Decomposition rate and litterfall dynamics of a mangrove forest in Mempawah Regency, West Kalimantan, Indonesia

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Abstract. Sustainability of the nutrient cycle in mangrove forests is one of the key factors in maintaining the ecosystem, in addition to protecting and replanting mangrove stands. This study aims to estimate land productivity related to the rate of decomposition and litter production in the mangrove forest area of Mempawah Regency, Indonesia. Monitoring litter production and decomposition were conducted during ten weeks, with a two-week interval between measurements, in two study sites, using litter traps and litterbags. The results show that litter production in the two locations ranged from 67.21 to 79.82 g m^{-2} $month^{-1}$. The decomposition rate ranged from 1.94 to 9.50 g day^{-1}. The highest decomposition rate was found in the first two weeks, and the lowest was found in the last observation. We found a positive correlation between rainfall and air temperature to litter production, but it was not significant. Rainfall and air temperature have a negative correlation with decomposition rate, but it was not significant.
Key Words: diameter growth rate, height growth rate, Peniti, Sungai Pinyuh, true mangrove.

Introduction. Mangrove forests are one of the typical ecosystems commonly found in Indonesia, as a characteristic of an archipelago country that has a wide coastline. The estimated mangrove area in Indonesia is quite diverse; according to the Directorate of the INTAG Development Program, the mangrove area was 3.5 million ha in Indonesia in 1996 (Rusila Noor et al 1999). Based on 1999 data, it was estimated that the area of Indonesia's mangrove forests reached 8.6 million ha, 5.3 million ha being in a damaged condition (General Directorate of Land Rehabilitation and Social Forestry 2001). Mangrove forests are economically utilized by the community as a source of fuel (wood, charcoal), building material (blocks, boards), as well as textiles, food, and medicine (Dahdouh-Guebas et al 2000; Rakhfid & Rochmady 2014). In addition, mangrove forests have an ecological function in maintaining stable coastal conditions, protecting coastal cliffs and river cliffs, preventing abrasion and seawater intrusion; they are a habitat for fish, shrimp, and crab in early life stages (Rusila Noor et al 1999; Gunarto 2004).

The mangrove forest ecosystem is highly influenced by the seawater tides, and its constituent species are adapted to high salinity and inundated soils (FAO 2007). The diversity of mangrove species in Indonesia is very high, with 202 species of mangroves found, 43 of them being true mangroves (Rusila Noor et al 1999). In the world, there are 60 true mangrove species recorded (Rusila Noor et al 1999).

Mempawah Regency's mangrove forest area is located along the west coast of Mempawah Regency, West Kalimantan, Indonesia. This area is a very important natural resource, with direct and indirect benefits for the surrounding community. The direct benefits of the coastal mangrove forest in Mempawah Regency include wood, non-timber forest products, and wildlife, while indirect benefits appear in the form of environmental services, serving as a water regulator, presenting aesthetic functions, and as a supplier of oxygen and carbon sink (Saenger et al 1983; Howard et al 2014). The declining quality and quantity of mangrove forests in the Mempawah Regency causes worrying impacts, such as reduced fishing yields, coastal abrasion, and farther seawater intrusion towards the coast (Khairuddin et al 2016; Oktaviani et al 2016). This condition also occurs in several areas along the coast of West Kalimantan, Indonesia.

Mempawah mangrove forest productivity and its sustainability in a nutrient cycle are important factors that need to be further studied. Rafdinal et al (2019) reported that mangrove tree density in Peniti Village, Mempawah, Indonesia, ranged from 38 to 185 individuals ha^{-1}, and aboveground biomass ranged from 8.85 to 84.82 Mg ha^{-1}. In another report, Rafdinal et al (2020) estimated that the survival rate of mangrove communities in Mempawah Regency ranged from 73.33 to 86.67%. This study aims to determine some key factors in order to optimize the economic, social, and ecological functions of mangrove forests in the future.

Material and Method

Study sites. This study was conducted from April to July 2018, in the mangrove forest area of Sungai Pinyuh and Peniti villages, Mempawah Regency, West Kalimantan, Indonesia (Figure 1). The study began with the installation of litter traps and litterbags, then monitoring was carried out 6 times in a span of 3 months (2 weeks interval). The first monitoring (I) is carried out in the third week of April (14^{th} day), the second monitoring (II) on the first week of May (28^{th} day), the third monitoring (III) on the third week of May (42^{nd} day), the fourth monitoring (IV) on the first week of June (56^{th} day), the fifth monitoring (V) on the third week of June (70^{th} day) and the last monitoring (VI) on the first week of July (84^{th} day),

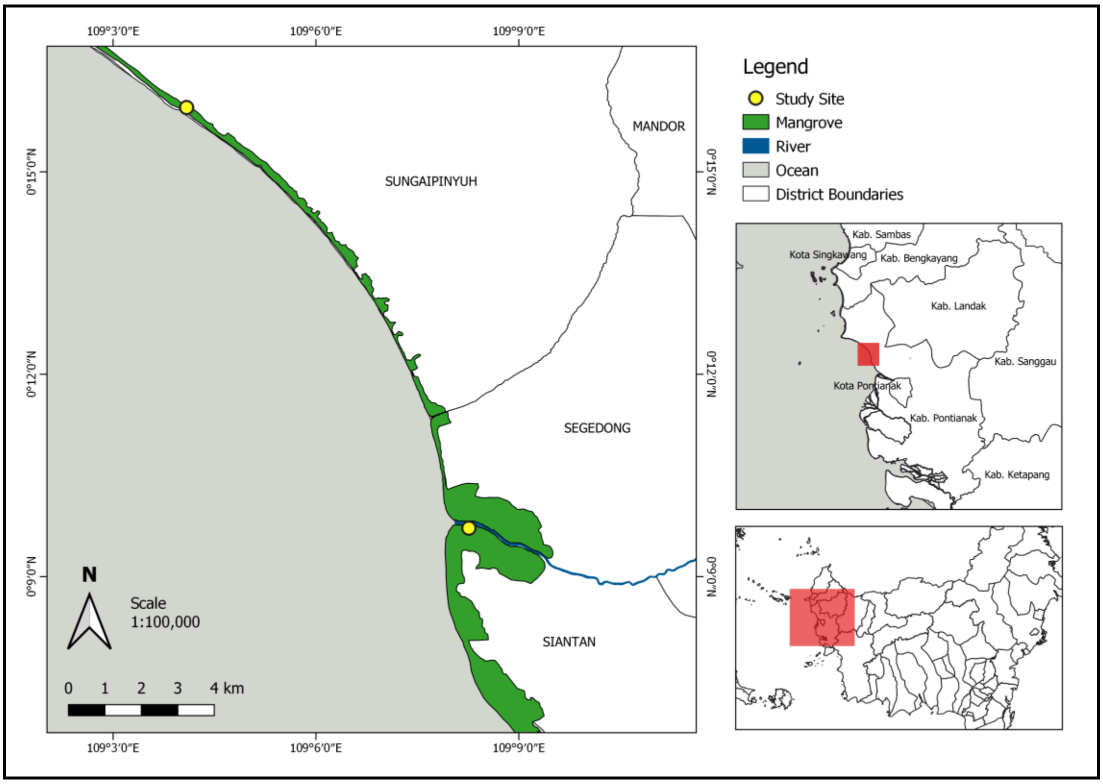

Figure 1. Study site at Mempawah Regency mangrove area, Indonesia.

Litterfall dynamic. 10 litter traps were randomly placed at each study site. 1 x 1 m traps made of a framed plastic net (0.1 cm diameter) were placed 1 m above ground. The litter collected in each litter-trap was placed into a bag and air-dried for at least 2 days. After drying, the contents of each bag was sorted into 4 plant parts, following the method of Proctor et al (1983), namely: (1) leaf litter; (2) twig litter (<2 cm in diameter); (3) flower litter + fruit; and (4) mixed litter. The sorted segments were weighted using an analytical balance (accuracy of 0.0001 g) and combined into a litter mixture for each portion every two weeks. Each portion was dried in an oven at 105°C and weighed again, resulting in oven-dry weight. The data obtained from the observations at each station were processed in a tabulated form. The data was presented as average litter produced (g m^{-2} $month^{-1}$).

Decomposition rate. The rate of decomposition and nutrient release in the Mempawah mangrove forest area was determined by placing 100 g of fresh litter into a net bag with a size of 25x22 cm, which was placed on the forest floor (this is intended to make the decomposition process as natural as possible) (Moore et al 1984). The monitoring of litterbags was carried out at certain intervals to estimate the rate of litter mineralization (Haraguchi et al 2002). Therefore, 15 litterbags were placed at each observation location where the litter was collected. Every 2 weeks, 3 litterbags were taken from each location. The litterbags were air-dried, oven dried, and weighed. The litter decomposition rate was estimated using the following equation (Andrianto et al 2015):

$$R = \frac{Wo - Wt}{t}$$

Where: R - decomposition rate (g day^{-1}); t - observation time (days); Wo - initial litter dry weight (g); Wt - litter dry weight after t-time (g).

The percentage of litter decomposition was calculated the following (Boonruang 1984):

$$Y = \frac{Wo - Wt}{Wo}\ x\ 100\%$$

Where: Y - percent of decomposed litter; Wo - initial litter dry weight (g); Wt - litter dry weight after time-t (g).

Relationship to climatic factors. The relationship between the litterfall dynamic and decomposition rate to climatic factors was analyzed using Spearman's regression and correlation. All statistical analyses used the SPSS Graduate Pack™ 14.0 program for Windows. Significant differences were considered at $p<0.05$. Rainfall and air temperature values were collected from the meteorological and climatic stations of the Indonesian government, the source of the climatic data being the Statistics Bureau of Mempawah Regency (2019).

Results and Discussion

Mangrove litterfall dynamic. The inventory of mangrove species from previous research in the mangrove forest area of Mempawah Regency revealed 8 mangrove species, namely *Avicennia alba, Avicennia officinalis, Bruguiera* sp., *Rhizophora apiculata, Sonneratia alba, Acanthus ilicifolius, Hibiscus* sp., and *Nypa fruticans* (Rafdinal et al 2019). *A. officinalis* was the dominant species found in the two research locations and the most dominant contributor to the production of litterfall in both locations.

The average production of mangrove forest litter in Mempawah Regency is presented in Table 1. The total average production of mangrove litter at the first location in Sungai Pinyuh Village was 2.24±0.78 g m^{-2} day^{-1}, estimated at 8.07 tonnes ha^{-1} $year^{-1}$. At the second location in Peniti Village, it was 2.66±1.34 g m^{-2} day^{-1}, estimated at 9.58 tonnes ha^{-1} $year^{-1}$. The dynamics of the amount of litterfall in the two locations tend to be similar, with the highest production in the fifth collection (from the first week to the third week in June). The lowest production of litter occurred in the first collection (from the second week to the fourth week of April).

Table 1

The average weight of mangrove forest litterfall in Mempawah Regency, Indonesia

Location	*Leaf (g)*	*Branch (g)*	*Generative organs (g)*	*Others (g)*	*Total (g m^{-2} day^{-1})*	*Total (g m^{-2} $month^{-1}$)*	*Total (tonnes ha^{-1} $year^{-1}$)*
Sungai Pinyuh	1.46	0.19	0.57	0.02	2.24	67.21	8.07
Peniti	1.61	0.56	0.43	0.06	2.66	79.82	9.58

Based on the litter constituent components (Figure 2), the leaves represent the largest part of the litter production in the two locations by more than 60%. Fallen moss and tree bark and others (excluding the leaves, twigs/branches, and generative organs) contributed with the least amount of litter production, ranging from 0.73 to 2.26% in both locations. The twigs/branches of the tree contributed with 8.65 to 21.08%, while the generative portion contributed with 16.20 to 25.46% of the litter in the two locations. The highest amount of generative organ litter (flowers and fruit) falls in the first week to the third week of June (the fifth collection period).

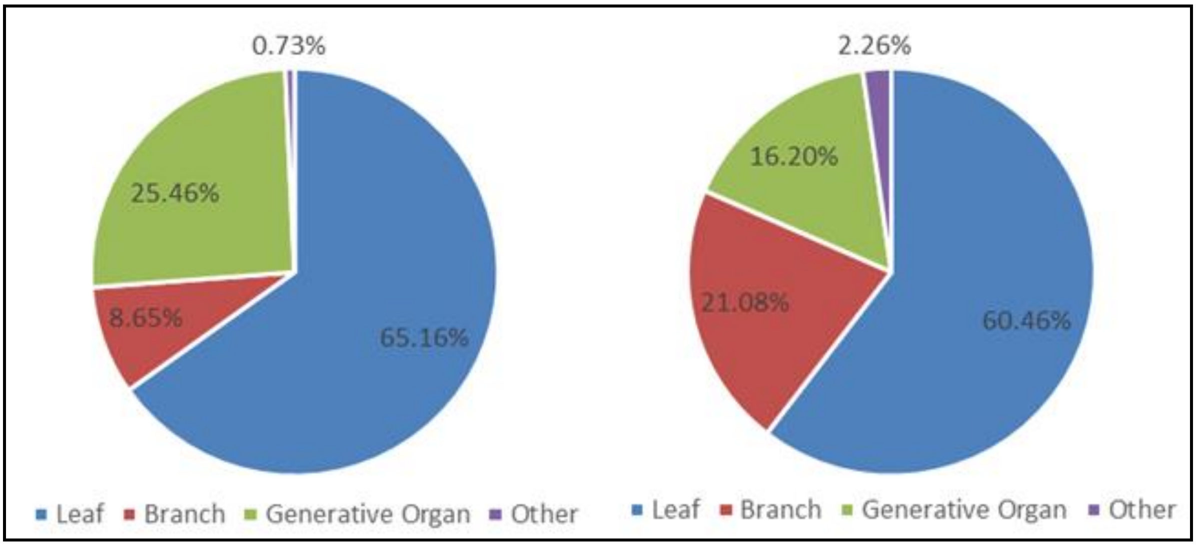

Figure 2. Percentage of mangrove litterfall in the mangrove forest of Sungai Pinyuh Village (left) and Peniti Village (right), Mempawah Regency, Indonesia.

Estimated litter production at the two study sites was found to be large when compared to similar studies, such as in the study of Tang et al (2016) in a mangrove area in Konawe Selatan District, Southeast Sulawesi Province, Indonesia. Litter production in the current study ranged from 2.24 to 2.66 g m^{-2} $days^{-1}$ or twice greater than the estimated mangrove production in the research of Tang et al (2016), where the average value was 1.04 g m^{-2} $days^{-1}$. However, the value from the current study is smaller when compared to several studies in other areas (Table 2). The difference in the amount of litter production might appear due to the differences in tree density, forest areas with higher tree density producing more litter. The differences in the constituent species of the mangrove forest area may cause differences in the amount of litter production, as noted by Zamroni & Rohyani (2008) in the mangrove forest area of Sepi Bay, where different species of mangroves result in different amounts of litter. A comparison of litter production at different locations is presented in Table 2.

Table 2

Mangrove litterfall production in several locations

Location	*Constituent species*	*Litterfall production (g m^{-2} days^{-1})*
South Konawe, Southeast Sulawesi, Indonesia	*Rhizophora apiculata, Bruguiera gymnorrhiza*	1.04[1]
Pesawaran Regency, Indonesia	*Rhizophora* sp.	0.56[2]
Tangerang Regency, Banten, Indonesia	*Avicenia marina, Avicenia alba, Rhizophora mucronata, Sonneratia caseolaris*	3.45[3]
Teluk Sepi Beach, West Lombok, Indonesia	*R. apiculata, R. mucronata, R. stylosa, Sonneratia alba, Aegiceras corniculatum*	2.71[4]
Tanjung Api-Api, South Sumatra, Indonesia	*A. marina*, *S. caseolaris*	2.99[5]
Bintuni Bay, Papua, Indonesia	*Rhizophora* sp., *Bruguiera* sp.	3.04[6]
Benoa Bay, Bali, Indonesia	*Rhizophora apiculata*	3.81[7]
Peninsular Malaysia	*R. mucronata, R. apiculata*	2.79[8]
Mempawah Regency, Indonesia	*Avicennia* sp.	2.24-2.66[9]

Note: the superscript numbers denote references: 1) Tang et al 2016; 2) Andrianto et al 2015; 3) Aida et al 2014; 4) Zamroni & Rohyani 2008; 5) Ulqodry 2008; 6) Pribadi 1998; 7) Kitamura et al 1997; 8) Ashton et al 1999; 9) Current study.

Decomposition rate. The estimation of the mangrove litter decomposition rate at the first location in Sungai Pinyuh Village showed a large decrease on the fourteenth day of observation. It further decreased to approximately half on the next observation (after twenty-eight days) and reached 90% decomposition after forty-two days of observation. Weight calculation on the fourteenth day of observation showed a significant decrease from the first day, with 88.63% decomposed litter, with a decomposition rate of 9.5 g day^{-1}. The decomposition rate continued to decrease on each observation day, until it reached a final weight of 7.75 g at the last observation. The estimation results and analysis of the rate of litter decomposition at the first location can be seen in Table 3.

Table 3

Average decomposition rate ±SD of mangrove litter in Sungai Pinyuh Village, Mempawah Regency, Indonesia

Observation day	*Initial weight (g)*	*Final weight (g)*	*Decomposed litter (g)*	*Decomposed litter (%)*	*Decomposition rate (g days^{-1})*
14	150	17.06±7.29	132.94±7.29	88.63±4.86	9.50 ± 0.52
28	150	17.27±5.32	132.73±5.32	88.49±3.55	4.74 ± 0.19
42	150	11.01±1.77	138.99±1.77	92.66±1.18	3.31±0.04
56	150	9.04±2.13	140.96±2.13	93.97±1.42	2.52±0.04
70	150	7.75±0.94	142.25±0.94	94.83±0.63	2.03±0.01

Table 4 shows the estimation results and analysis of the mangrove litter decomposition rate at the second location, Peniti Village. Significant weight loss occurred at the first observation (fourteenth day), with more than 85% of litter decomposition. On the second observation (after twenty-eight days), the litter had decomposed more than 90%. The decomposition rate decreased for each observation, with the highest decomposition rate estimated in the first two weeks, of 9.12 g day^{-1}. Then the decomposition rate decreased in the second week by approximately half, and at the end of the observation, the average decomposition rate per day was estimated to be 1.94 g day^{-1}.

Table 4

Average decomposition rate ±SD of mangrove litter in Peniti Village, Mempawah Regency, Indonesia

Observation day	*Initial weight (g)*	*Final weight (g)*	*Decomposed litter (g)*	*Decomposed litter (%)*	*Decomposition rate (g days^{-1})*
14	150	22.30±7.94	127.70±7.94	85.13±5.29	9.12±0.57
28	150	10.63±1.48	139.37±1.48	92.91±0.98	4.98±0.05
42	150	12.51±2.77	137.49±2.77	91.66±1.85	3.27±0.07
56	150	11.81±3.15	138.20±3.15	92.13±2.10	2.47±0.06
70	150	13.98±0.35	136.03±0.35	90.68±0.23	1.94±0.005

The range of average air temperature at the research location based on data from the Statistics Bureau of Mempawah Regency (2019) was 26.4 to 36.7°C, average humidity ranged between 81-96% and the range of average rainfall is between 57-461 mm. The lowest rainfall was found in February and the highest in May; the lowest temperature was found in February and the highest in January, and the lowest humidity was found in August and the highest in January (Figure 3).

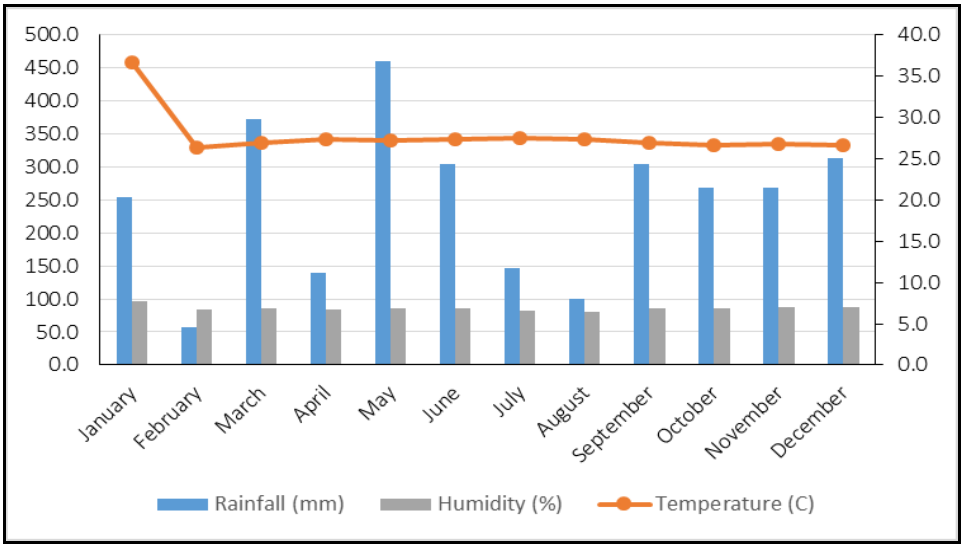

Figure 3. Average climate factors (rainfall, humidity and temperature) at Mempawah Regency in 2013-2018 (data sourced from Statistics Bureau of Mempawah Regency 2019).

Based on the Pearson correlation, there is a positive relationship between rainfall and humidity factors on litter production, so that when rainfall and humidity increase, litter production also increases. However, for temperature, we found a negative correlation to litterfall production, but not significant. The dynamics of litter production occur mainly due to the large number of leaf fall caused by rain, but not significant (Table 5).

Based on the Pearson correlation, we found a positive relationship between temperature and litter production, so that when temperature increases, litter decomposition also increases. For rainfall and humidity, we found a negative correlation to litter decomposition, but not significant. The litter decomposition is mainly affected by temperature and humidity, but not significantly (Table 5).

Table 5

Correlation matrix between climate factors and production and decomposition of mangrove forest litter

Variables	*Locations*	
	Sungai Pinyuh	*Peniti*
Rainfall and litterfall production	0.728	0.396
Temperature and litterfall production	-0.577	-0.40
Humidity and litterfall production	0.577	0.40
Rainfall and litter decomposition	-0.645	-0.934^{ns}
Temperature and litter decomposition	0.640	0.927^{ns}
Humidity and litter decomposition	-0.640	-0.927^{ns}

Note: ns - not significant.

Conclusions. The production of litterfall in the mangrove forest of Mempawah Regency is estimated at 67.21-79.82 g m^{-2} $month^{-1}$ or 8.07-9.58 tonnes ha^{-1} $year^{-1}$. The rate of decomposition of litter at the two study sites in the first observation was estimated at 9.12-9.50 g day^{-1}, then it decreased in the last observation at 1.94-2.03 g day^{-1}. A positive correlation occurs in the variables of rainfall to the litterfall production, but the value is not significant. A negative correlation occurs in the variables of rainfall and humidity to litter decomposition, but it is not significant.

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Conflict of Interest. The authors declare that there is no conflict of interest.

References

Aida G. R., Wardiatno Y., Fahrudim A., Kamal M. M., 2014 [Litterfall production of mangrove in Tangerang coastal area, Banten]. JIPI 19(2):91-97. [In Indonesian].

Andrianto F., Bintoro A., Yuwono S. B., 2015 [Production and decomposition rate of mangrove litter (*Rhizophora* sp.) in Durian and Batu Menyan villages, Padang Cermin District, Pesawaran Regency]. Sylva Lestari 3(1):9-20. [In Indonesian].

Ashton E. C., Hogarth P. J., Ormond R., 1999 Breakdown of mangrove leaf litter in a managed mangrove forest in Peninsular Malaysia. Hydrobiologia 413:77-88.

Boonruang P., 1984 The rate of degradation of mangrove leaves, *Rhizophora apiculata* B. L. and *Avicennia marina* (Forsk) Vierh. at Phuket Island, western Peninsula of Thailand. University of Malaya & UNESCO, 9 p.

Dahdouh-Guebas F., Mathenge C., Kairo J. G., Koedam N., 2000 Utilization of mangrove wood products around Mida Creek (Kenya) amongst subsistence and commercial users. Economic Botany 54(4):513-527.

Gunarto, 2004 [Mangrove conservation to support biological resources. Coastal fishing]. Journal of Litbang Pertanian 23(1):15-21. [In Indonesian].

Haraguchi A., Kojima H., Hasegawa C., Takahashi Y., Iyobe T., 2002 Decomposition of organic matter in peat soil in a minerotrophic mire. European Journal of Soil Biology 38(1):89-95.

Howard J., Hoyt S., Isensee K., Telszewski M., Pidgeon E., 2014 Coastal blue carbon: Methods for assessing carbon stocks and emissions factors in mangroves, tidal salt marshes, and seagrasses. Conservation International, Intergovernmental

Oceanographic Commission of UNESCO, International Union for Conservation of Nature. Arlington, Virginia, USA, 184 p.
Khairuddin B., Yulianda F., Kusmana C., Yonvitner, 2016 Degradation mangrove by using Landsat 5 TM and Landsat 8 OLI image in Mempawah Regency, West Kalimantan Province year 1989 - 2014. Procedia Environmental Sciences 33:460-464.
Kitamura S., Anwar C., Chaniago A., Baba S., 1997 Handbook of mangroves in Indonesia: Bali and Lombok. Ministry of Forestry Indonesia and Japan International Cooperation Agency, Jakarta, 199 p.
Moore T. R., Bubier J. L., Frolking S. E., Lafleur P. M., Roulet N. T., 1984 Plant biomass and production and CO_2 exchange in an ombrotrphic bog. Journal of Ecology 90(1):25-36.
Oktaviani Z., Manurung T.F., Utomo K.P., 2016 [Changes in shorelines due to damage of the mangrove forest in Terusan Subdistrict, Mempawah Hilir District, Mempawah Regency]. Teknologi Lingkungan Lahan Basah Journal 4(1):1-10. [In Indonesian].
Pribadi R., 1998 The ecology of mangrove vegetation in Bintuni Bay, Irian Jaya, Indonesia. PhD Thesis, Department of Biological and Molecular Sciences, University of Stirling, Scotland, 121 p.
Proctor J., Andeson J. M., Fogden S. C. L., Vallack H. W., 1983 Ecological studies in four contrasting lowland rain forest in Gunung Mulu National park, Sarawak. II. Litterfall, Llitter-standing crop and preliminary bservations on herbivory. Journal of Ecology 71(1):261-283.
Rafdinal, Linda R., Minsas S., 2019 [Distribution pattern of aboveground biomass in Peniti mangrove forest area, West Kalimantan]. Life Science 8(1):1-9. [In Indonesian].
Rafdinal, Linda R., Raynaldo A., Minsas S., 2020 Growth and survival rate analysis of *Avicennia lanata* seedlings in Mempawah mangrove areas, West Kalimantan, Indonesia. AACL Bioflux 13(2):825-832.
Rakhfid A., Rochmady, 2014 [Analysis of the economic value of the mangrove forest in Muna District (case study in Labone Village Lasalepa District and Wabintingi Village, Lohia District)]. Agribisnis dan Perikanan Scientific Journal 6:82-104. [In Indonesian].
Rusila Noor Y., Khazali M., Suryadiputra I. N. N., 1999 [Guide and introduction of mangroves in Indonesia]. PHKA/WI-IP, Bogor, Indonesia, 220 p. [In Indonesian].
Saenger P., Hegerl E. J., Davie J. D. S., 1983 IUCN Commission on Ecology, Netherlands, 88 p.
Tang M., Nur A. I., Ramli M., 2016 [Study of mangrove ecosystem conditions and detritus production in the coastal district of Lalowaru Village, North Moramo District, South Konawe Regency]. Journal of Manajemen Sumber Daya Perairan 1(4):439-450. [In Indonesian].
Ulqodry Z., 2008 [Mangrove litter productivity and potential contribution of nutrients in Tanjung Api-Api waters, South Sumatra]. MSc Thesis, Bogor Agricultural Institute, Bogor, 87 p. [In Indonesian].
Zamroni Y., Rohyani I. S., 2008 [Production of mangrove forest litter in the waters of Teluk Sepi Beach, West Lombok]. Biodiversitas 9(4):284 287. [In Indonesian].
*** FAO, 2007 The world's mangroves 1980-2005. FAO Forestry Paper 153, Rome, 77 p.
*** General Directorate of Land Rehabilitation and Social Forestry, 2001 [Final report on monitoring, control and evaluation of the implementation of community forestry activities, SPL OECF INP-22, project planning, development and evaluation of central community forestry development]. Department of Forestry and Wanacipta Lestari, Jakarta. [In Indonesian].
*** Statistics Bureau of Mempawah Regency, 2019 [Mempawah Regency in figures]. BPS Mempawah Regency, Mempawah, Indonesia, 436 p. [In Indonesian].

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