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Suitability formulation and prediction of Seaweed (*Gracilaria verrucosa*) productivity in a Pond area

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ABSTRACT

Gracilaria verrucosa is one of red algae that can be cultivated in the pond area. A pond is an artificial ecosystem so that all abiotic components that work can be controlled to get the expected productivity. This study aims to formulate land suitability for seaweed *Gracilaria verrucosa* cultivation based on abiotic factors that have significant influence by considering the interrelationship and effect of each factor on productivity. The research sample was 161 ponds of total 670 ponds, with the independent variable is abiotic components including pH, surface current, brightness, turbidity, depth, dissolved oxygen, N fertilization, salinity, pond substrate, water temperature, and the dependent variable is wet weight seaweed harvest per unit area. The measurement data for abiotic components are classified in three categories according to the range of suitability for *Gracilaria verrucosa* growth, that is category 3 (suitable), category 2 (less suitable), and category 1 (not suitable). Multiple linear regression analysis is performed to determine the contibution value (weight) of each abiotic component on seaweed productivity. Cluster analysis to classify suitability and productivity scores, and Mann Withney test for comparison between groups were used. The result of this study is the Land Suitability Formula for *Gracilaria verrucosa*. The equation of relationship between suitability score (x) with seaweed productivity (y) in the dry season is $y = 1.7081x + 0.7181$, while in the rainy season is $y = 1.7247x + 1.101$. The formulation test shows that the relationship between the suitability score and seaweed productivity can be grouped into three based on the similarity of their numerical characters with the limitation of the suitability score for the dry season <3.359 = not suitable, 3.359 – 4.240 = less suitable, > 4.240 = suitable. For the rainy season is <3.549 = not suitable, 3.649 – 4.196 = less suitable, > 4.196 = suitable. The results of predicted productivity in the dry season <6,454 ounces/m^2 = not suitable, 6.454 – 7.958 ounces/m^2 = less suitable, > 7.958 ounces/m^2 = suitable, while in the rainy season <7.394 ounces/m^2 = not suitable, 7.394 – 8.338 ounces/m^2 = less suitable, > 8.338 ounces/m^2 = suitable. Statistical tests show that *Gracilaria verrucosa* productivity of the three groups for both dry and rainy seasons is significantly different.

Key words: *Gracilaria verrucosa, Productivity, Seaweed, Suitability formulation*

Introduction

Seaweed commodity is one of the most favored and developed marine products in Indonesian waters (Sahat, 2013). Seaweed that is widely cultivated and traded in Indonesia are Caraginophyte (*Eucheuma* *spinosium*, *Eucheuma edule*, *Eucheuma serra*, *Eucheuma cottonii*, and *Eucheuma spp*), Agarofit (*Gracilaria spp*, *Gelidium spp*, and *Gelidiella spp*), and Alginophite (*Sargassum spp*., *Laminaria spp*, *Ascophyllum spp*, and *Macrocystis spp*), which are the raw materials of various industries since those types of seaweed are the source of carrageenan (seaweed flour), agar, and alginate (Sahat, 2013).

Gracilaria verrucosa is one of red algae that can be cultivated in Indonesian pond areas (Dhargalkar and Kavlekar, 2004; Suharyanto and Muhammad, 2012). Jabon District, especially in the north of the Porong River is the largest producer of *Gracilaria verrucosa* seaweed production in Sidoarjo Regency, even in East Java with a pond area of around 802,233 Ha.

The problem faced at the study site is that productivity is not optimal due to the uneven growth of *Gracilaria verrucosa* in all ponds. In some ponds *Gracilaria verrucosa* can grow well, which is characterized by thallus growing vertically with lots of branches (seaweed grows thick), with a blackish green color. Whereas in other places seaweed grows short, rare, lots of algae (Javanese: *dadut*) on the thallus surface, and seaweed thallus with indigo, brown and yellow colors. The unequal condition of seaweed growth is "not yet able" to be controlled by farmers. The seaweed with short talus and yellow thallus color generally have poor growth, and are not in demand by the market (field observation result).

A pond is an artificial ecosystem so that all abiotic components that work can be controlled to get the expected productivity. In a system all factors work in an integrated manner holistically (Odum, 1971), as well as pond system. Therefore, efforts to increase productivity can be done by considering all the factors that work in the pond system. For this reason, a formulation is needed that can be used as a consideration in controlling abiotic components that work in a pond system.

This study aims to formulate land suitability for seaweed *Gracilaria verrucosa* cultivation, which has been tested for feasibility and can be implemented by farmers. Land suitability formulations for *Gracilaria verrucosa* cultivation can be prepared based on abiotic factors that have a significant influence by considering the interrelation and influence of each factor on productivity, which can be considered in the development of *Gracilaria verrucosa* cultivation.

Materials and Methods

The study uses a quantitative descriptive approach, carried out in the area of seaweed aquaculture ponds in Kupang Village, Jabon Subdistrict, Sidoarjo Regency, East Java, Indonesia from January 2017 to November 2019. The type of seaweed that is cultivated is *Gracilaria verrucosa*. The cultivation was performed by using traditional stocking method or still relying on natural conditions without special treatment in its management.

Population and Sample

The population and sample of this research were 161 ponds which were systematically determined in six clusters from a total of 670 ponds. Environmental abiotic factors as observed variables included pH, surface current speed, water transparency, turbidity, depth, dissolved oxygen (DO), N ratio (fertilization), salinity, pond substrate, water temperature, and wet basis of harvested *Gracilaria verrucosa* per m^2; each of them was measured in four replications.

Tools and Materials

The tools used in this study were measuring instruments for physical, and chemical factors which were research variables, namely the sacci plate (secci disk) for measuring brightness, digital thermometer for measuring water temperature, refractometer for measuring salinity, DO meter (multitester) for measuring dissolved oxygen, a digital pH meter to measure water pH, a wooden ruler to measure water depth, floating balls and a stop watch (modification of a kite string) to measure surface currents, a stratified filter to measure sand content. To measure the amount of fertilizer applied, data were obtained from interviews with seaweed cultivators. A quadratic frame of 1 x 1 m^2 was also used for biotic (seaweed) sampling and table scales to measure the wet weight of seaweed.

Procedures

Mapping Pond Area

The study focused on the location of the pond in the north of the Porong River since it could be planted seaweed all year long. Mapping was carried out to find out the pond area that is overgrown with seaweed. The area covers each pond as well as the ownership or seaweed cultivator. Mapping was done using the help of a basic map (satellite photos via Google in 2017) and field observations using GPS. The results of GPS georeferencing and digitization were then overlaid using the Opensource Quantum Gis Program version 2.18 (QGIS 2.18) into a map of the potential productive areas of seaweed cultivation (Fig. 1).

Determining Pond Clusters

Based on the homogeneity of the environment, seaweed pond area was classified into six clusters. The determination of homogeneity was based on field observations and information from the cultivator regarding the growth and yield of seaweed.

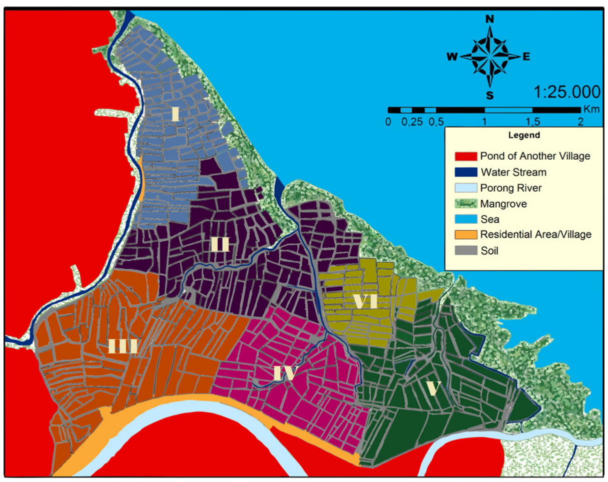

Fig. 1. Homogeneity Map and Seaweed Cultivation Pond Cluster in Kupang Village, Jabon Subdistrict, Sidoarjo Regency. The Roman number indicating the clusters: I = Cluster 1; II = Cluster 2; III = Cluster 3; IV = Cluster 4; V = Cluster 5; VI = Cluster 6.

Determining Data Sampling Locations

For each cluster, 25 ponds were determined to be the locations for sampling. Determination of pond samples cannot be done randomly because; (1) seaweed plants did not grow at the same time in all ponds, (2) some ponds were still in the process of land improvement, (3) some ponds still had the seaweed which grew less than three months since being planted (not harvested).

Sample collection was done by systematic Sampling, determining the location of the ponds was done by selecting the location that can represent groups in each cluster. The number of ponds in the sampling location is 161 ponds from the total 670 ponds.

Sampling

The sampling process in this study was performed by collecting the data on pond waters conditions to determine the numerical character of the research variables that have been determined. Then, the numerical characters were measured randomly on four sides of each of the ponds. Those were used for repetitions.

The measurement was set at a distance of two meters from the edge of the pond. Then, the abiotic samples were measured randomly by using measuring instruments on four sides of the pond. The samples of abiotic components were pH, surface current speed, water transparency, turbidity, depth, dissolved oxygen, fertilization, salinity, pond substrate, and water temperature. Those were measured randomly at sampling locations.

Biotic sampling for seaweed was done by using the quadratic method with a square area of 1 x 1 m^2. Seaweed plant in the frame was taken along with its root. Then, seaweed was drained on a stretch of fishing net with a net mesh of 0.05 mm. The next process was weighing to find out the biomass. Seaweed collection was also carried out on each side of the pond which was determined randomly.

The biotic and abiotic samplings were performed during the dry and rainy seasons.

Abiotic Factor Suitability Classification

Data from the measurement of abiotic environmental factors were analyzed for its suitability based on the tolerance range of each factor grouped in 3 categories, namely category 3 (Suitable), category 2 (Less Suitable), and category 1 (Not Suitable).

Compilation of Suitability Formulation

The compilation of the suitability formulation begins with study on literature and research results that had been published. This was done to look for references to determine factors that have a dominant influence on seaweed productivity and their tolerance range related to optimal growth, less optimal, and not optimal. In addition, field observations were also carried out to support and correct findings from literature study that were technically difficult to implement in the field.

Then, the Table was made to compile the result of literature study, field measurement data, and analysis of each measured variable. The Table consisting of seven items. (1) Pond number was the number of measured variable. (2) Measured variables were abiotic factors based on literature study known to had a dominant influence on seaweed growth. (3) Tolerance range was a limitation of the abiotic environmental conditions of the measured variable that is physiologically responded to by seaweed, with seaweed thallus growth indicators. If the tolerance range gives an optimal effect on seaweed growth, the tolerance range is said to be suitable. If the effect on growth is less than optimal, the tolerance range is said to be less suitable. If the effect on seaweed growth is not optimal, the tolerance range is said to be not suitable. (4) Suitability class was the value of the scale specified for each tolerance range. If it is suitable the given value is 3, if it is less suitable 2, and if it is not suitable 1. (5) Weight (contribution value) was a value set that shows how much influence the measured variable had on the growth of seaweed. This value set was obtained from the results of statistical analysis which can show the partial effect of each variable. 6) The suitability score was the result of multiplying the value of suitability class with the weight value of each variable. 7) The total score was the sum of all suitability scores.

The land suatibility formulation for *Gracilaria verrucosa* cultivation was arranged as combination of grouping result (using variables suitability score and productivity) and an equation that show the rationship of suitability score with *Gracilaria verrucosa* poductivity (wet basis of harvested seaweed per m^2) based on statistical analysis.

Data Analysis

Multiple Linear Regression Analysis

In this study the independent variable was measured variable (environmental abiotic factors) which the value of suitability class was transformed from ordinal to interval scale using MSI (Methods of Successive Interval). While the dependent variable was seaweed productivity, which is determined by wet seaweed biomass per m^2. The multiple linear regression model was described with the following equation:

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10}$$

Description:

Y = Dependent variable (Productivity)

X_{1-n} = Independent variable (Abiotic Factor)

α = Constanta

β_{1-n} = Slope or Estimate Coefficient

The results of multiple regression analysis indicated the value of Cumulative Contribution (R square) and Relative Contribution (SR) of measured variables on seaweed productivity. From the results of multiple regression analysis will get an R square, a value that states the contribution of all independent variables to the dependent variable (Effective Contribution). Furthermore, the Relative Contribution (SR) variable was calculated, which shows the amount of contribution of each measured variable to seaweed productivity. This relative contribution will be the weight of each variable in the table of suitability score determination. Statistical analysis were performed with SPSS software (version 23.0).

Cluster Analysis

Cluster analysis was used to group ponds that have similarity based on suitability score and seaweed productivity. Cluster analysis was conducted using a cluster hierarchy because the source of the similarity of the variables was unknown.

Mann Whitney Analysis

Mann Whitney analysis was used to find out whether there were differences in productivity (with biomass per m^2 indicator) of seaweed harvested in pond areas with different categories of suitability (suitable, less suitable, and not suitable).

Results and Discussion

Results

Formulation of land suitability for *Gracilaria verrucosa* cultivation

Measurement data which is biotic and abiotic environmental factors as research variables include the degree of acidity (pH), surface current speed, brightness, turbidity, water depth, dissolved oxygen (DO), fertilization, salinity, substrate, water temperature, and *Gracilaria verrucosa* biomass per unit area. Then, the average data of measured independent variables for both the dry and rainy seasons were classified in three classes: suitability class 3 (suitable); suitability class 2 (less suitable); and suitability class 1 (not suitable).

The weight needed in the preparation of Land Suitability Formulation is obtained from the contribution value of the influence of each abiotic factors on *Gracilaria verrucosa* productivity (biomass per m²). The results of Multiple Linear Regression analysis show that the cumulative contribution (R^2) of the measured variable to productivity in the dry season was 73.6%. While partially, each component had an influence on productivity, with partial contributions from the largest to the smallest were water temperature (26.8%), depth (22.6%), DO (22.5%), fertilization (18.5%), brightness (15%), pH (13.75), turbidity (12.8%), surface current (12.7%), substrate (11.9%), and salinity (11.6%).

The results of the Multiple Linear Regression analysis show that the cumulative contribution (R^2) of the measured component to productivity in the rainy season was 97.6%. While partially, each component had an influence on productivity, with partial contributions from the largest to the smallest were fertilizing (25.2%), DO (24.0%), brightness (18.6%), pH (17.9%), turbidity (16.6%), water temperature (15.2%), surface current (13.0%), substrate (11.3%), depth (10.8%), and salinity (7.5%).

The contribution that gives the effect of each measured variables to productivity then becomes the weight of each variable. The multiplication result between weight (contribution value) and suitability class of measured variable will determine the suitability score of land for *Gracilaria verrucosa* seaweed cultivation (Table 1).

Table 1. Land Suitability Score for *Gracilaria verrucosa* Cultivation

No	Measured Variable	Tolerance Range		Suitability Class	Weight (contribution value)		Suitability Score
					Dry	Rainy	
1	Acidity (pH)	7.5 - 8.5		3	0.137	0.179	
		6.0 - <7.5		2			
		<6.0 ; >8.5		1			
2	Surface Current Speed	0.2 - 0.3		3	0.127	0.130	
	(meter/ minutes)	0.1 - 0.19; 0.31 - 0.4		2			
		<0.1 ; >0.5		1	0.150	0.186	
3	Brightness (m)	>0.5		3			
		0.3 - 0.5		2			
		<0.3		1			
4	Turbidity (mG/L)	0 – 4		3	0.128	0.166	
		4 - 8		2			
		>8		1			
5	Profundity (cm)	40 - 60		3	0.226	0.108	
		30 - 39.9; 60.1 - 80		2			
		<30; >80		1			
6	Dissolved oxygen/ DO	>8		3	0.225	0.240	
	(mG/L)	5 - 8		2			
		<5		1			
7	N ratio (Fertilization)	Rainy Season	Dry Season	3	0.185	0.252	
		40 - 60	20 - 40	2			
		20 - <40	10 - <20	1			
		<20; >60	<10 ; >40				
8	Salinity (ppt)	28 - 30		3			
		25 - 27.9; 30.1 - 33		2			
		<25; >33		1	0.116	0.075	
9	Basic Substrate	25 - 30		3	0.119	0.113	
	(Sand Content)	15 - 24; 31 - 74		2			
		0 - 14; 75 - 100		1			
10	Water temperature	28 - 29		3	0.268	0.152	
	(^{o}C)	26 - 27.7; 29.1 - 30		2			
		<25 ; >30		1			

Total Score

Note: Suitability Score was obtained from the multiplication results between Suitability Class and Weight (Contribution Value) in the Dry Season/ Rainy Season.

Testing of land suitability formulation for *Gracilaria verrucosa* cultivation

Classification of suitability that had been determined was a grouping of suitability scores. If the suitability score was grouped into three groups based on the numeric character of ten measured variables followed by a grouping of *Gracilaria verrucosa* productivity values with consideration of linear relationship between suitability scores and *Gracilaria verrucosa* productivity, then the formulation can be said to be feasible. For this reason, an analysis of the relationship between suitability score and *Gracilaria verrucosa* productivity, as well as grouping of suitability score and *Gracilaria verrucosa* productivity was conducted.

The suitability score indicates that the more suitable condition of measured variable for *Gracilaria verrucosa* growth, the higher the suitability score. The more suitable environmental conditions will be followed by increasing *Gracilaria verrucosa* growth. Thus the suitability score will be directly proportional to the productivity value.

The analysis result of relationship between total suitability score (x) and *Gracilaria verrucosa* productivity (y) in the dry season was a linear line with the formulation y = 1.7081x + 0.7161. The calculation results show that the lowest productivity was at suitability score 2.418 and wet seaweed per m^2 was 4.846 ounces. While the highest productivity was at suitability score 4.673 and wet seaweed per m^2 was 8.698 ounces.

The analysis result of relationship between total suitability score (x) with *Gracilaria verrucosa* productivity (y) in the rainy season was a linear line with the formulation y = 1.7247x + 1.101. The calculation results show that the lowest productivity was the suitability score 2.615 and wet seaweed per m^2 was 5.611 ounces. While the highest productivity suitability score 4.803 and wet seaweed per m^2 was 9.385 ounces.

The results of Cluster Analysis from 161 sample ponds based on the suitability score and *Gracilaria verrucosa* productivity variables for the Dry Season are presented in Fig. 2 and for the Rainy Season presented in Fig. 3.

Cluster analysis results for the dry season

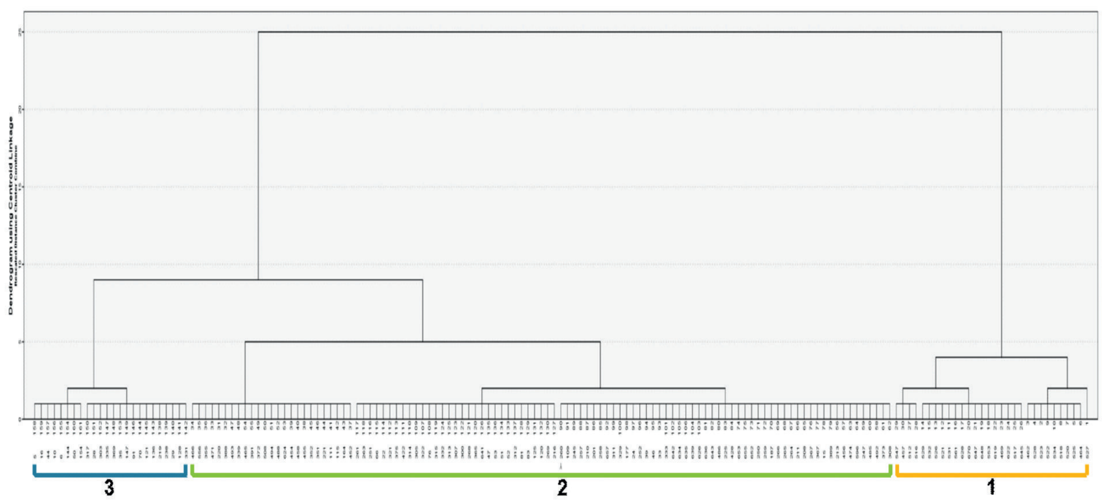

Fig. 2. Dendrogram of Cluster Analysis Results for Dry Season. **Group 1** = 1:527, 2:523, 3:462, 4:528, 5:525, 6:464, 7:520, 8:518, 9:522, 10:534, 11:531, 12:521, 13:526, 14:529, 15:532, 16:561, 17:628, 18:553, 19:648, 20:670, 21:647, 22:619, 23:469, 24:622, 25:517, 26:645, 27:512, 28:516, 29:547, 30:457. **Group 2** = 31:220, 32:388, 33:471, 34:466, 35:556, 36:355, 37:452, 38:455, 39:454, 40:458, 41:111, 42:115, 43:164, 44:221, 45:352, 46:351, 47:493, 48:339, 49:372, 50:508, 51:494, 52:488, 53:624, 54:465, 55:391, 56:213, 57:456, 58:492, 59:247, 60:485, 61:373, 62:308, 63:474, 64:596, 65:208, 66:211, 67:264, 68:265, 69:266, 70:187, 71:250, 72:259, 73:652, 74:653, 75:655, 76:267, 77:367, 78:15, 79:389, 80:486, 81:636, 82:643, 83:225, 84:428, 85:258, 86:201, 87:210, 88:257, 89:245, 90:260, 91:109, 92:657, 93:33, 94:39, 95:46, 96:252, 97:24, 98:177, 99:311, 100:329, 101:333, 102:642, 103:626, 104:639, 105:634, 106:635, 107:322, 108:76, 109:305, 110:314, 111:422, 112:321, 113:375, 114:22, 115:66, 116:251, 117:261, 118:263, 119:315, 120:365, 121:268, 122:300, 123:307, 124:332, 125:313, 126:641, 127:216, 128:81, 129:83, 130:269, 131:125, 132:120, 133:52, 134:51, 135:47, 136:53, 137:312. **Group 3 =** 138:219; 139:238, 140:29, 141:128, 142:331, 143:136, 144:70, 145:121, 146:91, 147:335, 148:369, 149:147, 150:317, 151:28, 152:303, 153:35, 154:144, 155:6, 156:10, 157:44, 158:5, 159:16, 160:50, 161:154.

showed that the dendrogram was divided into three groups on scale of 5. This illustrates that all ponds were grouped into three groups that have a numerical similarity of suitability scores and seaweed productivity. Group 1 consists of 30 ponds, group 2 consists of 107 ponds, and group 3 consists of 24 ponds.

Cluster analysis results for the rainy season show that dendrogram was divided into three groups on scale of 5. This illustrates that all ponds were grouped into three groups that have a numerical similarity of suitability scores and seaweed productivity. Group 1 consisted of 29 ponds, group 2 consisted of 36 ponds, and group 3 consisted of 96 ponds.

The combination of grouping results and the relationship between suitability score and productivity in the dry and rainy season gives an illustration of productivity values distribution which was divided into three group. The relationship of *Gracillaria verrucosa* productivity with suitability scores in each group in the dry season can be seen in Fig. 4 and the rainy season in Fig. 5. The results of analysis with Mann Whitney Test show that productivity between groups was significantly different (Asymp. Sig. = 0.000) both in dry and rainy season.

Calculation by using the formula y= 1.7081x + 0.7161 in each group in the dry season and y= 1.7247x + 1.101 in the rainy season will get an interpretation of total suitability score as an application results of suitability formula. Furthermore, the suitability formula based on the relationship between suitability score and productivity can be used to predict *Gracilaria verrucosa* productivity. Calculation results that show the interpretation of suitability score were presented in Table 2 and productivity predictions are presented in Table 3.

Discussion

The measurement results of measured variables include acidity (pH), surface current speed, brightness, turbidity, water depth, dissolved oxygen (DO),

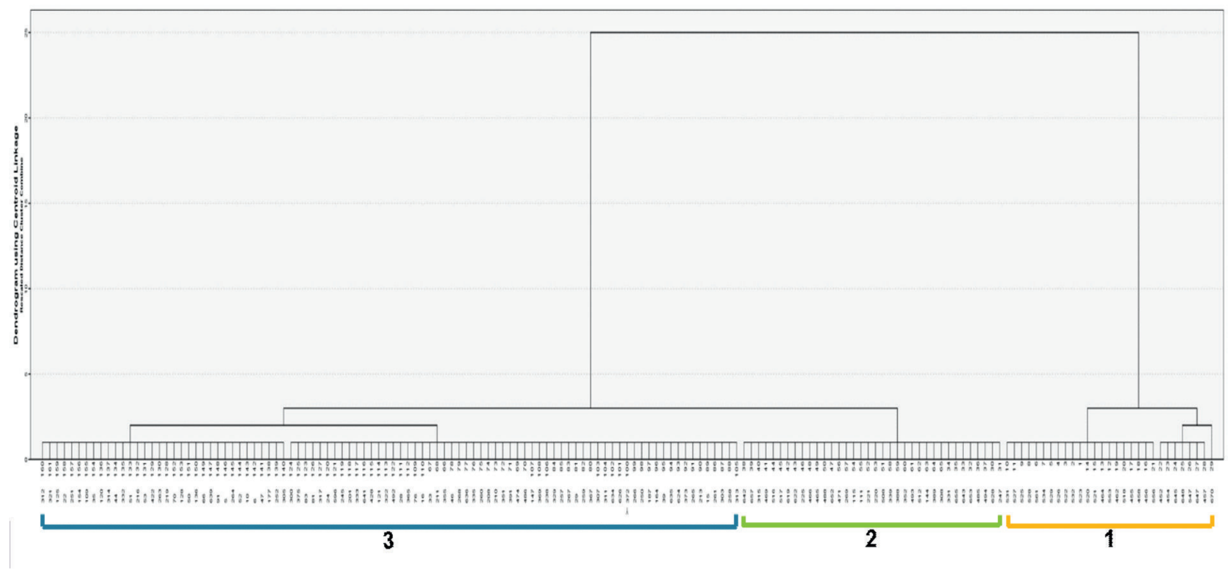

Fig. 3. Dendogram of Cluster Analysis Results for Rainy Season. **Group 1** = 1:523, 2:532, 3:522, 4:526, 5:529, 6:561, 7:534, 8:528, 9:525, 10:531, 11:527, 12:553, 13:464, 14:520, 15:521, 16:456, 17:455, 18:458, 19:462, 20:518, 21:556, 22:452, 23:454, 24:645, 25:648, 26:547, 27:647, 28:457, 29:670. **Group 2** = 30:628, 31:247, 32:653, 33:643, 34:331, 35:655, 36:485, 37:494, 38:642, 39:657, 40:315, 41:469, 42:619, 43:622, 44:516, 45:517, 46:225, 47:652, 48:466, 49:465, 50:488, 51:508, 52:221, 53:220, 54:115, 55:111, 56:471, 57:269, 58:339, 59:388, 60:352, 61:493, 62:512, 63:144, 64:389, 65:308. **Group 3** = 66:355, 67:33, 68:211, 69:474, 70:486, 71:391, 72:351, 73:210, 74:208, 75:260, 76:335, 77:636, 78:46, 79:268, 80:367, 81:29, 82:259, 83:267, 84:329, 85:257, 86:261, 87:303, 88:258, 89:15, 90:213, 91:265, 92:373, 93:624, 94:635, 95:39, 96:164, 97:187, 98:250, 99:266, 100:372, 101:626, 102:634, 103:307, 104:311, 105:313, 106:238, 107:147, 108:369, 109:76, 110:16, 111:28, 112:365, 113:322, 114:121, 115:428, 116:641, 117:333, 118:201, 119:245, 120:24, 121:596, 122:492, 123:83, 124:300, 125:375, 126:81, 127:317, 128:219, 129:422, 130:263, 131:53, 132:216, 133:51, 134:44, 135:332, 136:120, 137:314, 138:177, 139:252, 140:305, 141:47, 142:6, 143:10, 144:52, 145:264, 146:5, 147:639, 148:91, 149:66, 150:136, 151:50, 152:70, 153:128, 154:35, 155:109, 156:154, 157:251, 158:22, 159:125, 160:312, 161:321.

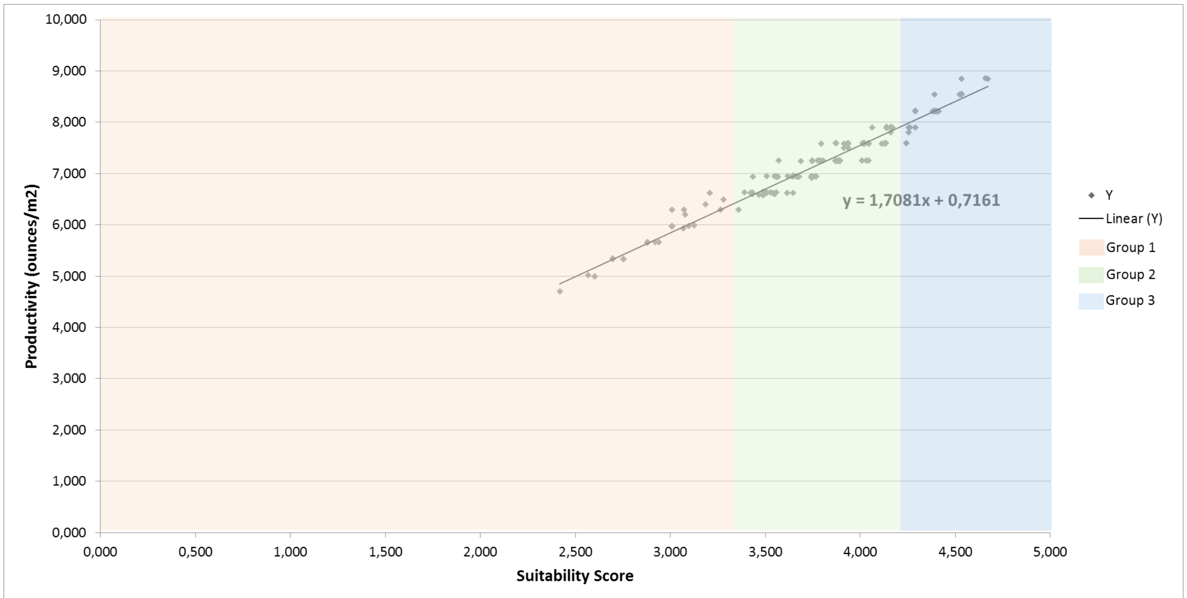

Fig. 4. Combination of grouping and relationship of *Gracilaria verrucosa* productivity with suitability scores (Dry Season)

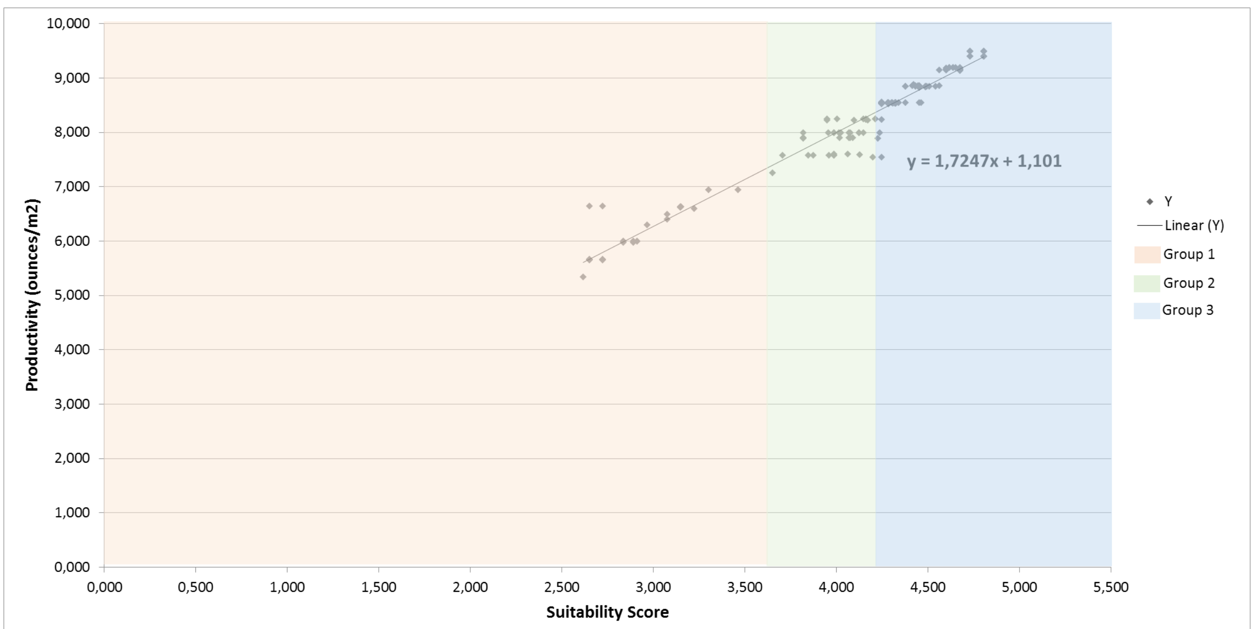

Fig. 5. Combination of grouping and relationship between *Gracilaria verrucosa* productivity and suitability scores (Rainy Season)

fertilization, salinity, basic substrate, and water temperature vary between ponds and have differences between the dry season and rainy season. In the dry season, the measured variables approach the category of less suitable and not suitable compared to the rainy season, which approaches the suitable category. Likewise with *Gracilaria verrucosa* productivity, the average measurement results of wet seaweed weight per m^2 in the rainy season are higher than the dry season.

The grouping of total suitability scores is an attempt to simplify the set of suitability score values that have a gradual increase, from low scores to higher scores into three groups. The division into these three groups is based on the similarity of numeric characters through cluster analysis.

Table 2. Interpretation of Pond Land Suitability Score for *Gracilaria verrucosa* Seaweed Cultivation

Dry Season		Rainy Season	
Score	< 3.359 = 1 (not suitable) 3.359 – 4.240 = 2 (less suitable) > 4.240 = 3 (suitable)	Score	< 3.649 = 1 (not suitable) 3.649 – 4.196 = 2 (less suitable) > 4.196 = 3 (suitable)

Table 3. *Gracilaria verrucosa* Productivity Prediction Based on Suitability Score

Dry Season (ounces/m^2)		Rainy Season (ounces/m^2)	
Productivity	< 6.454 = 1 6.454 – 7.958 = 2 > 7.958 = 3	Productivity	< 7.394 = 1 7.394 – 8.338 = 2 > 8.338 = 3

Cluster analysis with suitability score and productivity as variables, it was found three groups both in the dry and rainy season with different number of group members. In the dry season, it shows that Group 1 consists of 30 ponds with a range of suitability scores <3.359 and predicted productivity <6.454 ounces/m^2, group 2 consisted of 107 ponds with a range of suitability scores of 3.359 - 4.240 and productivity predictions between 6.454 - 7.958 ounces/m^2, group 3 consisted of 24 ponds with a range of suitability scores >4.240 and predicted productivity >7.958 ounces/m^2. In the rainy season shows that group 1 consists of 29 ponds with a suitability score <3.649 and predicted productivity <7.394 ounces/m^2, group 2 consisted of 36 ponds with a suitability score of 3.649 – 4.196 and predictions of productivity ranged from 7.394 – 8.338 ounces/m^2, group 3 consisted of 96 ponds with a suitability score >4.196 and predicted productivity >8.333 ounces/m^2.

If it is compared, then there are differences in grouping between the dry season and the rainy season. In the dry season, productivity is lower than in the rainy season. This difference is seen in the linear equation constant value of the relationship between productivity and suitability score, which in the dry season is lower than the rainy season. This condition is probably because in the dry season, the environmental pressure is greater than in the rainy season. This environmental pressure in dry season can be seen mathematically from the influence of measured variables which is 73.6% in comparison with remining 26.4% is another factor that is not measured in the study. While in the rainy season, the measured variables give an influence with contributions of 97.6%, and the remining 2.4% is another factor that is not measurable.

Environmental factors that have the most dominant influence on the productivity of *Gracilaria verrucosa* in the dry season are water temperature, depth, and DO, which total contribution more than 50%. Whereas in the rainy season, the most dominant environmental factors are fertilization, DO, and brightness.

The difference in the effect of each variable on productivity in the dry and rainy seasons is caused by differences in sunlight intensity. In the dry season, the intensity of sunlight is higher than the rainy season. Physically the intensity of the light entering the pond waters is influenced by the brightness, turbidity, and depth of the pond. Sunlight entering the waters affects photosynthesis, photosynthesis, respiration, metabolism, growth, and reproduction (Dawes, 1981). The incoming light will increase the temperature of the water.

In the dry season, the temperature has the highest effect. This is because of the location of ponds that are open with uneven water depths so that during the dry season, the pond waters are exposed to sunlight with relatively high intensity, which causes an increase in water temperature. The increase in water temperature into the waters depends on the light entering the liquid, whose intensity is influenced by water brightness, turbidity and pond depth (Ruslaini, 2016; Susilowati *et al.*, 2012). Temperature affects the solubility of the gases needed for photosynthesis, such as CO_2 and O_2. These gases are easily dissolved at lower temperatures than at high temperatures. As a result, the speed of photosynthesis is increased by low temperatures. This is indicated by Ruslaini's research results (2016), the higher the temperature, the growth rate of *Gracilaria verrucosa* decreases. High water temperatures can cause dissolved oxygen (DO) and pH to be low

(Budiyani *et al.,* 2012). Water temperature also affects several physiological functions of seaweed, such as photosynthesis, respiration, metabolism, growth, and reproduction (Dawes, 1981). Increasing water temperature, salt content, and pressure of dissolved gases decreases the solubility of oxygen in water (Wardoyo, 1981).

In the rainy season, ponds get enough from the rainwater. On the contrary, in the dry season, some ponds tend to lack water that is known from its low depth. Depth is one of the determining factors in the growth rate of seaweed, with the increasing depth of the pond bottom, the circulation of oxygen is lower, and the light penetration is lower (Kune, 2007). In ponds whose depth is low, water temperatures tend to be higher, and the color of seaweed tends to be brighter yellowish. This is in accordance with the opinion of Ramus (1976) and Gómez (2005). That macroalgae that grow at deeper depths, usually synthesize more pigments to compensate for the effects of low light availability. Increasing the concentration of pigment with depth is a strategy used by algae to capture more light for photosynthesis to optimize its metabolism (Morinho-Soriano, 2012). Therefore, in seaweed fields that grow at an appropriate depth are darker, blackish green.

In the rainy season, the water temperature tends to be lower, compared to the dry season. Besides that, a raindrop falling on the surface of pond water mechanically cause aeration. The low temperature and the presence of aeration cause high DO in the rainy season.

Dissolved oxygen in waters generally comes from photosynthesis by algae and diffusion from the air (APHA, 1995; Novotny and Olem, 1994; Susilowati *et al.,* 2014) In the rainy season Dissolved oxygen has a relatively high effect on productivity compared to the dry season. Dissolved oxygen levels in water are affected by temperature, water turbulence, water flow, waves, the partial pressure of gases in the atmosphere, and salinity (Ross, 1970; Jeffries and Mills, 1996).

Dissolved oxygen is needed in performing respiration and decomposing organic matter by microorganisms (Harvey, 1982). Dissolved oxygen is used by all organisms in ponds for respiration (Susilowati *et al.,* 2014). This is followed by decreasing pH and increasing ammonia and nitrite. Sufficient oxygen in the pond can convert ammonia into nitrate as a nutrient of seaweed with the help of Nitrosomonas and Nitrobacter bacteria (Mangampa and Burhanuddin, 2014).

Fertilization in the rainy season has the highest effect compared to other measurable variables. In the dry season, fertilization gives the third biggest contribution. In the rainy season, due to precipitation and excessive water input, dilution of fertilizer concentration will occur, and excess water will be removed from the pond. In the dry season, the optimal limit of fertilizer concentration needed for *Gracilaria verrucosa* growth is lower than the rainy season. Excessive fertilizer in the dry season results in the growth of algae (Javanese: *dadut*) on the surface of the thallus, thus inhibiting the process of photosynthesis and reducing the quality of the harvest (productivity) of seaweed.

Fertilization is not a factor caused by nature, but because of human activities, in this case, are farmers, so it is very subjective. The amount of fertilizer introduced into the pond is very dependent on many personal factors that are not measurable. However, the presence of fertilizer in ponds as nutrients provides a significant influence on seaweed productivity. *Gracilaria* sp. can grow quickly if the element N content is high in nature (Yang *et al.,* 2015; Lobban and Harrison, 1994). Nitrogen is a major element for plant growth because it is a constituent of proteins and nucleic acids, and thus constitutes the whole protoplasm constituent (Sarief, 1986; Lobban and Harrison, 1994).

Seaweed is a strong absorber of inorganic nutrients (Chopin *et al.,* 2010). Gracilaria has a role as phytoremediation, which has a strong ability to accumulate Nitrogen, so it is called as Nitrogen Starved Glacilaria (Komarawidjaja, 2005). Thalus Glacilaria can absorb and accumulate Nitrogen and Phosphorus (Boyajian and Carreira, 1997). Pramesti (2013) states that the process of absorption of nutrients in seaweed is carried out by osmotic diffusion through all parts of the body.

In conclusion, the formulation of land suitability for *Gracilaria verrucosa* cultivation is a combination of grouping and relationship between *Gracilaria verrucosa* productivity and suitability scores in both dry and rainy season. The equation of relationship between suitability score (x) and *Gracilaria verrucosa* productivity (y) in the dry season was $y = 1.7081x + 0.7181$, while in the rainy season was $y = 1.7247x + 1.101$. Formulation test results show that the relationship between suitability score and seaweed productivity can be grouped into three groups based on the similarity of their numerical characters with the limitation of the suitability score for the dry season <3.359 = not suitable, 3.359 - 4.240 = less suitable, >4.240 = suitable. For the rainy season is <3.549 = not suitable, 3.649 - 4.196 = less suitable, >4.196 = suitable. Based on the suitability score and linear equation, *Gracilaria verrucosa* productivity can be predicted. In the dry season <6.454 ounces/m^2 = not suitable; 6.454 - 7.958 ounces/m^2 = less suitable, >7.958 ounces/m^2 = suitable, while in the rainy season <7.394 ounces/m^2 = not suitable, 7.394 - 8.338 ounces/m^2 = less suitable and >8.338 ounces/m^2 = suitable. The results of statistical analysis show that productivity between groups was significantly different both in dry and rainy season. The combination of grouping results and the relationship between suitability score and productivity in the dry and rainy season gives an illustration of land suitability for *Gracillaria verrucosa* cultivation.

With the formulation of land suitability for *Gracilaria verrucosa* cultivation, it can be seen how the condition of land suitability for cultivation and efforts to increase productivity by considering the influence of abiotic factors whose influence is dominant in the dry and rainy seasons.

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