

Seagrass Chlorophyll-a, Biomass and Carbon Algorithms Based on the Field and Sentinel-2A Satellite Data at Karimunjawa Island, Indonesia

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Abstract

Chlorophyll-a in seagrass biomass is functioned for the photosynthetic process and store the organic carbon in their biomass of the leaf, rhizome, and root. Ecologically has functioned as blue carbon in reducing global warming adaptation and mitigation strategy. The study aimed to explore seagrass species, chlorophyll-a content, biomass and carbon stock at Karimunjawa Island. Develop algorithms of the Sentinel-2A satellite data based on field seagrass chlorophyll-a, biomass and carbon and at Pokemon and Bobby beach Karimunjawa Island. Four species of seagrass found at Bobby and Pokemon beach are *Holodule pinifolia* with a density of 160.44 ind.m⁻², *Enhalus acoroides* with 26.22 ind.m⁻², *Halophila ovalis* with 6.67 ind.m⁻² and *Thalassia hemprichii* with 4.44 ind.m⁻². The lowest seagrass chlorophyll-a is 5.854 mg.ml⁻¹ found in *H. pinifolia* and the highest is 20.819 mg.ml⁻¹ found in *E. acoroides* at Pokemon beach. The range of seagrass chlorophyll-a at Bobby beach was 3.485 - 14.133 mg.ml⁻¹ in *T. hemprichii*. The smallest individual biomass dry weight was found in *T. hemprichii* with 1.32 g.dry.weight per individu, and the biggest in *E. acoroides* with 6.98 g.dry.weight per individu. The highest seagrass biomass at Pokemon beach was in *E. acoroides* with 236.93 g.m⁻² which has a wide leaf morphology and the lowest in *H. pinifolia* with 75.91 g.m⁻² with the smallest leaf morphology. The range of seagrass biomass at Bobby beach is 97.62 - 264.48 g.m⁻² which is dominated by *T. hemprichii*. The range of seagrass carbon was 109.63 - 136.82 gC.m⁻² at Pokemon beach, and in the range of 95.00 - 114.01 gC.m⁻² at Bobby beach. Algorithm of seagrass chlorophyll-a = -36.308 (B3/B4)² - 140.41(B3/B4) + 83.912 ; biomass = -7028.3 (B3/B4)² + 14948 (B3/B4) - 7764.4; carbon = -17.529(B2/B3)² + 143.82(B2/B3) - 5.3362 for Pokemon beach. Algorithm of chlorophyll-a = 455.02 (B2/B4)² + 823.72 (B2/B4) + 375.48; biomass = -14699 (B3/B2)² + 28395(B3/B2) - 13537; and carbon = - 0.001(B3/B4)² + 0.209(B3/B4) - 10.203 for Bobby beach. The use of Band-2 (0.490 μm), Band-3 (0.560 μm) and Band-4 (0.665 μm) Sentinel-2A satellite data in the development of seagrass chlorophyll-a, biomass and carbon algorithm was found to be significant.

Keywords

Seagrass, Algorithms, Chlorophyll-a, Biomass, Carbon

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1. INTRODUCTION

Chlorophyll-a in the epiderm of seagrass has a capability for the absorption of the green spectrum in the photosynthesis process. Mentioned by Zubra, 2018 that the main photosynthesis process of seagrass was happened in the epiderm layer, with high content of chlorophyll-a. Mashoreng et al., 2019 photosynthetic process of carbon dioxide from the atmosphere had been transferred into seawater by means of diffusion into bicarbonate (HCO₃⁻) with the role of pH. In the case of pH increase up to 8.2 will limit carbon dioxide and where seagrass will absorb bicarbonate for the photosynthesis process. The main process of atmospheric carbon dioxide absorption is biosequestration in the photosynthetic process. Ganefiani

et al., 2019 that the seagrass ecosystem plays a significant role in carbon sink and source. Kahirunissa. et al., 2018 coastal vegetation carbon stock was found in the range of 234 - 450 tonC per year which is stored such as in the seagrass biomass for a period of time. Review through the previous research that Ferwerda et al., 2007 the need for satellite-based monitoring of tropical seagrass vegetation current techniques and future developments. Wicaksono and Hafizt, 2013 study the use of seagrass Leaf Area Index using ALOS-AVNIR and ASTER satellite data. McKenzie et al., 2020 reviews the global distribution of seagrass meadows. Wicaksono et al., 2019 analyse the reflectance spectra of tropical seagrass species using absolute reflectance values of 200 (0.200 μm) and 900 nm (0.900 μm) WorldView2 satellite images which beneficial for the classifica-

tion of seagrass species. Nahirnack et al., 2019 had developed a mapping delineation of seagrass habitats using Unoccupied Aerial Systems (UAS). A'an et al., 2020 had developed the field seagrass carbon stock using Robust Linear Mixed Models (rLMMs) found the above ground carbon stock 80–314 ktC, below ground carbon stock 196–696 ktC and carbon sequestration capacity 1.6–7.4 MtC/year of seagrass ecosystems in Indonesia.

The need for an effective, fast and accurate way for blue carbon seagrass chlorophyll-a, biomass and carbon estimation by means of spatial database over a large coastal area using the application of satellite data analysis is inevitable. The use of satellite data algorithm method can be controlled spatially and spectral accuracy, spatio-temporal and wide area coverage capability. As well as efficient for continuous monitoring and database development (Hartoko et al., 2015). The aim of the research is to develop a new paradigm or approach of using seagrass chlorophyll-a, biomass and carbon algorithm based on a step-wise logical ecology approach of the field and spectral values of Sentinel-2A satellite data at Karimunjawa Island. The seagrass chlorophyll-a using Band-4 with 0.665 μm wavelength, and using Band-2 with 0.490 μm and Band-3 with 0.560 μm the short wavelength which had the capability of shallow water sub-surface penetration for seagrass biomass reflectance.

2. METHODS

2.1 Materials

The study areas are Pokemon and Bobby beach of Karimunjawa island (Figure 1). Seagrass ecosystem at Karimunjawa island was selected based on consideration of almost the year period of clear water or seawater transparency, thus give much better satellite reflectance. Seagrass coverage measurements using Seagrass Monitoring of CoreMap-LIPI, 2014. Seagrass species identification using Seagrasswatch (McKenzie, 2003). Satellite data using Sentinel-2A which is a polar-orbit satellite launched by European Space Agency (ESA). Sentinel-2A has 13 bands with a spatial resolution of 10 m and 20 m and acquisition from the website of https://scihub.copernicus.eu/dhus/ (Yanuar et al., 2018). Field variable measured are seagrass species, density, chlorophyll-a, biomass and carbon. Field survey using three-line transect each with 100 m length, each line consist of three square transects with 25 m distance, transect quadrant size 50 x 50 cm all with GPS coordinates.

2.2 Methods

Measurement of seagrass density using methods in (Duarte, 1990; Fahrudin et al., 2017). Wet samples of seagrass leaf, rhizome and root were stored in a plastic zipper and compiled in Cool box. Fresh sample seagrass leaf was macerated for chlorophyll-a spectrophotometric analysis in a glass column with 90 percent of acetone. Seagrass biomass was split into three part of leaf, rhizome and root and weighed separately. Seagrass biomass measurement using loss on ignition (LOI)

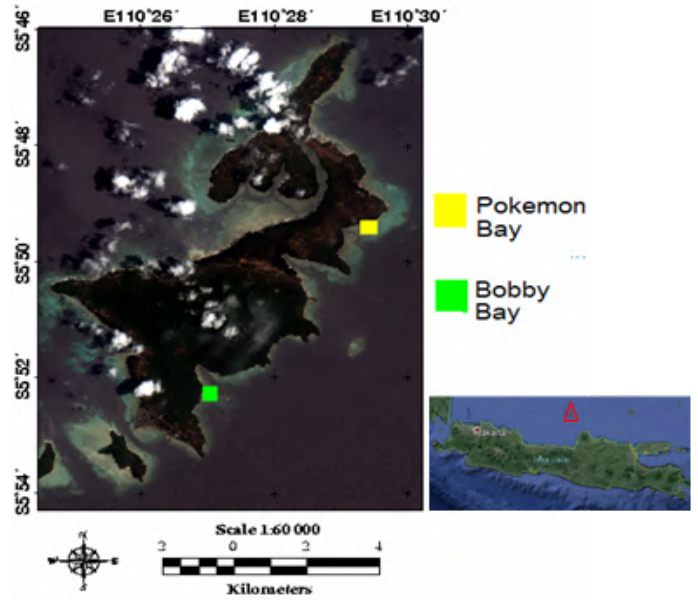


Figure 1. Study Area of Pokemon and Bobby Beach Karimunjawa Island

method with drying oven and ash-furnace 550 °C for three hours (Campbell et al., 2015; Hartoko et al., 2019).

$$\text{Seagrass cover(\%)} = \frac{\text{Total cover of transect}}{\text{Total quadrant of transect}} \quad (1)$$

Seagrass density (Fahrudin et al., 2017),

$$Ki = \frac{Ni}{A} \quad (2)$$

Where *Ki* is density of species-*i* (individu/m²), *Ni* is Total individu of species-*i* (ind) and *A* is Area of sampling (50 x 50 cm² = 2500 cm² = 0.25 m²). Seagrass biomass, using method of Duarte, 1990:

$$B = W \times D \quad (3)$$

Where *B* is biomass of seagrass (grams.m⁻²), *W* is dry weight of segrass individu (grams.ind⁻¹) and *D* is Density of seagrass (individu.m⁻²). Seagrass organic biomass using Loss of Ignition method Helrich, 1990:

$$\text{Ash} = \frac{c - a}{b - a} \times 100\% \quad (4)$$

Where *a* is weight of cup, *b* is weight of cup and dry weight of dry segrass, and *c* is weight of cup and weight of seagrass ash. Dry weight biomass was calculated using Helrich, 1990;

$$\text{D.W.biomass} = \frac{[(b - a) - (c - a)]}{b - a} \times 100\% \quad (5)$$

Where a is weight of cup, b is weight of cup and weight of sample, c is weight of cup and ash. Then seagrass carbon was calculated using Helrich, 1990 equation :

$$\text{Carbon} = \frac{\text{organic}}{1.724} \quad (6)$$

Where 1.724 is the constant for seagrass carbon.

Chlorophyll-a content was measured using a spectrophotometry method, where macerated seagrass leafs leaves was mix in 90 % of acetone then measured using the wavelength of 630 nm, 647 nm and 664 nm. The development of operational algorithm for chlorophyll-a, biomass and carbon estimation using Sentinel-2A satellite data. The field data of seagrass chlorophyll-a, biomass and carbon was used to develop series of polynomial regression to the numeric data of the Sentinel-2A satellite. Using a single Band and Band-Rationing methods of three combination Band-4, Band-3 and Band-2. The operational algorithm was selected from the polynomial regressions that had been made, with the highest value of correlation coefficient (r) or determination coefficient (R^2).

3. RESULTS AND DISCUSSION

Eight species of seagrass had been found in the whole 27 Karimunjawa Islands are *Cymodocea rotundata*, *Thalassia hemprichii*, *Syringodium isoetifolium*, *Hophilla minor*, *Enhalus acoroides*, *Halophila ovalis*, *Cymodocea serrulata* and *Halodule pinifolia*. Only four species were found at Pokemon and Bobby beach, with seagrass density at Pokemon beach (Table 1) and Bobby beach (Table 2).

The current study had found 4 seagrass species at Pokemon and Bobby beach are *Holodule pinifolia*, *Enhalus acoroides*, *Halophila ovalis* and *Thalassia hemprichii*. The lowest seagrass density is 4.44 indv.m⁻² of *Halophila ovalis* and the highest density is 160.44 indv.m⁻² of *Holodule pinifolia* found at Pokemon. The lowest density of 3.55 indv.m⁻² of *Enhalus acoroides* and the highest density is 126.66 indv.m⁻² of *Thalassia hemprichii* at Bobby beach. According to Baeti et al., 2019 variable affecting seagrass photosynthesis is seawater transparency and its length period in the year. While the affecting variables for seagrass density are the seagrass beds nutrient and salinity (Gosari and Haris, 2012). Diversity and density of seagrass species in the coastal ecosystem also play important support for the associate organism such as fish larvae, crustacean, and mollusc (Pratiwi, 2010; Rawung, 2018). The range of seagrass percent cover at Pokemon beach is 44.5 - 57.5 %. The range of seagrass percent cover at Bobby beach was 50 - 70 %. Pragunanti, 2016 mentioned that seagrass percent cover, in general, is affected by seawater quality, pollution level and its substrate type. Which will affect the density, cover and biomas of above ground and below ground (rhizoma and root) and the relationship between

the density towards seagrass biomass of *Thalassia hemprichii* and *Enhalus acoroides* at Lobam island, Seri Kuala Lobam sub-district, Bintan regency coastal area (Prarikeslan et al., 2019). Serrano et al., 2018 stated that the extent of soil organic carbon (C-org) stocks and its accumulation rates in seagrass meadows of *Thalassia hemprichii*, *Enhalus acoroides*, *Halophila stipulacea*, *Thalassodendrum ciliatum* and *Halodule uninervis* in Saudi Arabia was found in the value of 3.4 ± 0.3 kg C-org m⁻² in a one meter thick soil deposits, which had been accumulated at about 6.8 ± 1.7 g C-org m⁻² yr⁻¹ over the last 500 to 2,000 years. For example in extreme conditions as in the Red Sea, that nutrient limitation had become a reducing factor for seagrass growth rates. While high seawater temperature will increasing the substrates' respiration rates, may explain their relative low C-org storage compared to the temperate meadows. Seagrass habitats encompassed as low to moderate levels of sedimentary organic carbon range of 0.20 - 1.44 %. Depending on species and site-specific variability suggesting that some of the seagrass areas at tropical Zanzibar, in particular, are potentially important as carbon sinks (Gullström et al., 2018). According to Andika et al., 2020, chlorophyll-a content of seagrass will differ from one to another species due to its leaf morphological feature. Higher chlorophyll-a synthesis and carbon stock of *T.hemprichii* when compared to *Cymodocea rotundata*. The result of seagrass chlorophyll-a measurement at Pokemon beach was presented in Table 3. The lowest chlorophyll-a content at Pokemon beach was found in *H. pinifolia* as the dominant species is 5.854 mg.ml⁻¹ and the highest was found in *E.acoroides* with 20.819 mg.ml⁻¹. The range of chlorophyll-a content at Bobby beach is 3.485 - 14.133 mg.ml⁻¹ in the dominant species of *Thalassia hemprichii* (Table 4). As stated by Zendrarto et al., 2014 that optimum chlorophyll-a photosynthesis is affected by a neutral seawater pH.

Before the further step of spatial analysis, it is needed to prove the variable correlation of actual field value of chlorophyll-a, biomass and seagrass carbon based on a statistical test. The result of the analysis of variance (ANOVA) test with a multiple regression analysis was presented as in Table 5 that the three main variables had confirmed a significant correlation with the F-count of 96.697 was higher than the F-table of 3.63 and R² value of 0.928.

a. Dependent Variable: Y1 : carbon

b. Predictors (Constant), independent variable X2 : biomass, X1 : chlorophyll-a

After exploration on a series of polynomial regression of the field variables and the Sentinell-2A satellite data (Table 6), the selected algorithm of seagrass Chlorophyll-a = 0.0001(B4)² - 0.3301(B4) + 269.23 based on the highest coefficient of determination (R²) of 0.743 and coefficient of correlation (r) of 0.861, and the root mean square of error (RMSE) of 0.3. The use of a single Band-4 in the algorithm had given the best spatial seagrass area delineation. In which that Band-4 with a wavelength of 0.665 μm had functioned for the chlorophyll-a pigment reflectance absorption. This was also assumed based on the seawater transparency at Pokemon beach during the

Table 1. Seagrass Density at Pokemon Beach

Line	Species	Density (Ind.m ⁻²)	Category
1.	<i>Halodule pinifolia</i>	160.44	Dense
2.	<i>Enhalus acoroides</i>	26.22	Rare
3.	<i>Halophila ovalis</i>	4.44	Very rare

Table 2. Seagrass density at Bobby beach

Line	Species	Density (Ind.m ⁻²)	Category
1.	<i>Thalassia hemprichii</i>	126.66	Dense
2.	<i>Enhalus acoroides</i>	3.55	Very rare

Table 3. Chlorophyll-a at Pokemon Beach with Domination of *H. pinifolia*

Line	Quadrant	Species	Chlorophyll-a (mg.ml ⁻¹)
1.	1	<i>Halodule pinifolia</i>	13.868
	2	<i>Halodule pinifolia</i>	5.854
	3	<i>Enhalus acoroides</i>	11.881
2.	4	<i>Halodule pinifolia</i>	14.394
	5	<i>Halodule pinifolia</i>	9.751
	6	<i>Halodule pinifolia</i>	12.986
3.	7	<i>Halodule pinifolia</i>	12.962
	8	<i>Halodule pinifolia</i>	13.572
	9	<i>Enhalus acoroides</i>	20.819*

Table 4. Chlorophyll-a at Bobby Beach with Domination of *T. hemprichii*

Line	Quadrant	Species	Chlorophyll-a (mg.ml ⁻¹)
1.	1	<i>Thalassia hemprichii</i>	7.095
	2	<i>Thalassia hemprichii</i>	8.673
	3	<i>Thalassia hemprichii</i>	6.240
2.	4	<i>Thalassia hemprichii</i>	12.534
	5	<i>Thalassia hemprichii</i>	14.133*
	6	<i>Thalassia hemprichii</i>	3.485
3.	7	<i>Enhalus acoroides</i>	3.716
	8	<i>Thalassia hemprichii</i>	9.153
	9	<i>Thalassia hemprichii</i>	9.504

Table 5. Analysis of Variance (ANOVA)^a

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	6778.379	2	3389.190	96.697	F-tab : 3.63
Residual	525.743	15	35.050		
Total	7304.122	17			

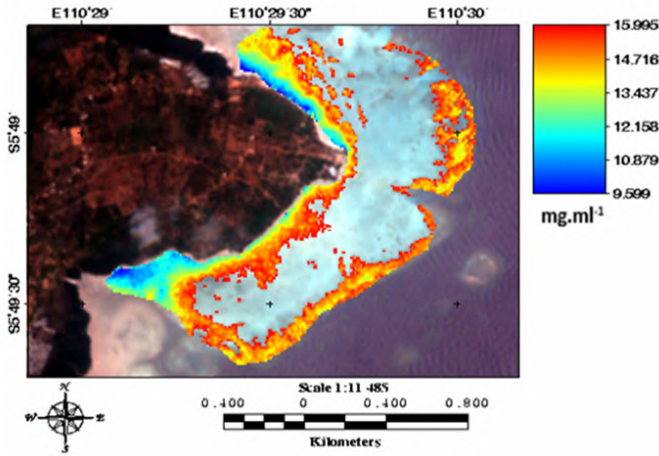


Figure 2. Spatial Distribution and Value of Seagrass Chlorophyll-a Using Algorithm of Sentinel-2A at Pokemon Beach

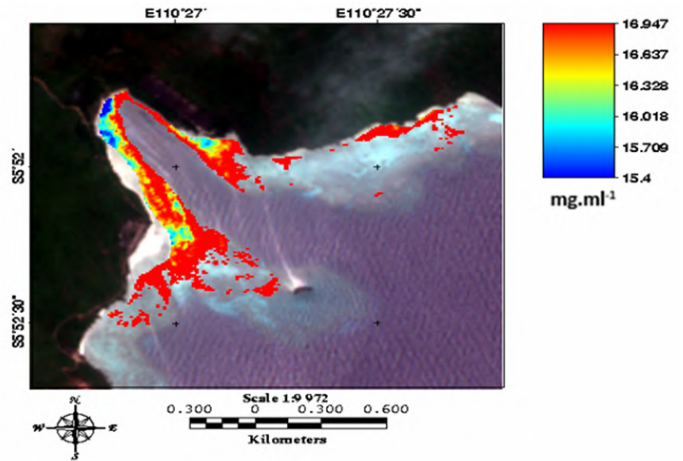


Figure 3. Spatial Distribution and Value of Seagrass Chlorophyll-a of Sentinel-2A Algorithm at Bobby Beach

study was very clear up to the bottom of the seagrass beds. The actual seagrass chlorophyll-a at Pokemon beach ranges from 5.854 - 20.819 mg.ml⁻¹. While the result of the algorithm estimate of seagrass chlorophyll-a using Sentinel-2A for Pokemon beach was in the range of 9.559 – 15.995 mg.ml⁻¹.

Algorithm for seagrass chlorophyll-a = 455.02 (B2/B4)² + 823.72 (B2/B4) + 375.48 give the highest coefficient of determination (R²) is 0.520 and coefficient of correlation (r) is 0.721 and RMSE of 0.189 (Table 7). The actual seagrass chlorophyll-a at Bobby beach with the domination of *T. hemprichii* is in the range of 3.485 - 14.133 mg.ml⁻¹. Using the algorithm of Sentinel-2A, the estimated seagrass chlorophyll-a at Bobby beach is in the range of 15.4 – 16.947 mg.ml⁻¹. Spatial distribution and value of chlorophyll-a at Bobby beach as in Figure 3. The different result of the estimated chlorophyll-a value was assumed as the high seawater turbidity in Bobby beach during the study. The ideal of coastal seawater transparency can be found such as in Melalayang beach north Celebes (Rosang and Wagey, 2016; Sakey et al., 2015).

Results of the field measurement found the lowest seagrass biomass at Pokemon beach was 75.91 g.dryweight.m⁻² in *H.piniifolia* and the highest was 236.93 g.dryweight.m⁻² in *E.acoroides*. Algorithm had been found for seagrass Biomass = -0.004(B4)² + 15.241(B4) + 14264 based on the highest coefficient of determination (R²) is 0.544 and coefficient of correlation (r) is 0.738 (Table 8), with RMSE of 0.33. Spatial distribution of seagrass biomass at Pokemon beach using algorithm of Sentinel-2A was in the range of 60 – 220 g.dryweight.m⁻² as presented in Figure 4, Zulfikar.A et al., 2016 stated that *E.acoroides* has higher biomass in its bigger leaf morphological size compared to other seagrass species.

Results of field measurement found that the actual range of seagrass biomass at Bobby beach is 75.91 - 264.48 g.dryweight.m⁻². Selected algorithm for seagrass biomass = -14699

(B3/B2)² + 28395(B3/B2) – 13537 with the highest R² of 0.2986 and the highest correlation coefficient (r) of 0.545 as in Table 9 with RMSE of 0.34. Spatial distribution and the range of seagrass biomass based on the selected algorithm using Sentinel-2A was in the range of 50 - 168 g.dryweight.m⁻² (Figure 5). Linear model relationship between *in situ* above-ground biomass and seagrass percentage cover per seagrass species was estimate biomass using high resolution Quickbird satellite data. This resulted in predicting biomass of *Cymodocea serrulata* and *Syringodium isoetifolium* with a predicted error of about 3g.dryweight.m⁻² (Lyons et al., 2015). Runtuboi et al., 2018 mention that seagrass biomass will affect the carbon stock.

Results of field measurement found that the range of field seagrass carbon at Pokemon beach is 12.44 - 77.30 gCm⁻². The selected operational algorithm for seagrass carbon at Pokemon beach is Carbon = -17.529(B2/B3)² + 143.82(B2/B3) – 5.3362 with R² : 0.7741 and coefficient of correlation (r) : 0.879 and RMSE : 0.31 (Table 11). The range of seagrass carbon at Pokemon beach using the algorithm of Sentinel-2A is 45 – 64 gC.m⁻². The important use of Band-2 which has a short wavelength of 0.4 μm is concerned with its capability to penetrate into the coastal seawater column. While the use of Band-3 and Band-4 is its capability for chlorophyll-a reflectance and absorption that functions known as vegetation index. The result of seagrass carbon value and spatial distribution was presented in Figure 6.

The range of field seagrass carbon at Bobby beach is 12.44 - 77.30 gCm⁻². Algorithm selected as in Table 11, carbon = -0.001(B3/B4)² + 0.209(B3/B4) - 10.203, with highest R² : 0.472 and (r) : 0.687 and RMSE : 0.34. Spatial distribution of seagrass carbon at Bobby beach as in Figure 7. The result of seagrass carbon estimation using the algorithm had found the range of 7 – 32 gCm⁻². The lower seagrass carbon estimated result using the algorithm was supposed caused by the high turbidity at Bobby beach during the study.

Table 6. Algorithm of Seagrass Chlorophyll-a at Pokemon Beach Using Sentinel-2A

Bands	Algorithms	R ²	r
B4	Chlorophyll-a = 0.0001(B4) ² - 0.3301(B4) + 269.23	0.743	0.861*
B2	Chlorophyll-a = 0.000000005(B2) ² - 0.2962(B2) + 291.79	0.596	0.772
B3	Chlorophyll-a = 0.0017(B3) ² - 6.9646(B3) + 7093.6	0.277	0.526
B2/B3	Chlorophyll-a = 290.32(B2/B3) ² - 553.26(B2/B3) + 274.72	0.628	0.792
B3/B2	Chlorophyll-a = 386.65(B3/B2) ² - 804.4(B3/B2) + 429.44	0.638	0.798
B4/B3	Chlorophyll-a = -36.308(B4/B3) ² - 140.41(B4/B3) + 83.912	0.694	0.835
B3/B4	Chlorophyll-a = -36.308(B3/B4) ² - 140.41(B3/B4) + 83.912	0.701	0.837
B4/B2	Chlorophyll-a = 1641.5(B4/B2) ² - 2978.8(B4/B2) + 1362.7	0.158	0.397
B2/B4	Chlorophyll-a = 1194.4(B2/B4) ² - 2639.2(B2/B4) + 1469	0.182	0.426

Table 7. Algorithm of Seagrass Chlorophyll-a at Bobby Beach Using Sentinel-2A

Bands	Algorithms	R ²	r
B4	Chlorophyll-a = 0.0132(B4) ² - 68.217 (B4) + 90904	0.225	0.504
B2	Chlorophyll-a = - 0.2634(B2) ² + 1092.4 (B2) - 0.06	0.501	0.707
B3	Chlorophyll-a = 0.000000005(B3) ² + 0.0787(B3) - 276	0.076	0.275
B2/B3	Chlorophyll-a = 17.241(B2/B3) ² - 21.739(B2/B3) + 12.601	0.034	0.184
B3/B2	Chlorophyll-a = 17.241(B2/B3) ² - 21.739(B2/B3) + 12,601	0.035	0.187
B4/B3	Chlorophyll-a = - 50.42(B4/B3) ² + 82.16(B4/B3) - 23.001	0.194	0.440
B3/B4	Chlorophyll-a = - 45.694(B3/B4) ² + 112.83(B3/B4) - 58.501	0.189	0.434
B4/B2	Chlorophyll-a = 425.73(B4/B2) ² - 94.46(B4/B2) + 522.56	0.511	0.714
B2/B4	Chlorophyll-a = 455.02(B2/B4) ² - 823.72(B2/B4) + 375.48	0.520	0.721*

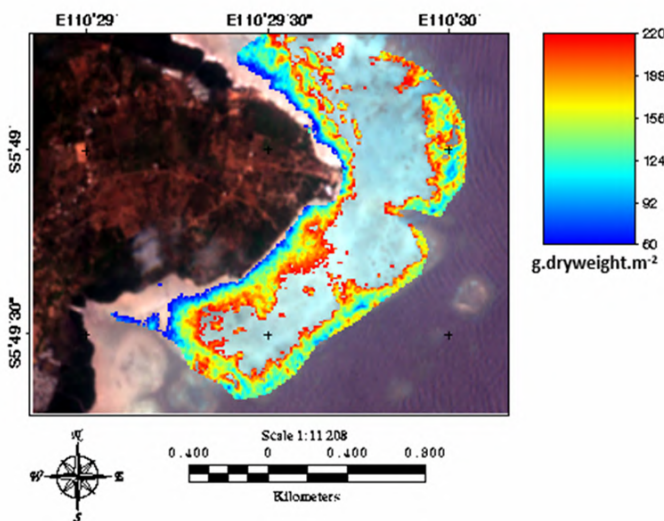


Figure 4. Spatial Distribution and Value of Seagrass Biomass Using Sentinel-2A at Pokemon Beach

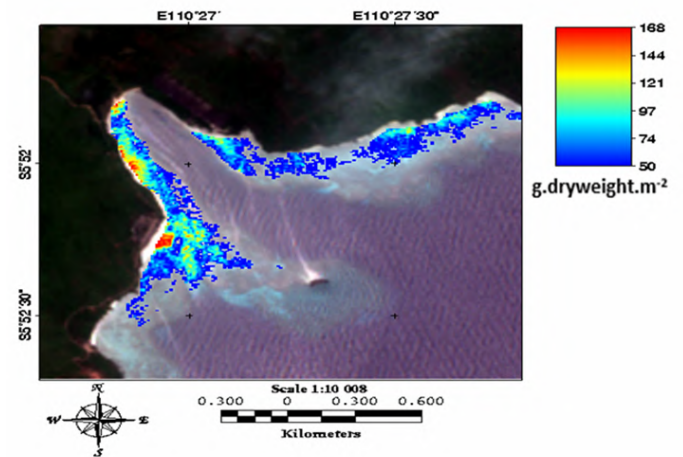


Figure 5. Spatial Distribution and Value of Seagrass Biomass Using Sentinel-2A at Bobby Beach

Using the similar approach and method, an earlier study (Hartoko et al., 2015), using the combination of Band-3 and Band-2 GeoEye satellite data had developed for mangrove chlorophyll-a, biomass and carbon spatial algorithm. The use of such data had been able to be used up to the level of mangrove species. This was since the high resolution data with a resolution of 0.6 x 0.6 m of GeoEye or 1 x 1 m of Ikonos

Table 8. Algorithm of Seagrass Biomass at Pokemon Beach Using Sentinel-2A

Bands	Algorithms	R ²	r
B4	Biomass = - 0.004(B4) ² + 15.241 (B4) - 14264	0.544	0.738*
B2	Biomass = 0.00000005(B2) ² - 0.0925(B2) + 51.464	0.099	0.314
B3	Biomass = 0.0289(B3) ² - 117.4(B3) + 118737	0.184	0.428
B2/B3	Biomass = 1541.9(B2/B3) ² - 2959.1(B2/B3) + 1558.2	0.072	0.268
B3/B2	Biomass = 2122.9(B3/B2) ² - 4385.9(B3/B2) + 2403.2	0.075	0.274
B4/B3	Biomass = -10206(B4/B3) ² + 19251(B4/B3) - 8893.5	0.331	0.578
B3/B4	Biomass = -10206(B3/B4) ² + 19251 (B3/B4) - 8893.5	0.344	0.587
B4/B2	Biomass = 5137.7(B4/B2) ² - 8742.8(B4/B2) + 3851.5	0.101	0.318
B2/B4	Biomass = 4282(B2/B4) ² - 9938.6(B2/B4) + 5900.4	0.103	0.320

Table 9. Algorithm of Seagrass Biomass at Bobby Beach Using Sentinel-2A

Bands	Algorithms	R ²	r
B4	Biomass = 0,005 (B4) ² + 0,1101 (B4) - 0,103	0.0071	0.083
B2	Biomass = 0,0004 (B2) ² - 1,596 (B2) + 1875,4	0.0165	0.246
B3	Biomass = -0,0011 (B3) ² + 4,5475 (B3) - 4485,5	0.093	0.304
B2/B3	Biomass = -12738 (B2/B3) ² + 26505 (B2/B3) - 13609	0.2923	0.541
B3/B2	Biomass = -14699 (B3/B2) ² + 28395 (B3/B2) - 13537	0.2986	0.545
B4/B3	Biomass = -3561,7 (B4/B3) ² + 7543,7 (B4/B3) + 3828,8	0.1275	0.356
B3/B4	Biomass = -4342,1 (B3/B4) ² + 8280,1 (B3/B4) - 3782,1	0.1462	0.382
B4/B2	Biomass = -7558,8 (B4/B2) ² + 16310 (B4/B2) + 8581,7	0.2541	0.503
B2/B4	Biomass = -8282,5 (B2/B4) ² + 15468 (B2/B4) - 7016,5	0.2542	0.503

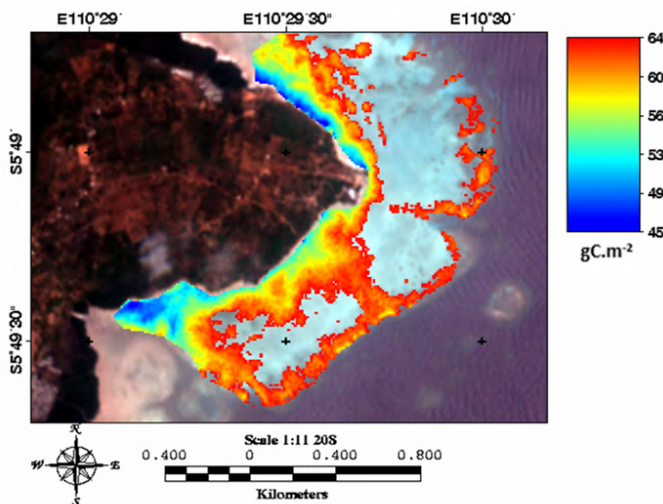


Figure 6. Spatial Distribution and Value of Seagrass Carbon Using Sentinel-2A at Pokemon Beach

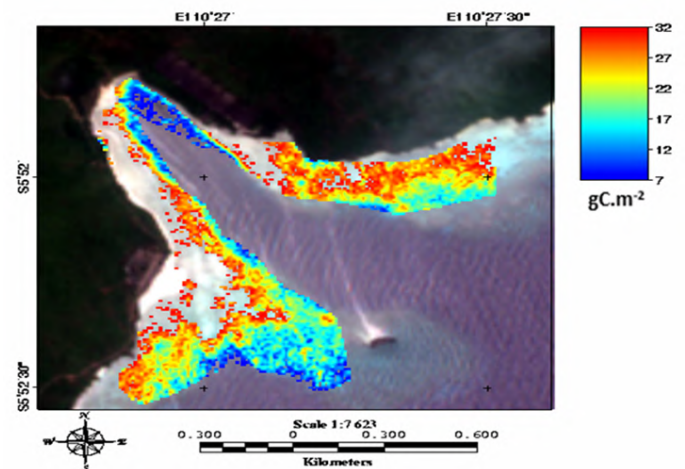


Figure 7. Spatial Distribution and Value of Seagrass Carbon at Bobby Beach

satellite data had been significantly possible to represent the mangrove canopy. The use of relevant and correct satellite data bands will increase the result of spatial accuracy (Hartoko et al., 2019). The series of algorithms that had been developed as above would be new and efficient and controllable spatial accuracy for rapid assessment by means of spatial measurement. As

Table 10. Algorithm of Seagrass Carbon Using Sentinel-2A at Pokemon Beach

Bands	Algorithms	R ²	r
B4	Carbon = 0.0003(B4) ² - 1.1968(B4) + 1147.9	0.3902	0.624
B2	Carbon = - 0.0002(B2) ² + 0.8913(B2) - 887.8	0.7741	0.879*
B3	Carbon = 0.0021(B3) ² - 87447(B3) + 9033.1	0.1682	0.409
B2/B3	Carbon = -17.529(B2/B3) ² + 143.82(B2/B3) - 5.3362	0.6147	0.785
B3/B2	Carbon = 39.184(B3/B2) ² - 190.28(B3/B2) + 272.21	0.6144	0.783
B4/B3	Carbon = 1376.4(B4/B3) ² - 2391.8(B4/B3) + 1156.8	0.4635	0.680
B3/B4	Carbon = 944.36(B3/B4) ² - 2177.4(B3/B4) + 1372.7	0.4503	0.670
B4/B2	Carbon = - 1271.6(B4/B2) ² + 2177.4(B4/B2) - 807.63	0.2445	0.493
B2/B4	Carbon = - 833.02(B2/B4) ² + 1946.9(B2/B4) - 1012.9	0.2385	0.487

Table 11. Algorithm of Seagrass Carbon at Bobby Beach Using Sentinel-2A

Bands	Algorithms	R ²	r
B4	Carbon = 0.005(B4) ² + 0.0391(B4) + 68.635	0.1161	0.340
B2	Carbon = - 0.00000005(B2) ² - 0.3021(B2) + 419.47	0.0445	0.209
B3	Carbon = - 0.0002(B3) ² + 0,8626(B3) - 783,08	0,3038	0,550
B2/B3	Carbon = - 948,88(B2/B3) ² + 1934.4(B2/B3) - 881.64	0.3067	0.553
B3/B2	Carbon = - 140,6(B3/B2) ² + 2246.6(B3/B2) - 1002	0.3107	0.556
B4/B3	Carbon = 0.001(B4/B3) ² - 0.217(B4/B3) + 12.648	0.465	0.681
B3/B4	Carbon = - 0.001(B3/B4) ² + 0.209(B3/B4) - 10.203	0.472	0.687*
B4/B2	Carbon = - 373.05(B4/B2) ² + 777.37(B4/B2) - 300.66	0.1023	0.319
B2/B4	Carbon = - 431.55(B2/B4) ² + 837.57(B2/B4) - 302.39	0.1003	0.316

stated by [Vieira et al., 2018](#) had established an efficient tool for biomass and density to describe space occupation by seagrasses was successfully used to evaluate their meadows as an ecological indicator for the healthiness of coastal ecosystems.

4. CONCLUSIONS

The novelties through the study had reached the new paradigm on the algorithm development of the field seagrass chlorophyll-a content and the use of single Band-4 (0.665 μm) as the specific band for chlorophyll-a pigment reflectance. The algorithm using Band-4 and Band-2 (0.490 μm wavelength) rationing method also gives a good seagrass chlorophyll-a content estimation. Especially for seagrass beds with higher turbidity, since the use of Band-2 with short wavelength can be able for shallow water column penetration. The algorithm development was using field biomass and carbon content with the LOI method (which gives a more accurate carbon measurement), also a combination of Band-3 (0.560 μm) and Band-2 (0.490 μm wavelength). Both data bands, with short wavelength and have the capability of shallow water column penetration had given significant representation for seagrass biomass and carbon. Then, the achievement of algorithm development can be applied for seagrass chlorophyll-a, biomass and carbon estimation with effective, accurate repeatable or continuous monitoring programs. The need of these 'blue-carbon' measurements for spatial database representing tropical seagrass data, in re-

gard to the need for green issues database at the global level is inevitable.

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