Strategy to gain the target of shrimp production in Karawang District coastal area

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Abstract. Most of the shrimp farming areas develop without detailed planning and strategies for achieving science-based production. The aim of this study was to develop the strategies required for optimal use of pond areas in the coastal zone, which is scientific-based and relatively easy and inexpensive to implement. The selection of prospective pond sites use Geographic Information System (GIS) demands some considerations, including the suitability (1) of land physical properties, (2) of designation in spatial patterns, (3) ownership and direction of spatial use, and also (4) in terms of community social-economy. The GIS analysis shows the land that is highly suitable for traditional/extensive ponds represents an area of 1,299.99 ha and for semi-intensive and intensive ponds 1,667.91 ha, and other lands covering an area of 55,458.22 ha are marginally suitable for all technologies. Meanwhile, the carrying capacity analysis uses water volume availability approach of the coastal area, which was able to sustain a production of 16,804.48 tons/year^{-1}, hence the utilization for aquaculture has exceeded the land use in the spatial pattern, with the possibility of an upsurge in output. Therefore, more effort is required to increase land productivity. The results of Analytical Hierarchy Process (AHP) show the following as priorities of alternative strategies, presented in the sequence: revitalization of mega-cluster in Cilebar Sub-district, rejuvenation of people's ponds and social forestry, and development of shrimp area clusters.
Key Words: GIS analysis, AHP, carrying capacity, shrimp ponds area.

Introduction. The inception of land development in the coastal area of Karawang District featured the creation of shrimp ponds (1987-1990) at a rate of 105.79% year^{-1} (Sachoemar 1994). However, a decline ensued subsequently, due to environmental problems and disease attacks on shrimps, which resulted in losses and business failures (Komarudin 2013). Furthermore, these challenges were affiliated with uncontrolled land clearing, including mangrove conversions, as well as the absence of area planning and irrigation systems, where outlets and inlets are un-differentiated, and the conduction of shrimp farming, which is not in accordance with recommended technology. Environmental problems and disease outbreaks occurred in areas with intense advancements in shrimp farming activities, over a period of 4-10 years (Bournazel et al 2015). Simultaneously, environmental degradation is also influenced by other factors affecting the coastal area.

The accuracy in selecting a location is a major determinant of business success (Widigdo 2013), because mistakes at this point causes large capital requirement, high operational costs, low productivity and the emergence of environmental problems (Poernomo 1992). The land suitability criteria for the aquaculture has been developed by Widigdo (2000), Murdjani et al (2007), Mustafa (2012), Alaudin (2010), Supito et al (2013), Mustafa et al (2014) and Farkan (2016), which differed based on the commodity and technology applied (Mustafa 2012). These are further grouped into: (1) minimum conditions, comprising the absolute requirements to be fulfilled, e.g. the physical land. And (2) optimal and ideal conditions, which is assumed to largely depend on the technological advancements adopted.

Furthermore, the production target while cultivating in brackish waters of Karawang District is estimated at 41,519.93 tons in 2021 (District Fisheries Services 2016). This creates the need to intensify efforts towards achieving the objectives initiated with representative and effective regional planning. The coastal area utilization model for the existing shrimp farm area was compiled by Alaudin (2010), Asbar (2007), Farkan (2016), Prasita (2007) and Prianto et al (2006), with emphasis limited to physical suitability, spatial patterns and carrying capacity. These were specifically considered in anticipation of natural resources as well as the propensity for environmental degradation (Soewardi 2017). This parameter is also contemplated in predicting the extent of development (Farkan et al 2017) and while setting production targets. Furthermore, numerous data and information is needed, and a series of analyzes ought to be conducted to ascertain the land suitability and carrying capacity, and this process demands substantial costs. The existing model is, faced with adoption and implementation difficulties, hence the need to develop an optimization strategy for aquaculture in the coastal areas. This approach is necessary in attempts to achieve shrimp production targets through inexpensive and relatively easy methods.

Material and Method

Time and location. This research was performed from February to September 2019, and the location was the coastal area of Karawang District with an area of 74,578.05 ha and consisting of nine administrative sub districts. Geographically, the study site is between 107°02′-107°40' east longitude and 5°56'-6°34' south latitude (Central Statistics Agency Karawang District 2019).

Data collection. Data collected were primarily obtained from interviews as well as field observations, and secondarily from the research results, reports, and regulations/laws, encompassing spatial plans, local and ministerial regulations, and others. Primary data i.e. socio-economic conditions of farmers, ownership and land use were collected during interviews and field survey. Filed survey held in order to explore the problems and aspects studied (Sugiyono 2008).

The respondents were elected with non-probability sampling method, at least 30 persons (Roscoe 1975) from 9 coastal area sub-districts. Determination of priorities from the intuition of 5 key persons is outlined in the AHP questionnaire.

Data analysis

Land suitability analysis. Spatial analysis using GIS was applied in the determination of specific land suitability (Malczewski 2004; Pantjara et al 2006; Widiatmaka et al 2015). The criteria used in terms of physical attributes were height from sea level, distance from the coast, and land use as stated by Alauddin (2010), Murdjani et al (2007), Mustafa et al (2014), Prianto et al (2006), and Supito et al (2013) (Table 1).

Criteria for physical and land use suitability according to the spatial pattern in the spatial planning were estimated through weighting and scoring (weight linear combination), followed by overlapping maps (overlays). Hardjowigeno and Widiatmaka (2007) developed five land suitability classes, which include S1 (highly suitable), S2 (suitable), S3 (marginally suitable), N1 (currently not suitable) and N2 (permanently not suitable).

The descriptive analysis conducted to ascertain the suitability of land ownership status, spatial use, as well as the socio-cultural property of the community involved interviews with farmers in the field and data from literature studies.

Table 1

Criteria of physical land suitability for shrimp ponds

No.	Parameter	Score				
		Highly suitable (S1)	*Suitable (S2)*	*Marginally suitable (S3)*	*Currently not suitable (N1)*	*Permanent not suitable (N2)*
A.	Extensive/traditional					
1.	Height from sea level (m)	0 – 2.0	-	< 2.0; > 4.0	-	-
2.	Distance from the coast (m)	130 - 300	50 – 129; 301 – 600	< 50; > 600	-	-
3.	Land use	Pond, bush	Multi farm	Paddy field	Water body	Settlements and other designations
B.	Semi intensive and intensive					
1.	Height from sea level (m)	2.0 – 2.5	2.6 – 4.0	< 2.0; > 4.0	-	-
2.	Distance from the coast (m)	130 - 600	601 - 900	< 130; > 900	-	-
3.	Land use	Pond, multi farm, moor	Shrubs	Paddy field	Water body	Settlements and other designations

Analysis of environmental carrying capacity. The carrying capacity of the environment within the shrimp pond area was calculated using the approach of the coastal waters availability (Farkan 2016; Wigiani et al 2019). This required the calculation of volume, using the formula from Widigdo and Pariwono (2003), as shown below:

$$V_0 = 0.5\ h\ y\ (2x - \frac{h}{tg\theta})$$

Description:
V_0 = the volume of sea water entering coastal waters at high tide (m^3)
h = tidal range (m)
θ = the slope of the beach base (degrees)
y = the width of pond area parallel to the coastline (m)
x = the distance from the coastline (time of tide) to the location of sea water intake (m)

f times the tide = $V_{tot}\ (m^3) = V_0\ x\ f$

The waters can receive 1/100 of pond waste (Rakocy & Allison 1981), therefore:

$$V_{pond\ waste}\ (m^3) = V_{total}/100$$

The pond water replacement during maintenance is 10% day^{-1} (Boyd & Tucker 1998), hence the volume of waste is 10% of the total pond volume:

$$V_{pond\ water} = V_{pond\ waste}\ x\ 10$$

The maximum area of the pond if the assumed depth is 1 m is estimated as follows

$$V_{pond\ water} = L_{pond}\ x\ t$$

$$L_{pond} = V_{pond\ water} \,/\, t$$

Description:
V = volume (m^3)
L = area (m^2)
t = the high of water in the pond (m)

The comparison assumption of pond area projected to support facilities and infrastructure, including channels in a pond area was 60:40, hence the total area is:

$$L_{pond\ area} = L_{pond} + \left[L_{pond}\ x\ \left(\frac{40}{60}\right)\right]$$

The assumption for sustainable pond productivity is 7.5 tons ha^{-1} MT^{-1} (Boyd & Musig 1992), hence the environmental carrying capacity (CC) is estimated as:

$$CC = L_{pond}\ x\ 7{,}5$$

The assumptions for the planting season are 2.5 times in 1 year, hence the carrying capacity per year is projected at

$$= \text{CC x 2.5}$$

Priority analysis strategy. Strategy priorities for optimizing shrimp ponds are determined using Analytical Hierarchy Process (AHP). This outlines a complex multi-factor/criteria problem into a hierarchy, which further serves as a representation, as shown in Figure 1.

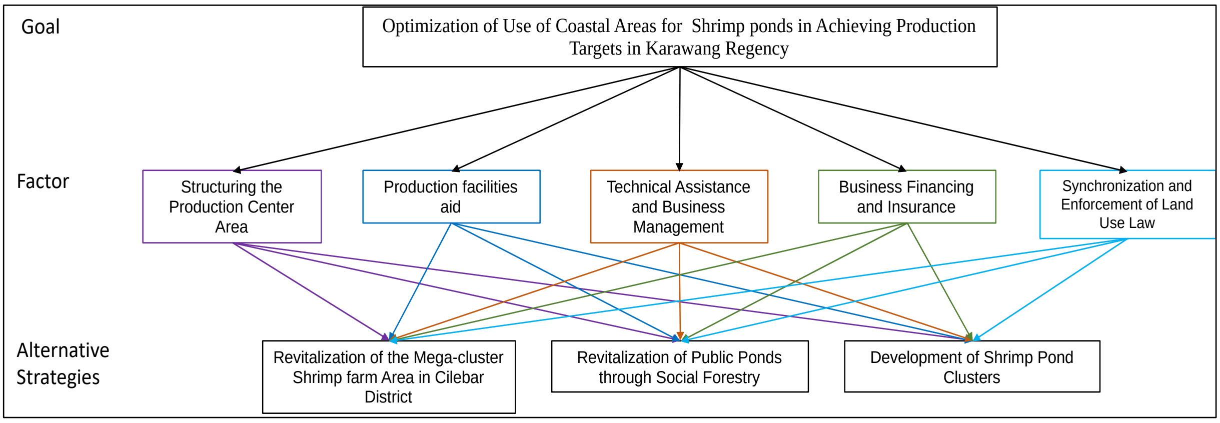

Figure 1. Hierarchy chart of AHP analysis.

The stages of analysis using AHP include system identification, hierarchy structuring, generating the pairwise comparisons of each element for the respective hierarchy, calculating the eigenvectors of each paired comparison matrix, and checking the consistency (Saaty 1993).

Results and Discussion

Land suitability for shrimp ponds in the Coastal area of Karawang District

Physical suitability. The distribution and area of the coastal area in Karawang District along 48.22 km, is estimated to be physically suitable for traditional/extensive, and semi-intensive and intensive cultivation (Table 2 and Table 3).

Table 2
Distribution and area of fishpond (ha) with traditional/extensive technology based on physical suitability

No.	Sub-district	S1	S2	S3	N1	N2	No Data	Total
1	Batujaya	20.14	48.29	6,557.03	75.34	774.00	0.00	7,474.80
2	Cibuaya	208.68	471.12	9,088.89	151.96	1,746.00	0.56	11,667.22
3	Cilamaya Kulon	0.18	0.45	6,058.38	14.90	698.57	0.20	6,772.67
4	Cilamaya Wetan	0.00	2.56	6,798.06	71.85	693.28	2.66	7,568.40
5	Cilebar	117.79	242.04	5,860.82	64.71	385.58	0.63	6,671.57
6	Pakisjaya	162.95	357.75	5,787.78	69.41	378.52	2.52	6,758.92
7	Pedes	35.43	35.75	5,859.89	55.32	606.30	1.11	6,593.81
8	Tempuran	117.22	272.06	9,095.46	43.91	852.94	1.02	10,382.62
9	Tirtajaya	103.93	239.71	9,498.06	90.07	755.39	0.88	10,688.04
	Total	766.32	1.669.73	64,604.37	637.47	6,890.58	9.58	7,578.05

The area of the study location ascertained to be physically suitable for cultivation with traditional/extensive technology is 2,436.05 ha (S1 and S2).

Table 3
Distribution and area of fishpond (ha) with semi-intensive and intensive technology based on physical suitability

No.	Sub-district	S1	S2	S3	N1	N2	No Data	Total
1	Batujaya	59.25	40.96	6,525.26	75.34	774.00	0.00	7,474.80
2	Cibuaya	577.75	382.30	8,808.65	151.96	1,746.00	0.56	11,667.22
3	Cilamaya Kulon	0.52	0.09	6,058.39	14.90	698.57	0.20	6,772.67
4	Cilamaya Wetan	2.53	2.42	6,795.66	71.85	693.28	2.66	7,568.40
5	Cilebar	301.01	122.72	5,796.92	64.71	385.58	0.63	6,671.57
6	Pakisjaya	446.08	291.95	5,570.45	69.41	378.52	2.52	6,758.92
7	Pedes	51.48	10.26	5,869.34	55.32	606.30	1.11	6,593.81
8	Tempuran	333.60	172.44	8,978.70	43.91	852.94	1.02	10,382.62
9	Tirtajaya	299.64	198.67	9,343.39	90.07	755.39	0.88	10,688.04
	Total	2,071.86	1,221.81	63,746.75	637.47	6,890.58	9.58	74,578.05

Meanwhile, the area of the study site ascertained to be physically suitable for cultivation with semi-intensive and intensive technology was estimated at 3,293.67 ha (S1 and S2).

Suitability of land use in spatial patterns. The distribution and area of physically and spatial patterns suitable coastline for ponds is located along 28.81 km (Figure 2 and Figure 3). Conversely, 1,299.99 ha (S1 and S2) were established for traditional/extensive cultivation, which is reduced by 1,136.06 ha, while the N2 land area increased by 9,217.48 ha, in terms of physical suitability. Moreover, 1,667.91 ha (S1 and S2) were determined for semi-intensive and intensive cultivation, while 55,458.22 ha were categorized as S3.

The reduced land area for S1, S2 and S3 were due to the spatial pattern designated for protection and borders. In addition, the mangrove protected forest zones were previously determined in Karawang regional spatial planning for the period of 2011-2031 (Regent of Karawang 2013) and strengthened by Governor of West Java (2019). Conversely, the beach border is estimated to cover a distance of at least 100 m from the coastline (President of Republic of Indonesia 2016).

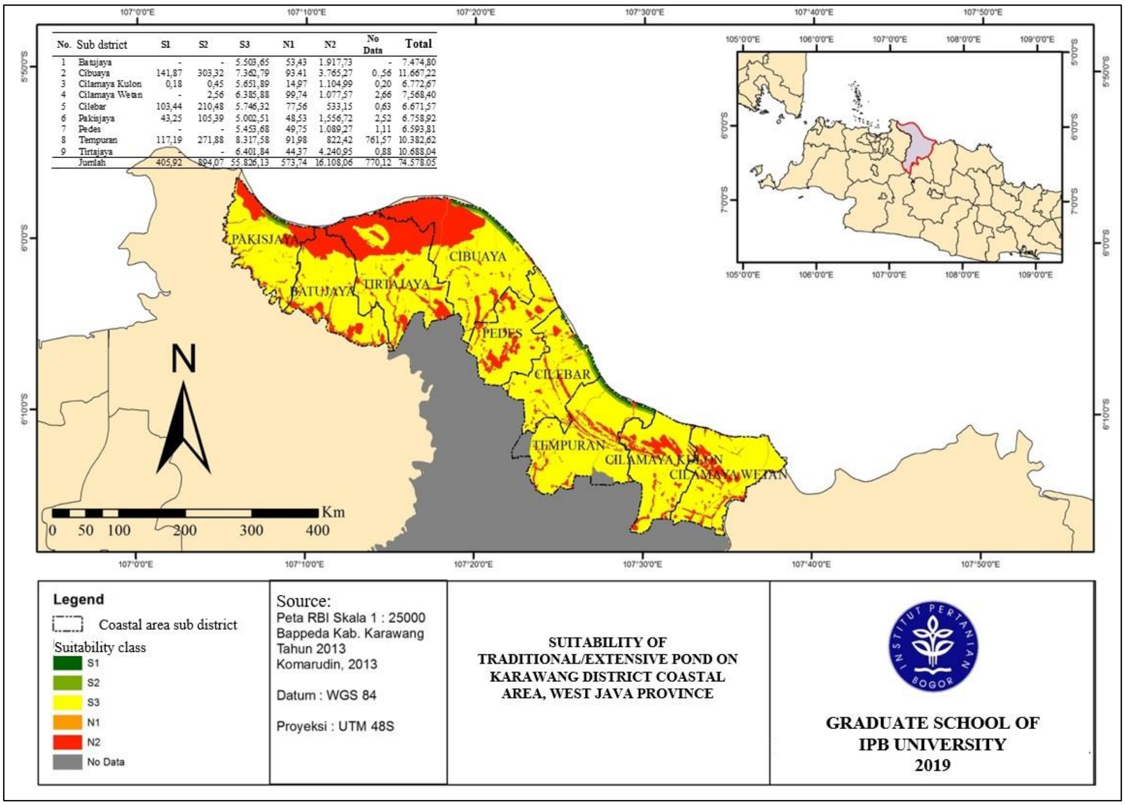

Figure 2. Suitability of traditional/extensive pond lands based on physical criteria in spatial patterns.

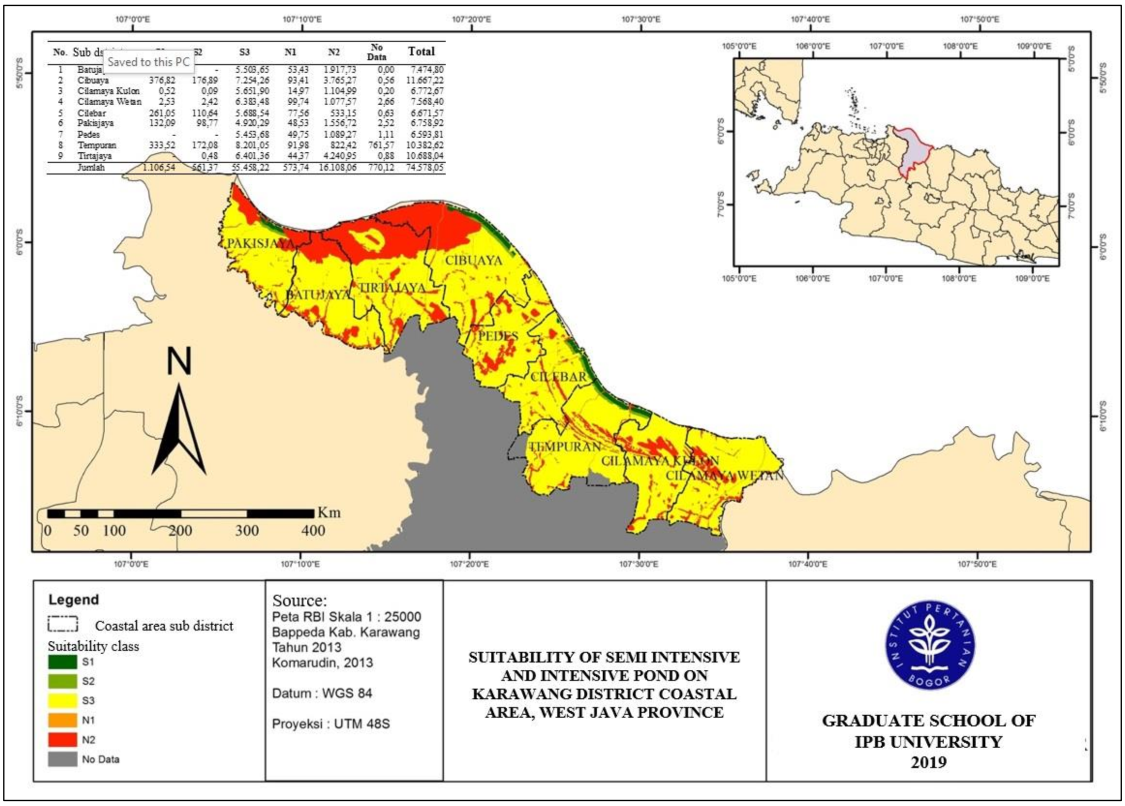

Figure 3. Suitability of semi-intensive and intensive pond lands based on physical criteria in spatial patterns.

The suitability of land ownership and direction of spatial utilization. Based on statistics, only 17.05% of the coastal lands have individual proprietorship status, as the remaining 82.95% belong to the Perhutani (Forestry Company) (Budiyana 2005). This is the reason why the arable land ownership and controlled by each fish farmer range from 0.5 ha - 8 ha, with an average of 1.81 ha, and about 50% occupy less than 1 ha, respectively (Febrina et al 2016).

Komarudin (2013) estimated the course of spatial use in 2030 to be consistent with the Karawang regional spatial planning (absolute consistency 6.23%), where rice fields were predicted to be significantly converted into shrimp ponds and settlements. This was due to the relatively higher profitability compared to other agricultural businesses. Conversely, over 50% of the pond area is in accordance with the actual use (Komarudin 2013), although support for the implementation of regional spatial planning in future requires the adoption of the following recommended policies: coastal border implementation, mangrove forest rehabilitation and protection of paddy field conversion.

Social-economic compatibility of the community. The pond farmers in Karawang District are 3,391.00 fisheries households, which apply 97.05%, 1.47%, and 1.47% of traditional/extensive, semi-intensive, intensive cultivation techniques, respectively (District Fisheries Services in 2018). The average productivity of extensive, semi-intensive and intensive ponds is 2.1 tons ha^{-1}, 5.79 tons ha^{-1}, and 15.62 tons ha^{-1}, respectively. The extensive pond is a polyculture system so that the production of not only shrimp but also fish and seaweed.

The preference for a cultivation technology and the adoption capacity is closely related to financial conditions and capital. According to Febrina et al (2016), 22.22% of farmers in South Pusakajaya Village use personal capital, while the largest source of business funding is acquired through loans. In contrast, the Northern region obtains 83.33% of finance individually and 16.67% otherwise.

The business revenues in the household income structure of farmers is a determinant of effort intensity and time expended. Furthermore, 85.95% of the people living in the coastline, and attaining the fulfillment of daily needs are indigenous, while only about 14.05% are migrants (Budiyana 2005).

Environmental carrying capacity, utilization level of Karawang Regency coastline for aquaculture, and the potential for development. The Cilamaya waters bottom slope is 0.76% (Triatmodjo 2008; Yuwono & Sidad 2017), and this area experiences tides twice a day (Yuwono & Sidad 2017), measuring an average height of 0.87 m. The volume of coastal waters available in the Karawang Regency is estimated at 74,686,578.10 m^3, while the acceptable effluent volume is 1/100 (Rakocy & Allison 1981), i.e., 746,865.78 m^3 or 10% of the pond, which is discharged during water replacement (Boyd & Tucker 1998). The source of fresh water was two large rivers (Citarum and Cilamaya), and also three technical irrigation systems, comprising of the North, Central, and West Tarum Main Channel. Moreover, the aquatic Environmental Quality Index in Sungai Tegal village is categorized as medium qualification (58.71-67.78), hence the tendency for use in aquaculture activities (Suriadarma 2011).

The total pond water volume of about 7,468,657.81 m^3 is contained in a maximum area of 7,468,657.81 m^2 or 746.87 ha, assuming the average depth is 1 m. In addition, the sustainability of pond productivity was projected at 7.5 tons ha^{-1} (Boyd & Musig 1992), which is estimated to accommodate a maximum yield of 5,601.53 tons in each planting season or 16,804.59 tons year $^{-1}$. This increase in intensive and semi-intensive cultivation activities are according to the 2021 target of 12,360.48 tons, which is attainable, assuming the proportional output of each technology is similar through the years.

The total fishpond areas in the coastline is currently 14,411.30 ha, which features 1,440.00 ha for intensive and semi-intensive and 12,971.30 ha for traditional/extensive cultivation. The yield of 2.15 tons ha^{-1} (comprising mainly of fish and seaweed), 5.79 tons ha^{-1}, and 15.62 tons ha^{-1}, were respectively obtained using traditional/extensive, semi-intensive, and intensive cultivation (District Fisheries Services in 2018). In addition, the use of traditional ponds has exceeded the benchmark of S1 and S2, hence the need to increase productivity, especially for non-shrimp commodities, including fish and seaweed. References to application of 9,970 ha in brackish water cultivation show the development of 8,302.09 ha for ponds, which is in the S3 category.

The coastal water dynamics is projected to be a limiting factor in the development of shrimp ponds area in the future. Moreover, shrimp farming and other activities are known to influence the coastline and pond water properties, hence the need to implement Best Management Practices (BMPs), which is expected to minimize the environmental impacts (Boyd 2003). In addition, poor quality is indicated by an increase in turbidity, and also elevated concentrations of ammonia, nitrates, nitrites and sulfides, which trigger phytoplankton blooming in the rainy season (Aliah 2013).

***Strategies to optimize the use of coastal areas for aquaculture and actualize the production targets in Karawang Regency**.* The results of AHP showed that the following criteria were considered while choosing alternative strategies: arrangement of the production area, synchronization and enforcement of land use regulations, support for facilities, technical and business management assistance, as well as financing and business guarantees, which respectively weighed 0.513, 0.261, 0.097, 0.064 and 0.043. However, the alternative sequence of strategies required to optimize the income of aquaculture in the coastline include: (1) revitalization of mega-cluster in Cilebar Sub-district; (2) rejuvenation of people's ponds and social forestry; as well as (3) development of shrimp pond clusters, which respectively weighed an average of 0.302, 0.258 and 0.227.

Revitalization of mega-cluster in Cilebar Sub district. Cilebar mega cluster is an area in Karawang, which once produced tiger shrimp on a semi-intensive cultivation scale and featuring an average output of 1.8-3.8 tons $ha^{-1}/cycle^{-1}$ (Widigdo & Soewardi 1999). The initial design of this shrimp pond area was in accordance with the commodities and technology applied, which was also supported by the topographical arrangement, availability of infrastructure, and accessibility to the area, in terms of irrigation systems, jetties for the supply of clean sea water, electricity and road networks. In addition, the management of each area is integrated with the partnership model, and the social problems reported from the year 1998 have led to sub-optimal utilization. These challenges were identified from discussion and interview, and further ascertained to include: (1) partial and sporadically management of each farmer and business actor, (2) the fact that white shrimp (*Litopenaeus vannamei*) was the most developed commodity for intensive cultivation, when the existing construction is suitable for giant tiger shrimp (*Penaues monodon*) on a semi intensive scale. There is also a need for re-construction, due to siltation and damage at the inlet and outlet channels, and also to pond structure. Furthermore, some reports show the presence of jetty mutilation, limited number and quality of sea and fresh water supply, as well as an increase in the intensity of shrimp disease attacks, and land ownership status.

The Cilebar mega cluster area is in accordance with the spatial use designation of the Karawang District regional spatial planning. However, proper functioning demands the conduction of repairs and maintenance on existing infrastructure, as well as the need for integrated management. The applicable alternative models for area management include partnerships, as seen in nucleus-plasma, corporate farming, cluster cultivation and area management in each unit. Therefore, more effort is needed to identify alternative sources of fresh water besides the Ciwadas River flow, resulting from the propensity for industrial, urban, agricultural and residential activities-based pollution. Conversely, wellbore was the source of fresh water widely used by intensive farmers in the Cilebar mega cluster area.

***Rejuvenation of people's farms and social forestry**.* Figure 2 shows the traditional/extensive pond area located on S1 and S2 lands, and production optimization requires proper arrangement and management according to the recommended irrigation systems and technologies. In addition, the traditional cultivation of sylvofisheries (mina wana) in the Perhutani Company pond model ensures the maintenance of forest functions.

The proportion of mangrove stands compared to the suggested sylvofisheries pond water area is 60%:40% (Amrial et al 2015), and this aquaculture activity contribute higher total household income to the farmers (Budiman et al 2016). The management and utilization of mangrove forests is generally regulated by the President of Republic of Indonesia (2012a; 2012b), while the forest utilization for community welfare is controlled by the Ministry of Environment and Forestry (2016).

Other traditional ponds require improvements to semi-intensive and intensive cultivation. This process demands a series of empowerment activities, which include capacity building, through the modification of mindset, technical and management skills, as well as capital reinforcement. Conversely, demonstration farm (Demfarm) is assumed to be effective in changing an individuals' mindset, which is in accordance with the recommended technology (Rahman 2015). Also, some government programs have the capacity to stimulate business development, through insurance and land certification for fish farmers.

The diligent enforcement of rules and the provision of clear and firm sanctions for violators is expected to effectively restore and maintain the function of mangroves on the Karawang coastline (Lovapinka et al 2014). These approaches play a role in regulating climate control (Chen et al 2016; Rahman et al 2017), despite the intense damage to the ecosystems (Macintosh & Ashton 2002) through carbon deposits (Bianchi et al 2013; Hilmi et al 2017; Kauffman et al 2014; Liu et al 2014; Siikamäki et al 2013) and CO_2 absorption.

The development of shrimp pond clusters*.* Shrimp pond cluster is a cultivation area for business management, which measures about 10 Ha each. Furthermore, risk management strategies during farming against disease attacks, limited access to forest utilization rights, capital availability and price dynamics from market uncertainty are carried out through a collaborative approach (Ha et al 2013). Therefore, product quality and productivity improvement are obtainable by upgrading the applied technology, minimizing the environmental impacts, and harmonizing the relationships between the businesses in the market chain (Umesh et al 2010).

The development plans for shrimp pond cluster are initiated with the determination and selection of a location, which is performed in accordance with the land suitability. Furthermore, it is also necessary to attain the detailed criteria and parameters, including the optimal and ideal requirements for commodities and technology. This phase is followed by the site arrangement, involving the use of detailed engineering design (DED) to possibly attain synergism between the shrimp pond clusters and the processing industries. Also, proper planning of the eco-industrial cluster model is required to streamline the value chain, minimize waste and simultaneously generate by-products in the form of low-level tropic commodities (Anh et al 2011).

Conclusions. The Karawang District coastal area is characterized by a physically suitable land spatial pattern measuring 1,299.99 ha and 1,667.91 ha (S1 and S2), respectively for the development of ponds for traditional/extensive, and semi-intensive and intensive cultivation. Based on the assumptions of shrimp pond sustainable productivity, these coastal waters have the capacity to accommodate 16,804.48 tons of production year^{-1}. Furthermore, land suitability, environmental support and utilization level ought to be evaluated before applying semi-intensive and intensive cultivation to achieve targets. This goal is also achievable in traditional ponds, due to the wide application dynamics in the broad area of suitable lands. This is attainable by encouraging the production of non-shrimp commodities, including seaweed and fish.

Therefore, fishponds in the coastal area are optimally utility by adopting the following strategies sequentially: (1) Mega-cluster revitalization of the former people's main ponds in Cilebar District; (2) People's ponds rejuvenation and social forestry; and (3) development of shrimp pond clusters.

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