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Gaining aquaculture blue growth with Low Carbon Emission Shrimp Farming Technology

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Abstract*. Carbon emissions and their relation to shrimp farming activities are getting more attention from researchers and environmentalists. Emissions of carbon and other greenhouse gases are concluded as drivers of climate change due to global warming. On the contrary, climate change is proven to determine the continuity and sustainability of shrimp farming activities. The dynamics of carbon and profitability are different for the three cultivation technologies (extensive, semi-intensive, and intensive). It is caused by differences in the number and types of production inputs, facilities, and infrastructure, and also differences in productivity. This study aims to formulate the blue growth of aquaculture areas in the coastal area of Karawang Regency-West Java related to carbon emission within the DPSIR framework and use trade-off analyses to obtain shrimp farming technologies alternatives that is low in carbon emissions. The results show that to be able to reduce the carbon emissions and increase the carbon sequestration and stock as an effort for shrimp farming blue growth through optimizing the spatial use supervision and increase the productivity of shrimp farming. The lowest carbon emissions of shrimp farming technology are semi-intensive, intensive, and extensive, respectively.*

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INTRODUCTION

The accumulation of carbon emissions and other greenhouse gases results in global warming and ultimately triggers climate change (Nellemann *et al.*, 2009). Climate change is causing a decline in shrimp's survival, growth, and production (Abdullah and Khoiruddin, 2009; Ahmed and Diana, 2015; Bournazel *et al.*, 2015; Ahmed *et al.*, 2017a, 2017b; Ahmed and Thompson, 2019). Minimizing carbon emissions will support the sustainability of aquaculture (Ahmed *et al.*, 2017b) and maximize carbon sequestration or adsorption and stock as the contribution of aquaculture activities to blue carbon deposits.

The potential of carbon emissions from aquaculture consists of converting mangroves into ponds and emissions during shrimp farming. The most significant emission due to mangrove conversion is the release of carbon gas stored in the mangrove substrate 262-1 084 tonnes ha^{-1} (Siikamäki *et al.*, 2013; Kauffman *et al.*, 2014; Liu *et al.*, 2014). The potential CO_2 emissions of shrimp ponds are 4.37 kg m^{-2} years^{-1} from the embankment and 1.60 kg m^{-2} years^{-1} from the bottom of intensive shrimp ponds (Sidik and Lovelock, 2013), from the use of fossil fuels of 89.48-751.87 kg CO_2 day^{-1}, and CH_4 emissions of 0.45-64.61 mg kg^{-1} of waste year^{-1} in semi-intensive ponds (Dewata, 2013). The CO_2 and CH_4 air-water interface fluxes from pond waters differ in three shrimp cultivation technologies (Rifqi *et al.*, 2020).

On the other side, shrimp culture in ponds can adsorb carbon by phytoplankton photosynthetic activity, and biomass of phytoplankton and fish/shrimp as carbon stocks (Mitra and Zaman, 2015; Widigdo *et al.*, 2020). Meanwhile, phytoplankton biomass as a carbon stock is still discussed by the experts because of its relatively short life cycle and does not own its organic-rich sediments. Phytoplankton biomass is a significant carbon source of detritus that accumulated on the bottom of shrimp ponds, and it is a carbon donor to the ecosystem (Hill *et al.*, 2015). The difference in the population and composition of phytoplankton species in ponds is influenced by the availability and composition of nutrients (Burford, 1997) so that the types and abundance of phytoplankton differ between intensive, semi-intensive, and extensive ponds.

The global warming potential (GWP) is one of the environmental indicators to measure the sustainability of aquaculture (Valenti *et al.*, 2018), which in its determination, can use the blue carbon parameter. The concept of blue growth and sustainable aquaculture areas management should not only consider the carrying capacity of the environment but also to minimize CO_2 and CH_4 emissions, maximize carbon sequestration and stock, and also business profitability. This study formulates a blue growth of shrimp farming development by asses the lowest carbon emissions of three shrimp farming technology.

METHODS

Time and Location

This research was conducted from February 2019 to February 2020 in the coastal area of Karawang Regency, which includes nine administrative sub-districts, as shown in Figure 1.

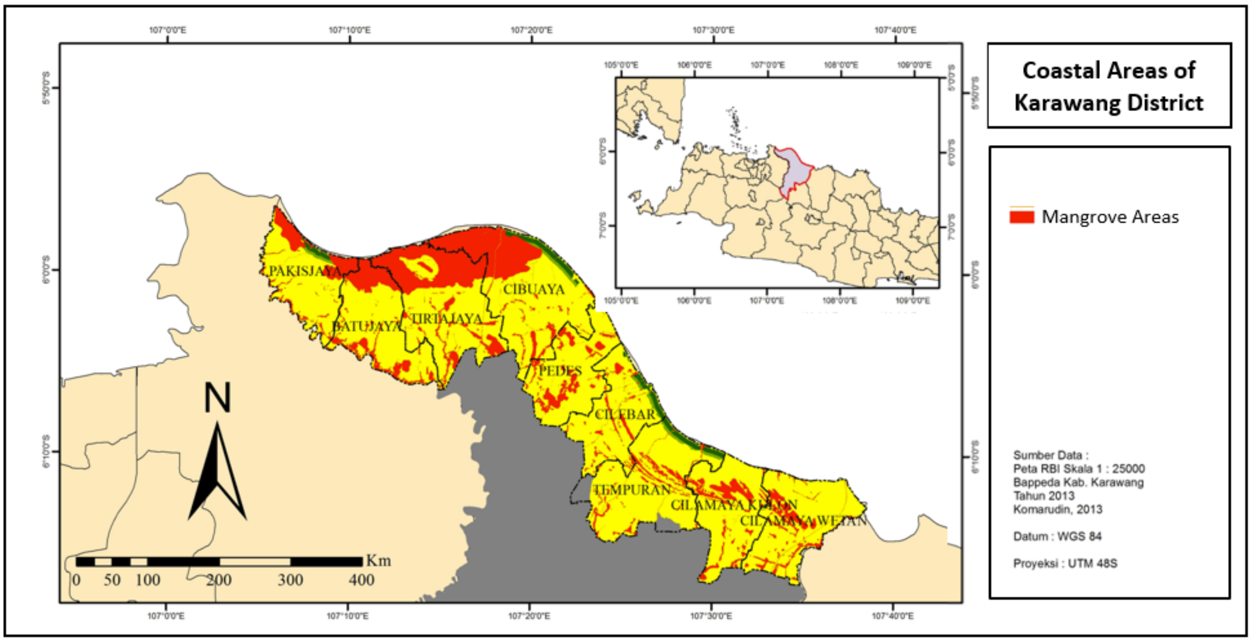

Figure 1 Sub-district in coastal areas of Karawang District

Data Collection

Primary data is obtained from in-depth interviews and field observations, while secondary information is obtained from a scientific publications, government reports, Etc. During the field survey, interviews were conducted with business actors to explore the problems and aspects being studied (Sugiyono, 2008). The sampling technique was a descriptive non-probability sampling of 30 people (Roscoe, 1975) spread over nine coastal districts.

Data Analysis

Driver-Pressure-State-Impact-Respond (D-P-S-I-R)

The DPSIR framework is used to formulate the relationship between carbon dynamic factors in the aquaculture area of the coastal area of Karawang Regency, which is comprehensively formulated into five categories. DPSIR describes a cause-and-effect relationship between the five categories (Cooper, 2013; Semeoshenkova *et al.*, 2017) and can be operationalized in limited data availability (Martin *et al.*, 2018). The essential strength of DPSIR is its ability to simplify causal-effects relationships on ecosystem services between factors in social and natural systems (Svarstad *et al.*, 2008; Martin *et al.*, 2018; Nopiana *et al.*, 2020; Rahman *et al.*, 2020).

Trade of Analysis (ToA)

The priority of three shrimp farming technologies was assessed with Trade-off Analysis (ToA). ToA is a multi-criteria analysis used to evaluate and compare the alternative to obtain the best decision (Amrial *et al.*, 2015). The criteria can be defined with stakeholders (Brown *et al.*, 2001a), suitable for multidimensional problem solving (Huylenbroeck and Coppens, 1995), and a multi-user, multi-user system. Complex relationships and feedback between ecosystems and economic aspects (Brown *et al.*, 2001b). The ToA stage consists of compiling the effects table, determining the scale for benefits and costs, determining preferences and weights, and determining ratings. Determination of the criterion value scale with the following equation:

For the benefit criteria = $X_s = \frac{X - X_{min}}{X_{max} - X_{min}} \text{ x } 100$

For the cost criteria = $X_s = \frac{X_{max} - X}{X_{max} - X_{min}} \text{ x } 100$

Information:
X_s = Score value
X = The value that will be transformed into a score
X_{max} = Maximum value
X_{min} = Minimum value

RESULTS AND DISCUSSION

D- P-S -I-R Factors

Population growth and the development of coastal community activities in Karawang Regency have driven significant land-use changes (Komarudin, 2013). Due to a lack of space utilization supervision, some activities do not use the space according to its allotment. The mangrove area has been partially converted for ponds and settlements (DLHK, 2018), tourist sites, and drill wells for oil companies (Pranoto *et al.*, 2019). Low productivity of shrimp cultivation in ponds and forest areas that are not used according to agreements/cooperation encourages farmers to convert mangroves.

The extent of converted mangroves and low land productivity (Kauffman *et al.*, 2017), inefficient production inputs, and improper management of wastewater (Rifqi *et al.*, 2020) have resulted in high carbon emissions per unit volume of production. Carbon emissions will accumulate with other greenhouse gases in the atmosphere. Degradation of mangrove ecosystems leads to reduced biodiversity and environmental services, including carbon sequestration capacity and carbon stocks (Kauffman *et al.*, 2014; Kauffman *et al.*, 2015; Hilmi *et al.*, 2017; Rahman *et al.*, 2017), and natural filters of pollutants leading to coastal waters (Pranoto *et al.*, 2019). It will have an impact on the sustainability of coastal resources and also the sustainability of activities in coastal areas, including shrimp farming in ponds.

Efforts to control that can be done are optimizing supervision and enforcement of regulations on land use in the coastal area of Karawang Regency and increasing aquaculture productivity in ponds by improving cultivation technology. The aquaculture area's structural factors in the coastal area of Karawang Regency and their relation to the carbon mentioned above can be formulated in the DPSIR framework (Figure 2).

Figure 2 Schematic of Driver (D) - Pressure (P) - State (S) - Impact (I) - Response (R) of shrimp farming activities in Karawang Regency coastal area

Land use that is not in accordance with its designation and low land productivity (factor D) encourages the conversion of coastal ecosystems such as mangroves (factor P). Conversion of coastal ecosystems such as mangroves (factor P) is the contributor to carbon emissions and causes loss of carbon uptake and stock, and uncontrolled land use leads to habitat degradation (factor S). Carbon emissions and loss of carbon uptake and storage (factor S) cause an increase in the accumulation of carbon gas along with other greenhouse gases in the atmosphere (factor I), and habitat degradation (factor S) causes the loss of environmental services (factor I). Efforts that can be made (factor R) are the enforcement of space utilization rules and increasing land productivity to resolve factor D, decrease factor P, improve factor S and mitigate factor I.

Coastal resources generally consist of dynamic and complex ecosystems, habitats that interact with ecological functions, and various but vulnerable ecosystem services (Dahuri *et al.*, 1996). Harmonization of spatial use dramatically determines the continuity of business and community life. Returning the mangrove protection function and planting mangroves in the shrimp farming cluster will return environmental services, including increasing the environmental carrying capacity for shrimp farming activities and carbon uptake and storage (Alongi, 2018).

In order to optimize spatial use supervision and increase the productivity of the shrimp pond, the response is expected to reduce mangrove conversion so that it can reduce emissions and, at the same time, increase carbon sequestration and stock. Rahman *et al.* (2015) stated that the factors that affect the productivity of shrimp ponds are technology, human resources, capital, natural resources, and infrastructure.

Cost and Benefit Criteria of Shrimp Farming

To arrange a coastal area management plan for blue growth and a sustainable shrimp culture area with low carbon emissions could consider dynamics of carbon (CO_2 and CH_4 emissions), sequestration and stock carbon, and shrimp farming profit (Table 1).

Table 1 Average of total CO_2 and CH_4 emissions, stock, and carbon sequestration (tonnes ha^{-1}) and business profit (Rp ha^{-1} $year^{-1}$) of three shrimp farming technology

No.	Items	Extensive	Semi Intensive	Intensive
a.	Cost Criteria			
1.	Emission from mangrove substate[1)]	673.00	673.00	673.00
2.	CO_2 during shrimp farming[2)]	0.97	66.39	91.59
3.	CH_4 during shrimp farming [2)]	0.0017	0.0007	0.0006
b.	Benefit Criteria			
1.	Carbon sequestration[3)]	0.7139	7.8069	9.0752
2.	Carbon stock[3)]	0.0071	0.1560	0.2663
3.	Profit	6 163 050	138 928 040	431 090 000

Source: [1)]= Processed from Siikamäki *et al.*, (2013); Kauffman *et al.*, (2014); Liu *et al.*, (2014); [2)]= Processed from Rifqi *et al.*, (2020); [3)]= Widigdo *et al.*, (2020)

Blue growth of shrimp farming areas gains by minimizing CO_2 and CH_4 emissions, maximizing carbon sequestration, carbon stock, and business profit from shrimp farming activities, and harmonizing the use of coastal resources with users and other activities. Minimizing carbon emissions as a greenhouse gas will support the continuity and sustainability of aquaculture (Ahmed *et al.*, 2017b), and maximize carbon sequestration and stock contributed by aquaculture to carbon deposits.

Alternative of Technology of Shrimp Farming based on Cost and Benefit Criteria

Based on ponds productivity, it can be determined that the area of ponds to produce a ton of shrimp is 3.33 ha, 0.16 ha, and 0.06 ha, respectively, for extensive, semi-intensive, and intensive technology. The value of carbon dynamics parameters and business profit (Table 1) is converted to produce a ton of shrimp on extensive, semi-intensive, and intensive shrimp farming technology (Table 2) by multiplying those values by the area of land for each cultivation technology to produce a ton. Recommended for shrimp farming technology alternatives assessed by trade-off analysis (ToA). Priority is determined based on the dynamic of the value of the source and sinks categories as well as business profits. Emissions due to land conversion, $CO_{2,}$ and CH_4 emissions during shrimp culture are cost criteria. Whereas stock, carbon sequestration, and business profit are benefit criteria for the conversion process to a value scale (Table 3).

Priority alternative to shrimp farming technology that meets the principles of carbon management and blue growth is semi-intensive, intensive, and extensive ponds. Whereas the ponds operated by most of the current cultivators on the coast of Karawang Regency, namely extensive ponds (97.05%), only a small proportion of them operate semi-intensive and intensive ponds (Noviyanti *et al.*, 2016; Dinas Perikanan, 2018).

Table 2 Assumed land productivity and parameter values of each cultivation technology to produce a ton of shrimp in the pond

No.	Items	Extensive	Semi Intensive	Intensive
1.	Shrimp farming productivity (ton ha^{-1})	0.30	6.35	15.62
2.	Pond area (ha)	3.33	0.16	0.06
3.	Source categories			
a.	Emission from mangrove conversion	2 243.33333	116.23489	43.08579
b.	CO_2 during shrimp farming	3.23333	11.46632	5.86364
c.	CH_4 during shrimp farming	0.00567	0.00012	0.00004
4.	Sink categories			
a.	Carbon sequestration	2.37967	1.34834	0.58100
b.	Carbon stock	0.02367	0.02694	0.01705
5.	Profit	20 543 500	23 994 480	27 598 592

Table 3 Scores and rankings of three shrimp farming technologies in ponds

No.	Items	Extensive	Semi Intensive	Intensive
1.	Emission from mangrove conversion	0.00	96.68	100.00
2.	CO_2 during shrimp farming	100.00	0.00	68.05
3.	CH_4 during shrimp farming	0.00	98.53	100.00
4.	Carbon sequestration	100.00	42.66	0.00
5.	Carbon stock	66.89	100.00	0.00
6.	Profit	0.00	48.91	100.00
	Total	266.89	386.79	368.05
	Ranking	3	1	2

To increase land productivity, extensive ponds located on land that is physically and purpose suitable can be encouraged to apply extensive-plus technology and the extent possible be, semi-intensive technology. Compared to Indonesian Standard (SNI as the ideal production target), the productivity of semi-intensive ponds can still be improved, and cultivation units may be upgraded to intensive. The empowerment of shrimp farmers is carried out to increase the productivity of semi-intensive and intensive ponds. In addition, to the aspects of capital and business financing, the improvement of cultivation technology that will be applied needs to be followed by strengthening the capacity of cultivators (technical and management capabilities), adjusting the construction of ponds with the technology to be used, and the provision of other infrastructure facilities.

Empowerment also needs to be done to improve cultivation technology from extensive to semi-intensive and intensive. To reduce the impact of aquaculture activities on the potential for water quality degradation, integrated aquaculture technology based on a recirculation system, known as Integrated Multi Tropic Aquaculture (IMTA), can be applied (Aliah, 2013). This technology can also increase land productivity because organic material waste is used for shellfish and seaweed (Aliah, 2013). The control of land use in coastal areas can be carried out through business location permits and building construction permits, while monitoring land use changes needs to be a severe concern of the government and the community.

CONCLUSION

The relationship of blue carbon dynamics factors in the aquaculture area in the coastal area of Karawang Regency can be comprehensively formulated into five categories of the DPSIR thinking framework. Efforts to optimize spatial use monitoring and increase the productivity of ponds are expected to reduce mangrove conversion so that it can reduce emissions and, at the same time, increase stock and carbon sequestration. Alternative shrimp culture technology in ponds based on carbon management principles are semi-intensive,

intensive, and extensive ponds, respectively. The priorities can change if the source side can be minimized and the sink side is increased. This priority can also change if the addition of components on both sides (source and sink) can be calculated in other studies in the future.

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