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ARTICLE

Integrated Coastal Management Dynamic Models: A Case Study of Development Seaweed Cultivation in the Waters Luwu and Palopo Regency Bone Bay, South Sulawesi

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ABSTRACT

Waters carrying capacity in seaweed of Eucheuma cottonii cultures should be a concern for optimum seaweed culture. Carrying capacity can determine by Ecological Footprint (EF) analysis, which in this research use footprint production, and mas balance nitrate analysis. This research on Mei 2015 (1st transitional season) and September 2015 (2nd transitional season) in Luwu and Palopo, South Sulawesi. Map and land use analyzed with geographic information systems (GIS).The results showed that the Ecological Footprint production (EFP)in Luwu waters is 67,88 ton/capita/year, or equivalent to 235.823,93 tons/year.Based on the analysis of the availability of water for seaweed is 38.374,69 hectares, it can produce seaweed (biocapacity) for 922.928,96 tons/year and the number of farmers that allows for use the waters is 13.595 capita. The Ecological Footprint production (EFp) in Palopo waters is 3,08 ton/capita/year, or equivalent to 4.589,99 tons/year. Water availability analysis is 979,82 hectares are able to produce seaweed (biocapacity) for10.115,34 ton/year and the number of farmers that allows for use the waters is 3.276 capita. Based on the four scenario simulation management results of the development seaweed cultivation Eucheuma cottonii in Luwu and Luwu Regency is based on the present waste input, pressing inputs of waste into the waters of 10%, 25% and 50% yield different waters biocapacity. The results comparison between biocapacity and Ecological Footprint, ecological status for Luwu and Palopo waters are still in sustainable use.Based on those simulation results showed that in second scenario by pressing the waste input by 10% from the existing waste input, as well as assuming the availability of water utilizing the entire area of 38.374,69 hectares continuously (on the years scale of 2008-2030), it will produce the highest biocapacity waters in the amount of 8.257.274,94 tons/year. So with the management of seaweed in Palopo with second scenario, assuming the availability of water utilizing the entire area of 979,82 hectares will produce the highest waters biocapacity of 14.306,92 tons/year.

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1. Introduction

Seaweed is a leading commodity in South Sulawesi Province, especially in Luwu Regency and Palopo City.Based on the Luwu Regency Marine and Fisheries [1,2], the production of dried seaweed species of Eucheuma cottonii since 2010- 2014 in both regions each year continues to increase. Seaweed production in Luwu Regency in 2010 and 2014 amounted to 183,202.80 tons and 356,385.50 tons with the percentage increase on average each year by 18.50% [1].While the production of seaweed in Palopo 2010 and 2014 amounted to 2,227.04 tons and 3,112.31 tons with an average percentage increase every year amounted to 40.38% [2]. In addition, the area of water used for seaweed cultivation every year also increases, where the area of water used for seaweed cultivation in Luwu Regency in 2014 was 10,469.24 hectares [1] and in Palopo City by 313.60 hectares [2].

Based on data from DKP Luwu Regency (2015) states that the average productivity of seaweed from 2008-2014 reached 24.05 tons/hectare/year, while the productivity of seaweed in Palopo City from 2008-2014 reached 10.32 tons/hectare/year [2].Aquatic productivity in Luwu Regency is very high due to among them being extensive aquaculture land and more seaweed cultivators than in Palopo City. The average cultivator in LuwuRegency in 2008-2014 reached 3.472 capita, while in Palopo City it only reached 1.503 capita.

The productivity of seaweed in the waters besides being influenced by the area of cultivated land, is also strongly influenced by the quality of the waters. While the quality and productivity of the waters are strongly influenced by how much input of organic and inorganic materials originating from the land that enters the waters through the river flow. For example waters in the Regency of Bua, Luwu, a key input load is domestic waste as well as waste from a plywood factory (plywood) is right near Bua River Estuary. While the waters in Ponrang Sub Regency, Luwu Regency, the main burden of water is domestic waste as well as waste from ponds in the form of fertilizer residues, pesticides, food waste and other organic materials. As for the waters of Palopo City, the main load of water is waste from activities at the Ponrap Fish Auction Place (TPI) and the Indonesian Fisheries Port (PPI).Thus, the input characteristics of runoff greatly affect the quality and productivity of the waters, which in turn will affect the growth of seaweed.

Based on some of the above which shows that the waters in Luwu Regency and Palopo City have enormous potential for seaweed cultivation, it is very necessary for an integrated management effort so that it can maintain and improve both the production factors and the quality of seaweed in Luwu Regency and Palopo City. Therefore it is necessary to analyze the water carrying capacity for sustainable management. The carrying capacity of the waters is needed to determine the optimum capacity of seaweed cultivation. Carrying capacity in this study include how much land these waters which can be used optimally, large such waters can produce seaweed, as well as how many human resources that allow to take advantage of available land. By knowing the level of utilization and carrying capacity of a waters, it can be used as a foundation in the management of a waters so that the utilization rate does not exceed the existing carrying capacity.

Knowing how big the carrying capacity of waters that can be utilized for seaweed cultivation is very important for sustainable management. Approach which can be applied to find out the carrying capacity of waters in an effort to sustainably manage seaweed farming in this study is by Ecological Footprint (EF) analysis and mass balance nitrate concentration (NO_3).The EF approach is based on the level of resource utilization and productivity of an existing water (biocapacity/BC) [3].The approach to the mass balance model of nitrate concentration is based on how much availability of nitrate nutrients is capable of optimally supporting the growth of seaweed in a certain area of land.

The purpose of this study was to measure the carrying capacity of waters for Eucheuma cottonii seaweed cultivation, as well as model management of seaweed cultivation in Luwu Regency and Palopo City with the concept of Ecological Footprint (EF) analysis and mass balance nitrate concentration.

2. Methodology

2.1. Time and Location of Research

The research was conducted in two stages, namely stage 1 was carried out in May 2015 (first transition season) and stage 2 in September 2015 (second transition season) in the coastal waters of Luwu Regency and Palopo City, Bone Bay, South Sulawesi. Primary data collection is carried out at 18 station points. The map of the research location is shown in Figure 1.

2.2. Tool and Materials

The tools used in this study are several tools for retrieving oceanographic parameter data namely thermometer, refractometer, pH meter, DO meter, current meter, niskin bottle, ice box and several bottles of samples for storing sea water samples. While the material used was the sea water flow from HyCom+NCODA data in May and Sep-

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tember 2015, NOAA imagery in 2004-2014 in the form of data on the distribution of sea surface temperature, turbidity of water and chlorophyll-a content and questionnaire to obtain social primary data, economic and related stakeholders . Some of the stakeholders included the Head of the Maritime and Fisheries Agency (DKP), Kabid, Kasie and DKP staff in Luwu Regency and Palopo City, seaweed entrepreneurs and seaweed farmers, with a total of 30 respondents

2.3 Data

The primary water data taken and analyzed in situ includes seawater temperature, salinity, pH, dissolved oxygen and current. Temperature and dissolved oxygen data were measured using DO meter, salinity using a refractometer, pH using a pH meter and current using a current meter and from HyCom+NCODA data in May and September 2015. Tidal secondary data came from Geospatial Information Bureau (2015), slope and length data the coastline comes from the DKP of Luwu Regency and Palopo City. Data analyzed in the laboratory of Brackish Water Aquaculture Research and Development Center, Maros, South Sulawesi included total suspended solid (TSS) data, chemical oxygen demand (COD), nitrate, phosphate, ammonia, chlorophyll-a, and heavy metals Pb, Cd and Hg. All water data was taken using poor bottles at a depth of 2 meters.

2.4 Data Analysis

Data analysis was conducted to determine the carrying capacity of water that can be used for the cultivation of seaweed. Analysis of waters carrying capacity was carried out using the Ecological Footprint analysis (EF) approach and analysis of mass balance nitrate concentration (NO_3). The carrying capacity analysis of waters with EF approach includes three main components that must be known, namely: (1) how much the level of water use (in this case is the Ecological Footprint of production/EF_P), (2) how much water space is available and the ability to produce (biocapacity /BC) seaweed , and, (3) how much resources humans who make it possible to utilize the available water space. By comparing the biocapacity to the Ecological Footprint, it will produce how much the carrying capacity of the waters. Analysis of waters carrying capacity based on mass balance nitrate concentration (NO_3) is based on how much nitrate concentration is able to support the growth of seaweed in a waters.

Carrying capacity of waters with EF analysis approach [4,5,6,7] based on the results of conformity analysis using Geographic Information Systems (GIS), like according to the [8], which describes the carrying capacity of waters based on existing land suitability, but has not considered nutrients (especially nitrates) which are the main factors for seaweed growth. Thus a further analysis is needed to determine the actual carrying capacity of the waters by considering the availability of nutrients in an ecology, namely by approaching the mass balance nitrate concentration (NO_3). The difference between the results of carrying capacity extents EF with mass balance analysis of nitrate concentrations describe as a buffer area (buffer zone) to balance the nutrient supply to remain stable and sufficient for the cultivation of seaweed. The next analysis is to compile a dynamic model using the Stella version 9.0.2 program with the aim of knowing integrated coastal management models in the development of seaweed cultivation in Luwu Regency and Palopo City.

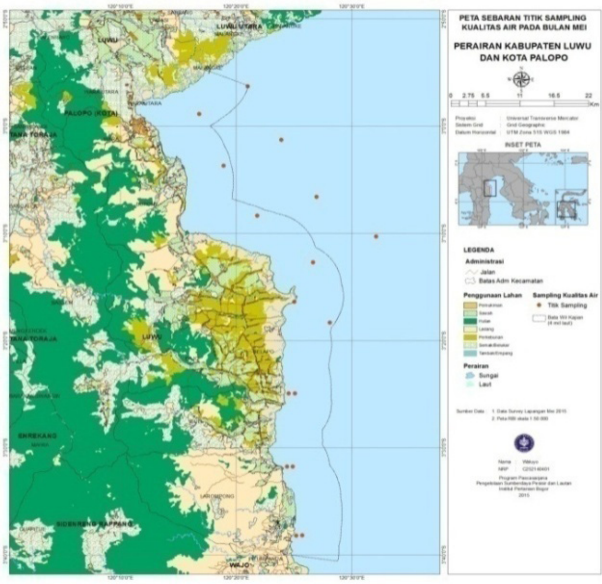

Figure 1. Map of the research location.

2.5. Management Dynamic Model

Making a dynamic model is done using the software Stella version 9.0.2. Creating a dynamic model of coastal area management with a special study on the development of seaweed cultivation is carried out in several stages, namely conceptual model, model formulation, model testing and model implementation [9,10,11,12].

2.5.1 Conceptual Model

The conceptual model starts with the identification of various needs to create a model, so that it can produce a system operation that is considered effective. This step is done by looking for all the important factors that are very influential on the dynamic system.

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Model Formulation

Building a dynamic model aims to determine system behavior in assisting strategic planning in coastal area management in Luwu Regency and Palopo City.

A. Population Sub Model

Population sub models in the Luwu Regency and Palopo City are the function of the rate of population growth and the rate of decline in population. The rate of increase in population is influenced by immigration and birth. The rate of decline in population is influenced by emigration and death. Thus the total population at a certain time (t) is:

Population (t) = Population (t-dt) + (rate of increase-rate of decline) x dt

People who live in coastal areas will produce domestic waste that will enter the waters, where the waste that enters the waters is affected by the input fraction of waste into the water and the dilution of waste that occurs in the waters.

B. Cultivated Land Area Sub Model

The broad sub model of cultivated water greatly affects the level of seaweed production, density, production per hectare and business capital. Water area is strongly influenced by the level of unused water area and water use. The level of land use is also influenced by the number of farmers and nurseries, while the unused water is affected by the unused water fraction.

C. Seaweed Production Sub Model

The seaweed production sub model is influenced by the level of seedling and the mortality rate of seaweed seedlings. The level of nursery is strongly influenced by the fraction of the nursery, while the mortality rate of seaweed seedlings is influenced by wastewater entering the seaweed and the mortality fraction of seaweed seedlings.

D. Carrying Capacity Sub Model

The waters carrying capacity sub model is divided into two, namely carrying capacity based on Ecological Footprint (EF) and based on mass balance nitrate concentration. Several factors that affect the carrying capacity based on EF include the area of existing water area, the area of suitability, the number of cultivators, production and productivity of the waters as well as biocapacity. While carrying capacity that is based on mass balance nitrates include the volume of sea water that goes to the beach at high tide (Vo), the volume of sea water that comes out at low tide (Vs), the concentration of nitrate in (inflow), the concentration of nitrate exit (outflow), maximum nitrate inflow (MNI), maximum nitrate outflow (MNO), removal rate of nitrate (R) and total nitrate loading (TNL).

2.5.2 Model Testing and Implementation

The dynamic model that has been built is then tested to determine the behavior of the system and to ensure that the model is truly in accordance with the objectives to be achieved. The model that is in accordance with the objectives, then implemented to take policy from several alternatives.

3. Results and Discussion

3.1. Profile of Oceanography Parameters

Parameters of sea water temperature very important for growth grass the sea. Average sea water temperature waters in LuwuRegency and Palopo City is 29.19 °C. The most important factor for do photosynthesis for algae is sun radiation and sea water temperature compared factor nutrient, where rate photosynthesis maximum on range temperatures of 24-30 ºC [13,14], 23-30 ºC [15], 25-30 ºC [16,17] and photosynthesis will downhill on range temperatures of 35-40 ºC [14,15], growth downhill on temperature in under 20 ºC[15].

Salinity is a parameter that affects growth, carrageenan and structure cellular on Eucheuamcottonii [18]. The level growth highest on salinity 25-30 ‰ [16], whereas the optimum salinity for growth Eucheuma cottonii is 25-35 ‰ [19].Salinity also greatly affects carrageen, which is the highest carrageenan at salinity 25 ‰ [18]. The results of the analysis in this study indicate that the average salinity is 34.11 ‰, which can be said that the average salinity is suitable for the growth of Eucheumacottonii seaweed[20].

Effect of pH of sea water very important for seaweed caused that pH is very influence levels of protein contained in seaweed [21].Growth at pH 8.4 (as a control) has growth the daily high of 3.57 cm/day or ± 0.34%/day. While at extreme alkaline pH that is 9 points right growth daily is 2.44 cm /day or ± 0.42% / day and on condition acid with a pH of 6 growthdaily reaching 0.61 cm /day or ± 0.07% /day [21]. On generally range between 7.7-8.4 where pH is affected by capacity buffer that is existence salt carbonate and bicarbonate contained in seawater [22]. Eucheuma cottonii will grow optimally at pH 7.5-8.5 [23]. Appropriate pH value for cultivation the sea is range between 7.8 -8.4. Based on results water analysis pH that an average of 7.80.

Ocean current flow is one of the key factors for controlling or influencing the growth of seaweed. It plays an important role in preventing an increase in pH (caused by consumption of carbon dioxide) and functions in supplying nutrients in the waters. Eucheuma cottonii will grow optimally at the average ocean currents on ± 20 cm / sec. [23].Speed water current will influence process absorption nutrient, where rate absorption maximum on speed current 0.04-0.06 meters/second [24]. Based on results filed analysis, average speed current is 0.14 meter/second. With so, with average speed current 0.13-0.15 meters/second corresponding seaweed [25].

Dissolved Oxygen (DO) considered as one of the most important aspect from cultivation. If dissolved oxygen <5 mg/l could to be excessive pressure on fish, and if up to <2 mg/l could cause dead on fish and organism certain in waters [26].Lowest limit value concentration of dissolved oxygen value in the sea for safe life of organism is 4 mg/l [27].Based of results analysis showed that averages dissolved oxygen 6.32 mg/l

Chemical Oxygen Demand (COD) is defined as total oxygen is needed for oxidize particulates material dissolved in water, where COD is indicator practical concentration from ingredients organic and water quality [13]. It in line with statement that COD is the total amount of oxygen required for oxidize all organic material to be carbon dioxide (CO_2) and water through process oxidation chemistry [28].COD is a lot oxygen is needed for oxidize all over ingredients organic, both easy explained nor difficult decompose. Material organic easy explained generally originated from waste domestic or settlement, while the difficult one decompose generally originated from waste industry, mining and agriculture [29]. With thus big small COD concentration can be made into indicator pollution something waters, that Chemical Oxygen Demand (COD) is combined indicator for measure level pollution caused by ingredients organic in sea water. Based on results analysis to show that the average COD is 494.51 mg/l [30]. The limit safe value of COD in the water is ≤ 40 mg/l [31]. The COD is high possibility caused there is ingredients very organic difficult for described by bacteria in waters. Chemical Oxygen Demand (COD) is total oxygen needed for parse all over ingredients organic contained in water [32].

Total solid refers to on any material either suspended or dissolved in sea water. All something being held back by filter is considered as solids suspended, while the one passing through the filter is classified as solids dissolved, i.e. usually sized 0.45μm. Both materials are concentrated in water called as Total Suspended Solids (TSS) and Total Dissolved Solid (TDS) [33].The TSS concentration waters generally composed from phytoplankton, zooplankton, waste activity human, mud and waste industry [34]. Solid material suspended in waters natural not is nature poison, will but if the amount excessive could improve value turbidity hereinafter inhibit penetration light sun to water column. The limit value of TSS against organism safe in the sea is allowed enhancement maximum of 10% of seasonal average concentration [27],and the limit value of TSS concentration for organism safe in the sea is <10 mg /l [26]. Results analysis to show that the average TSS is 27.53 mg/l.

Seaweed need various kind of nutrient for used in growth process. Nitrogen and Phosphor is two nutrients that limit growth of seaweed [35].There are element nutrient that is made factor delimiter for growth and breeding of seaweed. The most important limiter factor is element of nitrogen (N), then is phosphorus (P) as well substance iron (Fe). Third element nutrients contained in waters that is very influence biology activity. This be marked that concentrations of N, P and Fe in network is 104 to 105 more bigger of the concentration in sea water [36].There are very main parameters influence growth and abundance macroalgae (seaweed) on all ecosystem that is availability nutrient especially nitrogen (N) and phosphorus (P) as well factor power herbivores [37]. Nutrients (N and P) are factor delimiter in primary productivity at almost every ecosystem in all over world [38].That nutrient such as nitrogen (N), phosphorus (P) and substance iron (Fe) is factor delimiter for growth macroalgae and phytoplankton at the sea [39].If nutrient too high will impact on growth grass the sea because bring up the algae as competitors in get nutrition. According to the analysis this research show that average concentrationof nitrate is 0.58 mg/l. Based on Decision State Minister of Environment Life number 51 of 2004 concerning raw quality, concentration maximum nitrate is 0.008 mg/l, and or 0.06 mg/l [27], or 0.02 mg/l [26].According to the analysis this research show thataverage concentration phosphate reaching 0.38 mg/l, where standard limit secure for life organism in the sea and for health human to concentration phosphate is 15 μg/liter (0.015 mg/l) (at coast) [27], and or 0.05 mg/l [26]. Based on Decision State Minister of Environment Life number 51 of 2004 concerning raw quality, concentration maximum decent phosphate 0.015 mg/l for marine life. Results analysis Ammonia concentration on average was 0.17 mg/l, where standard limit safe for life organism in the sea and for health human to concentration ammonia (NH_3) is 70 μg/liter (0.07 mg/l) [27], and or 0.02 mg/l [26].

3.2. Suitability of Waters for Seaweed

To determine the suitability of waters in Luwu Regency and Palopo City for the cultivation of Eucheuma cottonii seaweed, an overlay of several oceanographic parameters was carried out. However, before doing an overlay, scoring and weighting of each of these parameters is first

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performed for each suitability criterion. Furthermore, an overlay of each of these parameters is performed to obtain a water suitability map using software ArcGis version 10. Scoring data and weighting of sea level suitability are shown in Table 1.

Table 1. Suitability matrix Eucheuma cottonii.

No	Parameter	Unit	Suitability	Range	Score	Weight (%)	Total value
1	Phosphate	mg/l	S1	0,2 – 0,5	30		420
			S2	0,1 – 0,2 & 0,5 - 1	20	8	280
			N	< 0,1 &> 1	10		140
2	Nitrate	mg/l	S1	0,9 – 3,2	30		420
			S2	0,1- < 0,9 & 3,3 – 3,4	20	10	280
			N	< 0,1 &> 3,4	10		140
3	Ammoniac	mg/l	S1	< 0,3	30		150
			S2	0,3 – 0,5	20	5	100
			N	> 0,5	10		50
3	Current	m/s	S1	0,2 – 0,3	30		300
			S2	0,1 – 0,2 & 0,3 – 0,4	20	10	200
			N	< 0,1 &> 0,4	10		100
4	Temperature	°C	S1	24 - 30	30		240
			S2	20 - 24	20	8	160
			N	< 20 &> 30	10		80
5	Salinity	‰	S1	30-32	30		390
			S2	22-30 & 32-34	20	12	260
			N	< 22 &> 34	10		130
6	pH		S1	6,5 – 8,5	30		240
			S2	4 – 6,5 & 8,5 – 9,5	20	5	160
			N	< 4 &> 9,5	10		80
7	DO	mg/l	S1	> 6	30		150
			S2	4 - 6	20	5	100
			N	< 4	10		50
8	COD	mg/l	S1	10 - 90	30		150
			S2	91 - 100	20	3	100
			N	> 100	10		50
9	Chlorophyll-a	mg/l	S1	3,5 - 10	30		150
			S2	0,2 - < 3,5	20	2	100
			N	< 0,2	10		50
10	Turbidity	NTU	S1	≤ 10	30		240
			S2	< 10 - < 40	20	7	160
			N	> 40	10		80
11	Distance from the beach	m	S1	150 - 1500	30		150
			S2	1200 - 2000	20	5	100
			N	> 2000	10		50
12	Depth	m	S1	2 – 15	30		420
			S2	16 - 20	20	14	280
			N	> 20	10		140
	Total					100	

Note: 1. Score based on Prahasta (2002).

2. Weight based on the consideration of the influence of the dominant variable.

To better reflection and describe the suitability of the waters for Eucheuma cottonii seaweed cultivation for 1 year, which is a combined representative of the 1st transition season and the 2nd transition, then overlay the suitability maps of the 2 seasons were carried out. This is done so that it can be used as a basic for making policies both by the Regional Government and or related stakeholders in determining which locations are truly safe and very suitable for seaweed cultivation. Some reasons for consideration in making a policy for determining the appropriate location for seaweed cultivation include that if the seaweed cultivation community is able to adapt to seasonal changes followed by changes in location and suitability of cultivated water area, the farming community can cultivate in a very suitable location and suitable for each season. However, if the cultivation community is unable to adapt to seasonal changes, the farmers are advised to choose a location that is truly safe and very suitable for seaweed cultivation, namely the location of the combined suitability of the 1st transition season and 2nd transition.

Based on the results of a combined analysis of suitability from 1st transition season and 2nd transition, a suitability map is produced that reflects the representative suitability in 1 year. Based on the results of the analysis show that in general the waters in Palopo City and most of the waters of northern Luwu are not suitable for seaweed cultivation. While in the southern part of Luwu Regency waters are generally suitable for seaweed cultivation, but specifically in South Ponrang SubRegency it is very suitable for seaweed cultivation. The area of water in Luwu Regency with a very suitable category (S1) is 13,618.85 hectares, the appropriate category (S2) is 46,882.26 hectares and the inappropriate category (N) is 9,089.49 hectares. If assuming the very appropriate (S1) and appropriate (S2) categories are combined into appropriate and suitable waters for seaweed, then the appropriate total area is 60,501.11 hectares. In addition, based on the location of the MPA plan in Luwu Regency with an area of 280.48 hectares, where the Marine Protected Area DPL is included in the area with the appropriate category (S2), the area of very suitable fixed category is 13,618.85 hectares, the corresponding category being 46,162.94 hectares , so that the total area that is feasible and in accordance after deducting the DPL area becomes 59,781.79 hectares.

The area of water in Palopo City with a very suitable category (S1) is 0 hectares, the appropriate category (S2) is 1,771.41 hectares and does not match (N) 6,941.33 hectares. If assuming the very appropriate (S1) and appropriate (S2) categories are combined into appropriate and suitable waters for seaweed, then the corresponding

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total area is 1,771.41 hectares. Data on water suitability results are presented in Table 2 and Figure 2.

Table 2 . Suitability of waters in Luwu Regency and Palopo City

No	Criteria	Area aquatic (Ha)		
		Luwu Regency		Palopo City
		Initial area	Area minus MPA[1]	Large
1	Very suitable (S1)	13,618.85	13,618.85	-
2	Suitable (S2)	46,882.26	46,162.94	1,771.41
3	Not suitable (N)	9,089.49	9,089.49	6,941.33
Total (S1+S2)		60,501.11	59,781.79	1,771.41

Note: Area of MPA = 280.48 ha

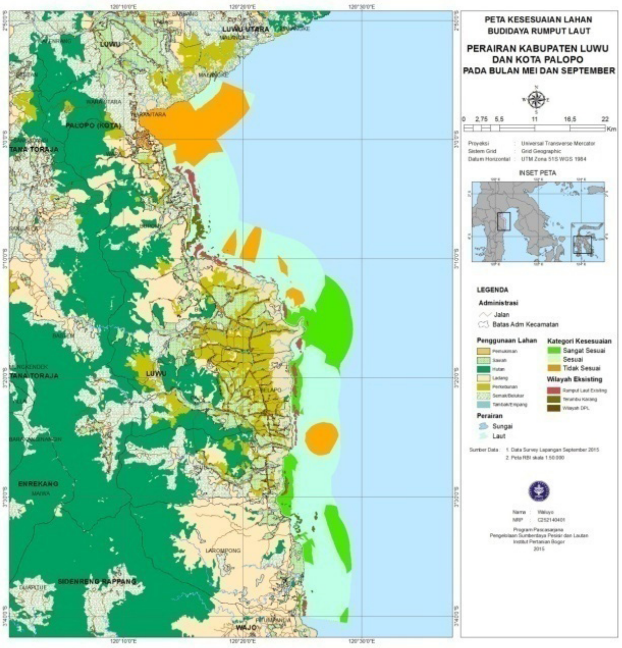

Figure 2. Extent of suitability of aquatic in Luwu Regency and Palopo City

3.3 Utilization of Water Spaces

Analysis of the use of water space for seaweed cultivation in Luwu Regency and Palopo City was carried out using the Ecological Footprint approach. The Ecological Footprint (EF) analysis is an analysis that states a productive ecological area to provide marine resources as a supply of consumption for residents in the area concerned [40]. In other words, the Ecological Footprint analysis is the total area needed to support a population and/or certain activities. The EF analysis can also determine how much of the resources that can be produced (Ecological Footprint Productions/EF_P) pitch toward the available land area. The EF analysis in this study is an analysis of Ecological Footprint Production (EF_P) which describes the total amount of resources produced (Eucheuma cottonii seaweed production) on existing water area.

The production of Eucheuma cottonii seaweed in Luwu Regency and Palopo City starting in 2008-2014 tended to increase, but the number of fish farmers in the two regions showed a different trend. The number of cultivators in Luwu Regency increases every year, but in Palopo City tends to decline. Based on production data and number of cultivators, EF_P can be calculated for each of these regions.

The EF_P value of seaweed in Luwu Regency shows that waters with an average area of existing utilization of 9,709.24 hectares and utilized by seaweed farmers as many as 3,472 capita, the waters are capable of producing seaweed production (EF_P) of 67.8883 tons/capita/year. Likewise with EF_P in Palopo City with an average land area of 438.61 hectares and utilized by seaweed farmers as much as 1,503 capita, these waters produce seaweed (EF_P) as much as 3.0876 tons/capita/year. The EF_P values in Luwu Regency are higher than in Palopo City due to high production levels and wider cultivation land. With wider land has the opportunity and potential to produce more seaweed production. The results of the analysis of EF_PLuwu and Palopo presented in Table 3.

3.4. Availability of Aquatic Space (Biocapacity)

The availability of water space (Biocapacity/BC) for Eucheuma cottonii seaweed cultivation in Luwu Regency and Palopo City will illustrate two main components, namely 1) how much of the entire waters is capable of supporting seaweed cultivation, and, 2) how big is the product seaweed that can be achieved (assuming overall use of available water).

Biocapacity analysis is based on the suitability of the waters that support seaweed cultivation. To determine the suitability of aquatic spaces that can be used spatially seaweed cultivation using the concept of land suitability evaluation. This concept is based on physical, chemical and aquatic biology parameters which are ecologically feasible prerequisites for seaweed cultivation. For this reason, a Geographic Information System (GIS) technique is used to determine the area of waters suitable for seaweed cultivation in Luwu Regency and Palopo City. Spatially, the waters of Luwu and Palopo for the development of seaweed Eucheuma cottonii right grouped into three categories namely very appropriate class (S1), appropriate (S2) and is not suitable (N).

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Tabel 3. Ecological Footprint production of Eucheuma cottonii in Luwu Regency danPalopo City.

No	Year	Cultivator (capita)		Production (Ton/year)		EF_P (Ton/capita/year)	
		Luwu Regency	Palopo City	Luwu Regency	Palopo City	Luwu Regency	Palopo City
1	2008	3,456	1,543	174,875.44	2,195.51	50.6005	1.4229
2	2009	3,465	1,569	178,361.34	2,219.83	51.4751	1.4148
3	2010	3,473	1,578	183,202.80	2,227.04	52.7506	1.4113
4	2011	3,476	1,464	229,017.00	3,416.25	65.8852	2.3335
5	2012	3,476	1,479	256,257.85	6,416.00	73.7221	4.3381
6	2013	3,479	1,479	272,667.60	12,543.00	78.3753	8.4807
7	2014	3,480	1,407	356,385.50	3,112.31	102.4096	2.2120
Average		**3,472**	**1,503**	**235,823.93**	**4,589.99**	**67.8883**	**3.0876**

Biocapacity calculations in this study divided into partial biocapacity (based on each category of S1 and S2 classes) and total biocapacity (total area of aquatic from the S1 and S2 classes). Based on the biocapacity analysis in the waters of Luwu Regency, the results showed that the waters in the very appropriate category (S1) were 327,539.62 tons and the corresponding category (S2) was 1,110,239.98 tons. If assuming the S1 and S2 categories are combined, the total biocapacity reaches 1,437,779.60 tons, which means that assuming the utilization of all available water is 59,781.79 hectares, then the waters are capable of producing seaweed production of 1,437,779.60 ton/year.

Biocapacity in the waters of Palopo City showed that the waters with the very appropriate category (S1) were 0 tons, while in the appropriate category (S2) was 18,287.46 tons. If assuming the S1 and S2 categories are combined, the total biocapacity in Palopo City reaches 18,287.46 tons, which means that assuming the utilization of all available land is 1,771.41 hectares, the waters are capable of producing seaweed production as much as 18,287.46 ton/year. The biocapacity analysis results are shown in Table 4.

3.5. Water Carrying Capacity

Carrying capacity of waters is the ability of a system to support activities at a certain level, in this case is the cultivation of seaweed species Eucheuma cottonii. In other words, carrying capacity is related to the coastal area system which has certain limits or has a threshold for an activity [41].

3.5.1. Water Carrying Capacity based on Ecological Footprint (EF) Analysis

To find out the carrying capacity of a waters based on the analysis of ecological footprint (EF), there are three main components that must be known, namely: 1) how much the level of water utilization (in this case ecological footprint production/EF_P), 2) how much space is available waters (Biocapacity/BC) that are able to support these activities, as well as, 3) how much amount of human resources (capita) makes it possible to utilize the available water space. By comparing the biocapacity to the ecological footprint, it will produce how much carrying capacity of the waters.

Based on the results of the analysis of the water carrying capacity in Luwu Regency shows that the level of water utilization (EF_P) is 67.8883 tons/capita (235,823.93 tons/year), while the availability of water space (Biocapacity/BC) is 59,781.79 hectares which is capable of producing seaweed as much as 1,437,779.60 tons/year. When using the assumption that the utilization of all available water lands (59,781.79 hectares), then the carrying capacity of the number of human resources that are possible to be able to utilize the water is 21,432 capita.

The water carrying capacity in Palopo City shows that the level of water utilization (EF_P) is 3.0876 tons/capita (4,589.99 tons/year), while the availability of water space (Biocapacity/BC) is 1,771.41 hectares which is capable of producing seaweed as much as 18,287.46 tons/year. When using the assumption that the utilization of all available water lands (1,771.41 hectares), the carrying capacity of

Table 4. Water Biocapacity di Luwu Regency and Palopo City

Season	Luwu Regency				Palopo City			
	Production (Ton)[1]	BC Partial (Ton)		BC Total (Ton)	Production (Ton)[1]	BC Partial (Ton)		BC Total (Ton)
		S1	S2			S1	S2	
1st Transition	235,823.93	569,061.80	575,685,06	1,144,746.86	4,589.99	15,232.48	41,017.09	56,249.56
2nd Transition		387,802.62	867,751.21	1,255,553.83		0	1.66	1.66
Total 2 season		32,539.62	1,110,239.98	1,437,779.60		0	18,287.46	18,287.46

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the number of human resources that are likely able to utilize the water area is 635 capita. The results of the analysis of waters carrying capacity are presented in Table 5.

Tabel 5. Water carrying capacity based on Ecological Foot print analysis for Eecheuma cottonii seaweed in Luwu and Palopo regency.

Season	Luwu Regency			Palopo City		
	EF_P (Ton/capita)	BC (Ton)	Carrying capacity (capita)	EF_P (Ton/capita)	BC (Ton)	Carrying capacity (capita)
1st Transition		1,144,746.86	17,064		56,249.56	1,954
2nd Transition	67.8883	1,255,553.83	18,716	3.0876	1.66	0.60 ≈ 1
Total 2 season		1,437,779.60	21,432		18,287.46	635

Source: Analisis result (2015)

3.5.2. Carrying Capacity based on Mass Balance Total Nitrate Concentration Model.

Water carrying capacity based on mass balance total nitrate concentration (NO_3-N), which explains that in the case of the growth of seaweed. If the supply and availability of water is insufficient for growth with a certain area of cultivation, it is likely that seaweed production will not be optimal. Thus, it is necessary to support the growth and production of seaweed. In the analysis of the waters carrying capacity based on the mass balance model using nitrate parameters as the main key factor to determine the carrying capacity of the waters. This is the most important material for photosynthesis.

The analysis of a waters carrying capacity based on mass balance nitrate concentration, there are several main factors that play a role in determining the ability to support a healthy cultivation business. Nitrate concentration in the water mass at high tide and low, how much nitrate concentration enters and exits the water, and it will affect the availability of nitrate loading [42].

(1) Volume of Seawater Mass at pairs (V_o) and Low (V_s)

Based on the results of the show the average height in the waters of Luwu Regency is 1.5 meters with a frequency of 2 times/day, with a coastline length reaching 116,161 km and the beach slope average is 3 degrees. In the presence of tidal waves (tide) will affect the frequency of inundation of a waters. At the time of receding, the distance from the coastline at low tide to the minimum depth of 2 meters towards the sea is an average of 350 meters. The 2 meter depth limit is a benchmark for the minimum suitability of depth and the rate of fishing boats for cultivation mobility. Based on the analysis of the volume of water mass at tide (V_o) in Luwu Regency is 61.901,286.10 m^3, and the volume of water mass at low tide is 60,111,988.69 m^3.

The tidal type in Palopo City is the same as in Luwu Regency, which is a semi-annual type, with a non-average height of 1.5 meters with a frequency of 2 times/day. The coastline length in Palopo City is 25 km and the coast slope is on average 3 degrees. The distance from the beach at low tide is the minimum limit of 2 meters towards the sea is 200 meters on average. Thus the calculation of the volume of water mass at time of tide (V_o) in Palopo City is 7,697,303.98 m^3 and the time of low tide was 7,312,214.01 m^3. By knowing the mass of water at the time of tide (V_o) and at low tide (V_s) it can be used as a basis for the supply of nitrates and the dilution process of waste that is in the sea.

(2) Total Nitrate Inflow (TNI), Total Nitrate Outflow (TNO) and Removal Rate

Nitrate inflow into the water (nitrate inflow) at the time of tide and out at low tide (outflow nitrate) will determine the rate of loss of nitrate concentration (removal rate) in the waters. The size of the nitrate inflow and nitrate outflow isalso strongly influenced by the volume of water mass during tide (V_o) and low tide (V_s). Based on the calculation that the inflow of nitratein Luwu Regency was 75,767,174.18 kg/day and nitrate outflow was 73,577,074.15 kg/day, the removal rate of nitrate was 0.97 kg/day. Whereas in the waters of Palopo City the inflow value of nitrate was 9,421,500.07 kg/day and the nitrate outflow was 8,950,149.95 kg/day, so the removal rate of nitrate was 0.95 kg /day.

(3) Maximum Nitrate Inflow (MNI) and Maximum Nitrate Outflow (MNO)

The maximum value of nitrate inflow is strongly influenced by the volume of sea mass at high tide (V_o) and nitrate concentration based on the quality standard at sea (C_b). While the maximum value of nitrate outflow is influenced by the removal rate and the maximum value of nitrate inflow. In this study using the optimum nitrate standard for seaweed based on Aslan (1998) which is equal to 0.3 mg/l. Based on the calculation results, the maximum value of nitrate inflow in the waters of Luwu Regency is 66,853,388.98 kg/day and the maximum nitrate outflow is 64,920,947.78 kg/day. While the maximum nitrate inflow in Palopo City is 8,313,088.30 kg / day and the maximum nitrate outflow is 7,897,191.14 kg/day.

(4) Total Nitrate Loading (TNL) and Water Carrying Capacity

The availability of total nitrate (total nitrate loading) is strongly influenced by total nitrate concentration and total nitrate concentration (total nitrate outflow) on the area of existing seaweed cultivation. The existing area of

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the average seaweed cultivation area in Luwu Regency is 9,709.24 hectares and in Palopo City is 438.61 hectares. Thus the total nitrate of loading in the waters of Luwu Regency is 225.57 kg/ha/day, while the total nitrate loading in the waters of Palopo City is 1,074.65 kg/ha/day.

Based on some calculations of reviews these variables, it can be known the water carrying capacity based on mass balanceof nitrate concentration able to support seaweed cultivation. The flow rate is influenced by how much nitrate outflow is and the maximum nitrate outflow to the total supply of nitrate in the water (total nitrate outflow). Thus the waters that can be utilized for cultivation in Luwu Regency are 38,374,69 hectares and the maximum area that can still be tolerated is 48,083.93 hectares. Whereas the watershed can be utilized for cultivation in Palopo City is 979.82 hectares and the maximum limit that can be tolerated is 1,418.43 hectares. The results of the calculation of the carrying capacity of the waters based on concentration Mass Balance are shown in Table 6.

Table 6. Water Carrying Capacity Based on Mass Balance Nitrat

Parameter	Unit	Luwu Regency	Palopo City
		Value	Value
Tidal mass volume (V_o)	m^3	61.901.286,10	7.697.303,98
Low tide mass volume (V_s)	m^3	60.111.988,69	7.312.214,01
Total nitrat inflow (TNI)	kg/day	75.767.174,18	9.421.500,07
Total nitrat outflow (TNO)	kg/day	73.577.074,15	8.950.149,95
Removal rate nitrat (R)	kg/day	0,97	0,95
Maximum nitrat inflow (MNI)	kg/day	66.853.388,98	8.313.088,30
Maximum nitrat outflow (MNO)	kg/day	64.920.947,78	7.897.191,14
Total nitrat loading (TNL)	kg/ha/day	225,57	1.074,65
Water carrying capacity (CC)	ha	38.374,69	979,82
Maximum carrying capacity (MCC)	ha	48.083,93	1.418,43

Source: Analisis result (2015)

3.5.3. Combination Carrying Capacity based on EF and Mass Balance Nitrate

(1) Water Carrying Capacity in Luwu Regency

Luwu Regency based on the ecological footprint(EF) shows that the total area that can be utilized for seaweed cultivation is 59,781.79 hectares. While the capacity based on mass balance nitrateare 38,374.69 hectares, there is a difference in area of 21,407.10 hectares. If it will make use of the extent that it can be tolerated by water, then the maximum area are 48,083.93 hectares, so that there is a difference in the area of 11,697.86 hectares. This difference is used as a buffer zone so that the supply and availability of nutrients for seaweed growth are maintained. In other words, from the available area (based on EF analysis), only 64.19% (maximum 80.43%) which can be utilized optimally for the cultivation cultivation locations, while the rest is as a buffer zone .

Based on the analysis of mass balance nitratein Luwu Regency waters, the water carrying capacity covering 38,374.68 hectares is capable of producing seaweed (biocapacity) as much as 922,928.96 tons and human resources to the which can make use of the area for seaweed cultivation of 13.595 people (capita). The maximum area of 48,083.93 tons of seaweed and human resources will enable it to be extended by the waters, which can enable it to utilize 17,034 people for seaweed cultivation (capita).

(2) Water Carrying Capacity in Palopo City

Results of the watershed in Palopo City are based on the ecological footprint(EF), which shows that the total area that can be used for cultivation is 1,771.41 hectares. The current capacity based on mass balance nitrateis 979.82 hectares, so there is a difference in area of 791.59 hectares. If it will make use of the waters that are still tolerable, the maximum area is 1,418.43 hectares, so that there is a difference in the area of 352.98 hectares. This difference is used as a buffer zoneso that the supply and availability of growth inPalopo City is maintained. In other words, available area (based on EF analysis), only 55.31% (maximum 80.07%) can be used as optimally for seaweed cultivation locations, while the remainder is the buffer zone.

Based on the analysis of mass balance nitrate in the waters of Palopo City, the water carrying capacity covering an area of 979.82 hectares is capable of producing seaweed (biocapacity) of 10,115.34 tons and human resources can use of the area of 3,276 seaweed cultivation

Table 7. The Combination Carrying Capacity based on EF and Mass Balance Nitrate

Carrying capacity models	Luwu Regency			Palopo City		
	Area (ha)	Biocapacity (ton)	Carrying capacity (capita)	Area (ha)	Biocapacity (ton)	Carrying capacity (kapita)
Ecological Footprint	59,781.79	1,437,779.60	21,432	1,771.41	18,287.46	635
Mass Balance nitrat	38,374.69	922,928.96	13,595	979.82	10,115.34	3,276
Buffer zone	21,407.10					
Maximum tolerated area	48,083.93	1,156,440.66	17,034	1,418.43	14,643.41	4,743
Buffer zone	11,697.86					

Source: Analisis result (2015)

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(capita). If we will use the maximum to the extent that can still be tolerated by water carrying capacity, the maximum area is is 1,418.43 hectares and can be produced as much as 14,643.41 tons and human resources that can enable the use of the area for seaweed cultivation of 4,743 people (capita). The combination results of the water carting capacity based on EF and mass balance nitrate analysis are shown in Table 7.

3.6. Dynamic Management Model System

The dynamic management models system approach can be used as a tool to analyze and make a policy in managing coastal areas for the development of Eucheuma-cottonii seaweed cultivation business based on the water carrying capacity in Luwu Regency and Palopo City. The results of the dynamic system analysis are a function of time (time domain) for seaweed farming activities, where the results obtained are not a prediction (forecasting) of a phenomenon, but only reflects of the trend of a phenomenon that might occur. The fundamental difference from the notion of trends and predictions (variability) is a trend (tendency) is a general description of the timing of a certain time(time domain), while predictions (variability) is a prediction of events that may be repeated based on certain frequencies (frequency domain).

The success of the Eucheuma cottonii seaweed has been influenced by the quality of the water, which is strongly influenced by how much anthropogenic waste enters the waters. Thus, controlling the level of pollution is a key factor in maintaining water quality, so that it will be maintained. Based on these considerations, the step management strategy for seaweed development uses the input of antopogenic waste as a management scenario control. Some alternative scenarios for management of development systems in the dynamic model of the input from waste in the current conditions, suppressing waste by 10%, 25% and 50%. The results of the four management scenarios are shown in Figure 3 and Table 8.

Based on the simulation results of four management scenarios for the development of seaweed cultivation in Luwu Regency, it shows that in 2nd scenario by reducing waste input by 10% from the current input of existing waste, and assuming that all of the available waters are 38,374.69 continuously (on the scale of 2008-2030), it will produce the highest water biocapacity, which is 8,257,274.94 tons/year. Likewise with seaweed management in Palopo City with 2nd scenario, assuming that utilizing all available watershed areas of 979.82 hectares will produce the highest water biocapacity of 14,306.92 tons/year. If it is connected between the average nitrate concentration of 0.34 mg/l and management by pressing the waste input by 10%, it will produce the highest water biocapacity. It can be interpreted that by pressing waste by 10% it will produce the optimum nitrate concentration for the growth of Eucheuma cottonii seaweed, which is 90% of the nitrate concentration in the waters (90% of 0.34 mg/l) which is equal to 0.30 mg/l. In generally, each type of seaweed is different from the different concentration of nitrate for its growth. Nitrate can also be a limiting factor for seaweed. Based on Harrison and Hurd (2001) states that we will consume more of nitrate than phosphate, and we will be vulnerable to the limitations of nitrate.

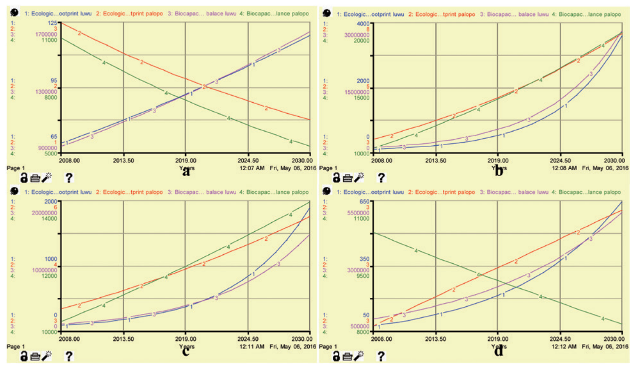

Figure 3. Results of management scenarios, a). current waste input, b). pressing waste 10%, c). pressing waste 25% waste, c). pressing waste 50%.

Table 8. The results of seaweed management scenarios

Scenario	Luwu regency			Palopo city		
	Biocapacity (ton/year)	EF_P (ton/capita)	Carrying capacity (capita)	Biocapacity (ton/year)	EF_P (ton/capita)	Carrying capacity (capita)
Waste present	1.262.284,08	92,25	13.668	7.506,88	2,16	3.477
Pressing waste 10%	8.257.274,94	930,65	10.439	14.306,92	4,74	3.069
Pressing waste 25%	5.121.751.01	566,37	10.439	12.011,63	3,96	2.069
Pressing waste 50%	2.453.202,10	260,85	10.439	9.164,39	2,99	3.069

Eucheuma cottonii of seaweed can grow at concentrations of nitrate in water ranging from 1 -3.5 mg/l[43], and also tolerance limit of nitrate concentration for algal growth was 0.1 mg/l while the highest limit was 3 mg/l [44]. If the nitrate level is below 0.1 or above 3 mg/l, then nitrate becomes the limiting factor. While based on Ministry of Environment Republic Indonesia (2004) [45] states that the minimum limit of nitrate concentration for marine biota is 0.008 mg/l. The opinion of Boyd and Lichtkoppler (1982) [44] becomes a standard reference, then the nitrate results in 0.34 mg/l and the dynamic model results show that nitrate value of 0.3 mg/l is the optimum concentration for seaweed, the nitrate concentration in the field it is still normal for seaweed growth. But if by the Ministry

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of Environment Republic Indonesia (2004) [45] became a standard reference, then the water in Luwu Regency and Palopo City was not an experience of the blooming of phytoplankton.

4. Conclusion

Based on the analysis of the water carrying capacity of the combined two seasons illustrate representative of carrying capacity of water for one year in Luwu Regency and Palopo City, it can be referenced and scientific considerations for decision making in managing and developing a seaweed cultivation in both regions. By considering this potential, seaweed farming is expected to produce more optimal production. To find out the optimum biocapacity of water fluctuations, a dynamic model system was prepared using Stella Software. In models of dynamic systems management scenarios is done by considering the input of waste as a primary control, of the which four are input waste management scenario at this point, pressing waste 10%, 25% and 50%. Based on the scenarios, the 10% waste that is the water of the waters, it will produce the highest water biocapacity compared to other scenarios. Thus, the steps that need to be controlled are the input of anthropogenic waste originating from land.

5. Suggestion

One of the success methods of cultivation of Eucheuma-cottonii seaweed with the long line method is to consider the existing season. West season (December to February) is the season with the characteristics of the wave and flow of the sea is strong enough, so that it can result in damage to the rope on the seaweed. It can cause the capacity of the waters to decrease. East monsoon (June to August) the characteristics of the high intensity of solar radiation so that the temperature of the sea water will also increase is, then it must be taken into consideration to the seaweed farming. It considers the second season, it is necessary to the proper and scientific information that is truly safe and appropriate for a n farms. Based on the results of the suitability map analysis for the cultivation of Eucheuma-cottonii seaweed, it is advisable to choose a location based on the two seasons combined suitability analysis, so that the location may not experience significant changes due to seasonal changes.

6. Recommendation

Policy making is based on several choices/alternative considerations that exist. In this study there are two analytical approaches to policy making, namely an approach based on the analysis of waters carrying capacity and analysis of dynamic system models.If a policy is based on analysis of the carrying capacity of the waters, it is recommended to choose a location based on the analysis of the suitability of a combination of two season with the widespread availability of water to support the cultivation of sea beveled area of 38,374.69 hectares and the maximum utilization of the waters is an area of 48,083.93 hectares. When making policy for development seaweed cultivation based on system dynamics models, it is recommended to carry out the waste by pressing the input waste anthropogenic waters sea big 10%. Thus the management steps are taken by controlling waste on land.

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