	27500	27500	0	30000	30000	27500
2	5000000	20000	0.893	4465	17860	5500	4911.5	17860	6000	5358	4911.5
3	500000	20000	0.797	3985	15940	5500	4383.5	15940	6000	4782	4383.5
4	500000	20000	0.712	3560	14240	5500	3916	14240	6000	4272	3916
5	500000	20000	0.636	3180	12720	5500	3498	12720	6000	3816	3498
6	500000	25000	0.567	2835	14175	5500	3118.5	14175	6000	3402	3118.5
				43025	74935		47327.5	74935		51630	47327.5
				NPV	31910		NPV	27607.5		NPV	-4302.5
				BCR	1.741		BCR	1.58		BCR	0.92

Remarks:
On increasing the cost of the project taking into consideration the different risks involved the computed NPV and the BCR values indicate that the project is feasible and economical to a discount level rate of less than 20 percentage cost increase. At 20 percentage increase in the total cost of the project the NPV appears to be negative and the BCR is lesser than one that are negative indicators of project appraisal.

CASE III: Uncertainties resulting due to the differences in the price receivables

Year	Cost	Benefit	DF at 12%	DC at 12%	DB at 12%	Reduction in benefit of 10%	Discount-ed benefit	Reduction in benefit of 20%	Discount-ed benefit	Reduction in benefit of 30%	Discount-ed benefit
1	250000	0	1	25000	0	0	0	0	0	0	0
2	5000	20000	0.893	4465	17860	18000	16074	16000	14288	14000	12502
3	5000	20000	0.797	3985	15940	18000	14346	16000	12752	14000	11158
4	5000	20000	0.712	3560	14240	18000	12816	16000	19392	14000	9968
5	5000	20000	0.636	3180	12720	18000	11448	16000	10176	14000	8904
6	5000	25000	0.567	2835	14175	22500	12757.5	20000	11340	17500	9922.5
				43025	74935		67441.5	84000	59948	73500	52454.5
				NPV	31910	NPV	24416.5	NPV	16923	NPV	9429.5
				BCR	1.71	BCR	1.56	BCR	1.39	BCR	1.21

Remarks:
The uncertainties in the project benefit stream can be sensitised by the *exante* approach of reducing the anticipated project benefit stream at 10,20, 30 percentages. The computed NPV and BCR ratios indicate that the project can withstand uncertainties to the tune of even 30 percent reduction in the yield due to the different uncertainties. The NPV and BCR at 30 percentage reduction in the yield in the project benefit stream was found to be Rs. 9,429 and 1.21 respectively.

.

Conclusion: The above tools namely cost and return indicators, budgeting analysis and financial feasibility indicators including sensitivity analysis provides various opportunities in assessing the economic efficiencies – *exante* and *expost*. However it is important to include social and environmental assessment too so as to ensure that the business option is inclusive and sustainable. The sustainable farming would encompass the facets of ecologically sound, environment friendly, socially acceptable, technologically sound, financially feasible, economically viable, user friendly, culturally compatible, indigenously resource sourced and market driven.

Suggested further readings

Battese, G.E. and T.J. Coelli, 1992. Frontier production functions, echnical efficiency and panel data with application to paddy farmers in India, 1992. The Journal of Productivity Analysis 3:153-169.

Battese G.E. and T.J. Coelli, 1995. A model for technical inefficiency effects in astochastic frontier production function for panel data. Empirical Economics 20:325-332.

Coelli, T. 1996. 'A guide to FRONTIER version 4.1: a computer program for stochastic frontier production and cost function estimation, CEPA Working Paper96/08, University of New England.

K.R. Shanmugam and Atheendar, Venkataramani 2006. Technical efficiency in agricultural production and its determinants: an exploratory study at the district level. Ind. Jn. of Agri. Econ. Vol. 61, No. 2, April-June 2006.

Gopakumar, G., K.R. Manmadhan Nair and V. Kripa. 2007. Mariculture research in India status, constraints and prospects. In: Status and Perspectives in Marine

Narayanakumar, R and Krishnan, M (2013) Socio-economic assessment of seaweedfarmers in Tamil Nadu - A case study in Ramanathapuram District. Indian Journal of Fisheries, 60 (4). pp. 51-57.

Narayanakumar, R (2009) Economic analysis of cage culture of sea bass. In: Course manual: National training on cage culture of seabass. Imelda, Joseph and Joseph, VEdwin and Susmitha, V,(eds.) CMFRI & NFDB, Kochi, pp. 120-122.

Rao, G Syda and Narayanakumar, R and Imelda, Joseph (2009) Successful Open Sea Cage culture demonstration at Balasore, Orissa: A New Horizon in Mariculture. CMFRI Newsletter (123). pp. 3-6.

SAS Institute Inc. 2014. SAS/ETS® 13.2 User's Guide. Cary, NC: SAS Institute Inc.

Sathiadhas, R. and R. Narayanakumar, 2010. Economic analysis of Open sea cagefarming. In Course Manual. Training Programme on Sea cage farming of seabass and lobsters CMFRI, 2010.

Narayanakumar, R and Shyam, S Salim and Shinoj, P and Ramachandran, C (2017) Methodological Tools for Socioeconomic and Policy Analysis in Marine Fisheries. CMFRI Special Publication (127). Central Marine Fisheries Research Institute, Kochi.

Shyam, S Salim and Biradar, R S and Pandey, S K (2005) Fisheries Economics and Marketing- An introduction. Central Institute of Fisheries Education, Mumbai.

Shyam, S Salim and Biradar, R S and Pandey, S K (2004) Economic analysis of fisheries projects. Central Institute of Fisheries Education, Mumbai.

Shyam, S Salim (2002) Business Strategies for Venturing into Fisheries enterprises. [Teaching Resource]

Pandey, S K and Shyam, S Salim and Biradar, R S (2005) Economics of Freshwater Aquaculture Technologies. Central Institute of Fisheries Education, Mumbai.