ECOLOGICAL AND ECONOMICAL ANALYSIS FOR IMPLEMENTING INTEGRATED MULTI TROPHIC AQUACULTURE (IMTA) IN AN ABRADED AREA TO RECOVER AQUACULTURE PRODUCTION IN KALIWLINGI, BREBES, INDONESIA

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Abstract. Coastal abrasion is a phenomenon with large ecological implications at global level and with major impact on the farming production and farmers' income in many areas, such as in the peculiar case of the village Kaliwlingi, of Brebes Regency, west of the Central Java Province, Indonesia. In order to ensure long term sustainability of aquaculture production in the area, the present study proposed an integrated approach based on the analysis of significant ecological and economic factors important in the decision making process of selecting the best suitable sites to perform this activity. Three species were chosen to be cultivated in accordance with the concept of Integrated Multi Trophic Aquaculture (IMTA), which will bring benefits both to ecosystem by maintaining its balance and to farmers'incomes as well. These species are: the milkfish (*Chanos chanos*), the seaweed (*Gracilaria verucosa*), and the green mussel (*Perna viridis*). By using Geographic Information System (GIS) and based on the results of the ecological analysis it has been shown that 2,759 ha of the study area could be deemed as *suitable* for sustainable cultivation, while 1,852 ha - *less suitable*. The Specific Growth Rate (SGR) (%.d^{-1}) of *C. chanos, P. viridis* and *G. verucosa* in the *Suitable area* were 2.67 ± 0.1, 0.57±0.1.89, and 3.65 ± 0.21, respectively. To determine the potential production of the abraded area, the mass yield was calculated. The production (tons) in the *suitable area* yielded 755 tons of milkfish, 525 tons of green mussel and 952 tons of seaweed. In addition, the results of economic analysis showed a B/C ratio of 1.7 million IDR with Payback Period of 2.7 cycles and Break Even Point of 5,612,350 IDR. However, at *less suitable area*, due to the ecological limiting factors, the aquaculture production was lower, as well as the economic efficiency.

Key words: Integrated Multi Trophic Aquaculture (IMTA), Brebes, Coastal abrasion, Ecological sustainability, Economic efficiency

1. INTRODUCTION

Coastal ecosystems play an important role in ensuring aquaculture production as well as the farmers' income. Fish farming in the coastal area has become one of the most successful aquaculture activity in Indonesia. Currently, over 88% of shrimp, milkfish and seaweed are produced by the coastal aquaculture (The Fisheries and Marine Department of Brebes Regency, 2012). In 2012, Brebes contributed with 50 million tons to the aquaculture production and an economic value of more than IDR 80.8 trillion (The Fisheries and Marine Department of Brebes Regency, 2014). Furthermore, Brebes supplied 18,109 tons of milkfish, 1,436 tons of shrimp and 8,134 tons of seaweed. However, the production has continuously decreased due to a number of constrains, including coastal abrasion. The Fisheries and Marine Department of Brebes Regency (2012) reported that the abrasion in Kaliwlingi village, Brebes, affected 800 ha of ponds as result of destruction of natural green belt of mangroves that used to protect the coast. Currently, other 75 ha of pond area are vulnerable to abrasion, hence an estimated 150 tons of pond production will be lost. Degradation of aquaculture production resulted in a decrease of farmers' income. The abrasion caused damage to the ponds' infrastructure, which cannot be any longer used for aquaculture activity. Hence, a solution is needed to overcome the problem of sustainability of aquaculture activity in the abraded area. According to Jin, 2008, the ecological analysis enhances understanding of potential of abraded area utilization for aquaculture and facilitates application of specific mitigation measures. While an appropriate technology should be determined in accordance with the condition of the abraded pond, the Integrated Multi-Trophic Aquaculture (IMTA) is considered a proper method in this case.

Integrated Multi-Tropic Aquaculture (IMTA) is a technology developed to improve the efficiency and productivity of an area. Cal *et al.*, 2013 suggested that IMTA is a zero - waste concept, where a residue material removed from the higher trophic level becomes the input energy for the organisms within the lower trophic level. Milkfish, green mussel and seaweed are species from three different trophic levels, which can be cultivated in the same farm, where the residues of fishes feed the other two species (Cruz-Suarez *et al.*, 2008). MacDonald *et al.,* 2011 stated that the cultivation of salmon and mussels with the IMTA concept was based on the fact that mussels have the ability to capture the particles removed from the fish farms. Thus, nitrification is reduced, while economically valuable products are obtained from the co-cultured species.

To establish the appropriate IMTA technology to be used in the Brebes area and to accurately determine the suitable location, a quality assessment of the environment has been carried out. Thus, for the purpose of cultivation of milk fish (*Chanos chanos*), green mussels (*Perna viridis*) and seaweed (*Gracilaria verucosa*), there were analyzed the physical, chemical and biological parameters of water. GIS has been applied to determine the suitable location for seaweed cultivation on Long line method (Ariyati *et al.*, 2007), and to analyze the pond's fertility based on its primary productivity (Widowati *et al.*, 2013a,b). Other authors (Corner *et al.*, 2006) reported, for example, using of nutrients distribution model in the GIS analysis to determine the suitable area for aquaculture development. In Japan, Meaden and Aguilar-Manjarrez, 2013 suggested that area suitabile for certain species and/or certain life stages of a species can be estimated through GIS. Based on the analysis of several environmental parameters, the suitability level may be grouped into several categories which may affect the cultivation result.

Empirical evidence on the successful cultivation can be obtained through a financial analysis. Thus, we assessed the impact on the economic revenues and on the farmers' incomes of IMTA application in aquaculture activities within the recommended abraded area. Jin, 2008 conducted an analysis of bio-economic models for fish cultivation in open water, which combine the interaction during the production process of economic and biological factors such as the species, technology and location. It resulted that fish cultivation could be economic feasible if the production costs are lower than or compensated by the market price by the time of commercialization.

Shi *et al.*, 2013 suggested that IMTA provides higher ecological sustainability index and higher profitability. The application of IMTA was recommended to optimize the economic and ecological advantages. Kurtoglu *et al.*, 2010, Nobre *et al.*, 2010 suggested that IMTA is a method that has both ecological and economic advantages.

Milkfish (*C. chanos*) is one of the most recommended aquaculture commodities in the IMTA systems, due to the fact that it has mutualism symbiosis with seaweed (Cal *et al.*, 2013). Due to their natural abundance and suitable ecological conditions, seaweed and oyster were used to be cultured in the area, the cultivation methods being appropriate even in the physically damaged areas. Rejeki *et al.,* 2014 suggested that the abrasion impacted area in Brebes was suitable for the cultivation of mussels and blood clams but no longer usable for fish/shrimp cultivation. In 2013, the Community Service Program set the *Gracilaria sp* cultivation in Randusanga Wetan village, Brebes district, where it reached a yield of 3,000 g within 60 days from an initial weight of 100 g (Widowati *et al.*, 2013b).

The study focused on three objectives. First, to find the *suitable area* for IMTA's production, second, to analyze the growth and survival rate of milk fish, seaweed and green mussel, according to the area suitability and the third, to examine the feasibility of IMTA's implementation by economic analysis.

2. METHODOLOGY

2.1. Ecological analysis

The study was conducted in Kaliwlingi Village, Brebes, Central Java Province from May to October 2016. Satellite data Ikonos imagery with a resolution of 1.1 x 1.1 m acquired in 2013, ALOS_AVNIR imagery with resolution of 10 x 10 m acquired in 2014, Indonesian topographic map with 1:25,000 scale and Indonesian coastal environment map of 1:50,000 scale, issued by the Department of Geospatial Information, 2013) were used within the analysis. GIS data processing was done by helping of ER Mapper 7.2 and ArcGIS 9.3 softwares. The equipment and materials used for the sampling and experimental activities were: Garmin GPS, videocamera, sampling bottles, cool box, plankton net, Sedgwick Rafter, microscopes and chemicals for laboratory analysis purposes.

Sampling for ecological analysis of suitability for cultivation of milkfish (*C. chanos*), seaweed (*G. verucosa*) and green mussels (*P. viridis*) was carried out in fifteen stations (Table 1). In-situ measurements were performed in order to assess the water quality parameters such as the salinity, dissolved oxygen (DO), pH, water temperature and depth. In laboratory, there were analyzed the concentration of nitrate, phosphate, heavy metal (Pb), chlorophyll-*a* and the abundance of phytoplankton. The nitrate diazotization and the phosphate ascorbic acid method followed by spectrophotometer measurements at various wavelengths were used for the nitrate and phosphate analysis, respectively.

Table 1. The field sampling sites

Station	Latitude	Longitude
1	6º48'37"S	109º01'38"E
2	6º48'03"S	109º00'57"E
3	6º48'26"S	109º02'34"E
4	6º48'30"S	109º02'15"E
5	6º48'57"S	109º02'14"E
6	6º48'20"S	109º02'39"E
7	6º45'23"S	109º03'44"E
8	6º47'35"S	109º01'46"E
9	6º47'32"S	109º03'46"E
10	6º47'59"S	109º03'54"E
11	6º47'36"S	109º02'25"E
12	6º45'25"S	109º03'50"E
13	6º47'16"S	109º03'22"E
14	6º46'58"S	109º02'54"E
15	6º46'03"S	109º03'52"E

Atomic absorption spectrophotometer was used for heavy metal analysis. The plankton samples were collected by filtering 10 L water with a 25- µm mesh plankton net and subsequently stored in 350 ml sample bottles with a 4% formalin solution. The samples for the chlorophyll-*a* were collected in 2L dark bottles and analyzed according to APHA, 1985 at the Integrated Laboratory of Diponegoro University.

The matrices used for determining the *suitability area* for *C. chanos*, *G. verucosa* and *P. viridis* are shown in the Tables 2, 3 and 4 These matrices were done by weighting each water quality parameter, whereas the parameters with a dominant influence had a greater weight. In order to find out the potential location for cultivation, in the next step, a score based on the level of suitability of area for each of the three species was inferred. The parameters such as the temperature and the dissolved oxygen (DO) were weighed as 5, more than the pH and salinity (weighted as 4) and nitrate and phosphate (weighted as 3). We assumed that the effect of DO and temperature is more important than that of other parameters, since *C. chanos* suffers when these are not in the optimum range. Considering the same principle, the most important parameters for the *G. verucosa* were depth, water transparency, current, nitrate and substrate, while those for the *P. viridis* were plankton abundance, depth, current, and the heavy metal content (Pb). The maps of *Suitable area* for all three species were done by helping of GIS.

Table 2. Land Suitability Matrix for *C. chanos* (modification from Hartoko and Widowati, 2008)

No	Parameter	Range	Value (V)	Weigh (W)	Score (V×W)
1.	Temperature (ºC)	28-30 26-28; 31-33 >33 or <26	3 2 1	5	15 10 5
2.	Dissolved Oxygen (ppm)	5-7 3-5 <4	3 2 1	5	15 10 5
3.	pH	7.5-8.5 6.5-7.4 <6.5	3 2 1	4	12 8 4
4.	Salinity (ppt)	23-32 15-22 <14	3 2 1	4	12 8 4
5.	Nitrate (ppm)	0.05-0.2 0.02-0.049 < 0.02	3 2 1	3	9 6 3
6.	Phosphate (ppm)	0.5-1.5 0.1-0.49 <0.1	3 2 1	3	9 6 3
	$Total\ Score = \sum_{n=1}^{6} V \times W$				

For the milk fish, a total score of 48-74 was in the range of *Suitable area*, of 24-73 - *Less Suitable* and less than 24 - *Not Suitable*.

Table 3. Land Suitability Matrix for *G. verucosa* (modification from Ariyati *et al*, 2007)

No	Parameter	Range	Value (V)	Weigh (W)	Score (V×W)
1.	Temperature (⁰C)	27-30 25-<27 or 30-32 <25 or > 32	3 2 1	1	3 2 1
2.	Water transparency (m)	>1.5 1-1.5 < 75	3 2 1	2	6 4 2
3.	Depth (m)	>1,5 0.8-1.4 < 0.8	3 2 1	3	9 6 3
4.	pH	7 – 8,5 6.5 - < 7 or > 8.5 – 9.5 < 6.5 or > 9.5	3 2 1	1	3 2 1
5.	Salinity (ppt)	29 – 33 25 - < 29 or > 33 – 37 < 25 or > 37	3 2 1	1	3 2 1
6.	Current (cm/sec)	20 -40 10 – 20 or 40 – 50 < 10 or >50	3 2 1	2	6 4 2
7.	Nitrate (mg/l)	0.1 – 0.7 0.01 – < 0.1 < 0.01	3 2 1	2	6 4 2
8.	Phosphate (mg/l)	0.1 – 0.2 0.02 – < 0.1 < 0.02	3 2 1	1	3 2 1
9.	Substrate	sand / coral fragment sandy clay clay	3 2 1	2	3 2 1
	$Total\ Score = \sum_{n=1}^{9} V \times W$				

As a result, the value of scoring for the *G. verucosa* from 29 to 42 was in the range of *Suitable area*, 15-28 - *Less Suitable*, while less than 14 - *Not Suitable*.

Table 4. *Land Suitability* Matrix for *P. viridis* (modification from WWF Indonesia, 2015)

No	Parameter	Range	Value (V)	Weigh (W)	Score (V×W)
1.	Current (cm/sec)	15 -25 10–15 or 25–30 < 10 or >50	5 3 1	3	15 9 3
2.	Plankton abundance (cells/L)	$>15x10^3$ $2x10^3$ or $15x10^3$ $< 2x10^3$ or $> 10^6$	5 3 1	3	15 9 3
3.	Total Suspended Solid (mg/L)	<25 26-80 >80	5 3 1	3	15 9 3
4.	Lead (Pb) in mussel's tissue (mg/kg)	< 1 1-1.3 >1.3	5 3 1	3	15 9 3

Table 4 (continued)

No	Parameter	Range	Value (V)	Weigh (W)	Score (V×W)
5.	Average Lead (Pb) concentration in water (mg/L)	>0.006 0.006-0.010 <0.10	5 3 1	3	15 9 3
6.	Depth (m)	>1.5-3 0.5-1.5 < 0.5	5 3 1	3	15 9 3
7.	Lead (Pb) in sediment (mg/L)	< 30 30-35 >35	5 3 1	2	10 6 2
8.	Dissolved Oxygen (ppm)	>7 5-7 <5	5 3 1	2	10 6 2
9.	Water Transparency (m)	>3 1-2 < 1	5 3 1	2	10 6 2
10.	pH	7 – 8.5 6.5 - < 7 or > 8.5 – 9.5 < 6.5 or > 9.5	5 3 1	1	5 3 1
11.	Salinity ($^0/_{00}$)	27 – 33 23 - < 27 or > 33 – 37 < 25 or > 37	5 3 1	1	5 3 1
12.	Temperature (^{0}C)	27-33 24-26 or 30-32 <24 or > 33	5 3 1	1	5 3 1
	$Total\ Score = \sum_{n=1}^{12} V \times W$				

The score results ranged within 79-130 for *Suitable area*, 27-78 within *Less Suitable* and less than 26 within *Not Suitable*.

2.2. Aquaculture production

According to GIS analysis, 2 levels of area suitability (*suitable* and *less suitable*) were selected for the cultivation experiment applying IMTA concept. The experiment involved milkfish (*C. chanos*), green mussel (*P. viridis*) and seaweed (*G. verucosa*) for each location. In the *suitable area*, *C. chanos* was cultivated in pond, while *P. viridis* using stick method and *G. verucosa* on long lines. In *less suitable area*, *C. chanos* was cultivated in cage, while *P. viridis* and *G. verucosa* were cultivated with long line method.

The production was analyzed by calculating the Specific Growth Rate (SGR) of organisms, using the formula (Busacker *et al*., 1990):

$$SGR = \frac{\text{LnWt} - \text{LnWo}}{\text{t}} \times 100\%$$

where, Wo: initial weight (g), Wt: final weight (g), and t: the cultivation period.

Calculation of the survival rate (SR) was based on the remaining population at the end of the observation, calculated with the following formula (Busacker *et al*., 1990):

$$SR = \frac{\text{Nt}}{\text{No}} \times 100\%$$

where, No is the number of organisms at the beginning of cultivation and Nt is the number of organisms at the end of experiment.

The total estimated production was calculated by multiplying the area with the yield of each organism.

2.3. Economic analysis

The economic analysis was performed by calculating cost benefit (B/C), Pay Back Period (PP), and Break Even Point (BEP). B/C ratio was obtained by dividing the total income by the total production costs, where if the result had a value greater than 1, it means that the cultivation would be feasible. The Pay Back Period (PP) was calculated by dividing the total investment by the annual expenses from aquaculture production. The Break Even Point is the point at which the total cost and the total revenue are equal. It was calculated by dividing the total fixed cost by the benefit per unit product. Data for economic analysis collected took into consideration all components of operational costs during cultivation time, as well as the income from harvesting. The operational cost refers to the costs related to pond preparation, buying milk fish fry and seeds of seaweed and green mussel, as well as to the costs for labor and feed.

Formulas used for cost benefit analysis are given below:

$$\frac{B}{C} = \sum_{t=to}^{T} \frac{\dfrac{Bt}{(1+r)^{t-to}}}{\dfrac{Ct}{(1+r)^{t-to}}} \quad \left(\text{Wambua, 2018}\right) \qquad (1)$$

$$NPV = \sum_{t=1}^{n} = \frac{Bt - Ct}{(1+\delta)t} \quad \text{with } t(\text{time}) = 1,2,3\ldots.n \ \left(\text{Hakim, 2017}\right) \ (2)$$

where, *Bt* in equation (1) is the benefit at the period time t, *Ct* is the cost at the period time t; the project period or terminal year is T; **r** is the discount rate;

NPV in equation 2 is the Net Present Value (the present value of the net benefits of the development project); *Bt* is total benefit in time t, *Ct* is total costs in time *t*; *n* is the time horizon, *t* denotes the year, *δ* is the discount rate, while 1/(1+ *δ*)*t* is called the discount factor.

3. RESULTS AND DISCUSSION

3.1. Ecological analysis for applying IMTA

For GIS data processing, the weights and scoring method based on consideration of optimal requirements (water quality parameters) for growing of cultivated organisms (fish, seaweed and mussels) was used. Afterwards, the scored water quality variables were integrated into the GIS analysis and the layers obtained were superimposed in order to determine the suitability level. Kapetsky and Manjarez, 2007 stated that GIS is a good method to be used when going to perform analysis of land with a variety of organisms and a variety of complex variables. It is because GIS processes a wide variety of data being able to provide information on the coverage area. The maps which describe the coverage area of *land suitability/less suitability* for all three species (milk fish, *P. viridis* and *G. verucosa*) are shown in the Fig.1, Fig 2 and Fig. 3.

Two categories of suitability were obtained using the GIS analysis in the study area. The *Suitable area* for IMTA culture covered 2,759 ha and the *Less Suitable* one - 1,852 ha (Table 5). According to the results of field observation, the *Less Suitable area* was the area affected by the damaged pond dikes and by abrasion and therefore it is difficult to be used for cultivation. However, it still could be used to carry out aquaculture activities. The experiment carried out by Rejeki *et al.*, 2014 showed that the daily growth rate for tilapia and mussels in the abraded pond were 2.14% day^{-1} and 1.89% day^{-1} respectively.

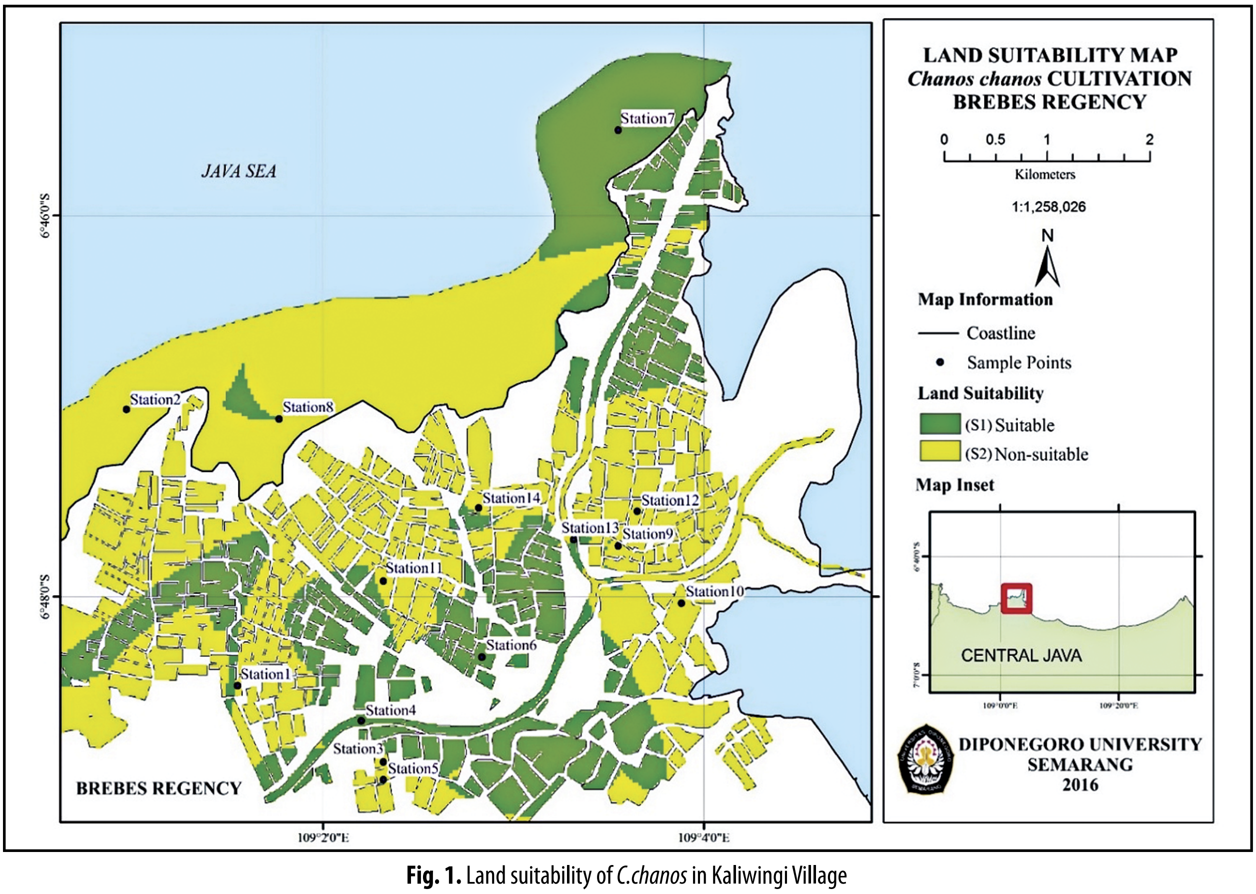

Fig. 1. Land suitability of *C.chanos* in Kaliwingi Village

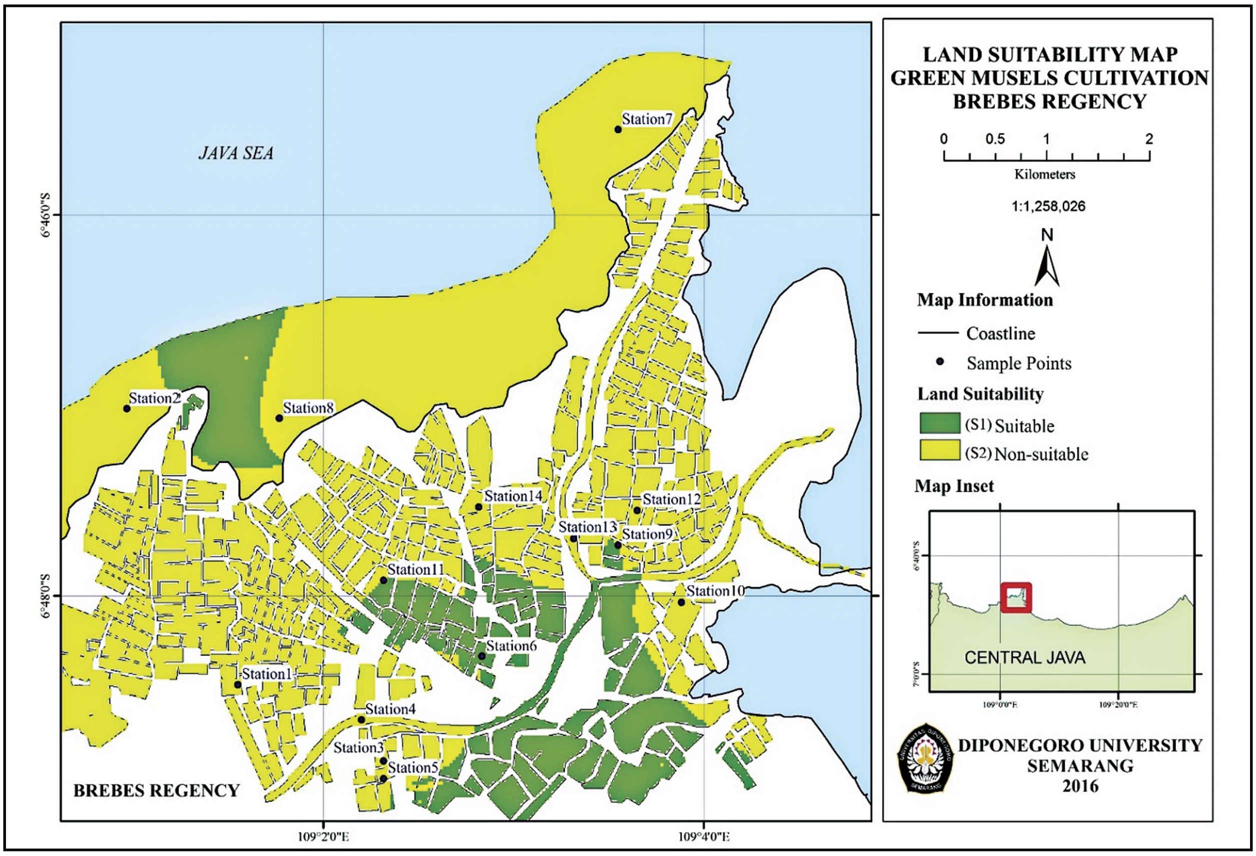

Fig. 2. Land suitability of *G. verucosa* in Kaliwingi Village

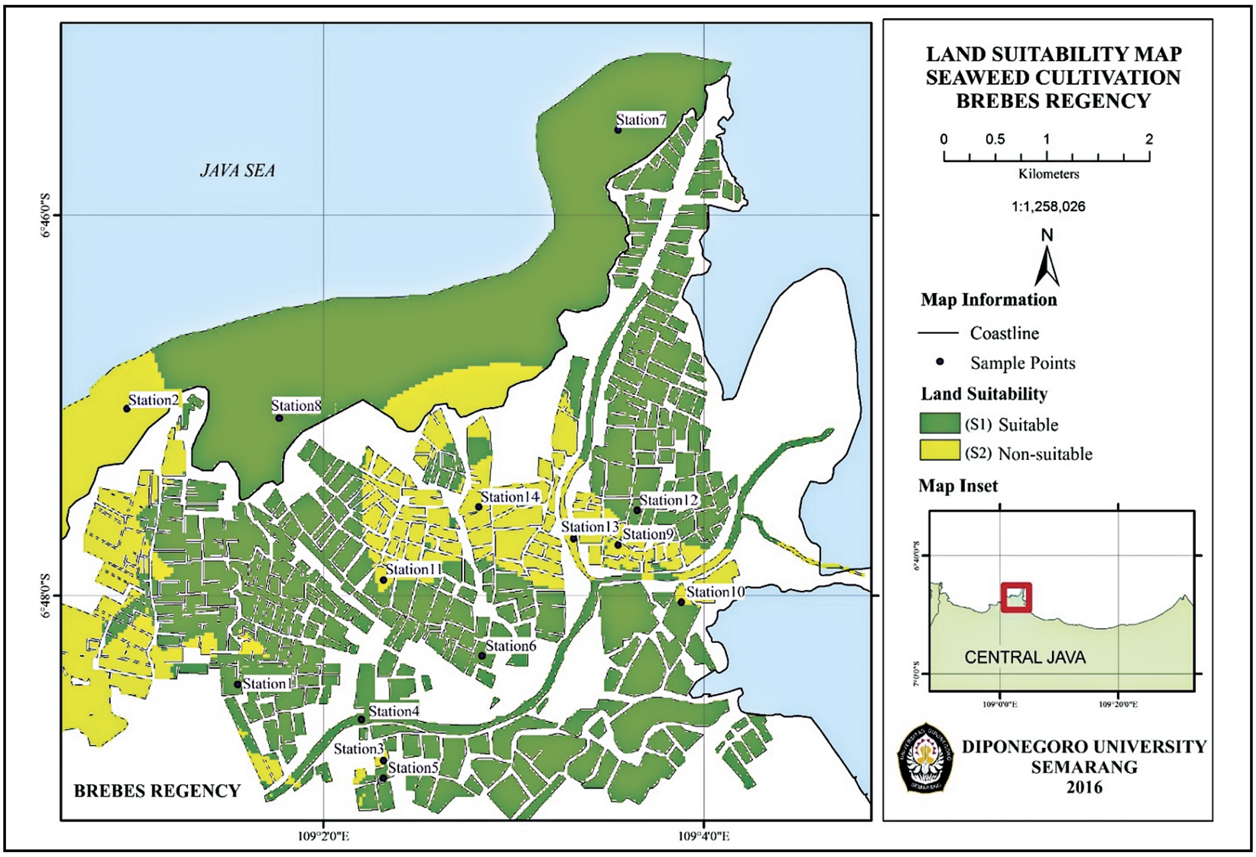

Fig. 3. Land suitability of *P. viridis* in Kaliwingi Village

Table 5. The total area of cultivation (ha) at various levels of suitability

No.	Land Suitability	Area (ha)			
		Milk fish	Green Mussel	Seaweed	Total
1	Suitable	919	722	1,116	2,759
2	Less Suitable	616	484	748	1,852

Table 6. Estimation of production (tons) and SGR (%/day^{-1}) at various levels of suitability

No.	Land Suitability	SGR (%/day^{-1})			Production (tons)		
		Milkfish	Green Mussel	Seaweed	Milkfish	Green Mussel	Seaweed
1	Suitable	2.67 ± 0.15	0.57±0.1.89	3.65 ± 0.21	755	525	952
2	Less Suitable	2.01± 0.21	0.53 ± 0.17	2.42 ± 0.16	410	269	450

3.2. Aquaculture production

According to suitability analysis, aquaculture production calculated in the area is shown in the Table 6.

The SGR (% day^{-1}) of *C. chanos,* P. *viridis* and *G. verucosa* in the *Suitable area* were 2.67 ± 0.1, 0.57±0.1.89, and 3.65 ± 0.21, respectively (Table 6). The SGR of milkfish was still lower compared to the value of 5.6% day^{-1} obtained in a silvo-fishery pond by Sulardiono *et al.*, 2013. However, Mangampa and Burhanuddin, 2014 showed that a SGR of milk fish greater than 2% day^{-1} means that the organisms grow well during cultivation.

Our results showed that the green mussels reached a growth rate of 0.57%.day^{-1}in the *Suitable area*. This value was higher than that suggested by the WWF Indonesia, 2015, which stated that green mussels with an initial length of 2-3 cm may reach a growth rate of 0.03 %.day^{-1}. This may be due to the appropriate water quality in the *Suitable area* which supports the high abundance of plankton. Elfitasari *et al.*, 2013 stated that the growth rate of green mussels is related to the abundance of phytoplankton consumed by these filter feeder organisms. As a first trophic level organism, seaweed had the highest production in the IMTA system. The SGR was 3.65 ± 0.21% day^{-1}, which indicates that seaweed grew optimally.

In *Less Suitable area*, the SGR was lower than in the *Suitable area*. It means that organisms can be cultivated within that area, but do not grow optimally as result of environmental natural and anthropogenic stress factors such as: the strong currents, depth greater than 2 m, plankton abundance, limiting nutrients, and physical damage of dikes. To cope with all these potential limitations, the milk fish was cultivated in cage, the seaweed on long lines and the green mussels attached to sticks. In this way, the SGR of organisms cultivated in IMTAs can be maintained in good state. However, for better results the area still needs a lot of expenses and effort. The results can be recommended for the application of Ecosystem Approach to Aquaculture (EAA) to ensuring the production, the advantage being the prediction of suitability of cultivation (Silva *et al.*, 2011). By understanding the connection between species and the surrounding environment in IMTA system, the appropriate methods for cultivation within *Suitable* and *Less Suitable* area could be recommended. (Fang *et al*, 2016).

3.3. Economic Analysis of cultivation based on the IMTA concept

The economic analysis showed that the values of all economic parameters in the *Less Suitable area* were lower than in the *Suitable area* (Table 7). B/C ranged from 1.1 to 1.7. This means that in both categories, aquaculture with IMTA can be implemented. According to Shi *et al.*, 2013, if the B/C ratio is more than 1, then the business is worth doing. The higher the value of B/C ratio, the more efficient business and the higher profit can be obtained. Judging from the above analysis, the obtained B/C ratio value of 1.7 at the *Suitable area* points out to a more economically valuable location for cultivation than others. According to the Break Even Point (BEP) analysis, it appears that in the *Suitable area* there are needed 2.7 cultivation cycles to obtain an advantage. In the *Less Suitable area*, a longer time for the funds expended in investment to be recovered is needed. This is in line with the previous study of Haryono *et al.*, 2013 that integrated the culture of tiger shrimp and of milk fish and obtained a value of B/C of 1.7 and a Payback period of 2.44 years or equal to 4 cycles of cultivation.

Table 7. Economic analysis (B/C, BEP and PP) in the *Suitable* and the *Less Suitable* area

No.	Land Suitability	B/C	BEP	PP (Cycles)
1	Suitable	1.7	3,525,452	2.7
2	Less Suitable	1.1	4,150,125	3.5

The limiting factors in the *Less Suitable area* are related to its poor ecological condition, hence, to higher investment/costs needed. For instance, due to the strong current, the construction of cages for milk fish was much expensive. Thus, even this area can be used for aquaculture it needs a higher investment.

4. CONCLUSION

According to the results of the ecological analysis, there were recommended a *Suitable area* surface of 2,759 ha and a *Less Suitable* one of 1,852 ha to apply the IMTA. In the *Suitable area*, the SGR and the aquaculture production (tons) were higher than in the *Less Suitable area*. The SGR (%/day^{-1}) of *C chanos, P viridis* and *G. verrucosa* reached 2.67, 0.57 and 3.65, respectively, whereas their production yielded 755, 525 and 952 respectively. Moreover, economic analysis of B/C, Payback period and BEP for suitable area showed 1.4-1.7, 2.7-2.9 cycles, and 3.5-3.7 million IDR respectively. In order to recover the incomes for the farmers, application of IMTA system in the abraded area, mainly in the *suitable area*, was recommended.

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