SPATIAL ANALYSIS: THE EFFECTIVENESS OF SEAWEED AS A CATALYST FOR IMPROVING ECOLOGIC AND ECONOMIC QUALITIES IN TAKALAR WATER AREA, SOUTH CELEBES

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Abstract

The Development of Takalar water area as a center of seaweed commodity has a dual role, namely as economic source and carbon binder. Cultivation of seaweed with a long line system that continuous to grow makes the role of seaweed in the binding of carbon, especially for water areas can't be ignored. The number of population, infrastructure, and economic society co-developed along with the widespread of seaweed cultivation in Takalar. Kappaphycus Sp. is the most widely cultivated seaweed in Takalar water territory.

The purpose of this research are (a) for analyzing and calculating the amount of potential areas for seaweed cultivation in Takalar water area. (b) for measuring the amount of carbon absorbed when the potential areas for seaweed cultivation utilized optimally, and (c) for estimating the likely increase in the local economy if the potential areas for seaweed cultivation utilized optimally. Delineation of potential areas for seaweed cultivation is obtained through spatial analysis and primary data collection in the field with a systematic sampling method. Economic improvement is expected by looking at statistical data and the possibility of seaweed production if the potential areas for seaweed cultivation empowered optimally.

The amount of minimal carbon content in Eucheuma Cottonii or commonly known as Kappaphycus Alvarezii in Takalar water area is 20.73 ± 1.73 (%). The results of primary data and image processing show that the vast of potential areas for seaweed cultivation in Takalar is 597.31 km2. Based on the data of total potential area for seaweed cultivation and the large amount of carbon content obtained The number of carbon emission that can be absorbed is equal to 71,531,381.82 to 120,578,542.70 Ton C / Cycle Plant. The increasing of GDP from the agricultural sector if the cultivation of seaweed in Takalar has been optimized is 28%.

Keywords: Seaweed, Zoning, Carbon binder, Improving economy, Takalar

1. Introduction

1.1. Background

Plants have a dual role in the chain of carbon cycle, namely as the source of emissions through the respiration process and as the carbon sinks through photosynthesis. Nevertheless, in the tropical region that has a day long approximately 10 ± 2 hours throughout the year, the process of photosynthesis will be more dominant (Sinha, 2008). Plants are the main actors in CO_2 reduction processes through the photosynthesis. This process is not only restricted for land plants but also aquatic plants. IPCC (Intergovernmental Panel on Climate Change) data reveals that the oceans can absorb up to 2 billion tons of CO_2 per year. Even Japan's Ministry of Environment has reported in Japanese waters that overgrown by seaweeds (Sargassum, Ecknolia, Seagrass, and Laminaria) can absorb up to 2.7 tons CO_2 / year including the results of the sea culture (Muraoka, 2004). Celebes water territory is the largest seaweed culture area in Indonesia with one of aquaculture center in Takalar, South Celebes. The most widely cultivated seaweeds in Takalar are Kappaphycus alvarezii species that better known as Eucheuma cottonii, and Sargassum denticulatum. Total seaweed production in Indonesia continued to increase in recent years. In 2009, it was targeted to reach 1.9 million tons with a concentration of cultivation in Celebes region.

The increased production of seaweed cultivation will have an impact on potential carbon absorption in territorial waters. Until now, there has been not much research done on the amount of influence and effectiveness of seaweed as an ecological balance through its role for carbon binding. Therefore, it is necessary to study and measure the rate of carbon binding from seaweed aquaculture activities with a long rope system (longline). Furthermore, the mapping of potential area for seaweed cultivation is also needed, so that the total amount of carbon sink from the optimal wide area of seaweed cultivation with long line system in waters of Takalar can be estimated. From now on, optimizing the application of seaweed cultivation will be equal to the increasing of society incomes in particular and the increasing of regional economy in general.

1.2. Purpose

The objectives of this study are to:

a. analyze and calculate the potential areas for seaweed cultivation in Takalar water area,
b. estimate the carbon absorbed when the potential areas for seaweed cultivation utilized optimally, and
c. estimate the increase in the local economy if the potential areas for seaweed cultivation utilized optimally.

1.3. Research Location

This study is carried out at the seaweed cultivation area in the coastal area of Takalar district, South Celebes province, Indonesia. Figure 1 shows the location of this study. The site is chosen due to the presence of seaweed cultivation in that area. Coastal area in Celebes island is known to be the center of marine cultivation in Indonesia and provides the national income for seaweed, shrimp, kerapu fish cultivation.

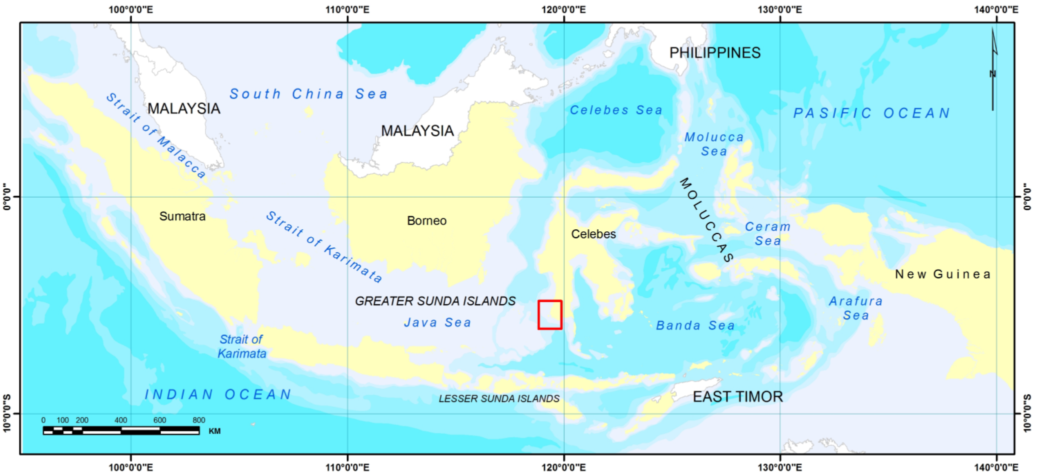


Figure 1. The study area in South Sulawesi province

The seaweed cultivation spreads over the whole coastal area in Takalar district. The biggest seaweed cultivation is at Mangarabombang in the Gulf of Teluk Laikang and Mappakasunggu island. The cultivation is carried out with longline method in which the seaweed is tied on long line near the coastal area. The rope length is about 30m with the distance between them is about 1m. The production of seaweed is relatively quick because it takes about 40 days from implantation to harvesting. From the field survey, the most dominant seaweed species in Takalar District are *Eucheuma Cottoni* and *Gracilaria*.

Figure 2. Seaweed cultivation in Takalar

2. Methodology

This section explains the methodology to complete the research in Takalar District.

2.1. Overview

The methodology of this study is depicted in Figure 3. The data inputs are satellite imagery, base map, spatial data from MCRMP and field survey for collecting water quality characteristics. The existing seaweed cultivation is plotted on the basis of field survey. The suitability analysis is preformed to identify the potential area for seaweed cultivation. The carbon is estimated from the values of Carbon content on the potential area.

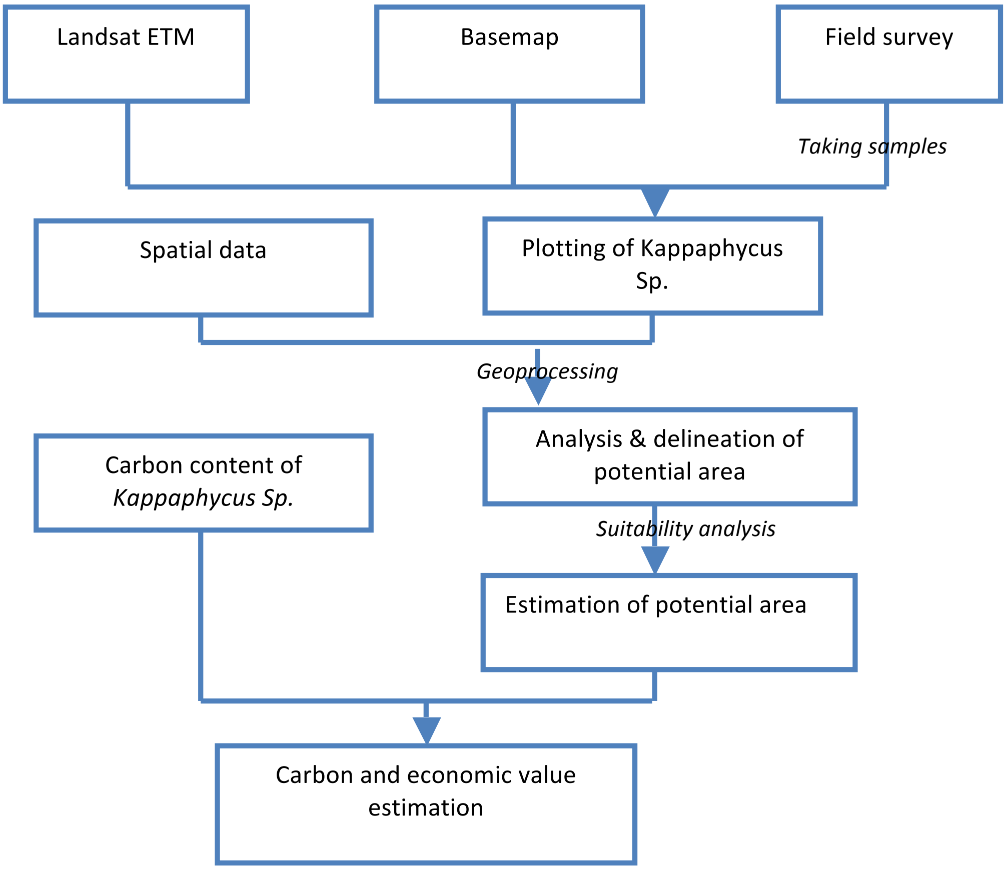


Figure 3. The flow diagram of research methodology

2.2. Data Acquisition

The field survey was conducted from May 1 to May 10, 2011. Twenty two water quality samples were acquired systematically in the coastal of Takalar district. Figure 4 shows the map of water surface sample locations. The data obtained in the survey are water depth, acidity, dissolved oxygen, salinity and current speed. The samples were taken at the water surface (less than 1 meter depth) during calm water condition from the morning until noon. The devices for measurement are Global Positioning System (GPS), turbiditymeter, PCS tester, oxygenmeter, refractometer and flowatch. The acquired data is used to validate the data provided by MCRMP (Marine Coastal and Resource Management Project) in 2008.

The existing seaweed cultivation is also plotted to know the real spread of seaweed cultivation in Takalar district. GPS tracking was recorded and mapped for further analysis. The existing seaweed distribution is important for verifying the results of suitability analysis. If any discrepancies between the calculation and the reality, the model should be calibrated to achieve the best prediction.

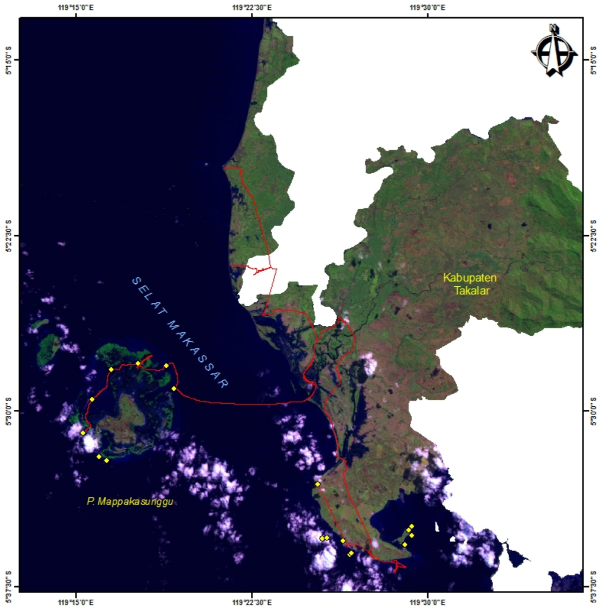


Figure 4. The locations of water samples

2.3. Suitability Analysis

The suitability analysis is performed to find areas which are potential for the seaweed cultivation. The analysis is based on the water characteristics acquired from spatial data of MCRMP and field survey such as flow depth, dissolved oxygen, salinity, temperature, clarity and acidity. Table 1 shows the matrix of the parameters and their suitable conditions.

There are four classes of suitability such as S1, S2, S3 and N. The explanation is as follows:

a. S1 (very suitable) is an area which has no limitation for cultivation,
b. S2 (suitable) is an area which has few limitations for cultivation which affects the production yield,
c. S3 (conditionally suitable) is an area which has some limitations, but it can be minimized by using more advanced approach,
d. N (not suitable) is an area which has many significant limitations so that the cultivation will be unsuccessful.

The suitability analysis can be performed using matching or scoring approach. The difference between these methods is explained as follows.

Table 1. The suitability values for seaweed cultivation (After Poernama, 1992 in Bakosurtanal, 1995)

Parameter	**S_1** *[80]*	**S_2** *[60]*	**S_3** *[40]*	**N** *[1]*
Depth (m) [35]	1 – 5			< 1 > 5
Dissolved Oxygen (mg/l) [10]	> 6	5 – 6	4 - 5	< 4
Salinity (ppt) [10]	28 – 36	>20 – 28	12 - 20	< 12 > 36
Temperature (^{0}C) [10]	26 – 31	24 – <26 >31 - 33	20 – <24 >33 – 35	< 20 > 35
Clarity (%) [25]	>75	50 - 75	25 – <50	< 25
Acidity [10]	7,5 - 8,3	7 – <7,5 >8,3–8,5	6.5 – <7 >8.5 – 9	< 6.5 > 9

2.3.1. Matching Approach

Matching method finds the lowest suitability level and employs it for the suitability result. The potential of an area ($Suit_{match}$) is determined by the lowest potential from all parameters ($Suit_{par}$). The equation is as follows:

$$Suit_{match} = Min\ (Suit_{par-1}, .., Suit_{par-n})$$

For example, if one of the parameter has the suitability level of N, the resulted suitability will be N. As a result, for S1 suitability, all parameters must be at S1 level.

2.3.2. Scoring Approach

Scoring method considers all parameters using different weight due to the level of importance. The weight is judged on the basis of rehearsal and previous empirical experiences. More field application will increase the accuracy of the weight.

There are four steps in performing scoring methods. The explanation is as follows:

a. Weight for suitability (W_{suit}) is designed to differentiate value at suitability level which will be considered when performing scoring method. The weight value is defined as follows:
   - S1 (very suitable): 80
   - S2 (suitable): 60
   - S3 (conditionally suitable): 40
   - N (not suitable): 1
b. Weight parameter (W_{par}) is used to represent the role or importance of each parameter on the success of cultivation. The most influential parameter has

greater value than other less significant parameters. The sum of all weight parameters is 100.

c. Weight for scoring (W_{score}) is made to estimate the potential of an area on the basis of weight for suitability and weight for parameter. For parameter 1 to n, the calculation is as follows:

□□□□□□=(□□□□−1∗□□□□−1)+…+(□□□□□−□∗□□□□−□)□□□□−1+□□□□−□

d. Suitability for scoring ($Suit_{score}$) is defined on the basis of weight for scoring and value as follows:
   - S1: $W_{score} \geq 80$
   - S2: $60 \leq W_{score} < 80$
   - S3: $40 \leq W_{score} < 60$
   - N : $W_{score} < 40$

2.4. Carbon Estimation

The carbon content is estimated using the approach by Muraoka (2004) which considers the potential area for cultivation (km^2), standing stock (g/m^2), production-biomass ratio, and carbon content (%). The carbon absorption per cycle is as follows :

□□□□=□×□□×□□×□□

in which:

- C_{abs}: The total absorbed Carbon (ton C/cycle)
- A: total potential area (km^2)
- SS: Standing stock or productivity (g/m^2)
- PB: ratio of production and biomass
- CC: Carbon content (%) which is Carbon weight/biomass weight

The Carbon absorption for seaweed Genus Kappaphycus sp. using longline cultivation system in Takalar district can be seen at Table 2. K. denticulatum has the highest Carbon content, while K. alvarezii has the lowest Carbon content.

Table 2. The Carbon content for several Genus Kappaphycus spp in Takalar District

Seaweed	Standing Stock (g/m^2)	P-B Ratio	Carbon Content (%)
K. alavarezii (Maumere)	508,00±48,37	12,45±0,12	23,09±3,74
K. denticulatum	473,00±28,60	14,98±0,23	43,10±5,13
K. alvarezii (golo-golo)	502,50±74,02	15,15±0,44	20,73±1,73
K. striatum	624,00±119,07	13,13±0,27	29,76±6,80

2.5. Economic Value Estimation

The economic value is estimated from the average production multiplied by the ratio between estimated potential area and average potential area derived from the analysis of cultivation using matching or scoring method. The equation is as follows:

□□□□=□×□□□□□
in which:

- □□□□= Estimated total production
- □□□□= Estimated potential area for cultivation
- □= Average production
- □= Average potential area for cultivation

3. Results

The results of this research are explained in this section

3.1. Area of Suitability

The area of suitability is divided into S1 (very suitable), S2 (suitable), S3 (conditionally suitable), and N (not suitable). Figure 5 shows the results of suitability analysis using matching approach. Some deeper areas are considered as N (not suitable). The seaweed cultivation can be performed in the area of S2 and S3. The total potential area that can be cultivated is 59,731 hectares. Figure 6 shows the results of suitability analysis using scoring approach. By using scoring method, the total suitable area is 423,741 hectares.

According to the water characteristics and existing seaweed cultivation, the results from the matching method is more acceptable. The area about more than 2 km from the coast can not be cultivated for the seaweed due to the water depth constraint. In that area, the seaweed cultivation is not present on the basis of field survey. Therefore, the area which has potential for seaweed cultivation is 59,731 hectares.

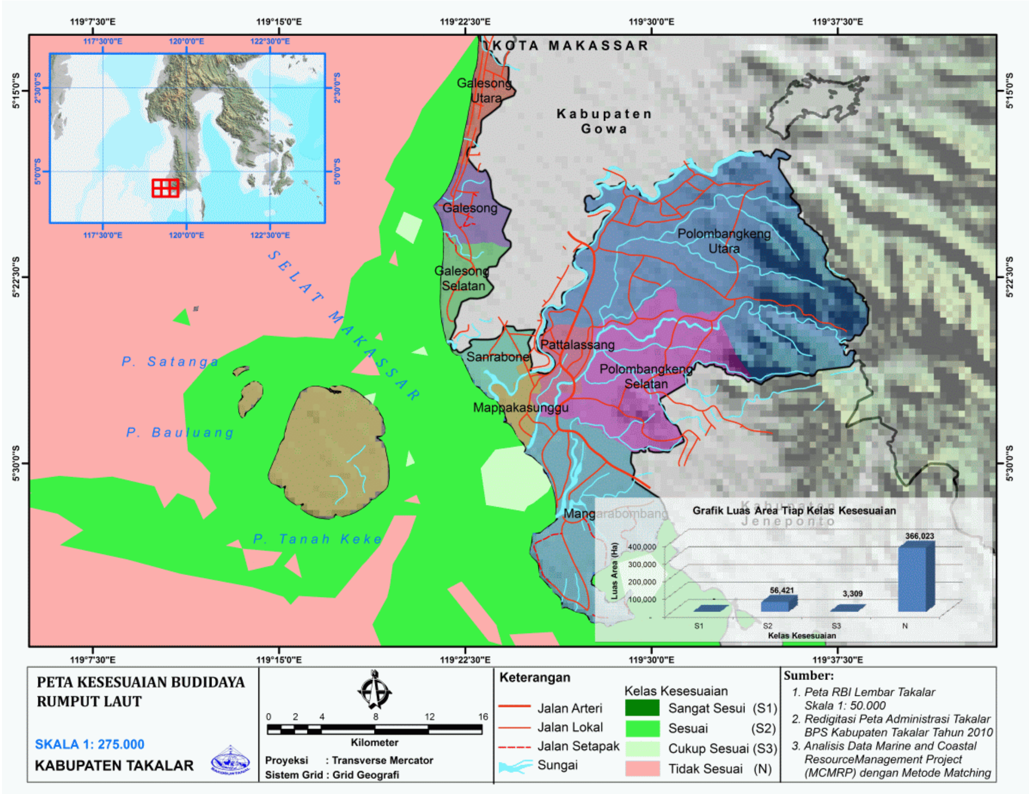


Figure 5. The result of suitability analysis using matching approach

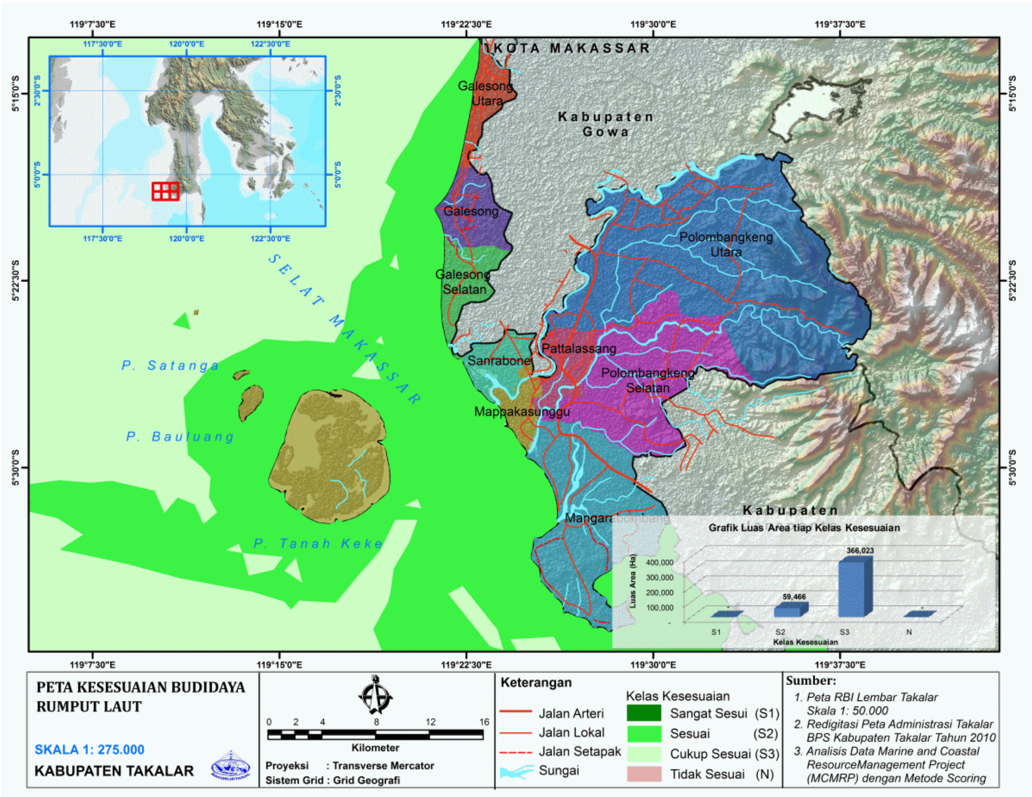


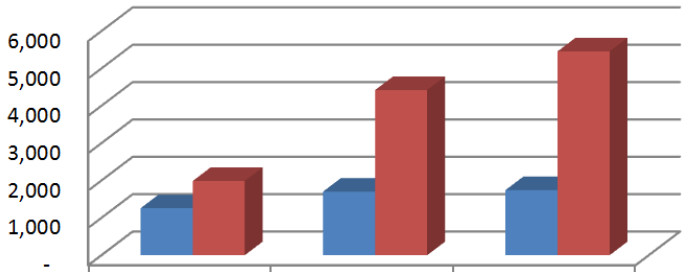
Figure 6. The result of suitability analysis using scoring approach

3.2. Carbon Estimation

Using Muraoka approach and matching approach, the estimated Carbon in Takalar District is between 71,530,867 and 120,577,675 tons C per cycle. The calculation is using the absorbtion of Kappaphycus alvarezii which has standing stock of 502.50±74.02 g/m^2, P-B ratio of 15.15±0.44 and Carbon content of 20.73±1.73 %. Looking at this result, the seaweed cultivation can be considered as an effort for Clean Development Mecanism (CDM) through carbon trade (Certificate Emmission Reduction – CER).

3.3. Economic Values

Figure 7 shows the area and production of seaweed (Gracilaria sp.) in Takalar from 2007 to 2009 (BPS, 2010). There is an increase in both area and production of seaweed. The average area is 1,566 hectares and the average production is 3,954 tons. If the area potential for seaweed cultivation is 59,731 hectares, the estimated production is 150,834 tons. The price of seaweed per is about $ 0.30/kg. Therefore the price of the harvested seaweed can reach up to $ 45,250,334.



	2007	2008	2009
Area (Ha)	1,257	1,700	1,740
Production (Ton)	1,985	4,420	5,456

Figure 7. The area and production of seaweed in 2007-2009

4. Conclusion and Recommendation

From this research, it can be concluded that spatial analysis can be employed to define the potential area for seaweed cultivation. The matching method is found to provide more accurate result on the basis of field survey. The existing cultivation in the area covers less than 10% of the potential area which is 59,731 hectares. More efforts should be carried out to cultivate the potential area. The Carbon estimation is between 71,530,867 and 120,577,675 tons C per cycle. In terms of economic value, the total price of seaweed can reach $ 45,250,334 if the potential area is used for seaweed cultivation. Therefore, the seaweed cultivation can provide better environment by capturing the Carbon and economic benefits for the people in Takalar district.

Further study is recommended to improve the suitability analysis for more accurate estimation of suitable area. The Carbon content for various seaweed species at different water conditions should also be studied to obtain better Carbon estimation. The results of this research should also be further applied in other coastal areas in Indonesia to verify the approach.

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