Physical waters suitability for floating net cages cultivation mapping using landsat 8 oli and worldview-2 imageries in part of Hurun Bay, Lampung Province, Indonesia

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Abstract. Marine aquaculture has become an important contribution in sustainable world food provision. Sumatra, Indonesia contribute significantly on marine aqua production through intensive floating net cages development which has been long become a source of marine products in domestic and international markets. However, less research conducted on the water quality suitability in this region due to its vast areas and costly water analysis. This research aims: 1) to identify the appropriate spatial resolution between Landsat 8 OLI and Worldview-2 imageries to obtain the chlorophyll-α parameter and total suspended solid data; and 2) to perform spatial analysis to determine the suitable area for floating net cages using remote sensing and GIS for decreasing the analysis cost. The research area is located in Hurun Bay, the southwestern part of Lampung Bay. Biophysical factors considered for the suitability of floating net cages are: water clarity, temperature, salinity, pH, water depth, total suspended solid, and chlorophyll-α, which were obtained from remote sensing imagery and field measurement data. Each parameter value is described based on the level of suitability for a floating net cage. The final map is determined using a weighted overlay approach on all parameters. Biophysical factor data measured were sampled using systematic sampling method. The result shows that Landsat 8 OLI imagery is more appropriately applied in the research area compared to Worldview-2 imagery according to the analyses of correlation, regression, and accuracy assessment. Most of the floating net cages (28.8%) in the research area were classified as conditionally suitable meaning that the research area is less potential for cultivation and thus requires special treatment to improve its capability. The used of remote sensing and GIS approach perform good synoptic overview on the research area and provide multi-temporal data for better analysis on different seasons effectively. The floating net cages cultivation suitability mapping delivered in this research provides powerful data for coastal water planning decision makers.

Keywords: Worldview-2, Landsat 8 OLI, Total Suspended Solids, Chlorophyll-α, Suitability, Hurun Bay

1. Introduction

The coastal areas in Hurun Bay, Pesawaran Regency of Lampung Province is one of the potential prospective areas for marine aquaculture in Indonesia. Various potential marine aquaculture commodities include shrimps, milkfish, snapper, and groupers. Sea cultivation in coastal areas of

Pesawaran Regency becomes one of the sub-sector in aquaculture which has a big chance to increase its production volume to continuously supply consumer demand. Based on statistical data from the Ministry of Marine and Fisheries in 2015, the trend of Indonesian fishery production has increased since 2010. The average increase of 2010-2014 was 15.80 % with an average production of 16.2 million tons, the standard deviation of 3.8 million tons and 95 % confidence interval between 11.4 million-21.0 million tons. The contribution of aquaculture continues to increase since 2010 about 6.42 % and the average contribution for five years was 62.35 %. This shows that in the last 5 years and several years ahead, aquaculture has been considerably stable and potential for fishery production in Indonesia. One of the methods that have been applied to increase the productivity of coastal waters is applying the floating net cage for fish culture [1]. The productivity of marine aquaculture in coastal waters is greatly influenced by the increasing demand of coastal areas and resources by other activities that lead to competition in the utilization of space and resources, particularly port activities and shipping routes and other domestic activities [2]. To minimize this destruction of fish habitat and to increase marine aquaculture business, it is necessary to have a spatial coastal suitability research in order to plan the cultivation that can be taken place in a sustainable way. This research is taking the characteristics and carrying capacity of the environment into account to minimize the impact and to conserve natural resources.

The availability of remote sensing data can be utilized for the acquisition of various information such as information on the condition of natural resources and the phenomenon of human activities as well as marine aquaculture. Utilization of remote sensing and Geographic Information System (GIS) has contributed significantly to the development of aquaculture fisheries [3]. In the field of aquaculture fisheries, remote sensing and GIS applications can be utilized at various stages ranging from planning, management, and monitoring with respect to parameters that affect the aquaculture fisheries. The integration of remote sensing data and GIS approach is used to store, analyze, and display data and information on the suitability of floating net cages based on water quality properties. However, the development of algorithms to obtain total suspended solids (TSS) and chlorophyll-α is still rarely to be conducted. Several reference studies on this topic were carried out by [4] and [5], but both are conducted in regions with different geographic conditions compared to the Hurun Bay. Therefore, this research attempts to develop algorithms for the extraction of total suspended solids and chlorophyll-α data using Worldview-2 imagery. The Worldview-2 imagery has a higher spatial resolution than the Landsat 8 OLI imagery although it has more band. The initial hypothesis of this research is the higher the spatial resolution of the imagery used in this water quality analysis the more accurate data can be obtained. Therefore, this research aims: 1) to know the appropriate spatial resolution between Landsat 8 OLI and Worldview-2 imagery to obtain the chlorophyll- α parameter data and total suspended solid in the floating net cages cultivation suitability mapping; and 2) to perform spatial analysis to determine the suitable area for floating net cages using remote sensing and GIS to decrease the analysis cost.

2. Research Methods

Data used in this research are remote sensing imageries, bathymetry, and field data. Remote sensing imageries used are Landsat 8 OLI TIRS imagery recorded from January 2016 to March 2017; Terra-MODIS imagery recorded from January 2016 to March 2017; and Worldview-2 imagery recorded on 6 August 2016. Biophysical factors considered for the suitability of floating net cages are: water clarity, temperature, salinity, pH, water depth, total suspended solid, and chlorophyll-α. GPS tools was used to plot the location of the samples, pH meter to measure pH, *secchi disk* to measure water clarity, refractometer to measure salinity, current meter to measure current velocity, digital thermometer to measure temperature, depthmate portable sounder to measure water depth, sample bottle, and bottle pickers. The data was processed using ArcGIS software. To get the suitability level for a floating net cage, each parameter is scored according to [8] in **Table 1**. Research flow diagram can be seen in **Figure 2**.

Table 1. Weighted score of physical waters suitability for floating net cages parameters according to Trisakti [8] with modification

Parameter - (Weight)	Very Suitable (S1)		Ssuitable (S2)		Conditionally Ssuitable (S3)		Not Ssuitable (TS)	
	Criteria	Score	Criteria	Score	Criteria	Score	Criteria	Score
Water ddepth (m) – (9)	$8<S1\leq12$	18	$12<S2\leq16$	14	$16<S3\leq20$ $4<S3\leq8$	10	$TS>20$ $TS\leq4$	5
Sea surface temperature (SST) (^{o}C) – (7)	$28<S1\leq29$	14	$29<S2\leq31$ $26<S2\leq28$	12	$31<S3\leq32$ $24<S3\leq26$	10	$TS>35$ $TS\leq24$	5
Salinity (ppm) – (7)	$31<S1\leq32$	14	$32<S2\leq33$ $30<S2\leq31$	12	$33<S3\leq35$ $28<S3\leq30$	10	$TS\leq28$ $TS>35$	5
Water clarity (m) – (6)	$5<S1\leq10$	12	$3<S2\leq5$ $10<S2\leq15$	10	$0<S3\leq3$ $15<S3\leq20$	8	$TS=0$ $TS>20$	3
Total suspended solids (mg/l) – (6)	$S1\leq25$	12	$25<S2\leq80$	10	$80<S3\leq400$	8	$TS>400$	3
Chlorophyll-α (µg/l) – (5)	S1›30	10	$20<S2\leq30$	9	$10<S3\leq20$	7	$TS\leq10$	5
pH – (5)	$6.5<S1\leq8.5$	10	$6<S2\leq6.5$ $8.5<S2\leq9$	9	$5<S3\leq6$ $S3>9$	7	$TS<5$	5

Remote sensing data were processed before conducting sampling in the field. Data processing performed included applying the algorithms to extraction of sea surface temperature, chlorophyll-α, and TSS values. Sea surface temperature data was derived using thermal bands from Landsat 8 OLI and MODIS Terra imageries using split window algorithm [6]. Chlorophyll-α data can be extracted using Landsat 8 OLI imagery with the formula developed by Hanintyo *et al.* (2015) in [7]. Distribution of chlorophyll-α from Landsat 8 OLI was obtained from the equation (1).

$$\text{Chl-}\alpha = 0.2818 \times \left(\frac{L_4+L_5}{L_3}\right)^{-3.497} \quad (1)$$

where:
Chl- α : concentration of chlorophyll-α (in mg m^{-3})
L_3, L_4, L_5 : reflectance of band 3, 4, 5

The concentration of TSS data can be extracted using Landsat 8 OLI imagery using Normalized Suspended Material Index (NSMI) formula in equation (2).

$$\text{NSMI}=\frac{L_4+L_3-L_2}{L_4+L_3+L_2} \quad (2)$$

where NSMI is concentration of TSS (in mg/l) and L_2, L_3, L_4 are reflectance of band 2, 3, 4.

The extracted data were superimposed to produce a water mapping unit. This new mapping units were used to determine the number and location of sample point using systematic or grid sampling method. This sampling method is a type of sampling technique with a systematic sample sites, where there is a similar probability to select each unit that representing the population of units. The systematic method sampling is chosen because it has several advantages which is reducing the potential of bias in the selected sample points. Systematic sampling also provides a highly representative sample based on the population under research, assuming if there is missing data. **Figure 1** shows the distribution of sample in the research area.

Field work is done to obtain parameters that cannot be extracted from imageries or other secondary data. It is also used to perform the regression between the value of extracted field data. 31 samples taken in the field, which 16 samples is used to build model and 15 samples is used to test the accuracy of model. Salinity, pH, water clarity, temperature, and water depth data were obtained by direct measurement in the field. While chlorophyll-α and TSS data were obtained by conducting laboratory examination. In addition, salinity data is also laboratory tested for more accurate results. The field data has been obtained then processed to construct and validate the model results made from imagery extraction. After processed all data, they were used for accuracy assessment, doing data regression, and testing the correlation between field data and pixel values in the image.

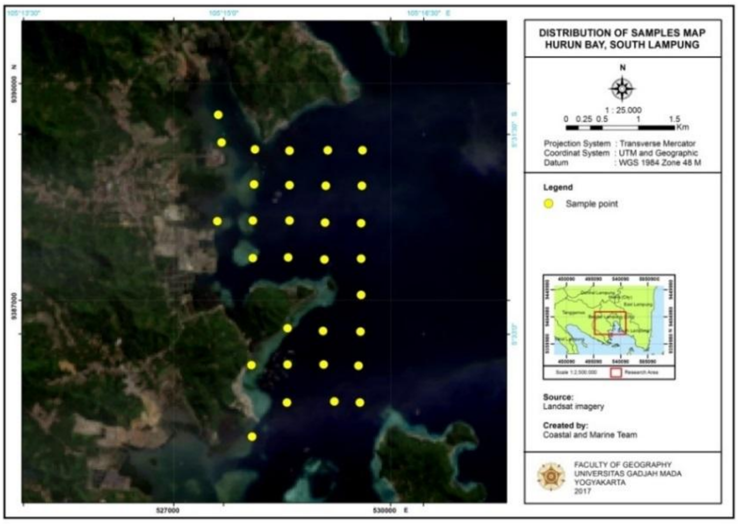


Figure 1. Distribution of samples

The Worldview-2 imagery was used in this research for several uses: 1) plotting the existing floating net cages location, 2) delineating more detailed research area, and 3) obtaining TSS and chlorophyll-α. Image capability of Worldview-2 was tested by correlation analysis between each radiometric correction band with the measurement data in the field. After that, the correlation value of the Worldview-2 imagery was compared to the correlation value of Landsat 8 imagery to determine the extent of Worldview-2 imagery's capability in obtaining TSS and chlorophyll-α data compared to Landsat 8 imagery. Landsat 8 and Worldview-2 imageries specification can be seen in **Table 2.**

Table 2. Landsat 8 and Worldview-2 imageries specification

Imagery	Spectral resolution	Spatial resolution
Worldview-2	Coastal (400 – 450 nm) Blue (450 -510 nm) Green (510 – 580 nm) Yellow (585 – 625 nm) Red (630 – 690 nm) Red Edge (705 – 745 nm) Near-IR1 (770 – 895 nm) Near-IR2 (860 – 1040 nm)	1.85 meters
Landsat 8 OLI	Coastal/Aerosol (435 – 451 nm) Blue (452 – 512 nm) Green (533 – 590 nm) Red (636 – 673 nm) NIR (851 – 879 nm) SWIR-1 (1566 – 1651 nm) SWIR-2 (2107 – 2294 nm) Cirrus (1363 – 1384 nm)	30 meters

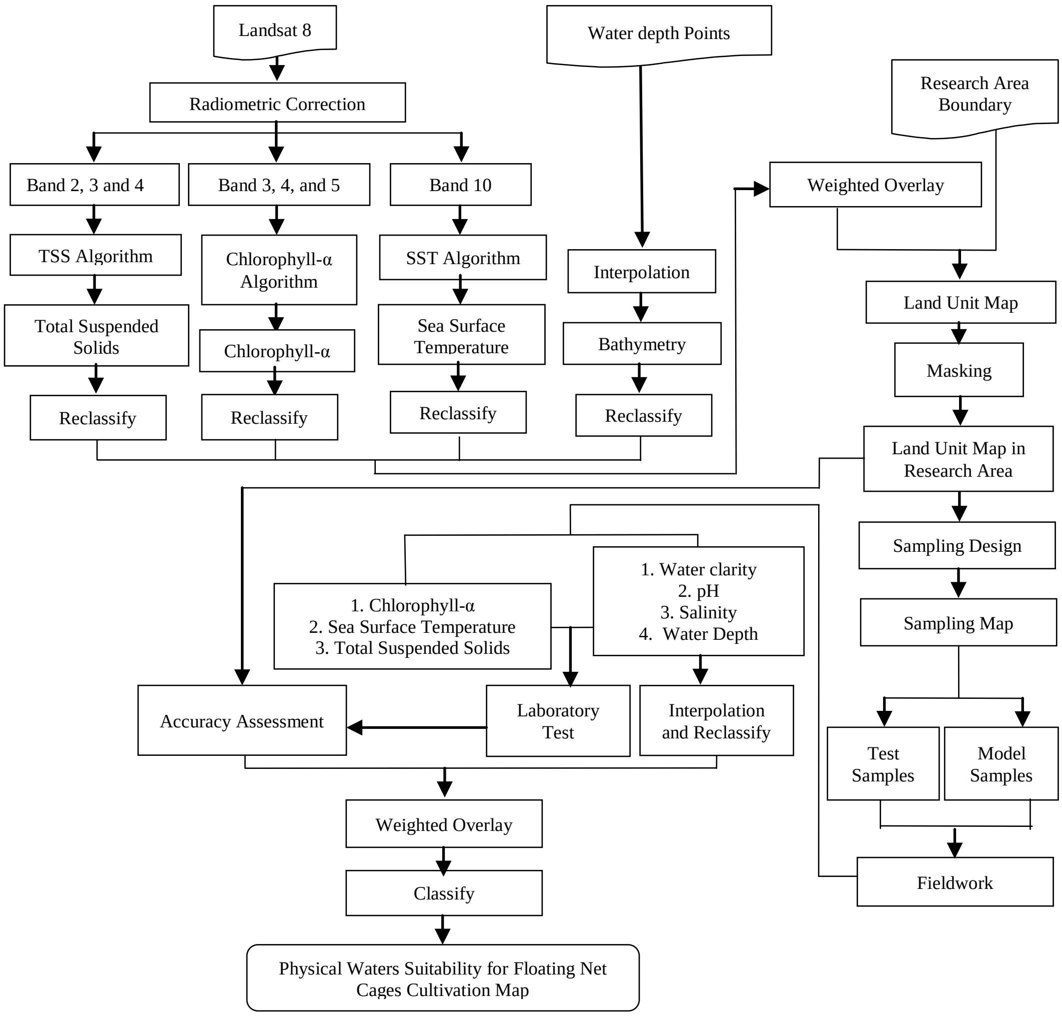


Figure 2. Research flow diagram

3. Result and Discussion

3.1. Accuracy Assessment of Chlorophyll-α and Total Suspended Solid Parameter from Landsat 8 OLI and Worldview-2 Imageries

Water parameters extraction using different spatial resolution remote sensing imageries produce different results. To find out which band is best used in water environment suitability parameters extraction for floating net cages, it is necessary to compare water quality parameters value extracted from both Landsat 8 OLI and WorldView-2. Comparing these two results is only done on two types of parameters, i.e. chlorophyll-α and TSS parameters. Comparison method for two imageries is regression and correlation between the field results and parameter extracted from remote sensing imageries (**Figure 3 and Figure 4**). Image correction for Landsat 8 OLI imagery is differ from Worldview-2 imagery. In general, Landsat 8 OLI is sufficiently corrected by using geometric and atmospheric correction. Whereas for Worldview-2, sunglint correction is required. Sunglint is a disturbing factor in remote sensing, especially on the shallow water bottom habitat mapping. Sunglint is derived from wave. Sunglint correction is considering the number of resolution in the satellite imagery. In fact Worldview-2 imagery has a higher spatial resolution, so sunglint is more visible than in Landsat 8 OLI imagery.

The correlation value for field TSS and NSMI of Landsat 8 OLI is 0.31 (low correlation), whereas the correlation value for field TSS and Worldview-2 image is 0.33 (low correlation). With such a correlation value, the Landsat 8 and Worldview-2 algorithms were not very appropriately applied in extracting TSS in the research area. Meanwhile, the correlation value for field chlorophyll-α data and Landsat 8 OLI image processing is -0.64 (high correlation), while for Worldview-2 image is 0.17 (very low correlation). The Landsat 8 OLI is considered more appropriately applied in the research area for chlorophyll-α data extraction than Worldview-2 imagery due to higher correlation values. Using Landsat 8 OLI, the accuracy of TSS is equal to 91.59% with value RMSE 0.01, while the accuracy of chlorophyll-α is 61.15% with RMSE 24.91.

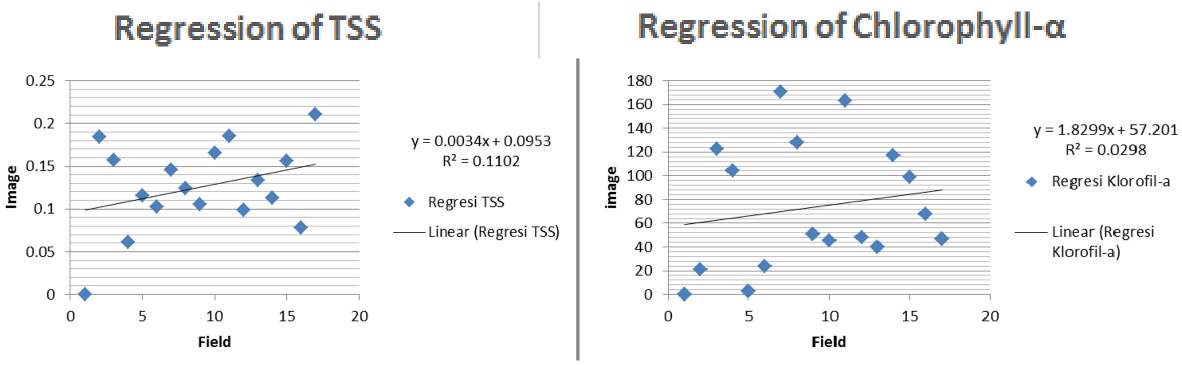


Figure 3. Regression of TSS and Chlorophyll-α of Worldview-2 Imagery

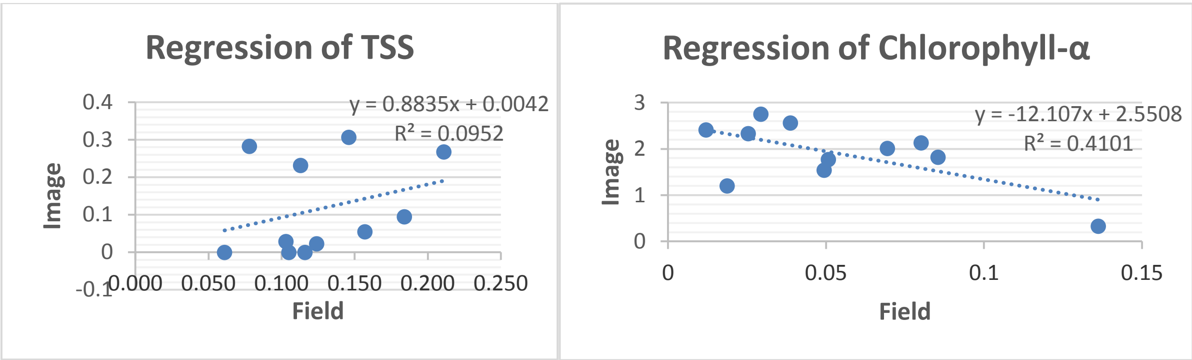


Figure 4. Regression of TSS and Chlorophyll-α of Landsat 8 OLI Imagery

The comparison of correlation values indicates that Landsat 8 imagery is better in obtaining data of TSS and chlorophyll-α compared to Worldview-2 imagery. This result can be explained from the type of band used, seen in **Table 3**. Image processing by using multiple channel combinations is able to give each band advantage so that the result is better than just using a single band. Then, Worldview-2 Imagery has not done geometric correction using local GCP data so that with high spatial resolution it is possible to experience a larger shift so the field data does not match the pixel position in the image and resulting low correlation. In contrast, Landsat 8 OLI imagery which has a spatial resolution of 30 m still has 900 m^2 tolerance so when there is an error in sampling, the correlation between field data and pixel values in the image is still acceptable. Higher spatial resolution imagery does not guarantee higher accuracy of its obtain data because both spectral and spatial resolution have more influencece in this issue. In the future work, we recommend to use same recording date and same spectral resolution imagery for getting the better result.

Table 3. Comparison of correlation and the best band results

Imagery	**Total suspended solid**		**Chlorophyll-α**	
	Best band	R^2	**Best band**	R^2
Worldview-2	Green	0.11	Green	0.03
Landsat 8 OLI	Blue, Green, Red	0.09	Green, Red, NIR	0.41

3.2. Total Suspended Solids

There are 23 existing floating net cages which have been visually interpreted using Worldview-2 imagery recorded on August 6, 2016. It can be seen in **Figure 5**. The water environment consists of fields, ponds, and mangrove forests. There are no river estuaries but only a ditch outlet that served as a drainage channel from settlements or irrigation canals. In July 2016, the average rainfall was 1.85 mm, while the average rainfall in November was greater, at 9.54 mm. Using multi-temporal analysis, it is known that the distribution of TSS each month has been changing, even though they are not significant. Based on these observations, it can be concluded that TSS concentration is less dynamic but it affected suitable areas distribution for floating net cages cultivation at different time. Image processing result for TSS parameters before and after field survey are presented in **Figure 6**.

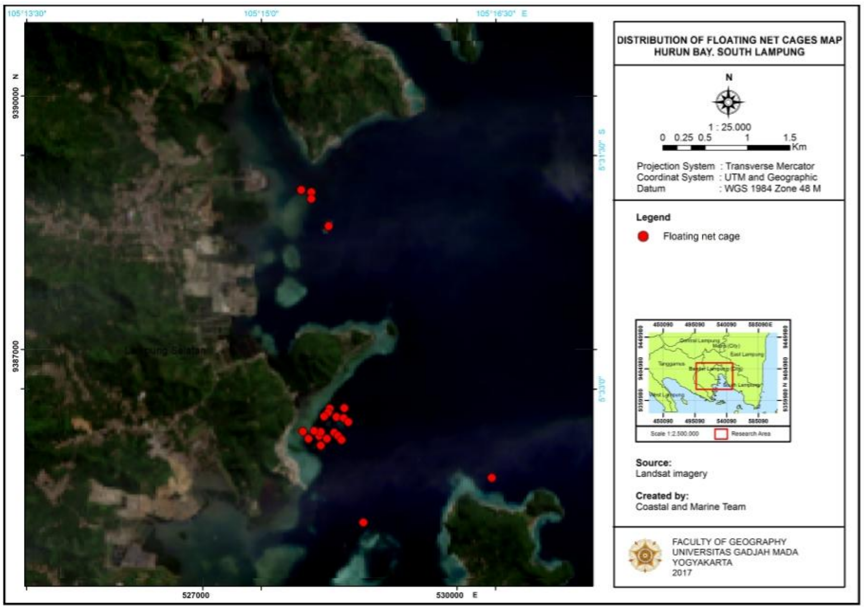
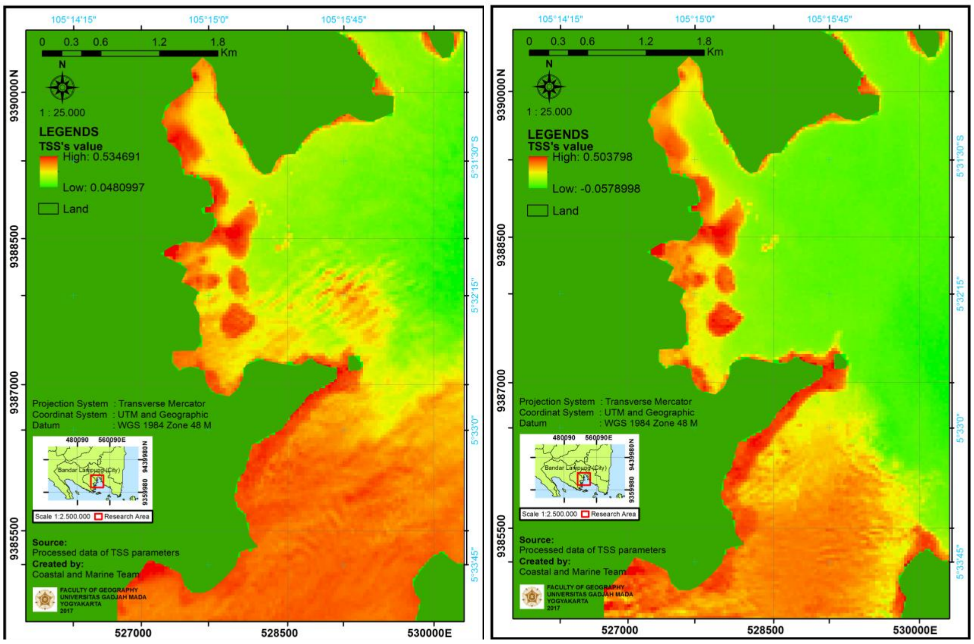


Figure 5. Maps of existing floating net cages

3.3. Bathymetry

Water depth map (bathymetry) was obtained from interpolation process of 162 number of points, provided by Geospatial Information Agency, record on 2016. The validation of water depth parameter data was conducted using field measurement on 2017 using a sounder measuring instrument covering 31 points which were evenly distributed. For water suitability criteria purpose, this parameter was classified into four classes as presented on **Table 1** [8]. According to suitability criteria in [8], the water depth parameter has the highest value weight among the 6 other parameters used, which means it has significant influence in determining the suitability class for floating net cages cultivation.

The depth value of the observed data ranges from 0.27 to 29.3 meters. Meanwhile, the depth value of the field measurement ranges from 1.1 to 27.7 meters. Most of the research areas are classified as not suitable class and as conditionally suitable class because their depths are considered as deep sea (16—20 meters) and located in the central part of Hurun Bay. The depth of the net for cultivation also varies from 3 to 5 meters, depending on the type of commodity and the amount of fish put into the cage. In fact, very shallow depths (<5 meters) can affect water quality due to accumulated residual feed and residual decay of rotting fish. On the other hand, a water depth that is more than 15 meters requires quite long anchor ropes that makes the installation of binding systems even more complicated. Current speed for good floating net cages cultivation generally ranges from 0.1 to 0.3 m/sec.



(a) (b)

Figure 6. The results of imagery processing for TSS parameters before (a) and after (b) field survey around Hurun Bay

3.4. Sea Surface Temperature

Sea surface temperature affects the metabolism and development of marine organisms. Sea waters temperature also gives influence to biological activity in it so that temperature give influence to density of fish population in waters. The result of temperature treatment using band 10 of Landsat 8 TIRS has a range of values between 29.59 to 30.59˚C. The band 11 of Landsat 8 TIRS has a range of values between 30.07 to 30.16˚C. Split window algorithm has a value of 29.77 to 30.35˚C. Field temperature measurement using a digital thermometer results a range of values between 29.5 to 30.8˚C.

3.5. Salinity and Water clarity

Salinity is related to the levels of salt presence in the ocean. The shore has a lower salinity level caused by the more intake of fresh water supply than offshore and inshore marine. The research area has a salinity classification that is dominated by conditionally suitable category.

A clear water depth of more than 5 meters is good for floating net cage cultivation. The result shows that the research area has a water clarity value of 3.5 to 11 meters. The results of water clarity data visualization indicate that the water clarity value distribution is dominated by ranges from 5 to 10 meters. Based on the suitable classification in [8], the research area is classified to conditionally suitable.

3.6. Chlorophyll-α and pH

The concentration of chlorophyll-α phytoplankton in waters can be used as a measure of phytoplankton biomass and used as a guide in seeing the fertility of the waters. Good water quality is a good place for phytoplankton to live and grow because the content of chlorophyll-α phytoplankton itself can be used as an indicator of low productivity of the water [9]. Based on the test of chlorophyll-α concentration, the research area is highly suitable for the placement area of floating net cages. This classification is obtained from the suitable classification [8] which states that the chlorophyll-α is >30 µg/L and is categorized as suitable. Therefore, there is no problem in floating net cages placement in this area in terms of chlorophyll-α parameters. The measurement of pH, one of the important parameters in determining aquaculture area, show that the research area has a pH value ranging from

8—8.1. Based on the criteria of suitability of floating net cages cultivation water environment [8], the research area is classified as a very suitable for cultivation of floating net cages.

Based on the information obtained through the interview activity, it concludes that most of the cultivators do not conduct water quality test on and also did not test the quality of seeds to seed that will be stocked on cages. There are no waste related issues that interfere the continuity of floating net cages cultivation in the research area, because the cultivation area is less affected by the landuse and human activities. The waste from urban activity to the sea waters through rivers or other outlet that can reduce the quality of sea water is not present.

3.7. Physical Waters Suitability for Floating Net Cages Cultivation Mapping

Through the application of GIS, the research area based on the suitability class for cultivation of floating net cages can be calculated. Synthesis results show that the dominant floating net cages are laying on the conditionally suitable class, meaning that the research area is less potential for cultivation and thus requires special treatment to improve its capability. The reason for choosing the location of floating net cages in this area is based on the distance from the tourism area (beach and snorkeling), and far from the coastal ecosystem, such as coral reefs and seagrasses, and other cultivation, namely pearl shellfish cultivation. Water environment suitability class area are presented in **Table 4** and **Table 5**, while the spatial distribution is presented in **Figure 7**.

Table 4. Class area of water environment suitability parameters for floating net cages

Parameter	Very Sustain (S1)		Sustain (S2)		Conditional Sustain (S3)		Not Sustain (TS)	
	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)
TSS	1385.1	100	-	-	-	-	-	-
Bathymetry	99.44	7.2	246.85	17.87	397.69	28.8	637.25	46.13
Sea surface temperature	-	-	1385.1	100	-	-	-	-
Salinity	425.3	30.8	955.33	69.2	-	-	-	-
Water clarity	1016.74	73.3	242.41	17.5	126.35	9.11	-	-
Chlorophyll-α	1385.1	100	-	-	-	-	-	-
pH	-	-	-	-	1385.1	100	-	-

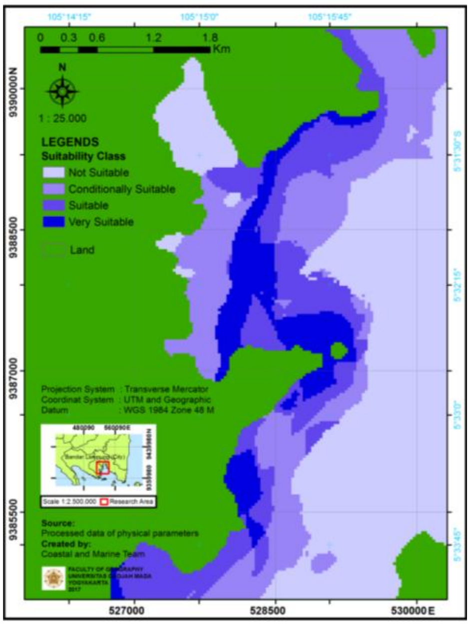


Table 5. Water environment site suitability class area

Suitability class	Hurun Bay		Amount of floating net cages
	Area (ha)	Area (%)	
Very suitable	99.44	7.2	2
Suitable	246.85	17.87	3
Conditionally suitable	397.69	28.8	10
Not suitable	637.25	46.13	8

Figure 7. Physical waters suitability for floating net cages cultivation map in Hurun bay, Pesawaran Regency

4. Conclusion

According to correlation value, Landsat 8 OLI is considered more appropriately applied in the research area for TSS and chlorophyll-α data extraction than Worldview-2 imagery. Higher spatial resolution imagery does not guarantee higher accuracy of its obtain data because both spectral and spatial resolution have more influence in this issue. On the other hand, field measurements show varying results for each physical water suitability parameters for floating net cages cultivation.

Analysis results show that the dominant floating net cages is in the conditionally suitable class, meaning that the research area is less potential for cultivation and thus requires special treatment to improve its capability. The floating net cages area selection also have to consider the distance of the area from the tourism area (i.e. beach and snorkeling), and the coastal ecosystem, such as coral reefs and seagrasses, and other cultivation, namely pearl shellfish cultivation, to achieve the highest level of water suitability. The use of remote sensing and GIS presents important contribution in this research at lower cost and higher accuracy. Integration of remote sensing and GIS can be utilized to map physical waters suitability parameters for floating net cages cultivation. Moreover, it can also help to perform spatial analysis to determine the suitable area for floating net cages.

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