GROWTH RATE AND PRODUCTIVITY DYNAMICS OF *ENHALUS ACOROIDES* LEAVES AT THE SEAGRASS ECOSYSTEM IN PARI ISLANDS BASED ON *IN SITU* AND ALOS SATELLITE DATA

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Abstract. *Enhalus acoroides* is the largest population of seagrasses in Indonesia. However, growth rate and productivity analyses of *Enhalus acoroides* and the use of satellite data to estimate its the productivity are still rare. The goal of the research was to analyze the growth rate, productivity rate, seasonal productivity of *Enhalus acoroides* in Pari island and its surroundings. The study was divided into two phases i.e., *in situ* measurments and satellite image processing. The field study was conducted to obtain the coverage percentage, density, growth rate, and productivity rate, while the satellite image processing was used to estimate the extent of seagrass. The study was conducted in August 2011 to July 2012 to accommodate all four seasons. Results showed that the highest growth rate and productivity occurred during the transitional season from west Monsoon to the east Monsoon of 5.6 cm/day and 15.75 mgC/day, respectively. While, the lowest growth rate and productivity occurred during the transition from east Monsoon to the west Monsoon of 3.93 cm/day and 11.4 mgC/day, respectively. *Enhalus acoroides* productivity reached its maximum during the west Monsoon at 1081.71 mgC/day/m^2 and minimum during east Monsoon with 774.85 mgC/day/m^2. Based on ALOS data in 2008 and 2009, total production of *Enhalus acoroides* in the proximity of Pari islands reached its maximum occur during the west Monsoon (48.73 – 49.59 Ton C) and minimum during transitional season (16.4-16.69 Ton C). Potential atmospheric CO_2 absorption by *Enhalus acoroides* in Pari island was estimated at the number 60.14 – 181.82 Ton C.

Keywords: *Enhalus acoroides, growth rate, productivity rate, productivity, ALOS, Pari island*

1. INTRODUCTION

Seagrass is a plant with arteries, leaves, rhizomes, and roots that submerge in the shallow water. Seagrass reproduces both sexually and asexually. In sexual reproduction, the seagrass yields flowers and spread the pollens from the male flower to the female flower and then produce seeds. The seeds will remain dormant for few months and if it finds a suitable habitat then the seeds will grow into new plants. Seagrass can also reproduce asexually (*vegetative*). Vegetative reproduction can be done by rhizome extending and ramification. In general, with asexual reproduction, seagrass can recover after a stricken storm or eaten by herbivores (Coles *et al*., 2004).

Seagrass usually forms an overlay of plants which also known as seagrass bed or seagrass ecosystem and covers a certain area at the shore/shallow water. The seagrass bed is spread over the coastal region from tropical to subtropical region. A seagrass bed may consist of one type of seagrass (monospecies seagrass bed) or more than one type of seagrass (mix seagrass bed). Seagrass ecosystem has a density ranging from dense/thick to sparse (Duarte, 2002; Short *et al*., 2006).

Enhalus acoroides is one of the 12 species of seagrasses in Indonesia and inhabits most of Indonesian waters, contains relatively large diameter of rhizomes, and normally covered with densely, thick, rigid hairs. *Enhalus acoroides* also has largae amount and unbranced string-like roots. Its leaf shape like ribbons with even sides and blunt edge with length that can reach up to one meter. *Enhalus acoroides* can grow in muddy seafloor, muddy sand, sands, and sands of coral fragments. *Enhalus acoroides* tends to form a pure vegetation seagrass bed, but there are also other species associated with it such as *Halophilaovalis, Cymodo-ceaserrulata, C. rotundata, Thalassia-hemprichii, Halodule uninervis* and *Syringodium isoetifolium*.

Enhalus acoroides found in the Pari island seagrass ecosystem grows on muddy sand sediments, sands, and sand of coral fragments. They form monospecies seagrass bed spots on the southern part of Pari islands and can be found associating with other types of seagrass such as *Thalassia hemprichii, Halodule uninervis, Cymodocea serrulata* and they spread out evenly all over the Pari islands seagrass ecosystem. A study in growth and productivity rate of *Enhalus acoroides* needs to be conducted to obtain its role in carbon regulation in Pari island.

Nelleman *et al*. (2009) said that the seagrass potency is not only it stores carbon in biomass but also able to keep deteriorating and decomposing biomass in the sediment. Seagrass root system with its rhizome and canopy-forming leaves allows it to pile up organic carbon from the deteriorating or decomposing biomass for thousands of years in a healthy seagrass ecosystem.

In order to acknowledge the seagrass role in carbon utilization, information on seagrass extent is required. One of the techniques to estimate the seagrass extent is by using remote sensing satellite data. Several researchers had reported that the accuracy of seagrass map using remote sensing satellite data can be more than 90%. However, such information for the Pari island is still lacking. Therefore, in this study, we combined *in situ* measurements and remote sensing satellite data to evaluate growth and production rate of *E. acoroides* and to estimate its extent in Pari island seasonally.

2. MATERIALS AND METHOD

2.1 Study area

The research was conducted in Pari island starting in August 2011 to July 2012. Pari island is an island formed on the coral reefs foundation (Figure 1). The research consists of two phase, *in situ* observations and ALOS satellite image processing. The *in situ* observations were conducted with eight measurements taken during west Monsoon, transitional from west to east Monsoon (Transiotional-I), east Monsoon, and transitional from East to west Monsoon (Transiotional-II). Seagrass observation was conducted to acquire the coverage percentage and density of *E. acoroides*.

2.2 Field measurements and data analyses

Growth rate investigation was done using Zieman method with a unit of cm/day (Short and Duarte, 2001). Measurement was conducted for 10 buds with 3 repetitions on a seagrass plot with known breadth and density. The buds selected had to have the following categories: intact and matured, undamaged leaves, and more than three leaves in a bud. The marking of the leaf was done by making a hole at the base of the leaf directly above the midrib, the position of the hole then marked by driving a stake beside the individual and the tip of the stake was positioned right next to the leaf's hole. After a few days, it was harvested (cut) by giving a mark/hole at the stake's rim. Growth length was measured on each leaf from the last hole's mark to the first hole's mark.

Net productivity of the seagrass leaves were obtained by weighing wet weight on the site. Dry weight and carbon weigh were measured in laboratory by putting the leaves in the oven at 60^{o}C for approximately three days until a stable weigh acquired. Then, we analysed its carbon weight using the equipment Truspect Analysis CHNS (LEGGO brand) in the Laboratory of Soil Biotechnology, Soil and Land Resources Department, Faculty of Agriculture IPB. Net productivity of the seagrass leaf was using unit C/m^2/day (Short and Duarte, 2001).

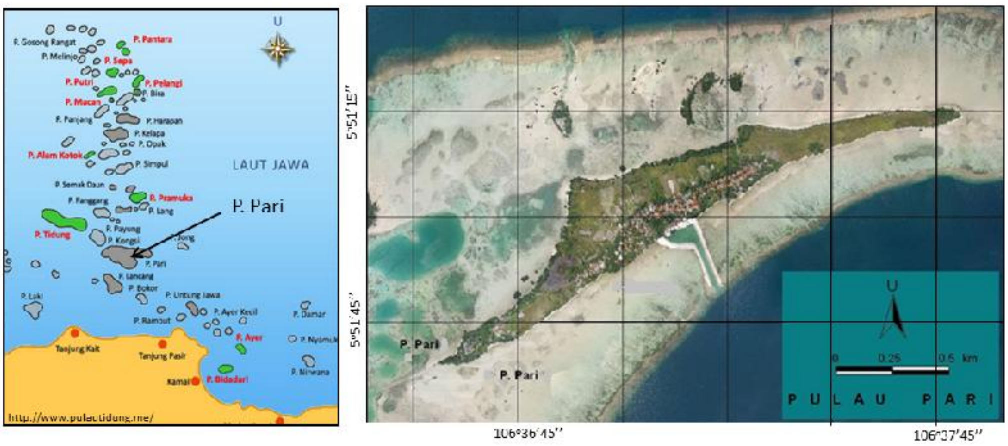

Figure 1. Study site at reef flat of Pari island, Pari island, Seribu Islands, Jakarta

Satellite data processing was done in several phase in accordance to the general standard such as atmospheric and geometric corrections, clarification and data accuracy test based on the field survey data. Flowchart of the satellite data processing is presented in Figure 2. The satellite data used in this research was the ALOS data acquired in September 18th, 2009.

3. RESULTS AND DISCUSSION

The seagrass ecosystem in Pari Island is an ecosystem developed at the coral reefs bed which part of the small group of isles known as Pari Islands. Sediments found on site mostly consist of sands, fragments of corals, and in several place with heavy coastal vegetation such as mangrove and seagrass. There is also found muddy sand substances. According to the previous study, there are seven seagrass species found in Pari Islands i.e., *Enhalus acoroides*, *Thalassia hemprichii*, *Cymodocea rotundata*, *Cymodocea serrulata*, *Halodule uninervis*, *Halophila ovalis*, and *Syringodium isoetifolium*. Based on observation in August 2011, *Enhalus acoroides* inhabited of 18.3% of seagrass coverage in Pari Islands and this was the second largest coverage. The greatest percentage coverage was *Thalassia hemprichii* of 75%. Coverage percentage and density for *Enhalus acoroides* with season are described in Table 1.

3.1 Growth rate

The *E. acoroides* leaves growth rate in Pari island was measured within one year span from August 2011 to July 2012 in four-seasons. Figure 3 showed that the growth rate of the *E. acoroides* leaves starting from the new leaf (leaf 1) all through to the outer leaf (leaf 7) in average tend to decline. The fastest growth observed on the juvenile leaves which were leaf 1, 2, and 3, but afterwards declining as general trend of growth regression of *E. acoroides.*

The correlation of growth rate and age of *E. acoroides* leaves during west Monsoon and east Monsoon (R^2=0.935 and 0.794) were in general better than in transitinal Monsoon (R^2=0.644 and 0.521) (Figure 3).

The growth rate of *E. Acoroides* leaves at the same location in Pari Islands during transitional season I (April 2009) range between 0.1 – 1.24 cm/day, and the greatest growth rate observed in leaf 2 at 1.24±0.19 cm/day, while the lowest observed in leaf 4 at 0.1±0.02 cm/day. During east Monsoon (July 2009), the growth rate of *E. acoroides* leaves ranged of 0.46–1.81 cm/day with the highest rate observed in leaf 2 at 1.81±0.11 cm/day and the lowest at 0.46±0.27 cm/day. Growth rate in transitional II ranged of 0.282 –1.273 cm/day. The growth rate during east Monsoon ranged of 0.297–1.168 cm/day which was lower than in west Monsoon.

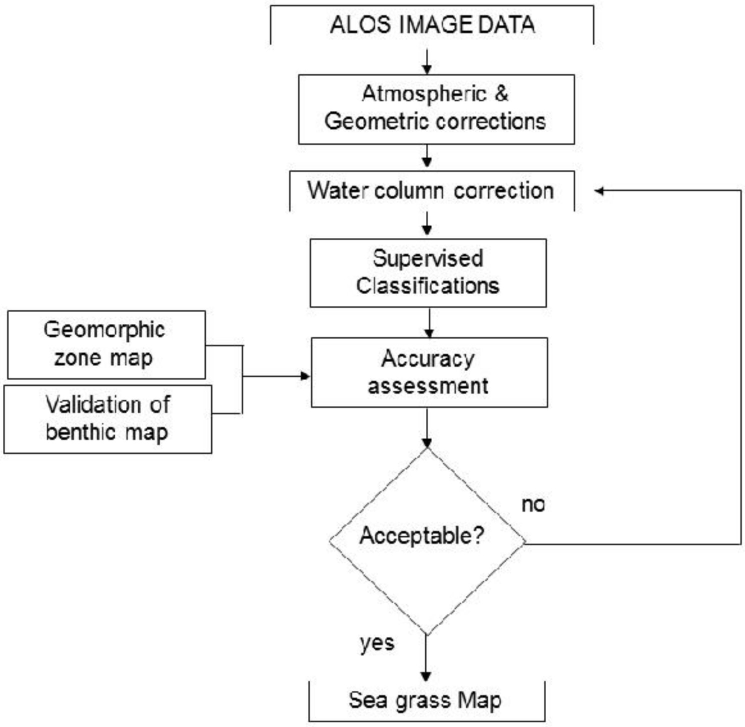

Figure 2. Flow chart of satellite data processing.

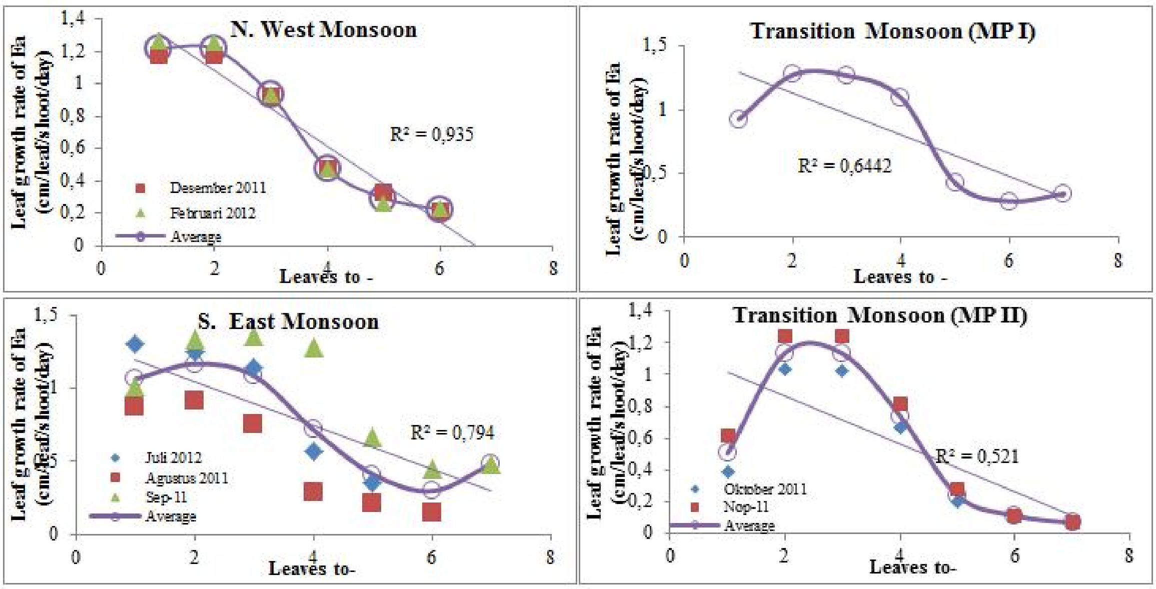

Figure 3. The leaf growth rate of *E. acoroides* at Pari Island in 2011 – 2012

Table 1. Density and prosentage coverageof *Enhalus acoroides*at sudy site in research (2011-2012).

Monsoon	Coverage percentage	Density (shoot/m^2)
N. West Monsoon	22,5	76
Transition Monsoon I	15,3	68
S. East Monsoon	17,6	68
Transition Monsoon II	20,1	72

This study and previous studies illustrated that the fastest growth rate usually found in the second leaf and tend to decline in older leaves (Kiswara, 2010).

Rattanachot and Prathep (2011) discovered that *E. acoroides* leaves found in the Haad Chao Mai National Park, Thailand which located in the Eastern Indian Ocean had an average growth rate of 2.07±0.04 cm/day per bud. This value was lower than Kiswara (2010) and the result of this study. Kiswara (2010) observed that *E. acoroides* leaves had a growth rate of 3.1 – 5.75 cm/day per bud, while this research obtained values between 3.9 – 5.6 cm/day (Table 2).

The total growth rate of *E. acoroides* leaves in one bud was at its peak in September 2011 (east Monsoon) with rate of 6.587 cm/day. While, the growth rate of *E. Acoroides* leaves per bud based on the season showed the highest rate during transitional season I with 5.604 cm/day (Figure 4). Kiswara (2010) found that the highest growth rate for *E. Acoroides* leaves occur during July 2009 (east Monsoon) at the value of 5.5 cm/day in one bud.

3.2 Production rate

The daily production rate of the *E. acoroides* leaves was observed using the carbon weight (Figure 5 and 6) in the calculated leaf growth.

Figure 5 showed the production rate with the increase of length of *E. Acoroides* leaves in Pari Islands during a whole year observation (August 2011 to July 2012) in four seasons. Figure 5 did not demonstrate that the *E. Acoroides* leaves had a steady failing production rate starting from the new leaf (leaf 1) to the outer leaf (leaf 7), but using the second order polynomial regression, we found that there was a correlation between production rate of the *E. acoroides* leaves for young and old

Table 2. The leaf growth rate of *E. acoroides* (cm/day) at Pari island in 2011 – 2012.

Leaves to-	Monsoon			
	N. West	Transition I	S. East	Transition II
1	0.796	0.926	1.064	0.505
2	1.222	1.273	1.168	1.138
3	1.216	1.267	1.085	1.132
4	0.930	1.091	0.715	0.741
5	0.475	0.423	0.412	0.238
6	0.294	0.282	0.297	0.112
7	0.225	0.342	0.482	0.067
Total (cm.day^{-1}.shoot^{-1})	5.157	5.604	5.223	3.933

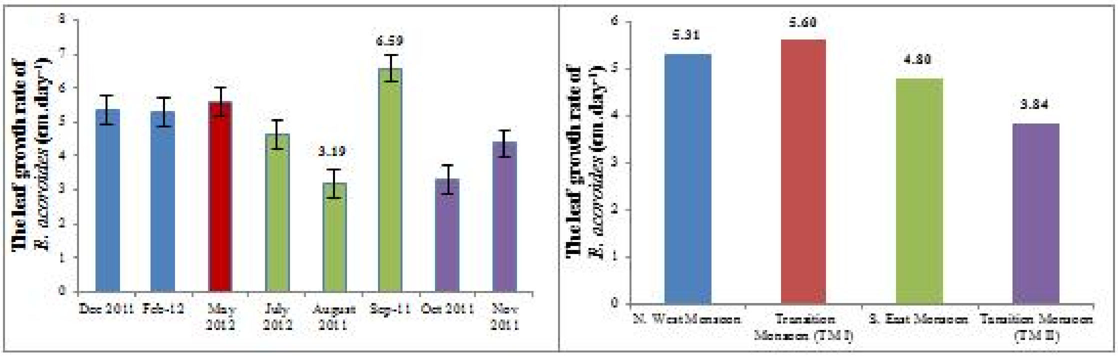

Figure 4. The leaf growth rate of *E. acoroides* at Pari island in 2011-2012.

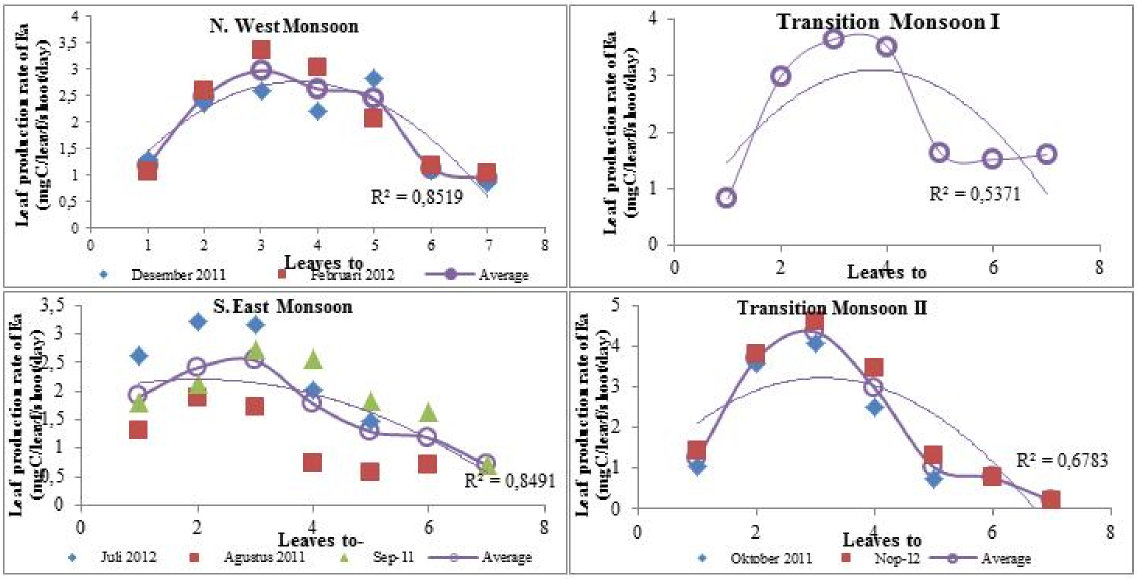

Figure 5. The leaf production rate of*E. acoroides*at Pari Islandin 2011 – 2012.

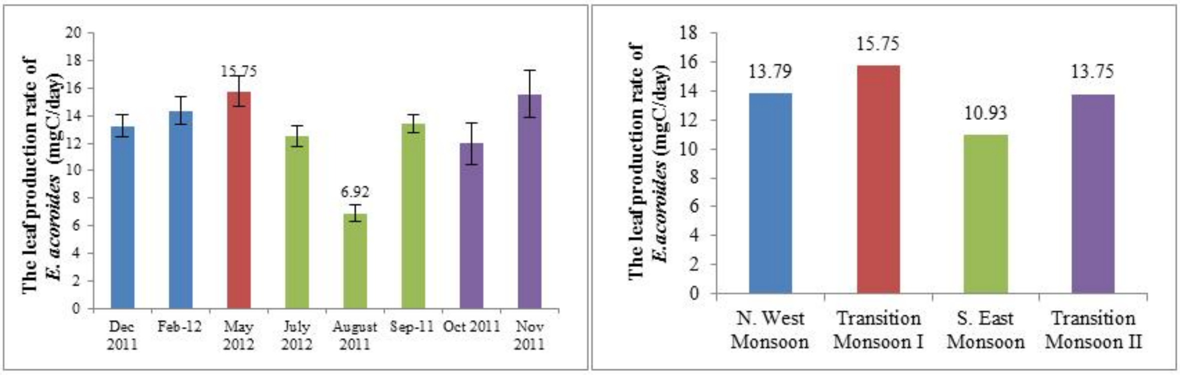

Figure 6. The leaf production rate *E. acoroides*at Pari Island in 2011 – 2012.

Leaves with production peak produced by leaf 2 and 3. The correlation values (R^2) between growth rate and leaves age ranged R^2 ranging between 0.537–0.851 (lowest in transitional I and highest in West Monsoon).

E. Acoroides leaf production per bud during west Monsoon, transitional I, east Monsoon, and transitional II in carbon weight each season is presented in Table 3. Production rate of *E. Acoroides* leaves with correlation to seagrass density was 1081.71 mgC/day/m^2 during west Monsoon; 1070.88 mgC/day/ m^2 during transitional I; 774.85 mgC/day/ m^2 during east Monsoon; and 999.54 mgC/day/m^2 during transitional II. The highest growth and daily production rate of *E. acoroides* leaves was found during transitional I and the lowest was during transitional II. This occurred as a result of value of coverage percentage and seagrass density measured during both transitional I and II were lower than that during west and east Monsoon (Table 1) resulting in the falling production rate.

3.3 Seagrass production in accordance to satellite image

In the shallow water resources map obtained from ALOS satellite image on 18 September 2009 (east Monsoon), we observed coral, seagrass, mangrove, and coral associated with algae resources in the study region (Figure 7). The seagrass in Pari islands covered the area of 164.1 hectares or

1.641 km^2. According to the coverage percentage and density of *E. acoroides* (Table 1) and seagrass extent from the image, the *E. acoroides* leaves production during east Monsoon was 27.30 Ton C (Figure 8). Based on Silfiani (2011) estimation of seagrass extent using ALOS image on 28 November 2008, the seagrass extent in Pari islands was about 1.67 km^2, therefore, this can yield the total production of the *E. acoroides* leaves during transitional II of 20.7 Ton C (Figure 8).

Table 3. The leaf production of *E. acoroides* (mgC.day^{-1})at Pari Island in 2011 – 2012

Leaves to-	Monsoon			
	N. West	Transition I	S. East	Transition II
1	1,237	0,824	1,905	1,250
2	2,560	2,986	2,407	3,725
3	3,059	3,648	2,534	4,395
4	2,702	3,521	1,775	2,997
5	2,535	1,640	1,288	1,038
6	1,171	1,522	0,786	0,382
7	0,967	1,608	0,699	0,096
Total (mgC.day^{-1}.shoot^{-1})	14,233	15,748	11,395	13,882

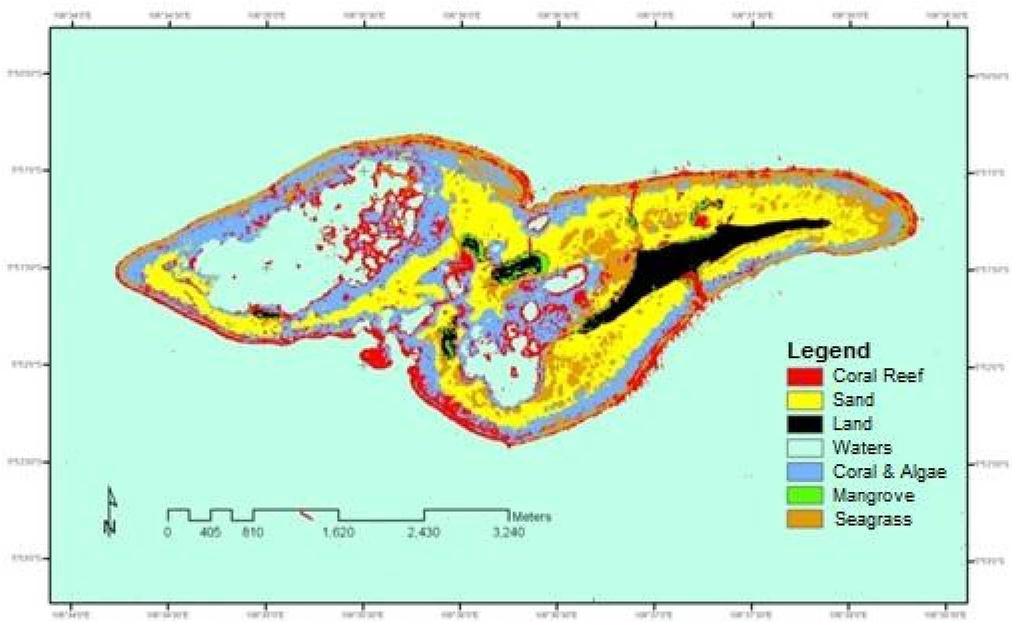

Figure 7. Shallow water resources map of ALOS imagery at Pari island cluster.

Figure 8 shows the *E. acoroides* leaves production yielded according to *in situ* and image processing data during East Monsoon and transitional II. Based on the observation during the year 2011 to 2012, the total seagrass coverage percentage was fluctuated and tends to degrade. This might occur by an increasing human activities in the region. During this study there was a reclamation project for resort construction in Tengah Island causing seagrass was partly covered with sands while measuring the seagrass community structure in permanent location (Figure 9).

3.4 CO_2 atmospheric potential absorption

A plant needs CO_2 in the photosynthesis process to construct its body structure (biomass) and release oxygen (O_2). The amount of CO_2 stores in the biomass can be assumed using the atomic weight of CO_2. The carbon atomic weight is 12, oxygen is

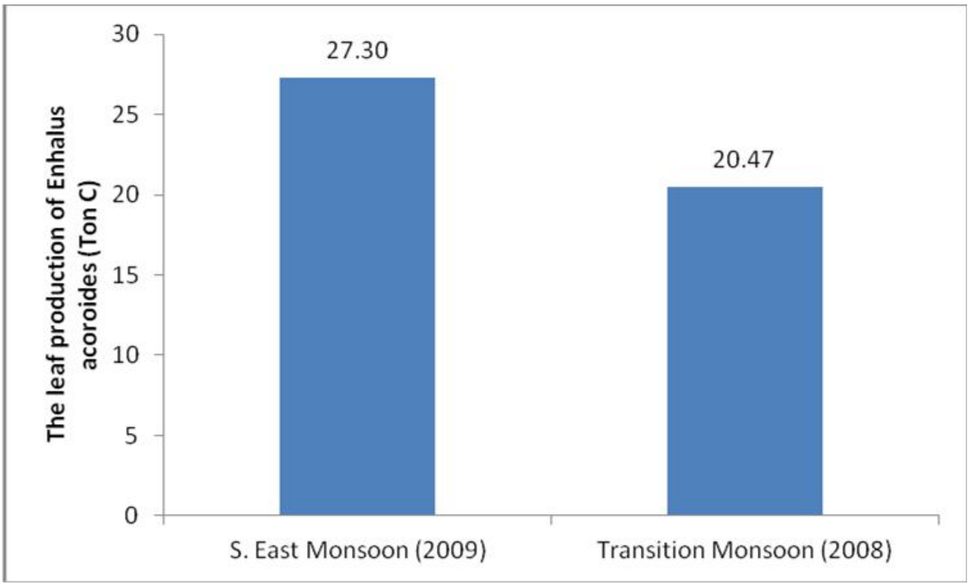

Figure 8. Leaf production *E. acoroides*at in Pari island based on ALOS imagery on 28 November 2008 during transition Monsoon (Silfiani, 2011) and ALOS imagery on 18 September 2009 during SE. Monsoon

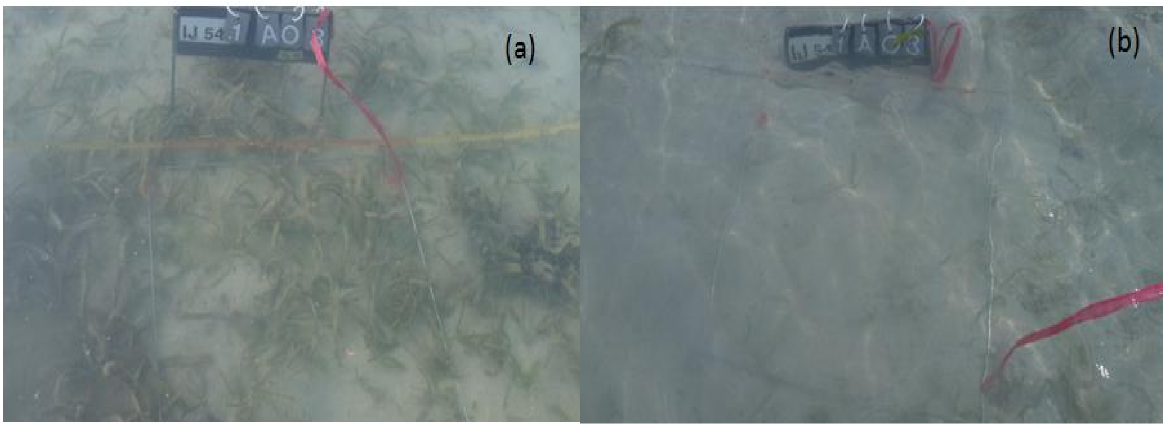

Figure 9. Coverage seagrasses at Pari island (a) in Mei 2012 and (b) in July 2012 in the same position.

16, therefore, the atomic weight of CO_2 is 44. From the photosynthesis equation, one ton of carbon stored in the biomass can be assumed to utilize/absorb 44/12 CO_2 from the atmosphere or about 3.67 ton CO_2 from the atmosphere and releasing of 2.67 ton of oxygen back to the atmosphere (http://www.olivotto.com/carbon/index.html). In line with the theory, if the *E. acoroides* leaves production in Pari Islands was 20.47 Ton C during Transitiona-II and 27.30 Ton C during 2009 east Monsoon, therefore, the CO2 atmospheric absorption was 100.11 Ton C during east Monsoon and 75.04 Ton C during Transitional-II (Figure 10).

This assumption was based on CO_2 utilization for photosynthesis by ground plants. However, the seagrass occasionally soaked through the surface due to tidal waves and it alter its ability to aborsob CO_2 from the atmosphere. Therefore, thorough research is still needed to better understand the role of seagrass in carbon regulation.

4 CONCLUSION

Coverage percentage and density of seagrass varied throughout the seasons with total of 22.6% and 76 individu/m^2 during west Monsoon, 15.3% and 68 ind/m^2 during transitional I, 17.6% and 68 ind/ m^2 during east Monsoon, and 20.1% and 72 ind/m^2 during transition II. The highest coverage and density of *E. acoroides* were found during the west Monsoon. The leaves growth and productivity rate were at the highest in transitional II at 5.6 cm/day and 15.75 mgC/day, respectively and the lowest during transitional II with 3.93 cm/day and 11.4 mgC/day, respectively. Productivity of *E. acoroides* leaves reached its peak during west Monsoon at 1081.71mgC/day/m^2 and at its lowest during east Monsoon at 774.85 mgC/day/m^2.

The highest total production of *E. acoroides* based on ALOS satellite image was 49.59 Ton C in 2008 and 48.73 Ton C in 2009. While, the lowest productivity in 2008 was 16.4 Ton C and 16.69 Ton C in 2009. CO_2 atmospheric potential absorption by the *E.acoroides* leaves was estimated around 60.14 – 181.82 Ton C.

ACKNWOLEDGEMENT

This research was part of the writer's dissertation who received scholarship from the Department of Maritime and Fisheries Affairs.

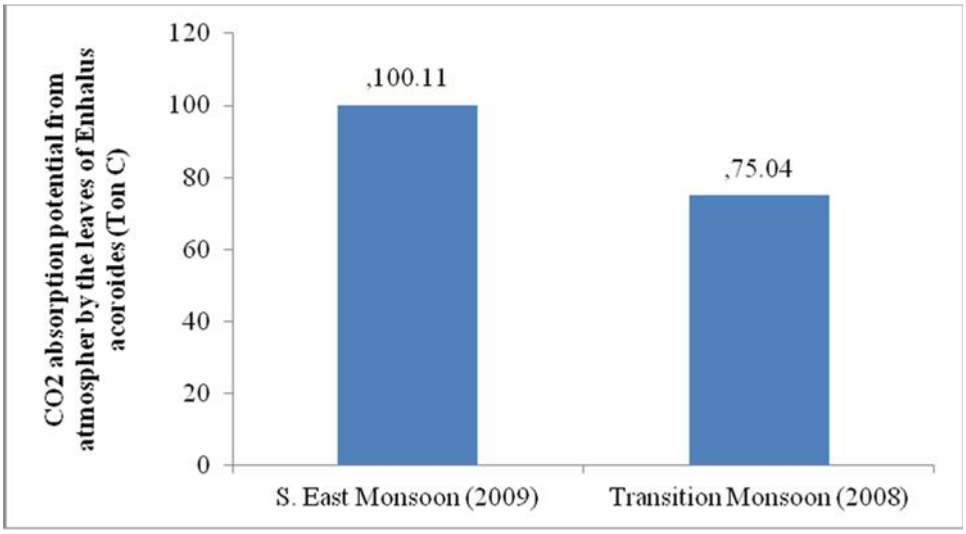

Figure 10. CO2 absorption potential from atmospher by the leaves of Enhalus acoroides ALOS imagery 28 November 2008 (Silfiani, 2011) in transition moonsoon and ALOS imagery 18 September 2009 in S. East Monsoon.

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