Litter Production and Decomposition in Dry Dipterocarp Forest and Their Responses to Climatic Factors

Phongthep Hanpattanakit and Amnat Chidthaisong

Abstract— *Understanding carbon processes in tropical forests is crucial for evaluating their sources or sink capacity, climate feedbacks, and hence the overall global carbon cycle. One of the important porcess of tropical carbon cycle is litter production and decomposition. The objectives of the present study are to quantify litterfall production and litter decomposition rate constant in a dry diptercarp forest and its responses to environmental factors. The study was carried out to determine the annual litterfall production by using litter traps method and the decomposition constant (k) of 4 dominant tree species of dry dipterocarp forest; Afzelia xylocarpa,* Barringtonia acutangula, *Dipterocarpus obtusifolius, and Dipterocarpus tuberculatns. Litter decomposition was carried out by using litter bag method during June 2009 – May 2010. The average annual litterfall was 7.26 ton ha^{-1} $year^{-1}$, of which 87% was leaf litter. Litter production occurred throughout the year but the high rate was found during dry period (November – April). The maximum litter fall was in January, 2010, which was 3.6 ton m^{-2} $year^{-1}$ or 34% of total litter fall during a year. The high soil temperature and low soil moisture have resulted in high total litterfall production in this forest. It was found that the litterfall production was positively correlated to soil temperature ($y = 52.46 x – 953.53$, $R^2 = 0.37$) but negatively correlated to soil moisture ($y = 1363.7 e^{-0.07}$, $R^2 = 0.32$). Based on the number of data points used in these regression analysis, these correlations are statistically significant at $p \leq 0.01$. Investigating the litter decomposition reveals that decomposition rate of leaf was higher than branch in all species. The average decomposition rate constant (k) of leaf and branch of 4-main species was 0.26 and 0.l4, respectively. The leaf of Afzelia xylocarpa showed the highest and leaf of Dipterocarpus tuberculatns the lowest decomposition rate constant. In contrast, the branch of Dipterocarpus Obtusifolius and Barringtonia acutangula shows the highest decomposition. Both compositions of all species were positively correlated to soil moisture and soil temperature. From these data, it was estimated that 7.26±0.94 ton dry matter $ha^{-1}year^{-1}$ of litter was decomposed annually and subsequently released 13.32 tonCO_2 ha^{-1} to the atmosphere..*

Keywords— **Litterfall Production, Litter decomposition, Dry Dipterocarp Forest.**

1. INTRODUCTION

Litter production and decomposition are the important components of carbon cycling pathway in the forest ecosystem. They are directly related to photosynthesis and microbial respiration which play an important role in the global carbon cycle. The tropical forests also contain higher carbon storage than other regions, approximately 60 percent of total carbon in biomass stock on the Earth [9]. It has annual net primary production about 32% of global terrestrial photosynthesis [11]. Dlioksumpun *et al.* (2009) studied the net primary production (NPP) in the Sakaeral Dry Evergreen (DEF) and the Maeklong Mixed Deciduous Forests (MDF) in Thailand. They found that NPP in DEF (15.3 tC ha^{-1} yr^{-1}) was higher than MDF (6.2 tC ha^{-1} yr^{-1}). However, the litter biomass product in MDF was higher than DEF about 7% because the plant in MDF shed leaves while in DEF did not.

The Litter on the forest floor acts as input-output system of nutrient and rates at which forest litter falls and subsequently, decomposes contribute to the regulation of nutrient cycling and primary productivity, and to the maintenance of soil fertility in forest ecosystems [12, 21, 23, 24, 28]. Plants and microbes in forest get benefits from nutrients released from litter decomposition. Therefore, it is critical to understand the amount and pattern of litterfall in tropical forest ecosystems [3, 15, 17, 18, 22, 32].

During litter decomposition, chemical compositions in litter are converted from fresh litter to humus. Microorganisms start degrading plant litter as soon as it has fallen to the ground and been invaded by decomposers, that is fungal mycelium and bacteria. In tropical forest ecosystem, decomposition processes of litter are rapid [30]. Glumphabutr (2004) studied the annual CO_2 release of litterfall in Moist Evergreen Forest (MEF), Dry Evergreen Forest (DEF), and Hill Evergreen Forest (HEF), Chanthaburi Province, Thailand. Their results showed that the decomposition rate of DEF, MEF and HEF were 7.44, 5.86, and 2.80 ton dry matter ha^{-1} yr^{-1}, respectively. These indicate that decomposition are different in each forest type depending on community of plants and climatic condition. The important issues related microorganism activity to biomass decomposition is physical and chemical properties of biomass such as

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the value of C/N ratio. Furthermore, climatic condition affects to the activity and amount of microorganisms. The important components of climatic condition are temperature and moisture [33]. These factors will affect the development of vegetation and microbial activity which decomposes organic matter on surface [27].

In the tropics, our understanding of carbon cycle responses to both short-term as climate variability and long-term changes as climate change is still very poor. Therefore, improving our knowledge on carbon processes in tropical forests is crucial for evaluating their sources or sink capacity, their climate feedbacks, and hence the overall global carbon cycle. The objectives of the present study are to quantify litterfall production and litter decomposition rate constant in a dry diptercarp forest and its responses to environmental factors.

2. MATERIALS AND METHIDS

a. Site Description

This study was carried out within dry dipterocarp forest of King Mongkut's University of Technology Thonburi, Ratchaburi Campus in Ban Ranbua, Tambon Rangbua, Chombung District, Ratchaburi province (13^o 35' 13.3'' N, 99^o 30' 3.9" E, elevation of 110 m above mean sea level). The total area of dipterocarp forest used in this study covers 187.2 ha. This area has been kept as the dipterocarp forest for approximately (more than) 50 years. Communities around this forest have utilized it for energy (wood and charcoal), timber, and other products such as mushrooms and local hunting. As a result, most of the trees are those from the re-generated ones after being cleared occasionally by villagers. In 2009, aboveground trees were 6-7 years old with the average height and perimeter of 5 m and 16 cm, respectively. This forest ecosystem has been preserved and protected, and cutting of trees is no longer permitted, allowing forest to grow and recover towards becoming an undisturbed ecosystem. According to Phiancharoen *et al.*, (2008) there are about 77 tree species found in this study area. The main species are *Dipterocarpus intricatus*, *D. obtusifolius*, *D. tuberculatus*, *Shorea obtuse and S. siamensis*. This forest ecosystem is unique that while the aboveground biomass is periodically cut by villagers, the belowground biomass stays intact. Therefore, the aboveground to belowground biomass ratio for most of dominant species is <1.

The annual average of precipitation, air temperatures, and soil moisture at the study site during May, 2009 to April, 2010 were 102.47 mm/month, 7.33% (%WPFS) and 28.50 ^{o}C, respectively. The annual average of precipitation, air temperatures, and soil moisture at the study site on wet season (during May – October, 2009), and dry season (during November, 2009 – April, 2010) were 194.62 mm/month, 10.47 %WPFS, 27.38 ^{o}C, and 11.32 mm/month, 4.14 %WPFS, 29.62 ^{o}C, (Fig. 1).

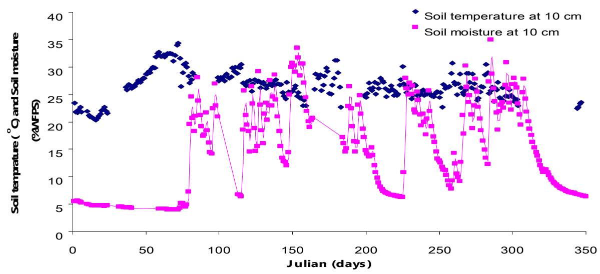

Fig. 1 Seasonal variation in soil temperature (^{o}C) (10 cm depth) and soil moisture (%WFPS) (10 cm depth) at dry dipterocarp forest, Ratchaburi site in the year 2009.

b. Litter Collection

Litterfall was measured from June 2009 to May 2011 by using permanent litter traps. Thirteen litter traps, each of 1 m^2 area, were randomly placed in 2500 m^2. Each trap consisted of 1-mm mesh nylon netting (on a PVC frame) suspended from a wire hoop and was raised 1 meter above the ground. The litterfall was collected at 30-day intervals. The collected litter at each time was oven-dried at 80 ^{o}C to constant weight. The dried litter was combined by month and plot at the end of each month.

c. Litter Decomposition

Branch and leaf litter decomposition was studied using the standard litter-bag technique [10]. Freshly fallen leaf litter was collected and air dried for decomposition study in April 2009. Leaf and branch decomposition of 4 dominant species in dry dipterocarp forest; *Afzelia xylocarpa* Kurz , *Barringtonia acutangula* Lin, *Dipterocarpus Obtusifolius* Teijsm., and *Dipterocarpus tuberculatns* Roxb were measured at the soil surface with three replications (36 bags per sample type of leaf and branch). The biggest size of leaf and branch of 4 dominant species were *Dipterocarpus tuberculatns* (26 wide x 40 lenght cm) and smallest of leaf and branch were *Afzelia xylocarpa* (4.5 wide x 6.5 lenght cm). One-hundred gram of air dried leaf and branch litters were placed inside 30cm x 30cm nylon bags with 1.0 mm mesh. Litterbags of each treatment (three plots) were randomly placed on the surface of forest soil in June 2009. The bags were attached to the forest floor by metal pins to prevent movement and to ensure contact between the bags and the litter layer. Tweenty-four litter bags per month were brought back to laboratory. The collected litters were oven-dried at 70 ^{o}C for 48 hours and brushed for cleaning out the soil contamination. The residual litter in each litter bag was weighed to find out the weight of biomass left or loss.

The study of leaf decomposition measures the lost weight of leaf through the period of time. The simplest model possible used to describe the decomposition rate is the exponential model or often called Olson's model [21] and the decomposition rate constant value (k) also can be calculated from this equation (Eq. 2.1).

$$Y_t = Y_o . e^{-kt} \qquad (2.1)$$

where; Y_o = initial weight of litter,

Y_t = weight of litter at time t

k = decomposition rate constant

e = natural logarithm

t = time of decomposition

Nevertheless, decomposition rate value may be shown in the form of percentage of annual decomposition by calculating the initial amount of litter and the amount of residual litter in the period of study time to show the value in the form of percentage of decomposition.

3. RESULTS AND DISCUSSION

a. Litter Production

Annual litterfall during June 2009 to May 2011at dry dipterocarp forest varied from 137 to 3583 g m^{-2} $year^{-1}$ (Fig. 2). The mean annual litterfall at this forest was 726 g m^{-2} $year^{-1}$or 7.26±0.94 ton dry matter ha^{-1} $year^{-1}$. The contribution of litterfall portion in total litterfall was 87 % or 9.06 ton dry matter ha^{-1} $year^{-1}$ of leaf, 11% or 1.17 ton dry matter ha^{-1} $year^{-1}$ of branch, and 0.29 ton dry matter ha^{-1} $year^{-1}$ of others including flowers and fruits.

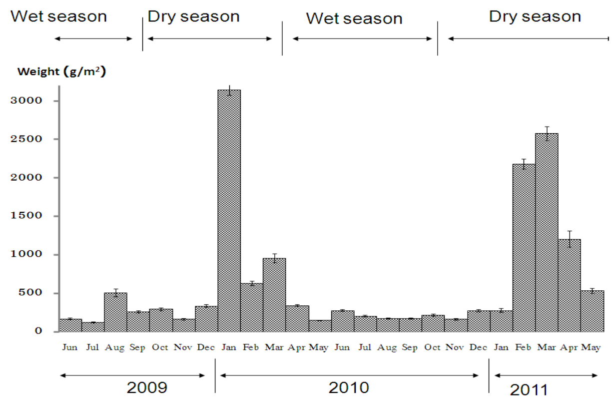

Fig. 2 Monthly litterfall in the dry dipterocarp forest during June 2009 to May 2011.

Seasonal variation in litterfall at the dry dipterocarp forest was showed in Fig. 2. Litterfall occurred throughout the year but the maximum rate of leaf shed occurred in cool and dry period (November - April). The maximum litter fall occurred on January, 2010 around 3.6 ton dry matter m^{-2} $year^{-1}$ or 45% of total litter fall during a year.

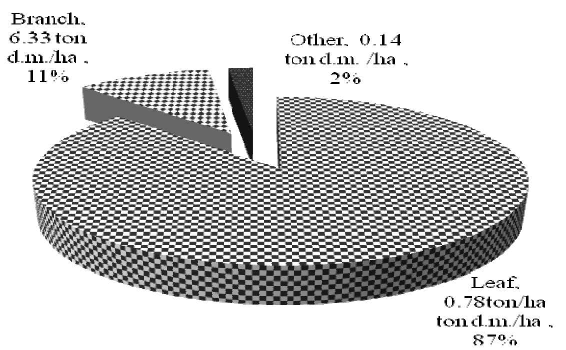

Fig. 3 Fraction of litterfall in the dry dipterocarp forest from June, 2009 to May 2011.

The forests in equatorial zone or tropical zone produce more litter product than temperate zone and polar zone [4, 14]. The comparisons of litter production in all regions of the world are done by O' Neill & De Angelis (1980) used woodlands data set from International Biological Programme (IBP). They reported that the averages litter production in arctic zone, cooling zone, and warm zone were 3.30, 4.60 and 4.70 $ton.ha^{-1}.yr^{-1}$, respectively, and the highest in tropical zone was 9.30 $ton.ha^{-1}.yr^{-1}$. The results are different depending on the temperature and precipitation in each zone. Normally, in tropical zone is higher temperature (approximately, 20-25 ^{o}C) and precipitation (more than 2000 mm.) than other zone.

The litterfall in the present study was concentrated during the cool and dry period (November-April) of the year and about 85% of total litterfall occurred during this period. Pattern of litterfall in this study was comparable with other results in other tropical forest in Thaniland [5, 17, 18, 29, 32]. The tendency of litterfall to be concentrated in cool and dry season is related to a combination of decline in temperature and lowered soil moisture during this period. Pascal (1988) had also reported that heavy litterfall of leaf occured during the dry season in evergreen forests of Attappadi, Western Ghats, India. This pattern can be explained by annual cycles of moisture and temperature. Leaf fall would occur to avoid seasonal moisture and temperature stress during dry period [15]. As mentioned above the annual litterfall in the dry dipterocarp forest was occurrence in dry period because the trees must adapt themselves to conform in dry-air condition by shedding their leaves to reduce evaporation so the amount of litterfall in this period is high. In the wet period which has high moisture content in the air, the trees do not need to reduce evaporation so the amount of litterfall is low. In addition, water stress could cause to synthesize abscissic acid in the foliage of plants which could stimulate senescence of leaves and other parts [19].

There are strong (99% confidence level) relationships between soil moisture (r^2 =0.32) and soil temperature (r^2 =0.37) with litterfall, as shown in Fig. 4-5.

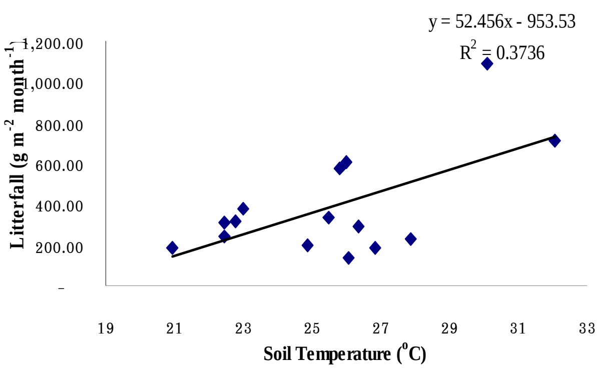

Fig. 4 The relationship between litterfall and soil temperature (n = 14; *p-value* = 0.01).

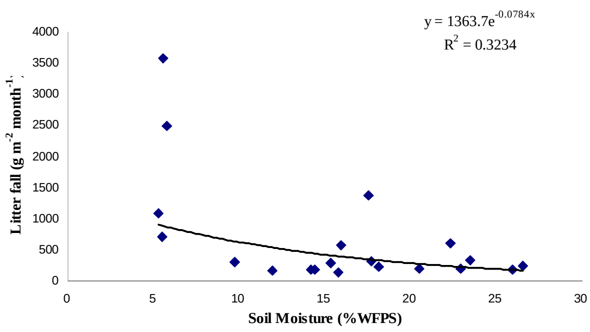

Fig. 5 The relationship between litterfall and soil temperature (n = 19; *p-value* = 0.008).

b. Litter decomposition

Mass loss of leaf and branch was significantly positively correlated (r^2 > 0.93, *p*-value < 0.05) with the time elapsed in months (Fig. 6-7). The decomposition rate of leaf litter in the dry dipterocarp forest was increased in the order: *Dipterocarpus tuberculatns* (DT) < *Dipterocarpus obtusifolius* (DO) < *Barringtonia acutangula* (BA) < *Afzelia xylocarpa* (AX). However, the branch litter decomposition rate was increaed in the order: *A. xylocarpa* < *D. tuberculatns* < *B. acutangula* and *D. Obtusifolius*. The leaf and branch litter disappearance was 13-16% during the first month. Rapid decline in leaf residual weights were noticed during the rainy months of July-October, nearly 55% in *B. acutangula* and *A. Xylocarpa*, 40% of *D. Obtusifolius* and 25% of *D. Tuberculatns*. In addition branch residual weights were noticed during the rainy season, nrarly 50% of *D. Obtusifolius*, 30% of *B. acutangula* and *D. Tuberculatns*, and 20% of *A. Xylocarpa*. The leaf litter were faster decomposed than branch litter of all plant species (Table 1). The relative mass loss trends amongst species observed during the 1st year but some of species were decomposed completely before a year.

Table 1. Decomposition rate constant (k) of four species leaf and branch litter in dry dipterocarp forest

Scientific name	*k* value of leaf (per month)	
	Leaf	**Branch**
Afzelia xylocarpa	0.36	0.10
Dipterocarpus Obtusifolius	0.29	0.17
Barringtonia acutangula	0.21	0.17
Dipterocarpus tuberculatns	0.17	0.13
Average	**0.26**	**0.14**

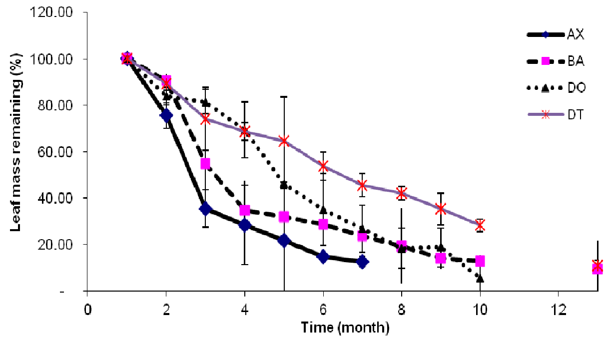

Fig. 6 Decomposition pattern of four species leaf litter in dry dipterocarp forest.

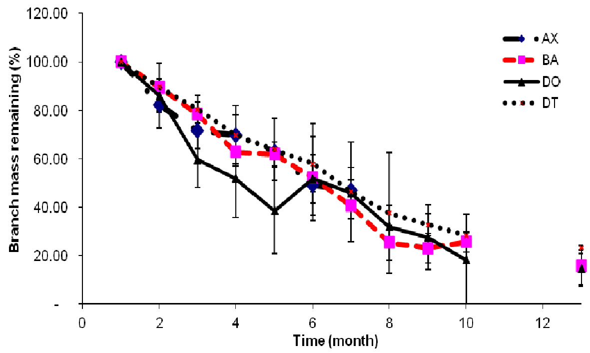

Fig. 7 Decomposition pattern of four species branch litter in dry dipterocarp forest.

In tropical forest ecosystem, decomposition processes of litter are rapid [30]. For example, the annual mass lose of hill evergreen forest, Doi-pui, Chiang Mai it was 56% per year [31]. In the dry evergreen forest, Sakaerat Environment Research Station, Nakhon Ratchasima was 48.77% per year [6]. Mangrove forest, Chanthaburi was 54.90% per year [1]. Tropicacal rain forest, Trinidad was 100% [7]. Our results show that the annual mass lose of the dry dipterocarp forest was 83% per year. Generally, the average value of *k*-value was calculated in each region of the world such as; in boreal region the *k*-value was in the rage of 0.223-0.446, cold temperate region was in the range of 0.140-0.693, warm temperate region was in the range of 0.162-0.751 and tropical region was in the range of 0.162-2.813 [19]. The average *k-value* of four species in leaf and branch litter at dry dipterocarp forest were 0.26 and 0.14, respectively (Table 1). The variability of decomposition rates is also high in tropical forest ecosystems but variability was not strongly related to site conditions and litter quality [3]. The high temperature and moisture ranges are probably the main driver for leaf and branch litter decomposition in the dry dipterocarp forest. There are strong (95% confidence level) relationships between soil moisture (r^2 = 0.22-0.96), soil temperature (r^2 =0.23-0.58) and litter mass loss as shown in Fig. 8-9.

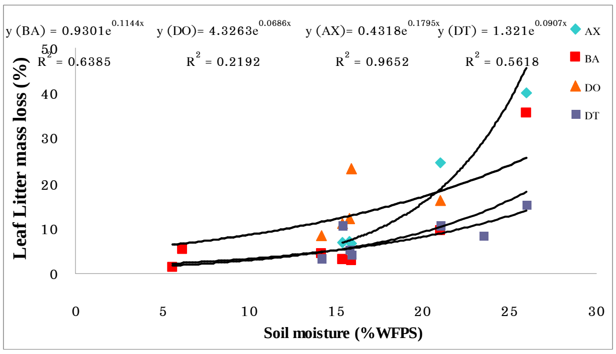

Fig. 8 The relationship between leaf litter mass loss and soil temperature (n = 7; *p-value* < 0.05).

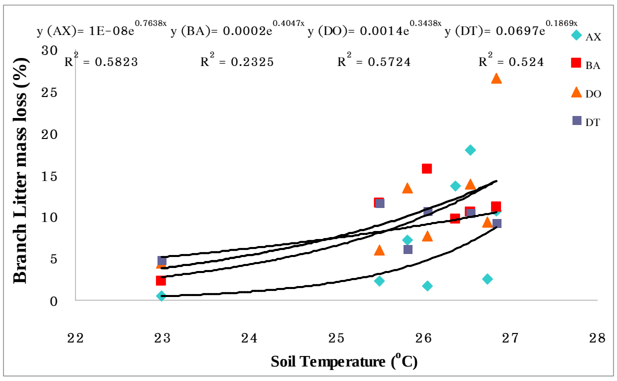

Fig. 9 The relationship between branch litter mass loss and soil temperature (n = 7; *p-value* < 0.05).

In addition, litterfall production and decomposition rate in each forest are related to CO_2 production and emission from soil surface. If litterfall production in forest is quite high and decomposition rate is rapid, the CO_2 emission to atmosphere is rapid, too. From the amount of litterfall and its decomposition rate, it was estimated that 7.26±0.94 ton dry matter ha^{-1} $year^{-1}$ of litter was decomposed annually and subsequently released 13.32 tonCO_2 ha^{-1} to the atmosphere.

4. CONCLUSION

This studies as dresses the litterfall pattern and decomposition rate constant in the dry dipterocarp forest. The average annual litterfall was 7.26 ton ha^{-1} $year^{-1}$, of which 87% was leaf litter. Litter production occurred throughout the year but the high rate was found during dry period (November – April). The litterfall production was positively correlated to soil temperature (y = 52.46 x – 953.53, R^2 = 0.37) but negatively correlated to soil moisture (y = 1363.7 $e^{-0.07}$, R^2 = 0.32). For litter decomposition, the average decomposition rate constant (*k*) of leaf and branch of 4-main species was 0.26 and 0.l4, respectively. Both compositions of all species were positively correlated to soil moisture and soil temperature.

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