Litter productivity and leaf litter nutrient return of three native tree species in drained tropical peatland, Riau-Indonesia

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Abstract. Information on litter productivity and its nutrient return of tree species are essential for consideration in selecting tree species. The study was carried out to quantify the litter productivity and macronutrient (N, P and K) deposition through leaf litter to forest floor under 2 – 3 years old three native tree species of tropical peatland forest. Those three species are mahang (Macaranga pruinosa), geronggang (Cratoxylum arborescens) and skubung (Macaranga gigantea). These three native species coincide with one exotic species krassikarpa (Acacia crassicarpa) were planted on the drained tropical peatland in Riau using a randomized completely block design. Litter trap was set up on this experimental plot for litter productivity measurement. Nutrient content of leaf litter was analyzed to quantify the nutrient return. Results showed that the maximum litter productivity and leaf litter nutrient return was found in geronggang. Litter productivity, N return, P return, and K return of this native tree species were 7.04 ton ha\(^{-1}\) yr\(^{-1}\), 60.69 kg ha\(^{-1}\) yr\(^{-1}\), 10.82 kg ha\(^{-1}\) yr\(^{-1}\), and 57.68 kg ha\(^{-1}\) yr\(^{-1}\), respectively. These results suggested that forest and land productivity could be better maintained by Cratoxylum arborescens plantation than other native tree species. In terms of litter productivity and leaf litter nutrient return, this species is, therefore, more recommended than Macaranga pruinosa and M. gigantea.

1. Introduction

Riau, one of the Indonesia provinces, covers a large area of tropical peat-swamp forests. The peat-swamp forests covered about 1.4 million ha in 2009, or about 48% of the total forested area of Riau [1, 2]. However, most of this peat-swamp forest was degraded due to some factors such as illegal logging, illegal land conversion, and forest fire, where these factors in practice were related to canal development. The recent effect of those illegal activities was choking smog in 2013, which was followed by broadly negative impacts on civilization (e.g., health, economic, social, traffic, etc.). This degraded forest needs to be rehabilitated because the forest has many essential functions such as conservation, hydrology, carbon sink, and the habitat of several highly economic value trees [3 - 5].
Tree species selection is vital in forest rehabilitation. Some studies suggested that litter productivity and nutrient return are essential inputs for species selection [6 - 10]. This information is required because it could be used as a parameter to predict the relationship between tree species and nutrient recycling in a forest ecosystem, and the relationship between tree species and forest productivity and its sustainability.

This study observed litter productivity and leaf litter nutrient return to forest floor under 2 – 3 years old three native species of tropical peat forest for species selection requirement. The native species studied were mahang (*Macaranga pruinosa*), geronggang (*Cratoxylum arborescens*) and skubung (*Macaranga gigantea*), which were selected based on their high potentials for degraded peat forest rehabilitation in Riau. All native species are a pioneer as well as fast-growing species and naturally distributed around peat forests in Riau [11]. Furthermore, the woods produced from those species were reported suitable for pulpwood, thus have the possibility for pulpwood forest plantation [12, 13].

2. Material and method

The study site was at Pelalawan District of Riau Province (101°41’06” – 101°41’10” E, 0°19’42” – 0°19’48” N, and 12 m asl). The peat soil type is dominated by hemist with peat depth about 3 m below the soil surface. The climate is type A, based on Schmidt-Ferguson classification with mean annual temperature and relative humidity were 26.2°C and 90 % (automatic weather Station data during the period of March 2011 – April 2012), while annual precipitation is 1959 mm (Observatorium data during the period of January – December 2013).

Three native species: mahang (*Macaranga pruinosa*), geronggang (*Cratoxylum arborescens*) and skubung (*Macaranga gigantea*) and one exotic species: krassikarpa (*Acacia crassicarpa*) were planted in 2011 in one experimental plot using a Randomized Completely Block Design (RCBD). Each species comprised of 5 blocks as replications and used 2 m x 3 m initial spacing, thus the experimental plot comprised of 20 units. The study was carried out in these experimental plots from March 2013 to February 2014, when all species had similar ages of 2 – 3 years old.

Litter trap (1 m x 1 m x 0.7 m) was set up in each unit for measurement of litterfall of all species, so a total of 20 litter traps were installed. The litterfall was collected monthly for 1-year observation (February 2013 – February 2014) for native species and for ten months observation for exotic species (May 2013 – February 2014). The litter samples from each trap were collected separately and were divided into different litter fractions, namely leaf, fine wood, branch and reproductive organ. The samples were then oven-dried at 70°C to get a constant weight (about two days) and then weighed to obtain monthly litterfall. These data were used to quantify annual litterfall per ha (litter productivity).

Leaf litter samples under each stand (3 blocks/replications per species) were collected for nutrient analysis. These samples were then sent to the laboratory for N, P and K content analysis. Total N and P were determined based on the Kjeldahl and Bray method, respectively, while K was determined by the leaching method (extracted in ammonium acetate solution 1 N and pH) [14]. This nutrient content and litter productivity data were then used to quantify annual nutrient return to the forest floor through leaf litterfall. The nutrient return was expressed as the percentage of nutrient content in leaf litterfall multiplied by annual leaf litterfall.

In order to obtain the relationship between growth and litter productivity, tree crown area was observed. This measurement was conducted at 2 and 2.5 years old.

Analysis of Variances (using the RCBD model) was used to determine the differences in litter productivity and its nutrient return between the studied species. However, data transformation with log (x+2) was used on litter productivity data before the one-way ANOVA test. Significantly different data were further analyzed using a Duncan test. Correlation analysis was used to define the relationship between litter productivity and tree growth.
3. Result and discussion

3.1. Litter productivity

Litter productivity is significantly different \((p < 0.05)\) among the 2 – 3 years old native species. In detail, litter productivity of geronggang \((7.04\ \text{ton ha}^{-1}\text{yr}^{-1})\) was significantly \((p < 0.05)\) higher than mahang \((4.74\ \text{ton ha}^{-1}\text{yr}^{-1})\) and skubung \((4.96\ \text{ton ha}^{-1}\text{yr}^{-1})\) (figure 1). It was found that only geronggang had marginally higher litter productivity than exotic species krassikarpa. Litter productivity between geronggang and krassikarpa was differed by 9.4%.

The maximum litter productivity of geronggang compared to other species is probably related to growth traits and crown form. All studied species are light-demanding species that require full sunlight \((21)\). However, the crown of geronggang was relatively thicker than mahang and skubung at 2 – 3 years old, thus more leaves were shaded. In pioneer tree, shade could induce leaf abscission through increasing the proportion of far-red radiation, triggering the expression of stress-responsive genes, inducing the level of plant stress hormones (ethylene, salicylic acid, jasmonic acid, and abscisic acid), and regulating cell wall degradation as well as programmed cell death \([15-17]\). Thus, more geronggang leaves were shed as litter to forest floor than two other species. Meanwhile, krassikarpa had a similar crown form with geronggang, but due to its higher tree mortality than geronggang, it had slighter litter productivity than geronggang.

![Figure1](image.png)

**Figure1.** Litter productivity of mahang, geronggang, skubung and krassikarpa observed during 2 – 3 years old stand in drained tropical peatland in Riau. Remarks: data \(\pm SE\); different letter above the bars means significantly different between the data \((p < 0.05)\).

Litter productivity and tree crown growth of mahang and geronggang were positively correlated \((r = 0.64 – 0.81)\), which means the higher the tree crown’s growth, the higher the litter productivity. This fact is related to the probability that the leaf will be shed as litter on the broader tree crown than the slighter tree crown. These results were similar to the study by \([18]\) on *Astrocaryum* sp. and *Eschweilera* spp. in the primary forests of Amazon, Brazilia. However, in contrast, the negative correlation was revealed in skubung. The other probability could explain this fact that leaf of skubung within a wider crown is more vigor than other trees; hence the leaf shed is relatively minimum than in slighter crown.
Table 1. Coefficient of correlation (r) between monthly litterfall of mahang, geronggang, skubung and krassikarpa with rainfall and tree crown growth variables in drained tropical peatlands in Pelalawan, Riau.

| Tree species | Crown diameter | Crown area |
|--------------|----------------|------------|
| Mahang       | 0.64<sup>a</sup> | 0.66<sup>a</sup> |
| Geronggang   | 0.60<sup>ns</sup> | 0.61<sup>ns</sup> |
| Skubung      | -0.59<sup>ns</sup> | -0.59<sup>ns</sup> |
| Krassikarpa  | 0.81<sup>a</sup>  | 0.73<sup>a</sup>  |

Remarks: ns = not significant (p > 0.05).
    s = significant (p < 0.05).

The fact that litterfall of tree species in this study was influenced by crown coverage indicated that some tree crown growth-related silviculture practices could be necessary for the nutrient cycling or soil productivity. One of those silviculture practices was spacing or tree density management [19, 20]. The spacing or tree density management in this study aimed for growth or tree productivity and soil productivity. Tree spacing must be managed to obtain the optimal crown growth that would result in optimal litterfall production, which will lead to maintained soil productivity.

Litter productivity ranged from 4.74 ton ha<sup>-1</sup> yr<sup>-1</sup> to 7.04 ton ha<sup>-1</sup> yr<sup>-1</sup> for all native tree species in this study. This productivity was higher than other native tree species of peat swamp forests such as *Kompassia malaccensis* (3.89 ton ha<sup>-1</sup> yr<sup>-1</sup>) and *Melaleuca cajuputi* subsp. *cumingiana* (2 ton ha<sup>-1</sup> yr<sup>-1</sup>), but lower than *Shorea uliginosa* (9.18 ton ha<sup>-1</sup> yr<sup>-1</sup>) [21, 22].

The litter productivity of the studied species was lower than average litter productivity in the tropics, i.e.,> 10 ton ha<sup>-1</sup> yr<sup>-1</sup> [23]. This result is probably due to the relatively young stand (2 – 3 years old) used in the study. However, litter productivity of young geronggang was almost similar to the older tropical tree species such as 4 years old *Eucalyptus pellita* [24] and 7 – 8 years old *Terminalia superba* [25] which had litter productivity of 7.38 ton ha<sup>-1</sup> yr<sup>-1</sup> and 7.10 ton ha<sup>-1</sup> yr<sup>-1</sup>, respectively.

3.2 Nutrient return of leaf litterfall

The highest amount of nutrients, i.e., nitrogen (N), phosphorus (P) and potassium (K), returned to the forest floor was from leaf litter of geronggang (Table 2). It was slightly higher than the nutrient return of krassikarpa and skubung (p > 0.05) but considerably higher than that of mahang (p < 0.05).

The orders of nutrient return of native species were slightly different for each nutrient element. N- and K-return were in a pattern of geronggang > skubung > mahang. N-return was not significantly different (p > 0.05), while K-return was only significantly different (p < 0.05) between geronggang and mahang. Meanwhile, P-return was in a pattern of geronggang > mahang > skubung. This P-return of geronggang was significantly higher than that of the two other native tree species (p < 0.05).

Table 2. The variation of nutrient return through leaf litterfall of mahang, geronggang, skubung and krassikarpa at 2 – 3 years old stand in drained tropical peatland in Pelalawan, Riau.

| Tree species | Nutrient return (kg ha<sup>-1</sup> yr<sup>-1</sup>) |
|--------------|-----------------------------------------------|
|              | N     | P     | K     |
| Mahang       | 38.12 ± 1.63<sup>a</sup> | 5.64 ± 0.44<sup>b</sup> | 34.54 ± 1.97<sup>b</sup> |
| Geronggang   | 60.69 ± 10.90<sup>a</sup> | 10.82 ± 1.81<sup>a</sup> | 57.68 ± 10.57<sup>a</sup> |
| Skubung      | 38.70 ± 4.74<sup>a</sup>  | 5.56 ± 0.40<sup>b</sup>  | 39.86 ± 5.37<sup>ab</sup> |
| Krassikarpa  | 54.49 ± 4.76<sup>a</sup>  | 8.32 ± 0.57<sup>a</sup>  | 54.61 ± 4.16<sup>ab</sup> |

Remarks: data = mean ± SE, different letters following the value in the same column mean it was significantly different (p < 0.05).
The fact that litter productivity of geronggang was considerably higher than the other native tree species and krassikarpa suggested that its nutrient return was better than that of those trees. High nutrient return is vital as nutrient resources to maintain productivity and stability of unfertile soil in peatland. Moreover, sufficient nutrients (amount and sustainability) would maintain not only tree productivity, but also the productivity of other organisms in the forest ecosystem [26].

Some previous studies on tree litter nutrient return had been conducted in a tropical zone. [6] investigated litter nutrient return on ten tropical tree species at 23 – 26 years old stands planted in 3 m x 3 m spacing in Puerto Rico. In comparison, geronggang (spacing 3 m x 2 m) in recent study had higher nutrient return than some species [6], e.g. *Pinus elliottii* (nutrient return: N = 49.4 kg ha\(^{-1}\) yr\(^{-1}\), P = 2.8 kg ha\(^{-1}\) yr\(^{-1}\), and K = 37.1 kg ha\(^{-1}\) yr\(^{-1}\)) and *Anthocephalus chinensis* (nutrient return: N = 55.3 kg ha\(^{-1}\) yr\(^{-1}\), P = 3.3 kg ha\(^{-1}\) yr\(^{-1}\), and K = 30.5 kg ha\(^{-1}\) yr\(^{-1}\)). However, the nutrient return of geronggang’s litter was fewer than four years old *Eucalyptus pellita* in Riau (spacing = 2 m x 3m). [24] reported that N, P, and K return of *Eucalyptus pellita* were 94.0, 1.9 and 56.4 kg ha\(^{-1}\) yr\(^{-1}\), respectively.

N and P return of mahang, geronggang and skubung in this study were higher than temperate tree species that had older age [27]. N return of mahang, geronggang and skubung were 2.77, 4.41 and 2.81 fold than Norway Spruce (one of the temperate species), respectively. While P return of three native tree species was 1.52, 2.92 and 150 fold than that of temperate tree species, respectively. The nutrient return is the function of litter productivity, so the higher nutrient return in this study than the temperate trees is due to the higher litter production of tropical tree species than temperate tree species [7, 28].

4. Conclusion
Geronggang (*Cratoxylum arborescens*) showed the highest litter productivity and nutrient return from leaf litterfall among the tested native tree species, and they were slightly higher than the exotic species krassikarpa. These higher litter productivity and nutrient return of geronggang could better maintain the forest and land productivity than the other two native tree species. Therefore, this native tree species is recommended for plantation in drained tropical peatland, either for rehabilitation or for pulpwood forest plantation.

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