Asian Journal of Fisheries and Aquatic Research

Volume 26, Issue 3, Page 48-61, 2024; Article no.AJFAR.114588
ISSN: 2582-3760

Suitability and Carrying Capacity of Aquatic Environment for Shrimp Culture in Sarjo District, Pasangkayu Regency West Sulawesi

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJFAR/2024/v26i3746

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/114588

Original Research Article

Received: 14/01/2024
Accepted: 18/03/2024
Published: 21/03/2024

ABSTRACT

The potential of coastal and marine resources in Indonesia is so diverse both in terms of quantity and quality, should be able to contribute greatly to the economic growth of the State of Indonesia. The purpose of this stydy is to assess the level of land suitability and carrying capacity of the pond environment for shrimp culture in Sarjo District Pasangkayu Regency. The research was conducted

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using survey method, measuring biological, physical and chemical parameters. The observed data consisted of temperature, turbidity, TSS, current direction and speed, tides, pH, salinity, dissolved oxygen, ammonia, nitrate, nitrite, phosphate, BOD, COD, BOT, and plankton. Based on biological, physical and chemical data, an analysis of the suitability of the pond area was carried out using the geographic information system (GIS) Arc View GIS Application Version 3.3. The results of the level of suitability of land for shrimp culture in Sarjo District was very suitable 154.88 hectare; 2) Suitable 77.16 hectare and quite suitable 27.26 hectare. Overall land for aquaculture in each area is traditional 732.95 hectare, semi-intensive 1,589.12 hectare and intensive 247.83 hectare. The environmental carrying capacity of intensive shrimp cultivation ponds with an estimated maximum production of 42.63 tons ha-1, with a permitted pond area that does not exceed the environmental carrying capacity is 166.07 ha; semi-intensive cultivation with a maximum production of 153.49 tons ha-1 MT-1, the permitted pond area so as not to exceed the environmental carrying capacity is 597.85 hectare, traditional cultivation with a maximum production of 3.4 tons MT-1 with a supported pond area of 2,569 ha in Sarjo District, Pasangkayu Regency.

Keywords: Suitability; land carrying capacity; aquatic environment; shrimp culture; brackish aquaculture.

1. INTRODUCTION

The potential of fisheries and marine resources is so diverse both in terms of quantity and quality, it should be able to make a major contribution to the economic growth of the State of Indonesia. Coastal resources and small islands are very important resources for society and can be used as a prime mover of the national economy. This is based on the fact that *first*, Indonesia has high potential for coastal and small island resources with diverse characteristics of coastal areas and small islands. *Second,* most industrial activities in regencies/cities are located in coastal areas. *Third,* industrial activities in coastal areas have strong linkages with other industries. *Fourth,* coastal areas and small islands are the local resource base for the fishing industry or known as resource-based industries and fifth, coastal areas in Indonesia have a high comparative advantage as reflected in the potential of fish resources[1)].

Coastal areas and small islands are actually areas that have very high potential to be developed, one of which is brackish aquaculture, therefore in the management of marine resources and fisheries, coastal and marine areas need to be planned carefully and in accordance with the characteristics of the region. To optimize the development/exploitation of coastal resources, it is necessary to conduct planning activities that are useful to determine the type, location and economic value of resources as well as to determine the local ecological suitability of exploitation efforts as mandated in Law No. 27 of 2007 concerning Management of Coastal Areas and Small Islands [1] and PERMEN No. 16 of 2008 [2] concerning Coastal and Small Island Management Planning.

Pasangkayu Regency, especially Sarjo Sub-district, has a coastline of 37.03 km, which has the potential to become a large brackish aquaculture area and other potential coastal resources that have not been managed optimally. To develop the coastal area of Sarjo Sub-district, it is not enough just to prepare zoning, but also technical plans for coastal area management, especially related to the suitability and carrying capacity of the aquatic environment for brackish water aquaculture activities. This management system is important because it will determine the balance of aquaculture resource management in the future. The purpose of this research study was to assess the level of land suitability and carrying capacity of the pond environment for shrimp farming in Sarjo District in order to improve the economic welfare of the community in the coastal area of Pasangkayu Regency.

2. METHODOLOGY

The research was conducted in the waters of Sarjo District, Pasangkayu Regency, West Sulawesi (figure), for six months, i.e. from March to September 2020.

The research used a direct survey method at the research site and measured biophysical parameters of the aquatic environment. The types of data and measurement methods are presented as Table 1.

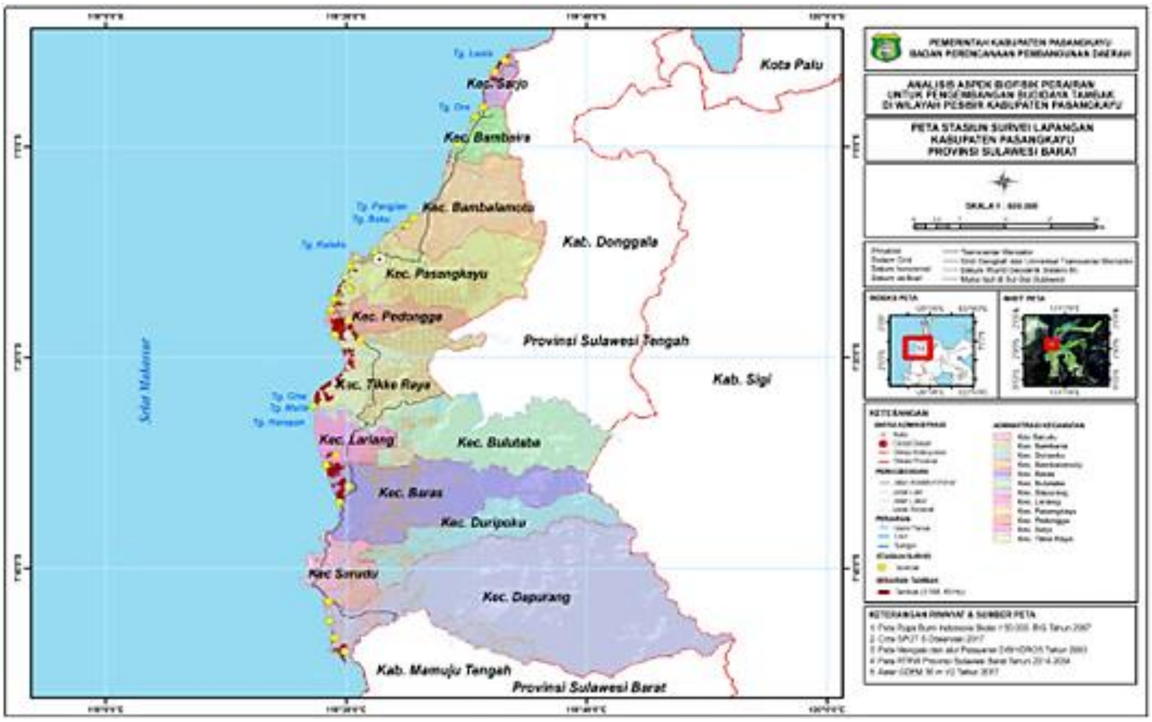

Fig. 1. Sampling location

Water quality observations were conducted in three areas: ponds, mangroves, and coastal waters. These observation aimeds to determine the status of the area related to its feasibility for shrimp farming. Observations were made once a month during the highest tide and lowest tide. Tidal observations were made in coastal waters at a depth of 3 meters at the lowest ebb using a scaled stick, for approximately 15 (fifteen) days. Tidal data issued by the Naval Hydroceanographic Service in 2016 was used for comparison. Current speed was measured with a current meter. While the current pattern was observed by tracing the direction of current movement.

The study of aquatic biology includes plankton and benthos which aims to determine the ability of waters to assimilate organic matter into inorganic. The suitability analysis used a geographic information system (GIS) using the Arc View GIS Version 3.3 application. The analysis conducted is its suitability as an area of aquaculture ponds. In conducting the analysis of land suitability in general there are four stages, namely: (1) compiling a map of coastal areas, (2) compiling a matrix of suitability of each activity in the coastal area, (3) weighting and scoring, and (4) spatial analysis to determine the suitability of each area in the coastal area.

The preparation of area maps was done with a Geographic Information System (GIS), by querying GIS data using the principles of the area discussed earlier, so that spatial information can be known: (1) which areas are available for the development of aquaculture ponds using traditional, semi-intensive, and intensive technology, or which areas are used as conservation areas; (2) what use of the area is allowed and what is not allowed; (3) conflicts that occur between: (a) the suitability of the area with its designation; (b) land use in accordance with its designation; (4) the results of the preparation of maps of areas that have been in accordance with its designation may be different from its current use.

The suitability of utilization of coastal areas for aquaculture activities is based on land suitability criteria. These criteria are based on physical, chemical and biological parameters relevant to each activity, divided into four classes, namely: 1) Class S1 (highly suitable); 2) Class S2 (Suitable); 3) Class S3 (Conditionally Suitable) and 4) Class N (Unsuitable). The division of the class is adjusted to the use of technology in shrimp farming, namely traditional methods, semi-intensive methods, and intensive methods.

Table 1. Physic-chemical and biological parameters, tools and methods used for analysis

No	Parameter	Unit	tools	Location
A	**Physical Parameters**			
1	Temperature	(°C)	Thermometer	In situ
2	Turbidity	(NTU)	*Turbidity meter*	In situ
3	Total Suspended Solid (TSS)	(ppm)	Sample bottle and cool *cool box*	Laboratory
4	Tide	(cm)	Tide gauge	In situ
5	Current	(m/dtk)	*Current meter*	In situ
B	**Chemical Parameters:**			
1	pH	-	pH-meter	In situ
2	Salinity	(ppt)	Refractometer	In situ
3	Dissolved oxygen	(ppm)	DO-meter	In situ
4	Ammonia	(ppm)	Sampel bottle, Spectrophotometer	Laboratory
5	Nitrate	(ppm)	Sampel bottle, Spectrophotometer	Laboratory
6	Nitrite	(ppm)	Sampel bottle, Spectrophotometer	Laboratory
7	Phosphate	(ppm)	Sampel bottle, Spectrophotometer	Laboratory
8	Biological Oxygen Demand (BOD)	(ppm)	Bottle BOD Spectrophotometer	Laboratory
9	Chemical Oxygen Demand (COD)	(ppm)	Sampel bottle, Spectrophotometer	Laboratory
10	Total organic matte	(ppm)	Sampel bottle, Spectrophotometer	Laboratory
C	**Biological parameters:**			
1	Plankton abundance	Ind/l	Filtering 50 liters of water with plankton net No. 25	In situ Laboratory (NTU Ind/l m/dtk)

Table 2. Weighting and scoring of suitability parameters for traditional aquaculture

Parameter	Weight	Categories and Scores							
		S1	**score**	**S2**	**score**	**S3**	**Score**	**N**	**score**
Slope (%)	0,20	0 – 3	4	3 – 6	3	6 – 9	2	> 9	1
Beach distance (m)	0,10	200 – 300	4	300 – 400	3	< 200	2	> 4000	1
River distance (m)	0,10	0 – 1.000	4	1.000-2.000	3	2.000-3.000	2	-	1
Soil Type	0,10	Coastal alluvial	4	Hydromorph alluvial	3	Regosol, Gleihumus	2	Regosol, Gleihumus	1
Elevation (m)	0,15	0 – 3	4	3 – 6	3	6 – 9	2	> 9	1
Drainage	0,10	Flooded	4	Flooded	3	Not flooded	2	Not flooded	1
Geology	0,10	Loose sediment	4	Loose sediment	3	Compacted sediment	2	Compacted sediment	1
Salinity (ppt)	0,3	12 – 20	4	20 – 30	3	5-12;30-45	2	<5; >45	1
Temperature (^oC)	0,3	25 – 32	4	23 – 25	3	32 – 34	2	0 – 23	1
Dissolved oxygen (mg/l)	0,3	6 – 7	4	3 – 6	3	1 – 3	2	<1; <8	1
H_2S (mg/l)	0,3	Tdk ada	4	<0,001	3	>0.003	2	>0,3	1
pH	0,3	8,1 – 8,7	4	7,6 – 8,0; 6,1 – 7,6	3	8,8-9,5;4,0- 4,5	2	9,6 - 11,0; <4,0	1

Source: Bakosurtanal [3] in Asbar and Fattah [4]; Yustiningsih [5] in Laili (2004) / Modified)

Table 3. Matrix of land suitability for semi-intensive aquaculture ponds

Parameter	S1 (Very suitable)	S2 (Suitable)	S3 (Marginally suitable)	N (Unsuitable)
Slope (%)	0 – 3	3 – 6	6 – 9	> 9
Beach Distance (m)	200 – 300	300 – 4000	< 200	> 4000
River Distance (m)	0 – 1000	1000 – 2000	2000 – 3000	> 3000
Soil type	Alluvial coastal	Alluvial Hydromof	Regosol, Gleihumus	Regosol, Gleihumus
Elevation (m)	0 – 3	3 – 6	6 – 9	> 9
Drainage	Flooded	Periodically flooded	Not flooded	Not flooded
Geology	Loose sediment	Loose sediment	Compacted sediments	Compacted sediments
Salinity (ppt)	12 – 20	20 – 30	5 – 12; 30 – 45	<5; >45
Temperature (^{o}C)	25 – 32	23 – 25	32 – 34	0 – 23
Dissolved oxygen (mg/l)	6 – 7	3 – 6	1 – 3	<1; <8
H_2S (mg/l)	none	<0,001	>0.003	>0,3
pH	8,1 – 8,7	7,6-8,0; 6,1-7,6	8,8 - 9,5; 4,0 - 4,5	9,6 - 11,0; <4,0

Source: Bakosurtanal [3] in Asbar and Fattah [4]; Yustiningsih [5] in Laili (2004) / Modified)

Table 4. Weighting and scoring of suitability parameters for semi-intensive aquaculture

Parameter	Weight	Categories and Scores							
		S1	**Scor**	**S2**	**Scor**	**S3**	**Scor**	**N**	**Scor**
Slope (%)	0,20	0 – 3	4	3 – 6	3	6 – 9	2	> 9	1
Beach Distance (m)	0,10	200-300	4	300-400	3	< 200	2	> 4000	1
River Distance (m)	0,10	0-1.000	4	1.000-2.000	3	2.000-3.000	2	-	1
Soil type	0,10	Alluvial coastal	4	Alluvial Hidromof	3	Regosol, Gleihu-mus	2	Regosol, Gleihumus	1
Elevation (m)	0,15	0 – 3	4	3 – 6	3	6 – 9	2	> 9	1
Drainage	0,10	Flooded	4	Flooded	3	Not flooded	2	Not flooded	1
Geology	0,10	Loose sediment	4	Loose sediment	3	Compacted sediments	2	Compacted sediments	1
Salinity (ppt)	0,3	12 – 20	4	20 – 30	3	5 – 12; 30 – 45	2	<5; >45	1
Temperature (°C)	0,3	25 – 32	4	23 – 25	3	32 – 34	2	0 – 23	1
Dissolved oxygen (mg/l)	0,3	6 – 7	4	3 – 6	3	1 – 3	2	<1; <8	1
H_2S (mg/l)	0,3	None	4	<0,001	3	>0.003	2	>0,3	1
pH	0,3	8,1 – 8,7	4	7,6 – 8,0; 6,1 – 7,6	3	8,8 – 9,5; 4,0 – 4,5	2	9,6 – 11,0; <4,0	1

Source: Bakosurtanal [3] in Asbar and Fattah [4]; Yustiningsih [5] in Laili (2004) / Modified)

Table 5. Matrix of land suitability for intensive aquaculture

Parameter	S1 (Very suitable)	S2 (Suitable)	S3 (Marginally suitable)	N (Unsuitable)
Slope (%)	0 – 3	3 – 6	6 – 9	> 9
Beach Distance (m)	200 – 300	300 – 4000	< 200	> 4000
River Distance (m)	0 – 1000	1000 – 2000	2000 – 3000	> 3000
Soil type	Alluvial coastal	Alluvial Hidromof	Regosol, Gleihumus	Regosol, Gleihumus
Elevation (m)	0 – 3	3 – 6	6 – 9	> 9
Drainage	Flooded	Periodically flooded	Not Flooded	Not Flooded
Geologi	Loose sediment	Loose sediment	Compacted sediments	Compacted sediments
Salinity (ppt)	12 – 20	20 – 30	5 – 12; 30 – 45	<5; >45
Temperature (^oC)	25 – 32	23 – 25	32 – 34	0 – 23
Dissolved oxygen (mg/l)	6 – 7	3 – 6	1 – 3	<1; <8
H_2S (mg/l)	None	<0,001	>0.003	>0,3
pH	8,1 – 8,7	7,6-8,0; 6,1-7,6	8,8-9,5; 4,0-4,5	9,6-11,0; <4,0
Phosphat (PO_4)	0	0,000001	0,00001	0,00001
Ammonia (NH_3)	0	0,000001	0,00001	0,00001
Nitrite (NO_2)	0	0,000001	0,00001	0,00001

Source: Bakosurtanal [3] in Asbar and Fattah [4]; Yustiningsih [5] in Laili (2004) / Modified)

Table 6. Weighting and scoring of suitability parameters for intensive aquaculture

Parameter	Bobot	Kategori dan Skor							
		S1	Skor	S2	Skor	S3	Skor	N	Skor
Slope (%)	0,20	0 – 3	4	3 – 6	3	6 – 9	2	> 9	1
Beach Distance (m)	0,10	200 – 300	4	300 – 400	3	< 200	2	> 4000	1
River Distance (m)	0,10	0 – 1.000	4	1.000-2.000	3	2.000-3.000	2	-	1
Soil type	0,10	Alluvial coastal	4	Alluvial Hidromof	3	Regosol, Gleihumus	2	Regosol, Gleihumus	1
Elevation (m)	0,15	0 – 3	4	3 – 6	3	6 – 9	2	> 9	1
Drainage	0,10	Flooded	4	Flooded	3	Not Flooded	2	Not Flooded	1
Geology	0,10	Loose sediment	4	Loose sediment	3	Compacted sediments	2	Compacted sediments	1
Salinity (ppt)	0,3	12 – 20	4	20 – 30	3	5-12; 30-45	2	<5; >45	1
Temperature (^{o}C)	0,3	25 – 32	4	23 – 25	3	32 – 34	2	0 – 23	1
Dissolved oxygen (mg/l)	0,3	6 – 7	4	3 – 6	3	1 – 3	2	<1; <8	1
H_2S (mg/l)	0,3	none	4	<0,001	3	>0.003	2	>0,3	1
pH	0,3	8,1 – 8,7	4	7,6 – 8,0; 6,1 – 7,6	3	8,8 – 9,5; 4,0 – 4,5	2	9,6 – 11,0; <4,0	1
Phosphat (PO_4)	0,1	0	4	0,000001	3	0,00001	2	0,0001	1
Ammonia (NH_3)	0,1	0	4	0,000001	3	0,00001	2	0,0001	1
Nitrite (NO_2)	0,1	0	4	0,000001	3	0,00001	2	0,0001	1

Source: Bakosurtanal [3] in Asbar and Fattah [4]; Yustiningsih [5] in Laili (2004)/ Modified)

Land utilization for aquaculture, based on the criteria of land suitability of aquaculture. The criteria used in determining the suitability of the land is based on a matrix of land suitability for aquaculture areas. Weighting and scoring system of each parameter suitability of aquaculture land use. Weighting and scoring values of the above parameters, determined the value of land suitability class for aquaculture areas, very suitable (S1): 3.26-4.00; suitable (S2): 2.51-3.25; conditionally suitable (S3): 1.76-2.50 and permanently unsuitable (N): 1,00-1,75.

a) Traditional Aquaculture Methods

Determination of the value of land suitability class for aquaculture areas adapted to traditional cultivation methods can be seen in Table 2.

b) Semi-Intensive Aquaculture Methods

Determination of land suitability class values for aquaculture areas adapted to traditional cultivation methods can be seen in Table 3.

c) Intensive Aquaculture Methods

Determination of land suitability class values for aquaculture areas adapted to traditional aquaculture methods can be seen in the following Table 5.

In analyzing the carrying capacity of the environment for the development of aquaculture ponds used three methods of approach, i.e.:

1) The carrying capacity of the environment using the method of the relationship between water quantity (availability of water volume for aquaculture activities) with waste load, referring to Rakocy and Alison [6] that the capacity of the waters to receive waste is directly proportional to the quantity of water. The carrying capacity of the waters to maintain the quality of the waters is still feasible, then the receiving waters must have a volume of 60 - 100 times the volume of waste discharged into the waters.

2) The carrying capacity of the aquatic environment based on the capacity of the availability of dissolved oxygen content in water bodies. The availability of dissolved oxygen in water bodies is the difference between the concentration of dissolved O_2 in the inflow (O in) and the minimum desired concentration of dissolved O_2 from the culture system (O out), which is 3 ppm [7].

If the inflow water discharge is assumed to be Qo m^3/min, the total dissolved O_2 over a 24-hour period is:

Qo m3/min x 1,440 min/day x (Oin - Oout) gr O_2/m^3 = X kg O_2 ;formula (1)

Where:

Qo = inflow water discharge (m3/min)
O in = dissolved oxygen content in the inflow
O out = minimum oxygen level required by organisms.

Oxygen needed to break down organic matter (TSS) every 1 kg of organic waste requires 0.2 kg O_2 per organic waste. The amount of organic waste that can be accommodated without exceeding the carrying capacity is:

$$\frac{dissolved\ oxygen\ capacity}{0.2\ kg\ O2/kg\ organic\ waste} = A\ kg\ organic\ waste\ ;$$
formula (2)

If it is known that the amount of organic waste / kg organism = B, then the carrying capacity of the aquatic environment (kg organism) for aquaculture:

$$Carrying\ capacity\ \frac{\text{A kg organic waste}}{\text{B kg organic waste / kg organism}}$$
= C kg organism; formula (3)

This carrying capacity analysis is based on the assimilation capacity of waters, namely the ability of waters to receive waste without causing the waters to be polluted. Waste parameters that become benchmarks in determining the assimilation capacity are nitrogen and phosphorus. The eligibility of nitrogen and phosphorus waste parameters referred to in Poernomo [8], MENKLH [9], Widigdo [10] and Made [11]. Water quality parameter eligibility criteria for aquaculture allowed for effluent nitrogen 1.0 mg Lt^{-1} and phosphorus 0.5 mg Lt^{-1}.

3. RESULTS AND DISCUSSION

3.1 Suitability of Pond Land for Shrimp Farming in Sarjo District

The results of the analysis conducted on the suitability of brackish water aquaculture in the center of the minapolitan area, Pasangkayu District showeds that in general, ponds in the coastal areas of Pasangkayu District, can be managed using aquaculture technology, among others: 1) traditional; 2) semi-intensive and 3) intensive. The level of land suitability of ponds in the region is categorized into 4 classes: highly suitable (S1), suitable (S2), quite suitable (S3) and unsuitable (N). The results of the suitability analysis were obtained pond area in each sub-district is presented in the Fig. 2.

The results of the analysis of the suitability of pond land in the coastal area of Sajo District Pasangkayu Regency obtained results include: 1) very suitable 154.88 hectare; 2) Suitable 77.16 hectare and quite suitable 27.26 hectare. While the results of the above analysis show that the overall pond cultivation land has an area of each is very suitable 732.95 hectare, suitable 1,589.12 hectare and quite suitable 247.83 hectare with a total area of 2,569.9 hectare.

Water quality in shrimp culture activities is dynamic and fluctuates over time [12]. The value of intensive aquaculture water quality parameters, namely dissolved oxygen levels ranging from 3.9-7.8 mg/L; pH 6.47-7.65; temperature 24-29 ^{o}C; brightness 20-39 cm; salinity 15-19 ppt, nitrite 0.010-0.052 mg/L, and ammonia 0.006-0.017 mg/L [13]. Meanwhile, according to [14], dissolved oxygen ranges from 4.83 - 6.51 mg/L; pH 8.1-8.5; temperature 28-31 ^{o}C; salinity 20-21 ppt, nitrite 0.3-0.4 mg/L; nitrate 1.25-1.35 mg/L and ammonia 0.01-0.03 mg/L. According to [15], the standardization of Vaname Shrimp water quality is dissolved oxygen> 4 mg / L, pH 7.5-8.5; temperature 26-33 oC; salinity 10-30 ppt; nitrite < 0.01 mg / L, and TAN < 1.0 mg/L. According to research [16], water quality includes pH in the range of 7-8.3, salinity 24-37 ppt, temperature 28-32 ^{o}C, DO 3-6.2 mg/L, alkalinity 80-140 mg/L, phosphates 0.6-5 mg/L, nitrites 0-4 mg/L, ammonia 0-0.12 mg/L and ammonium 0-0.5 mg/L.

In general, when compared to the analysis of the data contained in the direction of zones and sub-zones in the general utilization area of the zoning plan for the coastal area of Pasangkayu Regency in 2011, the area of aquaculture ponds is 11,465.52 hectare. Meanwhile, the data in 2009, and the results of the interpretation of Alos satellite imagery, in 2010 and the results of field checks in July 2011 the area of ponds in the coastal areas of Pasangkayu Regency was 1,842.13 hectare; with traditional cultivation methods and types of commodities cultivated are tiger shrimp and milkfish. When compared to the three there are differences in the area of ponds caused by several things, among others: 1) the area of ponds decreased due to conversion to oil palm plantations; 2) the area of ponds is

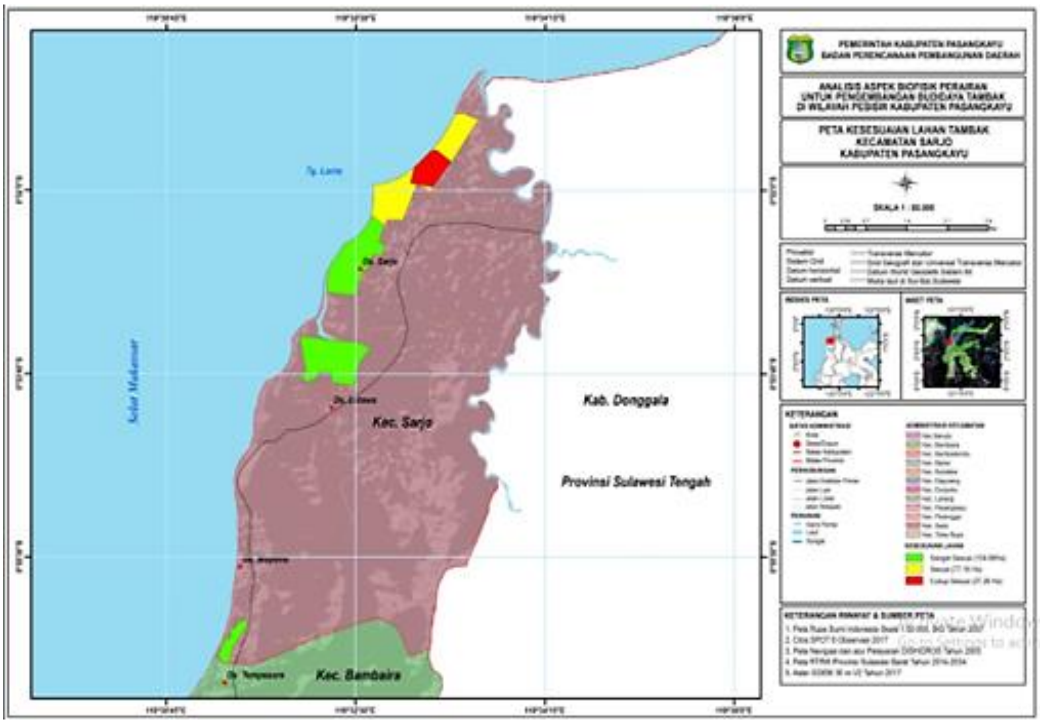

Fig. 2. Map of pond suitability in sarjo district

Table 7. Environmental carrying capacity based on the capacity to assimilate waste on aquaculture technology in coastal districts Pasangkayu regen

Technology	Amount of organic waste discharge (kg ha^{-1})	Area of pond supported (ha)	Production carrying capacity (Ton MT^{-1})	Environmental carrying capacity to assimilate waste (kg MT^{-1})
Intensive	117.27	166.07	42.63	19.475.747
Semi intensive	32.58	597.85	153.49	19.475.747
Traditional	1.46	13342.08	3425.31	19.475.747

different because it is likely that the intended at the time of the analysis is the suitability based on the potential of ponds 3) the area of ponds increased, especially on the scale of intensive cultivation in Pasangkayu District. The most prominent change in reducing the area of ponds is the improvement of the palm oil industry in Pasangkayu District, the price of palm oil is increasing and the supporting facilities and infrastructure are getting better such as palm oil processing plants.

The area of each coastal sub-district based on the Fisheries Service of Pasangkayu Regency, [17] that the results of the analysis of the suitability of aquaculture land shows that the overall area of aquaculture land with each area is traditional 732.95 Ha, semi-intensive 1,589.12 hectare and intensive 247.83 hectare. The total area of intensive, semi-intensive and traditional technology aquaculture ponds amounted to 2,569.9 hectare.

3.2 Environmental Carrying Capacity of Ponds for Shrimp Farming in Sarjo District

For maximum utilization of aquaculture land allowed in order not to exceed the carrying capacity of the aquatic environment based on the capacity to assimilate waste aquaculture ponds in Sarjo District Pasangkayu Regency:

Based on the results of the analysis obtained the amount of waste discharged into the waters of 10 coastal sub-districts of Pasangkayu Regency per unit area (ha) of ponds during one growing season an average of 176.98 kg TSS hectare a^{-1} for intensive cultivation methods, semi-intensive cultivation averaged 50.79 kg TSS hectare $^{-1}$, while traditional cultivation averaged 1.34 kg TSS hectare $^{-1}$. There needs to be caution in shrimp farming activities because the waste will give a burden on the aquatic environment that can degrade water quality. All existing pond land in Sarjo district developed intensive technology culture with an estimated maximum production of 1.28 tons ha^{-1}, then the area of pond land allowed in order not to exceed the carrying capacity is 166.06 hectare. If all the pond land in Sarjo district developed for semi-intensive culture with a maximum production of 862.97 kg hectare $^{-1}$ MT^{-1}, then the area of pond land allowed not to exceed the carrying capacity of 597.85 ha. If all the pond land is developed for traditional aquaculture in Sarjo district, the supported pond area is 13,342 hectare.

The results of the analysis of the environmental carrying capacity of milkfish ponds using the weighting method show that milkfish ponds (ponds 1 and 2) have a medium to high carrying capacity, namely with a value range of 29.5-32. Several parameters that meet the appropriate standards for pond carrying capacity include dissolved oxygen, which is in the range of 6.75-6.8 mg/l for pond 1 and 5.8-6.42 mg/l for pond 2 where for milkfish the range is this is still tolerable. Meanwhile, the pH value of the water obtained was 6.9-7.1, which according to Mustafa et al., [18] is included in the high category to support existing cultural activities. Likewise, water and soil temperature, carbon dioxide, nitrite and nitrate content and soil texture are still within the safe range to be used as aquaculture media. Some parameters that have exceeded the carrying capacity of the pond are ammonia content and salinity. From the measurement results obtained salinity values ranging from 33-34‰. The salinity value of milkfish can still survive because milkfish can tolerate salinity up to 40‰ [19]. Therefore milkfish are classified as euryhaline fish. The highest salinity occurs during the day, this is because during the day there is evaporation and rising tides of sea water entering the pond.

4. CONCLUSIONS

The results of the analysis of the level of land suitability and environmental carrying capacity of the environment for shrimp farming in Sarjo

District in order to improve the economic welfare of the community in the coastal area of Pasangkayu Regency, can be concluded as follows:

1. The level of land suitability for shrimp culture, among others: 1) very suitable 154.88 hectare;

2. Suitable 77.16 hectare and quite suitable 27.26 hectare. that the overall area of aquaculture ponds with each area is traditional 732.95 hectare, semi-intensive 1,589.12 hectare and intensive 247.83 hectare a. The total area of intensive, semi-intensive and traditional technology aquaculture ponds amounted to 2,569.9 hectare.

3. Environmental carrying capacity for intensive shrimp aquaculture ponds with an estimated maximum production of 1.28 tons hectare -1, then the allowed area of the pond so as not to exceed the carrying capacity is 166.06 hectare; for semi-intensive aquaculture with a maximum production of 862.97 kg hectare $^{-1}$ MT^{-1}, then the allowed area of the pond so as not to exceed the carrying capacity of 597.85 hectare and traditional aquaculture in Sarjo District, the area of the pond that is supported is 13,342 hectare. The government together with the community can comply with the research results as best as possible to maintain the sustainability of aquaculture resources.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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