Litterfall Production and Decomposition in a Mined Area Revegetated with *Cassia siamea*

Liris Lis Komara♥, Veronica Murtinah, Dian Anggraini, and Risma

Forestry Study Programe, East Kutai Agricultural College School, Sangatta, Indonesia
♥Correspondence: lirisliskomara@gmail.com

Abstract
Background: Soil nutrients in ex-coal mining land are very low, therefore it needs to be restored by restoring the nutrient cycle through litter productivity and decomposition. **Aim:** This study was conducted to determine the litter production and decomposition rates of *Cassia siamea* and nutrient return on the reclaimed land of PT. Kaltim Prima Coal. **Methods:** Litter production data were collected using litter traps for 6 months and for decomposition rates using litter bags for 3 months. The contents of C, N, C/N, P, K, cellulose hemicellulose and lignin were taken from the litter. **Results:** The results showed that there was a positive correlation between waste production and temperature and wind speed and a negative correlation between waste production and rainfall and humidity. Nitrogen and phosphorus content were positively correlated with reclamation age. Litterfall contributes nutrients to the soil in the following order C>N>K>P. Cassia siamea litter has an average decomposition rate of 0.073611 kg m^{-2} yr^{-1} or 0.736114 tons ha^{-1} yr^{-1}. The very large decomposition rate in the first two weeks was because at the beginning of decomposition the decomposed part of the litterfall contained high levels of water and nitrogen which could increase the decomposition rate. **Conclusion:** The rate of litterfall production increases with the age of reclamation. There is a positive correlation between litterfall production and temperature and wind speed. There is a negative correlation between litterfall production and rainfall and humidity.

Keywords: Cassia siamea; decomposition; litterfall; litterfall production; post-coal mining

Introduction

Indonesia is known as a country with high mineral potential, especially coal (Monica et al., 2023). To utilize the available coal, mining is carried out. mining provides many benefits to the community, but mining also has an impact on the environment (Mbachu, 2025). In general, there are two mining systems, namely the open mining system (surface mining) and the deep/underground mining system (underground mining) (Kabangnga et al., 2021). Mining with an open pit mining system is carried out by stripping the mine's overburden (Sabaruddin et al., 2023). Open pit mining is carried out in several stages, namely by opening land (land clearing), peeling topsoil (shipping topsoil), peeling and piling overburden (over load stripping), and cleaning and mining coal (Diharjo & Manik, 2024)

Coal mining activities cause the formation of overburden land (Fitriana et al., 2024). This can be seen from the loss of protective functions of the soil due to the absence of canopy closure which also results in disruption of other functions (Hasan&sarwono, 2024). In addition, it also results in the loss of biodiversity (gene pool), degradation of river basins, changes in land form, increased erosion, and the release of heavy metals that can enter the aquatic environment (Więckol-Ryk et al., 2023). Furthermore, the excavation process causes the loss of nutrients and organic matter content in the soil, changes in topography and landscapes, and water and soil pollution.

During reclamation, Overburden is spread with top soil ±30 cm (Gunathunga et al., 2023). Overburden that has been added by the top soil layer on reclaimed land usually has different physical, chemical and biological conditions compared to the initial soil conditions before mining. Overburden has a very low soil organic matter content with a value of 1.0% - 1.4%, so it does not allow for ecosystem development (Iskandar et al., 2022). The loss of soil organic matter as a source of soil organic carbon can cause serious problems (Qi et al., 2023), because organic carbon is very important for increasing water holding capacity (Masood & Ali, 2023), aggregates (Zhao et al., 2022), permeability (Yao et al., 2023), and infiltration (Bakri et al., 2025) which can reduce run off. The soil in ex-mining land contains low levels of nutrients (Gusmini et al., 2021), therefore it is important to carry out revegetation. Revegetation is an activity to re-green ex-mining land.

The presence of vegetation will affect the amount of organic matter. The role of organic matter is important in improving soil structure and increasing the ability to absorb and retain rainwater, adding nutrients, and reducing the dispersion strength of rainwater and the speed of surface flow. The selection of ground cover plants should have the following requirements: easy to propagate, the root system does not cause heavy competition for the main plant; has soil binding properties; grows quickly and produces many leaves, is tolerant of pruning, is drought resistant, is able to suppress weeds and is easy to eradicate if the land will be used for other types. Most of the nutrients returned to the forest floor are in the form of litter. According to (Asigbaase et al., 2021), litter is organic material produced by plants that will be returned to the soil.

Plant litter can be in the form of leaves, stems, twigs, and even roots. Litter is a term given to organic waste in the form of piles of dry leaves, twigs, and various other vegetation remains on the ground that have dried out and changed color from the original. Litter mostly has carbon-based compounds. Litter that has rotted (undergone decomposition) turns into humus, and eventually into soil (Meng et al., 2025). Reclamation and revegetation techniques have the potential to restore soil organic carbon and improve the properties of damaged soil by accumulating soil organic matter (Buta et al., 2019). To return nutrients to the soil, soil organic matter must be processed by soil microorganisms (Ho et al., 2022). through the decomposition process. Therefore, this study needs to be conducted. This study was conducted to know the litter production and decomposition rates of *Cassia siamea* and nutrient return on the reclaimed land of PT. Kaltim Prima Coal.

Methods

Litterfall production research was conducted to measure the amount of litterfall produced on the reclaimed land of PT. Kaltim Prima Coal. The fallen litterfall was collected with 4 litterfall traps per plot under the tree canopy, installed at a height of 1 m above ground level to avoid animals and other disturbances. The net was installed under the johar tree (*Cassia siamea*). The litterfall trap was made of a square-shaped polyethylene net measuring 1x1m. The litterfall collected in the litterfall trap was taken every 1 month for 6 months. The litterfall samples were then weighed, air-dried for several days. The litterfall samples were then oven-dried at a temperature of 70°C for 48 hours. After that, it was weighed with a digital scale (Kamruzzaman et al., 2019). Litterfall production analysis was carried out using the equation as follows:

$$Xj = \sum_{j=1}^{n} \frac{X\,i}{n} \ (\mathrm{g\ m^{-2}})$$

Where Xj is the average litterfall production for each replication in a certain time period, Xi = litterfall production for each replication in a certain time period (i = 1,2,3 ….., n) and n is the number of litterfall trap observations.

To determine the amount of nutrients contained in the litterfall, a chemical analysis was carried out on the johar litterfall. Chemical analysis was carried out for nutrients: Carbon, Nitrogen, Phosphorus, Potassium. Carbon content was tested using the Walkley and Black method, nitrogen content was tested using the Kjeidahl method, Phosphorus was tested using the Nitric Acis Molybdate Vanadate method, Potassium was tested using the wet destruction method

The measurement of the litterfall decomposition rate was carried out on Cassia siamea by inserting 10 grams of litterfall into a 20 x 16 cm litter bag made of 0.5 mm mesh. nylon bags. Then 18 litterfall bags were then stored in a 1 cm deep hole under the tree in each research plot (reclamation age). Every two weeks for three months, three bags of each type were taken randomly. After that, the litterfall was washed and dried in an oven for two days at a temperature of 65°C for 24 hours, then weighed until stable (Rosline, D 2006). The litterfall decomposition rate was calculated using the following formula:

$$r = \frac{\ln (W_0/W_t)}{t_t - t_0}$$

Where r is the rate of litterfall decomposition, W_0: Initial dry weight of litterfall (t = 0), W_t: Dry weight of litterfall at time t and t is time (Roseline, D 2006). The differences in litterfall decomposition rates were analyzed statistically using one-way ANOVA analysis of variance.

Analysis of cellulose and lignin content following Rahayu et al.,(2022) where One g (a) Dry sample was added with 150 mL of H_2O. Refluxed at 100°C with a water bath for 1 hour. The results were filtered, the residue was washed with hot water (300 mL). The residue was then dried in an oven until constant and then weighed (b). The residue was added with 150 ml of 1 N H_2SO_4 then refluxed with a water bath for 1 hour at 100°C. The results were filtered until neutral (300 mL) and dried (c). The dry residue was added with 10 mL of 72% H_2SO_4 and soaked at room temperature for 4 hours. 150 mL of 1 N H_2SO_4 was added and refluxed in a water bath for 1 hour on a reverse cooler. The residue was filtered and washed with H_2O until neutral (400 mL) then heated in an oven at 105°C and the results were weighed (d). Next, the residue is ashed and weighed (e). The calculation of cellulose content and lignin content is as follows:

$$\text{Cellulose content} = \frac{c-d}{a} \, x \, 100\%$$

$$\text{Lignin content} = \frac{d-e}{a} \text{ x } 100\%$$

Further data processing was carried out using Analysis of Variance and Pearson correlation test. Data was processed using SPSS Version 19 to determine the relationship between decomposition rate and rainfall, sunlight intensity, temperature and humidity.

Results and Discussion

Litterfall Production

From the research results at the age of 10 years, litter production was 74.5430 g m^{-2} $month^{-1}$ or 8.95 tons ha^{-1} $year^{-1}$. At the age of 15 years, there was another increase in the amount of litterfall production, namely 131.8795 g m^{-2} $month^{-1}$ or 15.83 tons ha^{-1} $year^{-1}$. At the age of 20 years, litterfall production reached 177.04632 g m^{-2} $month^{-1}$ or 21.25 tons ha^{-1} $year^{-1}$ (Table 1).

Table 1. Litterfall Production

Reclamation Age (Years)	Litterfall Production	
	g m^{-2} $month^{-1}$	tons ha^{-1} $year^{-1}$
10	74.54 ± 20.22	8.95
15	131.88 ± 70.45	15.83
20	177.05 ± 30.81	21.25

The results of litterfall production from one year to 15 years old increased by around 356.18%. Furthermore, there was an increase of 25.55% from 15 years to 20 years old (Figure 1). The results of the Analysis of Variance showed a significance below 0.05, which means that there is an effect of reclamation age on litterfall production of Pearson's correlation test results showed a very close positive correlation between reclamation age and litterfall production ($r = 0.582$; $p = < 0.05$) (table 2). This is in accordance with Komara's 2017 study which conducted a study on litterfall production of pioneer trees of paraserianthes falcataria, acacia and rain tree species in post-coal mining reclamation land in East Kalimantan. Litterfall production decreased at the age of 10 years, possibly because the location at the age of 10 years was close to a waste disposal area, so there were often human and wild animal activities such as wild boars and monkeys.

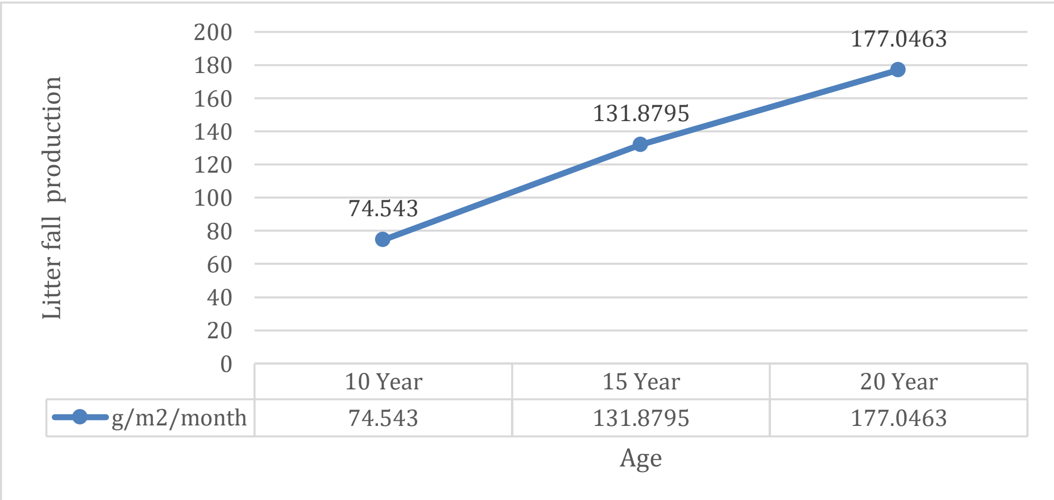

Figure 1. Dynamics of litterfall production at several revegetation ages.

Varied litterfall productivity can be caused by differences in tree age, crown or stand density. Stands with high diameters are usually older, so they produce more litterfall (Dalya et al., 2025). Crown or stand density is also a factor that affects litterfall fall, the denser the crown or stand, the more litterfall productivity will be produced. In dense crowns or stands, there is competition for sunlight so that the light obtained by plants is not enough to help the photosynthesis process. The results of Jayanthi & Arico, (2017) research showed that the highest average litterfall productivity was at a high density level of 14.5 gr m^{-2} $week^{-1}$, for medium density the litterfall decomposition rate was 12.125 gr m^{-2} $week^{-1}$ and low density was 10.625 gr m^{-2} $week^{-1}$).

Litterfall productivity in tropical rainforests is the highest compared to other regions. High litterfall productivity will provide benefits for vegetation to increase productivity because of the availability of abundant nutrient sources. According to (Qiu et al., 2023), the factors that influence litterfall in terms of quantity and quality are environmental conditions (climate, altitude, soil fertility), plant specier (natural forest and artificial forest) and time (season and age of the stand).

Table 2. Significant correlation at the 0.01 level

		Reclamation age	Litterfall Production
Reclamation age	Pearson Correlation	1	
	Sig. (2-tailed)		
	N	36	
Litterfall Production	Pearson Correlation	0.582**	1
	Sig. (2-tailed)	0.000	
	N	36	36

**. Correlation is significant at the 0.01 level (2-tailed).

From the analysis results, there is a negative relationship between rainfall and litterfall production ($r = -0.582$; $p = < 0.05$). Rainfall affects vegetation physiology because the higher the rainfall, the lower the shedding of leaves, twigs, flowers and fruits, when rainfall is high, humidity will increase, so leaf evaporation will decrease so that the leaves remain fresh and do not fall easily (Aprityanto et al, 2021)

There is a positive correlation between litterfall production and air temperature ($r = 0.710$; $p = < 0.05$) while humidity does not show a correlation with litterfall production, but the correlation tends to be negative, thus the higher the air temperature the greater the litterfall production and the higher the humidity the less litterfall production. There is a negative correlation ($r = 0.780$; $= < 0.05$) between temperature and humidity. This is in accordance with the research of Jayanthi & Arico, (2017) which states that temperature and humidity affect the fall of plant litterfall. Air temperature rising will cause a air humidity decrease so that transpiration will increase, and to reduce it, the leaves must be dropped immediately.

Table 3. Analysis between environmental conditions and litterfall production

	Reclamation age (year)	Litterfall production (ton ha^{-1})	Rainfall (mm week^{-1})	Temperature (℃)	Humidity (%)	Speed Wind (Km h^{-1})
Reclamation age (year)	1					
Litterfall production (ton ha^{-1})	0.582**	1				
Rainfall (mm week^{-1})	-0.460	-0.582	1			
Temperature (℃)	0.521	0.710	-0.766	1		
Humidity (%)	-0.026	-0.313	0.815*	-0.780	1	
Speed wind (Km h^{-1})	0.777	0.848*	-0.293	0.705	-0.220	1

There is a close positive correlation between litterfall production and wind speed (r=0.848; p=<0.05), thus the higher the wind speed the higher the litterfall production, this is in accordance with the research of (Yang et al., 2022) who concluded that the dominant factors affecting annual and monthly litterfall production were diameter and wind speed, respectively.

Macro nutrient analysis was carried out to determine the amount that would be subsidized into the soil if all the Cassia siamea litterfall had been decomposed (Table 4).

Table 4. Nutrient content of Cassia siamea litterfall at several reclamation ages (%)

NO	Age (Year)	C	N	C/N	P	K
3	10	29.89	2.86	10.46	0.052	1.18
4	15	29.77	3.25	7.86	0.044	1.28
5	20	32.41	3.16	10.34	0.055	0.63

From the results of the correlation analysis, it was found that along with the age of reclamation, the content of organic carbon, C/N and K did not correlate, but there was a strong correlation in nitrogen (r = 0.779; p = <0.05) and phosphorus (P) (r = 0.520; p = <0.05). This is in accordance with the results of aprianis's research (2011) with N nutrient levels of 1.27% and 1.29%, and P nutrient levels of 0.16% and 0.17% at the ages of 3 and 4 years. At the age of 10 years, C was 4.235592 tons ha^{-2} $year^{-1}$. At the age of 15 years, it was 9.712373 tons ha^{-2} $year^{-1}$. At the age of 20 years, C was 16.61787 tons ha^{-2} $year^{-1}$.

Table 5. Nutrient content of Cassia siamea at several reclamation ages (ha $year^{-1}$)

Reclamation Age	Litterfall production	C	N	C/N	P	K
10	14.1706	4.235592	0.405279	0.042392	0.007369	0.167213
15	32.6247	9.712373	1.060303	0.08334	0.014355	0.417596
20	51.2739	16.61787	1.620255	0.167534	0.028201	0.323026

The carbon (C) content in newly fallen Cassia siamea leaves of various ages is not much different, ranging from 29.77-38.05%. The high organic C source in the reclamation area is thought to come from plant remains mixed with topsoil during topsoil stripping before mining. Soil organic matter is formed from soil organisms consisting of flora and fauna, as well as decomposed and modified plant roots (Nivethadevi et al., 2021). There are seventeen element found in minute amounts in plants, are known to be essential for plant nutrition. These include carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, iron, manganese, zinc, copper, molybdenum, boron, chlorine, and nickel (Brown et al., 2022).

The nutrient content in plant biomass (leaves) can differ due to genetics and the environment, including: parent material, soil (fertility), climate, and location of human activities such as distance from industry and major roads (Brown et al., 2022).

The nitrogen content in Cassia siamea litterfall at the research location was relatively low, ranging from 2.53% - 3.47%. At the age of 10 years, N is 0.405279 tons ha^{-2} $year^{-1}$. At the age of 15 years, it is 1.060303 tons ha^{-2} $year^{-1}$. At the age of 20 years, it is 1.620255 tons ha^{-2} $year^{-1}$.

Leaf nitrogen content is a parameter that can indicate protein and nucleic acid synthesis that plays a role in the formation of new cells as an indicator of growth. Nitrogen must first undergo fixation into NH_3, NH_4 and NO_3, some nitrogen is involved in biological processes originating from the atmosphere in the balance of nitrogen released by microorganisms in the decomposition process.The average N content of plants is 2-4% and may also be as much as 6-11%. The high content of N nutrients is thought to be caused by the role of bacterial activity (Daunoras et al., 2024).

Table 6. Correlation between reclamation age and nutrient content of Cassia siamea litterfall

	Reclamation age	Watter content	C	N	C/N	P	K
Reclamation age	1						
KA	0.344	1					
C	0.127	0.080	1				
N	0.779	0.310	0.060	1			
CN	-0.441	-0.969**	0.109	-0.434	1		
P	0.520	0.810	0.059	0.753	-0.864*	1	
K	-0.516	-0.609	0.198	-0.053	0.657	-0.315	1

The C/N content in Cassia siamea litterfall at the research location was relatively low ranging from 0.042392 - 0.791706. At the age of 10 years C/N was 7.797205 g $month^{-1}$. At the age of 15 years it was 10.36573. At the age of 20 years N was 18.30659.

High organic C content and low total N cause the C/N ratio to be high. C/N ratio of less than 20 indicates nitrogen mineralization, while if it is greater than 30, nitrogen immobilization occurs (Geisseler et al., 2021). The high C/N ratio of reclaimed soils (15.15 - 30.52) implies that plants and microorganisms will compete for nutrient absorption from the soil, necessitating the addition of nitrogen to the soil at planting time. Nitrogen can be added by fertilizing or planting tree species that can create a relationship with Rhizobium bacteria. Furthermore, the drop in the C/N value indicates that the organic C content in the litterfall is rapidly depleted because it is consumed as food by bacteria, whilst the N content in the material will increase, indicating that the mineralization process continues. (Aprianis, 2011).

At the age of 10 years, P is 0.007369 tons ha^{-2} $year^{-1}$. At the age of 15 years, it is 0.044 g $month^{-1}$. At the age of 20 years, P is 0.028201 tons ha^{-2} $year^{-1}$. Litterfall production percentage from 10 years to 15 years there was a decrease of 118.1818%. From 15 years to 20 years there was an increase of 80%.

Potassium content at the age of 10 years it was 0.167213 tons ha^{-2} $year^{-1}$. At the age of 15 years it was 0.417596 tons ha^{-2} $year^{-1}$. At the age of 20 years Potassium was 0.323026 tons ha^{-2} $year^{-1}$. The increase in the percentage of potassium from 10 years to 15 years there was an increase of 92.1875%. From 15 years to 20 years there was a decrease of 203.1746%.

Potassium is the most actively moving nutrient. In the process, potassium (K) is converted into K^+ ions. Potassium can be a free element (Dookie et al., 2024), an ion form in plants, and in relation to litterfall it usually moves faster than other elements. In several types of forests in relation to young soil, the tendency for K^+ element loss is due to leaching (Paramisparam et al., 2021).

Decomposition Rate

The decomposition rate of cassia siamea litterfall at each time of collection, the largest was at the first collection in the second week, which was 0.020632 g m^{-2} 14 $days^{-1}$ and the smallest decomposition rate was at the collection in the 12th week, which was 0.001989 g m^{-2} 14 $days^{-1}$ (table 5.2) with an average decomposition rate of 0.008067 g m^{-2} 14 $days^{-1}$ or around 0.073611 kg m^{-2} yr^{-1} or 0.736114 tons ha^{-1} yr^{-1}. The very large decomposition rate in the first two weeks was because at the beginning of decomposition the decomposed part of the litterfall contained high levels of water and nitrogen which could increase the decomposition rate.

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Table 7. Decomposition Rate of Cassia Siasmea Litterfall Decomposed for 12 Weeks

Week Pick-up	Cassia siamea
0	0
2	0.020632
4	0.014129
6	0.005709
8	0.002186
10	0.003757
12	0.001989
Average	0.008067

The decomposition rate of Cassia siamea on 20-year-old coal mine reclamation land is greater than the decomposition rate from Roseline's (2005) study which examined the tree species C latebrosa, A spectabilis, Syzigium spp in the forest on Mount Tangkuban Perahu, which were 0.000165 g m^{-2} 14 $days^{-1}$, 0.000184 g m^{-2} 14 $days^{-1}$ and 0.000177 g m^{-2} 14 $days^{-1}$. This difference occurs due to several possible factors, namely the type of tree (Roseline, 2006; Dita, 2007), less sunlight in the forest compared to open reclamation land (Munawar et al., 2011), high rainfall in the Kalimantan area and hot air temperatures with high humidity (Komara, 2007).

The decomposition rate of Cassia siamea leaf litterfall decreased with increasing litterfall collection time (Figure 5.4), the relationship between the decrease in Cassia siamea litterfall and the decomposition time period follows the equation $Y = -0.0016x + 0.0187$ with a correlation of $R^2 = 0.5054$. This shows a relationship between the collection time period and the decrease in litterfall weight. The relationship between weight loss and collection time is in similar with (Bhattarai & Bhatta, 2019).

The results of the litterfall decomposition rate can be seen that each first litterfall bag collection has a high decomposition rate value, then decreases in the following months. This occurs at both bag planting locations. This can be interpreted that the longer the decomposition period, the lower the litterfall decomposition rate per period. Uniform vegetation conditions support the slow decomposition rate because they result in low diversity of microorganisms that play a role in the decomposition process. If the litterfall is suitable for soil microorganisms, especially if it is rich in nutrients and contains little wood or bark, and the humidity, drainage and aeration conditions of the soil are good enough, then organic matter will decompose quickly and will not accumulate in the soil. The decomposition of leaf litterfall is different each week where at first the decomposition rate value will be high and then continue to decrease, which means that at first the litterfall decomposes quickly and then becomes slower with the longer the litterfall decomposition period. This is because in the new litterfall there are still many supplies of elements that are food for soil microbes or for decomposing organisms, so that the litterfall is quickly destroyed. These elements are decreasing which means that the destruction is also slow until only elements that are not needed by decomposers remain. In addition, the water content in the new litterfall will easily evaporate so that the weight of the litterfall at the beginning of the week experiences a high decrease which also makes the rate of decomposition fast. As a dynamic process, decomposition has a speed dimension that may differ from time to time depending on factors that affect the growth of decomposers in addition to the material factors to be decomposed (Selviani et al., 2024).

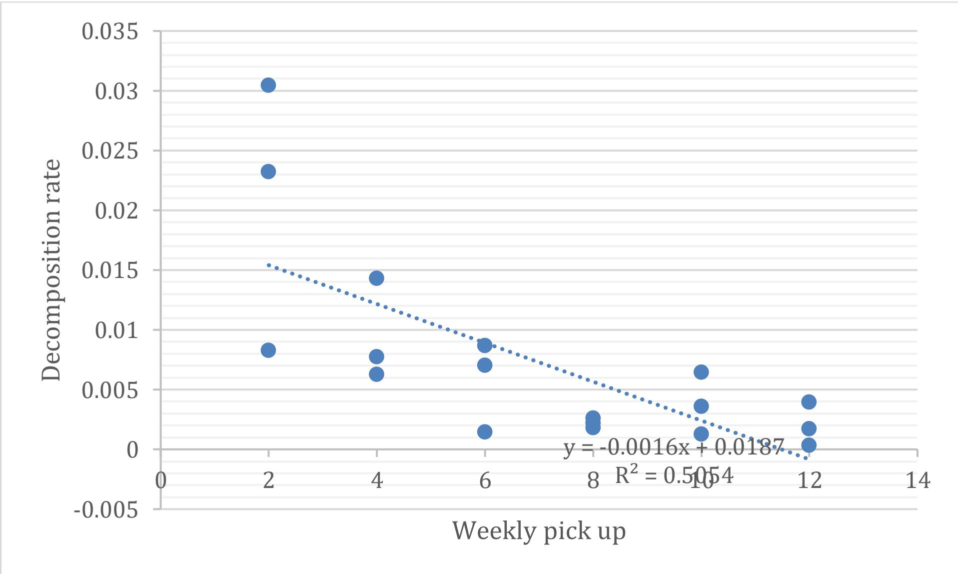

Figure 2. Changes in the rate of decomposition of litter that was decomposed for 12 weeks.

During the decomposition process, the decomposition rate of each treatment gradually decreases until the end of composting. The decomposition of leaf litterfall is different every week, where initially the decomposition rate value will be high and then decrease, which means that initially the litterfall decomposes quickly and then becomes slower with the longer period of time the litterfall is decomposed. This is because the available organic material is getting less and less due to the activity of microbes that decompose organic waste. This is because in new litterfall there are still many supplies of elements that are food for soil microbes or for decomposing organisms, so that the litterfall is quickly destroyed. These elements are decreasing, which means that the destruction is also slow until only elements that are not needed by decomposers remain. In addition, the water content in new litterfall will evaporate easily so that the dry weight of the litterfall at the beginning of the week experiences a high decrease which also makes the decomposition rate fast. As a dynamic process, decomposition has a speed dimension that may differ from time to time depending on factors that influence the growth of decomposers in addition to the material factors to be decomposed (Giweta, 2020).

The natural decomposition process of organic materials will stop when the limiting factors are not available or have been used up in the decomposition process itself. During the decomposition process, there will be a reduction in the volume of the material. This reduction reaches 30-40% of the initial volume of the material (Selviani et al., 2024).

Cassia siamea litterfall has an organic C content of 32.41%, total N of 3.16 and a C/N ratio of 10.34 plus higher P. When viewed from the content data, it is likely that C. siamea decomposes quickly compared to litterfall with a higher lignin content, which can cause a lower litterfall decomposition rate (Devianti and Tjahjaningrum, 2017).

Table 8 Nutrient, lignin and cellulose content in Cassia siamea litterfall

Content	***Cassia siamea***
Selulosa	4.53
Lignin	23.27

The content of nutrients, lignin and cellulose in litterfall determines the quality of litterfall from a tree species (Krishna & Mohan, 2017). Litterfall quality is also an important factor in the rate of litterfall decomposition. The lignin content in litterfall can also affect the rate of decomposition. Lignin plays an important role in the litterfall decomposition process and also several ecological processes. Some researchers say that lignin can be used as a predictor of the rate of litterfall decomposition. Lignin concentration is more influential than other chemical concentrations in determining the rate of litterfall decomposition (Zhao et al., 2022). The high lignin content will inhibit the decomposition process because lignin is a complex compound that is difficult to decompose by soil microorganisms (Cao et al., 2022). The higher the lignin content, the slower the decomposition (Zhao et al., 2022). This is because lignin is very resistant to degradation, both biologically, enzymatically, and chemically. Because of its relatively high carbon content compared to cellulose and hemicellulose, lignin has a high energy content.

There is a positive correlation between litterfall species and decomposition rate (Magh et al., 2024), but does not correspond to Dita's anova results (2007) which show that tree species factors do not have a significant effect on litterfall decomposition rate. This may be because both types of trees come from the same family, namely Dipterocarpaceae, the stands were planted in the same year and planting distance, namely 1959 with a planting distance of 6 x 6 m, and were planted in relatively the same soil and climate conditions.

Decomposition occurs through the transformation of energy within and between organisms. The decomposition process is a very important function, because if the decomposition process did not occur, all food would be bound to dead plants, and the world would be full of remains and carcasses. The destruction of each dead plant and animal is not the same. Fat, sugar and protein can be decomposed immediately but cellulose and lignin wood take a long time to be decomposed (Zhao et al., 2022).

If the decomposition process is slow as in the forest, then organic matter will accumulate on the forest floor and forest productivity may be low. The accumulation of organic matter can occur if there is no balance between the supply of organic matter and the rate of decomposition. The effectiveness of bacteria, fungi and other soil animals in decomposing litterfall is shown by how quickly or slowly the litterfall disappears from the forest soil surface as fast as the litterfall falls from plants. Complete decomposition takes years. Litterfall that is rich in nutrients tends to decompose faster than litterfall that is poor in nutrients on the same forest floor.

The natural decomposition process of organic matter will stop when the limiting factors are not available or have been used up in the decomposition process itself. Degradation of organic matter controls a number of functions in the ecosystem, such as the recirculation of nutrients through mineralization, and the formation of food from the detritus food chain.

Conclusion

The rate of litterfall production increases with the age of reclamation. There is a positive correlation between litterfall production and temperature and wind speed. There is a negative correlation between litterfall production and rainfall and humidity. The content of nitrogen and phosphorus nutrients is positively correlated with the age of reclamation. Litterfall contributes nutrients to the soil in the following order C>N>K>P. Cassia siamea litterfall for 12 weeks experienced a dry weight loss of 64% of the initial weight, with an average decomposition rate of 0.008067 g m^{-2} 14 $days^{-1}$. The highest litterfall decomposition rate occurred in the first week, namely 0.020632 g m^{-2} 14 $days^{-1}$.

References

Asigbaase, M., Dawoe, E., Lomax, B. H., & Sjogersten, S. (2021). Temporal changes in litterfall and potential nutrient return in cocoa agroforestry systems under organic and conventional management, Ghana. *Heliyon*, *7*(10). https://doi.org/10.1016/j.heliyon.2021.e08051

Bakri, B., Syazili, A., & Tampubolon, Z. P. (2025). Dynamics of soil organic matter , bulk density and infiltration rate on mining reclamation land. *Jurnal Lahan Suboptimal: Journal of Suboptimal Lands*, *14*(1), 77–87. https://doi.org/10.36706/JLSO.25.1.2025.723

Bhattarai, S., & Bhatta, B. (2019). Leaf Litter Decomposition and Weight Loss Pattern of Five Tropical Tree Species. *Journal of Agriculture and Forestry University*, *3*(January 2019), 125–131.

Brown, P. H., Zhao, F. J., & Dobermann, A. (2022). What is a plant nutrient? Changing definitions to advance science and innovation in plant nutrition. *Plant and Soil*, *476*(1–2), 11–23. https://doi.org/10.1007/s11104-021-05171-w

Buta, M., Blaga, G., Paulette, L., Păcurar, I., Roșca, S., Borsai, O., Grecu, F., Sînziana, P. E., & Negrușier, C. (2019). Soil Reclamation of Abandoned Mine Lands by Revegetation in Northwestern Part of Transylvania: A 40-Year Retrospective Study. *Sustainability*, *11*(12), 1–18. https://doi.org/10.3390/su11123393

Cao, Z., Yan, W., Ding, M., & Yuan, Y. (2022). Construction of microbial consortia for microbial degradation of complex compounds. *Frontiers in Bioengineering and Biotechnology*, *10*(December), 1–14. https://doi.org/10.3389/fbioe.2022.1051233

Daunoras, J., Kačergius, A., & Gudiukaitė, R. (2024). Role of Soil Microbiota Enzymes in Soil

Health and Activity Changes Depending on Climate Change and the Type of Soil Ecosystem. *Biology*, *13*(2), 1–39. https://doi.org/10.3390/biology13020085

Diharjo, D. F. M. W., & Manik, Y. B. S. (2024). Life Cycle Assessment a Coal Mining in East Kalimantan. *JST (Jurnal Sains Dan Teknologi)*, *12*(3), 613–621. https://doi.org/10.23887/jstundiksha.v12i3.68103

Dookie, S., Jaikishun, S., & Ansari, A. A. (2024). Soil and water relations in mangrove ecosystems in Guyana. *Geology, Ecology, and Landscapes*, *8*(3), 445–469. https://doi.org/10.1080/24749508.2022.2142186

Fitriana, I., Novianti, V., H. Marrs, R., Widodo, K., Humami, D. W., & Nugroho, A. D. (2024). Identification of biotic and abiotic factors coal mine overburden on Warukin rock formation of South Kalimantan. *Journal of Degraded and Mining Lands Management*, *11*(3), 5779–5791. https://doi.org/10.15243/jdmlm.2024.113.5779

Geisseler, D., Smith, R., Cahn, M., & Muramoto, J. (2021). Nitrogen mineralization from organic fertilizers and composts: Literature survey and model fitting. *Journal of Environmental Quality*, *50*(6), 1325–1338. https://doi.org/10.1002/jeq2.20295

Giweta, M. (2020). Role of litter production and its decomposition, and factors affecting the processes in a tropical forest ecosystem: A review. *Journal of Ecology and Environment*, *44*(1), 1–9. https://doi.org/10.1186/s41610-020-0151-2

Gunathunga, S. U., Gagen, E. J., Evans, P. N., Erskine, P. D., & Southam, G. (2023). Anthropedogenesis in coal mine overburden; the need for a comprehensive, fundamental biogeochemical approach. *Science of the Total Environment*, *892*(September 2024), 164515. https://doi.org/10.1016/j.scitotenv.2023.164515

Ho, T. T. K., Tra, V. T., Le, T. H., Nguyen, N. K. Q., Tran, C. S., Nguyen, P. T., Vo, T. D. H., Thai, V. N., & Bui, X. T. (2022). Compost to improve sustainable soil cultivation and crop productivity. *Case Studies in Chemical and Environmental Engineering*, *6*(May), 100211. https://doi.org/10.1016/j.cscee.2022.100211

Iskandar, I., Suryaningtyas, D. T., Baskoro, D. P. T., Budi, S. W., Gozali, I., Saridi, S., Masyhuri, M., & Dultz, S. (2022). The regulatory role of mine soil properties in the growth of revegetation plants in the post-mine landscape of East Kalimantan. *Ecological Indicators*, *139*(January), 108877. https://doi.org/10.1016/j.ecolind.2022.108877

Jayanthi, S., & Arico, Z. (2017). Pengaruh Kerapatan Vegetasi Terhadap Produktivitas Serasah Hutan Taman Nasional Gunung Leuser. *Elkawnie*, *3*(2), 151–160. https://doi.org/10.22373/ekw.v3i2.1888

Kabangnga, A., Purwant, Qaidahiyani, N. F., Djamaluddin, & Widodo, S. (2021). IJEScA Freeport Indonesia. *International Journal OfEngineering and Science Applications*, *8*(2), 80–87. https://scholar.google.com/scholar?q=+intitle:%27Support Technical evaluation Using Q-System Method in Development Area of Grasberg Block Cave (GBC) Mine PT Freeport Indonesia%27

Kamruzzaman, M., Basak, K., Paul, S. K., Ahmed, S., & Osawa, A. (2019). Litterfall production, decomposition and nutrient accumulation in Sundarbans mangrove forests, Bangladesh. *Forest Science and Technology*, *15*(1), 24–32. https://doi.org/10.1080/21580103.2018.1557566

Krishna, M. P., & Mohan, M. (2017). Litter decomposition in forest ecosystems: a review. *Energy, Ecology and Environment*, *2*(4), 236–249. https://doi.org/10.1007/s40974-017-0064-9

Magh, T., Mozhui, L., Kakati, L. N., Ao, B., Lemtur, T., & Jing, L. (2024). Litter decomposition and nutrient dynamics in a subtropical ecosystem: A comparison of natural and plantation forests (Duabanga grandiflora) in Nagaland, North-East India. *Global*

Ecology and Conservation, *56*(November), e03321. https://doi.org/10.1016/j.gecco.2024.e03321

Masood, T. K., & Ali, N. S. (2023). Effect of Different Soil Organic Carbon Content in Different Soils on Water Holding Capacity and Soil Health. *IOP Conference Series: Earth and Environmental Science*, *1158*(2). https://doi.org/10.1088/1755-1315/1158/2/022035

Mbachu, I. (2025). Assessing the perception gap: mining impacts from community and company perspectives in Nigeria. *Journal of Sustainable Mining*, *24*(1), 89–101. https://doi.org/10.46873/2300-3960.1441

Meng, D., Liu, J., Yan, L., Cheng, Z., Wei, Y., & Qin, S. (2025). The humus layer promotes needle litter decomposition but not carbon release or phosphorus accumulation in a Pinus sylvestris var. mongolica plantation. *Ecological Processes*, *14*(1), 45. https://doi.org/10.1186/s13717-025-00615-y

Monica, F., Fitri, M. M., Umar, I., Amran, A., & Gusman, M. (2023). Distribution of Potential Resources, Reserves and Use of Coal in Indonesia. *Science and Environmental Journal for Postgraduate*, *5*(2), 119–126. https://doi.org/10.24036/senjop.v5i2.191

Nivethadevi, P., Swaminathan, C., & Pandian, K. (2021). Soil Organic Matter Decomposition-Roles, Factors and Mechanisms. In S. S. Porte (Ed.), *Latest Trends in Soil Science (Volume - 1)* (Issue January). ntegrated Publications. https://doi.org/https://doi.org/10.22271/int.book.33

Paramisparam, P., Ahmed, O. H., Omar, L., Ch'ng, H. Y., Johan, P. D., & Hamidi, N. H. (2021). Co-application of charcoal and wood ash to improve potassium availability in tropical mineral acid soils. *Agronomy*, *11*(10), 1–30. https://doi.org/10.3390/agronomy11102081

Qi, Q., Yue, X., Duo, X., Xu, Z., & Li, Z. (2023). Spatial prediction of soil organic carbon in coal mining subsidence areas based on RBF neural network. *International Journal of Coal Science & Technology*, *10*(1), 30. https://doi.org/10.1007/s40789-023-00588-3

Qiu, L., Xiao, T., Bai, T., Mo, X., Huang, J., Deng, W., & Liu, Y. (2023). Seasonal Dynamics and Influencing Factors of Litterfall Production and Carbon Input in Typical Forest Community Types in Lushan Mountain, China. *Forests*, *14*(2), 341. https://doi.org/10.3390/f14020341

Rahayu, A., Hanum, F. F., Amrillah, N. A. Z., Lim, L. W., & Salamah, S. (2022). Cellulose Extraction from Coconut Coir with Alkaline Delignification Process. *Journal of Fibers and Polymer Composites*, *1*(2), 106–116. https://doi.org/10.55043/jfpc.v1i2.51

Sabaruddin, R., Anas, A. V., Amalia, R., & Tui, R. N. S. (2023). Mine Design of Laterite Nickel Ore Based on Pit Limit Optimization with Floating Cone Method at Meranti Pit of PT Ang and Fang Brother. *JURNAL GEOCELEBES*, *7*(1), 64–76. https://doi.org/10.20956/geocelebes.v7i1.23065

Selviani, S., Zamani, N. P., Natih, N. M. N., & Tarigan, N. (2024). Analysis of Mangrove Leaf Litter Decomposition Rate in Mangrove Ecosystem of Muara Pagatan, South Kalimantan. *Jurnal Kelautan Tropis*, *27*(1), 103–112. https://doi.org/10.14710/jkt.v27i1.21913

Więckol-Ryk, A., Pierzchała, Ł., Bauerek, A., & Krzemień, A. (2023). Minimising Coal Mining's Impact on Biodiversity: Artificial Soils for Post-Mining Land Reclamation. *Sustainability (Switzerland)*, *15*(12). https://doi.org/10.3390/su15129707

Yang, Y., Yang, H., Wang, Q., Dong, Q., Yang, J., Wu, L., You, C., Hu, J., & Wu, Q. (2022). Effects of Two Management Practices on Monthly Litterfall in a Cypress Plantation. *Forests*, *13*(10). https://doi.org/10.3390/f13101581

Yao, Y., Dai, Q., Gao, R., Yi, X., Wang, Y., & Hu, Z. (2023). Characteristics and factors influencing soil organic carbon composition by vegetation type in spoil heaps. *Frontiers in Plant Science*, *14*(October), 1–16. https://doi.org/10.3389/fpls.2023.1240217

Zhao, Y. Y., Li, Z. T., Xu, T., & Lou, A. R. (2022). Leaf litter decomposition characteristics and controlling factors across two contrasting forest types. *Journal of Plant Ecology*, *15*(6), 1285–1301. https://doi.org/10.1093/jpe/rtac073