IDENTIFICATION OF SUITABLE AREA FOR SEAWEED CULTURE IN BALI WATERS BASED ON REMOTE SENSING SATELLITE DATA

SAYIDAIH SULMA, ANNEKE K.S. MANOPPO AND MARTYANI HARTUTI

Abstract Mariculture is a pan of marine and fisheries sector that has important contribution to achieve fisheries production target Area suitability for mariculture information is necessary for coastal development management. The information can be derived using remote sensing satellite data and Geographic Information System (GIS). The aim of this research is to identify area suitability for seaweed culture in Bali waters by considering several water physical parameters. Those parameters are bathymetry, water sheltered area. Sea Surface Temperature (SST) and Total Suspended Matter (TSM). The parameters are extracted from Landsat 7-ETM and ALOS data. High temporal resolution data such as NOAA and Aqua/Terra MODIS arc also used to monitor the fluctuation of SST and TSM in particular period, so the occurrence of parameter fluctuation can be anticipated. The physical parameters generated algorithms are referred to the algorithms reported in the previous research. The result shows that remote sensing data can be used to produce area suitability for seaweed culture, and Bali waters has 3728.87 hectare of the area.

Keywords; area suitability, Bali Waters, mariculture. remote sensing, seaweed.

I. Introduction

Mariculture is a part of marine and fisheries sector that has important contribution to achieve fisheries production target, though in fact; capture fisheries still plays the role recently. According to the data from FAO (2002), world capture fishery production was decreasing due to over exploitation, and mariculture production significantly increases. While, Directorate General of Aquaculture Fishery has also reported that 8.36 billion hectare of Indonesian water area can be used for mariculture (www.indonesia.go. id).

Integration between marine and coastal information is needed for coastal development and exploitation management. To integrate all the information, remote sensing technology and GIS are required, because those techniques have several advantages, such as: providing multi temporal and high spatial resolution data, wide coverage area, and can cover remote area. According to the previous research (Trisakti *el a/.,* 2004). remote sensing and GIS technology has possibility to give early information related to area suitability for mariculture.

The aim of this research is to identify the area suitability for seaweed culture based on water bio-physical parameters. Here, the water bio-physical parameters such as Sea Surface Temperature, Total Suspended Matter, bathimetry, sheltered area was derived using high spatial resolution remote sensing data (Landsat-7 ETM, Advanced Land ^Observing Satellite (ALOS)) and bathymetry map. Beside that, the dynamic parameter such as: TSM and SST was also observed using high temporal remote sensing data (NOAA and MODIS) to anticipate *the occurrence of parameter fluctuation in the suitable area.*

Remote Sensing Application & Technology Development Center. LAPAN
* E-mail Milma_sayidahfti\ahtioco.ij

2, Material and Method

2.1. Data

The main data for this research are Landsat-7/ETM, AVNIR-2 ALOS, NOAA-12/AVHRR and Aqua-Terra MODIS (Table 1). Other data, such as: Topograhic map from Bakosurtanal. scale 1:25.000 and bathymetric maps from Dishidros-AL, scale 1:10.000, 1:25.000 and 1:50.000 are used as a secondary data.

Table 1. Image data and acquisition date.

Image Data	Acquisition Date
Landsat-7/ETM: Path/Raw 117/066 Path/Raw 116/066	 28 May and. 3 Oct. 2002, 21 Aug. 2004, 17 March and 24 Aug. 2005 21 May and 10 Sept. 2002, 26 May and 15 Sept. 2004, 1 Aug. 2005
ALOS AVNIR-2	28 Nov. 2006
NOAA-12/AVHRR	Feb. 2006 - Jan. 2007 (min. 4 data each month)
Aqua/Terra MODIS	April 2006 - Maret 2007 (min. 4 data each month)

2.2. Methodology

2.2.1. Data Preprocessing

Geometric and radiometric correction were conducted in pre-processing data. Geometric correction was done to match image position between image compare to the position on earth with base map. Radiometric correction as the next step is to convert digital number into reflectance value to omit the error of sun elevation angle and distance between sun and earth at different time of data.

2.2.2. Water Bio-physical Parameters Extraction

Bio-physical parameters for waters suitability analysis in this research are SST, TSM, bathymetry and water sheltered area. Those parameters were derived from satellite data.

2.2.2.1. SST

SST from Landsat-7/ETM is derived by converting radiance spectral value channel 6 into brightness temperature, and then converted to SST (Trisakti *et al*, 2004):

$$SST\ (°C) = 0.0684 * T_6^3 - 5.3082 * T«f + 137.59 * T_6 - 1161.2 \quad (1)$$

where: T6 = brightness temperature channel 6 Landsat-7/ETM

SST analysis from NOAA-AVHRR was done to observe fluctuation of water condition (temporal variation) in one year using the calibrated McMilin and Crosby algorithm *in* Pellegrini *et al.* (1986):

$$SST\ (°C) = 0.522 * [T„ + 2.702*(T_4 - T_5) - 273 - 0.582J + 13.68 \quad (2)$$

where: T4 = brightness temperature of channel 4 and T5 = brightness temperature of channel 5

2.2.2.2. TSM

The algorithm used to extract TSM concentration is from Trisakti *et al.* (2004). These are the algorithms to extract TSM parameter from the reflectance value of channel 2 Landsat-7/ ETM: .

If the reflectance value from channel 2 <= 0.0282 then:

$$TSM(mg/l) = 1.0585 * e^{'3593x} \quad (3)$$

If the reflectance value from channel 2 > 0.0282 then:

$$TSM(mg/l) = 32.918x - 46.616 \quad (4)$$

where:

$$x = [(-0.53 * b2) + 0.001]/[(0.03 * b2) - 0.0059] \quad (5)$$

TSM distribution can also be analyzed with high temporal satellite data (MODTS) to observe water fluctuation. The algorithm used to extract TSM from MODIS (Trisakti and Parwati, 2004):

$$TSM(mg/l) = 0.0478((b3+b4)/b3)''^{425} \quad \textbf{(6)}$$

2.2.2.3. Bathymetry

The bathymetry profile was derived from bathymetric map and Landsat-7 ETM data. To generate bathymetry profile from bathymetry map, the main process are geometric correction and bathymetry map digitising. More detail information particularly in shallow and clear water, bathymetry extraction developed from Landsat-7/ETM data with Depth of Penetration (DOP) modelling (Green *et ai,* 2000). Visible channels (channel 1, 2, and 3) and NIR (channel 4) of Landsat-7/ETM have the ability to penetrate water column. By utilized the difference penetration of this 4 channel, the depth water zone will be determined from the border of different penetration between 2 channels.

Finally bathymetry contour were produce from the interpolation of bathymetry point from Landsat-7/ETM image and bathymetric map.

2.2.2.4. Water Sheltered Area

Water sheltered area is identified as the covered and sheltered area from sea current and wave directly. Sheltered location identified by deliniating covered waters, such as bay, cape, narrow straits, lagoon, and reefs.

2.2.3. Suitability Analysis of Biophysical Water Parameters

GIS analysis is a • tool to determine suitability of water bio-physical parameters. Reference from previous research (Table 2) is used for water bio-physical suitability modelling for seaweed culture. Assuming that all parameters have the same influence for seaweed culture suitable determination, the same weight was apllied to all parameters, then each parameters divided into 3 specified criteria, suitable (SI), moderate suitable (S2), and not suitable (S3).

The next process was overlaying all parameters from Landsat-7/ETM with tree decision method, where suitablity class depend on the parameters with the same class or higher

Table 2. Criteria of water physical parameters for suitable area for seaweed culture.

No	Parameters	Suitable (SI)	Moderate (S2)	Not Suitable (S3)
1.	Bathymetry (m)	2,5 < SI < 5	5 < S 2 < 10	S3 > 10; S3 < 2,5
2.	Water sheltered area	Sheltered	Sheltered	Unsheltered
3.	Sea Surface Temperature (°C)	26<S1 <28	24 < S2 < 26 28 < S2 < 30	S3 < 24; S3 > 30
4.	Total Suspended Matter (mg/l)	S1<20	20 < S2 < 80	S3>80

Source: Sediadi *et ql.* (2000), Pratomo (1999), Nurfiarini, A. (2003)

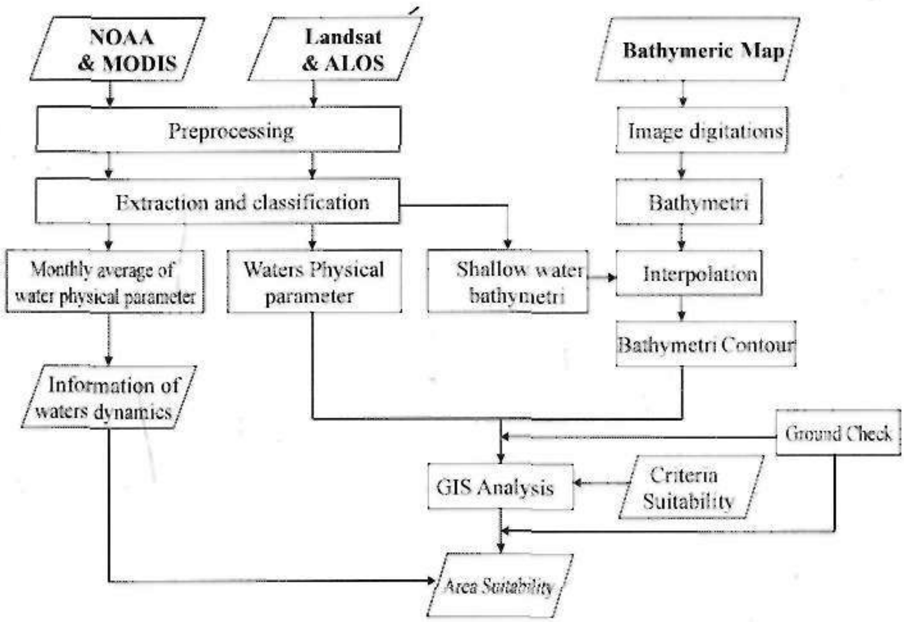

Figure 1. Flowchart of data processing and analysis

2.2.4. Water Dynamics Analysis

SST from NOAA-12/AVHRR satellite and TSM from Aqua/Terra MODIS in one year are the parameters to analyze the dynamic of water condition. This analysis was done by comparing SST and TSM monthly average. This analysis gives the variability of physical parameters information to know certain times that need special attention on seaweed culture because of the high fluctuation at every suitable area. The flowchart of data processing and analyzing is shown in Figure 1.

3. Result and Discusion

3.1. **Water** Bio-physical Parameters Extraction

Bali waters bathymetry information is derived from bathymetry map interpolated with Landsat-7/ETM and ground check measurement. Depth of Penetration (DOP) method to extract bathymetry from Landsat refer to previous research, where border zone DOP 1 and 2 is 13.8 m, DOP 2 and 3 is 5.7 m, and border zone DOP 3 and 4 is 2.5 m (Trisakti *et al.*, 2004). Bathymetry information derived from Landsat only occur in shallow and clear waters, i.e. northern and eastern coastal of Bali, coastal around Nusa Penida Island, and southern part of Benoa Cape (Figure 2).

Sheer area happened from the northern up to eastern of Bali coastal reached 1500 m. Wide shallow water and reefs area were delineated in the Benoa Cape up to northern and southern coastal, all around Lembongan and Ceningan Island, Lovina and Sumberkima village in west Bulelena regency.

From the criteria suitability, suitable bathymteri for seaweed culture (SI) is 2.5-5 m and moderate suitable (S2) between 5-10 m. Shallow water can cause seaweed dried off and turbid water while in the deeper water (depth more than 10 m), the wave is greater and need longer anchor line for seaweed growth.

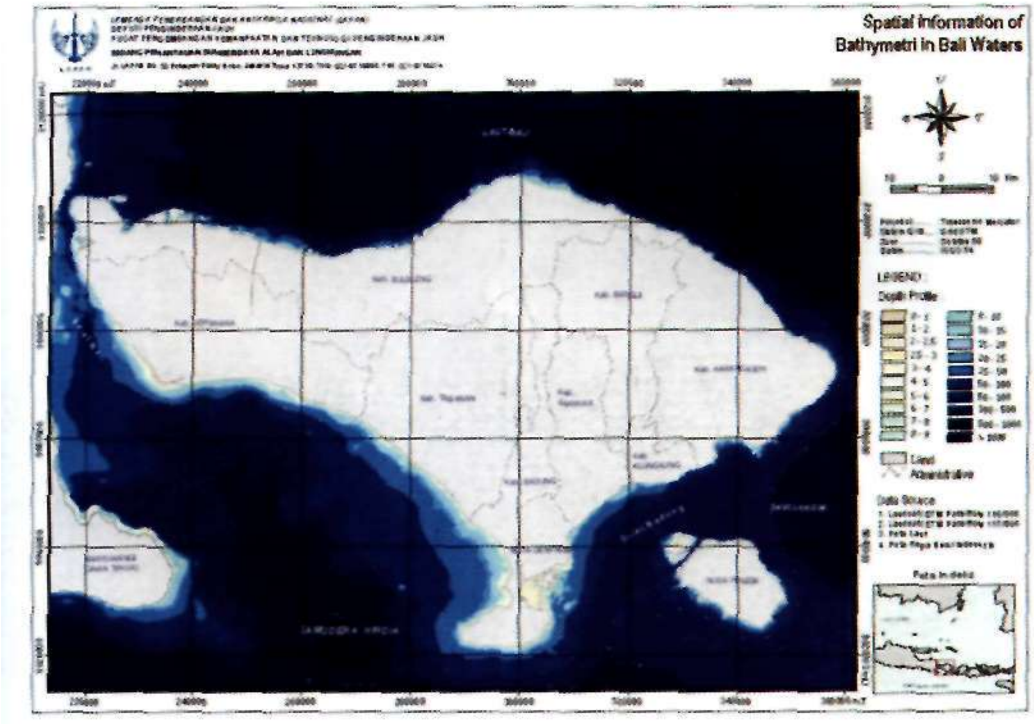

Figure 2. Bathymetry in Bali Waters.

The temperature between 26°C and 30°C is the best SST range for seaweed growth based on criteria suitability for seaweed culture (Sediadi *et al.*, 2000). Figure 3 shows SST information from Landsat-7 ETM data in South East Monsoon. SST in southern coastal of Bali was around 28.5°C - 30°C. Meanwhile, in the northern coastal of Bali was around 30°C - 31°C. SST information indicated that Bali waters generally in moderate suitable class (S2) for seaweed culture.

Turbid water from suspended matter will block sun light penetration through water column and it may affect seaweed growth. Water turbidity level or TSM indicates marine pollution.

TSM information in Bali waters derived from Landsat-7 ETM data in South East Monsoon (Figure 4). High TSM happened alongside southwest Bali coastal and around Benoa bay, reach 150 mg/1 and the main source of high TSM in this area came from water catchment area. Meanwhile, TSM concentration around small islands and offshore coastal area of Bali was around 0-10 mg/1. This value is suitable for seaweed culture. Generally, TSM concentration around Bali coastal was suitable for seaweed culture based on criteria suitability, where the range of TSM is 20-80 mg/1.

Determination of water sheltered area considers several physical conditions of water column i.e. current velocity, current direction, wave height and waters protection factor. Strong current and high wave will drift and break seaweed and also destroy raft. According to seaweed culture criteria, ideal current velocity is 20-40 cm/sec, while ideal wave height is less than 0.5 m.

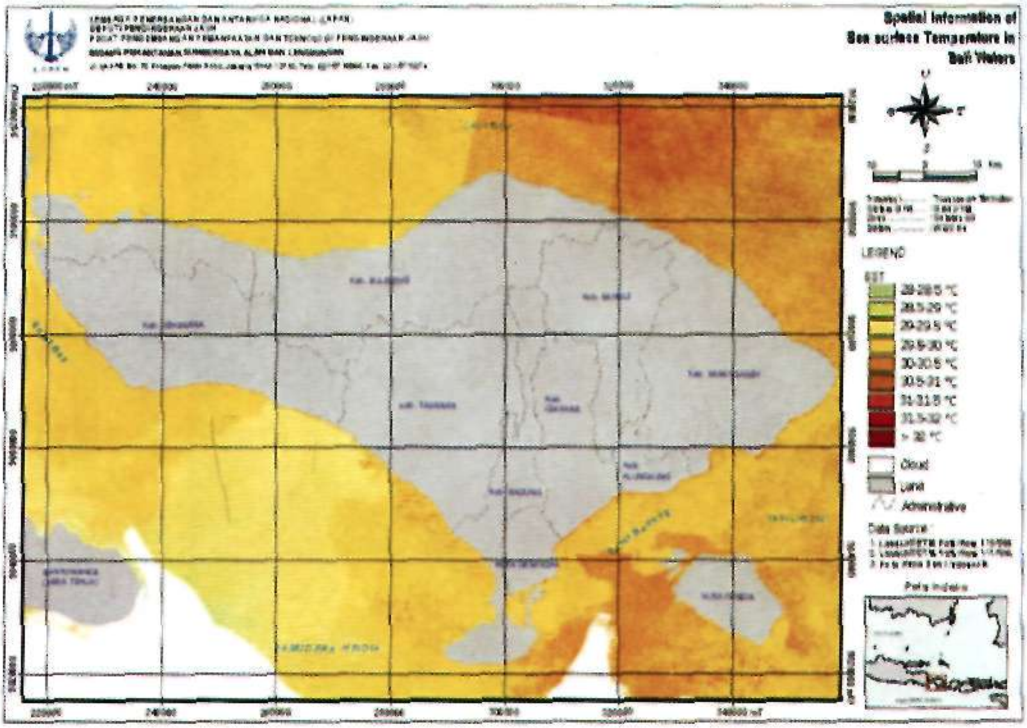

Figure 3. Sea surface temperature in Bali Waters.

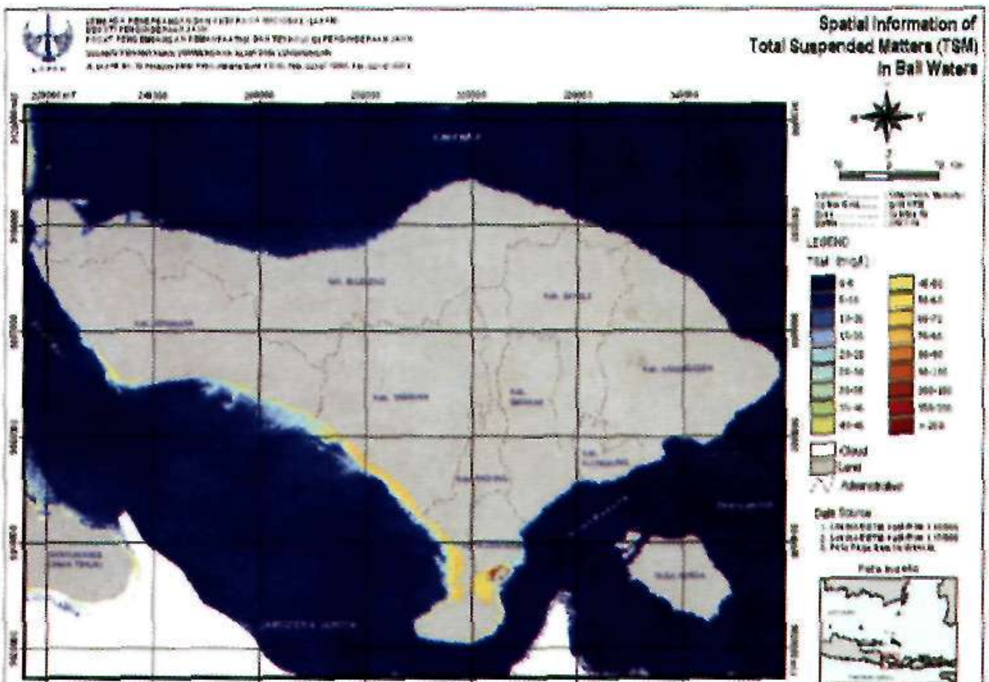

Figure 4. Total suspended matter in Bali Waters.

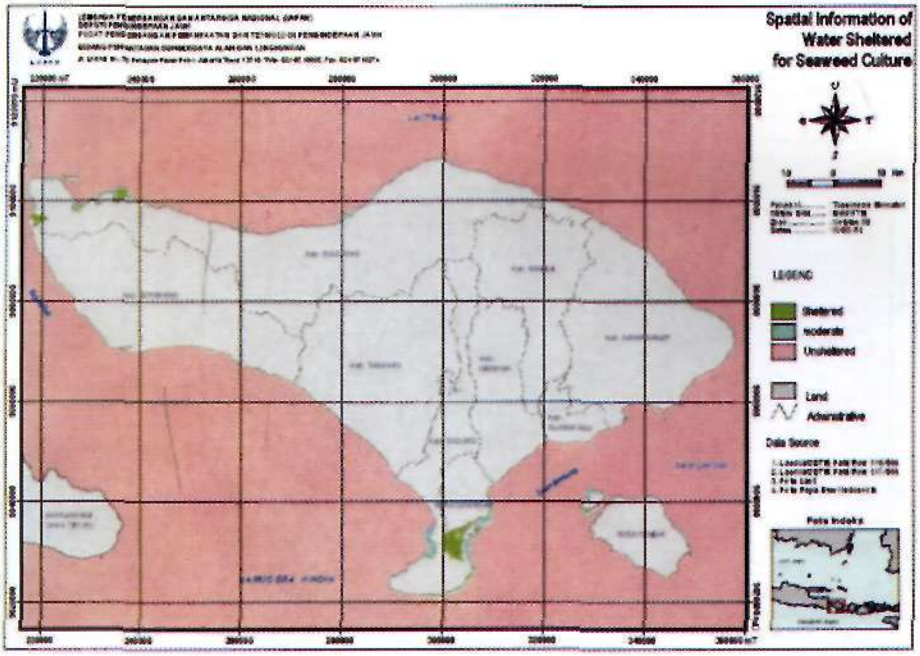

Figure 5. Water sheltered area information in Bali Waters.

Water sheltered area in Bali waters are bay and cape existence, narrow strait, lagoon, and fringing reefs. These area able to dim direct wave breaker. Water sheltered area classified into 3 classes that is shelter (SI), shelter enough (S2), and unshelter (TS). SI class include bay and cape area, strait, and lagoon, 52 class for fringing reefs area, and the rest is 53 class (unshelter). The result of water sheltered area analysis presented at Figure 5.

Sanur, Lembongan, Lovina and Sumberkima coastal sheltered by fringing reefs, while Benoa and west Buleleng sheltered by bay, and Ceningan strait sheltered by strait between Ceningan and Lembongan island. Those area are sheltered from waves and suitable for seaweed culture.

3.2 Bio-physical Water Parameters for Area Suitability

Figure 6 shows the result of area *vMftitx to s^wsadc&teere&ssadw water* #>sica\ parameter suitability.

From the suitability analysis, moderate class (S2) is the highest class for seaweed culture based on water physical parameter in Bali. This is mostly caused by high SST, appropriate water quality, suitable bathymetry and sheltered area which is dominated in almost all around Bali waters such as Lembongan Island, Ceningan Island, Penida Island, Sanur through southern coastal, northern and southern coastal of Karangasem regency, centre and western coastal of Buleleng Regency.

The estimation extensive of area suitability for seaweed culture in Bali waters is 3728.87 hectare residing in eight regency, where the largest is in Badung regency because it has large reefs covered (see Table 3). Field verification showed that seaweed culture has been developed around Lembongan Island, Denpasar coastal, Karangasem regency coastal, and Sumberkima village in western

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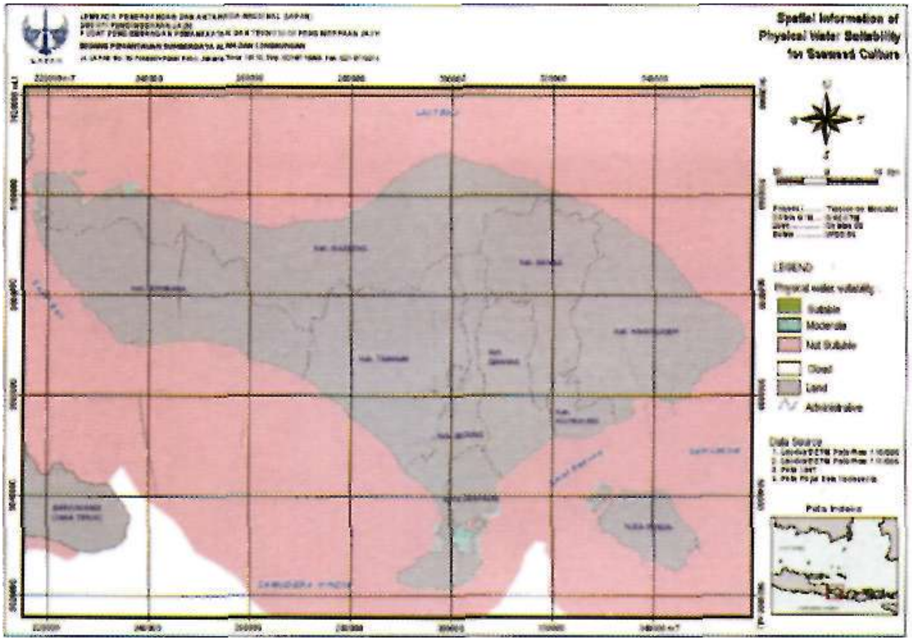


Figure 6. Area suitability for seaweed culture in Bali Waters based on water physical parameters suitability.

Tabel 3. Area suitability for seaweed culture.

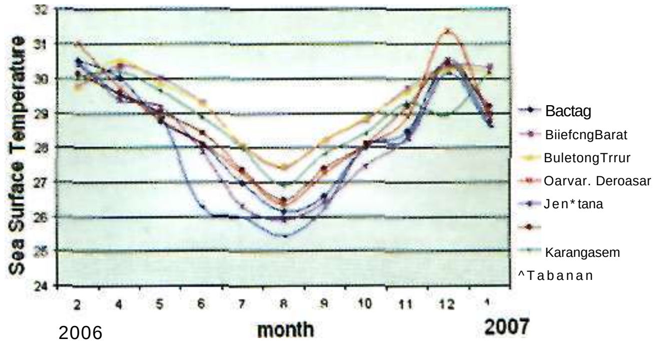
No.	Regency	Suitable Area (Ha)
1.	Jembrana	115.47
2.	Karangasem	69.11
3.	Klungkung	363.26
4.	Buleleng	1,086.26
5.	Badung	1,517.92
6.	Denpasar	504.40
7.	Gianyar	62.23
8.	Tabanan	10.23
TOTAL		3,728.87

3.3. Water Dynamic Analysis

Water physical parameter such as SST and TSM monitored temporarly to analyse water dynamic and fluctuation in one year. This analysis was done by comparing SST and TSM monthly average. This analysis give information about the moment when seaweed culture need special attention because of the water bio-physical fluctuation.

Figure 7 shows monthly average of SST and TSM in 8 locations, i.e. Badung, West and East Buleleng, Gianyar and Denpasar, Jembrana, Klungkung, Karangasem, and Tabanan coastal regencies from 2006 until 2007.

(a.)



(b.)

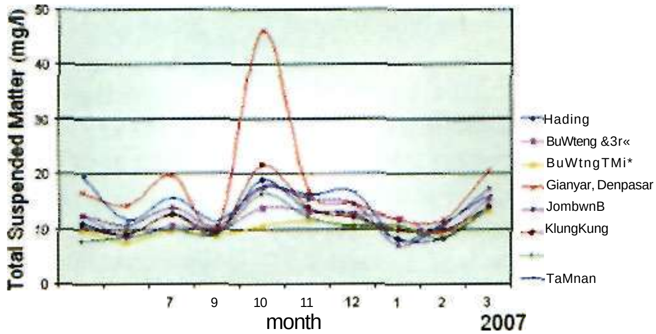


Figure 7. Monthly average of SST (a) and TSM; (b) Fluctuation in one year (2006-2007).

SST analysis shows that in southern coastal of Bali the temperature is lower than in the northern. During South East Monsoon, started from June through September, the wind blows from Australia continent and brings fresh water mass from the east. This periode is followed by cold SST that covered southern Bali waters. SST in Bali waters generally ideal. SST increase during North West Monsoon (December - February) and 2rd transition (October - November). In December 2006 highest sea surface temperature occured in Gianyar and Denpasar waters reach 31.5°C. SST fluctuation influence seaweed metabolism. Oxygen supply in the water tends to decrease along with the increasing of SST. Stable and ideal time for seaweed culture implementation happened during South East Monsoon where the temperature range was 26.0°C-28.5°C.

One year TSM analysis in Bali Waters generally did not show significant fluctuation. High TSM fluctuation occured in Gianyar and Denpasar during 2nd transition periode (October - November), reach 45 mg/1, while other area was stable and ideal reach 10-20 mg/1. High TSM concentration cause water turbidity and influence water quality. This condition will result seaweed disease.

4. Conclusion

Bali Waters that can be developed for seaweed culture based on water physical parameters are around Lembongan Island, Ceningan Island, Nusa Penida Island, Sanur coastal, southern and northern coastal of Karangasem Regency, centre and west coastal of Buleleng Regency. The extensive of area suitability for seaweed culture is 3728.87 hectare. According to Dinas Perikanan dan Kelautan Provinsi Bali (2006), area which have been developed for seaweed culture in Bali Province are Klungkung, Badung, Karangasem, Buleleng, Jembrana and Denpasar Regencies.

Water dynamic analysis as an important information to estimate best periode for seaweed culture. South East Monsoon (July - September) was the stable and ideal period for seaweed culture. Meanwhile, during North West Monsoon (December - February) and transition periode (April - June) and (October - November) seaweed culture need more attention and treatment for the implementation due to the water bio-physical parameter fluctuation.

Area suitability as a result for this research is a waters biophysical suitability and need more analysis by considering several limiting and supporting factors, such as accessibility, infrastructure, conservation zone, regional policy, social and economic.

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