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The Benefits of Constructed Wetlands Application in a Vannamei Shrimp (*Litopenaeus vannamei*) Cultivation System with a Mesohaline Condition

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Abstract
One of the negative impacts of vanname shrimp cultivation (*Litopenaeus vannamei*) activities is the decrease of rivers and coastal waters'quality for being functioned as a water source for the vanname shrimp cultivation and as a local fishing by traditional fishermen. This leads to the need to protect the water source which would require an additional cost and burdening the social cost. One of the effective methods for protecting the water resource is through the treatment of vanname shrimp cultivation wastewater by using constructed wetland-flow water surface system (CWs-FWS). The purpose of this research was to analyze the economic benefits the integrated system. The analysis was based on the direct and indirect benefits of CWs-FWS in vanname shrimp cultivation activities that were calculated in terms of Net Present Value (NPV) and Cost Benefit Ratio (CBR) of vanname shrimp cultivation activities. The research results showed that the vanname shrimp cultivation using CWs-FWS as wastewater treatment unit is economically feasible. The NPV after a period of 10 years provides a positive cumulative profit of 322,028 USD and CBR value of 1.62. The sensitivity analysis showed that the integrated system will be able to overcome the decline in shrimp price by 30% and the increased interest rates by up to 10 %.
Keywords: vanname shrimp cultivation, constructed wetland, integrated system, indirect benefit net

1. Introduction

The potency of Indonesia aquaculture reaches 57.7 million tons per year. It is used only by 23% or equivalent to a contribution of 68.54% of the total national fisheries production in 2013 (SI 2014). The aquaculture enterprises have increased significantly, from 5.4% in 2007 to 23% in 2013 (MMF 2010, SI 2014), and it is predicted to continue to rise as a result of new government policies and programs, which focuses on the fisheries sector, marine and maritime.

While the increase of aquaculture activities have positive impact, it also has negative effects. The negative effects include the exceeded carrying capacity of water, poor water quality, disruption of aquatic organisms, soil salinization, loss of mangrove forest vegetation, water quality degradation and eutrophication of the receiving waters (Riani 2014; FAO 2011; Boyd, 2003, Naylor et al. 2000). Poor water quality causes the spreading of various diseases of vanname shrimp. As a result, the cultivated vanname shrimp will fall sick and can, ultimately, lost in productivity. As stated by Riani (2015), poor water quality causes decreased immunity and the spreading of various diseases. The degradation of rivers and coastal waters' quality lead to the need for the source water treatment that would requires higher cost and burden the production cost.

The negative impact can be reduced by treating the wastewater produced from the vanname shrimp cultivation. The constructed wetlands (CWs) can be seen as an effective alternative for the water pollution control system that are environmentally friendly and sustainable. The operation and maintenance are relatively inexpensive and easy because it only uses natural energy to reduce pollutants. The operational cost is low and the system is suitable for medium and small-scale shrimp cultivation for they usually have relatively enough land area but labor and capital shortages.

The CWs system provides ecological and economic benefits because it can reduce the amount of pollutants discharged into the receiving water bodies and providing economical benefits, both direct (better water quality) and indirect (reduced cost for business due to the reduced cost for water treatment). However, research for the economical benefits of the wastewater treatment of vannamei shrimp cultivation with CWs has not been done.

This study aimed to analyze the direct and indirect benefits of the CWs-FWS application in vanname shrimp cultivation activities focusing on the analysis of net present value (NPV) and the analysis of cost-benefit ratio of the vanname shrimp (*Litopenaeus vannamei*) cultivation activities.

2. Research Methods

2.1 Scope of Research

This research was carried out to calculate the NPV by considering the value of positive and negative externalities. The externality occurs when production or consumption of the parties affecting the usability of the other parties is not desirable, and the maker of externalities does not provide compensation to the affected party externalities (Fauzi 2014). Both NPV and CBR were calculated in the case of the application of CWs-FWS in a vanname shrimp cultivation system. NPV and CBR were calculated by using a dynamic system modeling approach. According to Pizzol et al. (2014), NPV and CBR was intended to represent the externalities and the discount factor caused exposure to pollutant in the environment.

The discount factor is used to determine the present value of the benefits and cost that will occur in the future through the weighting (Fauzi 2014, USEPA 2014). The discounting represents the benefits and cost that occur in different time periods and comparable with the values in the current time.

The negative externalities are external cost (environmental cost), while the positive externalities are external benefits (environmental benefits). Suparmoko (2013) stated that the social costs consist of private cost, waste treatment cost, and environmental cost. The social benefits consist of private and environmental benefits. In this case, the negative externality covers the cost of wastewater treatment and operational cost by traditional fishermen. The positive externality covers the direct benefits received by owner actors of vanname shrimp cultivation units and of the catchings conducted by traditional fishermen in coastal areas around Aquaculture Bussines Development Centre (BLUPPB) Karawang.

2.2 Data and Methodology

The data used for simulating the economic models of CWs-FWS are primary and secondary data related to investments for processing CWs-FWS, especially CWs-FWS investment cost, operating cost (labor) and environmental cost (operating cost of traditional fishermen fishing). Benefits of CWs-FWS processing were calculated based on the direct benefits (investment) and environmental benefits (decreasing cost of water treatment source for vanname shrimp cultivation activities and increasing catchesment of traditional fishing and declining operating cost of fishing activities).

The method used in this analysis is the simulation using the dynamic model by looking at the parameters affecting the calculation of the cost-benefit analysis by taking into account the positive and negative externalities. According to Bunting and Shpigel (2009), the bioeconomic modeling was used to determine the feasibility of the business practice.

2.2.1 Structure and Simulation Model

Stock and flow diagrams (or the level and rate) were used to represent the structure of the model and generating system's behaviour. The flow is the variable that directly change the stock (VENSIM 2014). Model Dynamic system was built in a combination of stocks and flows and were simulated with computer (Ford 1999). The simulation model of an experimental stage model was performed to look at the behavior of the model that has been designed previously (Sterman 2000). The simulations were performed using software Vensim PLE version 6.3, the sensitivity-analysis of the scenarios were evaluated by the price decline of vanname shrimp by 30% of the projected price and the increasing of interest rates by up to 10%.

2.2.2 Model approaches and assumptions

Following data, approaches and assumptions were used in the model of the dynamic system:

1. The area of CWs-FWS is 20% of the overall farm area or 2000 m^2 of 10,000 m^2 ponds;
2. The CWs-FWS's efficiency is assumed to increase from 70% in year 1 to 75% in year 2, to 80% in year 3, to 85% in the 4th year, to 90% in year 5 up to - in year 10th;
3. The improved quality of coastal waters is comparable to the level of efficiency of CWs-FWS;
4. The economic value of shrimp farming vanname and CWs-FWS is 10 years;
5. The interest rate is based on the Indonesia Bank (BI) rate in February 2015, ie 7.5% (http://www.bi.go.id/en/moneter/bi-rate/data).
6. The selling price of vanname shrimp is 3.76 USD per kg;
7. The selling price of the average fish is 0.8 USD per kg;
8. Land rent conducted every 2 years 1200 USD;
9. The number of fishing trips per year is 240;
10. The number of fishermen is 25 individual;
11. Other data required to build the model was developed based on the direct and indirect cost to the market price method.

3. Results And Discussion

3.1 Analysis of Causal Loop

Figure 1 presents the causal loop in the economic analysis that illustrates the relationship between the elements involved in the assessed system. This becomes the important tool to represent the feedback on the structure of the system and the dynamics of the system. The diagram consists of variables that are connected one to other component. The arrow marks indicate the influence of causality between these variables and describe the important feedback in the model.

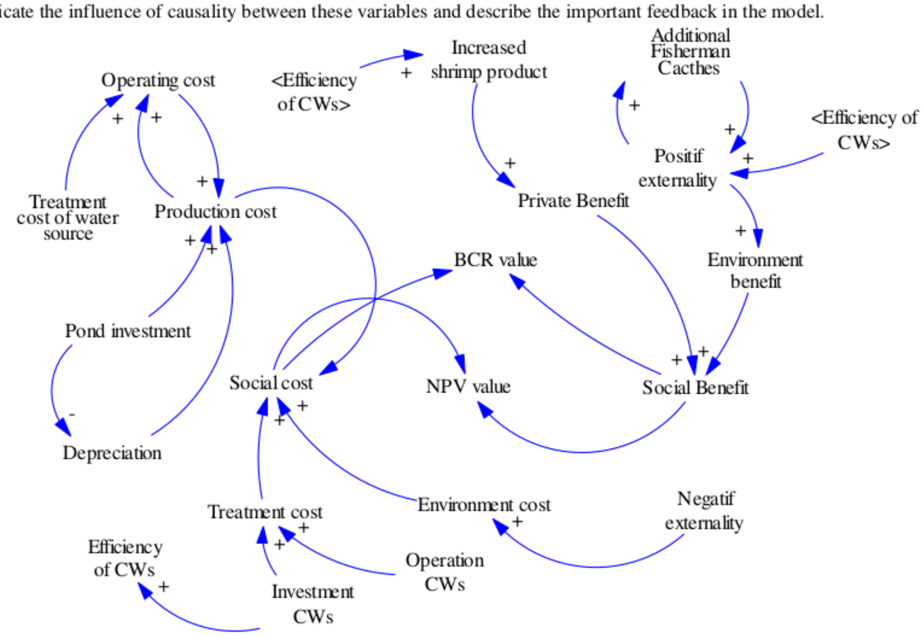

Figure 1. Causal Loop in the economic analysis of CWs-FWS

3.2 The Structure of the Model

First, the shrimp production process generates wastewater. The generated wastewater increases annually with the opening of new areas or the increased shrimp production rate. It will have an impact on marine environmental degradation, especially in coastal areas as the recipient of the discharged wastewater. With the increasing volume of wastewater it is necessary to include a wastewater treatment system in form of CWs-FWS in order to provide environmental benefits (positive externalities) and pressing environmental cost (negative externalities).

The dynamic system model was developed for analyzing the economic feasibility of the addition of a wastewater treatment unit in vannamei shrimp cultivation. The developed model was run by observing the value of the investment benefits of constructed wetlands to the value of positive and negative externalities as well as taking into account the cost of treatment. The structure of the dynamic model is presented in Figure 2.

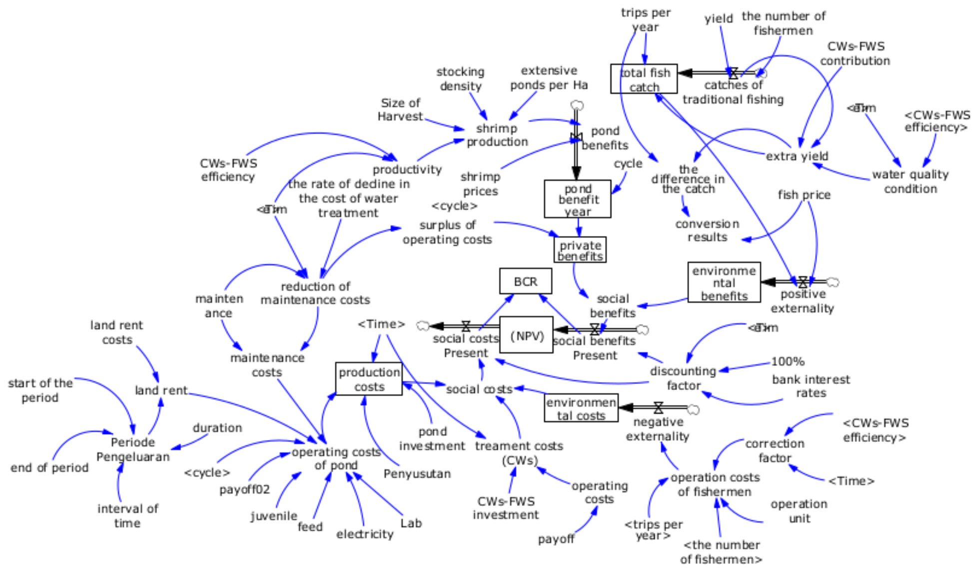

Figure 2. The structure of the analysis model of the investment benefits on CWs-FWS

3.3 Analysis of Investment Benefit Value

The investment benefits value on CWs-FWS was analyzed to see the effect of positive and negative externalities value, both directly and indirectly, on the feasibility of vanname shrimp cultivation. According to Gittinger (1984), two kinds of analysis were performed in study: (1) financial analysis, in which the views of the project direct interest in the project, (2) economic analysis, which is projected from the perspective of the overall economy.

The economic aspects are used to determine the extent to which the effectiveness of the wastewater treatment will provide the direct benefits to vanname shrimp farming activities. The considered aspects cover the total cost and the social benefits that were derived from the CWs-FWS application in the shrimp production system. A similar calculation on bioeconomic model in marine aquaculture activities using constructed wetland was performed by Bunting and Shpigel (2009), and was used here as reference.

The direct cost as capital investment consists of the cost of land lease per year and construction of CWs-FWS, vanname shrimp production and support facilities including guard house, barn, anco bridges, electrical installations, drains, pumps, water mill and infrastructure other. The operational costs consist of total cost for purchasing fry, feed, electricity, medicine, fertilizer, probiotics and labor. Moreover, the analysis of the benefits value also calculates the environmental cost as the value of the negative externalities of vanname shrimp cultivation activities. The direct benefits were based on the increase in productivity in vanname shrimp cultivation and the reduced maintenance cost (reduced cost of water source treatment). The indirect benefits or positive externalities consist of the increase in the production of traditional fishing and the quality of coastal waters.

The benefits derived from the investment of vanname shrimp cultivation and the cost and benefits were analyzed (ACB) are used to evaluate the projects that could interfere with the environment and public interest (Suparmoko 2013, Nick and Barbier 2009, Campbell & Brown 2003). The cost and benefits analysis is determined by calculating the social cost and the social benefits (Table 2). The social cost consist of production cost (operating expenses, depreciation of investment ponds and ponds), CWs treatment cost (operating cost, CWs investment and depreciation) and the environmental cost (negative externalities in the form of the cost of traditional fishermen fishing operations). The social benefits consist of private benefits (benefits of vanname shrimp production) and environmental benefits (benefits from fishing activities by traditional fishermen).

Table 2. The simulated social cost and benefits of vanname shrimp cultivation (USD)

Year to	Production cost	Treatment cost	Enviroment cost	Private benefits	Enviroment Benefit
1	86,135	1,858	31,200	91,360	48,138
2	79,177	864	30,000	97,886	48,148
3	70,566	864	28,800	104,411	48,157
4	76,354	864	27,600	110,937	48,167
5	67,742	864	26,400	117,463	48,177
6	74,942	864	26,400	117,463	48,177
7	67,742	864	26,400	117,463	48,177
8	74,942	864	26,400	117,463	48,177
9	67,742	864	26,400	117,463	48,177
10	74,942	864	26,400	117,463	48,177

The cost of treatment at the CWs every year on average accounted for 1.3% of the social cost, while the cost of the environment each year is averaging on 37% contribution to the social cost (Table 2). The increased social cost benefit analysis of the value of the investment is greatly influenced by the value of the negative externalities that are variables directly affected by vanname shrimp cultivation activities. The simulated negative externalities showed a average decrease by 39.47%. This decrease indicates that the wastewater treatment will be effective to vanname shrimp cultivation in term of cost reductions in the business environment. The reduced environmental cost ranged between 23.5% - 35.3% of the initial cost of the environment in the beginning of operation. The low cost of the environment is another additional positive effect of the CWs-FWS system for wastewater treatment in vanname shrimp cultivation. The integration of CWs-FWS contributes to increase the benefits is calculated as 13.3% with the addition rate of 2.41% per year of the total social cost to be incurred.

The private benefits counted averaging on 72% and the environmental benefits were approx. 28% of the social benefits (Table 2).

The positive externality of the CWs-FWS application as wastewater treatment unit prior to discharge to the receiving waters is that it will have positive impact on the improvement of traditional fishing income. The increase of catched fishes by traditional fishermen is averaging on 209.1 kg. This increase is still small because the wastewater treatment activities are performed only at 0.42% of the total area of ponds in BLUPPB Karawang (1 ha of 240 ha).

The feasibility analysis of integration of vanname shrimp cultivation and CWs-FWS system as a wastewater treatment unit was performed by the assessment of net present value, the external cost as well as the external benefits. This is intended to evaluate the business feasibility and so to show how much the business damage the environment and affects the incomes of traditional fishermen. According to Molinos-Senante *et al.* (2013), the results are expected to show an economic perspective of the constructed wetland application in term of the suitable option for treating wastewater. The criteria for assessment the feasibility of vanname shrimp cultivation with CWS-FWS system for the wastewater treatment are the NPV and CBR. The NPV and CBR assessment was analysed using BI rate in effect at February 2015 of as 7.5%. the calculation and simulation of the economic feasibility of vanname shrimp cultivation on the interest rate and performed for a period of 10 years found that with the additional business activities (the wastewater treatment unit CWS-FWS system), the cultivation is still feasible to be maintained.

Summary of the financial analysis for a period of 10 years is presented in Table 3. The results of the model simulations showed that the NPV—after a period of 10 years—provided a positive cumulative profit of 322,028 USD and CBR value of 1.62. The CBR value means that every expenditure of 1 USD will provide the benefits of 1.62 USD or benefit of 1.62 times of the social cost incurred. In year 1, the NPV of vanname shrimp cultivation with CWs-FWS is negative. The positive NPV value started in year 2 until year 10 with linear value-added benefits. The NPV value varies between 16,072 (negative) to 322,028 USD (Figure 3a).

The CBR value for a period of 10 years will be > 1, with the variation of the CBR in year 1 at 1.17 to 1.52 in year 4. In year 5, CBR will rise to 1.74. The CBR fluctuates with a range between 1.62 and 1.74. This situation illustrates that the CBR value in even-numbered years will decline because of additional expenditures, i.e. the land rent is paid once every two years (Figure 3b).

Table 3. Summary of the financial analysis results for a period of 10 years

Variable	Value
Social cost (USD)	102,206
Social benefit (USD)	165,640
Bruto benefit (USD)	63,434
Interest rate	7.5%
Social cost discounted (USD)	49,590
Soc.benefit discounted (USD)	80,367
Net Income (USD)	30,778
NPV (USD)	322,028
CBR	1.62

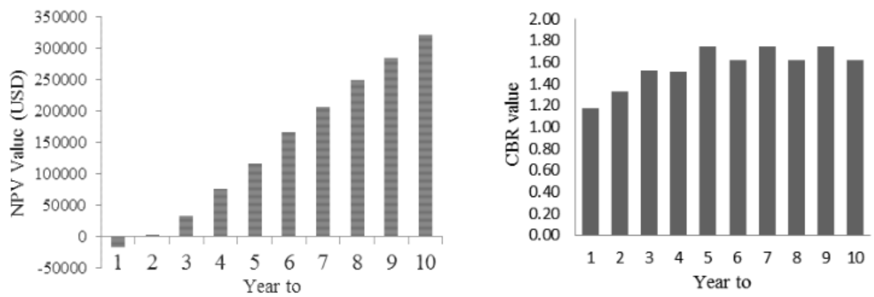

Figure 3. Dynamics of NPV value (a); Dynamics of CBR value (b) for a period of 10 years

3.5 Sensitivity Analysis of Economic Models

Uncertainty is an important thing in determining the feasibility to estimate the cost and social benefits. A sensitivity analysis was performed on the combined scenario of shrimp price reduction of 30% of the projected price of shrimp and the rising interest rates by 10%. A shrimp price reduction of up to 30% and a rising interest rate to 10% will certainly affect significantly to the income of vanname shrimp cultivation. The combination of both changes causes the NPV decrease to 86,260 USD, so that the profits decrease to be 31,904 USD. The CBR value also decreases by 0.27. The private benefits fell by 27% from the private benefits that CBR corrected projection to 1.35.

Results of the sensitivity analysis showed that the simulated profits derived from vanname shrimp production will still be able to cope with the decrease in shrimp prices by 30% and an increase in interest rates by 10%. Both of these changes together will reduce profit by 37% of the projected profit of 322,028 USD.

4. Conclusions

Economic analysis of the wastewater treatment of vanname shrimp cultivation using constructed wetland-flow water surface system provides direct and indirect benefits. The CWs-FWS treatment cost contributes to approx. 1% of the social cost, while the environmental cost annually contributed to approx. 30% of the social cost. The CWs-FWS application reduces the negative externalities value of up to 39.47%. The positive externality of the CWs-FWS application gives a positive impact by increasing the traditional fishing's revenue. The estimated catching conducted by traditional fishermen increases by 3.2%. The simulation of the economic feasibility of vanname shrimp cultivation with the wastewater treatment system at an interest rate of 7.5% and for a period of 10 years indicate that the business is economically feasible. The economic sensitivity analysis shows that the scenario in which private benefits derived from a decline in shrimp prices as much as 30 % and the interest rates increased up to 10% is still providing profitability.

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