Remote sensing and GIS application for water environment suitability evaluation in Lampung and Hurun Bay

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Abstract. Water environment suitability evaluation is a prominent requirement to determine the success rate of sustainable aquaculture business in coastal waters. This study aims to evaluate the site of floating net cages which already exist in Lampung Bay using water environment site suitability maps and interview data. Physical water suitability for floating net cage cultivation maps are generated using spatial modelling of some parameters, such as depth, sea surface temperature, water clarity, suspended solids, salinity, chlorophyll-α, and pH. There are 32 samples taken in the field for each parameter, both in Lampung Bay and in Hurun Bay using systematic grid sampling. Landsat 8 OLI imagery is used to obtain sea surface temperature, chlorophyll-α, and suspended solid data. Meanwhile, other parameters are collected in the field and mapped using kriging interpolation. Questionnaires were conducted to obtain water suitability characteristics information for floating net cages. All data are combined by using weighted overlay in a GIS environment, identified the characteristics of water environment quality on both sites. The result shows that the development of floating net cages around Hurun Bay has good suitability class whereas Lampung Bay does not meet the suitable class criteria of depth, surface temperature, and clarity parameters. Disparity on land use conditions and the understanding of floating net cage cultivation among the farmers on both sites are the factors that make those different level of suitability classes. The RS and GIS approach used in this study are able to overcome the challenges present in determining the cost and time effective sampling in the water environment. Thus, this study provides a robust and rapid method of potential environment assessment for floating net cages that is prominently needed by stakeholders and farmers.

1. Introduction

Indonesia fishery production has significantly increased since 2010. The production was 16.2 million tons in average, with standard deviation of 3.8 million tons and 95% of the confident interval between 11.4 million – 21.0 million tons [1]. The production of capture fisheries has contributed to the national fishery production of 13.11 percent while aquaculture’s contribution amounted to 68.89 percent. The sea cultivation in coastal waters in Pesawaran Regency became one of a big opportunity in the aquaculture sub-sector in attempt to increase production volume, either according to a commodity or by region producing areas. One of the efforts to improve the production of marine aquaculture is to use floating net cage [2]. The productivity of the sea cultivation in coastal waters are heavily influenced by the increase in fish consumption, cultivation site and coastal resources. Evaluation of water
environment site suitability needs to be done because the site selection will determine the success rate of sustainable aquaculture business in the coastal waters area. The discrepancy in the site determination for the development of the floating net cage can lead to unsustainable cultivation (Beveridge, 1996 in [3]). On the other hand, the utilization of remote sensing and GIS has a real contribution to the development of aquaculture in term of assisting water environment site selection [4]. The purpose of this research is to evaluate the existing floating net cage site in Lampung Bay using water environment site suitability approach and interview among the farmers.

There are two study sites as shown by Figure 1. The first was around the Lampung Bay with coordinates 104°56'–105°45'E and 5°25'–5°59'S, while the second one was around the Hurun Bay with coordinates 105°14′58.54″–105°15′11.89″E and 5°31′06.95″–5°33′40.50″S, with an area of 1136.349 ha and 1350.405 ha respectively. The locations have been chosen because both have differences in land use that possible to affect the water environment site suitability in each location.

![Figure 1. Study site](image)

2. Research methods
Water environment site suitability map for floating net cage cultivation was generated using spatial modelings for depth, sea surface temperature (SST), water clarity, suspended solids, salinity, chlorophyll-α, and pH parameters. How to obtain parameters in the field are as follows: depth using bathimeter, sea surface temperature using a digital thermometer, water clarity using secchidisk, suspended solids using laboratory test, salinity using a refractometer, chlorophyll-α using laboratory test, and pH using pH meter. These parameters were determined using GIS, that is weighted score method which provides a different type of scores representing each water parameter as presented in Table 1 [5].

Landsat 8 OLI imagery was used to obtain SST data parameters, chlorophyll-α, and suspended solid. Meanwhile, other parameters are collected in the field and mapped using kriging interpolation. SST data extraction was using channel 10 of Landsat 8 TIRS imagery. Distribution of chlorophyll-α from Landsat 8 OLI was obtained from the following equation (1)[6].
Chl-α = 0.2818 x \left( \frac{L_4 + L_5}{L_3} \right)^{3.497} \tag{1}

where:

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

L_3, L_4, L_5 : \text{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} \tag{2}

where:

\text{NSMI} : \text{concentration of TSS (in mg/l)}

L_2, L_3, L_4 : \text{reflectance of band 2, 3, 4}

| Parameter - (Weight) | Very Suitable (S1) | Suitable (S2) | Conditionally Suitable (S3) | Not Suitable (TS) |
|----------------------|--------------------|---------------|-----------------------------|-------------------|
| Criteria | Score | Criteria | Score | Criteria | Score | Criteria | Score |
| Water depth (m) – (9) | 8<S1≤12 | 18 | 12<S2≤16 | 14 | 16<S3≤20 | 10 | TS>20 | TS<4 | 5 |
| Sea surface temperature (SST) (°C) – (7) | 28<S1≤29 | 14 | 29<S2≤31 | 12 | 31<S3≤32 | 10 | TS>35 | TS<24 | 5 |
| Salinity (ppm) – (7) | 31<S1≤32 | 14 | 32<S2≤33 | 12 | 33<S3≤35 | 10 | TS<28 | TS>35 | 5 |
| Water clarity (m) – (6) | 5<S1≤10 | 12 | 3<S2≤5 | 10 | 0<S3≤3 | 8 | TS=0 | TS<20 | 3 |
| Total suspended solids (mg/l) – (6) | S1≤25 | 12 | 25<S2≤80 | 10 | 80<S3≤400 | 8 | TS>400 | 3 |
| Chlorophyll-α (μg/l) – (5) | S1>30 | 10 | 20<S2≤30 | 9 | 10<S3≤20 | 7 | TS≤10 | 5 |
| pH – (5) | 6.5<S1≤8.5 | 10 | 6<S2≤6.5 | 9 | 5<S3≤8 | 7 | TS<5 | 5 |

Interviews were conducted to obtain the aquatic characteristic information for the floating net cage from the interviewees who are directly related to the cultivation of floating net cage (fishers, farmers, and collectors). The questionnaire includes questions about kinds of fish caught in the study area, type of fish feed used, the marine environmental conditions, production and distribution of floating net cage. Data analysis was performed on all data parameters used for floating net cage suitability assessment. Each parameter was discussed based on the measurement value on the satellite imagery and field activities with taking into account the criteria of the reference value. The analysis of each parameter was also associated with the presence of floating net cage so that the suitability of floating net cage cultivation can be evaluated. Results analysis of the interviews data was performed to identify the general characteristics of floating net cage suitability at the study area. The research flow diagram is shown in Figure 2.
3. Result and discussion
3.1. Physical water parameters
Both study sites on this research are determined on the basis of existing land uses and river estuary near the study area. In the first study area, built-up land uses are settlements and industrial areas dominating the coastal area. Its site near the harbour at Bandar Lampung encourages the more intense development of built-up land use in the area than other areas on the coast of Lampung. While the general land use in the Hurun Bay is fields, fishponds, mangrove forests, vegetation cover and settlements, where is not as dense as the settlement on the Lampung Bay. The differences of land use in both sites have considerably influenced the water environment site suitability for floating net cage cultivation. Biophysical factors considered for the suitability of floating net cages are depth, salinity, water clarity, chlorophyll-α, pH, sea surface temperature, and total suspended solids. We have taken 32 samples for each parameter, both in Lampung Bay and in Hurun Bay using a systematic grid sampling method. Each parameter is interpolated using the kriging method. Figure 3 and Figure 4 show the data interpolation results of each physical water parameter in Lampung Bay and Hurun Bay.
Figure 3. Physical water parameters in Lampung Bay
Figure 4. Physical water parameters map in Hurun Bay

3.1.1. Bathymetry.
The depth values from secondary data in Lampung Bay ranges from 0.3—21.1 meters and for Hurun Bay ranges from 0.27—29.3 meters. The depth values from field survey data using bathymeter in Lampung Bay ranges from 1—21.1 meters and for Hurun Bay ranges from 1.1—27.7 meters. The
differentiation in both depth value data obtained in the different year shows little difference. These results indicate that submarine topographic dynamics and sedimentation processes in the study areas are small. In general, the depth variation on these two sites has gradually changed towards the sea. When it is associated with the suitability class for the floating net cage cultivation, the cultivation sites which are very suitable for those two spreads toward offshore. The topographic differences of the waters make these two study sites have a different area of suitability classes. As the Lampung Bay is part of the base of Lampung Bay and is shallow water hence most of the class are not suitable and conditional on Lampung Bay caused by relatively shallow water (between 0—8 meters). Meanwhile, most of the classes are unsuitable and conditional in Hurun Bay due to the relatively deep water (between 16—20 meters) as it is the central part of Lampung Bay.

3.1.2.

3.1.3. Salinity.
Lampung Bay generally has a current velocity ranging from 0.1—0.2 m/s, while the site around the Hurun Bay ranging from 0.03—0.22 m/s using currentmeter. Based on the salinity parameter which measured with refractometer, both sites have different ranges of salinity values. In the area of Lampung Bay, salinity parameter was dominated by very suitable and suitable class, the other belong to conditional suitable class. While in Hurun Bay only got two class of salinity classification that is very suitable and suitable, so there was no problem in floating net cage cultivation in this site related to the salinity parameter.

3.1.4. Water Clarity. Chlorophyll-α and pH.
Based on the water clarity condition which measured with secchidisk. Lampung Bay has a clarity value of 0.5—6.94 meters. Meanwhile, the second study area has a clarity value of 3.5—11 meters. Based on [4], the Lampung Bay belongs to the very suitable class while the Hurun Bay belongs to the suitable class. Based on the test of chlorophyll-α concentration in both sites, it was found to be highly suitable at both sites. Therefore, it is suitable for floating net cage cultivation in this site related to the chlorophyll-α parameter. Based on pH measurement using pHmeter at both sites, it was found that both sites were very suitable for floating net cage cultivation because it has pH value > 6.5 and ≤ 8.5.

3.1.5. Sea Surface Temperature (SST) and Total Suspended Solid (TSS).
The result of temperature treatment in Lampung Bay and Hurun Bay using band 10 of Landsat 8 TIRS has a range of values between 28.92—34.42˚C and 29.59 to 30.59˚C. The band 11 of Landsat 8 TIRS has a range of values between 29.12—33.78˚C in Lampung Bay and between 30.07 to 30.16˚C in Hurun Bay. Split window algorithm has a value of 29.77 to 30.35˚C. Field temperature measurement using a digital thermometer results in a range of values between 30.1—31.7˚C in Lampung Bay and between 29.5 to 30.8˚C in Hurun Bay.

3.2. Physical water suitability for floating net cages cultivation mapping.
GIS can be used to overlay all parameters using the weights score of each parameter. By using the application of GIS, the suitability class for floating net cage cultivation can be calculated as shown in Table 2, whereas the distribution of suitability class can be seen in Figure 5. In Lampung Bay, the suitable class was dominated by very suitable class which has an area of 324.5 ha or 28.2% of the total area of the Lampung Bay. Meanwhile, the suitable class in the Hurun Bay was dominated by unsuitable which has an area of 637.25 ha or 46.13% of the total area of the Hurun Bay.

| Suitability Class     | Lampung Bay | Hurun Bay |
|-----------------------|-------------|-----------|
|                       | Area (ha)   | Area (%)  | Area (ha) | Area (%) |
| very suitable         | 324.5       | 28.2      | 99.44     | 7.2      |
| suitable              | 149.73      | 13        | 246.85    | 17.87    |
| conditional suitable  | 516         | 44.84     | 397.69    | 28.8     |
| unsuitable            | 160.62      | 13.96     | 637.25    | 46.13    |

Table 2. The water environment suitability class area in both study sites
3.3. The socio-economic factors of the community in Pasaran Island

In addition to the physical factors, the floating net cage site was also influenced by the social condition of the community. It was closely related to the knowledge of society or floating net cage farmers toward maintenance. Therefore, interviews with farmers related to cultivation systems and land management, production, diseases that infect fish in floating net cage, information related to site selection, marketing, and other information related to floating net cages.

Based on the information obtained from the interview activity of four respondents at the site of the first study it was known that most of the farmers do not conduct water quality testing at the site that was chosen as the site of cultivation and also does not test the quality of seed which will be stocked in floating net cage. Information obtained from the four respondents and the results of field observations were considered sufficient to find out the social and economic conditions in the study site in supporting cultivation activities using floating net cage techniques because respondents stated that farmers in the study site had the same characteristics and behavior in managing cultivation of floating net cages. This information was considered to be able to represent socio-economic conditions that affected the floating net cage cultivation activities of grouper fish in Lampung Bay. The problems encountered by farmers are related to the waste affected by urban land use and the presence of ports in Bandar Lampung that trigger the rapid development of land use. In addition, there are also problems with fish diseases that require the provision of medicine in fish and regular fish bathing with fresh water. Cultivation attitude and knowledge of floating net cage farmer is very influential to the continuity of cultivation.

Based on interviews conducted on three respondents in the Hurun Bay, it was known that there are no problems related to waste that disrupt the continuity of floating net cage activities. Same as the interview activities at the first area, the information obtained from three respondents and the results of field observations were considered sufficient to find out the social and economic conditions in the study site in supporting cultivation activities using floating net cage techniques because
respondents stated that farmers in the study site had the same characteristics and behavior in managing cultivation of floating net cages. This information was considered to be able to represent socio-economic conditions that affected the floating net cage cultivation activities of grouper fish in Hurun Bay. This is different from the information obtained through the respondents at the first study site complaining about the waste problem. It was assumed that because human activities in urban areas at the Lampung Bay was quite dense, thus triggering the waste of urban activity into the sea waters through rivers or other channels resulting in decreased quality of sea water. The quality of seawater affects the quality of financially produced fish. Looking from the aspect of production and marketing of fish cultivated in the net cage in both sites, it was known that the fish cultivated on the Hurun Bay was sold by exporting overseas. While in the Lampung Bay was only sold in the local area or in Lampung region only. In relation to the knowledge and attitude of the farmers towards the net cage, the results of the interviews show that at Hurun Bay, the farmers have better attitude and knowledge than the farmers in the Hurun Bay because they pay attention to the water quality for floating net cage placement.

3.4. Floating net cage evaluation
The spread of the floating net cage that currently exists in Lampung Bay belongs to unsuitable class according to the criteria of the water depth, SST, and water clarity factors, while some are in conditional suitable class. The results from interviews of residents present that good planning regarding the selection of the floating net cage cultivation placement for the Lampung Bay is not available. Society tends to put the floating net cage around their residence, i.e. on the Pasaran Island. For fish seed, the society acquired it from the catches at sea and then transferred into a floating net cage so that there was no special treatment done by the owner for the cultivation. Over the years many farmers have switched to the mussels floating net cage cultivation that are considered more appropriate to the condition of the water in Lampung Bay, so currently, there are only a few floating net cage cultivators in the Lampung Bay. Waste from industrial and shipping activity around Lampung Bay influence the water quality for floating net cage aquaculture so that it is necessary to make coordination between the government and the community for the sake of sustainable floating net cage cultivation in the Lampung Bay.

Meanwhile, the floating net cage distribution in Hurun Bays found in the suitable and conditional suitable class. A clear difference in terms of planning and treatment is not only seen from the condition of the used floating net cage, but also from the scope of the market in selling floating net cage results. For the Hurun Bay, there is no constraints of depth, SST and water clarity factor as well as the Lampung Bay. Floating net cage site in the Hurun Bay are likely to be further away from land. The water conditions tend to be better and free from industrial waste. Problems that may become obstacles in this Hurun Bay is a conflict of interest due to other business, such as the oyster cultivation, beach for tourism and snorkelling at Sariringgung Beach. This makes the farmers should shift his floating net cage away from land so it doesn’t influence the water conditions and marine life which becomes the attraction of snorkelling. Floating net cage total in Hurun Bay is more than a Lampung Bay. The suitable water conditions are considered to be the attraction of the community and the private sector to develop floating net cage aquaculture in this site. The presence of Marine Fishery Cultivation Halls belongs to the Indonesia Ministry of Marine and Fisheries as well as fish auction can support the sustainable floating net cage aquaculture in the Lampung Bay.

4. Conclusion
The development of floating net cage aquaculture in Hurun Bays is considered to be better than the Lampung Bay. In term of the condition of waters based on a suitability map have been made aware that the distribution of the floating net cage site in the Hurun Bay is more suitable than the Lampung Bay. Land use factors and different understanding of floating net cage farmers are the reason why the level of development of floating net cage aquaculture in both sites differ from each other. Prospects and sustainability of floating net cage in Lampung Bay can be improved by providing supporting facilities and services by the government, such as the selection of seed, water quality testing, sewage problems and conflicts of interest resolution.
References

[1] Center for Statistical Data and Information 2015 Marine and Fisheries in Figures 2015 (Jakarta: Center for Statistical Data and Information)

[2] Mansyur A and Tonnek S 2003 Prospek Budi Daya Bandeng dalam Karamba Jaring Apung Laut dan Muara Sungai Jurnal Litbang Pertanian 22:79-85

[3] Perez O M, Telfer T C, and Ross L G 2003 Use of GIS- Based Models for Integrating and Developing Marine Fish Cages within The Tourism Industry in Tenerife, Canary Islands Coastal Management 31:355-366

[4] Meaden G J and Kapetsky J M 1991 Geographical Information System and Remote Sensing in Inland Fisheries and Aquaculture (Rome: Food and Agriculture Organization)

[5] Trisakti B, Sucipto U H and Sari J 2003 Pemanfaatan Data Penginderaan Jauh sebagai Tahap Awal untuk Pengembangan Budidaya Laut dan Wisata Bahari di Kabupaten Banyuwangi dan Situbondo in Laporan Akhir Kegiatan Bina Usaha (Jakarta: Lembaga Penerbangan dan Antariksa Nasional)

[6] Hanintyo R, Susilo E, Mahardika P, and Saputra A J 2016 Comparison of Chlorophyll-α Measurement Using Multispatial Imagery and Numerical Model in Bali Journal of Earth and Environmental Science 47:1-9