Factors influencing the Environmental and Financial Sustainability of Aquaculture Production in Jamaica

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Abstract

We use the Analytic Hierarchy Process (AHP) and the Cost Benefit Analysis (CBA) to evaluate the profitability and sustainability of aquaculture in Jamaica. We also examine the combined application of these methods to provide holistic and reliable information. In March 2010 we administered the AHP and the CBA survey instruments among 27 Jamaicans engaged in large- and medium-scale tilapia production and marketing. The overall ranking of criteria is reliable, with an inconsistency ratio (IR) of 0.075. Participants classified 'better feed conversion ratio' as their first criteria for increasing profitability and sustainability, with a rank score (RC) of 0.050. In second and third places were 'decreased disease problems' and 'decreased mortality,' with RCs of 0.036 and 0.031, respectively. The net operating income ($33,103.05), the IRR of 30.36% and P.I of 1.55 shows that tilapia production is profitable and feasible. When participants' preferences of methods for improving fish production and marketing from the AHP results were considered, fish production and marketing in Jamaica became more profitable and sustainable. The results show that the AHP method provides unique ranking of stakeholders' preferences and, when combined with the CBA, generates solid analyses for evaluating the profitability and sustainability of aquaculture enterprises.

Keywords: Jamaica,aquaculture, cost benefit analysis, analytic hierarchy process, tilapia

Introduction

Aquaculture production has been one of the fastest growing agricultural industries worldwide (Hishamunda and Ridler 2002). Its growth rate is much larger than that of the wild-caught fisheries sector. Aquaculture produced less than 10% of total fishery product globally in the 1970s, but today it produces about 50% of total fish output (Jolly et al. 2001; Diana, 2009). The increase in production is greatest in developing countries where more than 93% of aquaculture products originate, and most of that comes from small-scale aquaculture enterprises (FAO 2007). Asian countries account for 91.3% of the world aquaculture production while North

America, Latin America, and the Caribbean region account for only 3.6% of world aquaculture production. The highest growth rate of 21.3% of aquaculture production was achieved during the period 1950 to 2004 by Latin America and the Caribbean region (FAO 2007).

In the Caribbean, Jamaica is one of the most important contributors to the rate of growth in production levels for aquaculture enterprises. The local aquaculture industry in Jamaica was launched with the production of *Tilapia mossambica*, which was introduced from St. Lucia in the 1950 (Popma et al. 1984; Aiken 2002). Multiple crosses have been made with the red hybrids resulting in a mixed hybrid popularly known as the Jamaican red tilapia. Production from 1997 to 2007 has remained mostly between 4,000 and 6,000 metric tons with the exception of 2003 when it dipped to 2,968 metric tons and, in 2006, it increased to 7,543 metric tons (Appendix Table 1). The fish produced are predominantly red tilapia which is highly appreciated and are marketed locally. Notwithstanding the increased production levels over the years, the acreage in fish production and the number of farmers have declined significantly. At present, most aquaculture occurs on the south central plains of St. Catherine and Clarendon.

However, there remains significant interest in expanding the aquaculture industry at the stakeholder and ministerial levels around socio-economic factors that are important to Jamaica. For one, the production of tilapia is important as a source of additional revenue and animal protein for most Jamaican farmers. The industry also makes use of marginalized land and water resources that otherwise would have been under inefficient production of other crops or would have otherwise remained unutilized in advancing the economic prospects of the rural milieu. A survey on the economics of the fisheries sector was recently conducted through a joint Food and Agricultural Organization Government of Jamaica Fisheries Development (FAO/GOJ FD) project (Van Riel 2005, in press). The study estimated that approximately 800 people were directly employed in aquaculture, in addition to those indirectly employed in processing plants and post-harvest handling. The revenue generated from aquaculture sales is estimated at ($1 billion U.S).

The industry, however, faces several challenges. Chief among these are the availability of land and water for aquaculture (FAO 2012). Some areas that are ideal for aquaculture experience water scarcity during periods of drought, a high capital investment requirement, and competition from imported fish. Other challenges include burglary, inefficient markets, and the low quality of feed. Jamaican fish farmers are eager to understand the extent to which these and other factors affect the growth and economic viability of the aquaculture industry. Hence, it is important to interact with fish farmers and stakeholders to examine their problems, preferred solutions to these problems, and how removal of these constraints may enhance the financial profitability and sustainability of fish production.

Donor agencies and policy makers have examined numerous methods for evaluating the impacts of aquaculture and the means of soliciting information from stakeholders to measure profitability and sustainability (FAO 2009). Two chosen methods have been the Analytical Hierarchy Process (AHP) and Cost Benefit Analysis (CBA). The AHP has been used in ocean fisheries studies to evaluate fishers ranking of objectives and to determine a feasible and affordable solution for problems affecting sustainability of limited resource fishers (Leung et al. 1998; Soma 2002) but have rarely been used in aquaculture studies (Whitmarsh and Wattage 2006; Whitmarsh and Palmieri 2009). AHP makes explicit the preferences that individuals hold for one objective relative to another. The AHP methodology is employed in Jamaica to evaluate the factors influencing the sustainability of aquaculture because it imposes less cognitive burden on respondents than other multi-criteria methods. The CBA has been used in numerous aquaculture and fisheries studies (Boyce et al. 1993; Sumaila 2001; Jolly et al. 2004; Dey et al. 2006). Previous studies have listed advantages and disadvantages of using both methods for a comprehensive evaluation of aquaculture enterprises. The CBA is easy to understand. The quantitative discounted benefits are simply compared with the costs. Its simplicity means that doing a CBA is easily possible for various scenarios, locations and more. Hence we found that the CBA would be easy to apply in the evaluating long term feasibility of aquaculture production in Jamaica.

In this study, we use the AHP and CBA to analyze the profitability and sustainability of aquaculture. We also examine how both methods can be combined to provide more in-depth and concrete information for evaluating commercial aquaculture enterprises.

Principles of Analytic Hierarchy Process

AHP is based on a theory of measurement for dealing with quantifiable and intangible criteria decisions that have been applied to numerous areas, such as decision theory and conflict resolution (Vargas 1990). It is also flexible and allows stakeholder participation in the decision making process (Saaty 1983).

The AHP may help the decision maker set priorities and make the best selection by reducing complex decisions to a series of pairwise comparisons, then synthesizing the results. The AHP makes explicit the preferences that individuals hold for one objective relative to another (Whitmarsh and Wattage 2006), thus enabling consensus-reaching on a preferred decision point. The AHP considers a set of criteria and a set of alternative options among which the best decision can be made. The AHP follows four steps: Develop a hierarchy of interrelated decision-elements describing the problem; perform pairwise comparisons of decision elements using a 9-point weighting scale to generate input data; compute the relative weights of decision elements (A weight is generated for each criterion based on the decision maker's pairwise comparisons of the criteria.); and determine criteria management options by ranking the criteria and decision options (Soma 2003). The higher the weight, which is measured by the ranked score (RC) the more important is the corresponding criterion. The Expert Choice computer software is used to calculate the geometric means that provide the scores for ranking the priority options. It also generates the inconsistencies of the responses. Consistency implies that: if a>b, b>c, then a>c. However, if a>b, b>c, and c<a, this is inconsistent. The Consistency Ratio (CR), therefore, measures how consistent the judgments have been relative to large samples of purely random judgments. If the consistency is smaller than 0.1 then the level of inconsistency is acceptable. Hence an inconsistency ration (IR) which measures the deviation of the degree of consistency is estimated to determine how reliable the judgments of the respondents are.

Principles of Cost Benefit Analysis

Cost Benefit Analysis (CBA) has been used in the past by decision makers to evaluate the economic and financial desirability of a project or a business. The guiding principle of conducting the analysis is to list all benefits and costs accruing to the community. The CBA measures the cost effectiveness of different alternatives that will produce the most net benefits to individuals and communities over a sustainable period. The best way of conducting such an evaluation is to sum the net welfare gains to the individuals or the community over a sustained period (Sumaila 2001). Monetary values are used in this type of analysis as measure of the change in welfare over the time period. Here, the monetary value of the initial investment and periodic expenses are compared against the expected returns.

The method requires a consideration of all costs involved in generating the change in welfare and all benefits resulting from the investment in a given time period. Hence, a discount rate is chosen to deflate the future returns to their present values. Generally the discount rate chosen is the going market interest rate plus an additional amount for risk and anticipated inflation (Jolly and Clonts 1993). The costs of the project or undertaking include the initial investment, periodic operating costs, and other costs accruing to society due to the installation of that project or undertaking. The benefits include the sale of the output (in this case, fish production) plus all other products and benefits derived because of investment in the fish enterprise. This may include water use, additional employment, or infrastructure that enhances the wellbeing of the community.

The most common calculations used to conduct CBA are the estimation of net present value (NPV), the benefit cost ratio (*B/C*), and the internal rate of return (IRR).

Net Present Value

The NPV is used to evaluate the feasibility of the investment using a discounting technique where the initial investment is subtracted from the discounted net returns over time (Jolly et. al., 2004):

$$NPV = \int_0^n f(t,C)e^{-Kt}\,dt - C^{kt} \qquad (1)$$

where

NPV	=	net present value of investment
C	=	investment cost
t	=	point in time interval of T, and 0 ≤ T ≤ n
T	=	implementation, research, development, and adoption process period
k	=	cost of capital
e	=	present value of a $ earned years from now

The NPV is calculated simply as:

$$NPV = C - \sum_{i=1}^{n}\left[\begin{array}{l} P_1/(1+r)^1 + P_2/(1+r)^2 + \\ \cdots P_n/(1+r)^n + S/(1+r)^n \end{array}\right] \qquad (2)$$

where P_1 is the net benefit for a period, usually a year (that is the difference between the benefits minus the costs for that period); *r* is the discount rate; *S* is the sale value of the investment at the end of the period; and *n* is the length of the investment period *t*, and C is the initial investment. If *NPV*>0, the investment is acceptable; if *NPV*<0, the investment is unacceptable; and if *NPV*=0, there is an indifference.

Benefit Cost Ratio

A standard benefit-cost analysis will be employed to calculate the efficiency of the investment. The standard model used for the calculation of *B/C* (is this benefit/cost) is:

$$B/C = \frac{\int_0^n f(t,C)e^{-kT}\,dt}{C^{-kt}} \quad (3)$$

The benefit cost ratio is obtained by comparing net present value with the initial investment costs benefits. That is, the discounted net benefits are divided by the discounted costs:

$$B/C\ ratio = \frac{\sum_{i=1}^{n} B_t/(1+r)^t}{\sum_{i=1}^{n} C_t/(1+r)^t} \quad (4)$$

Where *B* stands for benefits, *C* for costs, *r* for the discount rate, and *t* for the time period; a *B/C* ratio that is greater (less) than 1 implies that the returns from the investment project are greater (less) than the cost of the investment project.

Internal Rate of Return

The internal rate of return is the discount rate that will reduce the NPV to zero or the discounted costs equal the discounted net returns. The internal rates of return *r** is the rate of return that satisfies the following condition:

$$\int_0^n f(t,C)e^{-r^*T}\,dt - C^{kt} = 0 \quad (5)$$

That is, the *r* in the NPV formula is treated as an unknown and must be determined through a trial and error process. Thus we search for the *r* that results in:

$$\left[\sum_{i=1}^{n} C_t/(1+r)^t\right] - \left[\sum_{i=1}^{n} B_t/(1+r)^t\right] = 0 \quad (6)$$

The RRR is the required rate of return on the investment of $1 as specified by the project. If *r**>RRR, accept the investment; if *r**<RRR, reject; but if *r**=RRR, be indifferent.

The IRR is most commonly used by lending agencies since the *r* generated by the project or undertaking has to be larger than the prevailing market interest rate or larger than a minimum required or acceptable rate by the investor. The appropriateness of the CBA implies that all costs and benefits are internalized and that the project generates positive net returns over a sustainable period.

Method

In October, 2009 a trip was made to Jamaica where contacts were initiated with the Ministry of Agriculture and the Fisheries Division in Jamaica to explain the purpose of the study. Contacts were made with Dr. Vincent Wright, the president of the Jamaica Fish Producers Association. Dr. Wright promised to send a list of problems facing the Jamaica Fish Producers Association.

We also contacted an individual who would provide logistics and who would serve as interviewer and execute the survey. The survey instrument was sent to Jamaica to be reviewed and tested. On March 23 to 29, 2010, we met in Jamaica and discussed with the interviewer and Dr. Wright the goals and purpose of the survey and the method of conducting the survey. We met at the Agricultural Marketing Board (AMC) and discussed with the director of the Jamaica Agricultural Investment Cooperation the purpose of our visit. Dr. Wright also addressed the eight farmers and stakeholders who were present and wanted to learn about the survey. We initiated the survey the same day after discussions with the participants who were assembled. The survey instrument was explained to those gathered and they were left to respond to the instrument. Where the farmers did not understand the questions, the interviewer assisted.

The survey instrument was also administered to other farmers in the field by the interviewer. A total of 27 farmers and individuals engaged in the aquaculture industry were interviewed using the AHP instrument. We also administered a questionnaire to obtain information to perform a cost benefit analysis (CBA).

General Method of Analytic Hierarchy Process

The question asked is how to improve the profitability of aquaculture to enhance its sustainability. The major problems and constraints influencing the profitability and sustainability of aquaculture in Jamaica were solicited from informants. The list was streamlined so that we choose the most important and common problems to both areas. The solution of the problems became the main objectives of the study. For instance the objectives were combined into six main objectives. To obtain solutions of the main problems certain aspects of the objectives had to be resolved. The resolutions became the sub-objectives. For instance if the six main objectives to attain the goal of profitability and sustainability are classified as "increase fish production, increase environmental sustainability, increase government influence or involvement, increase technological innovation, improve social and working conditions and increase industry and trade" (Table 1) and one of the objectives to be considered was increase fish production, certain sub-objectives as 'decreasing feed conversion ratio and reducing disease problems' has to be resolved (Table 2). These resolutions then became the sub-objectives. After this we developed the tree where the major criteria for evaluating the goals are listed. Pairwise groupings of the criteria were made using the Expert Choice software. Once the pairwise comparisons were developed, the decision trees were corrected by the informants to ensure that the terms used were familiar to farmers in both areas.

General Method of Benefit/Cost Analysis

The *B/C* analysis was conducted from data collected using a designed survey instrument with questions on production, secondary benefits, and costs. Secondary data and budgets from previous studies were used to improve the collected data base for the CBA evaluation. The NPV, IRR, and B/C ratio were used in the evaluation of aquaculture production. Risk and sensitivity analysis were used in the evaluation process.

Results

The results for the AHP analysis are given in tables 1 and 2. For attaining the goal of profitability and environmental sustainability, the participants were unified in their responses, with an IR of 0.082. The highest ranked objective was that of 'environmental sustainability,' with a score of 0.193 (Table 1) which is 160 percentage points higher than increase in fish production and 51 percentage points above government involvement. The second and third objectives were 'increase in government influence' and 'improve marketing and sales,' with RCs of 0.127 and 0.108, respectively. 'Technological innovation' was in fourth place, with an RC of 0.089, while 'increase in production' was in last place (RC=0.074).

The ranking of the criteria to meet the production objective was reliable. The IR was 0.089. Participants thought that 'better feed conversion,' with an RC of 0.208, was the best means of attaining aquaculture's main goals of profitability and sustainability. In a narrow second place was 'decreased disease problems,' with an RC of 0.203, but 323 percentage points higher than reduction of operating costs. In third and fourth places were 'higher stocking rate' (RC = 0.145) and 'higher yield' (RC = 0.11). In penultimate and last places were 'reduced investment' (RC = 0.51) and 'reduced operating cost' (RC = 0.048).

Participants' responses in ranking the objective of marketing and sales were unified with an IR of 0.008, which means that the responses are reliable. Participants revealed that an 'increase in fish price' (RC = 0.188) would enable them to attain their sales and marketing objectives. In second place was 'increase in harvest frequency' (RC = 0.179), and in third place was 'increase in market efficiency' (RC of 0.168). In last place was 'reduced marketing costs' (RC = 0.097).

The rankings for type of government intervention in Jamaican aquaculture are reliable, with an IR of 0.018. Participants ranked 'increase in extension effort' as the number one priority with an RC of 0.195. In second place was 'increase in government assistance' (RC = 0.18). 'Increased research funding' received third place with an RC of 0.175. In last place was 'reduced taxes' (RC = 0.081). The responses for the third objective, 'increased trade,' were fairly reliable with an IR of 0.086. To attain the objective of 'increased trade,' participants thought that 'increased final consumer price' was the best approach (RC = 0.219). In second and third places were 'increased fish consumption' (RC = 0.168) and 'increased fish export' (RC = 0.119). In last place was 'reduction in fish imports,' with an RC of 0.059.

The responses for the objective of technological innovation were reliable with an IR of 0.004. 'Better feed conversion' was scored the highest among the criteria, with an RC of 0.263. In second place was 'decreased mortality,' with an RC of 0.212. The 'reduction of feed cost' was last with an RC of 0.011. Participants were not so unified with their responses on the objective of 'improving social and working conditions' (IR = 0.281). This shows that respondents were not totally unified in their desires of improving social and working conditions, or that the criteria chosen for the evaluation of the objective were inappropriate. 'Improving harvesting service' received the highest ranking (RC = 0.281). Surprisingly, 'reduction of theft and burglary' received the lowest rank, an RC of 0.124, though it seemed a heated topic during the pre-survey discussion.

Farmers were unified in their responses of 'increased environmental sustainability,' with an IR of 0.019. 'Increased feeding rate' received the highest priority (RC = 0.247) as a means of attaining 'environmental sustainability.' In second place was 'increased production intensity,' with an RC of 0.183. In last place was 'reduce pond sedimentation,' with an RC of 0.097.

Results of Cost Benefit Analysis

The enterprise budget for producing a 300-gram tilapia in a 10-acre pond, stocking 20,000 per acre two crops per year, was developed from field and secondary data collected from reviewed documents. We assumed a feed conversion ratio of 1.9 pounds of feed to a pound of fish. The labor required per production cycle was 1,650 days at $5.65 per day. The famer used his own funds for operating the farm. The farmer constructed ponds at land costs of $2,260 per acre and pond construction cost of $3,390.00 per acre. The farm gate price of fish is $1.13 per pound and the production cycle is 5.5 months. No other associated costs and benefits were considered.

Feed and fingerling costs made up to 74.4% of operating costs and 56.7% of total costs. Fixed costs made up 23.8% of total costs. The average cost of producing a pound of tilapia was $0.86. At a farm gate price of U.S. $1.13 per pound, net returns of $0.27 per pound above all costs were obtained. The enterprise budget showed that tilapia production is profitable in the short run with net returns for the 10 acres of $33,103.30, which is $3,310.33

per acre. The break-even operating cost to produce a pound of tilapia is $0.65. That means the minimum cost the farmer will bear in the short run before considering closing down his operation is $0.65 (Appendix Table 1).

The NPV was calculated assuming a discount rate of 15% and the project continues for a 10-year period. The investment costs include funds for land and pond construction. In the long run tilapia production can be considered a profitable and financially sustainable venture. The NPV is $64,576.41. The IRR is 30.36% and the B/C is 1.55. If we assume an RRR by producers of 20%, the production of tilapia can still be considered financially acceptable.

Jamaican farmers usually produce vegetables, coconuts, and goats on their pond banks. Goats are most commonly produced since they help clean the pond banks and their sale contribute to the payment of labor costs of individuals who must reside on the pond location. Goat meat is a desirable protein source in Jamaica. Hence, the budget was modified to add the benefits and costs of growing goats on the farm. If we assume that the farmer acquires 6 acres of land for goat production and the benefits derived from goat production is the sharing of investment capital and labor costs, then goat production may enhance total farm profitability. We assume that the farmers sell 60 goats at 50 pounds per annum. The net return from goat production amounts to $3,390.00 per annum. The additional net benefits from goat production improve the NPV from the total enterprise to $79,370.97, an 18% increase. The IRR increased slightly to 33.62% and the B/C to 1.68.

Sensitivity Analysis with CBA Including AHP Ranking

The AHP results represent participants' revealed preferences of their desired goals. Hence the sensitivity was based on producers' preference on improvement of their fish farming venture. The costs and benefits were modified based on the percentage differences the farmers indicated from priority rankings.

The participants' rankings showed that a relative increase (the difference between the rank score of this sub-objective and the average rank score) in yield of at least 12% was desired. At present, farmers obtain 1.0 pound of fish per 1.9 pounds of feed. Farmers wish to reduce this to 1.0 pound of fish for every 1.48 pounds of feed. This was obtainable through a desired feed conversion ratio improvement of 22%. Farmers also desire an increase in stocking density of 8%, which translate into 20,000 fingerlings per acre. Farmers also expressed a desire for a 15% reduction in investment costs, from $116,390 to $98,931.

Achievement of farmers' objectives without consideration of secondary benefits in Sensitivity Analysis III would reduce the farmers' break-even costs to $0.70, a 19% decrease. The break-even cost to cover operating expense would fall to $0.52. The difference between break-even cost and selling price is $0.43. The net returns increased to $55,066.93 (Table 3). This is $2,196.36, a 66% increase. The NPV would then be $157,722.43. The IRR increased to 55.79% and the B/C increased to 2.59%. When secondary benefits and costs are included in the calculations, the NPV climbed to $172,516.89 and the IRR to 59.31%. The B/C increased to 2.74.

The second scenario is based on only half of the desired increase in yield (Sensitivity Analysis II) from 11,000 to 11,660 pounds per acre, a 6% increase. An 11% reduction in feed conversion ratio translates into a decrease from 1.9 pounds of feed to 1.6 pounds per acre. Stocking density increased from 20,000 to 20,800 pounds, which is a 4% increase. Investment changed from $116,390 to $107,661, a 7.5% decrease. An acceptance of these modifications resulted in an NPV increase to $106,227.36, and an almost doubling of the IRR to 44.53%. The B/C was 1.99. With the goat enterprise, the NPV was $121,021.81 and the IRR was 44.53%. The B/C was 2.112.

In the first scenario, (Sensitivity Analysis I), fish farming was neglected and yield decreased from 11,000 to 10,340 pounds, a drop of 6%. Feed conversion also decreased by 6% from 1.9 pounds of feed per pound of fish to 2.11 pound of feed to 1 pound of fish. This occurred while stocking density declined by 4%; that is, from 20,000 fingerlings to 19,200 fingerlings per acre. Investment costs also increased from $116,390 to $125,120, a 7.5% increase. Even with the worst scenario, tilapia production in Jamaica is still profitable. The NPV for a 10-acre pond is $23,949.44. The IRR is 20.57%, which is slightly greater than the IRR of 20%. The B/C is 1.19%. With the addition of a goat enterprise, the NPV is $38,743.90. The IRR increased to 23.83% and the B/C is 1.31.

Discussion

The participants were concerned about environmental and institutional factors. The highest ranked criteria were the increase in environmental sustainability and the increase in government influence. This is not strange because the sub-objective of environmental sustainability such as increase in feeding rate and increase in production intensity are related to increase in production and output. In terms of the technological criteria, the participants gave the highest rank to improving feed conversion efficiency. In second place was the reduction of diseases and mortality. Most participants indicated current low levels of mortality during pre-survey discussions but seemed concerned about diseases because of past occurrence of mortality due to diseases that, for a long time, remained unidentified. It is, therefore, important that policy makers place emphasis on the introduction of plant and animal species that will lead to increase efficiency and productivity.

Though there has been talk about competition from tilapia coming from China, participants were less concerned about trade issues. Trade was ranked next to last in importance, which suggests that the participants may have been thinking of trade as selling overseas and not as importation. The participants were not in agreement with the ranking of the criterion 'improvement in working and social conditions.' Though the rankings are unreliable because of an IR of 0.281, it is surprising to note that burglary/theft was given the lowest ranking among variables. Many participants believe that fish farmers are under constant threat of being harmed by robbers, but the fear of theft and burglary seemed not to be a major concern.

The CBA showed that the production of tilapia in a 10-acre pond was profitable in the long run. A study by Hanson (2008) also showed that tilapia production in Jamaica was profitable. The production of tilapia was slightly sensitive to changes in production and economic conditions. When we assumed that the production system was allowed to deteriorate by 6%, the production system and feed conversion efficiency declined and tilapia production was still, but less, profitable in the long run. Goat production enhanced the profitability of the farm business since its production as a separate enterprise is also positive. A consideration of farmers' preferences would significantly increase the production and farm profitability and sustainability. If farmers' wishes for improvement were only met by half, the long-term profitability would improve. If private costs can meet the changes farmers require, then advances can be made in aquaculture development without any major costs to the public sector.

Decision makers must have solid information to formulate policies to assist farmers. That is farmers participation in information sharing should be key in decision making at the policy level. Since resources are limited policy makers must give top priority to farmers' preferences. The AHP provides a method of generating ranking of farmers' problems. It also generates weights which can be used in conducting sensitivity analyses when evaluating the financial profitability and sustainability of aquaculture projects. In the case of aquaculture farming in Jamaica, we showed that tilapia production in Jamaica faced several challenges but those problems can be solved at the farm level with minor adjustments and consideration of farmers reveal preferences at the policy level.

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Table 1: Ranking of objectives and overall consistency by participants

Objectives	Ranking Score:	Overall Inconsistency
		0.082
Increase Environmental Sustainability	0.193	
Increase Government Influence	0.127	
Improve Marketing & Sales	0.108	
Technological Innovation	0.089	
Improve Social & Working Environment	0.087	
Increase Industry Trade	0.083	
Increase Production	0.074	

The overall ranking of criteria by participants can be considered as reliable, with an IR of 0.075. Participants ranked 'better feed conversion ratio' as their first criteria, with an RC of 0.050. In second place was 'decreased disease problems,' with an RC of 0.036, and in third place was 'decreased mortality,' with an RC of 0.031. In last place were 'reduction in feed cost' and 'reduction in fish imports,' both of which had RCs of 0.0.

Table 2: Fish farmers alternative objectives

Fish Farmers Main Objective Alternatives	Ranking	Overall Inconsistency
Production Alternative		0.089
Better Feed Conversion	0.208	
Decrease Disease Problems	0.203	
Higher Stocking Rate	0.145	
Higher Yield	0.110	
Increase Production Area	0.064	
Reduce Investment Costs (Pond, Machinery…)	0.051	
Reduce Operating Costs (Feed, Fingerling…)	0.048	
	Ranking	**Overall Inconsistency**
Increase Marketing and Sales		0.008
Increase Fish Price	0.188	
Increase Harvest Frequency	0.179	
Increase Market Efficiency	0.168	
Increase Sales For Your Operation	0.139	
Reduce Marketing Costs	0.097	
	Ranking	**Overall Inconsistency**
Increase Industry and Trade		0.086
Increase Final Consumer Price	0.219	
Increase Fish Consumption	0.168	
Increase Fish Exports	0.119	
Increase Fish Safety for Consumption	0.117	
Reduction in Consumer Price	0.100	
Reduction in Fish Imports	0.059	
	Ranking	**Overall Inconsistency**
Technology and Innovation Alternative		0.004
Better Feed Conversion	0.263	
Decrease Mortality	0.212	
Disease Resistance Traits	0.081	
Faster Growing Traits	0.052	
Higher Stocking Density	0.029	
Improve Water Quality	0.026	
More Efficient Aeration	0.016	
More Stress Resistance Traits	0.015	
Reduction in Feed Cost	0.011	
	Ranking	**Overall Inconsistency**
Improve Social & Working EnvironmentAlternative		0.281
Improve Harvesting Service	0.281	
Improve Individual Income	0.229	
Reduce Selling Stress	0.15	
Reduce Theft/Burglary	0.124	
	Ranking	**Overall Inconsistency**
Increase Government Influence Alternative		0.018
Increase Extension Efforts	0.195	
Increase Government Assistance	0.181	
Increase Research Funds	0.175	
Increase Subsidy	0.132	
Reduce Taxes	0.081	
	Ranking	**Overall Inconsistency**
Increase Environmental Sustainability Alternative		0.019
Increase Feeding Rate	0.247	
Increase Production Intensity	0.183	
Increase Stocking Density	0.154	
Reduce Invasive Species	0.139	
Reduce Pond Sedimentation	0.097	

Table 3: Sensitivity analysis for different scenarios for tilapia and goat production in Jamaica

	Original	Sensitivity Analysis 1	Sensitivity Analysis 2	Sensitivity Analysis 3
Net Operating Income	$33,103.35	$22,121.56	$44,085.14	$55,066.93
NPV for Tilapia	$64,576.41	$23,949.44	$106,227.36	$157,722.43
IRR for Tilapia	30.36%	20.57%	41.18%	55.79%
PI for Tilapia	1.55	1.19	1.99	2.59
NPV for Tilapia and Goats	$79,370.87	$38,743.90	$121,021.81	$172,516.89
IRR for Tilapia and Goats	33.62%	23.83%	44.53%	59.31%
PI for Tilapia and Goats	1.68	1.31	2.12	2.74

Appendix Table 1: Tilapia and marine fish production in Jamaica (Quantity in 1000kg)

Year	Tilapia	Marine Fish
1980	500	90,000
1981	600	77,220
1982	1,800	77,310
1983	2,250	84,270
1984	4,500	91,800
1985	9,900	92,250
1986	15,920	91,000
1987	23,300	84,240
1988	28,910	68,300
1989	31,870	72,860
1990	33,640	70,000
1991	31,000	71,000
1992	32,000	72,000
1993	33,000	73,000
1994	34,000	70,000
1995	35,000	76,880
1996	34,500	124,670
1997	34,000	55,790
1998	33,600	41,610
1999	41,000	62,840
2000	45,000	45,860
2001	45,000	44,000
2002	60,000	70,000
2003	25,130	79,720
2004	42,000	86,460
2005	47,950	71,580
2006	75,430	123,300
2007	56,000	110,480
2008	58,000	94,750

Appendix Table 2: Enterprise budget for producing of 300-gram tilapia stocking fingerlings in: 10-acre pond and selling goats in Jamaica

Gross receipts	Unit	price/unit	quantity	value/costs
Tilapia 300 gram	lb	1.13	110000	$139,216.00
Selling 60 goats with a weight of 50 lbs/each				$3,390.00
Total				$142,606.00
Variable costs				
Feed	lb	0.18	209000	$29,474.02
Electricity per cost/acre/month	$/acre/month	141.25	55.0	$7,768.75
Water per cost/acre/month	$/acre/month	13.56	55.0	$745.80
Seedstock	number	0.08	200000	$17,085.60
Labor	days	5.65	1650	$9,322.50
Maintenance & repair	dol			$598.90
Interest on oper. cap (9% for 7.5 months)	dol	0.00		$0.00
Total Variable Cost	dol			$64,995.57
Income above variable costs	dol			$74,220.43
Fixed costs				
Depreciation (equipment)	dol			$5,085.00
Interest on land, pond construction, equipment	dol			$17,458.50
Total Fixed Costs	dol			$22,543.50
Net return	dol			$55,066.93
Total Cost /lb of tilapia	dol			$0.70
Total Variable Cost/lb of tilapia	dol			$0.52
Total Fixed Cost /lb of tilapia	dol			$0.18
NPV for tilapia	$64,576.41			
IRR for tilapia	30.36%			
PI for tilapia	1.55			

NPV for tilapia and goats	$79,370.87
IRR for tilapia and goats	33.62%
PI for tilapia and goats	$1.68
NPV for tilapia using sensitivity analysis	$157,722.43
IRR for tilapia using sensitivity analysis	55.79%
PI for tilapia using sensitivity analysis	2.59
NPV for tilapia and goats using sensitivity analysis	$172,516.89

IRR for tilapia and goats using sensitivity analysis	59.31%
PI for tilapia and goats using sensitivity analysis	2.74

Assumptions:

1. Increase yield by 12%, which means the yield would increase from 11,000 pounds/acre to 12,320 pounds/acre
2. Improve feed conversion by 22%, which means that feed conversion changed from 1.9 pounds of feed per 1 pound of fish to 1.48 pounds of feed per 1 pound of fish
3. Increase stocking density by 8%, which means that the stocking density changed from 20,000 fingerlings/acre to 21,600 fingerlings/acre
4. Reduce the investment cost by 15%, which means that investment cost decrease from $116,390 to $98,931