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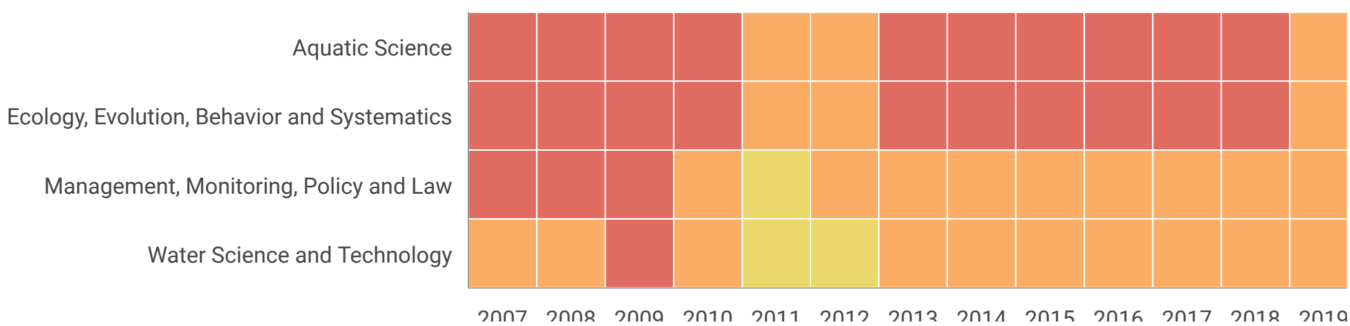

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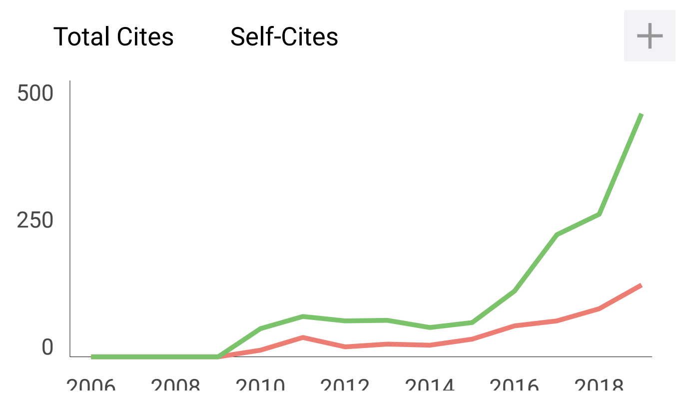

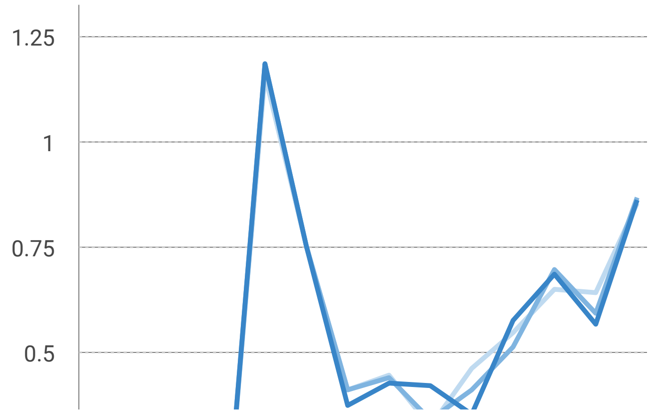

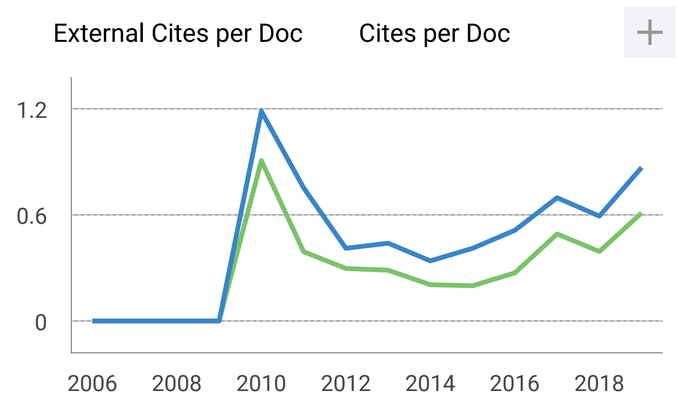

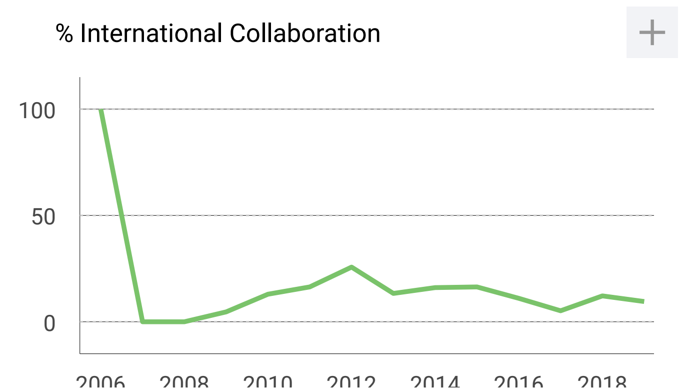

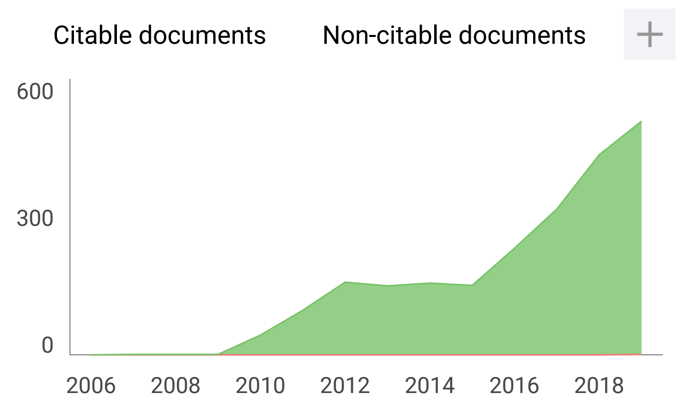

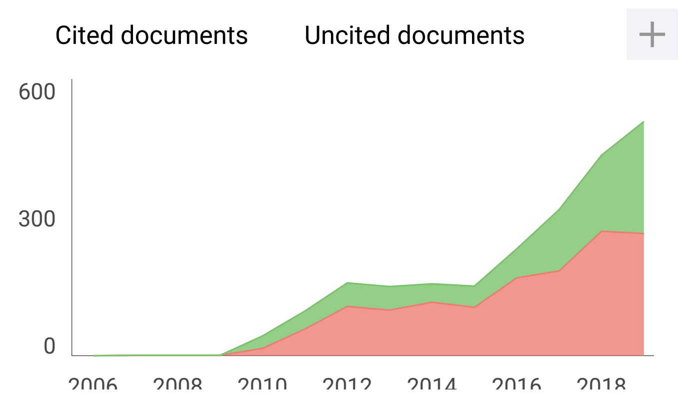

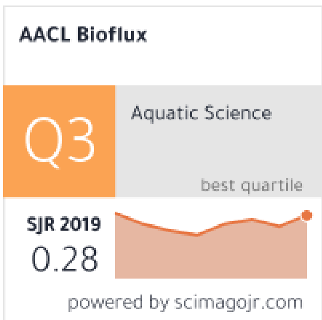

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Suitable location map of floating net cage for environmentally friendly fish farming development with Geographic Information Systems applications in Lake Limboto, Gorontalo, Indonesia

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Abstract. The study aimed to: (1) analyze the degree of floating net cage system suitability for fish farming in Lake Limboto waters; (2) analyze the extent and distribution of suitable area of Lake Limboto waters for fish farming by floating net cage (KJA) system. The method of study was the integration of survey and laboratory. The analysis was the integration between multi-criteria analyses and Geographic Information Systems (GIS). Based on the analysis result, it showed that among eight physical-chemical parameters there were two of them categorized as suitable, while the others were not feasible. Among 16 observation stations, 11 stations were categorized as unsuitable, while the remains were classified as marginally suitable. The total area of lake waters suitable for KJA systems was 8.03 ha (0.36%), while 2195.57 (99.64%) was unsuitable.

Key Words: Suitability of KJA system, site evaluation, cage culture, GIS, multi-criteria analysis (MCA).

Introduction. Lake Limboto (Indonesia) is located in the lowlands of Gorontalo Province. It has 23 rivers and creeks as the inlet, and only one outlet. According to Hasim (2012), with the management of status quo as now, Lake Limboto will be lost in 2025. Besides, the quality of Lake Limboto waters decrease as the impact of various economic activities in the region.

Floating net cages (hereafter referred to as cage culture) are dominant aquaculture fish farming systems found in Lake Limboto beside capture fishery systems. The cage culture system had been introduced first since 1988 as trials for fish farming system in Limboto Lake. In 1993 the cages has 500 units and developed into 1,962 units in 2007. Until in 2009, the number of cages in Lake Limboto was reported to be more than 2,000 units (Marine and Fisheries Research Agency 2007).

On the other hand, Mc Donad et al (1996), Pulatso (2003) and Janssen (2001) stated that intensive fish in the lake has an impact on nutrient enrichment and reduces the potential water quality of fish farming, as well as provides the multiplication of phosphorus content. Further, it is stated that these activities have an effect on the carrying capacity of the lake.

Site suitability evaluation is an initial stage to determine the suitability of location for cage culture fish farming. Selecting a precise and good location is one of the critical success factors in cage culture system. The choice of location should consider environmental factors and water quality since the location feasibility is in accord with the survival requirements and the growth of farming commodity toward the aquatic environment.

The development of cage culture system units in Lake Limboto has not yet integrated with the consideration of its environmental carrying capacity. Facts show that the location placement of the cage system does not consider the environmental conditions of the lake. The rapid development rate of cage unit number and the ignorance of environmental aspects will increase the ecological burden on Lake Limboto. The implication is that the lake water quality will decline. Further, a disease attack against the farmed fish will be high and cause economic losses.

Geographic information system (GIS) is one of the options in determining the ideal location to develop fish farming. It can integrate multiple data and information about fish farming in the form of layer which can later be overlaid with other data in order to produce a new output in the form of thematic maps with adequate high levels of efficiency and accuracy. Its utilization can assist or facilitate the data analysis and can help in determining the most appropriate location for fish farming.

Performing the management of Lake Limboto to achieve sustainability should be started from the economic activity which already exists in the lake, such as cage system fisheries. Therefore, planning and developing the farming fisheries of cage system in the lake must be based on scientific data. Studies evaluating the degree of suitability for fish farming of cage culture system using GIS technology ease the way to obtain the accurate information, because the GIS approach provides information based on spatial dimensions in order to obtain the exact extent and distribution of suitable area of fish fishing of cage system in Lake Limboto.

This study aimed to analyze the quality of water through some physical and chemical parameters and analyze the land suitability for cage culture fish farming system by GIS technology. The results of this study are expected to provide the scientific information on the status of fish farming for cage culture system and the information availability in the form of suitability map for cage culture fish farming system locations in Lake Limboto water.

Material and Method. This study was conducted in June-December 2015 and located in Lake Limboto which included several districts in the regency and municipality of Gorontalo, Gorontalo Province (Figure 1). The observation stations consist of 16 stations determined randomly (purposive random sampling) so that their spread represents Limboto Lake region. Each station is deployed in areas with and without floating net activities.

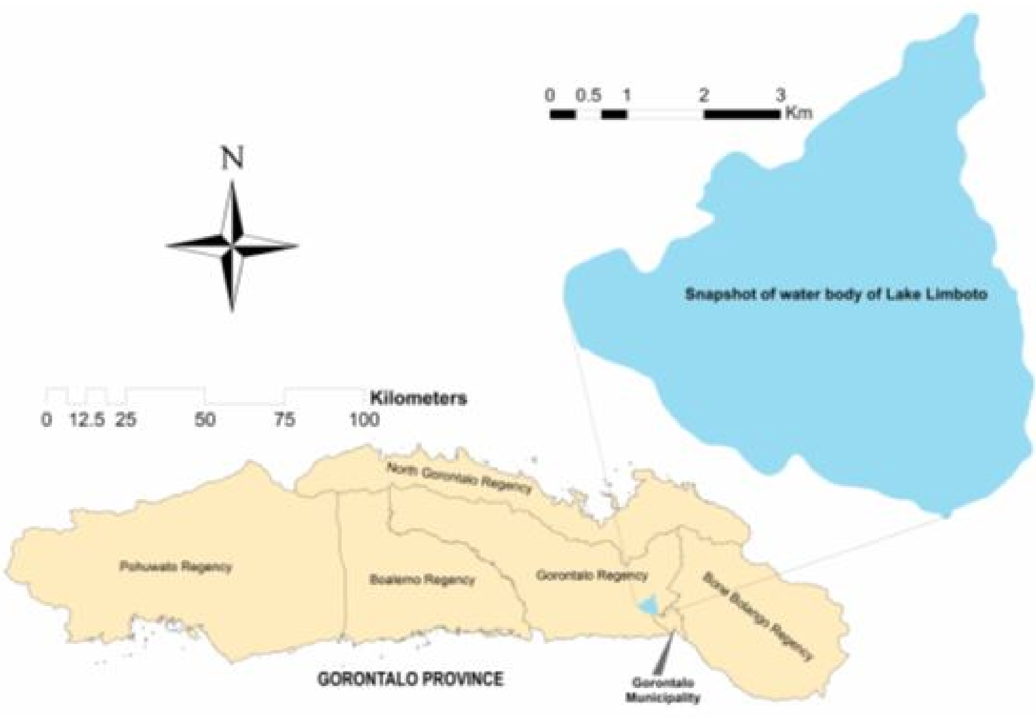

Figure 1. Site of research location and administration boundaries of Gorontalo Province.

Primary and secondary data were used in the study. Primary data was data from measurement results of chemical-physical parameter of the water, including measurements of temperature, current, DO, ammonia, depth, brightness, pH and BOD5 both performed in situ or ex situ whose outcomes were processed in the laboratory. While the secondary data was data related to the location map.

The suitability determination analysis was conducted by weighting or scoring methods through the area suitability matrix. In the weighting method, each parameter is calculated by different weighting and using the chemical physics parameters of the water as a reference. The determination of weighting and scoring was done to score the criteria supporting the farming activities. Weighting in the matrix can be seen in Table 1.

Table 1

Suitability matrix for cage culture area (modified from Nurfiarini 2003; Khairunnisa et al 2014)

No	*Parameter*	*Weight*	*S1 (very suitable)*	*Score*	*S2 (suitable)*	*Score*	*N (unsuitable)*	*Score*
1	Temperature (°C)	3	28-32	3	26 - < 28	2	<26 and >32	1
2	TSS (mg/L)	1	25	3	26-80	2	>80	1
3	DO (mg/L)	3	>6	3	3-6	2	<3	1
4	Nitrate (mg/L)	1	>3.5	3	1.6-3.5	2	>1.5	1
5	Depth (m)	2	10-25	3	4 - <10	2	<4 - >25	1
6	Brightness (m)	1	>5	3	3-5	2	<3	1
7	pH	2	7.5-8.0	3	7.0-<7.5 or >8.0-8.5	2	<7.0 or >8.5	1
8	BOD5 (mg/L)	1	<3	3	3-5	2	>5	1

Based on the categories in suitability matrix table, score 3 is 'very suitable', score 2 is 'suitable', and score 1 is 'unsuitable'. Each parameter had different contribution toward the suitability level of KJA land. Therefore, the determination of weight and scores for each parameter was coincided with the effect of these parameters on the suitability value. The suitability score in every location was calculated by the following formula (Jumadi 2011):

$$N_{ij} = B_{ij}\, x\, S_{ij}$$

N_{ij} = total score in location, B_{ij} = weight in parameter-*i* class *j*, and S_{ij} = score in parameter-*i* class *j*

Based on applied the formula above to matrix value on Table 1, then it were obtained the total maximum values ($N_{ij}max$) and total minimum values ($N_{ij}min$) are 42 and 14, respectively. These values obtained by calculated each weight of parameters with S1-score classes for $N_{ij}max$ and N-scores classes for $N_{ij}min$. From both values, Suitability category of lake area was calculated in MS Excel environmental based on suitability class on Table 1 using the equation:

$$Class\ interval = \frac{N_{ij}max - N_{ij}min}{3}$$

MS Excel was used to operate the formulas above. Result from this step is discrete value of interval of suitability categories class which are consisted three categories, including: S1 - very suitable, at interval value of ≥31 – 42, S2 - suitable, with interval 16-30, and N - unsuitable, range 0 – ≤ 16. Further analysis using GIS technique for MCA rule applied to all thematic map resulted from previous step using the range value suitability above to result final of distribution map of cage culture suitability area in Lake Limboto.

Results and Discussion

Temperature. Temperature is a parameter which must be considered in the process of fish farming. The optimum water temperature for farming fisheries, according to Aisha and Subekhi (2012), ranged between 27-32°C. From the results of temperature measurements carried out in the waters of Lake Limboto, they showed that the water temperature in almost the entire station were feasible for activities of fish farming (Figure 2).

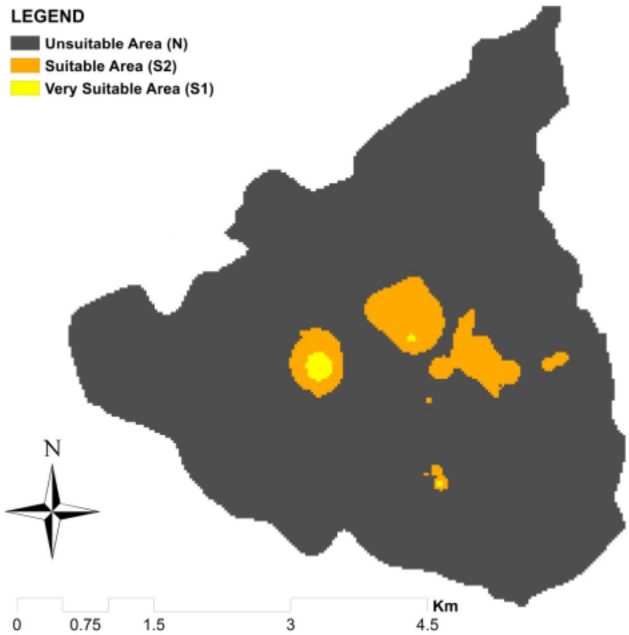

Figure 2. Suitability map of water temperature for cage culture system in Lake Limboto.

According to Supratno (2006), generally the growth rate of fish will increase in line with the rise of temperature to a certain extent. If the temperature rise exceeds the limit, it will cause the metabolic activity of aquatic organisms/animal increase. It will lead to reduction of dissolved gases in water which are essential to the life of fish or other aquatic animals. Although fish can adjust to the temperature rise, the temperature rise which exceeds the extreme tolerance limit (35°C) for a long time will cause the stress or death of fish.

Bathimetry. Bathimetry is a physical parameter indicating the size of water level from the bottom of a basin. It greatly affects activities of fish farming, especially of those using floating net cages. The minimum depth for farming activities with floating net cages is 2 m from the bottom. Based on the conducted measurements, the depth of Lake Limboto waters in overall stations was less than 2 m (Figure 3).

The biggest measurement result on the depth of water in Lake Limboto was found at station 14 (1.8 m) and the shallowest one was at station 4 (0.78 m). This situation showed that the depth parameters of Lake Limboto waters were classified in the category of 'unsuitable' for cage culture activities.

Based on field studies, there were two factors causing the depth of Lake Limboto become very shallow: (1) the ongoing drought in a long period and it was not expected to rain for five months. It was indicated by the drying of rivers to the estuary of Lake Limboto. Meanwhile, the other side of lake water evaporation was high due to the high intensity of sun; (2) there had been a cumulative sediment deposition in a long period as a result of sedimentation of particles carried by river water entering the body of lake. Shallowness of lake waters affected the reduction in column space of water, so that it became the limiting factor of fish survival.

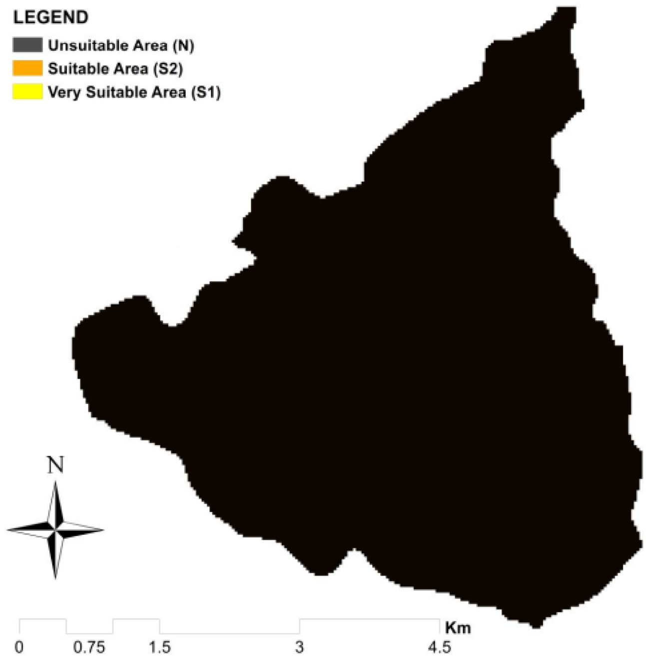

Figure 3. Suitability map of depth for cage culture system in Lake Limboto.

Transparency. Transparency is the light penetration in waters. Light penetration into water is greatly influenced by the light intensity, the angle of light, the condition of the water surface and the soluble or suspended particles (Boyd 1982). The surface layer of water receiving sunlight is called euphotic layer. In this layer, sunlight transforming into energy is important in the process of photosynthesis by phytoplankton as the primary producers of waters.

The Figure 4 shows that the transparency parameters of Lake Limboto waters are no longer suitable for activities of fish farming. It is because the parameter measurement result of brightness value throughout the station is less than 20 cm.

Meanwhile, the research conducted in 2006 revealed that the transparency of Lake Limboto waters ranged from 40 to 46 cm. Then in 2012 its transparency was 48-68.5 cm (Aisha & Subekhi 2012). The data directed that the transparency of Lake Limboto experienced fluctuation. Besides, the decrease of transparency values in 2012-2015 was very significant.

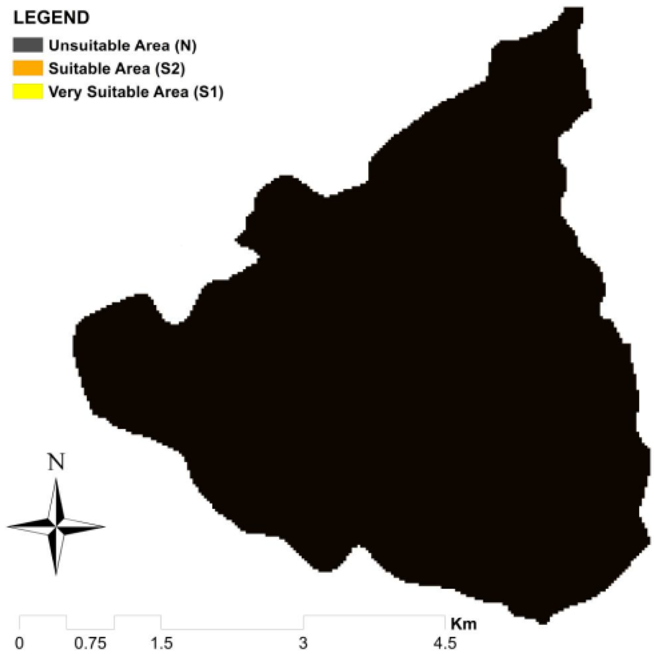

Figure 4. Suitability map of transparency for cage culture system in Lake Limboto.

Acidity (pH). pH is a measure of the hydrogen ion concentration of an aquatic medium. Mediums with a high concentration of hydrogen ions have a low pH and mediums with low concentrations of $H+$ ions have a high pH. pH value <4 and >11 cause the death of fish. According to Boyd (1982), an ideal pH for fish is 6.5-9.0. While Alabaster & Lloyd (1982) stated that the ideal pH is 6.7 to 8.6. Next, the low pH can cause an increase of toxicity in waters and in turn will cause a decrease in fish appetite (Alabaster & Lloyd 1982).

The results of pH value measurement in Lake Limboto waters showed a uniform value of 6 (Figure 5).

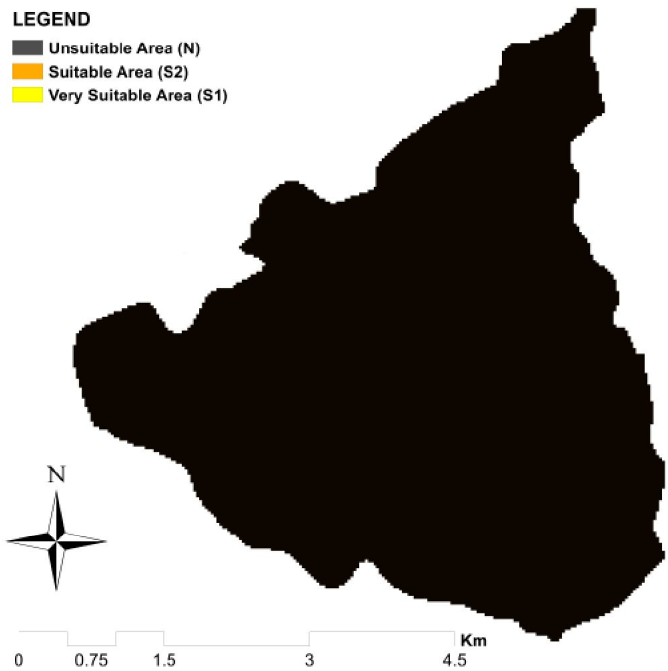

Figure 5. Suitability map of acidity for cage culture system in Lake Limboto.

According to the knowledge base which is arranged to determine the suitability category, Lake Limboto waters is classified as unsuitable for cage culture. As stated by Alabaster & Lloyd (1982), pH ranging of 5-6 may be lethal for fish.

Dissolved oxygen (DO). DO of waters is a water quality parameter which is the most critical in fish farming, since it could affect the survival of the farmed fish. According to Alabaster & Lloyd (1982) every species of fish has different sensitivity to the dissolved oxygen content. DO in waters is required for the respiration process, either of aquatic plants, fish, and other organisms living in water (Supratno 2006).

The optimum DO of waters for fish farming activities ranges between 5-9 mg/L (Alabaster & Lloyd 1982). Whole DO measurement result conducted in Lake Limboto waters was within the range of 7 mg/L and above (Figure 6). This showed that DO of Lake Limboto waters was very suitable for fish farming activities.

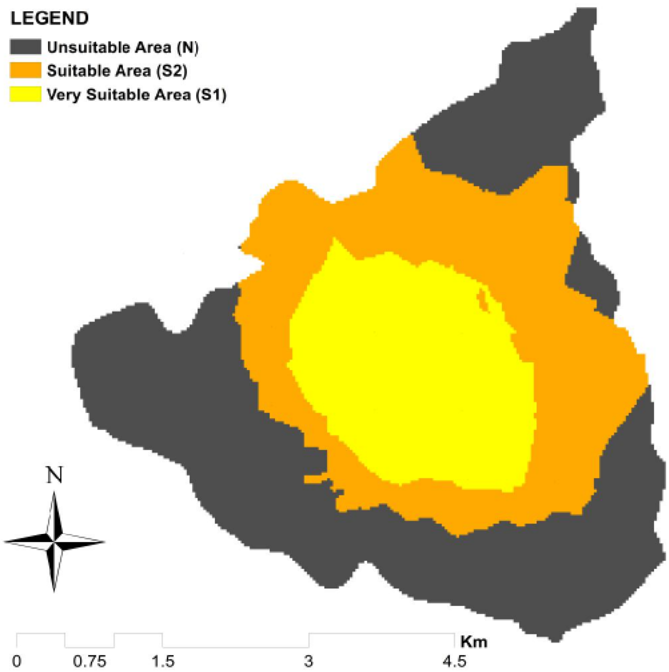

Figure 6. Suitability map of DO for cage culture system in Lake Limboto.

Nitrate (NO_3). Nitrate is a fertility parameter in waters. It affects nutrients which play a role in the biomass formation of aquatic organisms. Indrayani et al (2015) stated that good nitrate levels for water are 2-5 mg/L. Our field measurement to nitrate content resulted in overall stations in Lake Limboto waters has value <1 mg/L. Based on matrix of parameter suitability (Table 1), eligibility requirements of cage culture fish farming system for nitrate parameter are between 1.6-3.5 mg/L. The result indicated that overall station was 'unsuitable' since the results were below the suitable range of nitrate (Figure 7).

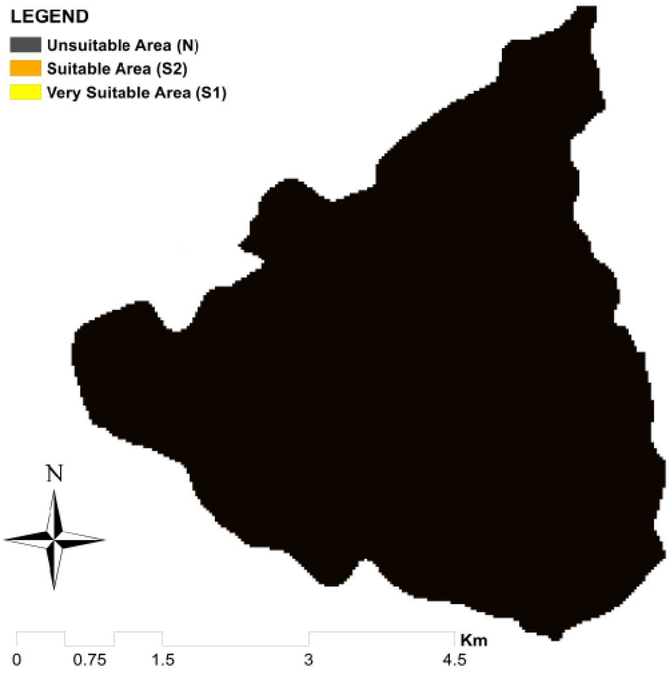

Figure 7. Suitability map of nitrate for cage culture system in Lake Limboto.

Total suspended solids (TSS). TSS is the concentration of suspended solids contained in waters. Alabaster & Lloyd (1982) stated that the increase in dissolved solids can directly kill fish, increase the disease and lower the growth rate, change the fish behavior and decline the fish reproduction.

The optimal water content of total suspended solids for fish farming activities are approximately <25 mg/L. The measurements result of TSS performed in Lake Limboto waters showed a value of >25 mg/L (Figure 8).

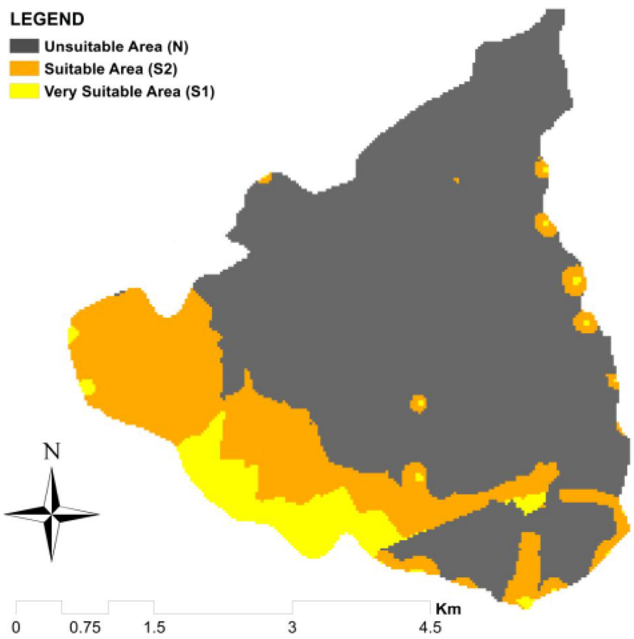

Figure 8. Map of TSS suitability for cage culture system in Lake Limboto.

Biological oxygen demand (BOD). Biological process in waters is a parameter indicating the amount of oxygen consumption in waters. According to Supratno (2006), high content of BOD is caused by high levels of water contamination due to accumulation of the residual unconsumed feed. High BOD indicates the amount of oxygen used by microorganisms, mainly bacteria to break down organic material in the water. Thus, BOD is the relative measure of organic matter amount in water so that it closely associates with the fertility of the water.

BOD range of 2 to 4 mg L^{-1} does not show pollution while levels beyond 5 mg L^{-1} are indicative of serious pollution (Bhatnagar & Devi 2013). The measurement results of BOD content in Lake Limboto waters showed that Lake Limboto waters was not suitable for activities of cage culture, due to the very high BOD content available in Lake Limboto waters (Figure 9).

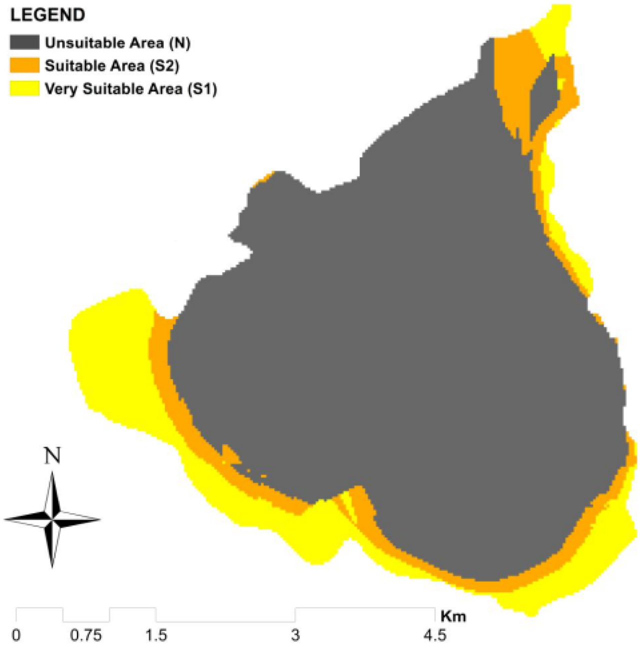

Figure 9. Map of BOD suitability for cage culture system in Lake Limboto.

Suitability map of Lake Limboto waters for cage culture. Based on the scoring and weighting results of the physico-chemical quality of the water, data and intersect results with the depth of waters, it formed the map of suitability level for cage culture of fish farming system in Lake Limboto (Figure 10).

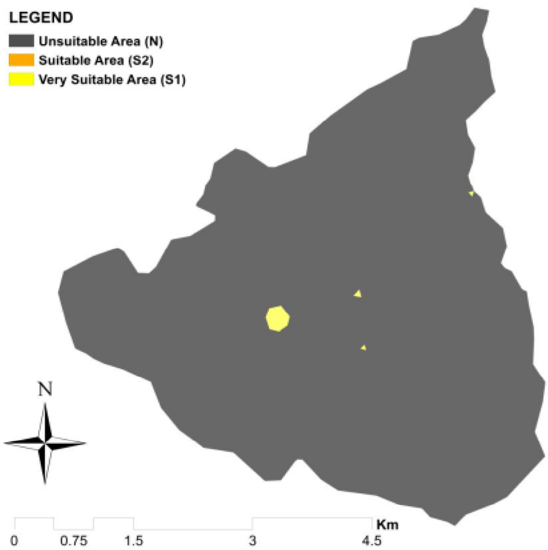

Figure 10. Suitability map of distributions area for cage culture in Lake Limboto waters.

Then, results from SIG tool known that assessment area of the feasibility level of cage culture for fish farming system in Lake Limboto were consisted of 2,195.57 ha (99.64%) was not suitable, while 8.03 ha (0.36%) was suitable or marginally appropriate. However, the area which was classified as suitable/marginally appropriate is not recommended to develop cage culture system due to the relatively shallow waters.

Conclusions. Some points which can be concluded from the discussion are:
1. There are eight physical and chemical parameters measured at 16 stations which demonstrate various values. In general, there are only two parameters satisfy the category of 'very suitable' namely temperature and DO;
2. Based on GIS analysis, the suitable waters for cage culture system based on appropriate marginal are 8.03 ha (0.36%), while the unsuitable area is about 2,195.57 ha (99.64%);
3. Overall, the depth of Lake Limboto waters is less than 2 meters, so it is not feasible for the development of cage culture system fish farming.

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