

# Mariculture Site Selection Based on Environmental Parameters in Tanjung and Gangga Sub-District, North Lombok

*by* Hayatun Fadillah

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## **Mariculture Site Selection Based on Environmental Parameters in Tanjung and Gangga Sub-District, North Lombok**

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### **Abstract**

This research was aimed to identify groupers, seaweed, oyster aquaculture suitability based on environmental parameters at Tanjung and Gangga Sub-district, North Lombok. Primary data or environmental data were collected from 21 stations on October 2016 using simple random method. Parametric data collection included: temperature, salinity, pH, visibility, dissolved oxygen, chlorophyll, depth, and current velocity. The supporting data were encouraged from the based map and thematic map. Environmental data were analyzed using a Geographical Information System (GIS) and multi-criteria analysis. This research revealed a potential aquatic area for supporting marine culture is 1,673.47 ha. However, marine culture area is effective to develop groupers, seaweed, and oyster at about 209 ha; 1,004 ha and 658 ha, respectively.

**Keywords:** mariculture, site selection, groupers, pearl oyster, seaweed.

### **1. Introduction**

North Lombok Regency is a coastal district with a coastline length of about 125 km and has 3 small islands (Gili) which are famous for Gili Matra (Meno, Trawangan, and Air). Gili Matra is a conservation area as an aquatic tourism park managed by the Ministry of Maritime Affairs and Fisheries. The beauty of the ecosystem, diversity of fish species, and the beauty of the beach on Gili Matra are direct benefits of marine tourism activities (Pratiwi et al., 2014). Besides being used as an aquatic tourism park, some of the other coastal and marine resource potentials of North Lombok Regency are used as aquaculture and capture fisheries.

The developing aquaculture activities on Lombok Island are marine aquaculture with commodities such as pearl oysters, groupers, starfruit, seaweed and lobster (KKP, 2014). Indonesia is an export-quality pearl country known as julukan south sea pear from the



*Pinctada shells maxima* (Wardana et al., 2013). In North Lombok Regency the potential for developing enlargement of pearl oyster seeds is very supportive with pearl products produced by export quality. Even one of the largest pearl companies in the world is located south of Gili Matra. While grouper and seaweed aquaculture activities are being developed by coastal communities in Tanjung and Gangga sub-districts located in the northeast of Gili Matra.

Aquaculture offers several benefits to coastal communities in their relations with conservation efforts, including alternative livelihoods, reducing pressure on the coastal environment by fishing activities that are not environmentally friendly, and increasing public awareness of the importance of conservation of natural resources (Albasri and Szuster, 2010). As the most important part in the development of the marine aquaculture area, in reality, the determination of the location of cultivation development is based on feeling or trial error (Hartoko and Helmi, 2004). This has led to the development of marine aquaculture not running optimally and can have an impact on the sustainability of the environment which will reduce conflict over regional use (Perez et al., 2003).

In determining the location of marine aquaculture development, in addition to relating to risk factors, determining the location must consider environmental factors and water quality. The feasibility of location is the result of conformity between the requirements of life and the development of a cultivation commodity on the environment and water quality. Environmental factors and water quality are important to be considered in marine cultivation including flow, depth, salinity, brightness, temperature, pH, dissolved oxygen, and water fertility (Prema, 2013). Furthermore according to Pillay (1990); Hartoko and Kangkan, (2009), considerations that need to be considered in determining the location are technical conditions consisting of physical, chemical, and biological and non-technical parameters in the form of the market share, security, and human resources. With the availability of both quality and quantity data, plus pay attention to the importance of each data, making the analysis of the feasibility of water locations more complex and time-consuming. Geographical Information Systems (GIS) make it possible to carry out the spatial analysis of the feasibility of water locations by combining various types of data and their importance (Burrough and McDonnell, 1998; Nath et al., 2000).



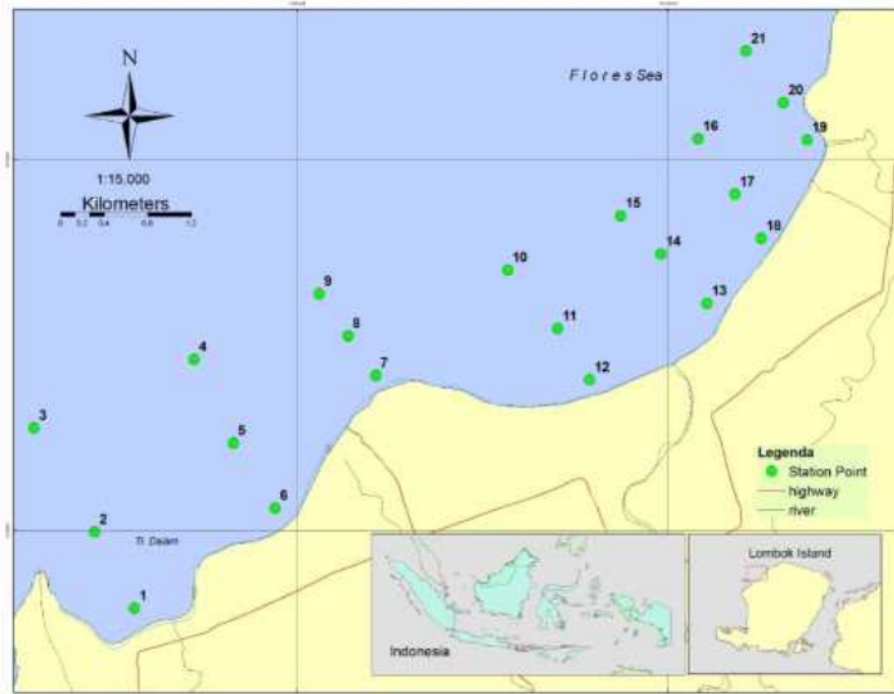
Geographical Information Systems (GIS) in aquaculture have been used in a limited way since the 1980s (Perez et al. 2015), with the development of today's technology, GIS has made it easy for spatial analysis quickly and systematically. Utilization of GIS in marine aquaculture is quite large since it was first published for various aquaculture commodities such as groupers (Amri et al., 2010; Albasri and Szuster, 2010a, 2010b; Affan, 2011; Purnawan et al., 2015; Ghani et al., 2015; Aggriawan, 2015), seaweed (Radiarta et al., 2007; Radiarta et al., 2011; Wantasen and Tamrin, 2012; Hidayat, 2013; Prasetya et al., 2013; Nirmala et al., 2014; Ratnasari et al., 2014; Akib et al., 2015; Yulius et al., 2016; Waluyo et al., 2016), and pearl oysters (Hidayah, 2012; Wisnawan, 2013; Jamilah, 2015; Sinaga et al., 2015).

The main obstacle in the development of marine aquaculture in North Lombok Regency, especially in the waters of Tanjung and Gangga Subdistricts is the availability of data and information on the location of marine aquaculture development that has not been identified, thus implicating overlapping the use of water space between sectors and across sectors. In this regard, this research was conducted with the aim of identifying the level of water feasibility for the cultivation of groupers, seaweed and pearl oysters by utilizing GIS. The results of this study are expected to provide data and information to support the program to increase aquaculture production and as an alternative livelihood for coastal communities in the Tanjung and Gangga Districts of North Lombok Regency.

## 2. Materials And Methods

### Location and time of research

This research was carried out from October 2016 in the coastal of Tanjung and Gangga Subdistricts in North Lombok Regency (**Figure 1**). The research location stretches from 8°16' - 8°22'South Latitude and 116°6' - 116°12'East Longitude. The waters of Tanjung and Gangga Subdistrict are in the northeast with Gili Matra which is one of the most famous marine tourism destinations on Lombok Island.



**Figure 1.** The study location and water quality observation point

**Data collection**

In this study, the feasibility study of waters is more focused on aspects of the aquatic environment that can affect growth and the cultivation techniques used. In general, the research method used is the survey method. The type of data needed is primary and secondary data. Primary data is the measurement of water quality directly in the field. Water quality collection is done by survey method designed based on geographic information system (GIS) analysis. Observation of temperature, salinity, pH, brightness and dissolved oxygen was carried out on 21 observation points (**Figure 1**), where the sampling point was determined randomly, according to the needs and distribution of sampling points that were considered to represent the overall research area (Morain, 1999). The sampling point tracking is done using the Global Positioning System (GPS). Tools and methods for measuring water quality in situ refer to APHA (2005).



Secondary data in the form of maps are obtained from relevant agencies which consist of basic maps and thematic datasets. Basics such as coastline maps, bathymetry, and territorial boundaries are sourced from the 1: 50,000 Indonesian Coastal Environment Map output by the Geospatial Information Agency (BIG). The thematic dataset map is in the form of a flow map sourced from a 1: 50,000 Physical Oceanographic Map and chlorophyll maps sourced from a 1: 50,000 Biological Oceanographic Map, both maps are output by the Ministry of Maritime Affairs and Fisheries.

All collected data is then converted into raster data through interpolation techniques. Water quality data were interpolated with the inverse distance weighted method. The entire data analysis was carried out using ArcGIS v.10.3 (The Environmental System Research Institute, USA). Spatial data used in the feasibility analysis of water locations is projected with the WGS 84 UTM zone 50S coordinate system.

### **Level of Conformity and Weighting**

Environmental factors that influence the cultivation of groupers, seaweed, pearl oysters and green oysters include various types of parameters. However, due to the limited availability of available data, in this study only eight parameters included: temperature, pH, salinity, brightness, dissolved oxygen, chlorophyll, current, and depth.

The criteria used as a basis for determining the suitability of marine aquaculture sites refer to and are modified from various research results. Determination of the suitability of marine aquaculture for each parameter is based on the effect of the parameters on each cultivation commodity. This study uses a scoring system of 1 - 3 (KKP, 2016), where a score of 3 is very appropriate (S1), which means that this area does not have limiting parameters that affect marine aquaculture or only has a limiting parameter that is less significant and does not significantly affect cultivation sea, score 2 is quite appropriate (S2), which means that this area has limiting parameters that will affect marine aquaculture, but the limiting parameters can be corrected, and score 1 is not suitable (N) means that the area has very high limiting parameters and is not possible to be repaired so that it is not possible to do sea cultivation.



The weighting system used in this research is the Analytical Hierarchy Process (AHP) (Saaty, 1977; Malczewski, 1999). AHP is done by a technique known as the pairwise comparison in the context of decision making which is a technique in amulti-criteria analysis. Each parameter is given a weight based on the study of literature and expert opinions. Parameters that have a dominant and relatively irreversible influence have the greatest weighting factor, whereas the less dominant parameter has a smaller weighting factor. The advantage of this technique is that the weight made can be tested by looking at the consistency ratio (consistency ratio, CR). A new consistency ratio can be accepted if  $CR < 0,1$  if the value is greater then the weighting must be done again. The suitability matrix for grouper, seaweed, pearl oyster and green oyster cultivation can be seen in Tables 1, 2, and 3.

Table 1. Environmental suitability of grouper aquaculture

Parameter	Weight	Very Appropriate S1 (3)	Sufficiently Appropriate S2 (2)	It is not in accordance with N (1)
Bathymetry(m)	0,274	10-20	5-10 or 20-25	< 5 or >25
Current velocity (cm/dt)	0,196	0-15	15-30	>30
Brightness(m)	0,153	>10	5-10	<5
Temperature(°C)	0,121	28-30	25-28	<25 and >30
Dissolved oxygen(mg/l)	0,096	>4	2-4	<2
pH	0,061	7,5-8,6	6,5-7,5	<6,5 and > 8,6
Chlorophyll(mg/l)	0,061	1-20	10-20	<10
Salinity (‰)	0,036	>75	25-75	<25

Source: Modifications from Amri et al. (2010); Albasri dan Szuster (2010a & 2010b); Affan (2011); Purnawan et al. (2015); Ghani et al. (2015); Aggriawan (2015); KKP (2016).



Table 2. Suitability of seaweed cultivation environment.

Parameter	Weight	Very Appropriate S1 (3)	Sufficiently Appropriate S2 (2)	It is not in accordance with N (1)
Brightness(m)	0,174	>10	5-10	<5
pH	0,153	>6	5-6	<5
Bathymetry(m)	0,149	>4	2-4	<2
Current velocity(cm/dt)	0,136	20-40	10-20 or 40-50	<10 or >50
Dissolved oxygen(mg/l)	0,130	>3.0	1-2	<1
Chlorophyll(mg/l)	0,128	3,5-10	0,2 -<3,5	<0,2
Temperature(°C)	0,068	27-30	25-<27 or >30-32	<25 or >32
Salinity (‰)	0,061	29-33	25-<29 or >33-37	<25 or >37

Source: Modifications from Radiarta et al (2007); Radiarta et al. (2011); Wantasen dan Tamrin (2012); Hidayat (2013); Prasetya et al. (2013); Nirmala et al. (2014); Ratnasari et al (2014); Akib et al. (2015); Yulius et al. (2016); Waluyo et al. (2016); KKP (2016).

Table 3. Suitability of pearl oyster farming environment

Parameter	Weight	Very Appropriate S1 (3)	Sufficiently Appropriate S2 (2)	It is not in accordance with N (1)
Chlorophyll(mg/l)	0,157	>20	10-20	<10
pH	0,147	7,5-8,6	6,5-7,5	< 6,5 and >8,6
Bathymetry(m)	0,132	1-3	3-10	>10
Dissolved oxygen(mg/l)	0,129	> 6.5	5,5-6,5	< 5.5
Current velocity(cm/dt)	0,114	0-15	15-30	>30
Salinity (‰)	0,112	>75	25-75	<25
Brightness(m)	0,106	>10	5-10	<5
Temperature(°C)	0,104	28-30	25-28	<25 and >30

Source: Modifications from Hidayah (2012); Jamilah (2015); Sinaga et al. (2015); KKP (2016)

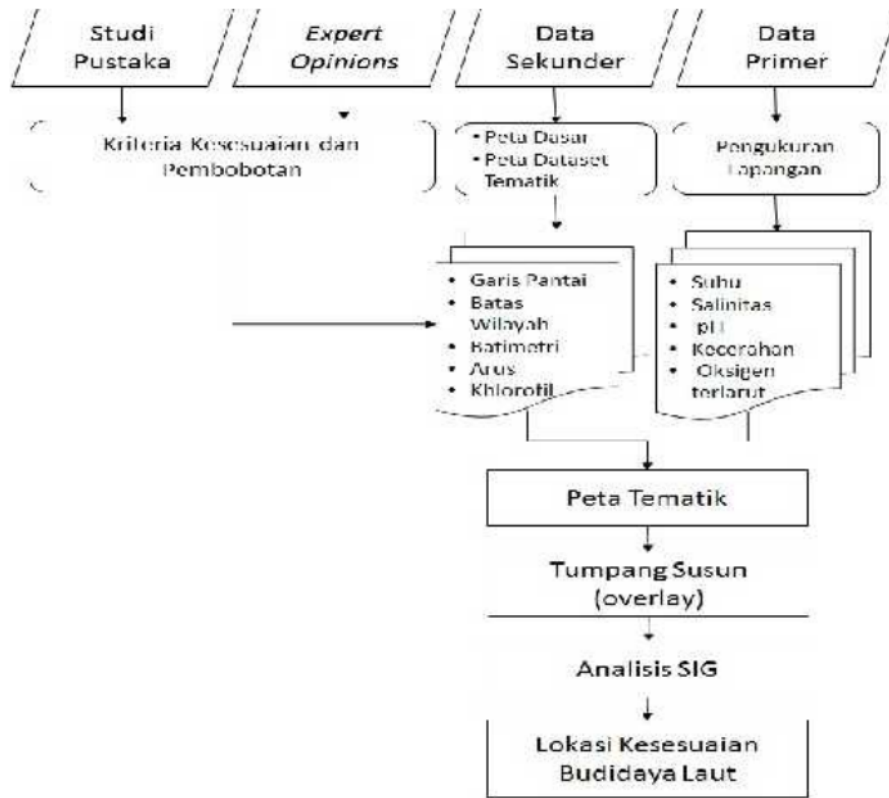
### Spatial Analysis

In spatial analysis and GIS, it aims to determine the suitability of marine aquaculture land with commodities such as fish, seaweed, and pearl oysters. In the analysis process using ArcGIS v.10.3 software, where the primary data results from each parameter are put together in a digital base map by interpolating at each observation coordinate point into an area (polygon) using the Nearest Neighbor method (Morain, 1999). From the results of interpolation of each parameter obtained, it is then arranged in the form of thematic maps with separate layers, through consideration of the weighting and rating scale, then overlaid to obtain land suitability values and current maps for land resource allocation





prospects coastal area in Tanjung Subdistrict and Gangga North Lombok district for the development of marine cultivation (groupers, seaweed, and pearl oysters). The flow chart for determining the feasibility of aquaculture can be seen in **Figure 2**.



**Figure 2.** Flowchart for determining the feasibility of marine aquaculture

### 3. Result and Discussions

North Lombok Regency is a coastal district, with geographic marine waters located in the Lombok Strait and Flores Sea covering an area of 503.24 km<sup>2</sup> or around 38.33% of the total area of North Lombok Regency and the coastline length of about 125 km. There are 3 islands that are famous as Gili Matra (Meno, Trawangan, and Air) and charming tourist destination. Besides being used as Gili Matra covering 29.54 km<sup>2</sup> (Pratiwi et al, 2014), the other coastal and marine resource potentials of North Lombok Regency are used as



aquaculture and capture fisheries. Marine aquaculture activities in North Lombok Regency have been ongoing and are limited to a number of cultivation systems and commodities. The cultivation systems used are floating nets and rafts, while the commodities cultivated include grouper (*Epinephelus* sp), seaweed (*Euchema cottonii*) and pearl shells (*Pinctada maxima*).

**Aquatic Environment Conditions**

The tidal type of waters in North Lombok Regency is very similar to the Indian Ocean tide type, which is a mixed semidiurnal tide. Tidal real-time data is updated through [www.ioc-sealevelmonitoring.org](http://www.ioc-sealevelmonitoring.org) in two months (September 1, 00:00 WITA) - November 1, 00:00 WITA) 2016, showing that the difference in average tide the lowest and lowest low tide are 3.274 m and 3.205 m (Figure 3). Thus, the tidal differences are relatively feasible for the development of marine aquaculture.

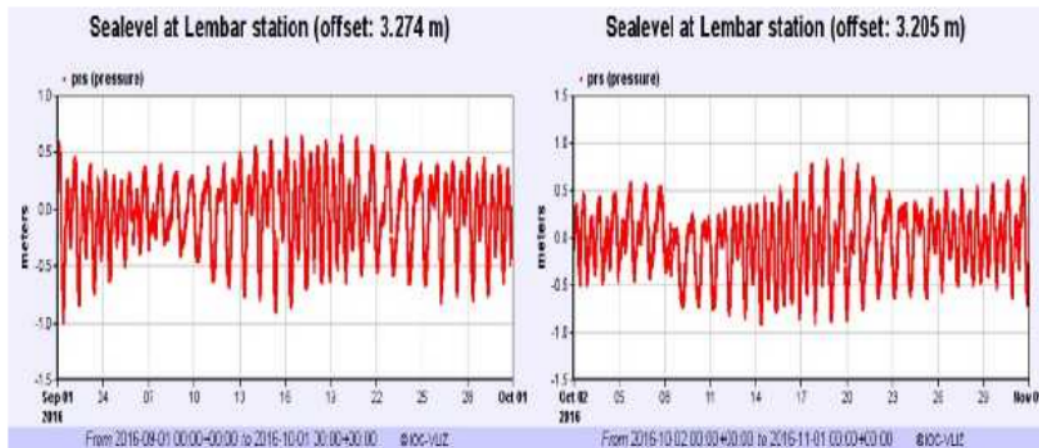


Figure 3. Tidal height in October- November 2016  
 Resource : <http://www.ioc-sealevelmonitoring.org>

Based on the results of field measurements of environmental parameters in Tanjung and Ganga Subdistricts of North Lombok Regency at 21 observation points, in general it is still within the limits of tolerance for marine aquaculture activities in floating net cages (groupers, seaweed, and pearl oysters). The distribution map of the aquatic environmental parameters from the observations is presented in Figures 4 and 5.



Marine waters of North Lombok Regency have very steep bottom waters, only a few tens of meters from the shoreline the depth can reach 10 m. The depth of the waters plays an important role in the life of biota in the ecosystem. The depth of the water is influenced by changes in the tides and contours of the water base and is very instrumental in determining the method of aquaculture. According to Amri et al. (2010), the ideal depth of waters at low tide between floating net cages with a minimum water base of 5m. This gives room for nutrient exchange or residual floating net cages waste, whereas according to Nirmala et al. (2014), for seaweed cultivation with the ideal depth floating raft method, the waters at the lowest tide are between rafts with a minimum water base of 4 m. According to Sinaga et al. (2015), for the cultivation of pearl oysters with a floating raft method, the optimal water depth is 10 m. The pattern of currents in the research location is to the south, then before reaching the coast, turn in the direction to the west, with a speed of about 20-30 cm/second. The current velocity is quite ideal for the development of marine cultivation with various cultivation commodities.

The condition of acidity (pH) results from field measurements illustrates that the pH conditions at the study site are waters that tend to alkaline with a pH range between 8.0 - 8.4, this indicates that these waters are quite ideal for the development of marine aquaculture with various commodities. According to FAO (1989) waters with neutral pH to slightly alkaline waters with ideal conditions for the development of marine aquaculture with various commodities. Tolerance for fish life to pH depends on many factors including temperature, dissolved oxygen concentration, the variation of various anions and cations, types and life cycles of biota.

The water salinity parameters measured were at the range of 27-33 ppt, this range is still good for aquaculture activities for both fish, seaweed and oyster because the optimal salinity for the cultivation of the three commodities is in the range of 27-35 ppt. Especially for fish farming, the salinity value needed is in accordance with the type of fish to be cultivated. This is because certain fish also need certain salinity. Fish have a tolerance to changes in salinity, some fish have salinity values that require different values. Groupers generally have optimum salinity in the range of 27 - 34 ppt (Affan, 2011).

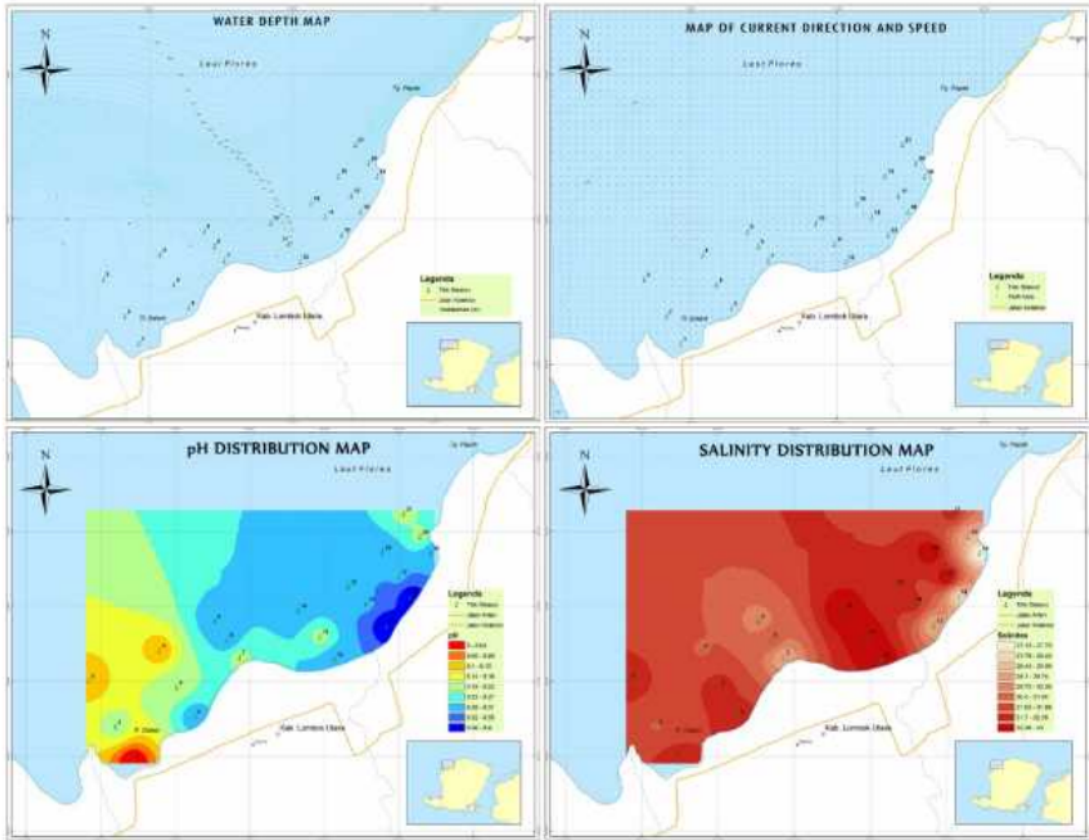


Figure 4. Depth map of depth, current pattern, pH and water salinity  
 a: depth; b: current pattern; c: pH; and d: salinity

The brightness value of the field measurements shows that the brightness conditions in the study location have a range of 1.0 - 7.5 m. Brightness shows the ability to penetrate light into the waters. The level of light penetration is strongly influenced by particles that are suspended and dissolved in water thereby reducing the rate of photosynthesis. Brightness levels are measured very relative to the depth of the water. The brightness of the waters is still in a good category for marine cultivation, which ranges from 60 - 100%

Dissolved oxygen (DO) results from field measurements have a DO range ranging from 6.3 - 12.6 mg/l which means it is still in a good range for fish farming activities in floating net cages, seaweed, and pearl oysters as desired by FAO (1989) namely for marine aquaculture the desired DO content is > 5mg/l.

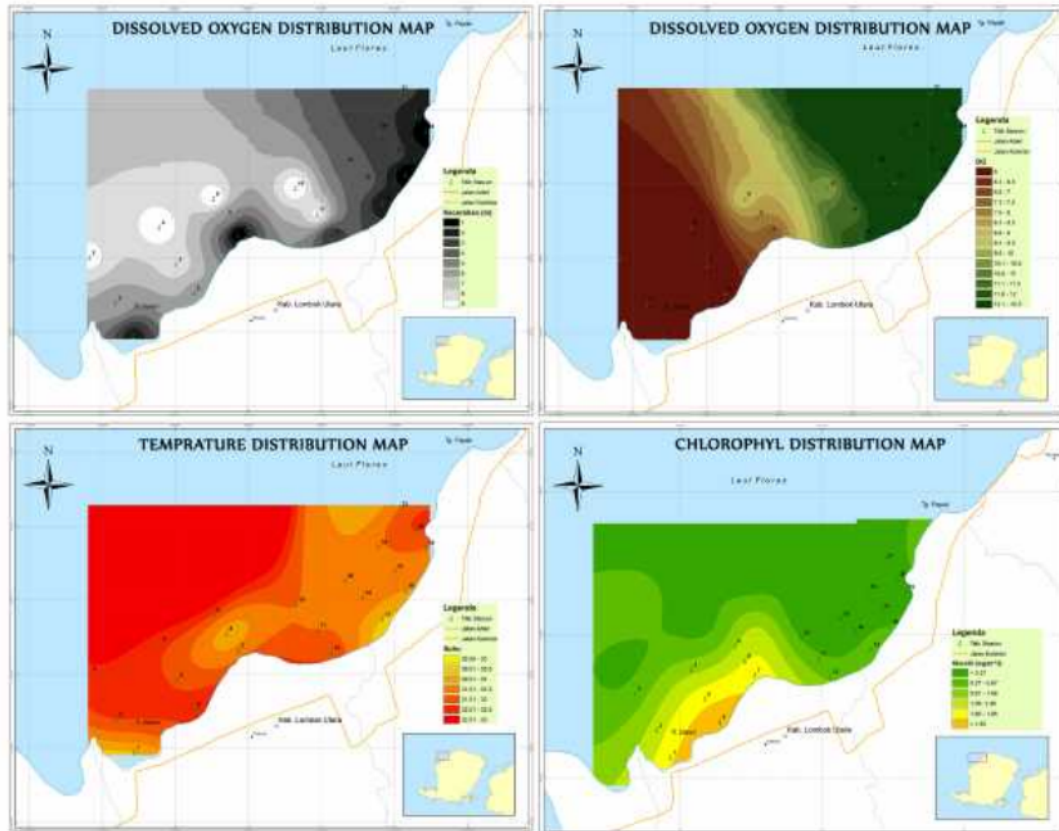


Figure 5. Brightness, DO, temperature and chlorophyll map a: brightness; b: DO; c: temperature and d: chlorophyll

<sup>1</sup> Dissolved oxygen is the most critical parameter in fish farming compared to seaweed and pearl oysters. Oxygen comes from the process of air diffusion and photosynthesis and is influenced by temperature, salinity, and air pressure. Increased temperature, salinity and pressure cause a decrease in oxygen and vice versa.

The water temperature from the field measurements illustrates that in the waters of the study location it has a temperature range of 30.4 °C- 32.4°C, so it is still classified as a good category for marine aquaculture. As stated by Albasri and Szuster (2010a & 2010b) that the water temperature for aquaculture activities is 26 °C-32°C, while for seaweed cultivation a



good temperature range is 20 °C - 28 °C (Yulius et al. (2016 ) Good water temperature for pearl oyster cultivation 25 °C-32 °C (KKP, 2016).

The results of processing chlorophyll data at the study site showed that chlorophyll ranged from <27 ->185 mg/l, this level is still considered good for marine cultivation, especially cultivation of grass and pearl oysters as suggested by KKP (2016). Chlorophyll is better known as leaf green matter which is a pigment found in producer organisms that functions as a modifier of carbon dioxide into carbohydrates, through photosynthesis. Chlorophyll is one parameter that greatly determines primary productivity in the sea. Distribution and high and low chlorophyll concentrations are strongly related to oceanographic conditions of waters.

### **Suitability of Sea Cultivation Location**

Analysis of the suitability of marine aquaculture locations by combining all thematic maps from aquatic environmental parameters, where the total area of the study site reached 1,673.47 ha. Suitability analysis produced two classes of waters suitability <sup>48</sup> for the development of grouper aquaculture in floating net cages, which were very suitable covering an area of 737.91 ha (44.1%) and quite suitable for an area of 935.56 ha (55.9%). For seaweed farming using the raft or longline method produced one class of conformity which is quite suitable for an area of 1,673.47 ha (100%), as well as the cultivation of pearl oysters with two classes of suitability which is quite suitable for 1,096.38 ha (65.5%) and not according to an area of 577.09 ha (34.5%). A map of the suitability of marine cultivation locations is presented in Figure 6.

For the development of <sup>28</sup> an environmentally friendly and sustainable marine culture business, <sup>33</sup> the potential that exists should not be fully utilized, but must be provided for buffer zones and other fisheries activities. Thus, in the development of marine aquaculture can reduce the negative impact due to a decrease in the quality of the water environment. The waters of the Tanjung and Gangga Subdistricts of North Lombok Regency with a potential area for grouper aquaculture in floating net cages covering an area of 1,673.47 ha can only be utilized at 12.5% (Sachoemar, 2006) which is an area of 209 ha. With consideration that each hectare of grouper cultivation can be built effectively by 60 units, where on the island of Lombok the floating net cages system for lobster and lobster shrimp



cultivation is built measuring 11x11 m for each unit, and each unit consists of 9 net bags (3x3) measuring 3x3x3 m (Junaidi and Heriati, 2016), the number of floating net cages that can be operated at the location of the development of grouper aquaculture areas reaches 12,450 floating net cages units.

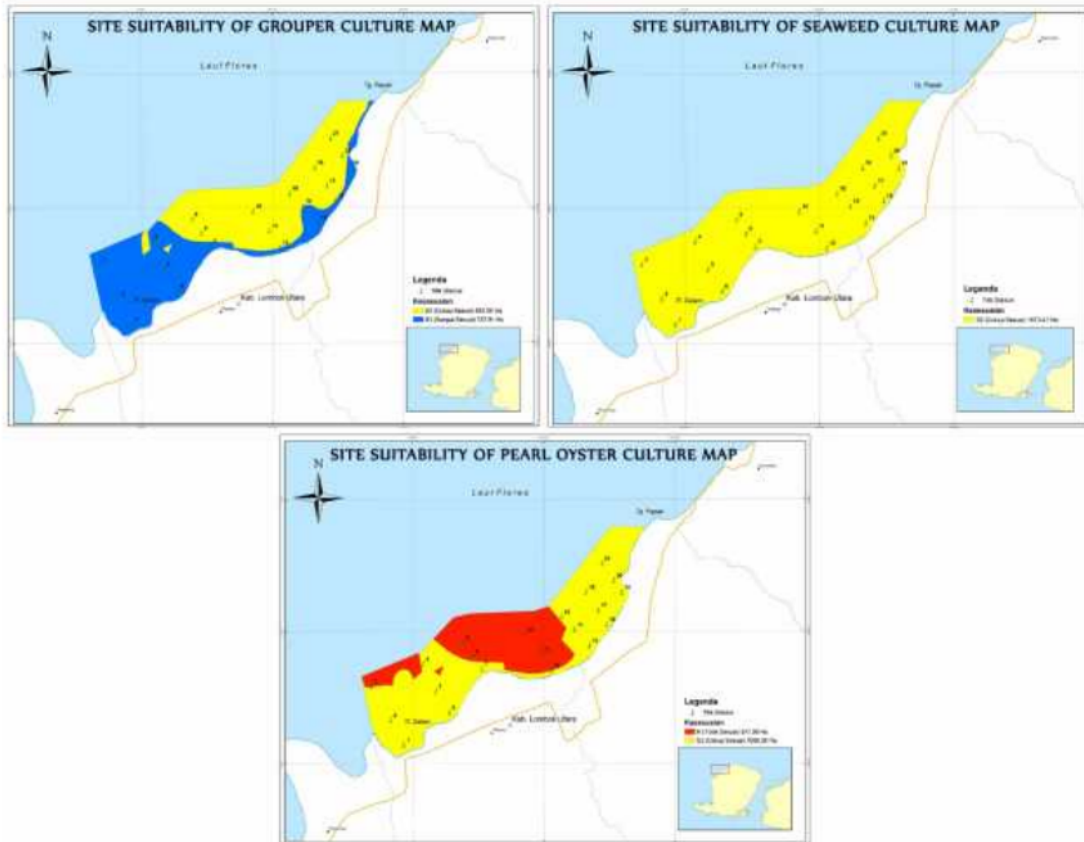


Figure 5. Map of marine suitability cultivation locations  
 a: grouper; b: seaweed; c: pearl oyster

<sup>11</sup> The carrying capacity of the waters for seaweed farming in the raft method is 55 units per hectare (Jailani et al., 2015), while the long line method is only 2 units (Nuryadin, 2015). In the raft method, where the raft is made of 8x8 m bamboo, according to the size of one bamboo stick that is available around the location, while the long line method in the form of a stretch of mine can be arranged so that it resembles a raft system construction in a larger dimension. Each seaweed long line unit is 50x100 m. Effective water <sup>34</sup> area that can be



developed for seaweed cultivation is 1,004 ha (60% of the area of waters classified as quite suitable), which are 55,220 units of rafts or 2,008 units of the long line. In the cultivation of pearl oysters by raft method, materials made of the wood size of 25x15 m, while with the long line method measuring 50x100 m. Pearl oyster cultivation using the raft or long line method for each hectare of land requires 20 raft units or 2 long line units. Thus, for the development of cultivation of pearl oysters in Tanjung and Gangga sub-districts in 658 ha of water, 13,157 raft units or 1,316 long line units are needed.

#### 4. Conclusion

The number of floating net cages grouper aquaculture that can be operated reaches 12,450 units, for seaweed cultivation as much as 55,220 raft units or 2,008 long line units, and cultivation of 13,157 pearl oyster units or 1,316 long line units.

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