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Site Selection Analysis for Grouper Culture in Floating Cage Using GIS-Based Weighted Linear Combination Analysis in Kulisusu Bay Southeast Sulawesi

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Abstract: Land suitability evaluation is a crucial component that supports the sustainable development of aquaculture. One economically valuable commodity in this field is the grouper fish. Kulisusu Bay, located in North Buton Regency, is an area with potential for grouper culture in floating cages. The objective of this research is to analyze the suitability of the land in Kulisusu Bay for floating cage aquaculture of grouper. The study begins by identifying key parameters that directly affect the success of aquaculture activities. These parameters include primary and secondary data that are used to build spatial data. Subsequently, a spatial model is constructed based on this data, resulting in a spatial database. Each parameter is then weighted and scored. The final step involves spatial overlay modeling, where the weighted and scored results are used to generate a land suitability map. The research results show that a significant portion of 2,253 hectares is highly suitable, with an additional 810 hectares being suitable for the activity. These areas are primarily concentrated in the central region of Teluk Kulisusu. Based on these findings, it can be concluded that the waters of Teluk Kulisusu have great potential for the development of grouper culture in floating cages. However, the support of various stakeholders, including the government, is necessary to ensure that this aquaculture activity is sustainable by implementing environmentally friendly culture practices.

Keywords: *grouper, aquaculture, GIS, suitability land, WLC*

Introduction

Sustainable aquaculture is very important because this sector is growing rapidly in terms of fisheries products. Globally, the production of fisheries products obtained from aquaculture activities has increased since 1985, and in the last decade, there has been a significant double increase, reaching 52.5 million tons in 2008.

Aquaculture activities, as one of the sources of fisheries production, also have the benefits of reducing poverty and improving the economy of communities around the coast. The rapid growth of aquaculture activities, covering small-scale aquaculture to corporate scale, is a benchmark that aquaculture activities contribute significantly to various developments in several sectors [2] in FAO [3].

According to FAO [4] in Andayani [5], the development of fish farming has shifted from a conventional approach to an ecosystem approach (Ecosystem Approach to Aquaculture). The EAA approach is an ecosystem-based aquaculture approach that emphasizes sustainable development, equity, and resilience, which are integrated into the social-ecological system.

One aspect that supports the development of sustainable aquaculture is the evaluation of potential land in search of a suitable location for aquaculture activities. Evaluation of land suitability is a method that explains or predicts the potential utilization of a water area [6] in [7].

Grouper fish is a high economic value fisheries commodity, and the export market share is widely cultivated in floating net cages (KJA) at sea [8] in [9]. The price of live grouper fish is 5 times more expensive than grouper fish in a dead/frozen condition [10] in [9]. Therefore, efforts are needed in the development of KJA aquaculture activities to increase the selling value of grouper which will increase the income of the farmers.

North Buton Regency is an area with the potential to develop fisheries and marine products. The area of Kulisusu Bay in North Buton Regency covers an area of ± 8718 Ha and currently has two types of aquaculture activities, namely floating net cage (KJA) and seaweed cultivation[11].

The placement of KJA in Kulisusu Bay currently only uses a trial and error method. This method is widely practiced by fishermen because it is caused by insufficient knowledge in the process of site selection, which results in the failure of aquaculture activities. According to Affan [12], the selection of culture sites must consider environmental factors and water quality. The location that is considered proper is the result of the suitability between the requirements of life and the development of a culture commodity with the physical environment of the waters. The physical environment includes oceanographic conditions and water quality, as well as seabed topography. In addition, according to FAO [3], non-technical factors that influence the success of grouper KJA cultivation activities are distance from settlements, distance from rivers, and distance from ports..

The selection of suitable aquaculture sites is based on the use of GIS technology by analyzing water condition data obtained from direct measurements in the field. The water condition data is then weighted and scored based on a suitability matrix to obtain a suitable location. The purpose of this research is to analyze the suitability of land for grouper floating net cage aquaculture activities in Kulisusu Bay as a first step in starting the development of sustainable aquaculture, so that it is expected to increase the selling value of grouper commodities.

Method

This research was located in Kulisusu Bay, North Buton Regency, Southeast Sulawesi Province. Primary data collection which includes physical-chemical oceanographic conditions was carried out on 16 observation points. Determination of the distribution of observation points is based on the representation of each landscape and the presence of each ecosystem in the research location. The following figure 1 presents a map of the research location.

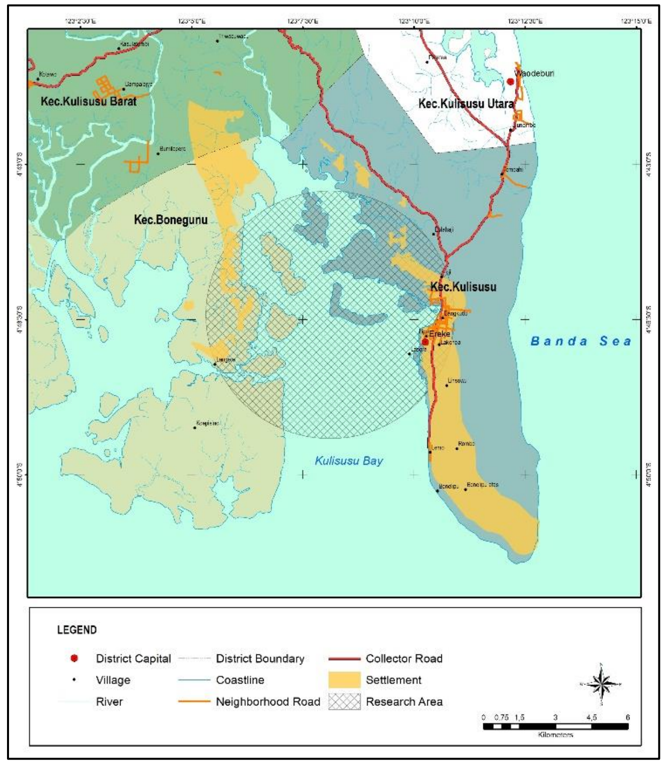

Figure 1. Research Map Location

Materials and Research Tools

Primary data collection activities are divided into three parts, namely: (1) Physical-chemical oceanographic conditions including: ammonia, nitrate, phosphate, water brightness, dissolved oxygen, salinity, temperature, pH, and current. (2) Environmental conditions, data such as area protection and bottom water substrate conditions were collected. (3) Social infrastructure conditions such as distance to settlements, distance to ports and distance to rivers. In its implementation, a ship with an outboard engine with a size of ± 3 GT is needed, Garmin GPS as a means of orienting direction and position during data collection. The secondary data collected were Indonesian landform maps at a scale of 1:25,000, Landsat 8 OLI/TIRS satellite imagery and water depth data obtained from the Bappeda Office of North Buton Regency. Table 1 presents the types and sources of data needed in this study referred to [3].

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Table 1. Research data requirements

No	Parameter	Unit	Data Source	Reference
Environmental				
1	Shelter Areas	-	Field data/Satellite data	FAO, 2015
2	Bathymetry	m	Map/ Satellite data	BIG/Dishidros
3	Wave Current	m/sec	Field data	APHA, 2005
4	Substrate	-	Field data	FAO, 2015
Water Quality				
1	Ammonia	mg/l	Field data	SNI, 2005
2	Nitrat	mg/l	Field data	APHA, 2005
3	Phosphat	mg/l	Field data	SNI, 2005
4	Transparency	m	Field data	APHA, 2005
5	Dissolve Oxygen	mg/l	Field data	APHA, 2005
6	Salinity	ppt	Field data	APHA, 2005
7	Water Temperature	°C	Field data	APHA, 2005
8	pH	-	Field data	SNI, 2005
Socio-Infrastructure				
1	Distance to settlement	km	Map/ Satellite data	FAO, 2015
2	Distance to harbour	km	Map/ Satellite data	FAO, 2015
3	Distance to river	km	Map/ Satellite data	FAO, 2015

Data Analysis

Site selection analysis based on the method used by FAO [3] consists of three parts, namely: 1. Identification of important parameters that directly affect the success of aquaculture activities. These important parameters include primary data and secondary data used to build spatial data. 2. Building a spatial model based on primary and secondary data that will produce a spatial database. After that, weighting and scoring of each parameter is carried out. In this stage, references and expert opinions are needed to evaluate the scores and weights of each parameter. 3. Spatial modeling overlaying the results of weighting and scoring to produce a land suitability map for floating net cage culture activities in the research location. The following is presented in Figure 2 of the flow chart in the site selection analysis. The weighting and scoring of each parameter are based on the suitability matrix created by FAO [3]. In this study, the matrix was modified to give weight to each parameter which was adjusted to the existing conditions of the research location. In addition, the weight value for each parameter is based on the opinions of several experts with the largest weight value of 0.5 and the smallest weight value of 0.15. The scoring value for each parameter is 4 as a representation of highly suitable parameters, score 3 for suitable class, score 2 for conditionally suitable class, and score 1 for unsuitable class. The following table 2 presents information on the suitability matrix for floating net cage culture.

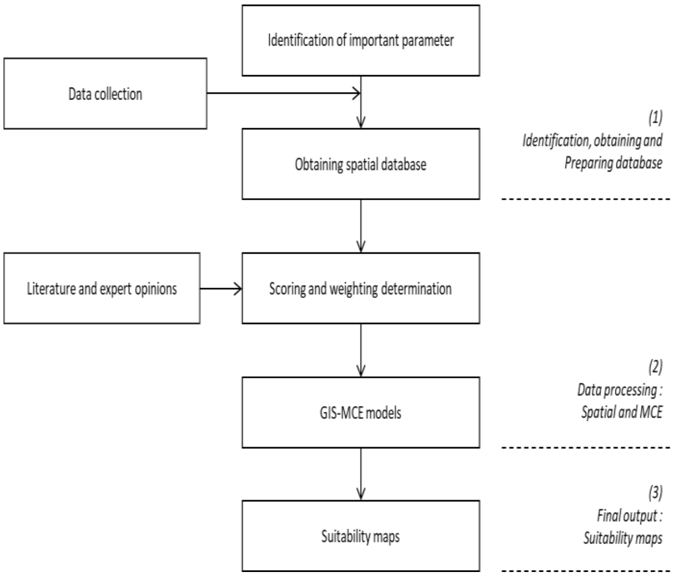

Figure 2. Flowchart of Site Suitability Analysis

Weighting and scoring for each parameter are based on the suitability matrix created by FAO [3]. In this study, the matrix has been modified to assign weight values to each parameter, adjusted to the existing conditions of the research location. Additionally, the weight values for each parameter are based on the opinions of several experts. The scoring values for each parameter are as follows: 4 as a representation of highly suitable, a score of 3 for suitable, a score of 2 for conditionally suitable, and a score of 1 for not suitable. Table 2 below provides information about the suitability matrix for floating cage aquaculture at the research location

Table 2. Suitability Matrix for Floating Grouper Cage

No	Parameter	Weight	Category and Score							
			S1	Score	S2	Score	S3	Score	N	Score
A	**Environmental**									
1	Area	40	Close	4	Semi Close	3	Temporary Close	2	Open	1
2	Bathymetry (m)		10-20	4	20-25	3	25-30	2	<10 & >30	1
3	Wave Current (cm/det)		5-15	4	15-25	3	25-35	2	<5 & >35	1
4	Substrate		Sand and Rubble	4	Muddy Sand	3	Sandy Mud	2	Mud	1
B	**Water Quality**									
1	Ammonia (NH3-N) (mg/L)	40	<0.1	4	0.1-0.2	3	0.2-0.3	2	>0.3	1
2	Nitrat (NO3-N) mg/L		<0.1	4	0.1-0.2	3	0.2-0.3	2	>0.3	1
3	Phosphat (PO4-P) (mg/L)		<0.2	4	0.2-0.4	3	0.4-0.6	2	>0.6	1
4	Transparency(m)		80-100	4	60-<80	3	40-<60	2	<40	1
5	Dissolve Oxygen (mg/L)		>5	4	3-5	3	1-3	2	<1	1
6	Salinity (ppt)		31-35	4	28-31	3	25-28	2	<25 & >35	1
7	Water Temperature (°C)		28-32	4	25-28	3	20-25	2	<25 & >32	1
8	pH (mg/L)		>7	4	6-7	3	4-6	2	<4	1
C	**Socio-Infrastructure**									
1	Distance to Settlement (km)	20	<3	4	3-4	3	4-5	2	>5	1
2	Distance to harbour (km		>1.5	4	1.00-1.50	3	0.75-1.00	2	<0.75	1
3	Distance to River (km)		>1.00	4	0.75-1.00	3	0.50-0.75	2	<0.50	1

Modelling GIS-MCE

The first step in spatial analysis is to build a database sourced from field sampling results. This sampling data is in the form of spatial and non-spatial data that will be integrated in the suitability analysis process.

The collected data is then spatially analyzed based on the type of data to be used. Data with point types are analyzed using the IDW (*Inverse Distance Weighting*) interpolation method, which is a simple deterministic method that considers the surrounding points [13] in [14]. The interpolation results using IDW will produce interpolated values that are closer to the sample data than those that are farther away. The weight change will change linearly based on the distance to the sample data so that the weight will not be affected by the location of the sample data [14]. For social infrastructure data, the buffer analysis method is used to calculate the ideal distance in the suitability analysis.

There are three types of approaches in analyzing GIS-based suitability, namely (a) computer-assisted overlay mapping, (b) multicriteria evaluation methods, and (c) AI (soft computing or geocomputation) [15]. The Multi-Criteria Evaluation (MCE) method functions in

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inventorying, classifying, analyzing, and organizing available information about decisions in planning activities [16] in [17]. MCE combines information from several criteria to create an evaluation index that will be used in making a decision [17]. One model that is widely used in the MCE method is the GIS-based Weighted Linear Combination (WLC) model, which is applied in land use activities/suitability analysis, site selection, and evaluation of natural resource problems [18]. The WLC analysis uses the equation below based on Hanbali [17].

$$S = \sum_j w_i \ x_i \tag{1}$$

S = Suitability
w_i = weighting of factor i
x_i = criterion score of factor i

The WLC method is easy to implement in geographic information systems using map algebra operations and cartographic modeling [19], [20], [18]. The steps required in using this method are (1) defining a set of attributes (goals and associated map attributes), (2) identifying a set of suitable alternatives, (3) obtaining equivalent map attributes, (4) determining criteria weights (i.e., weights of relative importance directly assigned to each attribute), (5) combining equivalent map attributes and weights using multiplication and addition overlay operations to obtain an overall score for each cell (alternative), and (6) ranking alternatives according to the total overall score, where the highest score is the best choice [18].

Results And Discussion

Environment

The area planned for grouper aquaculture is a large and protected (semi-enclosed) bay area. Semi-enclosed areas are recommended for grouper farming because the waters are protected from strong currents, waves, and winds. Consideration ofing the protection of the location has the benefit that the KJA installation is not damaged or lost due to strong currents, waves, and winds.

The current speed at the study site was found to be 5–50 cm/sec, with an average current speed that dominates this area of around 5–30 cm/sec. The calm current conditions in this area are caused by geomorphological conditions in the form of bays with circulating waters that are indirectly exposed to the open sea. Based on the scoring results, four classes are obtained: very suitable, suitable, conditionally suitable, and unsuitable. Areas with highly suitable to conditionally suitable classes are found in 75% of the total area of Kulisusu Bay, leaving 25% of the area in the unsuitable category. These unsuitable areas are locations with current speeds of up to 50 cm/sec. This condition occurs because the location is at the mouth of the bay, where the influence of the open sea is very dominant.

Water depth conditions range from 0 to 50 meters, where depth influences several important aspects of grouper culture, such as protection from weather disturbances, water temperature, dissolved oxygen, and fish growth. Floating net cages located at a depth of 10–25 meters will be better protected from external weather disturbances, such as storms and large waves. In addition, the appropriate depth will provide sufficient space for fish to grow without restrictions. Based on the scoring results, four classes were obtained: highly suitable, suitable, conditionally suitable, and unsuitable. The percentage of highly suitable and suitable class areas is about 67%, the conditionally suitable class area is about 18%, and the unsuitable class area is 15%.

The substrate types found at the study site are mud, sandy mud, muddy sand, and rubble sand. Substrates such as mud and sandy mud are not recommended for aquaculture activities because they can affect clarity and circulation. Mud-to-sand mud substrates were found in 43% of the sites because Kulisusu Bay has many mangrove formations. Sand and rubble substrates were found in as much as 57% of the study locations, which are quite far away or free from the influence of mangrove growth formations. The following map presents the condition of environmental parameters.

Water Quality

Seawater quality parameters are important variables to know in determining the suitable location for grouper KJA aquaculture activities. Water quality conditions are presented in the **Figure 3**. Based on the results of the study, ammonia water conditions ranged from 0.02-0.9 mg/l. Ammonia levels in water can have an influence on aquaculture activities, including causing stress, respiratory system disorders, growth, and digestion. In general, the waters of Kulisusu Bay have a safe ammonia value for grouper floating net cage aquaculture activities with a percentage area of about 90% of the total planned area.

The next parameter is phosphate, with measurement results ranging from 0.2-0.41 mg/l. Phosphate needs to be considered in floating net cage aquaculture activities because at high concentration levels it can cause an increase in nutrients, which can lead to the phenomenon of eutrophication. The phosphate concentration at the study site shows results that are suitable for aquaculture activities.

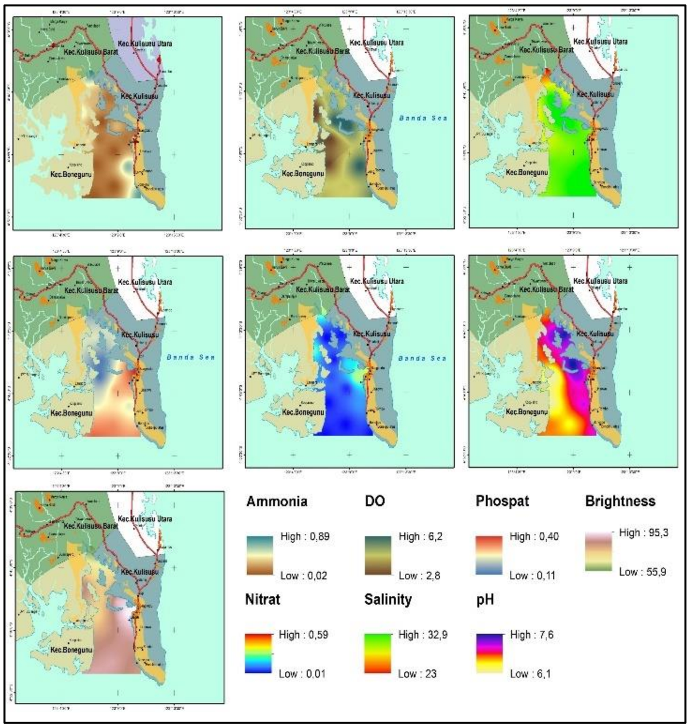

Figure 3. Water Quality Maps

Brightness conditions at the study site were obtained in the range of 56-95 m. Brightness affects several aspects of aquaculture such as growth, feeding behavior, and fish health. For the brightness value at the study site, the results are very suitable for aquaculture activities.

Dissolved oxygen ranges from 2.9-6.3 mg/l, and the dissolved oxygen level is suitable for grouper aquaculture activities. Dissolved oxygen plays an important role in the success of aquaculture activities because it has an impact on fish feeding behavior. Waters with low dissolved oxygen cause grouper to be less active in finding food, which can interfere with growth.

Water salinity ranges from 23-33 ppt. For grouper aquaculture activities, salinity ranges from 28-35 ppt. Salinity plays an important role in the grouper osmoregulation process. If salinity conditions are not suitable, it can cause difficulties in the grouper's osmoregulation system, which can affect the electrolyte balance in the fish's body.

Grouper is a tropical fish that is very sensitive to temperature changes. The water temperature ranges from 28-29 ^{o}C, which is ideal for grouper farming activities.

pH is an important parameter in grouper culture and significantly influences fish health, growth, and performance. The pH conditions of the waters in the selected candidate sites range from 6.1-7.7. Grouper fish prefer alkaline waters.

Socio-Infrastructure

Social infrastructure plays an important role in the success of grouper floating net cage farming. This research focuses on distance to settlements, distance to rivers, and distance to ports. The three parameters are interrelated in determining the location plan for grouper KJA cultivation activities. The distance to settlements from the ideal location of culture activities is <3 km, where most of the waters in Kulisusu Bay are close to settlements. The closer the distance between the settlement and the KJA location, the easier it will be for farmers to control the condition of the cages, and the costs incurred in culture activities can be minimized, especially related to fuel for the culture site. Socio-infrastructure are presented in the **Figure 4**.

The next parameter is the distance to the river from the aquaculture site. The larger the distance between the river and the culture site, the better. This is related to changes in water quality, especially salinity and turbidity. Good salinity for grouper KJA activities ranges from 31-35 ppt. If the planned location is close to the river mouth, changes in salinity can fluctuate, especially when the river discharge is large during the rainy season. The river also carries suspended material from the land that will have an impact on increasing TSS at the Grouper KJA site. Aquatic organisms such as grouper cannot tolerate an environment filled with suspended solids that can accumulate in the gills of fish, causing death because the oxygen diffusion process in the gills does not run properly.

The next parameter is the distance from the port to the culture site. The farther the distance from the port to the culture site, the better. This is related to the flow of ship traffic. Waters with many ship crossings allow grouper KJA to be hit by passing ships.

Land Suitability Assessment

Based on the results of spatial analysis, four suitability classes were obtained at the study site, namely, highly suitable class, suitable class, conditionally suitable class, and unsuitable class. The land suitability map is presented in the **Figure 5**. These suitability results are the result of overlaying thematic maps from the suitability matrix for floating net cage culture. The area for each suitability class is as follows: highly suitable class 2,253 ha, suitable 810 ha, conditionally suitable 1,878

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ha, and unsuitable 3,775 ha. The highly suitable and suitable classes on the map are concentrated in the center of Kulisusu Bay.

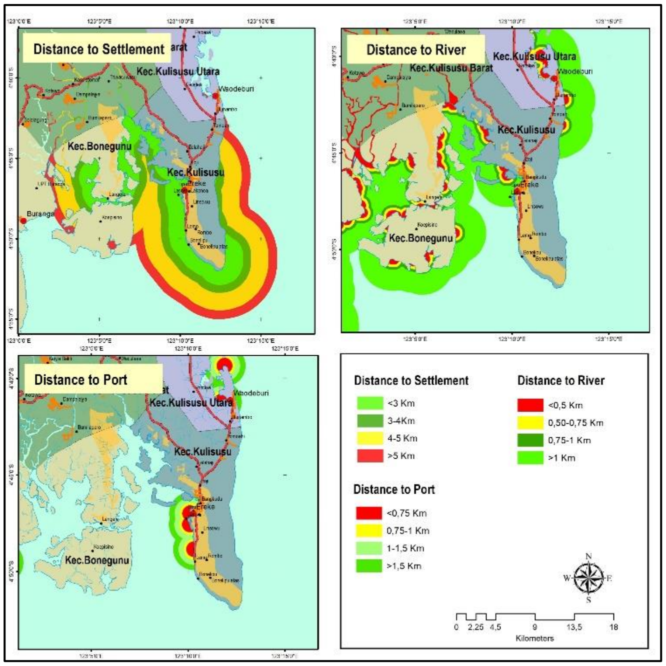

Figure 4. Socio-Infrastructure Map

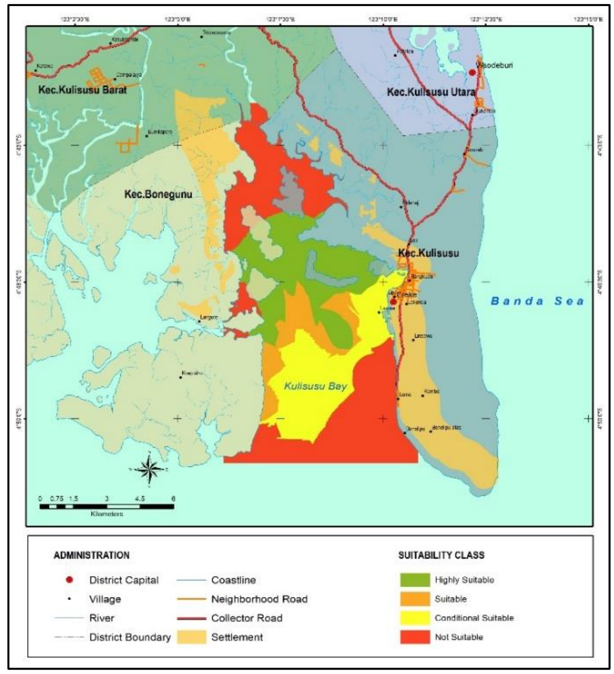

Figure 5. Land Suitability Map

Environmental conditions that tend to be closed and there are several islands around it make this area more protected from large currents and waves from the Banda Sea. Water quality factors in this area are better when compared to other areas. Infrastructure parameters such as the distance between the culture site and the settlement obtained ideal results to support culture activities in this area. The distance from the river is far enough in the selected area to avoid input from the river that will make salinity decrease, increase TSS which affects the development of grouper. The distance between the selected location and the harbor is far enough for aquaculture activities, providing the advantage of less ship traffic in the waters.

Conclusions

The waters of Kulisusu Bay, with a total area of 8,716 ha, have great potential for the development of grouper driftnet cage farming. Specifically, there is potential for 2,253 ha within the highly suitable class and 810 ha within the suitable class. This significant potential requires support from various parties, such as the government, to ensure that this aquaculture activity becomes sustainable by applying environmentally friendly principles. Additionally, it is important to consider other culture activities in the area to avoid overlapping use of Kulisusu Bay

Conflicts of interest

There is no conflict of interest in this research or journal writing.

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