Land characteristics and suitability for tilapia culture at different seasons in brackish water ponds of Bontoa Subdistrict, Maros Regency, Indonesia

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Abstract. Non-shrimp commodities diversification is an alternative for increasing aquaculture production, including brackish water ponds in Bontoa Subdistrict, Maros Regency, South Sulawesi Province, Indonesia. Therefore, a study was conducted to analyze land characteristics in an effort to determine land suitability for tilapia (Oreochromis niloticus) in ponds at different seasons. Factors considered in determining land characteristics and suitability are topography and tide, soil quality, water quality, and climate. Spatial analysis in Geographic Information Systems is used in determining land suitability for tilapia in ponds. The results showed that the land of ponds in the Bontoa Subdistrict has a slope of less than 2%, a tide of 1.38 m, dominated by acid sulfate soil, low water salinity in the rainy season and relatively high of salinity in the dry season with rainfall reaches 3,531 mm/year. In rainy season, from 3,072.6 ha of ponds in Bontoa Subdistrict, 252.2 ha classified as highly suitable (S1 class) and 2,820.4 ha is moderately suitable (S2 class) for tilapia, while in dry season which is moderately suitable (S2 class) area of 2,207.9 ha and classified as not suitable (N class) area of 864.7 ha. High water salinity in the dry season in Bontoa Subdistrict is the main limiting factor for tilapia in ponds.

1. Introduction
As a result of failures in shrimp culture in brackishwater ponds in Indonesia, the commodity diversification in ponds aquaculture can be an alternative to increasing the production of ponds aquaculture. Various commodities other than tiger shrimp (Penaeus monodon) that can be cultured in ponds are milkfish (Chanos chanos), tilapia (Oreochromis niloticus), rabbitfish (Siganus sp), grouper (Epinephelus sp), mangrove crab (Scylla sp), swimming crab (Portunus pelagicus), and seaweed (Gracilaria verrucosa).

Tilapia was one of the first fish cultured. Tilapia is sometimes known as "aquatic chicken" due to its high growth rates, adaptability to a wide range of environmental conditions, and ability to grow and reproduce in captivity and feed on low trophic levels [1]. Illustrations from Egyptian tombs suggest that tilapia was cultured more than 3,000 years ago [2]. Since its entry into Indonesia in 1969, tilapia has undergone many developments, particularly in genetic improvement. In Indonesia, tilapia is known as Nila fish (Indonesian name) and is also the second largest producer of tilapia (O.niloticus) in the world [3]. Tilapia cultured in ponds has a savory taste of meat, chewy, and not smelling mud. Tilapia is also land-based fish commodities, therefore it requires specific land requirements, which is related to the native habitat of tilapia from freshwater.
The land is a physical environment consisting of soil, topography, hydrology, vegetation, and climate in which to some extent affects the ability of land use [4]. Therefore, different combinations of land making up the physical environment will provide different land characteristics and eventually land suitability, and management are different. Thus, the proper evaluation of land suitability needs to be done in order to become the basis of consideration in decisions about land use matching commodity to be cultured.

Land suitability evaluation is a process of estimation variability of land when land is used for a specific purpose or as a method of describing or predicting the potential utility of the land [5-6]. If land potential can be determined, the land use planning can be based on rational considerations, not least of what can be offered by the land resources [7]. Thus, land suitability evaluation is a tool of strategic land use planning. Evaluation of land suitability for predicting the variability of the expected benefits of land use and land-use constraints are productive and environmental degradation is expected to occur due to the use of land. As a native of freshwater fish, water salinity may be one of the important factors that determine the success of tilapia cultured in ponds. In Indonesia, including in Maros Regency, differences in dry and rainy seasons are very clear and also affects water quality, especially salinity. Therefore, a study was conducted aiming at understanding land characteristics and suitability for tilapia culture in different seasons in Bontoa Subdistrict, Maros Regency, South Sulawesi Province, Indonesia.

2. Materials and methods

2.1. Time and study site
The study was conducted from March to April (rainy season) and from July to August (dry season) 2011 in Bontoa Subdistrict, Maros Regency, South Sulawesi Province, Indonesia. The whole observation points and sampling point coordinates are determined using the Global Positioning System (GPS).

2.2. Data collection
2.2.1. Primary data. Primary data collected from fields are topography and tide, soil quality, and water quality. Topography including the slope of the land was extracted from image satellite. Tidal measurements performed at one observation point at the mouth of the Binangasangkara River, Bontoa Subdistrict, Maros Regency. Tidal measurements performed for 39 hours with an hour interval measurement using the palm or sign observer tides. Measurements and sampling of soil conducted at a depth of 0 to 0.2 and 0.2-0.4 m in 46 points sampling. Soil quality measured in situ pHF (soil pH measured directly in the field) with a pH-meter and pHFOX (soil pH measured in the field after being oxidized with hydrogen peroxide (H2O2) 30%) with a pH-meter [8]. For analyzing other soil quality variables, the soil samples in a plastic bag were put in the cool box containing ice [8]. Previously, the remaining fresh herbs, pebbles, and other debris were removed. In the case that soil samples were acid sulfate soil (ASS), then soil samples were put in the oven at 80-85°C for 48 hours [8], while samples of alluvial non-sulfate soil were wind dried. Once dried, soil samples were pulverized by porcelain mortar and sieved through 2.0- and 0.5-mm hole sieves size and then analyzed at the Soil Laboratory of the Research Institute for Coastal Aquaculture and Fisheries Extension (RICAFE) in Maros. Soil quality-analyzed in the laboratory include pHKCI (pH of the extract KCl) [10], pHOX, Sp (sulfur peroxide) [10], SKCI (sulfur extracted with KCl) [11], SPOS (Sp-SKCI) [11], TPA (Titratable Peroxide Acidity) [9], TAA (Titratable Actual Acidity) [9], TSA (Titratable Sulfidic Acidity) (TPA-TAA) [13], pyrite (FeS2) [14-15], organic carbon, total-N, PO4 [15], iron (Fe), aluminium (Al) [17], and texture [18].

Measurements and water sampling were conducted in rivers, seas, channels, and ponds in 60 points sampling. Measurement and sampling of water in the pond were conducted following the soil sampling point. Water quality variables measured in the field were temperature, salinity, dissolved
oxygen, and pH using a Hydrolab® Minisonde. Water samples for laboratory analysis were taken using Kemmerer Water Sampler and preserved following the APHA instruction [19]. Water quality variables were analyzed at the Water Laboratory of RICAFE in Maros include NH₃, NO₃, NO₂, and PO₄ [17,19].

2.2.2. Secondary data. Secondary data were collected through reports, literature and research results of various related agencies. Maps collected include Indonesia Topographic maps 1:50,000 scale with index number 2010-63 (Maros Sheet) and 2011-31 (Pangkajene Sheet), map scale 1:250,000 Soil Types South Sulawesi (including West Sulawesi), and maps Maros District Administration. Monthly rainfall data for Maros in the past 10 years obtained from Climatological Station Class I Panakkukang in Maros.

2.3. Data analysis
Descriptive statistics such as minimum, maximum, and average procedures were used for each variable of soil and water quality. Maps of cover/land use derived from the results of image classification ALOS (Advanced Land Observing Satellite) AVNIR-2 (Advanced Visible and the Near Infrared Radiometer type 2) acquisition 21 July 2008 with the Er Mapper 1.7 Program were integrated with basic maps Topographic maps Indonesia.

Other spatial information derived from primary and secondary data were also integrated with the maps of cover/land use. Primary and secondary data, as well as maps of cover/land use that have been collected, were further processed using spatial analysis in Geographic Information Systems. In the process of analysis using the ArcView 3.3 program, each data variable was entered to produce thematic maps for each data variable. Analytical Hierarchy Process, known as the pair-wise comparison was applied to determine the weighting of each sub-model and variable (Figure 1) [20].

Assumptions applied in the evaluation of land suitability for tilapia in brackish water ponds were adjusted too low management. Infrastructure and socio-economic were not considered in the evaluation of land suitability. Another assumption is that land suitability is not intended for SRIKANDI (Ras Sukamandi) tilapia (Oreochromis aureus x O. niloticus) dan Nila SALINA which has salinity tolerance from 0 to 40 ppt. The results of the land suitability assessment process were displayed in the form of an actual land suitability classification system. The land suitability classification system was set to several levels of class categories.
3. Results and discussions

3.1. Land characteristics

3.1.1. Topography and tide. In general, the slope of the land for ponds in the Bontoa Subdistrict is less than 2%, indicating that the slope of the land can support pond aquaculture which is traditionally managed. The gentle slope is supported also by relatively low elevation so that the inlet and outlet of water by gravity or through the ups and downs still take effect. Ponds in Bontoa Subdistrict are also generally built on former mangrove areas which showed also that land can be reached by tides. Good land for aquaculture is relatively flat [21]. Locations should be chosen in a pond that has a certain elevation in order to facilitate water management, therefore, ponds will get enough water during daily tide and will drain effectively during daily low tide.

Results of tides measurements for the coastal area of the Bontoa Subdistrict indicate that the tidal range reaches 138 cm (Figure 2). The tidal range is sufficient to support ponds. Coastal area with a tidal range of less than 1 m is useless to fill and discharge pond water by gravity. On the other hand, coastal tidal range more than 3 m is not suitable for managing ponds. Dykes had to be made huge and tall to withstand water pressure when high tides and low tides occur [22].
3.1.2. Soil quality. Detailed information about soil quality is essential for initiating land suitability evaluation [5]. Overall soil quality in ponds of the Bontoa Subdistrict can be seen in Table 1. pH_F can be used for the rapid indicator of the presence and severity of actual ASS. In general, the pH_F of bottom soil at a depth of 0-0.2 m is higher than that in the depth of 0.2-0.4 m. It is thought to be due to more intense natural flushing of the soil surface of ponds. Long submerged condition of ponds bottom caused elements or compounds that triggered acidity flushed to ponds surface. In contrast to the results of measurements of pH_F is pH_FOX which the pH measurements were measured in the field after oxidized with H_2O_2 30%. The provision of H_2O_2 30% in the measurement pH_FOX intended to potential acidity in the soil can be oxidized completely by force. As a result, pH_FOX measured to be lower than the measurement results pH_F. As with pH_F, the value of the soil surface of the pond pH_FOX higher than the soil beneath. ΔpH (pH_F-pH_FOX) value can be used as an indicator of the value of the potential acidity in acid sulfate soil. Table 1 shows that the potential for soil acidity is relatively similar in both soil depth of ponds in the Bontoa Subdistrict.

ASS is characterized by pyrite content; therefore, one source of acidity is sulfur (S). Oxidized pyrite will produce sulfuric acid and ferrousulfate; ferrousulfate reacts with water releasing the next ferrisulfate back when oxidized and produce sulfuric acid [23]. Results of S analysis (S_KCl, S_P, S_POS) extracted with different extractors showed that low S content is found on the soil surface of ponds soil. As an important source of acidity in ASS, S is measured in the form of soil S_POS to determine the lime requirement for ASS [15].

Results of measurements of other variables describing soil acidity are TPA, TAA, and TSA which showed a trend of similar patterns with other variables such as soil acidity (ΔpH, S_KCl, S_P, S_POS). It also shows that the TPA, TAA, and TSA are also found in low content in soil from 0 to 0.2 m depth compared to 0.2 to 0.4 m depth. ASS of low organic matter content, the TSA correlates well with S_POS [24-25]. TSA also has a linear relationship with the content of pyrite on ASS [26].
Table 1. Soil quality from 0 to 0.2 m and from 0.4 to 0.4 m depth in brackish water ponds of Bontoa Subdistrict, Maros Regency, Indonesia (n = 46)

| Variables         | Depth of 0-0.2 m | Depth of 0.2-0.4 m |
|-------------------|-----------------|-------------------|
|                   | Minimum         | Maximum           | Average | Minimum | Maximum | Average |
| pH                 | 4.88            | 7.84              | 7.041   | 5.32    | 7.75    | 6.900   |
| pH_{FOX}           | 0.54            | 6.99              | 3.035   | 0.50    | 6.93    | 2.923   |
| ΔpH (pH_{F}-pH_{FOX}) | 0.34          | 6.76              | 4.006   | 0.01    | 6.67    | 3.977   |
| pH_{KCI}          | 2.83            | 8.03              | 6.583   | 1.38    | 7.86    | 5.884   |
| pH_{FOX}          | 0.78            | 7.09              | 2.691   | 0.56    | 7.03    | 2.606   |
| TPA (mole H^+/tonne) | 0.00         | 1,424.00          | 337.764 | 0.0     | 1,828.0 | 478.59  |
| TAA (mole H^+/tonne) | 0.00          | 56.00             | 3.160   | 0.0     | 68.0    | 6.24    |
| TSA (mole H^+/tonne) | 0.00        | 1,415.00          | 334.604 | 0.0     | 1,828.0 | 475.80  |
| S_{KCI} (%)       | 0.07            | 1.13              | 0.397   | 0.07    | 1.99    | 0.494   |
| S_{P} (%)         | 0.23            | 3.68              | 1.964   | 0.18    | 3.95    | 2.103   |
| S_{POS} (%)       | 0.01            | 3.19              | 1.567   | 0.01    | 3.39    | 1.612   |
| Organic matter (%) | 0.70            | 23.19             | 9.681   | 0.39    | 28.59   | 11.331  |
| Total-N (%)       | 0.0410          | 0.6858            | 0.30197 | 0.0302  | 0.8528  | 0.25349 |
| C:N ratio         | 3.79            | 40.34             | 17.606  | 1.95    | 94.53   | 26.562  |
| PO_{4} (ppm)      | 0.01            | 269.68            | 47.356  | 0.01    | 121.66  | 22.597  |
| Pyrite (%)        | 0.00            | 6.32              | 1.494   | 0.00    | 8.16    | 2.125   |
| Fe (ppm)          | 25.00           | 4,833.00          | 2,213.226 | 12.0 | 4,850.5 | 2,315.99 |
| Al (ppm)          | 3.00            | 4,815.00          | 868.406 | 0.5     | 4,690.0 | 894.74  |
| Clay (%)          | 0               | 36                | 9.2     | 0       | 46      | 7.8     |
| Silt (%)          | 16              | 58                | 35.4    | 12      | 64      | 36.4    |
| Sand (%)          | 40              | 72                | 55.3    | 36      | 74      | 56.3    |

The content of pyrite in the Bontoa Subdistrict is very contrast between the soil surface and soil depth of 0.2-0.4 m. A low content of pyrite found in the bottom soil surface. One cause of the low content of pyrite is that in the bottom soil surface occurs pyrite oxidation in which the result is flushed with the submerging water pond. As with pyrite content, the content of Fe and Al soil surface ponds is lower than the soil at a depth of 0.2-0.4 m. The content of Al in ASS is increased at lower pH, i.e. pH 4.0 to 4.5 [26]. In addition, the content of Al in ASS is associated with pyrite oxidation. The atmosphere is very acid accelerate mineral weathering alumina-silicate lattice due to the destruction of 2:1 type minerals (such as montmorillonite) into mineral type 1:1 (kaolinite) and dissolved by releasing more Al [27].

The content of total-N and high soil phosphate is found on the bottom soil surface as a result of the application of fertilizers containing N and P that accumulate on the pond surface. Ponds farmer in Maros Regency applied urea fertilizer (N source) from 66.67 to 500.00 with an average of 196.55 kg/ha/season and SP-36 fertilizer (P source) from 0 to 321.43 with an average of 122.98 kg/ha/season in the pond [28].

Soil texture is the ratio between the fraction of sand, silt, and clay of soil. Among the three soil fractions, the sand fraction is more dominant than the other soil fractions, namely 55.3% in the surface bottom soil and 56.3% at 0.2-0.4 m soil depth. Ponds soil was commonly founding as a fine-textured soil with a clay content of 20-30% to resist seepage in dike [29].

3.1.3. Water quality. Since commodities cultured in ponds live in bodies of water, the water quality is a decisive factor in the success of ponds aquaculture. Water quality was suspected to be the key factor responsible for the low yields [30]. Measured water temperature range was within the optimal for tilapia culture. Optimal water temperature for tilapia culture is 25-30°C [31-32]. In general, water temperature in ponds of Bontoa Subdistrict ranged between 20.87 and 35.89°C with an average of 31.966°C during the rainy season and ranged between 29.86 and 36.37°C with an average of 32.791°C during the dry season (Table 2). Tilapia can tolerate temperatures between 15 and 37°C [33], so the temperature in ponds of the Bontoa Subdistrict can support tilapia culture. The suitable temperature
for tilapia is 26-30°C, while the decline in growth performance possibly occurs when the temperature is higher than 34°C [33].

Table 2. Water quality in brackish water ponds of Bontoa Subdistrict, Maros Regency, Indonesia during the rainy and dry season (n = 60).

| Variables          | Rainy season | Dry season |       |
|--------------------|--------------|------------|-------|
|                    | Minimum      | Maximum    | Average | Minimum | Maximum | Average |
| Temperature (°C)   | 20.87        | 35.89      | 31.966 | 29.86   | 36.37   | 32.791  |
| Salinity (ppt)     | 0.48         | 31.65      | 10.445 | 16.71   | 63.74   | 36.773  |
| pH                 | 4.91         | 8.55       | 7.325  | 7.16    | 9.80    | 8.095   |
| Dissolved oxygen (mg/L) | 2.32       | 9.96       | 6.380  | 3.90    | 12.75   | 6.339   |
| NO₂ (mg/L)         | 0.0067       | 0.3107     | 0.03212| 0.0016  | 0.3206  | 0.05086 |
| NO₃ (mg/L)         | 0.0037       | 3.4112     | 0.20076| 0.0177  | 3.9808  | 0.34317 |
| NH₃ (mg/L)         | 0.0030       | 1.3236     | 0.19044| 0.0225  | 4.7649  | 0.60826 |
| PO₄ (mg/L)         | 0.0153       | 0.4461     | 0.08456| 0.0363  | 2.0162  | 0.57959 |

The salinity of pond water in the Bontoa Subdistrict is very contrast between rainy and dry seasons. In the rainy season, water salinity ranged between 0.48 and 31.65 ppt with an average of 10.445 ppt, while in dry season ranged between 16.71 and 63.74 ppt with an average of 36.773 ppt. High rainfall during the rainy season causes low salinity water in Bontoa Subdistrict, either in ponds or water sources. Tilapia is a euryhaline species that can live in a fairly wide range of salinity, so the fish can be cultured in two different ecosystems are freshwater and brackish water [32,35-36]. Compared to tilapia, other freshwater fish can only live on a limited range of salinity (stenohaline species). Tilapia (Oreochromis mossambicus) grows faster in brackish water than in freshwater [35]. Tilapia generally have a good growth performance up to salinity 15 ppt, while the blue tilapia (Oreochromis aureus) can grow well on salinity 20 ppt [31]. The average pH of pond water during the dry season is higher than the rainy season (8.095 vs 7.325). ASS in Bontoa Subdistrict oxidized in the dry season, causing a decline in soil pH and rainfall that bring acidity element of soil also affecting water pH is thought to be the cause of lower water pH in the rainy season. However, water pH is still relatively very supportive of tilapia culture, both in rainy and dry seasons. In general, tilapia can survive in water pH ranged between 5 and 10 but do best in a pH ranged between 6 and 9 [31] and between 6.5 and 7.5 [37].

The average dissolved oxygen content in ponds of the Bontoa Subdistrict is relatively the same during dry and rainy seasons (Table 2). Dissolved oxygen content is very supportive of tilapia growth and survival. Although tilapia can survive acute low dissolved oxygen content for several hours, tilapia cultured in ponds should be managed to maintain dissolved oxygen content more than 1 mg/L [31]. Tilapia has a high tolerance for turbidity, can grow well in a high hardness environment and is also resistant to high ammonia content [32,38]. Thus, other water quality measured at different seasons in ponds located in Bontoa Subdistrict can support the growth of tilapia.

3.1.4. Climate. One factor that greatly affects the culture in ponds besides soil quality and water quality is the climate, especially rainfall. Monthly rainfall in Bontoa Subdistrict shows that high rainfall (rainy season) occurs between November and April, while low rainfall (dry season) occurs between May and October (Figure 3). Rainfall in Bontoa Subdistrict reaches 3,531 mm/year. Rainfall between 2,000 and 3,000 mm/year with dry month 2-3 months is sufficient to support ponds aquaculture [22]. For culturing tilapia which is originally coming from freshwater habitat, the rainfall is sufficient to support tilapia growth which requires lower water salinity.
3.2. Land suitability

Results of land suitability evaluation for tilapia culture in ponds showed that from 3,072.6 ha of ponds in Bontoa Subdistrict, the 252.2 ha are classified as highly suitable (S1 class) and 2,820.4 ha areas moderately suitable (S2 class). There are no ponds classified as not suitable (N class) in the rainy season (Figure 4). In the dry season, land suitability in ponds of Bontoa Subdistrict changed significantly where there is no land classified as highly suitable (S1 class) and there are 864.7 ha ponds classified as not suitable (N class) for tilapia culture. In the dry season, there are 2,207.9 ha ponds in Bontoa Subdistrict which is moderately suitable (S2 class) for tilapia culture (Figure 5).

As previously explained ponds in Bontoa Subdistrict are dominated by acid sulfate soil which characterized by high potential acidity. However, the soil is not the main limiting factor in land suitability for tilapia in ponds of the Bontoa Subdistrict. Tilapia is known as having a high tolerance to soil acidity. Tilapia can grow well in soil that has high potential acidity such as peat and acid sulfate soils [39].

It was mentioned earlier those tilapia belongings to euryhaline species that can grow in a wide range of salinity, but for commercial purposes, it is still considered optimal salinity. As a result, the salinity of pond water becomes the limiting factor of land suitability for tilapia culture in ponds in the Bontoa Subdistrict during the dry season with an average water salinity of 36.773 ppt (Table 2). When more than 25 ppt salinity occurs, tilapia growth is slow and susceptible to hot spots disease [33]. However, these salinity conditions still support SRIKANDI tilapia which has the ability to adapt to a wide range of salinity. SRIKANDI tilapia has salinity tolerance of 0-40 ppt and grows optimally at 10-30 ppt salinity (Decision of Ministry of Marine Affairs and Fisheries of the Republic of Indonesia Number KEP.09/MEN/2012 about Release of SRIKANDI Tilapia). In the rainy season, water salinity is not a limiting factor for land suitability for culturing tilapia in ponds of the Bontoa Subdistrict (Figure 2). Salinity is a stressor on fish, especially if high daily fluctuations. Salinity above 25 ppt correlated a positive effect on the enzyme activity of Na+-K+-ATPase in the gills [40]. Activation of the enzyme Na+-K+-ATPase and other osmoregulation mechanisms that accompany changes in salinity requires the amount of energy that disrupts the allocation of energy to the growth of fish. It is characterized by increased levels of blood glucose and cortisol during exposure to the stressor [41].
4. Conclusions

Brackish water ponds in Bontoa Subdistrict, Maros Regency, South Sulawesi Province, Indonesia has a slope of less than 2%, the tidal height of 1.38 m, dominated by acid sulfate soil, low water salinity in the rainy season and relatively high-water salinity in the dry season with rainfall reaches 3,531 mm/year. In the rainy season, from 3,072.6 ha of brackish water ponds in the Bontoa Subdistrict, there is 252.2 ha classified as highly suitable (S1 class) while 2,820.4 ha is classified as moderately suitable (S2 class) for tilapia culture. In the dry season, there are 2,207.9 ha classified as moderately suitable (S2 class) and 864.7 ha classified as not suitable (N class). High water salinity in the dry season in Bontoa Subdistrict is the main limiting factor for tilapia culture in brackishwater ponds.
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