Estimation of Carbon Content in Mangrove Litter in the Forest of Dabong Village, Kubu Raya Regency

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Abstract

Mangrove ecosystems have a huge potential in controlling the effects of global warming through their ability to absorb carbon dioxide (CO_2) from the atmosphere. Mangrove litter is one component that becomes a carbon sink, contributing to the transfer and storage of organic carbon in coastal sediments. This study aims to calculate the rate of mangrove litter production and the rate of carbon production in mangrove litter in the Forests of Dabong Village, Kubu Raya Regency. Mangrove litter was collected using a 1x1 m^2 litter trap with a mesh size of 0.2 cm over a period of 15 days. The results of the study show that the rate of mangrove litter production is 15.01 tons/ha/year - 28.88 tons/ha/year, with leaf litter being the dominant fraction compared to twigs, flowers, and fruits.. The carbon content percentage of the litter samples obtain was 45.24%, with an estimated carbon production rate in the Forest of Dabong Village ranging from 7.69 tons C/ha/year to 12.92 tons C/ha/year. Leaf litter contributed the highest proportion of carbon production due to its greater biomass contribution and continous turnover. These findings highest the significant role of Dabong Village mangroves in coastal carbon sequestration and climate change mitigation.. Furthermore, the results are consistent with regional patterns of mangrove carbon dynamics, reinforcing the importance of conserving and sustainability managing mangrove forests as part of blue carbon strategies to reduce atmospheric CO_2 concentrations and enhance long-term carbon storage in coastal environments.

Keywords: Dabong Village, mangrove litter carbon, litter production rate, mangrove

INTRODUCTION

Global warming is the phenomenon of increasing average temperatures on the Earth's surface, in the atmosphere, and in the oceans (Leu, 2021). Global warming is caused by an increase in the greenhouse effect, especially carbon dioxide (CO_2) from anthropogenic activities. Global warming causes an increase in the Earth's surface temperature (Manuri *et al*., 2011; Pratama, 2019). Global warming has an impact on climate change, such as rising sea levels (Leu, 2021), increased intensity of natural disasters such as erosion (Eekhout dan Vente, 2022), flooding (Panguriseng *et al*., 2024), storms (Haryanti *et al*., 2022), and ocean acidification (Das & Mangwani, 2015). Carbon dioxide (CO_2) in the atmosphere can be absorbed and stored by terrestrial forests, grasslands, peatlands, and coastal ecosystems, including mangroves, which have a very high capacity to absorb carbon. Mangroves play an important role and have the ability to prevent global warming (Ketaren, 2023).

Mangrove forests have a huge potential in controlling the effects of global warming due to their ability to absorb CO_2 from the atmosphere (Kusumaningtyas *et al*., 2019; Melati, 2021; Widyastuti *et al*., 2018). Through the process of photosynthesis, CO_2 in the atmosphere is absorbed by mangroves, which then produce organic matter in the form of carbohydrates and oxygen (Hazmi *et al*., 2017). According to Alongi (2012), mangrove forests can store five times more carbon than other tropical forests on land. Mangroves store carbon absorption in various parts, such as biomass (25-350 tons/ha) (Komiyama *et al*., 2008), litter (1–20.30 tons/ha/year) (Rafael & Calumpong, 2018), and sediment (33-789 tons/ha) (Kauffman *et al*., 2020).

Mangrove litter absorbs less carbon than other parts of the mangrove. This is because the carbon content of mangrove litter is dominated by water and mineral nutrients rather than organic matter (Kusuma *et al*., 2022). Higher organic matter content in a particular part supports higher carbon content in that part. Several studies in

*Corresponding author http://ejournal.undip.ac.id/index.php/buloma Diterima/Received : 29-10-2025
DOI:10.14710/buloma.v15i2.78944 Disetujui/Accepted : 12-03-2026

Indonesia show significant variations in the rate of carbon production of mangrove litters Previous research on mangrove litter carbon production rates reveals significant variation across Indonesian sites. Razak *et al*. (2022) reported a rate of 3.68 tons C/ha/year in Ponto Village, North Sulawesi, while Islamiah *et al*. (2022) found a slightly higher value of 4.09 tons C/ha/year in Mendalok Village, West Kalimantan. Farhaby *et al*. (2023) recorded a much higher figure of 8.34 tons C/ha/year in Kurau Timur Village, Bangka Belitung. Meanwhile, Sofiana *et al*. (2025) reported the highest rate of 10.33 tons C/ha/year in Sungai Nibung Village, West Kalimantan, highlighting environmental factors influencing mangrove litter carbon productivity. From previous study carbon production from mangrove litter in Indonesia varies significantly, ranges from 3.68 to 10.33 tons C/ha/year. This variation indicates differences in environmental conditions, species composition, and forest structure between these locations. Therefore, more specific studies are needed to better understand the carbon production dynamics in mangrove ecosystems.

The area of mangrove forest in Kubu Raya based on BPSPL data in 2021 is 129,604.125 ha, where Kubu Raya district has a very large mangrove forest in West Kalimantan and is spread across various coastal villages in Kubu Raya district, one of which is spread across Dabong Village, Kubu Subdistrict. Dabong Village has a mangrove forest area managed by the LPHD covering 2,869 hectares (Badan Restorasi Gambut, 2018). Several types of mangroves that can be found in the area include *Rhizophora*, *Bruguiera*, *Avicennia*, *Sonneratia*, *Xylocarpus*, and *Nypa* (Badan Restorasi Gambut, 2018; Karlina & Pratiwi, 2021). Although there is some information about the condition of mangroves in Dabong Village, research on the carbon content of mangrove litter is still limited. Therefore, this study aims to calculate litter production rate and litter carbon production rate at Dabong Village Forest.

MATERIAL AND METHOD

The research location is in Dabong Village, Kubu District, Kubu Raya Regency, West Kalimantan Province. The sampling area is in the Village Forest, which is divided into three stations based on environmental conditions. The first station is located far from human settlements, at the convergence of four rivers, with the following coordinates 0°35'33.10"S 109°15'16.67"E. The second station is located in the transitional area between the forest and residential area with the following coordinates 0°35'38.03"S 109°15'21.33"E. The third station is located at the back of the residential area with coordinates 0°35'45.02"S 109°15'26.33"E. Each station will contain three litter traps (placed in a triangle) in a systematic manner. Sample collection was conducted over a period of 15 days (Supriadi *et al*., 2018) in June 2025. The sampling period was chosen based on the Australian wind season (easterly monsoon) in the period of June-August, which brings dry winds. Therefore, the litter collected was litter that fell naturally without any extreme disturbances.

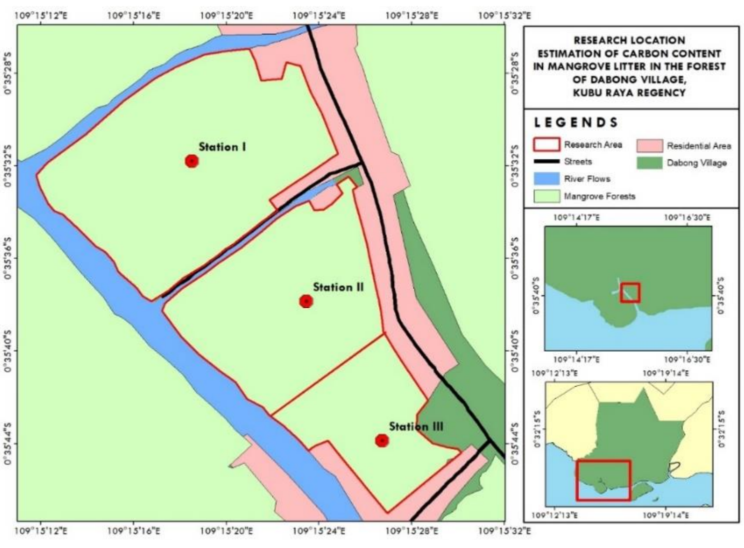

Figure 1. Sampling location map for mangrove littter in Dabong Village Forest, Kubu Raya District

Litter samples were collected using litter traps net (1 x 1 m^2) with a mesh size of 0.2 cm, installed 1.5 m above ground level to avoid tidal fluctuations. Litter samples were collected for 15 days (Farhaby *et al*., 2023). After the samples were collected, the litter was separated based on type (leaves, flowers, fruits, and twigs) and weighed to calculate the litter production rate. The litter samples were then stored in sample bags and labeled (Supriadi *et al*., 2018).

The litter production rate was calculated using the following equation (Esi *et al*., 2025):

$$X_i\ (g/m^2/day\ ) = \frac{G_{ti}}{A}$$

$$Annual\ rate\ (tons/ha/year) = X_i \times 0{,}01 \times 365$$

Where: X_i = litter production rate each type (g/m^2/day); G_{ti} = total weight of litter contained in the litter trap (each type) (g); A = litter trap area (m^2).

The weighed wet litter was stored in amounts of 100-300 grams from each litter component to be used as sub-samples. If each litter component weighed less than 100 grams, then the total sample weight of each component was used as a sub-sample (Hairiah *et al*., 2011). The litter that has been weighed is then stored in sample plastic bags and taken to the laboratory for water and ash content analysis.

Sample processing was carried out at the Soil Chemistry and Fertility Laboratory, Faculty of Agriculture, Tanjungpura University. The samples were dried using the gravimetric method, whereby the litter was dried in an oven at 70°C-105°C for 48 hours to remove water content (Selviani *et al*., 2024). Then the litter was weighed to determine its dry weight (G_{ks}). The dry litter samples were then used for carbon content analysis with reference to Rudiansyah *et al*. (2013).

Water content was calculated using the formula (Sudarmadji *et al*., 1996):

$$Water\ content\ (WC)(\%) = \frac{(G_{bs} - G_{ks})}{G_{bs}} \times 100\%$$

Where: G_{bs}= wet weight of litter sample (g); G_{ks}= dry weight of litter (g).

The dry matter content of the litter is calculated using the following formula (Rudiansyah *et al*., 2013):

$$Dry\ matter\ content\ of\ litter\ (\%) = 100 - water\ content\ (\%)$$

Carbon analysis of mangrove litter using the Loss on Ignition (LOI) method. It starts with preparing and weighing an empty porcelain crucible used as a sample container. Litter samples with known dry weight (G_{bk}) are placed in a crucible with known weight (G_{bc}). Next, the crucibles containing the litter samples were burned using a muffle furnace at a temperature of 500-600°C for 5 hours. The crucibles containing the litter ash were removed and weighed to obtain the final weight (G_{ba}) (Rudiansyah *et al*., 2013). The weight obtained was then calculated to determine the carbon concentration of the litter.

$$Ash\ content\ (AC)\ (\%) = \frac{(G_{ba} - G_{bc})}{G_{bk}} \times 100\%$$

Where: G_{ba} = final weight (porcelain crucible + ash) (g); G_{bc} = initial weight of porcelain crucible (g); G_{bk} = dry litter sample weight (g).

Calculation of carbon concentration and litter carbon production rate in mangrove litter are calculated using the following formula (Rudiansyah *et al*., 2013).

$$Carbon\ concentration\ (\%) = dry\ matter\ content\ of\ litter - ash\ content$$

$$Litter\ carbon\ production\ rate\ \left(\frac{g\frac{C}{m^2}}{day}\right) = carbon\ concentration \times G_{ti}$$

$$Annual\ rate\ (tons\ C/ha/year) = Litter\ carbon\ production\ rate \times 0{,}01 \times 365$$

Where: G_{ti} = total weight of litter contained in the litter trap (g)

RESULTS AND DISCUSSION

The proportions of litter collected in the litter traps varied between stations, with leaves (37.40-94.21%) dominating at all three stations, followed by fruits (0-47.38%), twigs (1.08-15.64%), and flowers (1.08-12.12%) (Table 2). Several previous studies in the mangrove areas of West Kalimantan also reported the dominance of leaf litter, such as in Mendalok Village (57.89%) (Islamiah *et al*., 2022), Mempawah Regency

(60.46-65.16%) (Rafdinal *et al*., 2021), and Sungai Nibung Village (53.62-93.06%) (Sofiana *et al*., 2025). Leaves become the largest component of litter because leaf biomass production in mangroves is very high (Tam *et al*., 1998), and the canopy structure is dense and extensive (Chen *et al*., 2009), resulting in a higher number of fallen leaves compared to other parts. In addition, the rate of leaf turn-over is rapid and leaf fall occurs throughout the year (Wang'ondu *et al*., 2014), thus producing large amounts of leaf litter.

The sampling sites contained *Rhizophora*, *Bruguiera*, and *Avicennia* mangroves, with *Rhizophora* being the dominant mangrove species at each station. *Rhizophora* mangroves have leaves that are large and thin, so when there are strong winds and high rainfall, *Rhizophora* leaves are relatively easier to fall (Andrianto *et al*., 2015; Asbar *et al*., 2024; Darwati & Destiana, 2022; Mahmudi *et al*., 2011; SM & Gobel, 2023). In addition, the leaves have a shorter lifespan than other components. The old leaves that are no more productive in the process of photosynthesis will fall, then be replaced by young leaves (Irawan *et al*., 2016). The lifespan of *Rhizophora* leaves is around 10-18 months, *Bruguiera* ±17.2 months (Wang'ondu *et al*., 2013), and *Avicennia* has a leaf lifespan of 11 months (Wang'ondu *et al*., 2010).

The results showed that the total litter production rate varied between observation stations. The highest production rate was found at station II (28.88 tons/ha/year), while the lowest production rate was found at station III (15.01 tons/ha/year) (Figure 2). In general, mangroves can produce litter at a rate of 1-20.3 tons/ha/year (Rafael & Calumpong, 2018). The mangrove litter production rate in this study (15.01-28.88 tons/ha/year) was higher compared to previous studies in Setapuk Besar Village, Singkawang City (3.35-27.05 tons/ha/year) (Darwati & Destiana, 2022), and Sungai Nibung Village, Kubu Raya Regency (4.95-30.07 tons/ha/year) (Sofiana *et al*., 2025). However, these results are lower when compared to mangrove litter production in Mendalok Village, Mempawah District (24.09 tons/ha/year) (Islamiah *et al*., 2022). Variations in litter production rates between regions can be influenced by several factors, such as mangrove species, density, rainfall, wind speed, temperature, air humidity, and salinity (Hafizi *et al*., 2017; Kusuma, 2023; Langi & Nurmawan, 2023; Nasir *et al*., 2017).

The type/species of mangrove affected the rate of litter production. The research location dominated by *Rhizophora* showed a relatively high rate of litter production. This is in line with the results of a study by Islamiah *et al*. (2022) in Mendalok Village, Mempawah Regency, which reported that the *Rhizophora* zone had a higher litter production rate (11.10 tons/ha/year) compared to the *Bruguiera* zone (8.28 tons/ha/year) and the *Avicennia* zone (4.71 tons/ha/year). Mangrove density also affects the amount of litter produced. High density results in high litter production, while low density results in low litter production (Muslimin *et al*., 2021).

Based on Anggraeni *et al.* (2026) shows that mangrove density in the Dabong Village Forest is relatively high, thereby playing a crucial role in litter production in that location. These results are also in line with the research by Muslimin *et al*. (2021) on Bintan Island, where high litter production occurs in locations with high density. The same results were also found by Supriadi *et al*. (2018) in Dompak Waters, Tanjung Pinang, where litter production rates increased along with high density values, while low density values resulted in low production rates.

Table 1. Percentage of mangrove litter components in the forest of Dabong Village

Litter component	Percentage of Mangrove Litter (%)								
	Station I			Station II			Station III		
	L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3
Leaves	94.21	70.71	87.36	53.51	62.03	76.64	83.87	64.66	37.40
Flowers	4.71	12.12	9.60	3.28	1.78	3.57	1.08	8.09	8.99
Twigs	1.08	2.02	1.12	2.29	2.22	15.64	15.05	9.90	6.23
Fruits	0	15.15	1.92	40.92	33.97	4.15	0	17.35	47.38
Total	100	100	100	100	100	100	100	100	100

*L = Litter traps

Based on litter components, the rates of production are leaves > fruits > flowers > twigs (Figure 3). Leaves have the highest production rate (8.59-17.36 tons/ha/year), followed by fruits (1.37-7.33 tons/ha/year), flowers (0.81-2.01 tons/ha/year), and twigs (0.30-2.02 tons/ha/year). Factors influencing the high production rate of leaf litter include size, shape, and thickness. Other influences include the physiological properties of leaves, which are easily blown away by wind and rain (Andrianto *et al*., 2015; Darwati & Destiana, 2022; Dewiyanti *et al*., 2019). Mangrove flowers and fruits produce high litter production during the rainy season. This is because rainfall affects litter production and the falling of mature mangrove flowers and fruits; mangrove fruits can fall if supported by environmental factors (Azad *et al*., 2021). Dali (2023) also revealed that the highest fruits litter production occurs during the rainy season. The twig litter component has the lowest litter production rate compared to other components. Twigs litter is not very sensitive to high temperatures, so when temperatures are high, twig litter production does not increase. Twigs litter is more influenced by physical activities, such as rainfall and wind speed (Anggriani *et al*., 2025; Kusuma, 2023; Wang *et al*., 2021).

The carbon content in litter represents the percentage of carbon contents in litter. The carbon content is determined by the biomass of litter and the percentage of organic fraction in the litter. Higher litter biomass and carbon percentage will produce higher carbon sinks (Budiman *et al*., 2015). Higher ash percentage in samples correlates inversely with carbon percentage, which means samples with high ash percentage produce low carbon percentage (Farhaby *et al*., 2023). Based on the results of the analysis of mangrove litter content in Table 3, the highest ash concentration was found at Station I (7.01%) with the lowest carbon concentrations also found at Station I (42.52%). This analysis is consistent with the previous statement, where high ash concentrations will result in low carbon concentrations. However,

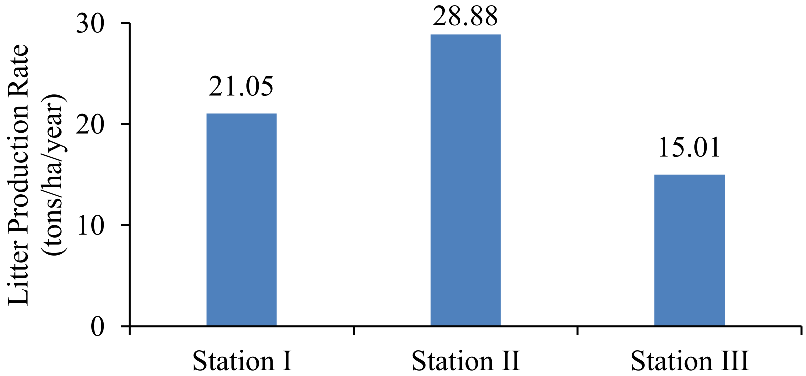

Figure 2. Total mangrove litter production rate at each station

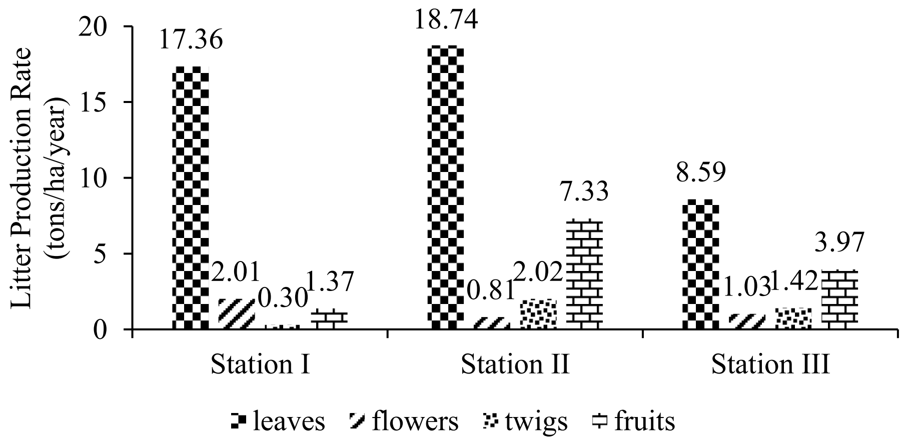

Figure 2. Litter production rate across all mangrove components

the highest carbon percentage was found at Station III (48.20%), with the lowest ash percentage also found at Station III (5.98%) relative to the other stations.

The carbon concentration in mangrove litter is an indicator of the mangrove's ability to sequester carbon (Bachmid *et al*., 2018). The carbon concentration in various parts of the litter varies. The carbon concentration shown in Table 4 shows an average carbon concentration of 45.24%. The carbon concentration in the Dabong Village Forest is slightly lower than the carbon concentration specified by the IPCC (2006) of 47%.

Twigs (61.19%) have the highest carbon concentrations, followed by leaves (43.56%), flowers (39.70%), and fruits (36.49%). Twigs have tighter structures than other components, contributing to their higher carbon concentrations. The main components found in twigs are hemicellulose (20-30%), cellulose (40-50%), lignin (15-35%) (Yang, 2007), and extractive materials (1-15%) with carbon as the main element (Budiaman & Elias, 2011; Nawawi *et al*., 2018).

The analysis of carbon production rates in mangrove litter indicates the amount of carbon produced by mangrove litter within a one-year period (Karim *et al*., 2019). The results in Table 5 show variations in carbon production values at the three stations. The carbon production rate of litter in the Dabong Village Forest ranged from 7.69 to 12.92 tons C/ha/year. This range is similiar to the reported values from Mendalok Village, Mempawah District (12.29 tons C/ha/year) (Islamiah *et al*., 2022), and from Sungai Nibung Village, Kubu Raya District (2.30-23.59 tons C/ha/year) (Sofiana *et al*., 2025). Compared to Kurau Timur Village, Central Bangka Regency (6.31-10.01 tons C/ha/year) (Farhaby *et al*., 2023), the values in Dabong are slightly higher, although the range of values slightly overlaps. Furthermore, the carbon production rate in Dabong is clearly higher than that reported in Ponto Village, North Minahasa Regency (3.68 tons C/ha/year) (Razak *et al*., 2022).

Overall, the carbon production rate observed in Dabong are within the range of values previously reported in various mangrove ecosystems in Indonesia. These difference are possibly influenced by difference environmental, litter production rates, species composition, and mangrove density, and seasonal factors (Islamiah *et al*., 2022; Karim *et al*., 2019; Nursofiati *et al*., 2020). Relatively high values in this study may be related to the dominance of *Rhizophora* species and the sampling period during the dry season. Karim *et al*. (2019) reported that on Payung Island, Banyuasin Regency, the carbon production rate (9.42 tons C/ha/year) was higher than the production rate. The similar pattern was also found in Kurau Timur Village, Central Bangka Regency by Farhaby *et al*. (2023), where a high carbon production rate (10.01 tons C/ha/year) was produced by a high litter production rate. These conditions demonstrate that the amount of carbon produced from litter is influenced by the amount of litter produced. Higher litter production will result in higher carbon production.

According to their types, all mangroves have different capacities for carbon sequestration. According to the results of litter carbon production in Mendalok Village, Mempawah Regency, by Islamiah *et al*. (2022), the carbon sequestration capacity of *Rhizophora* litter is 5.66 tons C/ha/year. This value is higher than that of *Bruguiera*, which is 4.23 tons C/ha/year, and *Avicennia*, which is 2.40 tons C/ha/year. *Rhizophora* mangroves are the dominant species at the study site, resulting in a significant carbon production role for *Rhizophora* litter. Besides influencing litter production, the dominance of *Rhizophora* species in the study area also contributes to high carbon production because *Rhizophora* has higher litter production capability and carbon concentration than other mangrove species.

Table 2. Analysis results of mangrove litter content in Dabong Village Forest

Station	Water content (%)	Dry matter content (%)	Ash content (%)	Carbon concentration (%)
I	42.13	49.54	7.01	42.52
II	48.96	51.04	6.06	44.98
III	37.49	54.18	5.98	48.20

Table 3. Carbon consentration at each parts

Litter components	Carbon concentration (%)
Leaves	43.56
Flowers	39.70
Twigs	61.19
Fruits	36.49
Average	45.24

Table 4. Carbont content of mangrove litter at Dabong Village Forerst

Litter components	Litter Carbon Production Rate (tons C/ha/year)		
	Station I	Station II	Station III
Leaves	6.26	7.94	4.44
Flowers	0.70	0.32	0.45
Twigs	0.19	0.92	0.98
Fruits	0.69	3.74	1.82
Total	7.83	12.92	7.69

Mangrove density is one of the factors affecting carbon production in an area. Mangrove forests with high density produce more litterfall, resulting in increased carbon concentration in the litter (Rositah *et al*., 2013). The results from the Dabong Village Forest study show high density values contribute to high mangrove litter carbon production. Similar results were found in the mangrove litter carbon production study by Nursofiati *et al*. (2020) in Kuala Singkawang, West Kalimantan, which showed high litter carbon production rates were supported by high density values. The same finding was also found by Karim *et al*., (2019), where high carbon production rates were found at high densities.

Leaves became the most dominant litter component contributing carbon at each station. The highest carbon production rate in leaves was found at Station II at 7.94 tons C/ha/year. The high carbon production at Station II was also influenced by the high litter production, especially the leaf component. Leaves has a big role in litter production, supporting high carbon production in leaf litter. Even though the carbon concentration in leaves is less than that in twigs, litter production is dominated by the leaf component, giving a higher carbon production rate for leaves compared to other components.

CONCLUSION

The total rate of mangrove litter production in the Dabong Village Forest, Kubu Raya Regency, ranges from 15.01 to 28.88 tons/ha/year. The main components of litter production are leaves > fruits > flowers > twigs. The carbon concentration of litter in Dabong Village Forest ranges from 7.69 to 12.92 tons C/ha/year. These data underscore the high carbon sequestration potential of Dabong Village mangroves, supporting conservation efforts in Kubu Raya. These findings show that the mangrove ecosystem in Dabong Village plays an important role in carbon sequestration and climate change mitigation. Therefore, sustainable management and conservation strategies are essential to maintain and enhance the ecological functions of this ecosystem, especially in supporting blue carbon initiatives and regional environmental sustainability programs.

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