SITE SELECTION OF SEAWEED CULTURE USING SPOT AND LANDSAT SATELLITE DATA IN PARI ISLAND

Bidawi Hasyim[1*], Wawan K. Harsanugraha[1], Yennie Marini[1], and Anneke K.S. Manoppo[1]

[1]Indonesian National Institute of Aeronautics and Space (LAPAN), Pekayon-Jakarta

[*]e-mail: bidawi_hs@yahoo.com

Abstract. One of several factors for seaweed culture success is to determine the suitable location for seaweed culture based on oceanographic parameters. The best location for seaweed culture is coastal waters with suitable requirements for total suspended solid (TSS), sea surface temperature (SST), and area with calm water that is sheltered from waves, strong current and predator, such as lagoon in the middle of an atoll. The purpose of this study was to locate the suitable area for seaweed culture in Pari island, Seribu island using SPOT and LANDSAT-TM data. The results showed that TSS in Pari island waters were in the range of 150 mg/l - 200 mg/l, SST in the range of 22-29°C, while coral reefs and lagoon was only available in some coastal locations. The analysis showed that most of Pari island waters were suitable for seaweed culture.

Keywords: *satellite data, seaweed culture , site selection, coastal waters*

1 INTRODUCTION

Seaweed culture has been one of the leading mariculture commodity in Indonesia for domestic and international market. Seaweed has important role and benefits – as food, raw material for cosmetics, pharmacy, and other chemical materials. The increase consumption and industry's raw material demands, either in domestic or international market, results in rapidly growing seaweed demands, but Indonesia has barely been able to take advantage of the market share optimally (Ekmaharaj, 2009).

Indonesia is blessed with vast marine territory, but has merely been able to produce 223.080 tons per year, significantly lower compared to Thailand. It has considerably smaller marine territory than Indonesia, but able to produce 894.857 ton, about 4 times bigger than Indonesia. This condition encourages Indonesia's government to increase seaweed culture as one of main priorities in marine and fisheries sector development.

Sediadi *et al.* (2000) stated that seaweed culture location has to fulfill requirements such as, sheltered location to avoid physical damage from wind exposure and substantial waves, water temperature about 27–30°C, ideal clarity about 1,5 m in transparancy, current velocity about 20 – 40 cm/sec, water salinity about 30–35 (the optimum around 33), and pH of 7–9. In addition, characteristics of an appropriate location for seaweed culture are sandy or rocky substrate, far from river estuary, and having moderate water movement. Such description fits in intertidal and subtidal area. Using simple technique by providing wooden stakes and ropes, production can increase to 2,5 tons/Ha in 45 days (Marine and Fisheries Department, 2001). Several studies about remote sensing data utilization and geographical information system for seaweed culture development have been done By Trisakti *et al*. (2004) in Situbondo, Sulma *et al*. (2005) in Seribu Island and Bali.

The objectives of this study was to develop application model of SPOT-4 remote sensing satellite data in order to determine the feasibility of seaweed culture location. The aim of this study implementation were to provide availability in application model of SPOT-4 remote sensing satellite data to determine the feasibility of seaweed culture location, and availability in spatial information of the feasibility of seaweed culture location in research area. In effort to enhance SPOT data utilization, this research was focused on identifying parameter extracted by using SPOT-4 remote sensing data, and parameter extracted by using Landsat-TM, specifically SST data.

2 MATERIALS AND METHOD

This research was conducted in Pari Island waters, Seribu Island (Figure 1). Main data in this research were SPOT-4 on 4 July 2010 and 20 August 2010, and Landsat-TM dated 5 July 2006. SPOT-4 data processing was implemented to obtain TSS and coral reefs cover, while Landsat-TM data was used to obtain SST distribution in Pari Island waters.

Geometric and radiometric correction for SPOT 4 and Landsat-TM were applied. Geometric correction was implemented to adjust satellite images position with actual position on the earth surface. On this research, ortho corrected Landsat-ETM data was used as ground control point (GCP). Radiometric correction was implemented by converting digital value into reflectance value which aimed to omit the error on sun elevation curve and sun distance from earth on other data period (Mumby and Clark, 2000; Landsat 7/ETM Satellite Manual). Phase on radiometric correction was conversion of digital values into radiance values.

2.1 SST extraction

Channel 6 on Landsat-5 data was used to determine sea surface temperature. Radiance value of chanel 6 was converted into effective temperature by using equation according to Landsat's handbook. Effective temperature was the SST in Landsat-TM. Method to convert digital number to effective temperature value was shown in equation 1 and 2 as folows:

$$L_\lambda = ((LMAX_\lambda - LMIN_\lambda)/ (DNMAX-DNMIN))^* (DN-DNMIN)+LMIN_\lambda \quad ..(1)$$

$$T_{Landsat} = K2/ \ln((K1/ L_\lambda)+1) - 273 \quad ....(2)$$

where,

L_λ	Spectral radiance watts/(m^2 sr µm)
DN	Digital Number
$LMIN_\lambda$	Spectral radiance which is correlate with DNMIN watts/ (m^2 sr µm)
$LMAX_\lambda$	Spectral radiance which is Correlate with DNMAX watts/ (m^2 sr µm)
DNMIN	Minimum value of DN (1 (LPGS Product) or 0 (NLAPS Product))
DNMAX	Maximum value of DN = 255
$T_{Landsat}$	Effective temperature (Celsius)

Value of K1 and K2 shown in Table 1.

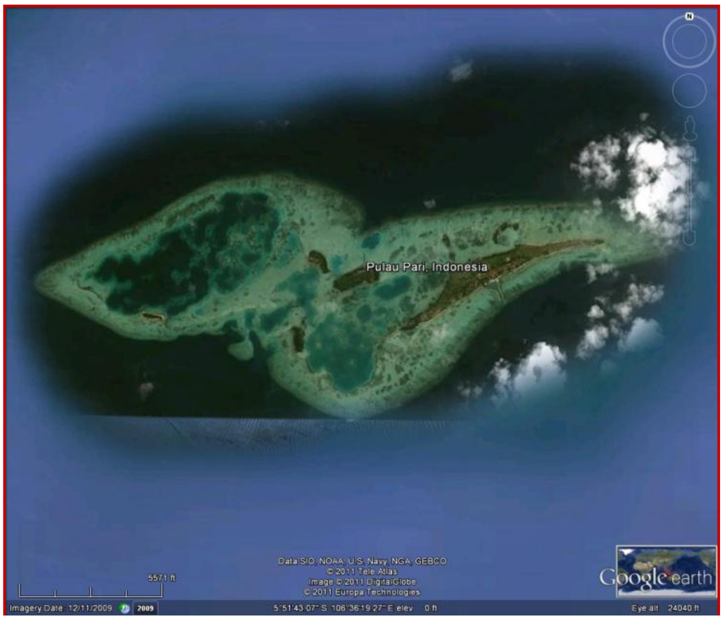

Figure 1. Pari island in Seribu Island (GoogleMap, 2011).

Table 1. Calibration constants band thermal ETM+ and TM

Satelitte	Constants 1- K1 watts/(m^2 sr μm)	Constants 2 - K2 (Kelvin)
Landsat 5	607.76	1260.56
Landsat 7	666.09	1282.71

2.2 Total suspended solids extraction

Total suspended solids (TSS) was extracted from satellite SPOT-4 data. Algorithm used for TSS was an algorithm developed by Budhiman (2004) which based on irradiance reflectance (R(0)) value as follows:

$$TSS\ (mg/l) = A * \exp^{(S*R(0-)\ red\ band)} \quad ......(3)$$

where A, S, and R^2 are coefficients for SPOT-4 parameters as shown in Table 2.

2.3 Benthic habitat mapping

Benthic habitat mapping determined using Lyzenga (1978) transformation model. Lyzengga developed the equation using 2 visible light channels (channel 1 and 2) from Landsat-TM imagery, which results in the following equation:

$$Y = \ln(TM1) - ki/kj \,.\, \ln(TM2) \quad ....(4)$$

Where, Y=depth invariant index; TM1= reflectance on channel 1; TM2=reflectance on channel 2; and ki/kj=coefficient ratio of channel 1 and channel 2. ki/kj values measured using the folowing equation:

$$ki/kj = a + \sqrt{(a^2 + 1)} \quad ....(5)$$

where, a=(var(TM1) – var(TM2))/2.cov (TM1 * TM2)

In this method, every pixel was converted into an index type of seabed which was free from the influence of depth. This method resulted in classification of coral reefs, seagrass beds, and sand grade. The next steps was to calculate the extents of each grade.

2.4 Sheltered waters

Among significant factors in determining seaweed culture development is sheltered water. The location has to be sheltered from wind and substantial or continuous waves, also strong ocean current with wave height not exceeding 30 cm. Fast current and high waves can cause damage to seaweed, such as broken, torn or detached from its substate. Futhermore, nutrient absorption will be hindered and ocean water will turn muddy (Indriani and Sumarsih *in* Pratomo, 1999). Water movement to seaweed growth is vital for supplying nutrient, aiding in nutrient absoption, cleansing dirt and holding CO_2 and O_2 exchange. Current speed suitable for seaweed growth ranging about 20 – 40 cm/sec.

2.5 Site slection of seaweed culture

With consideration of oceanography parameter extracted by remote sensing satellite data, determination method of seaweed culture location in this study refers to Pratomo (1999) and Nurfiarini (2003) *in* Sulma and Manoppo (2008) (Figure 2).

Table 2. Parameters for TSS extraction algorithm (Budiman, 2004)

Satelitte	Sensor	A	S	R^2
SPOT HRV	Band 1	2.9899	38.131	0.99
	Band 2	7.9038	23.942	0.95
	Band 3	14.195	64.208	0.82

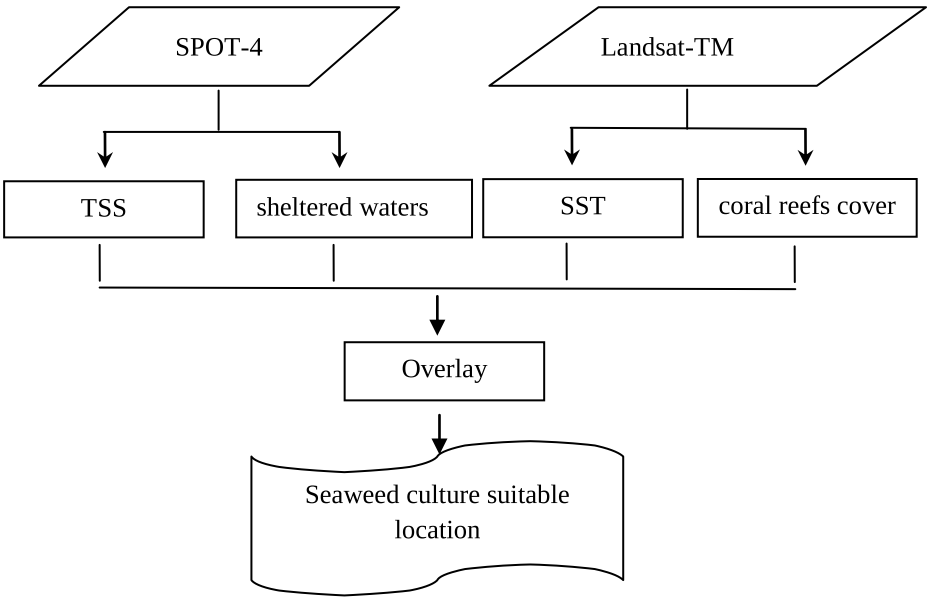

Figure 2. Seaweed culture suitable location flowchart

3 RESULTS AND DISCUSSION

Composite image of SPOT-4 data acquired on 4 May 2010 showed islands cluster in Seribu Island (Figure 3). Pari island cluster is one among Regency of Seribu Island, with total area 42 ha.

Pari island consisting mostly of resident housing, and small part of coastal or land border are covered by mangrove vegetation. Pari island's shallow waters are designated as ocean conservation by Ministry of Forestry. Pari island’s residents main profession are seaweed farmers since its surrounding depth is around 0-3 meters and oceanographic conditions support for seaweed culture.

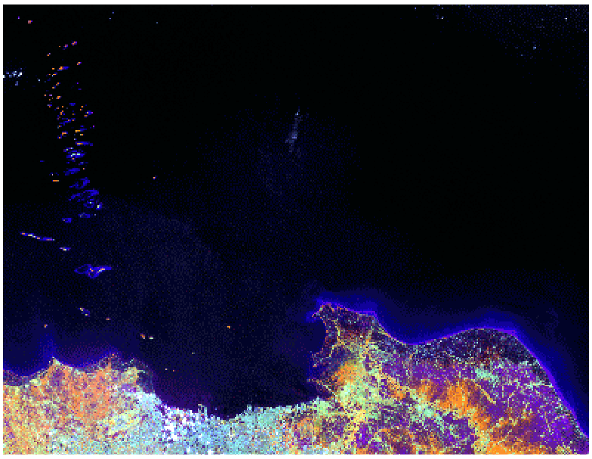

Figure 3. SPOT-4 color data composite of Seribu Island, 4 May 2010.

3.1 Sheltered water analysis

In determining seaweed culture location, sheltered water is a crucial factor. Water protection is required in seaweed culture. The Pari island is characterised as a lagoon and wide coral reef distribution. These factors provide a good shelter for seaweed culture from direct waves exposure. Pari island waters can be classified into sheltered class for lagoon area, moderately sheltered for coral distribution area, and the rest as unsheltered area (Figure 4).

Shelter water analysis result showed that Pari Island waters had major feasible sites to be developed into seaweed culture locations i.e., site on a fairly vast lagoon area, western part of the island.

3.2 Sea surface temperature

One of oceanographic parameters that can influence feasibility of seaweed culture location is SST. In this study, SST was derived from Landsat-TM satellite data acquired on 5 July 2006. Ideally, Landsat data to support this research was the most recent Landsat-7 data. However, inavailability of the data, the Landsat-5 data were utilized in this research. SST derived from Landsat-5 data had minimum temperature of 20°C (blue color) and maximum of 25°C (red) (Figure 5).

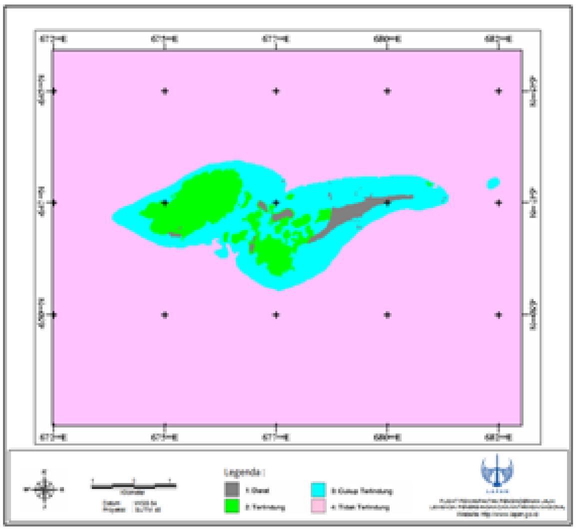

Figure 4. Sheltered waters area classification for seaweed culture activity in Pari Island.

3.3 Total Suspended Solid

Another oceanography parameter influential in seaweed culture location is TSS. In this research, TSS was derived from SPOT-4 satellite image acquired on 20 August 2010, using algorithm formulation developed by Budhiman (2004). This algorithm was applied not on the digital number value, but on the reflectant value.

TSS around Pari island waters ranged bentween 150 mg/l and 200 mg/l (Figure 6). This result showed that Pari island cluster waters possessed abundant amount of chlorophyll, or other suspended materials. This condition contradicts with resident's profession as seaweed culture farmers. Therefore, the available TSS algorithm was probably not suitable to be utilized in shallow waters, but in deeper waters.

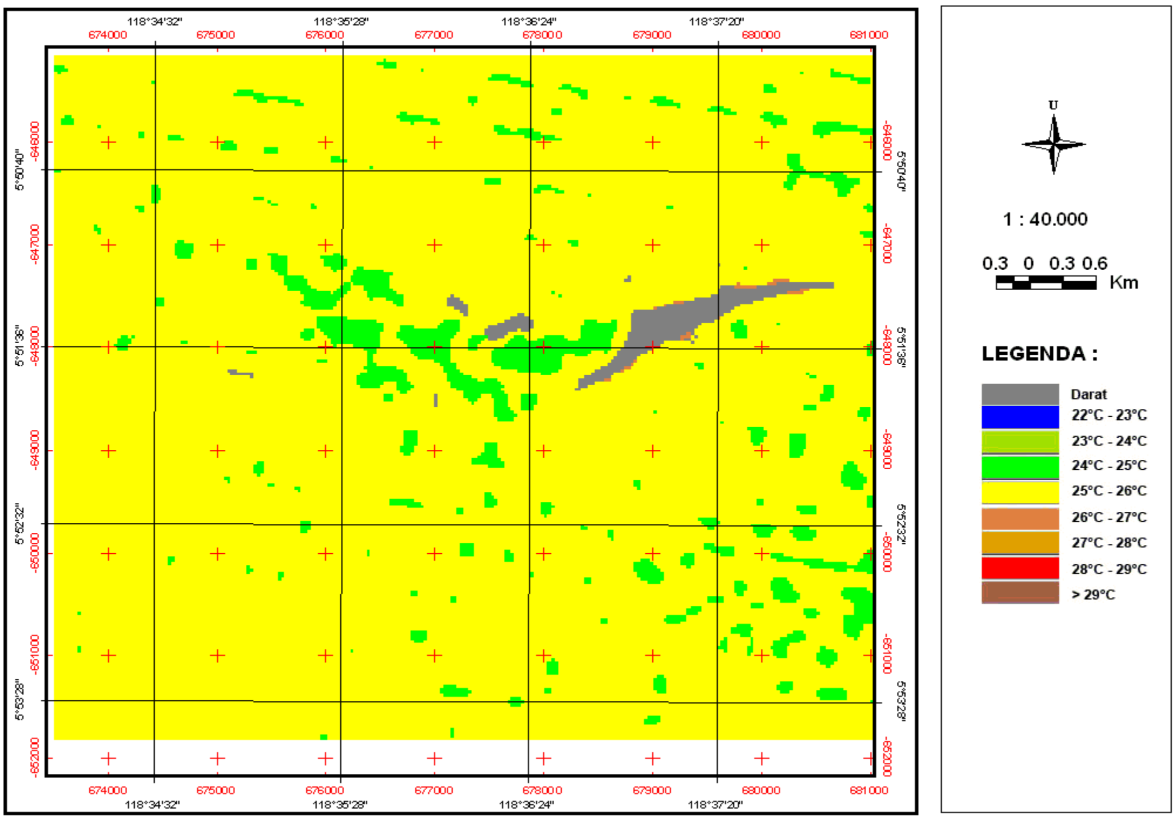

Figure 5. SST distribution according to Landsat-TM data acquired at July 5, 2006 in Pari island.

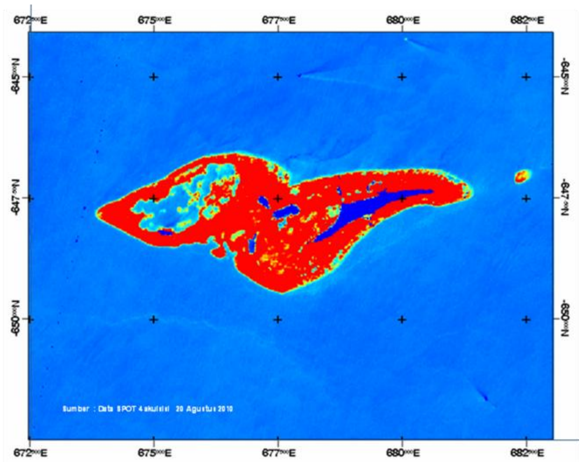

Figure 6. Total suspended solid in Pari island environment according to SPOT-4 data acquired on 20 August 2010.

3.4 Coral reef and seaweed culture location

Another influential parameter in seaweed culture location is the present of coral reef, although it does not critically determine feasibility of seaweed culture location, but merely functions as a 'border'. It implies that if coral reef ecosystem exists in a location, then the location is rendered unusable for seaweed culture to avoid damage on the coral reef ecosystem.

Based on SPOT-4 satellite data analyses accquired on 20 August 2010, Pari island waters consisted of coral reef (green color), seagrass (brown), and sand (yellow), while white was an area with no existing coral reef (Figure 7). From this analyses, most of Pari island waters can be used for seaweed culture (yellow and white locations) with fairly sheltered location, TSS distribution less than 20 mg/l, and SST ranging about 26 °C – 28 °C. The region that suitable for seaweed culture was about 113.25 ha and it was located mostly in the eastern part of Pari island (Figure 7).

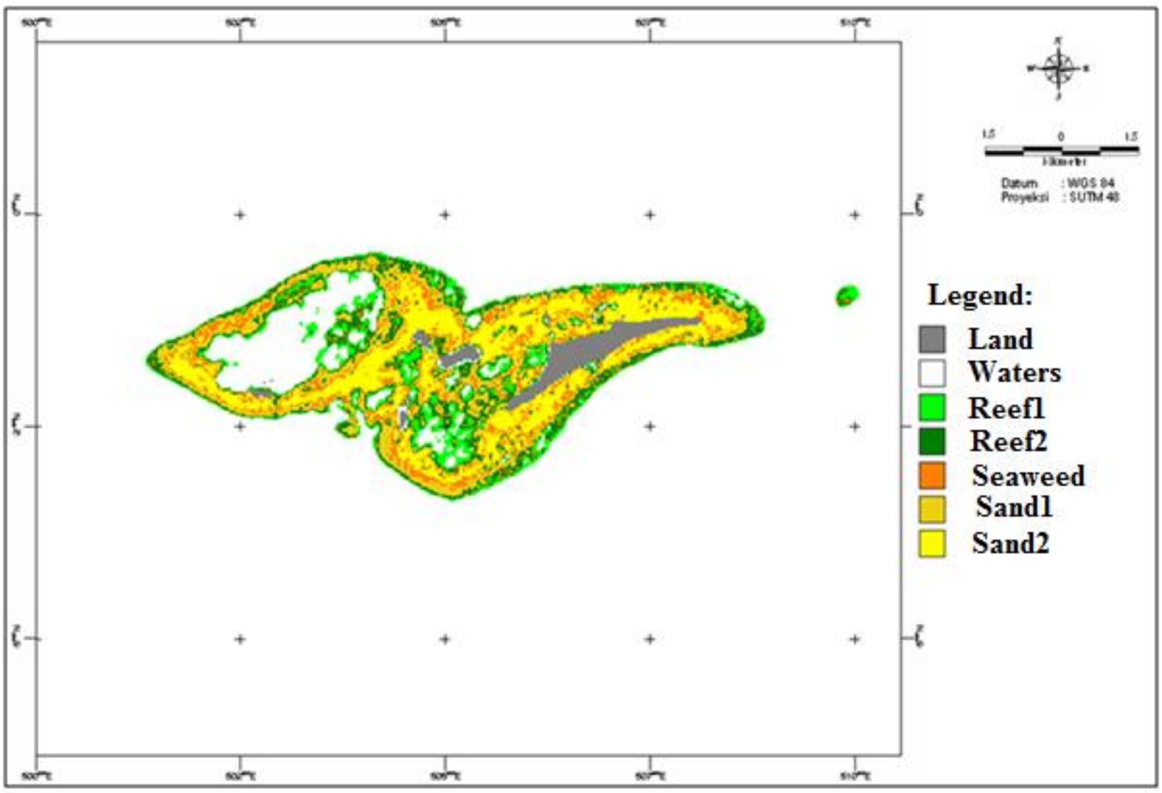

Figure 7. Spatial information based on SPOT-4 data on 20 August 2010 in Pari island and its surroundings.

4 CONCLUSION

Based on analyses result on sheltered water aspect and SST, Pari Island and its surroundings having fairly vast lagoon, are highly feasible for seaweed culture location with total area of about 113.25 ha located mostly in eastern part of the island.

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