Water Environment Suitability for Mari-culture using Landsat Image 8 OLI/TIRS

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ABSTRACT: Marine aquaculture (mari-culture) has been promoted prominently to increase fish productivity to fulfill the market demands. These raises of demands required information of which water environment that suitable for marine aquaculture so farmer or investor are able to get a picture before investing. Several studies utilizing remote sensing imageries for aqua-culture and mari-culture has been utilize intensively in last 10 years. However, scale and accuracy aspects haven't been discussed to provide robust method in using remote sensing data for deriving environment information related to mari-culture. Therefore, this research was conducted to determine the robust method, scale and accuracy for mapping the suitability of the water environment for mari-culture specifically for floating net cages based.

This study was conducted in Pannikian Island, Barru Regency, South Sulawesi, which is well knowns as potential for marine aquaculture, which is floating net cages ('fcn'). However, data and information suitability of waters for fish cultivation with floating net cages in these area not yet available. The water qualities analyzed in laboratory are pH, brightness, temperature sea level, suspended solid charge (MPT), salinity, and chlorophyll-α. Temperature parameters sea level, MPT, and chlorophyll-α can be extracted through Landsat 8 OLI/TIRS imagery acquired on 12 April 2019. The rest parameters refers to previous research and legacy data for validation using several regression methods.

Spatial analysis and interpolation in Geographical Information Systems used to determine the suitability of the waters for fish farming with 'fcn'. The final level of conformity is determined using the weighted overlay method for the whole parameters. The results showed that in the study area there were 4 (four) classes suitability, namely S1 (very suitable) covering an area of 247.68 ha; S2 (accordingly) covering an area of 1081.98 ha; and S3 (conditionally) covering an area of 255.24 ha, and S4 (incompatible) covering an area of 52.65 ha. The scale and accuracy are depended on the resolution and harmonizing the spatial environmental data process deriving from satellite imageries.

1. INTRODUCTION

The coastal areas of Barru Regency have big potential for marine aquaculture with total area of 1.400 ha and the total production reach up to 2.900 tons on 2010 with the number keeps increasing each year. The fish cultivations developed in coastal waters are greatly affected by water quality and environment factors, where those two factors must be considered when selecting the location for fish cultivation (Affan, 2012). The coastal around Pannikiang Island is part of the coastal in Barru Regency which is utilized for fish farming with floating net cages. Floating net cages became the technology that can increase the productivity of fish cultivation in national scale. It is proven from the production in 2016 that reached up to 6,9% from 11,5 million tons in 2015 to 13,2 million tons in 2016 (Deny, 2018). The site selection for floating net cage is affected by physical, chemical, and biological conditions of waters. Therefore, the parameters used are water depth, water clarity, sea surface temperature (SST), total suspended solid (TSS), pH, salinity, chlorophyll-α, and current velocity. The value of SST, TSS, and chlorophyll-α can be extracted through Landsat 8 OLI/TIRS imagery using different algorithms for each parameter. The waters suitability for floating net cage needs to be known before applying it for fish and marine cultivation. However, the data and information about suitability of waters for fish cultivation with floating net cages in these areas are not available yet.

Spatial analysis and interpolation in Geographical Information Systems used to determine the suitability of the waters for fish farming with floating net cages. The remote sensing imagery used is Landsat8 OLI/TIRS with 11 bands in total. Landsat 8 imagery is used because it has thermal bands (band of 10 and 11) which can be used to extract sea surface temperature values. This research aims: (1) to know the waters suitability of floating net cages in coastal waters around Pannikiang Island, and (2) to know how capable Landsat 8 imagery is in modelling some parameters of waters suitability through statistical tests.

2. RESEARCH METHODS AND MATERIALS

2.1 Study Area

The study area covering coastal waters around Pannikiang Island, Barru Regency is located at $4^0$21’47,40” - $4^0$21’51,47” S and $119^0$37’05,87”- $119^0$35’49,76” E. The study area is classified as 3 classes based on its condition, they are area with existing floating net cages, potential area to develop floating net cages, and area with dominant land influence.

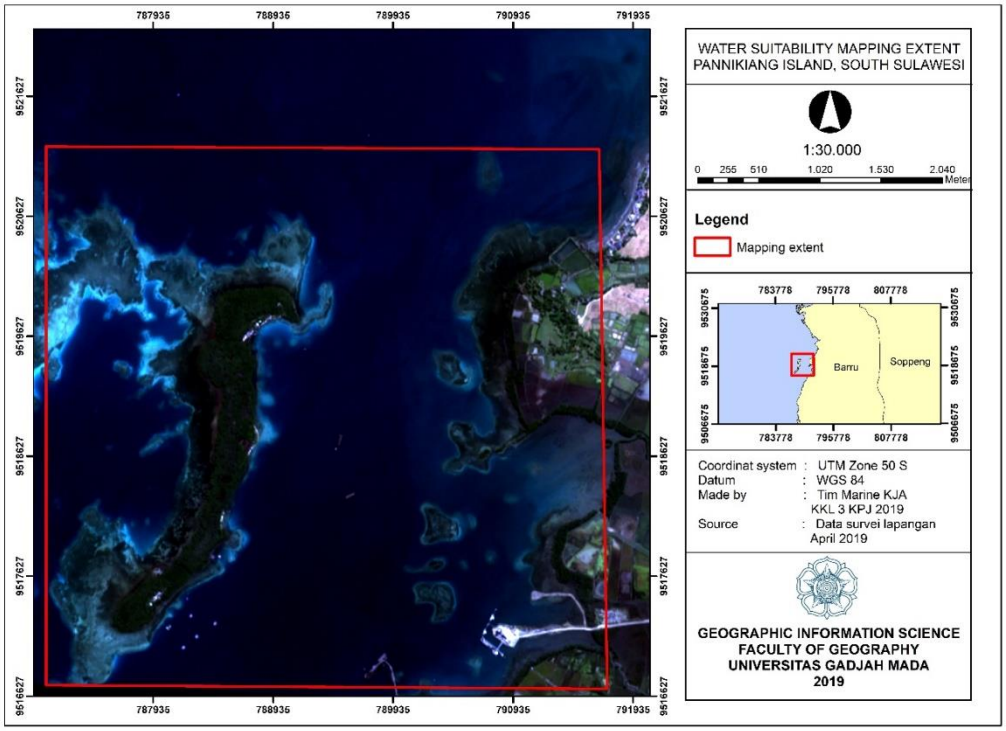

Figure 1. Map of the research area

2.2 Parameters of Waters Suitability

The parameters used are physical, chemical, and biological parameters. There are sea surface temperature, pH, salinity, water clarity, current velocity, water depth, total suspended solid, and chlorophyll-α. The parameters were obtained from field measurements using systematic sampling method. The mapping unit was built based on the overlay result of sea surface temperature, total suspended solid, and chlorophyll-α that were extracted through Landsat 8 imagery and also based on the visual interpretation of turbidity level. The mapping unit was later used to determine the location of samples which would be used to retrieve the field data. There were 35 samples in total for each parameter, except for total suspended solid and chlorophyll-α parameters where there were only 20 samples for those two parameters. The samples of total suspended solid and chlorophyll-α were later laboratory tested to know the field data values of those parameters. The field data values of each parameter were later interpolated using IDW (Inversed Distance Weight) method. IDW method was used because it is more to interpolate the physical data of the coastal area because it does not produce values that exceed the sampled data (Pramono *et al*., 2005). The interpolation results were later reclassified and weighted overlay using score weighted of Trisakti *et al* (2003). The overlay generated the total scores of all parameters that were used to classify the score into suitability classes.

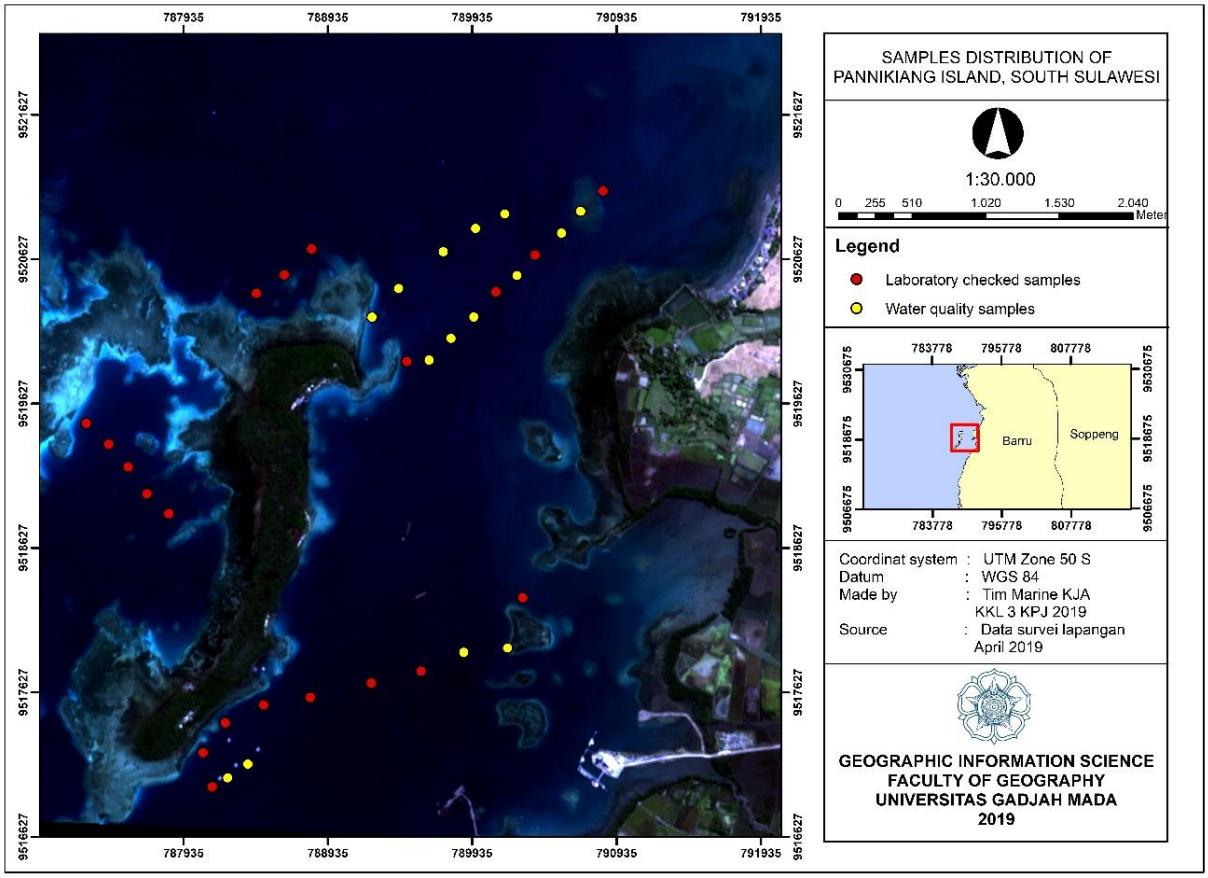

Figure 2. Distribution of samples

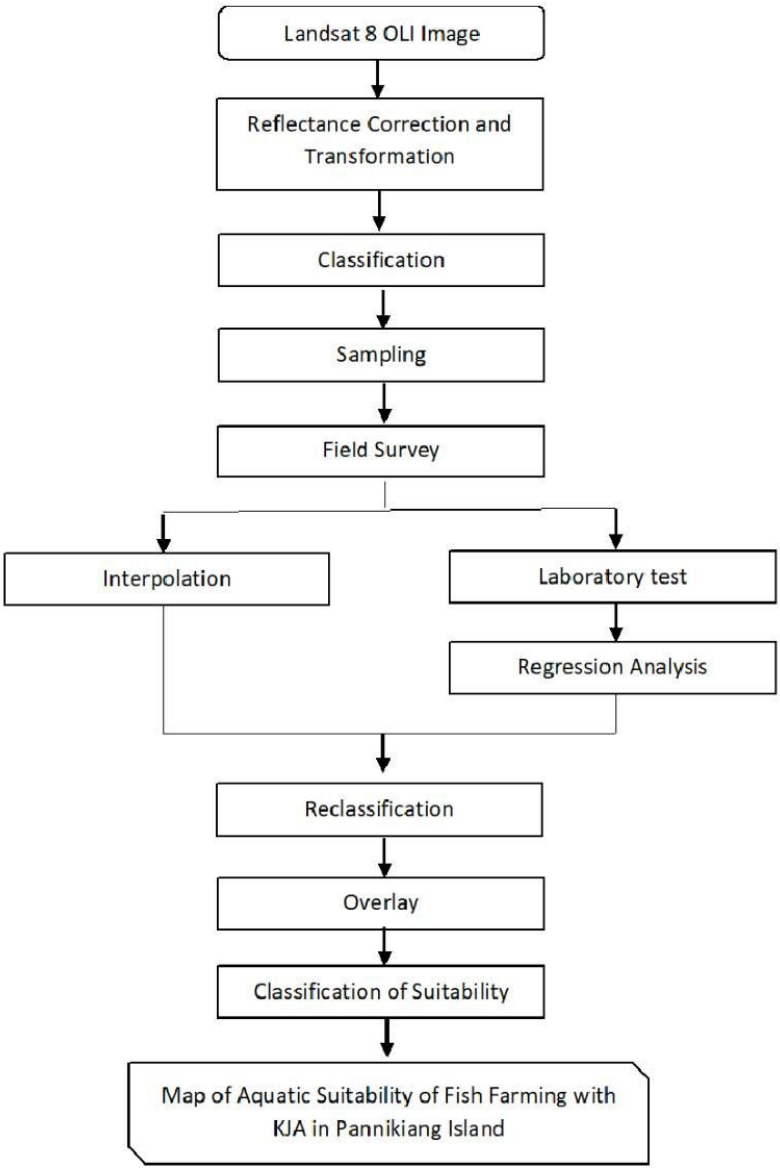

Figure 3. Research flow diagram

No	Parameter	Weight	Very Appropriate/ suitable (S1)		Appropriate/ suitable (S2)		Appropriate conditional (S3)		Not Appropriate (TS)	
			Criteria	Score	Criteria	Score	Criteria	Score	Criteria	Score
1	Depth (m)	9	8<S1≤12	18	12<S2≤16	14	16<S3≤20 4<S3≤8	10	TS>20 TS≤4	5
2	Protection - Direction / current velocity - wave height - wind velocity	8	Very protected	16	protected	15	Less opened	12	opened	5
3	Sea Surface Temperature (SST) (°C)	7	28<S1≤29	14	29<S2≤31 26<S2≤28	12	31<S3≤32 24<S3≤26	10	TS>35 TS≤24	5
4	Salinity (field (ppm))	7	31<S1≤32	14	32<S2≤33 30<S2≤31	12	33<S3≤35 28<S3≤30	10	TS≤28 TS>35	5
5	Turbidity (NTU)	6	S1<5	12	5<S2≤30	10	-	-	TS>30	3
6	Brightness (m)	6	5<S1≤10	12	3<S2≤5 10<S2≤15	10	0<S3≤3 15<S3≤20	8	TS=0 TS>20	3
7	Suspended Solid Load (mg/l)	6	S1≤25	12	25<S2≤80	10	80<S3≤400	8	TS>400	3
8	Chlorophyl-a (µg/l)	5	S1›30	10	20<S2≤30	9	10<S3≤20	7	TS≤10	5
9	pH (field) (-)	5	6.5<S1≤8.5	10	6<S2≤6.5 8.5<S2≤9	9	5<S3≤6 S3>9	7	TS<5	5

Figure 4. Score Weighted Each Parameter according to Trisakti *et al* (2003)

2.3 Remote Sensing Data

The remote sensing imagery used is Landsat 8 OLI/TIRS with acquisition date of April 12, 2019. Landsat 8 OLI/TIRS has 11 bands in total with spatial resolution of 30 meters for multispectral bands, 15 meters for panchromatic band, and 100 meters for thermal bands. The imagery was used to extract the values of SST, TSS, and chlorophyll-α using different algorithms for each parameter. The Landsat 8 imagery had been radiometric corrected before it was used to extract the values of 3 parameters needed. Sea surface temperature values were derived using thermal bands (band 10 and 11) with split window algorithm in equation (1). The concentration of chlorphyll-α was extracted using the formula developed by Hanintyo et al (2016) in equation (2) and the concentration of total suspended solid was extracted using NSMI (Normalized Suspended Material Index) algorithm in equation (3).

$$Ts = BT_{10} + (2.946 \times (BT_{10} - BT_{11}) - 0.038 \quad (1)$$

Where:

Ts : Sea surface temperature (K)

BT_{10} : Brightness temperature on Band 10

BT_{11} : Brightness temperature on Band 11

$$\text{Chl-}\alpha = 0.2818 \times \left(\frac{L_3}{L_2}\right)^{3.497} \quad (2)$$

Where:

Chl- α : concentration of chlorophyll-α (in mg m^{-3})

L_2, L_2 : reflectance of band 2 and 3

$$\text{NSMI} = \frac{L_4 + L_3 - L_2}{L_4 + L_3 + L_2} \quad (3)$$

Where:

NSMI : concentration of TSS (in mg/l)

L_2, L_3, L_4: reflectance of band 2, 3, 4 which has been atmospheric corrected.

3. RESULTS AND DISCUSSION

The visual interpretation of the existing floating net cages in coastal area around Pannikiang Island was done using SPOT 6 imagery because it has higher spatial resolution than Landsat 8 OLI/TIRS imagery. Based on the result of visual interpretation, there were around 10 existing floating net cages. The research area is not located near river estuaries, so that the total suspended solid concentration is not significantly affected by the materials from the land carried by the river.

Water depth has the highest value weight, as shown in **Figure 4**. It means that water depth has significant role and effect in determining the waters suitability for floating net cages. Water depth data were obtained through field measurement with 35 measurement points in total. The result of field measurement showed that the depth in coastal area around Pannikiang Island varies from 0,5 meter to 26,75 meters. According to score weighted shown in **Figure 4**, the variation of depths in research area are classified into 4 classes of suitability, i.e. very suitable class (S1) for the depth between 8 to equal to 12 meters, suitable class (S2) for the depth between 12 to equal to 16 meters, conditionally suitable class (S3) for the depth between 16 to equal to 32 meters and 4 to equal to 8 meters, and incompatible class (S4) for the depth that is more than 20 meters and less than equal to 4 meters. The existing floating net cages in research area are located between 10 to 15 meters under sea level. Waters environment at the depth of 0,5 to 4 meters consists of benthic habitats. Floating net cages cannot be put at depth less than 5 meters, because the residues from the cages can put the benthic habitats below in damage.

The measurement of field data showed that the research area has current velocity ranging from 0,01 – 0,1 m/s and classified as suitable class for floating net cage cultivation. Current has significant role in fish cultivation because it brings the nutrients which are needed by the sea organisms. The condition of water can be classified as good for the cultivation of floating net cages if the water clarity value ranges more than 3 meters because water clarity affects the

level of water turbidity (KLH, 2004). The water clarity measurement was performed using secchi disk and the measurement results showed that the clarity value in research area ranges from 4,5 to 11 meters.

Marine organisms are very sensitive to temperature change (Rusman, 2003) while sea surface temperature affects the biological activities of marine organisms and it also affects their development and metabolism. Based on those facts, sea surface temperature gives big influence to the number of fish population. The result of temperature value extraction using split window algorithm on thermal bands of Landsat 8 OLI/TIRS imagery ranges from 29,30°C to 30°C while the data from field measurement range from 29,30°C to 30,10°C. The concentration of total suspended solid will block the light from entering the waters. It also can be an indicator to measure the productivity of marine organisms. The highest value of total suspended solid concentration in research area is up to 0,7 mg/L. The salinity value around research area ranges from 31 ppm to 33 ppm.

The concentration of chlorophyll-α in waters shows the phytoplankton biomass as the food source of marine organisms and one of the indicators of good water quality is the existence of phytoplankton itself. The result of laboratory test shows that the concentration of chlorophyll-α ranges from 0,4 mg/m^3 to 0,76 mg/m^3 while result of image extraction shows that the concentration is around 0,34 mg/m^3 to 0,75 mg/m^3. The result of field measurement of pH parameter shows that the research area is dominated by pH values ranging from 7,4 to 8,2 and it is classified as very suitable class for floating net cage cultivation while the standard pH value for fish farming ranges from 6,5 to 8,0 (Boyd, 2012).

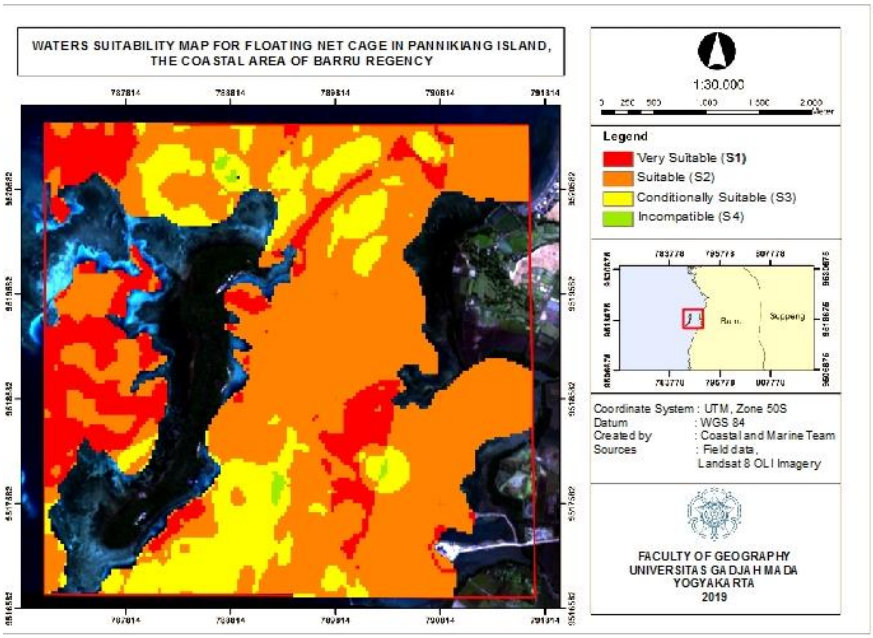

Figure 5. Map of waters suitability for floating net cage cultivation in coastal area around Pannikiang Island.

Based on the suitability map above, we suggest that the placement of floating net cages could be at the coastal waters in the west side of Pannikiang Island because the suitability classes in that area are dominated by very suitable (S1) and suitable (S2) class. However, the placement of floating net cages must consider the existence of benthic habitats since the residuals from floating net cages can damage the benthic habitats below the net cages. Therefore, the placement should not be near or above the benthic habitats and any other coastal ecosystems. Based on the information obtained through the interview with floating net cage farmers, there has not been any water quality tests before on the area of existing floating net cages, so the site selection is only based on the depth and the current protection.

The extracted data from remote sensing imagery needs to be validated with field data. The validation was done through statistic tests on 3 parameters (sea surface temperature, chlorophyll-α, and total suspended solid). The statistic tests applied were data normality test, data correlation test, and regression. Kolmogorov-Smirnov method was applied on the data normality test and the result showed that those 3 parameters were normally distributed so that the data could be parametrically analyzed. Data correlation test showed that the correlation between the extracted

data from remote sensing image and field data ranged from strong enough to strong correlation with correlation value (r) between field data and image extraction data for sea surface temperature, total suspended solid, and chlorophyll-α are 0,584; 0,754; and -0,462. Data correlation test also showed that there was positive correlation for sea surface temperature and total suspended solid, while chlorophyll-α had negative correlation. The result of regression analysis showed the determination coefficient (R^2) for sea surface temperature is 34,11%; 56,91% for total suspended solid; and 23,12% for chlorophyll-α. Chlorophyll-α had lower R^2 value because of the algorithm used to extract chlorophyll-α value from remote sensing s imagery could not describe the condition of chlorophyll-α concentration itself in the field (Hanintyo et al, 2016). The R^2 values show the ability of an image in representing data in the field. The results of the statistic tests were affected by the number of samples, weather, and also sampling time and the results of regression analysis are shown in **Figure 6, 7,** and **8.**

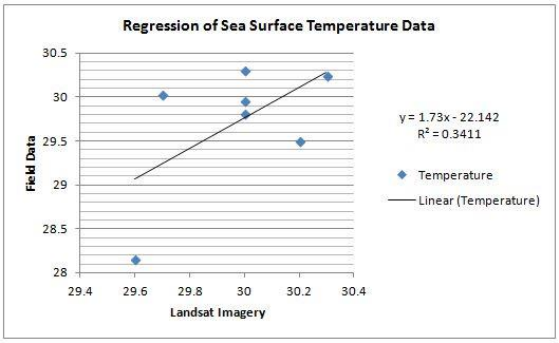

Figure 6. Regression of SST

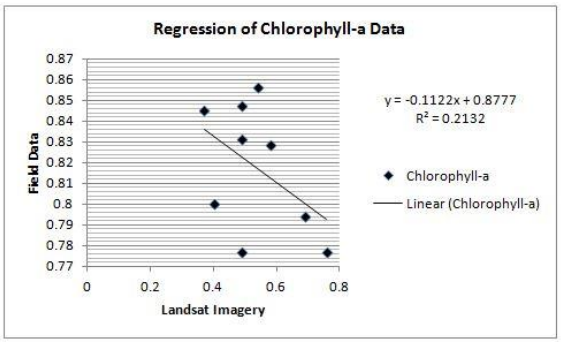

Figure 7. Regression of Chlorophull-α

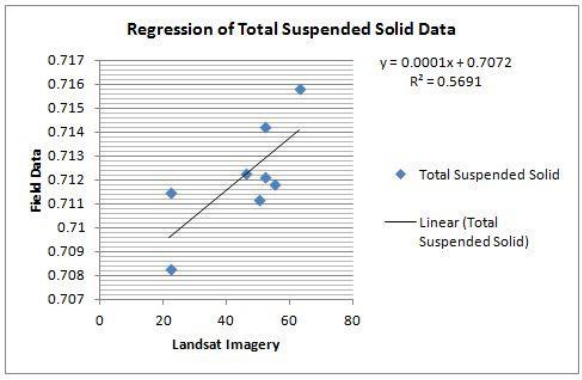

Figure 8. Regression of TSS

Through the spatial modelling in GIS (Geographic Information System), the result showed that the existing floating net cages are laying on the coastal waters with very suitable class. The results of this research can be used in policy making for the preservation of the area of the cultivation with floating net cages.

4. CONCLUSION

The result of field measurements show that the research area around Pannikiang Island has current velocity under 0.15 m/s, sea surface temperature ranging from 29.3°C to 30.1°C, the concentration of chlorophyll-α ranging from 0.4 to 0.76 mg/m^3 with pH value ranging from 7.4 to 8.2. The water depth in research area ranging from 0.5 m to 26.75 m under sea level. The concentration of total suspended solid is up to 0.7 mg/L in the research area and the salinity value ranges from 31 ppm to 32 ppm. The data processing and spatial modelling with GIS result 4 classes of waters suitability for floating net cage cultivation. The result is 15.125% or 247.68 ha of the total area are classified as very suitable class, 66.07% or 1081.98 ha are classified as suitable class, 15.59% or 255.25 ha are classified as conditionally suitable class, and 3.21% or 52.65% are classified as not suitable class. The area of very suitable class is located in the west side of Pannikiang Island that is protected from strong current.

The statistic tests done in this research result the determination coefficient (R^2) and correlation value (r). The correlation value (r) between field data and image extraction data for sea surface temperature, total suspended solid, and chlorophyll-α are 0,584; 0,754; and -0,462. Those values show that there is positive correlation for sea surface

temperature and total suspended solid and negative correlation for chlorophyll-α. The determination coefficient (R^2) for each parameter of sea surface temperature, total suspended solid, and chlorophyll-α are 0.3411, 0.5691, and 0.2312.

The map of waters suitability for floating net cage cultivation in Pannikiang Island can be a reference for the development of floating net cage in research area. Based on this research, the recommended location for floating net cage cultivation is the west side of Pannikiang Island where it is dominated by very suitable and suitable class. The reason for choosing that location for floating net cage is because it is protected from strong current. But the existence of some benthic habitats in that area needs to be considered because floating net cage can damage the existing benthic habitats.

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