Characteristics and environmental carrying capacities of coastal area in Yogyakarta Special Region for aquaculture

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Abstract. The purpose of this study were to determine characteristics and environmental carrying capacities of coastal area in Yogyakarta Special Region for aquaculture. This study was conducted in 2015 by characterizing land and water dynamics, land use, and the suitability of coastal environments for aquaculture. Evaluation on the coastal environments suitability for aquaculture ponds was based on the landform, soil properties, water quality and land. Selection of coastal locations for aquaculture development was based on the level of suitability of coastal environment. The results showed that the coastal in Kulon Progo and Bantul Regencies were characterized by sand dune and beach ridge with sandy soil texture, while in Gunungkidul Regency was characterized by limestone hill with rocky texture. Water sources of the coastal area were the sea, river, and ground water with the salinity of 31–37, 7–11, 7–31 ppt and pH of 7.4–8.4; 7.0–8.2 and 7.4–9.9, respectively. The coastal lands were used for seasonal/annual planting, ponds, fish landing sites, tourism areas and conservation areas. The coastal carrying capacity was rather suitable for aquaculture, especially in the sandy soil area. Aquaculture in that area can be done intensively for shrimp (Litopenaeus vannamei), using biocrete (biological material) or plastic sheet.

1. Introduction
Carrying capacity is an important concept for ecosystem-based management, which helps set the upper limits of aquaculture production given the environmental limits and social acceptability of aquaculture, thus avoiding “unacceptable change” to both the natural ecosystem and the social functions and structures. Carrying capacity for aquaculture is based solely on production, they have been developed further into a more comprehensive four-category approach based on physical, production, ecological and social carrying capacities [1].

Coastal areas have diverse natural resources with various functions, i.e. agriculture, fisheries, settlements, ports, tourism and/or industry. Some activities in the region often exceed the carrying capacity of the environment [2]. Responsible coastal management should be used as a basis for coastal development, both for fish farming and other sector activities. The fish/shrimp ponds were developed in order to optimize the utilization of coastal environment [3].

Production of aquaculture in some places within few years after the intensification has decreased, since the carrying capacity of the ponds become lower. This problem happened in ponds production centers such as the north coast of Java and the east coast of Lampung Province. About 80% of the land on the north coast was used for shrimp farms [4]. The coastal area has been damaged and affected by various diseases and pollution problems. The waste of residual feed and shrimp faeces into the aquaculture environment contributed the addition of nutrients to the aquatic environment [5]. On the other hand, coastal area of southern part of Java Island is a potential area for ponds development. Pond
construction in the area is one of alternatives to increase the land productivity, especially with regards to the good water quality and opening to the sea.

Coastal areas with diverse landforms and dynamic waters generally have a varied aquaculture fishery model. The landform units reflect the similar morphological and soil properties [6]. The dynamics of coastal waters throughout the year are determined by tidal sea water, freshwater supply from rivers and rain. The relation of land character and coastal waters, and their use has been used as the basis for determining the suitability (carrying capacity) of the coastal environment for aquaculture. The suitability of a particular land unit is a natural ability to support a specific use for aquaculture. The dynamics of waters throughout the year is also a factor that determines the model of aquaculture in relation to time (season) [7, 8].

The coastal area of Yogyakarta Special Region (Daerah Istimewa Yogyakarta) has a karst hill land, sand dune, swale and alluvial plains. The rivers that flows to the coastline have a water dynamic throughout the year. The current use of coastal sand is also varies. In the last four years, shrimp farming conducted by local communities has been growing rapidly on the coastal sandy land. Salt/brackish water source for shrimp ponds was pumped from coastal groundwater (wells). The coastal area of DIY have certain environmental characteristics (abiotic, biotic and culture). Therefore, shrimp farming in the coastal areas should be developed based on the specific location model [8]. The purpose of this study were to determine the characteristics and environmental carrying capacities of DIY coastal area for aquaculture ponds. In this study, especially on the physical carrying capacity is based on the suitability of aquaculture development by considering the physical factors of the environment and the farming system. The result of the present study is important for development of sustainable and eco-friendly coastal aquaculture fisheries along the coastline throughout the year.

2. Materials and Methods
Research has been conducted to assess the characteristics and carrying capacities of the land and coastal waters. This study was conducted in June–August 2015. Research location was coastal area of Yogyakarta Special Region (Daerah Istimewa Yogyakarta). The study area included rural/subdistrict along the coast of Kulon Progo Regency, Bantul Regency, and Gunungkidul Regency. The coastal area covered the area approximately 1 km from the coastline. In the coastal area there were river estuaries. The general condition of the coastal area were studied from secondary data, which included climatic conditions (rainfall), river water discharge, sea tides, landforms and coastal land uses. The research was conducted on spatial and temporal coastal physical factors including the characteristics of land and waters dynamics, land use, and suitability of coastal environment for aquaculture. The land parameters used were land shapes, soil texture and soil pH. Parameters of aquatic dynamics used included the fluctuations of water surface, water salinity and water pH. Land parameter data were collected from along the coast, while the water parameter data were collected from the coastal estuaries. The data of land, soil and water parameters were obtained from secondary data as well as direct observation on the coast of Yogyakarta Special Region (DIY).

The physical data for aquaculture was analyzed descriptively, both spatial pattern and temporal pattern. The coastal land uses was for aquaculture ponds. The research was conducted by survey, interview and observation methods. The surveys and interviews were conducted on the farmers of aquaculture ponds. The parameters in questionair sheet were the farm physical properties, distribution, type, season and shrimp production. The data obtained were presented descriptively in relation to environmental characteristics along the coast for a year. The suitability (carrying capacity) of the coastal environment for aquaculture was based on the land characteristics and land uses. Evaluation of conformity (carrying capacity) of coastal environments using land quality parameters covering: landform, slope, soil texture, soil pH, and land use, while water quality parameters include: water salinity, and water pH. The degree of conformity of the coastal environment for aquaculture were calculated based on the quality parameters of land and water.
3. Results and Discussion

3.1. State of territory
DIY region was bordered directly by the south Indian Ocean; Purworejo Regency in the west; Magelang, Klaten and Sukoharjo regencies in the north; and Wonogiri regency in the east. Along the coast of DIY there were rivers that flow into the Indian Ocean that included Bogowonto River, Serang River, Progo River, Opak-Oya River. Coastal area of DIY with coastline of approximately 120 km covering the coastal of Kulon Progo Regency (± 30 km), Bantul Regency (± 20 km) and Gunungkidul Regency (± 70 km).

3.2. Landforms and soil properties
Coastal landforms of DIY (table 1 and figure 1) included the landforms of marine origin, the origin of the wind, and fluvial processes. The landforms of the marine processes consist of whisper (beach) and swale (watery/wet and dry). The land form of the wind process is in the form of sand dunes. The fluvial processed forms are from alluvial plains and flood plains. The coastal area of Kulon Progo Regency and Bantul Regency were dominated by sand dunes, while the coastal area of Gunungkidul Regency was dominated by conical hills karst plain and doline complex (Figure 1). The coastal sand dunes in Kulon Progo and Bantul Regency were 2,022 ha (87.1 %) and 752 ha (49.6 %), respectively.

Slopes of the lower sand dunes ranged from 0.7 to 3.0 %, while the upper sandbanks and swale (wet or dry) were 3.0-9.3 % and 0-0.5 %, respectively. Areas with sand dune and beach ridge generally have a sandy soil texture, or textured loamy sand in some places. The degree of acidities (pHs) of soil in the coastal area were varied. The soil pHs in the sand dunes area were ranging from 6.6–7.4 (7.2 in average) [7]. The soil in sand dunes was dominated by coarse texture (granulated) with a neutral to slightly alkaline pH [9].

Table 1. Landforms of DIY Coastal Area.

| Landforms                          | Kulon Progo Regency | Bantul Regency | Gunungkidul Regency | DIY Region |
|------------------------------------|---------------------|----------------|---------------------|------------|
| Alluvial Plain                     | 72.71               | 335.72         | 0                   | 408.43     |
| Flood Alluvial Plain               | 119.11              | 140.38         | 0                   | 259.49     |
| Beach Ridge                        | 60.59               | 86.36          | 0                   | 146.95     |
| Wet Swale                          | 46.74               | 0              | 0                   | 46.74      |
| Dry Swale                          | 0.36                | 89.45          | 0                   | 89.81      |
| Sand Dunes                         | 2,021.93            | 751.58         | 0                   | 2,773.51   |
| Breccia Hills                      | 0                   | 112.2          | 0                   | 112.20     |
| Conical Hills Complex Karst and Doline Plains | 0                   | 0              | 6,618.89            | 6,618.89   |
| Total                              | 2,321.44            | 1,515.69       | 6,618.89            | 10,456.02  |

Source: Primary data based on Landforms Maps.

3.3. Climate, river water discharge and sea water tides
According to he climatic classification by Koppen, the climatic types found in the coastal area of Gunungkidul Regency was included into the Awa type, while the coastal areas of Bantul Regency and Kulon Progo Regency were included into the climate type Am. The Awa type has characteristics that the amount of rain in wet months (rainfall > 100 mm) can not offset the rainfall in dry months (rainfall < 60 mm), whereas the climate type Am has the characteristics of the amount of rain in the wet months that able to offset the shortage of rain in the dry months. The average annual air temperature in the
study area was 26.50 ºC with a minimum average temperature of 23.45 ºC and a maximum of 31.31 ºC. Wind direction in the rainy season blow from southwest to northwest, while in the dry season, the wind blows from south to southeast [10]. Most winds are less than 10 knots (5 m·sec⁻¹). In the western seasons (northwest monsoon winds), the flow of currents in the waters of the Indian Ocean to the west spreads between latitude 10–20 ºLS. In the east season (southeast monsoon wind), the flow of currents in the waters of the Indian Ocean to the east extends beyond the latitude of 10 ºLS [11]. Wind direction and current in the Indian Ocean affect the sedimentation and closing of estuary of rivers in coastal of DIY which generally occur in August until November [7].

The Bogowonto River water debit in 2008–2009 has a monthly value ranging from 11,436–2,253,287 m³·sec⁻¹ with the daily average ranges of 369–78,231 m³·sec⁻¹. In the dry season, low rainfall and small river water discharge, wind direction and speed as well as tides of the sea water caused sand sedimentation and closed the mouth of Bogowonto and Jali Rivers. The water flow at the mouth of the Bogowonto River turns westward through the Pasir-Jati River to the mouth of the Jali River [7] River water discharge was significantly affected by the rainfall. During the rainy season, the rainfall was high causing the high water flow rate in the river. In the rainy season, high rainfall and large river water discharges as well as the sea tides naturally gave a flashing effect the sediments in the mouth of Bogowonto River (estuary).

Tidal data of the Indian Ocean was obtained from the Observation Station at Cilacap Port under the Hydro-Oceanographic Service [12]. The monthly observations in 2008–2009 found a mean monthly tidal average of 1.1 m (ranging from 0.0 to 2.2 m), a mean full moon tidal of 1.08–1.20 m (min. 0.1 m and max. 2.2 m) and a 2nd Quarter Month tidal of 1.06–1.12 m (min. 0.3 m and max. 2.0 m) [7]. Sea tide on the Full Moon had a larger water level fluctuation compared to the second quarter. The monthly tide on the Full Moon and the 2nd Quarter of 2008–2009, has a mean of 1.1 m, including a low one, but was still appropriate as a pond water resource (with extensive system). The tides at that time ranged from 0.0 to 2.2 m including very low-high enough. Coastal areas with maximum tidal water of 2–3 m and average amplitude of 1.1–2.1 m were included as suitable for management of shrimp farming ponds in the intertidal area [13].

3.4. Coastal water salinity and pH
Coastal areas of Bantul Regency (from 30 locations of ground water and ponds) had an average groundwater salinity of 19 ppt (ranging between 7–31 ppt) and pond water 19 ppt (12–27 ppt), degrees of acidity (pH) of 8.8 (7.4–9.9) or 9.0 (8.0–10.2) for ground water or pond water. Observation of groundwater and ponds (24 plots) for 90 days (in November 2014–May 2015) in the Kuwaru beach area of Poncosari Village, Srandakan Subdistrict showed an average salinity of 20 ppt (ranging from 8–27 ppt) and 17 ppt (13–26 ppt), and the average acidity (pH) degree of 8.7 (7.6–9.8 ppt). White shrimp is able to live in water salinity of 4–45 ppt. White shrimp can live well (optimal) at water salinity of 10–30 ppt and pH 7–8.5 [14]. Water salinity might decrease because of freshwater supply from groundwater and run off of water rain. High acidity (pH) of water was found in open water during the day because photosynthesis reduced free CO₂ content.

Bogowonto River and Pasir River (Jangkaran Village, Temon District, Kulon Progo Regency), and the sea in FullMoon and the 2nd Quarter Moon started from August 2008 to July 2009 showed the water salinity of 7 ppt (ranged from 0–22 ppt), 10 ppt (1–28 ppt), and 34 ppt (31–37 ppt), respectively. Adequate water salinity for shrimp aquaculture ranges from 10–35 ppt (optimal 15–25 ppt) [13]. Pasir Jati River has relatively low water salinities of 2–11 ppt for aquaculture [7].
Figure 1. Landform maps of several regencies area in Yogyakarta Special Region [8]. (a) Kulon Progo Regency; (b) Bantul Regency; and (c) Gunungkidul Regency.
Bogowonto River and Pasir River (Jangkaran Village, Temon District, Kulon Progo Regency), and the sea in Full Moon and the 2nd Quarter Moon started from August 2008 to July 2009 showed the average water pH of 7.5 (ranged from 7.0 to 8.2), 7.5 (6.3–8.5), and 7.5 (7.0–8.4), respectively. The degree of acidity (pH) of water suitable for aquaculture ponds ranges from 7.5–8.7 (8.0–8.5) [13]. The water pH of the Pasir River ranged pH 7.2–7.7 that is categorized to be suitable for aquaculture. The degree of acidity (pH) of seawater was relatively stable ranging from 7.4–8.4 (alkaline), while pH of Bogowonto estuarine water was 7.0–8.2 (neutral–alkaline). The degree of acidity (pH) of water along the Pasir River throughout the year fluctuated between 6.2–8.5 (slightly acid–alkaline). The degree of acidity (pH) of water along the river is influenced by water sources from river mouths, springs and rain. Besides, the degree of acidity (pH) of water along the river is also strongly influenced by soil pH around each location of observation.

3.5. Landuse in Coastal Areas

Landuse of coastal area (table 2 and figure 2) were generally for rice fields, moor, buildings/yards, dry soil, ponds, forests and others (shrubs, meadows, swamps, deserts/vacant). Coastal villages of Kulon Progo, Bantul and Gunungkidul Regencies covered the area of 6,094.5; 3,943.0 and 31,878.8 Ha, respectively, while the wetland area covered 1,357.8; 1,156.0 and 144.6 Ha, respectively. Dryland in the area were 2,243.4; 1,156.0 and 23,704.5 Ha [15, 16, 17], respectively. Rice fields in the coastal villages of Kulon Progo Regency was the most widespread, whereas in Kabupaten Gunungkidul was the least. In contrast, dry land in the coastal villages of Gunungkidul Regency was the most widespread, whereas in Kabupaten Bantul was at least.

Table 2. Landuse of DIY Coastal Area.

| Landuse                              | Kulon Progo Regency | Bantul Regency | Gunungkidul Regency | DIY Region |
|--------------------------------------|---------------------|----------------|---------------------|------------|
| Irrigated rice fields                | 59.27               | 272.73         | 0                   | 332.00     |
| Moor                                 | 1,279.39            | 344.16         | 0                   | 1,623.55   |
| Garden                               | 363.18              | 99.44          | 0                   | 462.62     |
| Forest                               | 0                   | 85.76          | 6,068.61            | 6,154.37   |
| Open field                           | 119.78              | 40.23          | 547.41              | 707.42     |
| Open land and natural vegetation     | 245.42              | 313.24         | 0                   | 558.66     |
| Settlement                           | 65.34               | 162.94         | 2.87                | 231.15     |
| River                                | 77.11               | 160.17         | 0                   | 237.28     |
| Ponds                                | 111.95              | 37.01          | 0                   | 148.96     |
| **Total**                            | 2,321.44            | 1,515.68       | 6,618.89            | 10,456.01  |

Source: Primary data based on Landuse Maps.

Land use in coastal areas of DIY included Irrigated rice fields, fields, gardens, forests, open land, and vegetation, settlements, rivers/bodies of water, and ponds. Land use of coastal area in Kulon Progo, Bantul and Gunungkidul Regencies are presented in table 2. Ponds are in DIY were estimated 148.96 Ha, located in coastal area of Kulon Progo Regency of 111.95 Ha and Bantul Regency of 111.95 Ha, while in Gunungkidul was not recorded in the map.

The pattern of land use for cultivation of crops and aquaculture were largely determined by the state of coastal landform and availability of water resources. The availability of spatial water resources (along the coast) as well as temporal (year-round or seasonal) fluctuated. Land use for wetland farming depends on water sources mainly from rainfall and springs, whereas for dry land agriculture depends on rainfall and groundwater (bore or open wells). The use of land for ponds depends on the
sea/brackish water source of the river mouth and the tides. The brackish ponds developed in the coastal area used the groundwater water sources.

3.6. Coastal carrying capacity for aquaculture

Aquaculture development has consequences to increase in the pressure on aquatic and terrestrial resources, impact on environment and biodiversity, as well as impact on the society. The application of ecosystem approaches to aquaculture (EAA) is a sustainable aquaculture development effort while avoiding negative impacts. Carrying capacity is a major component of the ecosystem approach used to implement site selection for well-planned aquaculture [1]. Site selection for aquaculture development based on the level of suitability of coastal environment is crucial. The suitability of coastal environments for aquaculture (in sand dunes) which was included as suitable (S2) is only 10 % and somewhat appropriate (S3) as much as 90 % [7]. Pond construction on coastal sand land needs technology input using plastic (mulch) or biocrete (permanent).

The sand dunes are ± 3–5 m above sea level, so water should be pumped. Pond water resources can be directed pumped from sea water, river, or groundwater (drill). Sea water has a stable salinity and pH which are suitable for shrimp, but pumping process faced a difficulty due to the high and strong current and sea waves. River water has a fluctuated widely in salinity and pH, so sometimes they were not suitable for shrimp. In addition, the river water is easily polluted. Groundwater near the coast has a stable salinity and pH which is suitable for shrimp, but sometimes the salinity may decrease.

Based on International Principles for Responsible Shrimp Farming and good fish farming method (CBIB), the ponds should be located in the suitable environmental conditions, so that land and water uses are efficient with optimum ecosystem function [18]. The development of ponds is performed in areas that have not reached the maximal environmental carrying capacity. Ponds are designed and constructed to fulfill the adequate water quality for cultivated fish with integrated pond management. Disturbance to environmental ecosystem is kept as small as possible.
Figure 2. Landuse maps of several regencies area in Yogyakarta Special Region [8]. (a) Kulon Progo Regency; (b) Bantul Regency; and (c) Gunungkidul Regency.
4. Conclusion and Suggestion

4.1. Conclusion
1. Coastal area of the Kulon Progo Regency and Bantul Regency are characterized by sand land and beach ridge with sandy soil texture, whereas in Gunungkidul Regency is generally limestone hill (karst) with rocky texture.
2. Salinities and pHs of coastal water sources, such as seawater, river water and ground water (drilling well) are 31–37, 7–11 and 7–31 ppt, and 7.4–8.4; 7.0–8.2, 7.4–9.9, respectively.
3. The coastal lands were generally used as vacant land (bush), seasonal/annual plantation, ponds, fish landing sites, tourist areas and conservation areas.
4. The carrying capacities of the coastal sandy soil area of DIY are rather suitable for aquaculture ponds.

4.2. Suggestion
It is suggested that aquaculture pond that can be develop in the coastal area of Kulon Progo Regency and Bantul Regency are intensive system for white shrimp (L. vannamei) by using plastic or biocrete ponds.

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