

Biomass and Carbon Mapping in the Seagrass Beds at Blebak Beach, Jepara, Indonesia

Royhan Maulana, Kuku Prakoso*, Haeruddin and Arif Rahman

ABSTRACT

Seagrass is one of the important ecosystems in coastal areas, alongside mangrove and coral reefs. It plays an important ecological role, particularly in carbon storage. This study aimed to identify the seagrasses species, their distribution, biomass, and carbon stock at Blebak Beach, Jepara, Indonesia. The research utilized a survey method with purposive sampling based on seagrass distribution and the surrounding ecosystems. Biomass and carbon stock sampling focused on individuals with dominant density and coverage values. Biomass and carbon estimates were calculated using the Loss on Ignition (LoI) method, while seagrass distribution was mapped using the supervised classification method. Biomass and carbon stock distribution were analyzed using Inverse Distance Weighted (IDW) interpolation. The results identified four seagrass species: *Enhalus acoroides*, *Thalassia hemprichii*, *Oceana serullata*, and *Cymodocea rotundata*, covering a total area of 0.45165 ha with a patchy distribution pattern. *T. hemprichii* exhibited the highest density, at 85,143 stands·m⁻², with a total seagrass coverage of 23.91%. The seagrass biomass (dry weight) ranged from 220.89 to 1,320.03 g·m⁻², with belowground biomass contributing approximately 60% of the total biomass. The estimated total carbon stock ranged from 110.96 to 691.29 g·m⁻², with belowground carbon accounting for 61% of the total carbon stock.

Keywords: Biomass, Blebak Beach, Carbon, Seagrass

INTRODUCTION

Seagrass beds are extensive underwater ecosystems that interact with both living and non-living components to form a vital part of coastal ecosystems, alongside mangroves and coral reefs. These ecosystems play an essential role in supporting biodiversity, regulating the environment, and contributing to human well-being. Seagrasses are particularly significant for their ability to absorb and store carbon, making them important contributors to carbon sequestration. Seagrass plays an important role in coastal biodiversity as feeding and breeding grounds for a wide variety of coastal and marine organisms, coastal sediment stabilization, and for mitigating climate change (Mishra *et al.*, 2025). Through photosynthesis, seagrasses absorb carbon dioxide from the water and convert it into organic

matter, which is subsequently stored in their biomass and surrounding sediments. These stored carbon, known as "blue carbon" is crucial for mitigating the impacts of climate change (Suwandhahannadi *et al.*, 2024).

Blebak Beach, located in Jepara, hosts ecologically important seagrass beds that play a key role in maintaining local biodiversity and supporting coastal ecosystems. However, this ecosystem faces threats from rising tourist activity and the impacts of climate change, which could lead to the release of stored carbon from sediments, further exacerbating global warming. Safeguarding the seagrass ecosystem at Blebak Beach is critical to prevent such carbon emissions. Key measures include mapping the distribution of seagrass beds and assessing their biomass and carbon stock.

Currently, most blue carbon studies in Indonesia focus on mangroves, with limited data available on seagrass carbon stocks and distribution. Addressing this knowledge gap provides an opportunity to improve the understanding of seagrass carbon storage in Indonesia and inform better coastal management practices (Stankovic *et al.*, 2023a). Therefore, this research aims to identify the seagrasses species present at Blebak Beach, map their distribution, and evaluate the biomass and carbon stock within the seagrass beds in Jepara, Indonesia.

The study area covered coordinates ranging from 110°40'7.321"E, 6°30'6.053"S to 110°40'24.132"E, 6°30'5.518"S. Data processing was conducted at the Laboratory of the Faculty of Fisheries and Marine Science, Diponegoro University. In addition to the field data, 2023 satellite imagery from Google Earth was utilized to enhance the analysis. The purposive sampling method was employed to target specific seagrass conditions based on field observation. A map of the research location is presented in Figure 1.

Field data collection

Field data collection focused on seagrass species, coverage, density, water quality and individual seagrass samples. Observations were conducted using the method described by McKenzie and Yoshida (2021) utilizing tools such as line

MATERIALS AND METHODS

Field data on seagrass conditions were collected, including individual seagrass samples, from Blebak Beach, Jepara, Central Java, Indonesia.

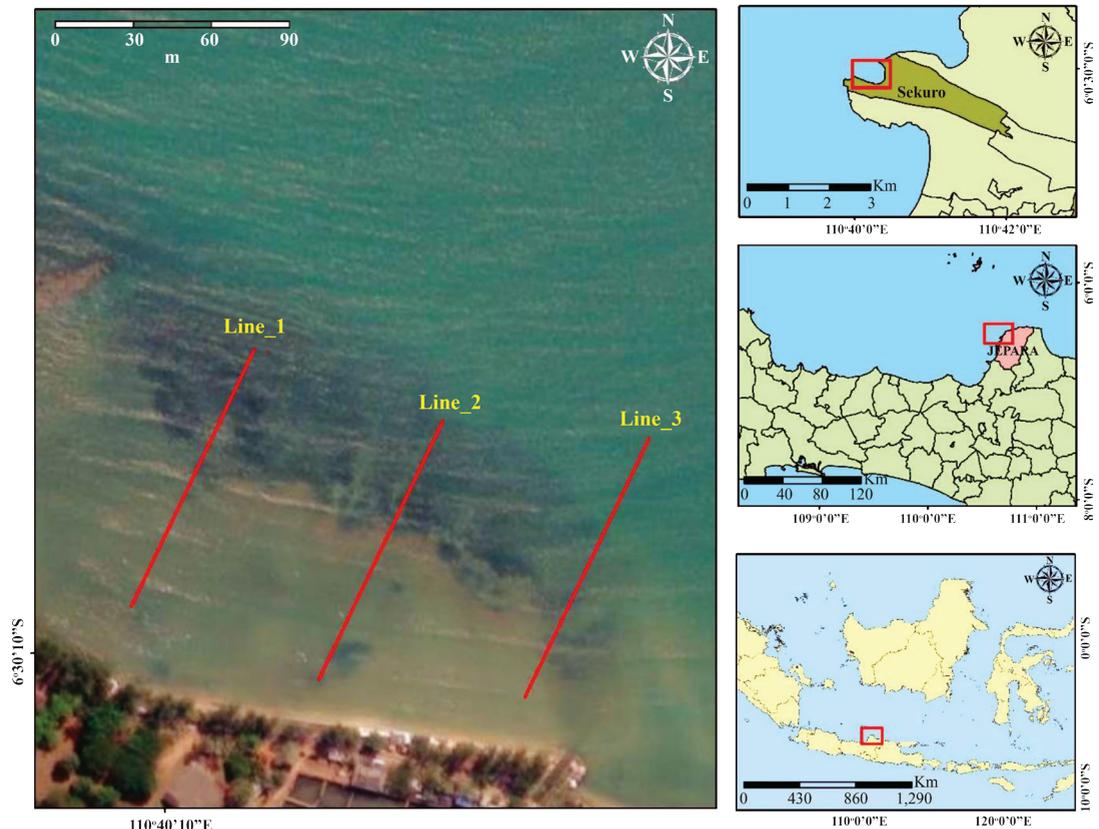


Figure 1. Research location map showing three sampling lines: Line 1 is located near the docking area of local vessels, line 2 is in a tourism area, and line 3 is located near the discharge outlet of shrimp farms.

transects, quadrat transects, GPS devices, snorkels, and sand shovels. In the field, three transect lines were established, with the spacing adjusted according to local seagrass conditions. The extent of the transect lines was influenced by the distribution of seagrasses, which can form either extensive meadows or distinct patches, a phenomenon known as patchiness. In oceanic environments, seagrass beds are typically classified as continuous or patchy meadows (Abadie *et al.*, 2019). The line transects extended 100 m perpendicular to the shoreline, starting at the first point where seagrasses were observed. To assess seagrass density, 50 cm × 50 cm quadrat transects (Figure 2) were placed along the transect lines. Additionally, individual seagrass samples were collected using sand shovels and stored in zip-top plastic bags for further laboratory analysis.

Seagrass coverage and density analysis

Field observation data were analyzed to

determine the percentage of seagrass coverage and the density of seagrass species. The percentage of seagrass coverage was calculated according to the seagrass monitoring guidelines provided by CoreMap-LIPI (2014).

$$\text{Coverage (\%)} = \frac{\sum \text{Total cover of all transects}}{\sum \text{Quadrat Transect}}$$

The density of seagrass species was also calculated based on the CoreMap-LIPI (2014) guidelines using the formula:

$$\text{Density (ind}\cdot\text{m}^{-2}) = N_i / A$$

where N_i is the number of individuals of species i (ind), A is the total area sampled (m^2). The calculated density values were then compared with the criteria for seagrass species density defined by Braun-Blanquet (1965) to categorize the observed species densities (Table 1).

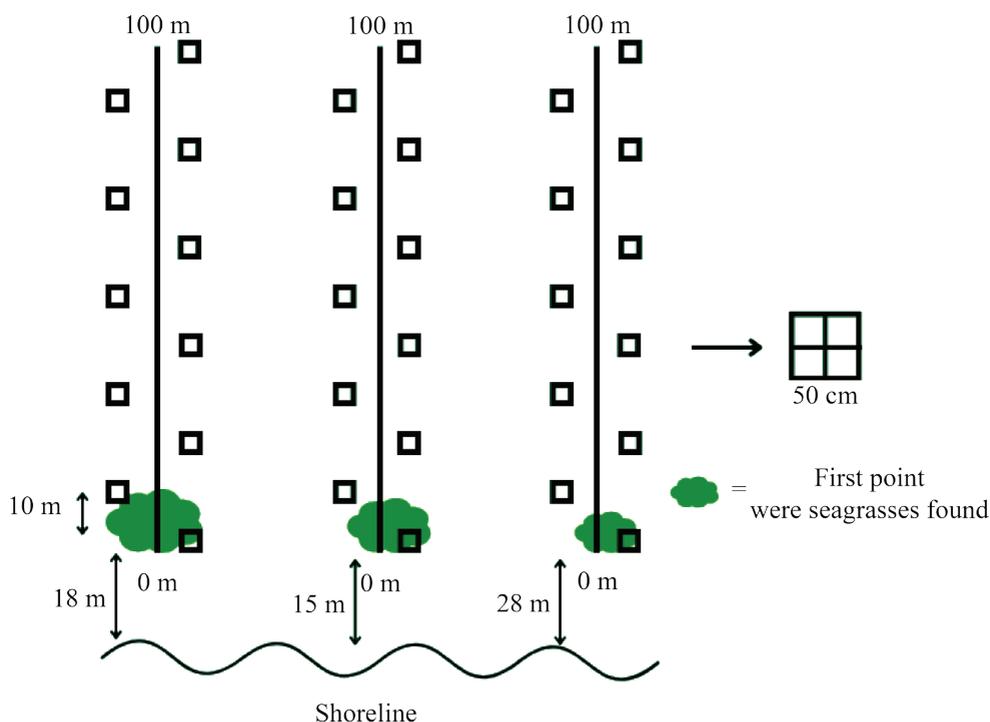


Figure 2. Line transects stretch and quadrat transects size in the field.

Table 1. Criteria for seagrass species density according to Braun-Blanquet (1965).

Scale	Density (ind·m ⁻²)	Seagrass condition
5	>175	Very dense
4	125–175	Dense
3	75–125	Rather dense
2	25–75	Rare
1	<25	Very rare

Biomass and carbon analysis

The nutrient content and biomass weight of seagrasses were calculated using the following formula (Duarte, 1990):

$$B = W \times D$$

where B is the biomass weight (g DW·m⁻²), W is the dry weight (g DW·ind⁻¹), and D is the seagrass density (ind·m⁻²).

The carbon content was determined using the Loss on Ignition (LOI) method, also known as the ignition method. Brenner *et al.* (2024) described this method, which involves placing seagrass samples in a crucible and heating them in a furnace at 550 °C to remove organic matter. This combustion process, lasting four hours, yields an ash percent value that is converted into organic carbon content.

The LoI method produces the following calculation as proposed by Helrich (1990):

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

where a is the weight of the empty porcelain crucible, b is the weight of the crucible containing the dry seagrass, and c is the weight of the crucible with seagrass ash after combustion. The final dry weight of seagrass biomass (LoI) is calculated as:

$$\text{Biomass (dry weight)} = [(b-a)-(c-a)] / (b-a) \times 100\%$$

The organic carbon content of seagrass is determined using the formula:

$$\text{Carbon content} = \text{Organic matter} / 1,724$$

The percentage of Above-Ground Carbon (AGC) and Below-Ground Carbon (BGC) are calculated as follows:

$$\text{Percentage of AGC or BGC} = (\text{Content of AGC or BGC} / \text{Total Carbon Content}) \times 100\%$$

Finally, the organic carbon stock value is calculated using the formula provided by Barrón *et al.* (2004):

$$\text{Stock carbon} = (\text{Biomass} / 100) \times \text{Percentage of Carbon.}$$

Imagery satellite data processing and mapping

Spatial data were sourced from Google Earth Imagery, which provides a resolution of 1 m and includes three bands: Red, Green, and Blue. Spatial data processing was performed to determine the distribution of seagrass biomass and carbon using a combination of Band 3 (Red) and Band 2 (Green).

Seagrass mapping was conducted using a supervised classification method. The carbon stock values derived from the carbon analysis were processed and overlaid onto the classified seagrass images using Inverse Distance Weighting (IDW) interpolation. This method enabled the visualization and quantification of biomass and carbon distribution in the seagrass habitat.

RESULTS

Seagrass distribution, coverage, and density

Physical characteristics of Blebak Beach

Blebak Beach is characterized by a white sandy shoreline and shallow waters. Coral formations are present at a depth of approximately 2 metres, while mangroves are located on the western side of the beach. The water quality parameters of Blebak Beach are presented in Table 2.

Field observations showed the presence of seagrasses at Blebak Beach. The seagrasses were distributed in isolated patches, separated from the main areas of coverage, forming patchy meadows. The spatial distribution of seagrasses at Blebak Beach is illustrated in Figure 3.

Table 2. Water quality parameters of Blebak Beach.

Parameter	Transect 1	Transect 2	Transect 3
Temperature (°C)	29	33.3	32.7
Total Suspended Solid (mg·L ⁻¹)	0.02	0.03	0.04
pH	8.1	8.1	8.0
Salinity (ppt)	29	30	30

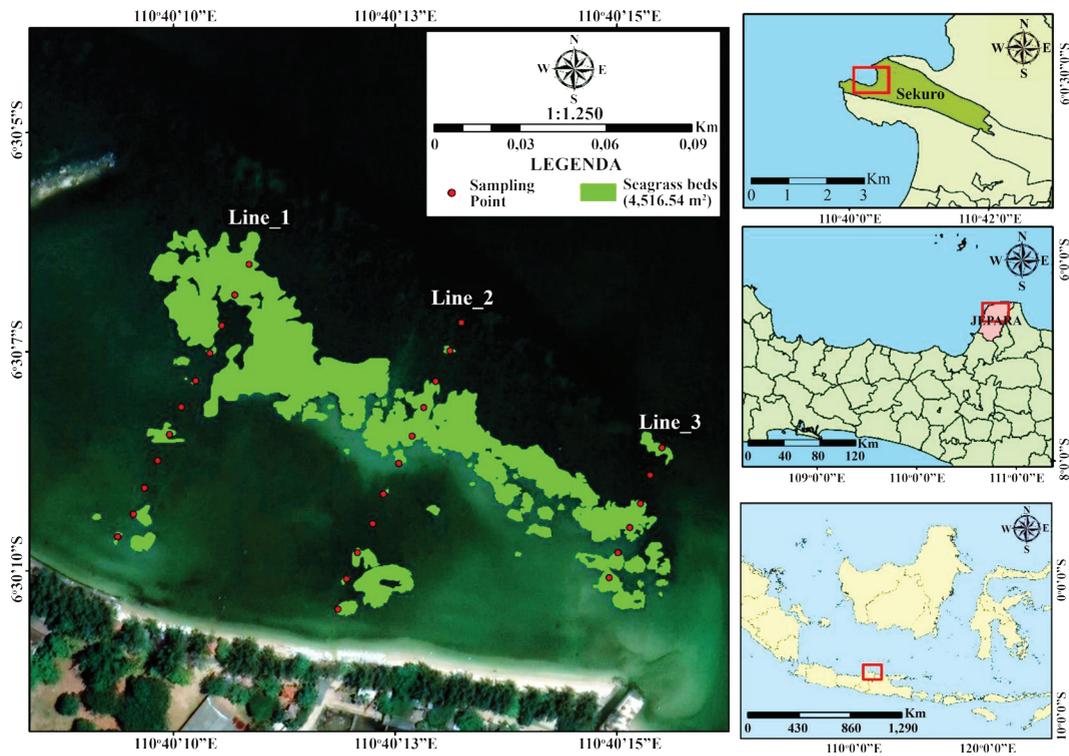


Figure 3. Seagrass distribution in Blebak Beach. Green colour in the legend indicates seagrass beds and red dots in the legend indicates sampling point.

There were four species of seagrasses observed at Blebak Beach: *E. acoroides*, *T. hemprichii*, *O. serullata*, and *C. rotundata*. These species were spread across an area of 4,516.54 m² (0.45 ha), with a sand substrate and coral rubble. Their distributions varied across the transects (Figure 4).

The distribution of seagrass at Blebak Beach shows that the largest number of stands was found in Transect 2, with a total of 686 stands comprising four seagrass species (Figure 4). This was followed by Transect 1, with 476 stands of four seagrass species, and Transect 3, which recored 346 stands of three seagrass species. In Transect 1, *T. hemprichii* had the highest number of individuals, totaling 247, while *C. rotundata* was the least abundant species, with only 53 individuals.

In comparison, Transect 2 exhibited a higher number of *C. rotundata* stands, totaling 232 individuals, whereas *E. acoroides* was the least abundant species, with 119 individuals. In Transect 3, *T. hemprichii* was again the most prevalent species, with a total of 178 individuals, while *O. serullata* was the least abundant, with 87 individuals.

The density of seagrass species at Blebak

Beach, categorized into the four species observed, showed variation. The lowest density was observed for *E. acoroides* at 27 ind·m², followed by *O. serullata* at 50 ind·m², *C. rotundata* at 53 ind·m², and the highest density was found in *T. hemprichii* at 85 ind·m². The total seagrass density across the study area was 215 ind·m².

Seagrass coverage percentages also varied according to species density. The lowest coverage was recorded for *E. acoroides* at 3.81%, followed by *C. rotundata* at 4.26%, *O. serullata* at 4.78%, and the highest percentage was observed for *T. hemprichii* at 11.06%. The overall seagrass coverage percentage at Blebak Beach was 23.91%.

The distribution of species and their coverage percentages revealed that *T. hemprichii* dominated Transects 1 and 3, while *C. rotundata* was predominant species in Transect 2. Transects 1 and 2 contained all four species of seagrass, whereas Transect 3 did not include *E. acoroides*. It is important to note that seagrass density and coverage values are not always directly correlated, as they can be influenced by various field conditions (Sugianti and Mujiyanto, 2020). These values are detailed in Table 3.

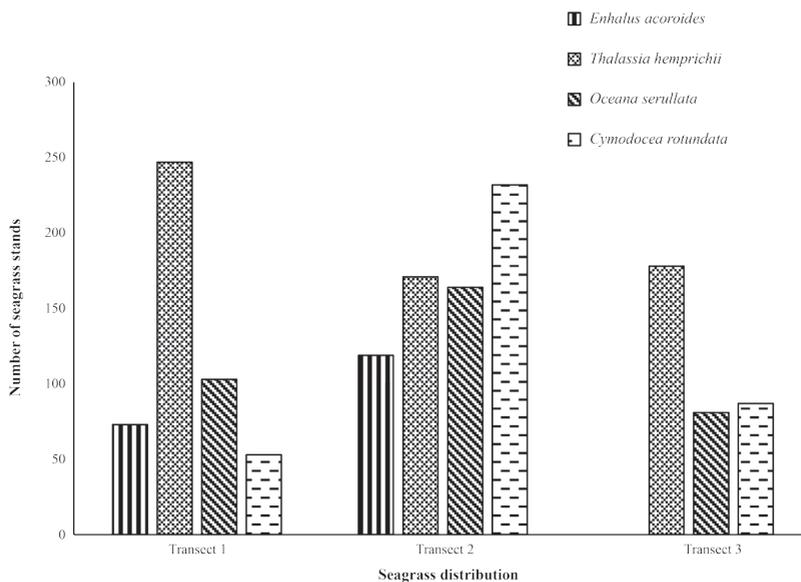


Figure 4. Bar chart representing seagrass distribution across three transects at Blebak Beach.

The highest seagrass coverage was recorded in Transect 2, with an average value of 24.49%, followed by Transect 3, also with an average value of 24.49%. The lowest coverage was observed in Transect 1, with an average value of 23.01% (Figure 5).

Seagrass biomass

Seagrass biomass measurements, based on dry weight, showed that the average aboveground

biomass was 221.01 g·m⁻², while the average belowground biomass was 332.98 g·m⁻². Belowground biomass values ranged from 55.24 to 967 g·m⁻², with the lowest value recorded at Transect 2, at the 30 m point, and the highest value at Transect 3, at the 0 m point. In contrast, aboveground biomass values exhibited a narrower range, spanning from 135.26 to 352.85 g·m⁻². The lowest aboveground biomass was observed at Transect 2, at the 50 m point, while the highest value was recorded at Transect 3, at the 0 m point. The biomass weight ratio between

Table 3. Density and coverage of seagrass in Blebak Beach.

Species of Seagrass	Density (ind·m ⁻²)	Coverage (%)
<i>Enhalus acoroides</i>	27	3.81
<i>Thalassia hemprichii</i>	85	11.06
<i>Oceana serullata</i>	50	4.78
<i>Cymodocea rotundata</i>	53	4.26
Sum	215	23.91

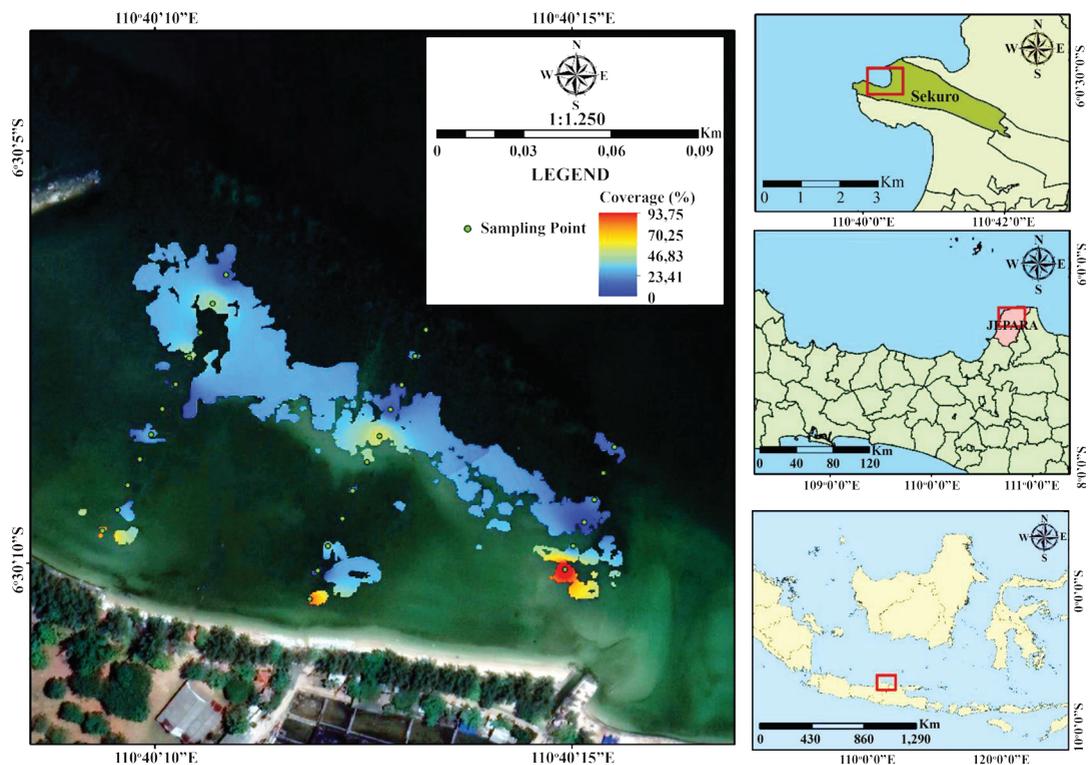


Figure 5. Seagrass coverage distribution in Blebak Beach.

belowground and aboveground components was found to be 60% to 40%. These results are illustrated in Figure 6.

Carbon stock of seagrass

The assessment of seagrass carbon stock at Blebak Beach revealed that the belowground carbon had an average value of 169.42 g C·m⁻² with a range spanning from 27.36 to 532.82 g C·m⁻². The lowest belowground carbon value was recorded at Transect 3, 30 m, while the highest was observed at Transect 3, 0 m. In comparison, aboveground carbon exhibited an average value of 108.22 g C·m⁻², ranging from 65.55 to 158.47 g C·m⁻². The lowest aboveground carbon value occurred at Transect 2, 50 m, whereas the highest value was also found at Transect 3, 0 m. This analysis highlights a distinct difference in the distribution of carbon between

aboveground and belowground components. Belowground carbon constituted 61% of the total stock, while aboveground carbon accounted for 39%. These findings are summarized in the carbon distribution map presented in Figure 7.

DISCUSSION

Seagrass distribution, coverage, and density

The seagrass at Blebak Beach comprised four species, namely *E. acoroides*, *T. hemprichii*, *O. serullata*, and *C. rotundata*. These species are considered major seagrasses, characterized by larger and broader leaves as well as extensive root and rhizome systems, as noted in tropical regions (Johannessen, 2022). The distribution of seagrass beds at Blebak Beach is predominantly patchy,

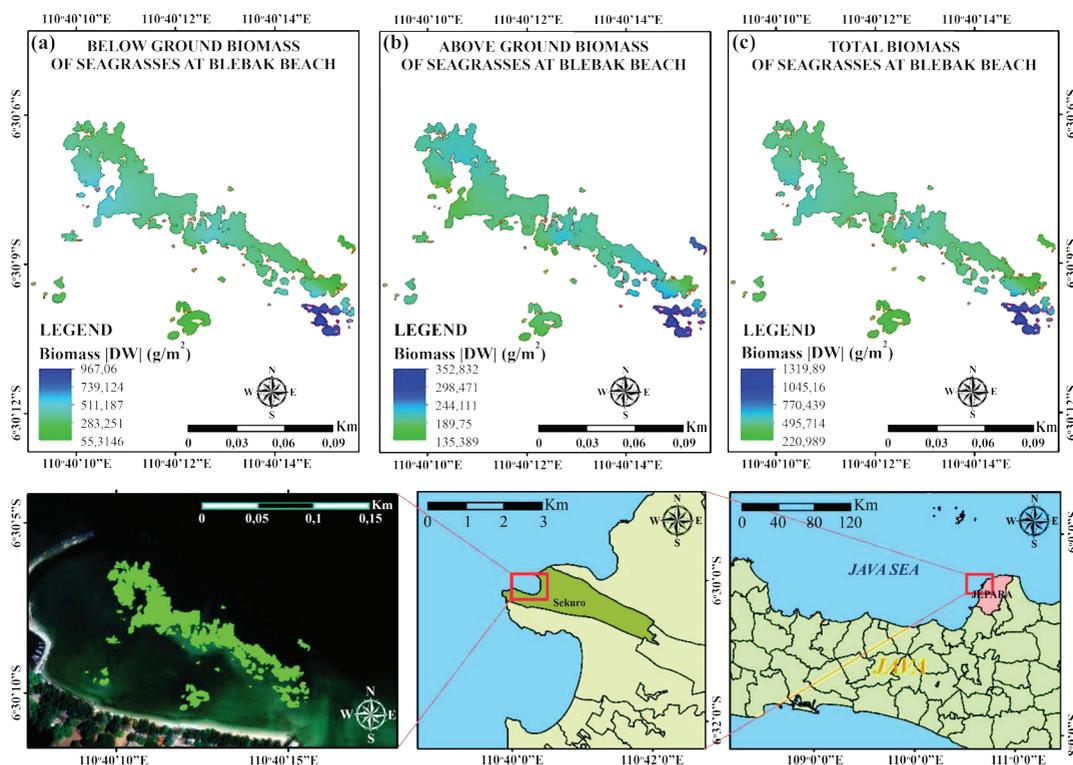


Figure 6. Distribution of seagrass biomass at Blebak Beach: (a) represents the distribution of belowground biomass, (b) shows the distribution of aboveground biomass, and (c) illustrates the distribution of total biomass. In the legend, dark blue indicates the highest biomass values, while green represents the lowest.

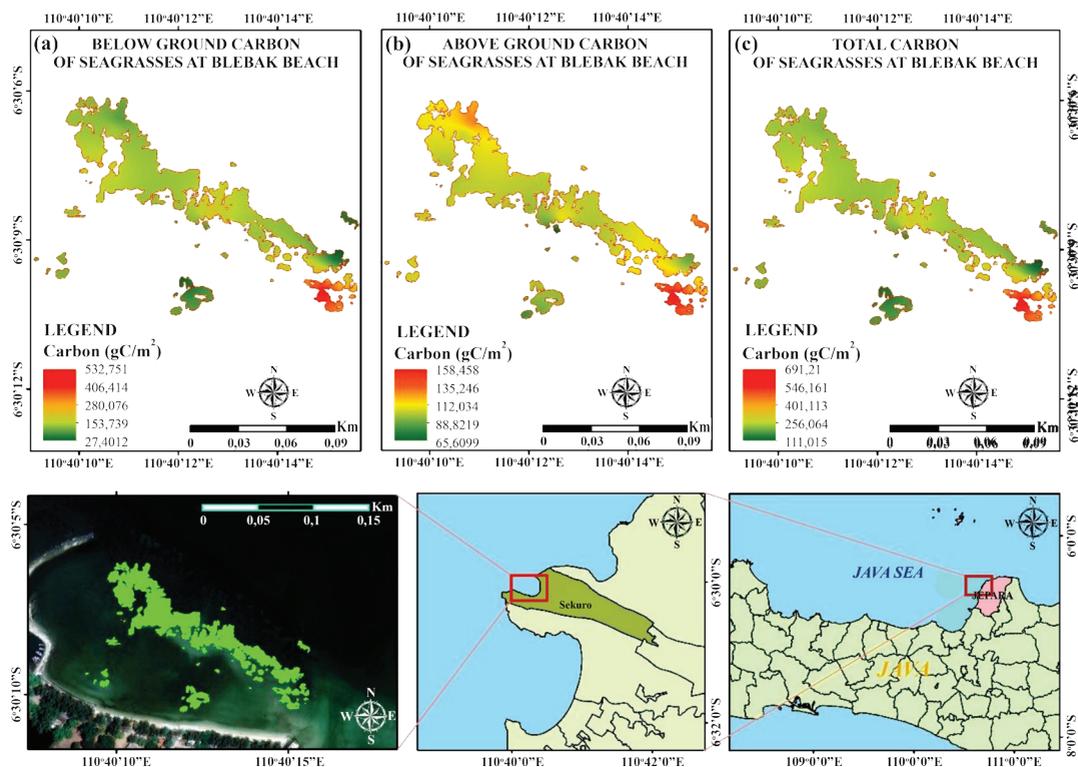


Figure 7. Distribution of seagrass carbon stock at Blebak Beach. (a) Represents the distribution of belowground carbon, (b) shows the distribution of aboveground carbon, and (c) illustrates the distribution of total carbon. In the legend, red indicates the highest carbon stocks values, while dark green represents the lowest.

with two large patches interspersed with smaller, closely spaced patches. Patchy seagrass beds, which can extend up to approximately 100 m, may arise due to both natural and anthropogenic factors. Natural events, such as recolonisation or storm damage, and human activities, including coastal development, are known to influence patch formation (León-Pérez *et al.*, 2020).

The species distribution and coverage at Blebak Beach varied across transects. In Transect 1 and 3, *T. hemprichii* dominated, whereas Transect 2 was primarily dominated by *C. rotundata*. All four species are present in Transect 1 and 2; however, *E. acoroides* was absent in Transect 3. This distribution is likely influenced by substrate and water conditions. Transect 1 and 2 have substrates of sand and coral rubble, which are more suitable

for *E. acoroides*, a species that prefers fine sandy and coral rubble substrates due to their moderate wave dynamics. In contrast, coarser sandy substrates, typically associated with stronger wave action, may inhibit its growth (Ambo-Rappe, 2022).

Seagrass density also varied across the transects. Transect 1 exhibited the lowest density, whereas Transect 2 had the highest. Among the species, *T. hemprichii* showed the highest density, while *E. acoroides* had the lowest. Seagrass density is generally correlated with the number of individual stands; however, this relationship is not always linear. Observational methods may influence these outcomes, as percentage coverage is determined by leaf canopy within the quadrat, while density is based on the number of individuals present (Satriani *et al.*, 2024).

Based on Braun-Blanquet (1965), the density values indicate that *E. acoroides*, *O. serullata*, and *C. rotundata* fall into category 2 (rare), while *T. hemprichii* is classified as category 3 (moderately dense). Overall, the seagrass in Blebak Beach is in poor condition, with natural and human factors, such as tourism activities and boat traffic, contributing to significant damage and reduced coverage (Sondak and Kaligis, 2022).

Seagrass biomass

Seagrass biomass is the total weight of individual plants, including both belowground and aboveground components. At Blebak Beach, the highest total biomass values were recorded in Transect 1 and 3. Factors contributing to these differences include species composition, the presence of older seagrass with more extensive rhizomes, and the influence of environmental and human activities. Species such as *E. acoroides* and *T. hemprichii* tend to exhibit greater biomass compared to others. In addition, human activities and natural influences, especially the type of substrate and the presence of waves, greatly affect the weight of seagrass biomass (Prarikeslan *et al.*, 2019). In contrast, Transect 2, which is more exposed to tourist activities and wave action, displayed lower biomass values. The belowground biomass constitutes the largest proportion of the total biomass due to substantial rhizomes present in the substrate. Larger seagrass species generally have higher biomass content (Githaiga *et al.*, 2016). At Blebak Beach, the average belowground biomass was 332.98 g·m⁻², while the average aboveground biomass was 221.01 g·m⁻². Biomass values serve as indicators of nutrient enrichment in aquatic ecosystems, particularly nitrogen enrichment. Seagrasses exposed to high nitrogen levels often experiences a significant reduction in biomass weight, highlighting its utility in monitoring ecosystem health (Gladstone-Gallagher *et al.*, 2018).

Carbon stock of seagrass

Seagrasses store carbon in their biomass, including leaves, roots, and associated coastal

substrates, with global storage estimates ranging from 1,732 to 21,000 TgC (Stankovic *et al.*, 2023b). At Blebak Beach, the largest belowground, aboveground, and total carbon distributions were observed in Transect 1 and 3. This distributions are influenced by several factors such as seagrass species, age, substrate variations, root and rhizome structures, leaf quantity, density, nutrient availability, and human activities.

Aboveground organic carbon content is largely determined by leaf density, which directly enhances carbon uptake. Belowground carbon storage in tropical seagrasses primarily occurs in rhizomes and roots, accounting for approximately 20–60% of the total, with the remainder stored in substrates (Lima *et al.*, 2022). At Blebak Beach, species diversity significantly influences carbon distribution, as it impacts stand density and leaf coverage, leading to variability in carbon values. Additionally, the patchy distribution of seagrasses contributes to these variations. Patchy seagrasses can store substantial carbon, both in plant biomass and sediments, particularly when they represent remnants of larger meadows that have experienced erosion (Ricart *et al.*, 2015).

The highest carbon concentration was observed in belowground biomass, averaging 169.42 g C·m⁻², compared to an aboveground averages of 108.22 g C·m⁻², yielding a total carbon stock of 277.64 g C·m⁻². These findings highlight the predominance of belowground carbon, consistent with its higher biomass content. This linear relationship between carbon stock and biomass weight highlights the critical role of belowground components (Lyimo and Hamisi, 2023).

Several factors influence seagrass carbon stock, including seagrass species composition, meadow structure (continuous vs patchy), species diversity, biotic interactions, wave exposure, turbidity, depth, nutrient availability, geographical location, and climate (Mazarrasa *et al.*, 2018). The study at Blebak Beach represents a novel contribution, as no prior data exists on seagrass carbon content at this site.

CONCLUSIONS

Seagrass at Blebak Beach, Jepara Regency consists of four species: *T. hemprichii* (most abundant), *C. rotundata*, *O. serullata*, and *E. acoroides*. These seagrasses are distributed in patchy beds over an area of 0.451 ha. The distribution of seagrass biomass and carbon in Blebak Beach, Jepara Regency is divided into three components: belowground, aboveground, and total. Belowground biomass and carbon constitute 60% of the total stock, while aboveground biomass and carbon account for 40%. These findings highlight the importance of belowground components in seagrass ecosystems and provide a foundational understanding of seagrass carbon storage at this location.

LITERATURE CITED

- Abadie, A., J. Richir, P. Lejeune, M. Leduc and S. Gobert. 2019. Structural changes of seagrass seascapes driven by natural and anthropogenic factors: a multidisciplinary approach. **Frontiers in Ecology and Evolution** 7: 190. DOI: 10.3389/fevo.2019.00190.
- Ambo-Rappe, R. 2022. The success of seagrass restoration using *Enhalus acoroides* seeds is correlated with substrate and hydrodynamic conditions. **Journal of Environmental Management** 310: 114692. DOI: 10.1016/j.jenvman.2022.114692.
- Barrón, C., N. Marbé, J. Terrados, H. Kennedy and C.M. Duarte. 2004. Community metabolism and carbon budget along a gradient of seagrass (*Cymodocea nodosa*) colonization. **Limnology and Oceanography** 49(5): 1642–1651. DOI: 10.4319/lo.2004.49.5.1642.
- Braun-Blanquet, J. 1965. **Pflanzensoziologie (Plant Sociology : The Study of Plant Communities)**. Springer, Vienna, Austria. 866 pp.
- Brenner, C.L., S.R. Valdez, Y.S. Zhang, E.C. Shaver, B.B. Hughes, B.R. Silliman and J.P. Morton. 2024. Sediment carbon storage differs in native and non-native Caribbean seagrass beds. **Marine Environmental Research** 194: 106307. DOI: 10.1016/j.marenvres.2023.106307.
- CoreMap-LIPI. 2014. **Guide for Seagrass Monitoring**. Indonesian Institute of Sciences (LIPI), Jakarta, Indonesia. 35 pp.
- Duarte, C.M. 1990. Seagrass Nutrien Content. **Marine Ecology-Progress Series** 6(2): 201–207.
- Githaiga, M.N., L. Gilpin, J.G. Kairo and M. Huxham. 2016. Biomass and productivity of seagrasses in Africa. **Botanica Marina** 59(2–3): 173–186. DOI: 10.1515/bot-2015-0075.
- Gladstone-Gallagher, R.V., R.W. Hughes, E.J. Douglas and C.A. Pilditch. 2018. Biomass-dependent seagrass resilience to sediment eutrophication. **Journal of Experimental Marine Biology and Ecology** 501: 54–64. DOI: 10.1016/j.jembe.2018.01.002.
- Helrich, K. 1990. **Official Methods of Analysis of the Association of Official Analytical Chemists**. Association of Official Analytical Chemists, Arlington, USA. 684 pp.
- Johannessen, S.C. 2022. How can blue carbon burial in seagrass meadow increase long-term, net sequestration of carbon? A critical review. **Environmental Research Letters** 17(9): 093004. DOI: 10.1088/1748-9326/ac8ab4.
- León-Pérez, M.C., R.A. Armstrong, W.J. Hernández, A. Aguilar-Perera and J. Thompson-Grill. 2020. Seagrass cover expansion of Cajade Muertos Island, Puerto Rico, as determined by long-term analysis of historical aerial and satellite images (1950–2014). **Ecological Indicators** 117: 106561. DOI: 10.1016/j.ecolind.2020.106561.
- Lima, M.A.C., R.D. Ward, C.B. Joyce, K. Kauer and K. Sepp. 2022. Carbon stocking Southern England's intertidal seagrass meadows. **Estuarine, Coastal and Shelf Science** 275: 107947. DOI: 10.1016/j.ecss.2022.107947.

- Lyimo, L.D. and M.I. Hamisi. 2023. The influence of seagrass and its associated sediment on organic carbon storage: a case of *Halodule uninervis* and *Syringodium isoetifolium* meadows of Western India Ocean, Tanzania. **Marine Environmental Research** 183: 105836. DOI: 10.1016/j.marenvres.2022.105836.
- Mazarrasa, I., J. Samper-Villareal, O. Serrano, P.S. Lavery, C.E. Lovelock, N. Marbà, C.M. Duarte and J. Cortés. 2018. Habitat characteristics provide insights of carbon storage in seagrass meadows. **Marine Pollution Bulletin** 134: 106–117. DOI: 10.1016/j.marpolbul.2018.01.059.
- McKenzie, L. and R. Yoshida. 2021. **Monitoring a seagrass meadow**. Seagrass-Watch: Proceedings of a Workshop for Monitoring Seagrass Habitats in the Port Curtis Coral Coast Region 2021: 30–36.
- Mishra, A.K., R. Rasheed and S.H. Farooq. 2025. Seagrass population dynamics and biodiversity assemblages indicate negative effects of short-term nutrient enrichment in tropical island ecosystem. **Journal of Environmental Management** 373: 123797. DOI: 10.1016/j.jenvman.2024.123797.
- Prarikeslan, W., D. Hermon, Y. Suasti and A. Putra. 2019. Density, coverage and biomass of seagrass ecosystem in the Lobam Island, Bintan Regency–Indonesia. **IOP Conference Series: Earth and Environmental Science** 314(1): 1–8. DOI: 10.1088/1755-1315/314/1/012024.
- Ricart, A.M., P.H. York, M.A. Rasheed, M. Pérez, J. Romero, C.V. Bryant and P.I. Macreadie. 2015. Variability of sedimentary organic carbon in patchy seagrass landscapes. **Marine Pollution Bulletin** 100(1): 476–482. DOI: 10.1016/j.marpolbul.2015.09.032.
- Satriani, S., Z. Imran, F. Kurniawan, P. Perdinan and A.A. Digdo. 2024. Health status of seagrass meadows arounds the Special Economic Zone (SEZ), West Likupang, North Sulawesi. **Journal of Research in Science Education** 10(1): 201–209. DOI: 10.29303/jppipa.v10i1.5908.
- Sondak, C.F.A. and E.Y. Kaligis. 2022. Assessing the seagrasses meadows status and condition: a case study of Wori seagrass meadows, North Sulawesi, Indonesia. **Biodiversitas** 23(4): 2156–2166. DOI: 10.13057/biodiv/d230451.
- Stankovic, M., A.K. Mishra, Y.P. Rahayu, J. Lefcheck, D. Murdiyarto, D.A. Friess, M. Corkalo, T. Vukovic, M.A. Vanderklift, S.H. Farooq, J.D. Gaitan-Espitia and A. Prathep. 2023a. Blue carbon assessment of seagrass and mangrove ecosystems in South and Southeast Asia: current progress and knowledge gaps. **Science of The Total Environment** 904: 166618. DOI: 10.1016/j.scitotenv.2023.166618.
- Stankovic, M., J. Panyawai, N. Khanthasimachalem and A. Prathep. 2023b. National assessment and variability of blue carbon in seagrass ecosystems in Thailand. **Marine Pollution Bulletin** 197: 115708. DOI: 10.1016/j.marpolbul.2023.115708.
- Sugianti, Y. and M. Mujiyanto. 2020. Current status and species diversity of seagrass in Panjang Island, Banten. **Indonesian Journal of Marine Sciences** 25(1): 17–22.
- Suwandhahannadi, W.K., D. Wickramasinghe, D.D.G.L. Dahanayaka and L. Le De. 2024. Blue carbon storage in a tropical coastal estuary: insight for conservation priorities. **Science of the Total Environment** 906: 167733. DOI: 10.1016/j.scitotenv.2023.167733.