Decomposition rate of some dominant tree species in Low montane forest of Gunung Halimun Salak National Park, West Java-Indonesia

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Abstract. The research of decomposition rate of Altingia excelsa Noroña, Schima wallichii (D.C.) Korth., Castanopsis acuminatissima (Bl.) A. DC., C. javanica (Bl.) A. DC., and Quercus lineata Blume was carried out in the low montane forest in Gunung Halimun Salak National Park, West Java. The aim of the research was to examine the decomposition rate of dominant species and their role in the nutrient cycling. The decomposition rate of those dominant species was carried out by using the litterbag methods. The highest decomposition rate was observed for Q. lineata followed by C. javanica, C. acuminatissima, S. wallichii, A. excelsa and the mixed litter in Cikaniki research station. Meanwhile, in the Wates plot, the highest rate was observed for C. acuminatissima followed by C. javanica, Q. lineata, S. wallichii, A. excelsa and the mixed litter. This research shows that C. acuminatissima decomposed faster compared to other dominant species due to their litter quality combination of high nitrogen and low lignin content. Carbon and nitrogen released pattern were almost similar for the five dominant species. Based on the decomposition rate and the nutrient released pattern, it showed that the high litter decomposition rate of dominant species contributed to the rapid nitrogen released.

1. Introduction
The return of nutrient in the forest ecosystem depends on the regular transfer of nutrients between components, one of the nutrient transfers was through litterfall in which the nutrients stocked in the forest biomass return to the forest soil through litterfall. It is the principal source of organic matter and starting point in the pathway of transferring organic matter and chemical elements from vegetation into the soil surface, and nutrients released during the decomposition process depend on the tree species [1,2]. In addition, the nutrients released from the litterfall are important for the production of biomass and plant growth. The combination of litterfall and biomass estimation will provide information on forest production, litter decomposition, and the nutrient cycling of the forest ecosystems [3,4]. The concentration of the litterfall element also indicates nutrient limit and the efficiency of nutrient that are used in the forests, as well as the pattern is specific for each forest ecosystem [5-7]. Hence, a study on
the role of litterfall and litter decomposition in a nutrient cycle is particularly important for forest ecosystem management.

During litter decomposition, the organic compounds are broken down into simple compounds and nutrients in the forest ecosystems. The process of decomposition is highly influenced by the litter production, litter quality, and released nutrient [2,8-14], soil humidity and temperature [15,16], seasonality and faunal activities [8,13], the site conditions, and vegetation types [16]. This process is a fundamental source of soil organic matter since it becomes a source of energy for microorganism activity and nutrients in the forest ecosystems. A research on the rate of litter decomposition in some tropical forests had been carried out [17]. The research showed that the annual turnover rate of litter decomposition is one year, as more than 95% litter mass decomposed in a year, almost in all locations. Nutrient released from decomposed litter is important source for primary production, particularly in the tropical forests, which is well known to have poor soil nutrient. Since the released nutrient was varied based on forest types, species, stand attributes, and the variation of environmental conditions, studies on the releasing of nutrients by decomposition have provided diverse results even for litter of the same species [7,18,19]. The various decomposition processes were highly correlated to the climate [15], soil organisms [20,21] and forest disturbance such as in the heath and peat swamp forests due to forest fire [7].

The study of the seasonality and litterfall quantity of dominant species rate has been carried out in tropical forests. This study mainly focused on mixed dipterocarp forests, alluvial forests, peat swamp forests, heath forests [1,4,7], low montane forest in Gunung Gede Pangrango National Park (GGPNP), and Gunung Halimun Salak NP [21,22], montane forest in Central Sulawesi [23], and Serayu, Central Java [24]. However, there is little attention for the study on the decomposition rate of trees dominant species. Studies on the decomposition rate of natural forests have also been carried out in karst, peat swamp, heath, and mangrove forest [7,25,26]. Therefore, further study for other ecosystem types is still needed to be conducted. The objectives of this study are to examine the decomposition rate of leaf litter, and to investigate the role of some dominant species contributions to nitrogen and carbon input in the forest.

2. Study Site and Methods

2.1. Study Site

The study was conducted in Gunung Halimun Salak National Park (GHSNP)-West Java, more specifically in Mt Halimun area. The 40,000 ha conservation area was established in 1992. Most of the area has an altitude more than 1000m above sea level. The annual precipitation of the study area was 4000 to 6000 mm yr⁻¹.

This study was conducted in two permanent plots that have been established in 1997 [27]. First plot was located on the ridge, north of Mt. Kendeng, close to Cikaniki Research Station (named: Plot 2) at altitude of 1100 m above sea level with coordinate point of 6º44’57” S and 106º32’08” E. The dominant species in this plot is Altingia excelsa Noronha, and the sub-dominant species is Schima walichii (DC.) Korth. Basal area was 32% and 10% for A. excelsa and S. walichii, respectively. The tallest tree was about 48m high and about 116 trees species are bigger than 15cm in girth. On the 2nd monitoring in October 1998, the basal area in this plot had decreased due to the tree loss by the death exceeded its growth. About 34 trees with 1.302m² ha⁻¹ of basal area died, and 33 trees have exceeded 1cm in girth [27]. The second plot was located in Wates area (Plot 3), close to the border of Bogor and Sukabumi Districts about 2 km from Plot 2, the altitude is 1100m above sea level. The dominant species is Castanopsis acuminatissima (Bl.) A. DC. and S. walichii as the sub-dominant species. The basal area of C. acuminatissima was 29% of the total BA, and 24% for S. walichii. The total recorded species was 105 species [28].
2.2. Field experiment

2.2.1 Litterfall and litterbag experiment.

In total of 25 litter traps were randomly set up within 1-ha permanent plots in each research sites, close to Cikaniki research station (Plot 2) and Wates area (Plot 3). A 1m square surface of litter traps and each of which was placed in 1m above the ground. Each litter traps were tied to four 1-m long PVC poles stuck into the soil. Trapped litterfall was collected monthly over a two-year period. Collected litterfall was separated for each trap at each sampling time. Litter fractions was then dried in oven at 75°C for 24 hours and weighed separately. The litterfall was separated into five dominant species, which are C. acuminatissima, S. wallichii, Quercus lineata Bl., C. javanica Bl. A. DC, and A excelsa.

Estimation of the decomposition rate was conducted by using the weight loss of litter from the litter bags [29]. The litter bag technique is the most standardized method for studying the early stages of litter decay [2]. Litterfall from the litter trap were separated into five dominant species, and the others were treated as mixed litter. Leave litters were then air dried and placed into 30 x 50cm litter bags made of nylon net with a mesh size of 2mm. Each bag contained 10 g of litter. Before setting of the bags, litter on the ground surface was gently removed to create direct contact between the bags and the soil surface. The litterbags were randomly set up at five locations inside permanent plots and were monitored for one year. Litter bags were randomly collected from each location in monthly intervals. In each location, four litter bags were collected for each species at every sampling time. The collected samples were transported in their respective plastic bags to minimize loss of litter during transportation. The remaining leaves and branches within each bag were weighed after being dried in oven at 75°C for 24 hours.

2.2.2 Chemical analyses.

Chemical analyses of litterfall collected from the decomposed litter in litter bags were homogenized by electric grinder and analysed for nitrogen and carbon content using an automatic C-N analyzer (Vario El, Elementar Analysensysteme GmbH, Hanau, Germany). Lignin analysis was performed using acid detergent fibre method [30].

2.2.3 Statistical analyses.

Decomposition rate (k) was estimated by fitting regression equation

\[ W_t = W_0 \exp(-kt) \]  

intercepting the Y axis at \( W = 100\% \) [31]. \( W \) represents the remaining litter mass and \( t \) is time expressed in day [31]. An analysis of variance (ANOVA) was used to detect any significant difference between the total remaining mass. When there were significant differences, it would be detected by ANOVA. In addition, to conduct the post hoc multiple comparison test, Scheffe was used in a posteriori comparison to examine significant differences among means \( (p<0.05) \). Turnover rate was estimated from the decomposition rate of mixed litter on the forest floor from the litter bags experiment.

3. Results

3.1. Decomposition rate of some dominant species

The decomposition rate of all species was higher in plot 2, than those were in plot 3 (figure 1); those rates were in the range of 0.55–1.12 \( y^{-1} \) and 0.66–1.09 \( y^{-1} \) in the plot 2 and plot 3, respectively. The highest rate was observed for Q. lineata (k = 1.21 \( y^{-1} \)), followed by C. javanica (k = 1.17 \( y^{-1} \)), C. acuminatissima (k = 1.13 \( y^{-1} \)), S. wallichii (k = 1.09 \( y^{-1} \)), A. excelsa (k = 0.99 \( y^{-1} \)) and the mixed litter (k = 0.55 \( y^{-1} \)) in the plot 2. While in plot 3, the highest rate was observed for C. acuminatissima (k = 1.09 \( y^{-1} \)), followed by C. javanica (k = 1.02 \( y^{-1} \)), Q. lineata (k = 1.02 \( y^{-1} \)), S. wallichii (k = 0.84 \( y^{-1} \)), A. excelsa (k = 0.69 \( y^{-1} \)) and the mixed litter (k = 0.66 \( y^{-1} \)). The decomposition rates were only significantly different for Q. lineata and S. wallichii \((p<0.05)\) in plot 2. While in plot 3, it was observed that the decomposition
rate of A. excelsa was significantly different to C. acuminatissima (p<0.01), C. javanica (p<0.05) and Q. lineata (p<0.05).

The turnover rate of dominant species can be determined based on the estimation of decomposition rate, which was in the range of 0.8–1.0 y in plot 2 and 0.9–1.5 y in plot 3. These values were in the range of annual turnover rate of litter decomposition found in some tropical forests [17,32]. The location affected decay rates, which was higher in plot 2 than those in plot 3. There were also significant differences among the species. These results indicate that both litter type and site affected litter decay rates. These results were supported by the findings of Tang et al. [33] in which the decomposition rates in different tropical forest systems are related to plant species composition.

![Figure 1](image.png)

**Figure 1.** The decomposition rate of some dominant species and the mixed litter in plot 2 (Cikaniki Research Station) and plot 3 (Wates).

3.2. N, C content and CN ratio of leaf litter during decomposition process

Nitrogen content released almost similar pattern for the five dominant species in the two locations. The nitrogen content increased from October to December. Furthermore, it then gradually increased or relatively remained constant until the end of the study period (figure 2). This pattern was almost similar in the case of carbon content where the carbon content increased from October until December, and gradually decreased or relatively constant until the end of study period (figure 3). C/N ratio in both plots decreased faster during September until November, and then decreased slowly until the end of study period (figure 4). These suggested that in the two forests, the first phase of decomposition where it was regulated by the nutrient level [34], occurred up to three months and was followed by non-soluble part decomposition.
Figure 2. Nitrogen content (%) during the decomposition process of some dominant species in plots 2 (Cikaniki Research Station) and 3 (Wates).
Figure 3. Carbon content (%) during the decomposition process of some dominant species in plots 2 (Cikaniki Research Station) and 3 (Wates).

Decreased pattern of C/N ratio was almost the same for all dominant species. C/N ratio of litter from dominant species decreased during the first to third months of study period, those were followed by releasing nitrogen content (figure 2). The pattern decreased gradually until the end of the experiment. C/N ratio of those dominant species were about 18.67-24.72 at the end of study period. The lowest of C/N ratio was documented for *Quercus lineata* in the range of 18.67-19.35, while the highest was about 22.30-24.72 for *A. excelsa* in plot 2 and plot 3. The C/N ratio was reflected by the decomposition rate of these two species, which were species with the highest and lowest decomposition rate (figure 1).
3.3. Lignin and nitrogen content of litter in some dominant species

It is well known that litter quality is one component that can control litter decay rate. Lignin, nitrogen, carbon, and phosphorus have been known as indicators for litter quality due to their influence on litter decaying rate [10, 35-39]. Combination of high nitrogen and lignin content of *C. javanica* and *Q. lineata* showed its high decomposition rate compared to *A. excelsa* and *S. wallichii* (figure 5). *A. excelsa* with the highest lignin content was decomposed slower than other dominant species in both study sites. Combination of low lignin content and high nitrogen content of *Q. lineata* showed a result of high decomposition rate. The rates were almost similar for *C. javanica* (figure 1, figure 5).

From the data of the litterfall dominant species collected at each study site, we estimated the nitrogen content of each dominant species. The high decomposition rate of *Q. lineata* and *C. javanica* related to the combination of high initial nitrogen and lignin content (figure 5). It resulted the low lignin/N ratio. Leaves with high nitrogen content decomposed faster than those with low nitrogen content [34,40], or in other words, litter containing high lignin concentration decomposed slower than those with low lignin content [7,12,38]. The lowest nitrogen level was observed for *S. wallichii*. This species was found to have the lowest decomposition rate. In case of *A. excelsa*, decomposition rate was low even though it has high nitrogen content. In accordance with this fact, that was due to the high lignin content which controlled the rate of decomposition (figure 1, figure 5).
Figure 5. Relationship between initial nitrogen (above) and lignin (below) contents of leaf dominant trees species.

4. Discussion

4.1. Decomposition rate of dominant species, and their initial nitrogen and lignin content

Decreasing carbon content almost had the same pattern as shown in figure 3. Nitrogen content of the dominant species was increasing until the fourth month of the decomposition process in both plots. It then increased or remained the same until the end of the study period. Nitrogen content of *C. javanica* and *C. acuminatissima* was higher than other dominant species in both forests, indicating that more nutrients from *C. javanica* and *C. acuminatissima* were released. This is a common phenomenon that the decrease of remaining weight during decomposition process was followed by the increase of nitrogen content [8], and the dynamics of nitrogen during the decomposition differed among species [41].

C/N ratio of leaf litter from the dominant species decreased in both study sites (figure 1). Initial C/N ratio was in the range of 28.76–39.68%. The order of C/N ratio from the highest to the lowest is as follow: *S. wallichii* > *A. excelsa* > *Q. lineata* > *C. acuminatissima* > *C. javanica*, which are 39.68 > 39.68 > 33.06 > 30.03 > 28.76 %, respectively. At the end of study period, C/N ratio of the dominant species was in the range of 18.67-24.72 (figure 3). The lowest C/N ratio was documented for *Quercus lineata* (18.67-19.35), while the highest was in the range of 22.30-24.72 for *Altingia excelsa*. During the decomposition processes, nutrient dynamics consisted of leaching, immobilization, and mobilization phases [19,34]. The phases from leaching to mobilization can be explained by the availability of carbon and nitrogen compounds [42-44]. In tropical forests, nitrogen mobilization commences at a C/N ratio of 30-40 [42,43]. Based on this finding, only C/N ratio of *A. excelsa* and *S. wallichii* were in the range of 30–40 until the second month of incubation. Those were decreasing below 30, followed by nitrogen mobilization occurred after this second month. Meanwhile, *Q. lineata*, *C. javanica* and *C. acuminatissima* were recorded to have lower C/N ratio after second month of incubation period until the end of experiment. Moreover, nitrogen mobilization occurred after the third month until the end of experiment.
(C/N ratio < 30), which was followed by the increase of nitrogen content (figure 2). This nitrogen release was subsequently available for the uptake by trees. Therefore, it is predicted that the high litter decomposition rate of dominant species contributed to the rapid release of nitrogen. This suggest the dominant species in both forests have a function in rapid nutrient release, which is related to litter quality [42,43,45].

4.2. The combination of litterfall and turnover rate of decomposed litterfalls

The combination of biomass production from the litterfall and its nutrient return is the major source of energy for microorganism during decomposition process, and mineral nutrient for plant growth. These components are important for the nutrient cycles in the ecosystem. The nutrient process is highly influenced by litterfall production, litter quality, tree species composition, seasonality and faunal activities, site condition, and the vegetation types [2,13,14,16]. Therefore, we compared some studies of biomass and litter production in several ecosystem types (Table 1). The result showed that litter biomass on the forest floor of Mt. Halimun was lower than other forests. High amount of annual litterfall in the area resulted in a lower accumulation of litter on the forest floor, due to the high rate of decomposition and leaf turnover rate. This suggests that nutrient cycling is faster in the Mt. Halimun than that of heath and peat swamp forests. In addition, the annual leaf litterfall rate was higher in Mt. Halimun than in mixed-dipterocarp forest, resulting in less leaf litter on the forest floor but similar turnover rate. Furthermore, the rate of nutrient cycling in the studied forests was higher than in the mixed-dipterocarp forests of Borneo [4]. It can be concluded that the nutrient cycles in Mt. Halimun occurred rapidly than other ecosystem types in Indonesia.

Table 1. Input and output of litter production in some forest type in Indonesia, based on several literatures.

|                              | HF<sup>b</sup> | PSF<sup>b</sup> | MDF<sup>a</sup> | GHSNP<sup>c</sup> |
|------------------------------|---------------|---------------|----------------|-----------------|
| Annual litterfall (t ha<sup>-1</sup> yr<sup>-1</sup>) | 6.2           | 6.5           | 8.3            | 7.0-8.2         |
| Annual leaf litterfall (t ha<sup>-1</sup> yr<sup>-1</sup>) | 3.4           | 3.5           | 4.4            | 5.4-6.1         |
| Leaf litter on the forest floor (t ha<sup>-1</sup>) | 7.5           | 15.8          | 5.7            | 2.3-2.7         |
| Leaf turnover rate (yr<sup>-1</sup>)<sup>**</sup> | 0.5           | 0.2           | 0.8            | 0.78 **         |

Mixed dipterocarp forest (MDF), heath forest (HF) and peat swamp forest (PSF). <sup>a</sup>[4], <sup>c</sup>GHSNP (Gunung Halimun Salak National Park, [46]).  <sup>b</sup>Turnover rate was estimated from the decomposition rate of mixed litter on the forest floor from the litter bags experiment, results of this study.

The turnover period of litter mass was longer for A. excelsa (1.0–1.5 y) than other species in the range of 0.9-1.2 y, those were C. acuminatissima, C. javanica, Q. lineata, and S. wallichii. This value is still in the range of turnover rate in some other tropical forests [17]. The slow and constant total turnover period could be derived from high lignin content of A. excelsa. Some other cases reported that lignin, lignin/N and lignin/C were the best predictors for the rate of decomposition [7,12,47]. Therefore, A. excelsa, that contained substantial lignin, should control the rate of decomposition. Turnover rate of C. acuminatissima was recorded for 0.88–0.92 y, in combination with low lignin content, this predicted that N and C/N are good predictors for the rate of decomposition of this species [9].

The decomposition rates were significantly higher in the plot 2 near Cikaniki research station than in the plot 3 (Wates/near the border). It is predicted that the stable soil temperature in the plot 2 maintains high level of microbial activity in the soil and leads to a high litter decomposition rate [46,48,49]. Furthermore, the higher weight losses of leaf litter in the plots 2 are possibly a consequence of moisture conditions [16,50,51].
5. Conclusions
The rates of litter decomposition of *Q. lineata* were higher than other species, due to the high nitrogen content. Meanwhile, the lowest decomposition rate was documented for *A. excelsa*. Carbon and nitrogen released pattern was almost similar for the five dominant species in two locations. The nitrogen released of tree dominant species occurred at the first until the third months of incubation time, and gradually released until the end of study period. Based on the rate of decomposition, it was predicted that high litter decomposition rate of dominant species contributed to the rapid release of nitrogen in the forests at both locations.

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