International Journal on Advanced Science Engineering Information Technology

Vol.12 (2022) No. 3
ISSN: 2088-5334

Dynamic System for Silvofishery Pond Feasibility in North Sumatera, Indonesia

Nindyah Wulandari [a], Yuntha Bimantara [b], Nurdin Sulistiyono [a,c], Bejo Slamet [a,c], Rizka Amelia [a] Mohammad Basyuni [a,c,*]

[a] *Department of Forestry, Faculty of Forestry, Universitas Sumatera Utara, Medan, Indonesia*
[b] *Magister Program of Forestry, Faculty of Forestry, Universitas Sumatera Utara, Medan, Indonesia*
[c] *Center of Excellence for Mangrove, Universitas Sumatera Utara, Medan, Indonesia*
*Corresponding author: *m.basyuni@usu.ac.id*

***Abstract*—Silvofishery is the planting of mangroves in pond area. The commodities selected for silvofishery ponds include tiger shrimp, milkfish, and mangrove crab. The purpose of this research was to find the best silvofishery system based on the average net present value (NPV) using a dynamic model simulation and provide information about the effect of price changes or production of selected commodities on silvofishery. The results of this research showed that tiger shrimp and mud crab are the best and most feasible combinations for silvofishery, having an average NPV of $755.71/ha/year. Meanwhile, silvofishery using tiger shrimp has an average NPV of $332.28/ha/year, and the silvofishery combination of milkfish and tiger shrimp has an average NPV of $-216.45/ha/year. The effect of price increases the variable cost price by 63.3%, which indicates that the silvofishery combination of tiger shrimp and mud crab is still feasible to run. The decline in the selling price of the commodities of tiger shrimps and mud crab by 70% and 50%, respectively, makes this combination still feasible to operate. On the other hand, the surrounding community's level of consumption greatly affects the level of sale of the silvofishery commodity. Environmental management must also be practiced as best as possible to maintain the functioning of the environment around the ponds to avoid major losses, and periodic maintenance must be done by managers to achieve the production targets. The present study suggested that pond farmers must be wise in making decisions to implement the appropriate combination of silvofishery.**

***Keywords*—Silvofishery; net present value; tiger shrimp; mangrove crab; milkfish.**

Manuscript received 8 Jan. 2021; revised 21 May 2021; accepted 1 Sep. 2021. Date of publication 30 Jun. 2022.

I. Introduction

Mangrove forests provide complex physical, biological, and potential economical functions. Biological functions of mangroves include spawning and growth of larvae (nurseries) fishery commodities, food provision (feeding sites) for organisms that live around mangrove ecosystems, protection against biodiversity, and carbon sinks and oxygen producers [1]. The physical functions of mangroves are acting as breakwaters, protecting the coast from erosion, preventing seawater intrusion into the soil, treating organic waste, retaining mud, and trapping pollutants. The economic functions of mangroves include firewood, ponds or aquaculture, and ecotourism [2].

The livelihoods of many people living in and bordering the mangrove areas are highly dependent on forest and fishery resources provided by the mangrove ecosystem [1], [2]. Mangrove ecosystems work as spawning grounds, nurseries, and eating places for aquatic animals such as shrimp, crabs, and fish and provide habitat for birds that live and migrate and other animals. However, mangroves are currently an endangered ecosystem, threatened primarily by direct and indirect degradation and deforestation [3]–[5]. Therefore, mangrove conservation, increased reforestation programs, and sustainable mangrove management are needed to retain the balance of mangrove forests. Many studies have been reported on the environment-friendly culture systems called silvofishery, an integrated system comprising mangrove trees and brackish-water aquaculture [6]–[9]. Silvofishery has shown economic and ecological advantages [6], [7]. Silvofishery ponds integrated between mangrove management and the utilization of fishery are a promising alternative to maintaining mangrove forests [7], [8]. Lubuk Kertang Village, Langkat, North Sumatra, has 120 ha of mangrove area, which is slowly getting degraded due to land conversion for aquaculture and oil palm plantation [9]. One of the ways to conserve mangrove ecosystems is by management through community-based silvofishery. Silvofishery is a form of mangrove conservation integrated with fishery cultivation to enhance the revenue of local societies adjacent to the mangrove forest [9]-[11]. Thus, this study is supposed to provide accurate results for business prospects supporting the lives of coastal and sustainable communities in terms of their economic and ecological aspects. Given the importance of silvofishery, this study aimed to get more insight into the best combination of fishery products from the silvofishery system practiced by the community and obtain information on the effect of changes in operational costs during the cultivation period and the selling price of the best silvofishery system.

II. Materials and Method

The sampling area was in the Langkat Regency of the North Sumatra Province. This study was carried out in three ponds, between 04º03'29.69" N and 98º15'48.59" E (Fig. 1). These silvofishery ponds were built in 2010, with an area of 2 hectares adjoining the rehabilitated mangrove forest and bounded by a flood gate so that the ponds are not affected by tides.

A. Sampling and Data Collections

Some communities use the ecological type of silvofishery for managing the pond, characterized by the plantation of mangroves surrounding aquaculture. The key respondents, community leaders who manage the silvofishery pond, were recruited to answer closed-ended questions. The respondents were given a list of questions about venture capital, the advantages, and disadvantages of managing a pond [12]. Then, the flow chart of dynamic system for silvofishery pond feasibility in North Sumatera, including developing a new simulation model was described in Fig. 2.

B. Data Analysis of Financial Feasibility

In this study, the financial feasibility of a pond is decided based on the calculation of the net present value (NPV) for each of the possible scenarios over varying lengths of time horizons (three phases) following the four steps as outlined in the Asian Development Bank (ADB) guidelines [13]. The steps are (i) identification of the economic (and financial) benefits and costs, (ii) quantification of the benefits and costs, (iii) valuation of the benefits and costs over the life or time horizon of the analysis, and finally, (iv) comparing the benefits with the costs using the benefit-cost ratios (BCRs). Fish farming is feasible if the total NPV value during the simulation year is > 0. NPV values can be obtained using the following formula:

Present value of benefits,

$$B= \frac{B0}{(1+i)0} + \frac{B1}{(1+i)1} + \cdots + \frac{BT}{(1+i)\mathrm{T}} = \sum_{t=0}^{t=T} \frac{Bt}{(1+i)t} \qquad (1)$$

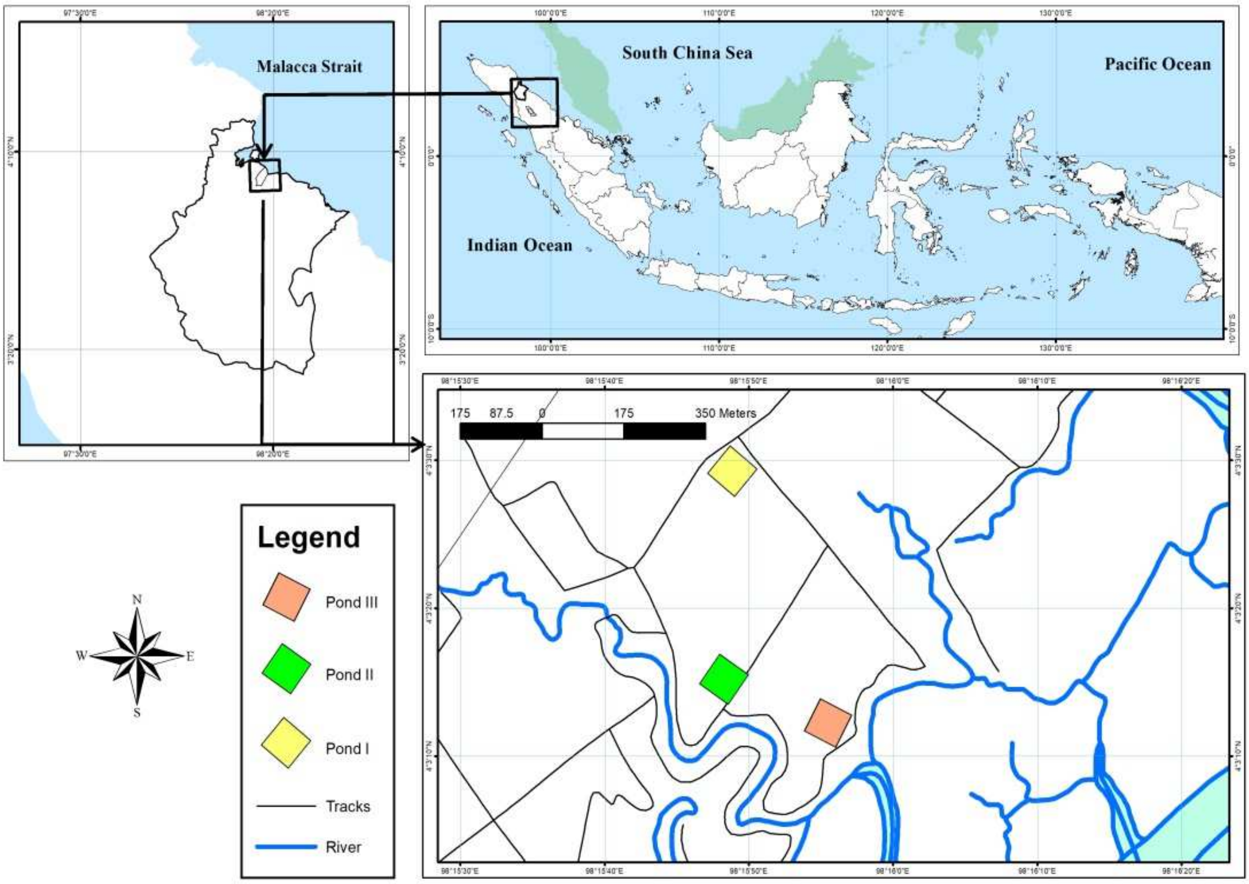

Fig. 1 Study area showing three silvofishery ponds for dynamic system development in Lubuk Kertang Village, Langkat Regency

Similarly, the present value of all the costs is as follows:

$$C = \sum_{t=0}^{t=T} \frac{Ct}{(1+i)t} \quad (2)$$

The net present value, NPV, can be estimated as follows:

$$NPV = \sum_{t=0}^{t=T} \frac{Bt}{(1+i)t} - \sum_{t=0}^{t=T} \frac{Ct}{(1+i)t} \quad (3)$$

Let the benefit derived at present (time t = 0) be B_0 and after t = T years be B_T. If the discounting rate for all future benefits remains constant at i%, the concept of financial profit is different from economic profit. The financial analysis of a project estimates the profit accruing to the project-operating entity or the project participants. All direct costs incurred under the mangrove restoration idea and the associated direct benefits were considered in the financial analysis. On the contrary, an economic analysis measures the effect of a project on society. For a project to be economically viable, it must be financially sustainable as well as economically efficient. Thus, financial and economic analyses are complementary to each other [13].

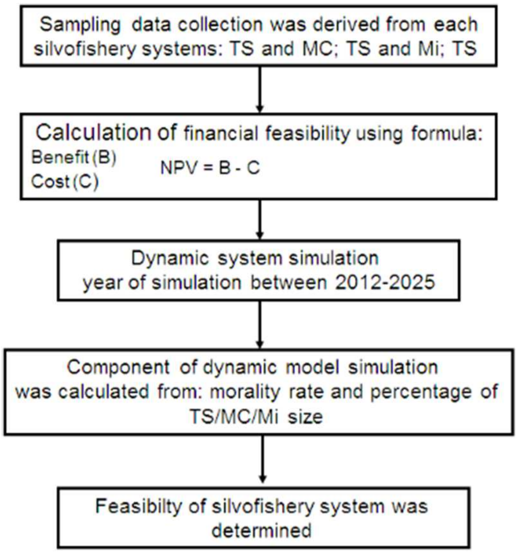

Fig. 2 Flow chart of dynamic system development for silvofishery pond feasibility in North Sumatera. TS = tiger shrimp, MC = mangrove crab, Mi = milkfish, NPV = net present value

C. Dynamic System Simulation

Simulation of the financial model of the financial feasibility of silvofishery was developed as a decision-making tool to look for the best dynamic financial feasibility model of silvofishery that has the largest total value and average NPV, and the effect will be seen with various changes in the sensitivity analysis. This simulation began in 2012 wherein that year, the business of silvofishery ponds ended in 2025.

The ratio of the land covered by mangrove and shrimp ponds varies significantly from country to country [14-16]. Our analysis analyzed the base ratio of mangrove land to shrimp land was 50:50 in our analysis. Silvofishery is a naturally harmonized mangrove–aquaculture system that provides greater ecological value to shrimp and crab by reducing viral attack and raises productivity with minimal or no chemical application. Thus, shrimps produced in this system are expected to raise a premium price in the international market.

D. Specifications of Equations in Dynamic Model Simulation

In a dynamic model simulation, several equations were needed to calculate the components of production and costs in formulating NPV values. These equations include the following:

Calculation of the number of live inputs of juveniles (tiger shrimp, mangrove crabs, milkfish) that live: The number of juveniles that live was determined by the rate of death and stocking of fry in units (tail/ha). The following formula can find the number of fry that can live:
The number of fry that live = spread fry – (mortality rate x spread fry).

$$Mortality\ rate\ (Z) = \frac{-\ln(\frac{Nt+1}{Nt})}{(t+1)-t} \quad (4)$$

Calculation of production input of fry (tiger shrimp, mangrove crabs, milkfish): Production input/fry are based on calculating the percentage of fry of each size, weight of fry of each size, and the number of fry that live. Tiger shrimp has three main classes, including size 10, size 40, and size 50. These measurements are based on the number of shrimps per kg. Size 10 means that in 1 kg, there are 10 tiger prawns and likewise for sizes 40 (40 tiger prawns in 1 kg) and 50 (50 tiger prawns in 1 kg). The weight of the tiger shrimp in the size 10 is 0.01 kg, size 40 is 0.04 kg, and size 50 is 0.05 kg. Meanwhile, the percentage of tiger shrimp is calculated as follows:

$$Percentage\ of\ tiger\ shrimp\ size = \frac{\text{mangrove crab size}}{\text{total number of mangrove crab in all sizes}} \quad (5)$$

Based on this formula, the production of mangrove crabs for each size can be obtained by the formula:
Mangrove crab production size n = weight of mangrove crab size n x percentage of mangrove crab size n x number of mangrove crabs that live.

Like the production of tiger shrimp and mangrove crabs, milkfish has three classes: size 7, size 13, and size 17. In size 7, there are seven milkfish weighing 0.14 kg/fish. In size 13, there are 13 milkfish weighing 0.07 kg/fish. In size 17, there are 17 milkfish with a weight of 0.06 kg/fish. The following formula calculates the percentage of milkfish:

$$Percentage\ of\ milkfish\ size = \frac{\text{milkfish size}}{\text{total number of milkfish in all sizes}} \quad (6)$$

From this formula, the production of milkfish for each size can be obtained by the following formula:
Milkfish production size n = weight of milkfish size n x percentage of milkfish size n x number of milkfish crabs that live.

III. Results and Discussion

The current study allows us to determine the silvofishery financial feasibility simulation. Three models were tested to get the best combination model that has the largest total value and average NPV. The three models included the simulation of the financial feasibility of a combination of tiger shrimp and mangrove silvofishery, the financial feasibility of a combination of milkfish and tiger shrimp, and the financial feasibility of tiger shrimp silvofishery. Each of these models had sub-models, including the production revenue sub-model, the expenditure sub-model, and the NPV sub-model. The production acceptance sub-model explains the total amount of revenue received by farmers from the sale of each commodity's harvest per size for a year. Expenditures during the cultivation period are calculated by adding fixed, variable, and investment costs. Fixed costs include land rent and taxes.

Several studies have shown variable costs consist of juvenile costs (tiger shrimp, mangrove crabs, and milkfish) stocking maintenance costs of investment cost components such as the purchase of damaged equipment, repair of flood gates and guardhouses, labor costs consisting of daily labor and harvesting labor, pond fertilizer costs (saponins, urea, and phosphorus), and commodity feed costs [14-16]. Investment costs include the construction of a guardhouse, the purchase of mangrove seedlings, the manufacture of flood gates, ponds, and the purchase of tools such as nets, hoes, and so on. Investment costs are only available in the first year of the simulation in the timetable.

Then, the sub-model of production and expenditure (total cost) during the cultivation period is used to calculate the amount of NPV in a dynamic model simulation. The NPV sub-model explains the amount of present-day income received by farmers. NPV calculation is based on income, expenses, and interest rates. The discount benefit was discounted income. Discount cost is the discounted expense.

A. Silvofishery Feasibility Simulation Combination of Tiger Shrimp and Mangrove Crab

The results of the silvofishery financial feasibility simulation of the combination of tiger shrimp and mangrove crabs consisted of four sub-models: the tiger shrimp sub-model, the mangrove crab the cost component sub-model, and the NPV sub-model.

Four sub-model arrangements were made based on the input and output of the tiger shrimp and mangrove crabs silvofishery system. The first tiger shrimp sub-model had components that were used to obtain a large amount of tiger shrimp revenue for a year. Second, the mangrove crab sub-model had components that were used to get a large number of mangrove crabs in a year. The third cost component sub-model had components that were used to determine the amount of expenditure (total cost) of silvofishery cultivation of a combination of tiger shrimp and mangrove crabs for a year. The fourth component forming the NPV sub-model was calculated based on the total revenue from the tiger shrimp sub-model and the mangrove crab sub-model, and the costs incurred during the cultivation period in the cost component sub-model.

After calculating the revenue results minus the amount of expenditure, a timetable was prepared that showed the NPV scheme through the reduction of the discount benefit with the discount cost. The table arrangement was based on a 14-year prediction as shown in Table I. Table 1 and Fig. 3 explain that the total NPV silvofishery of tiger shrimp and mangrove crabs is equal to $10,579.94. Based on the total NPV, the silvofishery of tiger shrimp and mangrove crabs is declared feasible to run. Discount cost is an expense that has been discounted every year. In the first year, the discount cost was $282.70 and a discount benefit of $-144.67. However, before being discounted, the costs incurred in the first year amounted to $4,349.19/ha and a total income of $2,123.47/ha. Tiger shrimp production reached 91.8 kg/ha with a revenue of $703.32/ha.

TABLE I
TIMETABLE OF NPV ON TIGER SHRIMP AND MANGROVE CRAB SILVOFISHERY SYSTEM

Year	Discount Benefit	Discount cost	NPV
2012	-144.67	282.70	-427.37
2013	-6.65	282.70	-289.34
2014	296.58	117.49	179.09
2015	434.61	117.49	317.12
2016	572.64	117.49	455.14
2017	710.66	117.49	593.17
2018	848.69	117.49	731.19
2019	986.71	117.49	869.22
2020	1,124.74	117.49	1,007.25
2021	1,262.76	117.49	1,145.27
2022	1,400.79	117.49	1,283.30
2023	1,538.81	117.49	1,421.32
2024	1,676.84	117.49	1,559.35
2025	1,814.87	117.49	1,697.37
	Total NPV		10,579.94

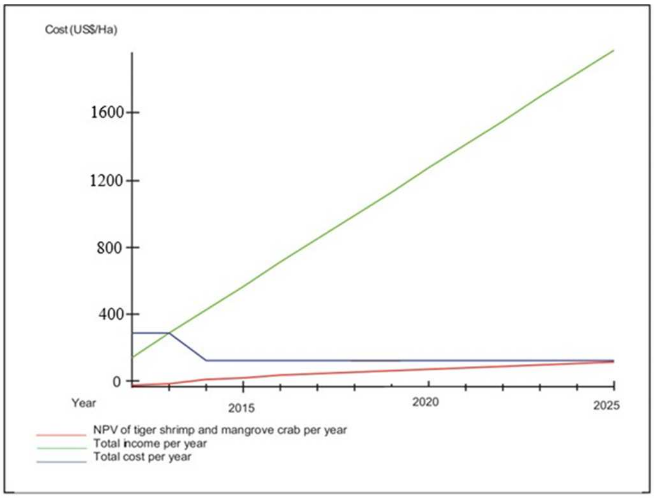

Fig. 3 Graphical representation of tiger shrimp and mangrove crab silvofishery system

Mangrove crab production reached 3,375 kg/ha with $1,420.15/ha revenue. In 2014, the NPV was positive ($179.09/ha). This circumstance was caused by the high selling prices of the two commodities caused by the selling power of these commodities and the nutritional content and transportation costs incurred by farmers moving them from the area of origin to urban areas for sale. The owner of a pond in the village of Lubuk Kertang sells harvests of tiger shrimp and mangrove crabs to urban areas.

B. Dynamic Simulation Model of Silvofishery Financial Feasibility of Milkfish and Tiger Shrimp Combination

The results of the silvofishery financial feasibility simulation of the combination of tiger shrimp and milkfish consisted of four sub-models: the tiger shrimp sub-model, the milkfish sub-model, and the cost component sub-model, and the NPV sub-model. Four sub-model arrangements were made based on the input and output of the tiger shrimp and milkfish silvofishery system. The first tiger shrimp sub-model had components that were used to get a large amount of tiger shrimp revenue for a year. Second, the milkfish sub-model had components that were used to get a large number of mangrove crabs in a year. The third cost component sub-model had components that were used to determine the amount of expenditure (total cost) of silvofishery cultivation of a combination of tiger shrimp and milkfish for a year. The fourth component forming the NPV sub-model was calculated based on the total revenue from the tiger shrimp sub-model and the milkfish sub-model, and the costs incurred during the cultivation period in the cost component sub-model.

The low selling price of milkfish as the main commodity whose fry is stocked in a larger amount compared to the tiger shrimp fry caused the total NPV to be negative, so the model is not feasible to run. Public interest influences the demand for milkfish and tiger shrimp. Farmers sell milkfish and tiger shrimp harvests in the village of Lubuk Kertang and the surrounding areas where community interest in the area is low; therefore, farmers reduce the selling price of milkfish so that the harvest is sold out [15-16].

The low level of community interest has caused a low demand for milkfish in Lubuk Kertang Village. This circumstance reflects that the local market for milkfish commodities in Lubuk Kertang Village is very low. Hence, the silvofishery of milkfish and tiger shrimp is not feasible to apply in this location.

Table II and Fig. 4 depict that the total NPV of silvofishery banding, and tiger shrimp is equal to $-3,030.34/ha. Based on the total NPV, the milkfish and tiger shrimp silvofishery are declared unfit to run. The discount cost was $294.46/ha in the first year and a discount benefit of $-282.56/ha. However, before being discounted, the costs incurred in the first year amounted to $4,530.13/ha and a total income of $183.09/ha. Total revenue was influenced by the amount of production and the magnitude of the selling prices of the two commodities. Tiger shrimp production reached 16.83 kg/ha with $128.94/ha revenue. Milkfish production reached 138.60 kg/ha with $54.15/ha revenue.

TABLE II
TIMETABLE OF NPV ON TIGER SHRIMP AND MILKFISH SILVOFISHERY SYSTEM

Year	Discount Benefit	Discount cost	NPV
2012	-282.56	294.46	-577.02
2013	-270.66	282.70	-553.35
2014	-93.55	129.25	-222.81
2015	-81.65	117.49	-199.14
2016	-69.75	117.49	-187.24
2017	-57.85	117.49	-175.34
2018	-45.95	117.49	-163.44
2019	-34.05	117.49	-151.54
2020	-2.21	117.49	-119.71
2021	-10.25	117.49	-127.74
2022	1.66	117.49	-115.84
2023	13.56	117.49	-103.94
2024	25.46	117.49	-92.04
2025	37.36	117.49	-80.14
	Total NPV		-3,030.34

C. Dynamic Simulation Model of Tiger Shrimp Silvofishery.

The results of the silvofishery financial feasibility simulation of the combination of tiger shrimp and milkfish consisted of three sub-models: the tiger shrimp production sub-model, the cost component sub-model, and the NPV sub-model. The following is a description of the three sub-models.

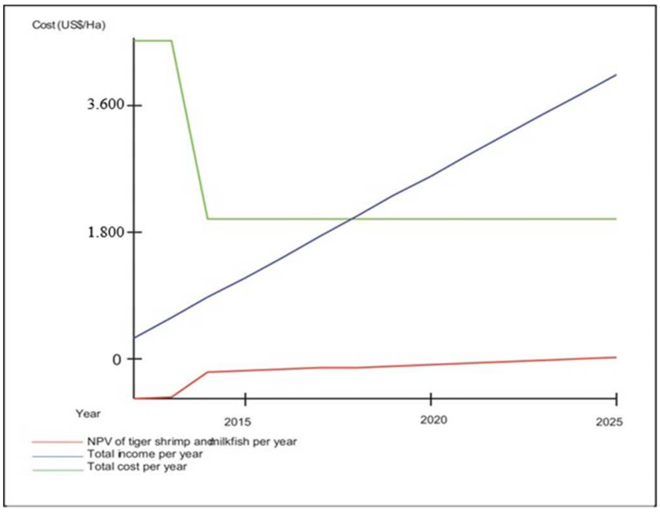

Fig. 4 Graphical representation of tiger shrimp and milkfish silvofishery system

Three sub-model arrangements were made based on the input and output of the tiger shrimp and milkfish silvofishery systems. The first tiger shrimp sub-model had components that were used to get a large amount of tiger shrimp revenue for a year. The second cost component sub-model had components that were used to determine the amount of expenditure (total cost) of silvofishery cultivation of a combination of tiger shrimp and milkfish for a year. The third component forming the NPV sub-model was calculated based on the total revenue from the tiger shrimp sub-model and the milkfish sub-model, and the costs incurred during the cultivation period in the cost component sub-model.

TABLE III
TIMETABLE OF NPV ON TIGER SHRIMP SILVOFISHERY SYSTEM.

Year	Discount Benefit	Discount cost	NPV
2012	-185.33	261.52	-446.85
2013	-109.13	282.70	-391.83
2014	132.65	95.92	36.73
2015	208.85	117.49	91.35
2016	285.04	117.49	167.55
2017	361.23	117.49	243.74
2018	437.42	117.49	319.93
2019	513.62	117.49	396.12
2020	589.81	117.49	472.32
2021	666.00	117.49	548.51
2022	742.19	117.49	624.70
2023	818.39	117.49	700.89
2024	894.58	117.49	777.09
2025	970.77	117.49	853.28
	Total NPV		4,651.95

Table III and Fig. 5 displayed that the total NPV silvofishery of tiger shrimp is equal to $4,651.95/ha. Based on the total NPV, the silvofishery of tiger prawns is declared feasible to run. In the first year, the discount cost is $261.52/ha and the discount benefit is $-185.33/ha. However, before being discounted, the costs incurred in the first year amounted to $4,023.38/ha and a total income of $1,172.18/ha with tiger shrimp production, reaching 126 kg/ha. Tiger shrimp farming systems can produce higher profits compared to the combination pattern because they have a higher life expectancy. Based on the NPV criteria, if NPV > 0, the business carried on is included in the feasible category. This finding shows that the cultivation of tiger prawns on silvofishery ponds is feasible and profitable [17-19].

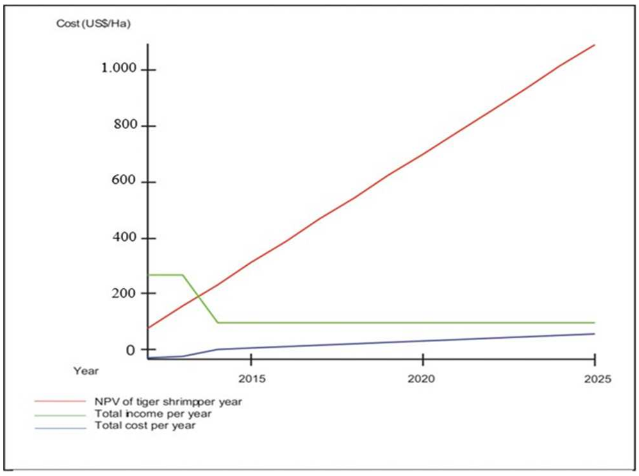

Fig. 5 Graphical representation of tiger shrimp silvofishery system

The factors that influence the demand for a fishery commodity include selling price, community income, and price of substitute goods. Urban communities have high purchasing power supported by high incomes. This high-income triggers urban communities to be more selective in choosing food ingredients [20-21]. The high interest of people in urban areas in consuming tiger shrimp and mangrove crabs causes the demand for tiger shrimp and mangrove crabs to be high, even though the yields obtained are small. To find silvofishery with the best combination, the NPV value of each model must be compared [22-23]. The following is a comparison of the NPV values of the three models.

TABLE IV
TIMETABLE OF NPV ON TIGER SHRIMP SILVOFISHERY SYSTEM

No.	Silvofishery Commodities	Total NPV ($/Ha)	Average of NPV ($/Ha/year)
1	Tiger shrimp and mangrove crab	10,579.94	755.71
2	Milkfish and tiger shrimp	-3,030.34	-216.45
3	Tiger shrimp	4,651.95	332.28

Table IV shows the silvofishery of tiger shrimp and mangrove crabs, and that of tiger shrimp is feasible to run. However, the silvofishery combination of milkfish and tiger shrimp is not feasible to run because the total value and the average NPV are negative, so they do not meet the proper criteria for NPV. The total and average NPV values of the three silvofishery models are influenced by the level of demand for each commodity. The level of demand is influenced by the selling prices, community interest, and community income in Lubuk Kertang Village and the region that allows farmers to sell their crops.

Consumer tastes regarding the consumption of a type of fishery commodity in an area affect the high and low demand for commodities in that area. The high and low demand for a type of commodity affects the value of the sale price offered. The public taste for tiger shrimp and mangrove crabs' consumption is greater than that of milkfish [24], [25]. The community still wants to buy tiger shrimp and mangrove crabs, so the demand for these two commodities remains, despite the high selling price offered. The taste or interest of the community is supported by the level of community income [8], [26], [27].

The management of mangroves by partially paying attention to the aspects of the management of forest areas in ponds indirectly influences production due to the role of detritus and supports the life of various aquatic ecosystems [28,29]. Management of environmentally friendly ponds can be implemented, such as the manufacture of flood gates for water circulation. Good water circulation in ponds affects the nutrients from organic and inorganic materials that decompose and enter at high tide [30], [31].

Therefore, the surrounding community's level of consumption greatly affects the level of selling of the silvofishery commodity. Environmental issues must also be addressed as best as possible to maintain the function of the environment around the ponds to ensure there are no major losses. Furthermore, managers must carry periodic maintenance to meet production targets.

IV. CONCLUSION

The commodities selected for silvofishery ponds included tiger shrimp, milkfish, and mangrove crab, of which the best combination of silvofishery ponds was that of tiger shrimp and mangrove crabs, with a total value and an average NPV of $10,579.94/ha/year and $755.71/ha/year, respectively. The sensitivity analysis showed that with an increase in variable costs by 63.3% and a decrease in the selling price of tiger shrimp and mangrove crabs by 70% and 50%, respectively, the silvofishery combination of tiger shrimp and mangrove crabs is still feasible to run. Therefore, it becomes the best recommendation and has the potential to be developed in the long run for quite a long time. The community still wants to buy tiger shrimp and mangrove crabs, but this does not mean that the commodities that have a low sale value, such as milkfish, do not have the potential to be developed. Farmers must be wise in determining the right market for selling their products. Further research is needed on the ecological aspects that affect the productivity of these silvofishery ponds.

ACKNOWLEDGMENT

This study was supported by a research grant from the Indonesian Science Fund and Indonesia Endowment Fund for Education (DIPI/LPDP-RCUK Joint Call) (Grant Number No. NE/P014127.1).

REFERENCES

[1] S. Mehvar, T. Filatova, A. Dastgheib, E. de Ruyter van Steveninck, and R. Ranasinghe, "Quantifying Economic Value of Coastal Ecosystem Services: A Review, "*J. Mar. Sci. Eng*., vol. 6, no. 1, p. 5, 2018, doi:10.3390/jmse6010005.

[2] M. Basyuni, Y. Bimantara, M. Siagian, R. Wati, B. Slamet, N. Sulistiyono, A. Nuryawan, and R. Leidonald, "Developing community-based mangrove management through ecotourism in North Sumatra Indonesia," *IOP Conf. Ser. Earth. Environ. Sci*., vol. 126, no. 012109, 2018, doi:10.1088/1755-1315/126/1/012109.

[3] M. Basyuni, and N. Sulistiyono, "Deforestation and reforestation analysis from land-use changes in North Sumatran Mangroves, 1990-2015." *IOP Conference Ser. Mater. Sci. Eng*., vol. 309, no. 012018, 2018, doi:10.1088/1757-899X/309/1/012018.

[4] A. Fauzi, A. Sakti, L. Yayusman, A. Harto, L. Prasetyo, B. Irawan, M. Kamal, and K. Wikantika, "Contextualizing mangrove forest

deforestation in Southeast Asia using environmental and socio-economic data products," *Forests*, vol. 10, no. 11, p. 952, 2019, doi:10.3390/f10110952.
[5] N. Thomas, R. Lucas, P. Bunting, A. Hardy, A. Rosenqvist, M. Simard, "Distribution and drivers of global mangrove forest change 1996–2010," *Plos One*, vol. 12, no. 6, e0179302, 2017, doi:10.1371/journal.pone.0179302.
[6] J. P. Udoh, "Sustainable nondestructive mangrove-friendly aquaculture in Nigeria II: Models, best practices and policy frame work," *AACL Bioflux*, vol. 9, no. 1, pp. 151–173, 2016.
[7] M. Basyuni, K. S. Nasution, Y. Bimantara, R. Hayati, B. Selamet, and N. Sulistiyono, "Mangrove vegetation supports milkfish production in silvofishery pond," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 305, no. 1, 2019, doi:10.1088/1755-1315/305/1/012038.
[8] M. Musa, M. Mahmudi, S. Arsad, and N. R. Buwono, "Feasibility study and potential of pond as silvofishery in coastal area: Local case study in Situbondo Indonesia," *Reg. Stud. Mar. Sci*., vol. 33, 100971, 2019, doi:10.1016/j.rsma.2019.100971.
[9] M. Basyuni, K. S. Nasution, B. Selamet, N. Sulistiyono, Y. Bimantara, L. A. P. Putri, E. Yusraini, R. Hayati, and I. Lesmana, "Introducing of a silvofishery pond on sapling and seedling density based in Lubuk Kertang Village, North Sumatera," *IOP Conf. Ser. Earth Environ. Sci*., vol. 260, no.1, 2019, doi:10.1088/1755-1315/260/1/012115.
[10] M. Basyuni, A. Fitri, and Z. A. Harahap, "Mapping and analysis land-use and land-cover changes during 1996-2016 in Lubuk Kertang mangrove forest, North Sumatra, Indonesia," *IOP Conf. Ser. Earth. Environ. Sci.*, vol. 126, no. 012110, 2018, doi : 10.1088/1755-1315/126/1/012110.
[11] M. Basyuni, P. Yani, and K. S. Hartini, "Evaluation of mangrove management through community-based silvofishery in North Sumatra, Indonesia," *IOP Conf. Ser. Earth. Environ. Sci*., vol. 122, no. 012109, 2018, doi :10.1088/1755-1315/122/1/012109.
[12] M. J. Kealy, and R. W. Turner, "A test of the equality of closed-ended and open-ended contingent valuations," Am. J. Agr. Econ., vol. 75, no. 2, pp. 321-331, 1993, doi:10.2307/1242916.
[13] Asian Development Bank, "Guidelines for the economic analysis of projects. In: Desai, V.V. (Ed.)," Economics and Development Resource Center. 1997.
[14] M. M. Rahman, and M. A. Mahmud, "Economic feasibility of mangrove restoration in the Southeastern Coast of Bangladesh," *Ocean. Coast. Manag*., vol. 161, pp. 211-221, 2018, doi:10.1016/j.ocecoaman.2018.05.009.
[15] M. I. Wamnebo, M. Y. Karim, R. Syamsuddin, B. Yunus, "Bio-physicochemical analysis of mangrove area of Kayeli Bay, Buru Regency, Maluku Province, Indonesia for the development of mud crab Scylla sp. culture with silvofishery system." *AACL Bioflux,* vol. 11, no. 4, 1130-1135, 2018.
[16] K. S. Rahman, M. N. Islam, M. U. Ahmed, R. H. Bosma, A. O. Debrot, and M. N. Ahsan. "Selection of mangrove species for shrimp based silvo-aquaculture in the coastal areas of Bangladesh," *J. Coast. Conserv.*, vol. 24, no. 5, pp. 1-13, 2020, doi:10.1007/s11852-020-00770-8.
[17] H. Susilo, Y. Takahashi, G. Sato, H. Nomura, and M. Yabe, "The adoption of silvofishery system to restore mangrove ecosystems and its impact on farmers' income in Mahakam Delta, Indonesia," *J. Fac. Agr. Kyushu U*., vol. 63, no. 2, pp. 433-442, 2018, doi : hdl.handle.net/2324/1955666.
[18] R. H. Bosma, T. H. Nguyen, A. J. Siahainenia, H. T. Tran, and H. N. Tran, "Shrimp-based livelihoods in mangrove silvo-aquaculture farming systems," *Rev. Aquac*., vol. 8, no. 1, pp. 43-60, 2016, doi:10.1111/raq.12072.
[19] A. Sahidin, Z. Zahidah, N. Kurniawati, H. Herawati, and A. Rizal, "Fertility Differences between Silvofishery Pond and Conventional Pond in Legonkulon, Subang District, Indonesia," *World Sci. News*, vol. 118, pp. 115-128, 2019.
[20] R. B. Hastuti, and E. D. Hastuti, Adaptability and growth performance of Avicennia marina seedling within Silvofishery pond," *J. Phy. Conf. Ser*., vol. 1025, no. 1, pp. 012050), 2018, doi:10.1088/1742-6596/1025/1/012050.
[21] E. D. Hastuti, and R. Budihastuti, "Potential of mangrove seedlings for utilization in the maintenance of environmental quality within silvofishery ponds," *Biotropia*, vol. 23, no. 1, pp. 58-63, 2016, doi:10.11598/btb.2016.23.1.606.
[22] L. R. Anneboina, and K.K. Kumar. "Economic analysis of mangrove and marine fishery linkages in India". *Ecosyst. Serv*., vol. 24, pp. 114-123, 2017, doi:10.1016/j.ecoser.2017.02.004.
[23] M. Musa, E. D. Lusiana, N. R. Buwono, S. Arsad, and M. Mahmudi, "The effectiveness of silvofishery system in water treatment in intensive whiteleg shrimp (Litopenaeus vannamei) ponds, Probolinggo District, East Java, Indonesia," *Biodiversitas*, vol. 21, no. 10, pp. 4695-4701, 2020, doi: 10.13057/biodiv/d211031.
[24] I. Sribianti, and A. H. Sambu, "Management model ecosystem mangrove based on business feasibility." *J. Entrep. Edu*., vol. 22, no. 1, pp. 1-9, 2019.
[25] B. Yunus, G. D. Dirawan, and A. Saru, "The behavior of fishpond farmers with silvofishery insight and its effects on biodiversity of macrozoobenthos in mangrove ecosystem of coastal area," Int. *J. Agr. Syst*., vol. 3, no. 1, pp. 65-77, 2015, doi: 10.20956/ijas.v3i1.49.
[26] T. T. N. Nguyen, H. C. Tran, T. M. H. Ho, P. Burny, and P. Lebailly, "Dynamics of Farming Systems under the Context of Coastal Zone Development: The Case of Xuan Thuy National Park, Vietnam," *Agriculture*, vol. 9, no. 7, p. 138, 2019, doi:10.3390/agriculture9070138.
[27] C. Agraz-Hernández, R. del Río-Rodríguez, C. Chan-Keb, J. Osti-Saenz, and R. Muñiz-Salazar, "Nutrient Removal Efficiency of *Rhizophora mangle* (L.) Seedlings Exposed to Experimental Dumping of Municipal Waters," *Diversity*, vol. 10, no. 1, p. 16, 2018, doi:10.3390/d10010016.
[28] P. Senff, S. Partelow, L. F. Indriana, N. Buhari, and A. Kunzmann, "Improving pond aquaculture production on Lombok, Indonesia," *Aquaculture*, vol. 497, pp. 64-73, 2018, doi:10.1016/j.aquaculture.2018.07.027.
[29] T. T. Luom, N. T. Phong, S. Smithers, and T. Van Tai, "Protected mangrove forests and aquaculture development for livelihoods," *Ocean Coast. Manag*., vol. 205, pp. 105553, 2021, doi: 10.1016/j.oceacoaman.2021.105553.
[30] L. de Souza Queiroz, S. Rossi, L. Calvet-Mir, I. Ruiz-Mallén, S. García-Betorz, J. Salvà-Prat, and de A. J. Andrade Meireles, "Neglected ecosystem services: Highlighting the socio-cultural perception of mangroves in decision-making processes", *Ecosyt. Serv*., vol. 26, pp. 137-145, 2017, doi:10.1016/j.ecoser.2017.06.013.
[31] M. M. H. Mozumder, M. M. Shamsuzzaman, M. Rashed-Un-Nabi, and E. Karim, "Social-ecological dynamics of the small scale fisheries in Sundarban Mangrove Forest, Bangladesh", *Aquac. Fish*., vol. 3, no. 1, pp. 38-49, 2018, doi:10.1016/j.aaf.2017.12.002 .