LAND SUITABILITY ANALYSIS OF WHITE SHRIMP (LITOPENAEUSVANNAMEI) AQUACULTURE IN THE COASTAL AREA OF BARRU DISTRICT SOUTH SULAWESI – INDONESIA

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ABSTRACT

The coastal area of Barru District has a wide brackishwater pond, but its productivity is relatively low. A research to determine land suitability as one of the brackish water pond productivity-raising projects is needed. Considerable factors in determining land suitability for white shrimp aquaculture covers topography and hydrology, soil conditions, water quality, and climate. Quality of water is observed during a rainy and dry season. Spatial analysis using Geographic Information System is applied in the determination of land suitability for shrimp aquaculture. The analysis shows the actual land suitability of the existing ponds in Barru district, namely 2.399 ha, where land is classified as highly suitable (S1 class), 232.94 ha (9.71%) classified as moderately suitable (S2 class), 1,444.20 ha (60.20%) classified as marginally suitable (S3 class), 721.14 (30.06%) and classified as marginally low suitable (N class), 0.72 ha (0.03%), Limiting factors during the rainy season are the flood, while salinity is the main limiting factor during a dry season. Generally, other limiting factors are of the water sources, low level of pH soil and roughness of soil texture in a certain area.

Keywords: Brackish water ponds, white shrimp, land suitability, coastal, Barru.

INTRODUCTION

One of the business activities in fisheries aquaculture in Indonesia is white shrimp (*Litopenaeusvannamei*) culture. Shrimp culture is a kind of business by coastal area in which it contributes to the coastal community's income and potential foreign exchange earnings.South Sulawesi Province is one of the centers for shrimp culture production and it has 104,240 ha of brackishwater pond or 21.27% by the total of brackish water pond in Indonesia.However, it only nationally contributes 600,241.00 tons or 40.1 % of the total production of shrimp culture in Indonesia in 2011 (Ministry of Maritime Affairs and Fisheries., 2005). The use of land for shrimp cultivation in the Barru district reached 2.399 ha, with production in 2015 reached 3,430.80

tons and production value reached about 62 billion rupiahs, while the commonly cultivated commodities in ponds are shrimp (Penaeusmonodon) and milkfish (Chanoschanos) (Ministry of Maritime Affairs and Fisheries., 2015).In the last few years, farmers have turned to white shrimp cultivation (*Litopenaeus vannamei*).

Land suitability is the degree of suitability of an area of land for a specific use, such as for shrimp culture in ponds.Land suitability analysis for brackishwater pond needs to be conducted for the principle of consideration in the decision of the suitable land use.

Based on Rossiter. D.G., (2007) land suitability analysis is very important because land has varied physical, social, economic, and geographical values which are influential for land use.Land suitability analysis is a process of estimating variability of land whenever it is used for a specific purpose (Howerton and Robert., 2001) or as a method to explain or to predict the potential use of land (Van Dieven, C. A.; Van Keulen, H.; Wolf, J. and Berkhout, J. A. A., 1991).If the potential of the land can be determined, then the land use planning can be based on rational considerations (Rayes, M. L. 2007). Thus, land suitability analysis is a strategic planning tool for land use that can predict the expected benefits and constraints of productive land use and environmental degradation that might occur due to the use of land.Land suitability is a key to success in aquaculture activities that affect the success and sustainability (Pérez, O, M.; Ross, L. G.; Telfer. T. C.; and del Campo Barquin, L. M., 2003).Therefore, the research aims to determine the suitability of land for white shrimp farming in ponds and the limiting factors to increase productivity and sustainability and to provide a general reference for policymakers in the determination of the Regional Spatial Layout Plan (Tantu.G.A.,Soemarno., N.Harahab., A. Mustafa.

METHODS OF STUDY

Time and Location of Study

The study was conducted from January to April 2018 in five coastal Villages, namely: TaneteRilau sub-regency, Barru sub-regency, Balusu sub-regency, SoppengRiaja sub-regency, and Mallusetasi sub-regency (Fig. 1) in the Barru district, South Sulawesi Province, Indonesia. Figure 1 illustrates also the point of measurement and sampling of soil and water.

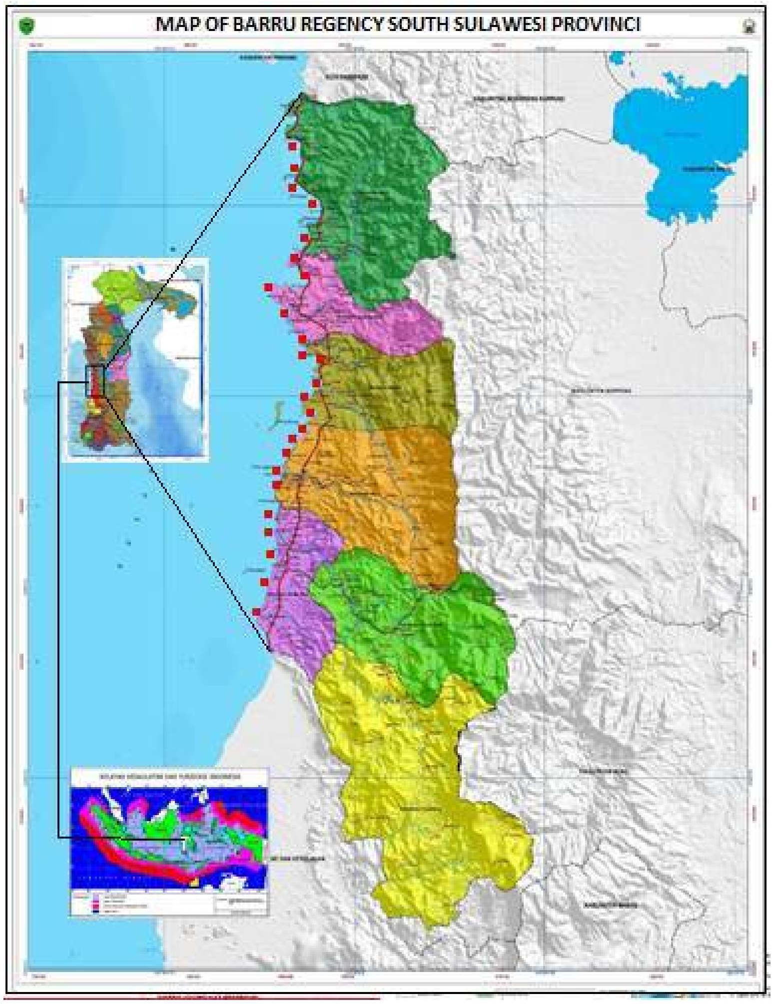

Fig.1. Soil and water sampling points in ponds area of Barru district, South Sulawesi province, Indonesia

Data Collection

Primary data

Primary data collected include biophysical data, namely: topography and tidal range, soil quality, and water quality.Topography is known by observation in the field and it is extracted from satellite imagery. The tidal measurement was conducted at one observation point located in the coastal area of TaneteRilau sub-district, Barru sub-district, Balusu sub-district, SoppengRiaja sub-district, and Mallusetasi sub-district. The tidal measurement was carried out for 39 hours with 1-hour interval measurement using the stick with scale.Measurements and soil sampling were conducted at depths of 0.5 m. Soil quality variables were measured in situ is pHF (soil pH was measured directly in the field) with pH-meter (Ahern et al., 2004), pHFOX (soil pH was measured in the field after oxidized with hydrogen peroxide 30%) with pH-meter (Ahern et al., 2004) and redox potential was measured with redox-meter.For analyzing other soil quality variables, then the soil samples in a plastic bag were inserted in a cool box containing ice as suggested by Ahern et al. (2004).The soil samples were put in the oven at a temperature of 80-85°C for 48 hours (Ahern et al., 2004). Once dried, soil samples were crushed in a porcelain mortar and sieved with 2,0 and 0,5 mm hole size sieve and then analyzed at Soil Laboratory of Department of Health Provisions of South Sulawesi.Soil quality that was analyzed at the laboratory include pHKCl (pH of the KCl extract) (McElnea and Ahern, 2004a), pH FOX (McElnea and Ahern, 2004b), SP (sulfur peroxide) (Melville, 1993; McElnea and Ahern, 2004c), SKCl (sulfur extracted with KCl) (Melville, 1993; McElnea and Ahern, 2004d), SPOS (SP - SKCl) (Ahern and McElnea, 2004), TPA (Titratable Peroxide Acidity or previously known as Total Potential Acidity) (McElnea and Ahern, 2004b), TAA (Titratable Actual Acidity or previously known as Total Actual Acidity) (McElnea and Ahern, 2004a), TSA (Titra table Acidity Sulfidic or previously known as Total Acidity Sulfidic) (TPA-TAA) (McElnea and Ahern, 2004b), pyrite (Ahern et al., 1998b, 1998c), organic carbon by Walkley and Black method (Sulaeman et al., 2005), total-N by Kjedhal method (Sulaeman et al., 2005), PO4 by Bray 1 method (Sulaeman et al., 2005), Fe with a spectrophotometer (Menon, 1973), Al with a spectrophotometer (Menon, 1973) and texture with the hydrometer method (Agus et al., 2006).

Measurement and sampling water were carried out in the river, sea, and ponds. Measurement and sampling of water in the pond followed the soil sampling point. Water quality variables which are measured in situ are temperature, salinity, dissolved oxygen, pH and total dissolved solids using Hydrolab® Minisode. Water samples were taken for analysis at the laboratory using Kemmerer Water Sampler and preserved following the instructions

APHA (2005). Water quality variables analyzed at the Water Laboratory of Department of Health Provisions of South Sulawesi include: NH4 (phenatemethod), NO3 (cadmium reduction method), NO2 (spectrophotometric), PO4 (ascorbic acid method), and total organic matter (titrimetry method) by following the instructions of Menon (1973), Grasshoff (1976), Parsons et al. (1989) and APHA (2005). Throughout the observation points and the sampling, point coordinates are determined using the Global Positioning System (GPS).

Data Analysis

Descriptive statistics were used for determining the minimum, maximum, average and standard deviation of each variable soil and water quality data. Maps of land use is derived from the results of image classification other land use or closure and coastline length from the location of the study were carried out by analyzing high-resolution images, namely high-resolution imagery, namely PORTAL ENVIRO acquisition February 10, 2017.The available water quantity was determined using 3-D analysis facilities in Geographic Information Systems. and the sampling points are determined by using the Garmin® 12CX Global Positioning System (GPS).

The method used for the interpolation of the data depends on the characteristics of the soil and water variables based on the instructions of Robinson and Metternicht (2006), Anuar et al. (2008), Akbarzadeh and Mehrjardi (2010) and Zare-Mehrjardi et al. (2010).(Fig.2).

Land suitability assessment process results are shown in the form of land suitability classification system set to Class and Sub-class (scale 1:50,000). In the Class category, they are: (a) Highly suitable class (S1): This field does not have a limiting factors for the sustainable use of land; (b) Moderately suitable (S2): This land has rather significant limiting factors for the sustainable use which can reduce productivity, and (c) Marginally suitable (S3): this land has severe limiting factors for sustainable use and they will reduce productivity, and (d) Not suitable class (N): this land has limiting factors that may preclude the possibility of its utilization. Criteria used in determining the suitability of land for aquaculture that refers to the existing criteria (Table 1).

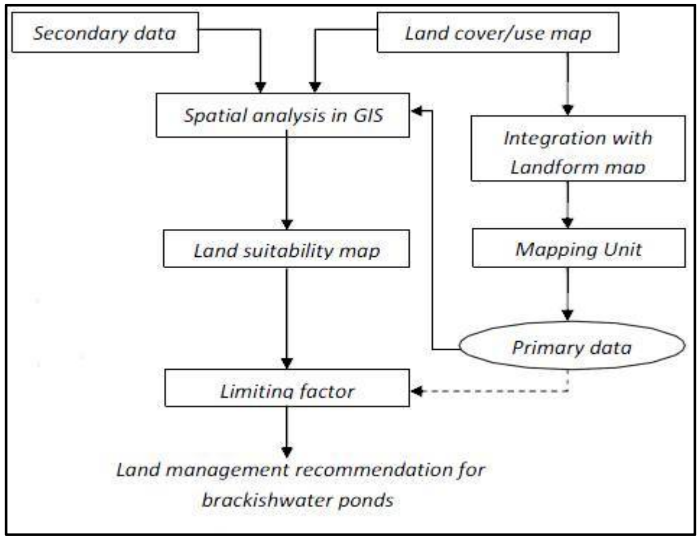

Fig. 1. Flow chart of spatial analysis to determine land suitability for brackishwater ponds

Table 1 Criteria that wereused to determinethe land suitabilityfor white shtimp (LitopenaeusVannamei in ponds of Barru district, South Sulawesi Province, Indonesia

Factors/Variables	Class/Score			
	S1 (4)	S2 (3)	S3 (2)	N (1)
Topography and Tidal				
Elevation (m)	2.0–2.5	2.5–4 ; 1–2	>4–5	>5 ; <1
Slope (%)	<1.0	1.0–2.0	2.0–3.0	>3.0
Tidal range (m)	1.5–2.5	1.0–1.5;2.5–3.0	0.5–1.0;3.0–3.5	<0.5 ;>3.5
Soil Quality:				
pH_F-pH_{FOX}	<0.5	0.5–1.5	1.5–4.0	>4.0
C-organic(%)	1.5–2.5	0.5–1.5	<0.5 ; 2.5–8.0	>8.0
Total nitrogen (%)	>0.5	0.4–0,5	0,25–0,4	<0,25
Phosphate (ppm)	>60	45–60	30–45	<30
Texture	Sandy clay loam	Sandy loam	Silty clay	Silt, Sand
Water Quality:				
Salinity (ppt)	15–25	10–15;25–32	5–10; 32–40	<5 ; >40
Temperature (^{o}C)	28–30	20–28;30–35	12–20;35–40	<12 ;>40
pH	7.5–8.5	6.0–7.5; 8.5–9.5	4.0–6.0; 9.5–11.0	<4.0;>11.0
Dissolved oxygen (mg/L)	4.0–7.0	7.0–10.0; 2.0–4.0	10.0–12.0;1.0–2.0	>12.0 ; <1.0
Phosphate (mg/L)	<0.05	0.05–0.2	0.1–0.2	>0.1
Nitrate (mg/L)	0.1–1.0	1.0–2.0	2.0–3.0	<3.0
Climate:				
Annual rainfall (mm/year)	2,500–3,000	2,000–2,500	3,000–3,500; 1,000–2,000	>3,500; <1,000
Dry month(month)	1–2	2–3	3–5	<1; >5

Poernomo (1992); Mustafa (2012);Soil Survey Staff (2001); Karthik*et al*. (2005); Mustafa *et al.* (2011); Ministry of Environment (2004); Effendi (2003).

RESULT AND DISCUSSION

Biophysical Characteristics

Conducted land suitability analysis is a qualitative analysis based on the physical potential of the land. Therefore, the biophysical characteristics of the farming areas in Barru District which are also being the common factors considered in the analysis of land suitability include topography and hydrology; soil condition; water quality and climate (Fernando A.L. *et al.*, 2012; David A. Chin., 2012; Shastri G.N; Sonar M.L; Das C., 2007; Boyd, C. E., 1995; Cayelan C. *et al*., 2012.

Topography and hydrology

The slope can affect the charging ability of the land and change of the water of ponds, especially traditionally managed ponds (extensively) and intermediate (semi-intensive). Aquaculture area Barru District is generally considered as flat with a slope of less than 0.02% and highly suitable for aquaculture. (Chanratchakool, P; *et al*., 1995.; (Fernando A.L. Pacheco.; Cornelis H. Van der Weijden., 2012) suggest a good slope land for aquaculture is relatively flat.

Distance from the water source to the pond water conditions is also determined by the slope, elevation and tidal difference. Those factors have an influence on the quantity and quality of water. Thus, it was found so many farms in Barru District that is low in productivity due to the distance away from the water source. In this case, areas which are far from water sources belongs to the class S3 and class N. Ponds with far distance are not only get inadequate water quality but also get insufficient water in terms of quantity.

Tidal range measured in January 2012 in Barru District was 1.75 m. Calculation results of Tidal Table (Hydro-Oceanographic Office., 2017) showed that the average tidal range is 1.53 m. Tidal range ideal for shrimp aquaculture is between 1.5 and 2.5 m. Thus the tidal range in Barru District is classified as highly suitable for aquaculture. Flood is one of the causes of yield loss in the pond. Flood in the farm areas usually occurs during the rainy season and high tide occurrence. Based on the criteria suggested by (Boyd, C. E., 1995), regional aquaculture of Barru District is considered to have a rare flood (20-year cycle).

Soil Condition

Analyzed soil conditions in the determination of land suitability for aquaculture include soil quality. For shrimp aquaculture ponds, required water depth is approximately 1.0-1.2 m. In Barru District, a relatively narrow stretch of rock is only found in the of Barru sub-district. Thus, the depth of the soil is highly suitable for white shrimp culture.

Pyrite (FeS2) is a compound that its content is high in acid sulfate soil, if pyrite is exposed to air due to the excavated pond, it will cause the oxidation of pyrite and drastically decrease soil pH and increased a solubility of toxic elements and causes the low productivity of farms (Shingo Ueda *et al.*, 2000). Because the ponds in Barru district are generally considered as non-acid sulfate soil, the content of pyrite is relatively low that is from undetected to 1.19% with an average of 0.15% (Table 1). Therefore, the presence of pyrite on the pond in Barru district is not a serious problem.

Peat soil is soil that contains organic materials more than 20% or more than 30% (soil contains clay ≤ 60%) (ZenghuiDiao*et al.* 2013). Similar with the presence of pyrite in the pond, peat soil is only found in six stations among 87 stations and found in the area that was once a mangrove forest which is generally not a problem for the ponds aquaculture. Measured soil pHs in the ponds are pHF and pH FOX which is typical of acid sulfate soil variables (Santín, C. Y. *et al.*, 2009). pHF calculation results of the ponds showed values between 3.08 and 7.79 with an average of 6.68 (Table 1). A low value of soil pHF is only found in acid sulfate soil ponds by which it can be a limiting factor in ponds aquaculture (belongs to the class S3). Pond soil with a pH between 6.5 and 8.5 was classified by (Karthik, M. *et al*., 2005) as slight because the soil pH value is quite good and very easy to overcome the barriers. Then (Gomez. E. *et al*, 1999) stated that the optimum soil pH for shrimp farming in ponds is between 7.5 and 8.3. The residual of pHF and pH FOX (pHF-pH FOX) can be used to determine the potential of acid sulfate soil acidity and it is found that the potential acid sulfate soil acidity in ponds is relatively low (Table 1).

Organic materials in the pond can affect the stability of the soil, oxygen consumption, sources of nutrients and habitat suitability of pond bottom (Nathaniel B. *et al* ., 2006). A surface of mineral soil used for agriculture rarely contains 5-6% organic materials and in the tropic and sub-tropic area, its organic material content is usually lower (OlivaPisani.; Youhei Yamashita.; Rudolf Jaffé., 2011). In high clay contained soil (greater 60%), (Boyd, C. E., 1995) defined the organic material content of less than 8% classified as slight that is good and easy to overcome the limiting factors for aquaculture. The organic content of ponds ranges from 0.35 to 20.55% with an average of 6.20% (Table 2).

Phosphate is an essential element as a source of energy in life. On aquatic systems, phosphorus is an essential element for primary production (Boyd, C. E., 1995). Phosphate availability of over 60 ppm in the pond soil can be categorized as slight or good with very easily solved limiting factors (Karthik, M. *et al.*, 2005). In ponds of Barru District, it is found that the average phosphate content is 2.05 ppm, so the actual farmland suitability is considered as not suitable with the limiting factors of soil fertility (class N). However, the potential suitability of land can be turned into a highly suitable land by the use of fertilizer containing phosphate.

Table 2. Soil quality of brackishwater ponds at ofBarru Regency, South Sulawesi Province (n = 87).

Variables	Minimum	Maximum	Average	Standard deviation
pH_F	3.08	7.79	6.68	0.69
pHFOX	0.6	7	4.82	1.58
pH_F-pH_{FOX}	1.27	6.37	1.8	1.51
Organic matter (%)	0.3	20.55	6.2	5.89
Pyrite (%)	< 0.01	1.19	0.15	0.31
Fe (ppm)	< 0.01	10.36	1.29	2.69
Al (ppm)	< 0.01	779	123	181.11
PO_4 (ppm)	0.27	8.26	2.05	1.65
*Texture**	C, SiC, SC, SCL, Si, L, SL, LS, S			

* : C = *Clay*, SiC = *Silty clay* , SC = Sandy clay, SiCL = Silty clay loam, SCL = Sandy clay loam, Si = *Silt*, L = *Loam*, SL = *Sandy loam*, LS = *Loamy sand*, S = *Sand*

Table 3. Water quality in brackishwater ponds area of Barru Regency, South Sulawesi Province in the dryseason (n = 87).

Variables	Minimum	Maximum	Average	Standard deviation
Temperature (^oC)	26	34.05	30.1	2.27
Salinity (ppt)	0	45	18	12.32
Dissolved oxygen (mg/L)	2.02	14	8.01	3.36
pH	8	9.5	8.75	0.49
$NH_{4\ (mg/L)}$	0.0015	0.8372	0.1079	0.1639
$NO_{3\ (mg/L)}$	0.546	4.7098	1.0399	0.7168
$NO_{2\ (mg/L)}$	0.0001	0.0732	0.0073	0.0119
$PO_{4\ (mg/L)}$	0.0016	0.7969	0.1082	0.169
$SO_{4\ (mg/L)}$	9.07	99.5	52.24	19.37
Total suspended solid (mg/L)	13	108	57	23

Fe content of farmland ranges from undetected by < 0.01 up to 10.36 ppm with an average of 1.29 ppm. The content of Al ranges from undetected by < 0.01 to 758 ppm with an average of 127 ppm. Pond soil texture and porosity highly affect the growth of algae that live in the bottom of the pond which belongs to the source of food for fish and shrimp. Ponds with coarse-textured soil have a high level of porosity which causes the pond cannot restrain the water in it. The soil in the pond is commonly found to have fine texture such as clay, dusty clay and sandy clay with a clay content of at least 20-30% to resist permeation (Boyd, C. E., 1995). Best texture of soil for the pond is soil that contains clay, sandy clay, sandy clay loam, and dusty clay. It is found nine classes of soil texture on the ponds soil surface, that are: clay, dusty clay, sandy clay, sandy clay loam, dirt, loam, sandy clay, argillaceous sand, and sand. Such soil texture can be classified as not porous and can restrain the water.

Water Quality

Because commodities cultivated in the ponds are living in the water, water quality is a deciding factor of the success. The quality of water is good if water can support life aquatic organisms and food remains at every stage of maintenance. Water quality variables that are important for shrimp farming is temperature, dissolved oxygen, salinity, pH, brightness, NH_4, NO_2, NO_3, PO_4 and total suspended solids (Jang, C.S.; Liang, C.P.; Wang, S.W., 2013). Water quality in the Barru District during the dry season can be seen in Table 2 and during the rainy season is in Table 3.

Table 4. Water quality in brackishwater ponds area of Barru District, South Sulawesi Province in the rainy season (n = 87).

Variables	Minimum	Maximum	Average	Standard deviation
Temperature (^oC)	26.9	35.1	29.28	2.36
Salinity (ppt)	3.5	70	36,5	22.1
Dissolved oxygen (mg/L)	2.02	14	8.01	2.46
pH	8	9.5	8.75	0.34
NH_4 (mg/L)	0.228	0.418	0.32	0.0945
NO_3 (mg/L)	0.0017	1.7858	0.921	0.7151
NO_2 (mg/L)	0.0005	0.2589	0.0169	0.041
PO_4 (mg/L)	0.0002	0.206	0.0169	0.0412
SO_4 (mg/L)	9.44	916.98	86.22	149.41
Fe (mg/L)	0.0136	0.3727	0.0826	0.0635
Total suspended solid (mg/L)	18	263	66	52

Water temperature in the area of aquaculture in Barru District ranges between 26.00 and 34.05^oC with an average of 29.28^oC during the dry season and ranges between 26.90 and 35.10^oC with an average of 30.10^oC during the rainy season. Proper water temperature for white shrimp ranges between 26 and 32^oC and the optimum is between 29 and 30^oC (James M.B.*at al*., 2011). At a temperature of 26-30^oC, the growth of black tiger shrimp is relatively high and it has relatively high survival rate (ASEAN (Association of Southeast Asian Nations., 1978). Water temperature in the area of aquaculture in Barru District is quite suitable and highly suitable for aquaculture. Water salinity in the aquaculture areas in Barru District ranges between 3.5 ppt and 70.0 ppt with an average of 36.5 ppt in the dry season and between 0 and 45.0 ppt with an average of 18.0 ppt during the rainy season. White Shrimp, a euryhaline organism, needs well maintained optimum salinity for its growth (Warnock. *at al*., 2002). White Shrimp can adapt to 3-45 ppt salinity, but its salinity necessity for optimum growth is 15-25 ppt (Nils Warnock *at al*., 2002) . It is seen that the salinity during dry season can be a limiting factor in aquaculture, but it does not cause significant problems during rainy season. Dissolved oxygen is essential for respiration and is one of the main components in aquatic metabolism. Dissolved oxygen content in the pond of Barru District ranges between 2.74 and 13.55 mg/L with an average of 8.14 mg/L during dry season and ranges between 2.02 and 14.00 mg/L with an average of 8.01 mg/L in during rainy season. Minimum dissolved oxygen requirement for shrimp is 2 mg/L (Donald H *at al.,* 1985). Dissolved oxygen limit for shrimp is 3-10 mg/L and its optimum is 4-7 mg/L (Donald H *at al.,* 1985).

Limit of pH tolerance for aquatic organisms are affected by temperature, dissolved oxygen, alkalinity and the presence of anions and cations as well as the type and stage of the organism. The pH range for shrimp is 8.0 to 8.5 and its optimum range is 7.5 to 8.7 (Jang et al. 2013). Water pH in the ponds of BarruDistrict is relatively high that ranges between 8.00 and 9.50 with an average of 8.75 (Table 2). Soil acidity sources such as pyrites and peat are rarely found in the ponds of Barru District which causes a high level of water pH. Hence, this pH level is highly suitable for ponds aquaculture. Sources of nitrogen that can be used directly by aquatic plants are nitrate (NO_3), ammonium (NH_4) and nitrogen gas (N_2). Nitrate is the main form of nitrogen in natural water and being a major nutrient for plant and algae growth. Nitrate is not toxic for aquatic organisms. NO_3 content in ponds water in Barru District ranges from 0.5460 to 4.7098 mg/L with an average of 1.0399 mg/L during rainy season and turning higher during dry season ranges from 0.0017 to 1.7858 mg/L with average of 0.9210 mg/L. It is known that nitrogen oxides in the form of NO_3 contained in the atmosphere and fall to the earth within rain water which contributes to the high content of NO_3 into the water during rainy season. Rainwater contains NO_3 around 0.2 mg/L (Vinatea, L *at al*., 2010) .

Nitrite (NO_2) is a transition between NH_3 and NO_3 (nitrification) and between NO_3 and N_2 (de-nitrification). Similarly with NH_3, NO_2 is also toxic for fish, because it oxidizes iron (Fe) in hemoglobin. In this transition form, blood's ability to bind dissolved oxygen is very degenerate (Bui, T.D., Luong-Van, J., Austin, C.M. 2012). On the shrimp’s body which blood contains copper (Cu) (hemocyanin) Cu oxidation may occur by the help of NO_2 and it gives the same result as in fish’s body (Rahouma, M.; Shuhaimi-Othman, M.; Cob, Z.C., 2013). Content of NO_2 in the ponds water of Barru District ranges from 0.0005 mg/L to 0.2589 mg/L with an average of 0.0174 mg/L during dry season and 0.0001 and 0.0732 mg/L with an average of 0, 0073 mg/L during rainy season. Content of NO_2 in the waters are relatively small because it is oxidized to nitrate immediately. Natural water contains NO_2 around 0.001 mg/L and it should not exceed 0.060 mg/L (Vinatea, L *at al*., 2010). In waters, the content of NO_2 rarely exceeds 1 mg/L (Sawyer, C. N. and McCarty, P.L., 1978). Content of NO_2 which is greater than 0.05 mg/L can be toxic to highly sensitive aquatic organisms (Moore, J. W., 1991). On the average, the content of NO_2 in pond water is still within the limits allowed for aquaculture, but it is found that the content of NO_2 still exceeds 0.060 mg/L.

Phosphorus plays a role in the transfer of energy within cells, such as those contained in Adenosine Triphosphate (ATP) and Adenosine Diphosphate (ADP). Phosphate (PO_4) is a form of phosphorus that can be utilized by plants. Content of PO_4 in pond water of Barru District ranges from between 0.0002 to 0.2060 mg/L with an average of 0.0169 mg/L during dry season and 0.0016 and 0.7969 mg/L with an average of 0.1082 mg/L during rainy season. Content of PO_4 in natural waters is rarely exceed 1 mg/L (Boyd, C. E., 1995).

Average total suspended solid in the water of Barru District's aquaculture is 66 mg/L during dry season and 57 mg/L during rainy season. Based on the criteria of (Alabaster, J.S. and R. Lloyd., 1982), the use of the deposition swath critical is needed to reduce the total suspended solids in the water ponds in Barru District.

Climate

Rainfall in the Barru District ponds ranges from 1,117 to 4,824 mm/year with an average of 2,539 mm/year. Rainfall is highly suitable for aquaculture. Rainfall between 2000-3000 mm/year with a 2-3 month dry season is good enough for the pond. Pond preparation is one of the activities that must be performed prior to seeding. At the preparation phase, ponds are dried up to reform the physical nature of the soil, to upgrade its organical mineralization, and to decompress its toxic such as hydrogen sulfide (H_2S), amonia (NH_3) and methane (CH_4). Drying up the ponds is performed during dry months (Figure 2) in order to bring the drying process perfect. Temperature in the coastal Barru District ranges from 23 to 32^{o}C (Muir, J. F. and Kapetsky, J. M., 1988) .

For ponds that are located far from the water sources, rain water can be a source of fresh water to reduce the salinity of the water, by which water salinity can be a limiting factor (which belongs to class S3, and class N) for the ponds during dry season and become problematic during rainy season. However, heavy rainfall during rainy season can also be a limiting factor (belongs to class S3 and class N).

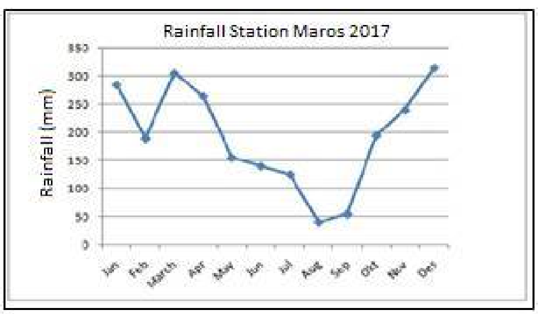

Fig 2. Monthly rainfall in the coastal area of Barru Regency, South Sulawesi Province

Land suitability for pond culture

The results showed that of the total ponds in Barru District, there are 2.399 ha, where land is classified as highly suitable (S1 class), 232.94 ha (9.71%) classified as moderately suitable (S2 class), 1,444.20 ha (60.20%) classified as marginally suitable (S3 class), 721.14 (30.06%) and classified as marginally low suitable (N class), 0.72 ha (0.03%),Limiting factors during the rainy season are the flood, while salinity is the main limiting factor during a dry season. Generally, other limiting factors are of the water sources, low level of pH soil and roughness of soil texture in the certain area (Tantu.G.A. et al., 2013).

In the dry season, the actual land suitability of Barru District shows that 5.88 ha (0.24 %) is classified as highly suitable (S1-class), 2.056.96 ha (85.74 %) ha is moderately suitable (S2 class), 129.44 ha (5.40 %) ha is classified as marginally suitable (class S3) and 206.73 ha (8.62 %) is classified not suitable (grade N) (Fig 4). High salinity is a major limiting factor of aquaculture during the dry season. The needs of fresh water are high enough during the dry season, the use of boreholes can be used to address the need for fresh water, but can cause problems that the sea water intrusion jutting inland (Tantu.G.A. *et al*., 2013).

Other major limiting factors of aquaculture in Barru District are the far distance of the water source and the less fertility of the soil in the land, relatively low soil pH and the rough soil texture on certain areas.

Lack of soil fertility in Barru district ponds can be overcome through fertilization, but fertilization will be more effective if the soil pH is increased through the remediation process for areas with low pH level. Fertilizer containing phosphorus is not effective if the soil pH is low, because it is bound by Fe and Al of the soil.

Coarse-textured soils can be a limiting factor and soil texture "fixing" technology is very difficult and very expensive (Soil Survey Staff, 1975; Zenghui D. *at al.*, 2013).

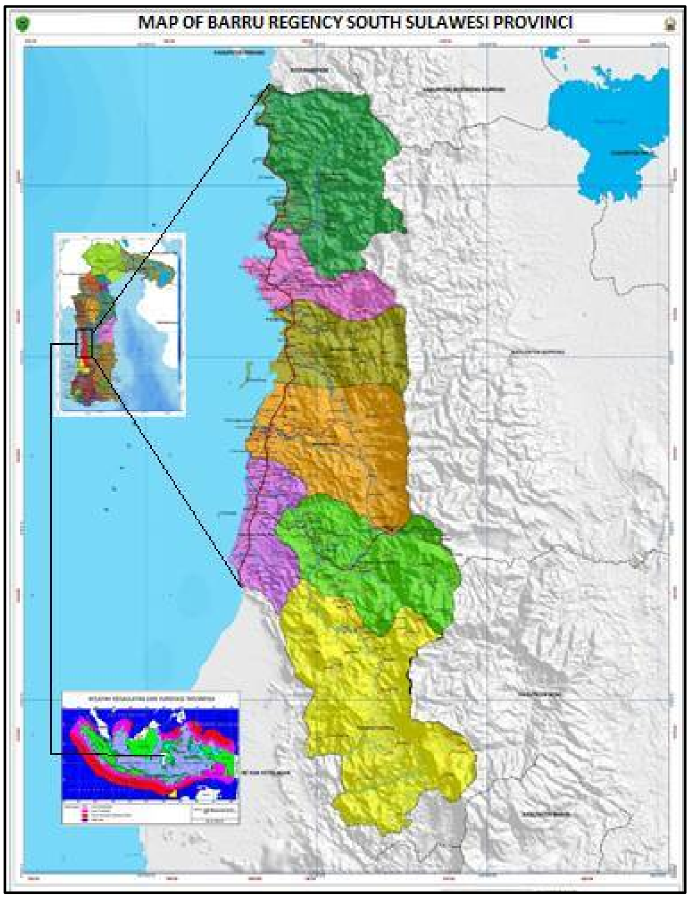

Fig 3. Map of actual land suitability for white shrimp culture in brackishwater ponds of Barru Regency, South Sulawesi Province, Indonesia.

Another effort can be done is assembling bamboo stub on the ponds' embankment slope and ponds' water channels. For the coarse base soil, manure can be given especially to the areas with the low level of organic contents under the expectation that its ponds' base soil structure will be improved.

Thus, the actual suitability of land in the rainy season and the dry season could turn into a potential land suitability where certain areas that belong to theclass of S1 turns to S2, and class S3 turns to be class S2 and class N turns to class S3 after managing the ponds which are managed by its limiting factors.

CONCLUTION AND SUGGESTION

From the total ponds of Barru District, 2.399 ha, it is 232.94 ha (9.71%) which is highly suitable (class S1), 1,444.20 ha (60.20%) of pond which is moderately suitable (class S2), 721.14 (30.06%) is marginally suitable (class S3) and 0.72 ha (0.03%) is not suitable (class N) during rainy season based on the actual land suitability for pond aquaculture. In the dry season, the actual land suitability of Barru District indicates that 5.88 ha (0.24 %) classified as highly suitable (S1-class), 2.056.96 ha (85.74 %) is moderately suitable (class S2), 129.44 ha (5.40 %) is classified as marginally suitable (class S3) and 206.73 ha (8.62 %) ha is classified as not suitable (class N).

As a major limiting factor of suitability in the Barru District during the rainy season floods, while the salinity is the main limiting factor during the dry season. Other limiting factors, in general, are the far distance of the source water, the relatively low fertility of soil, low soil pH and rough texture of soil in some places.

It also needs good planting pattern arrangement, water channel activation, and pumping efforts related to high water salinity during the dry season and far distance of water source. Low fertility can be overcome by fertilization and the low pH by remediation. The use of clay as a core of embankment is needed in the "biocrete" technology for pond embankment with a rough texture.

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Conflict of interest

None.

Ethical standards

This research project was approved by the Chairperson of the Institute for Research, Development and Community Service at the Bosowa University (File number 05/LP3M/ Unibos/I/ 2018) and conforms to the protocols therein.

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