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Above ground biomass and litter productivity in relation with carbon and nitrogen content in various landuse small watershed, Lower Northern Thailand

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Abstract

There have been few studies quantifying litterfall and litter decomposition in relation to carbon and nitrogen return to the soil in upland areas following forest conversion to agriculture such as with the establishment of Para rubber tree plantations. Mean annual litterfall production, litter decomposition rates and carbon and nitrogen returns in a secondary mixed deciduous forest were significantly higher than in a Para rubber tree plantation. The aboveground biomass carbon of the tree such as stems, branches and leaves have been collected and dried at laboratory, and the dry biomass of different sections of the tree are presented in Table 5. The result of carbon analysis through CHN Analyzer is presented in Table 6. It is observed with mixed deciduous forest for *Haldina cordifolia* that average leaf, stem and branch contained 43.32, 47.49, and 46.01% carbon, respectively. For *Albizia odoratissima*, average leaf, stem and branch contained 46.34, 45.98 and 46.61 % carbon, respectively. For *Lagerstroemia duperreana*, average leaf, stem and branch contained 47.61, 47.96 and 46.88 %. For *Croton roxburghii*, average leaf, stem and branch contained 45.29, 47.53 and 45.68 %. It is observed in para rubber plantation for *Hevea brasilliensis* that average leaf, stem and branch contained 51.20, 50.66, 49.83 %.

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Introduction

The continuing rise of atmospheric carbon dioxide (CO_2) concentration will most likely affect the stability of earth's climate system, the health of humans, and the sustainability of socioeconomic systems. Carbon dynamics in terrestrial ecosystems has been one of the major factors affecting CO_2 concentration in the atmosphere (IPCC, 2001). Quantification of the spatial and temporal variability of carbon sources and sink at regional to global scales has been challenging because land-atmosphere carbon exchange is influenced by many, including land use and land cover change, CO_2 fertilizer, nitrogen fertilizer and climate variability and change. Trees act as a sink for CO_2 by fixing carbon during photosynthesis and storing excess carbon as biomass. The net long term CO_2 source or sink dynamics of forest change through time as trees grow, die and decay. In addition, human influences on forests can further affect CO_2 source or sink dynamics of forest through such factors as fossil fuel emissions and harvesting or utilization of biomass (Nowak and Crane, 2002). As tree grow and their biomass increases, they absorb carbon from the atmosphere and store it the plant tissue (Mathew *et al.*, 2000) resulting in growth of different parts. Active absorption of CO_2 from the atmosphere in photosynthesis process and its subsequent storage in the biomass of growing trees or plants is the carbon storage (Baes *et al.*, 1977). Litterfall and litter decomposition and subsequent nutrient release represent major biological pathways for elemental transfer from vegetation to the soil and play an important role in regulating nutrient cycling and in maintaining soil fertility in forest and agro-ecosystems (L. Yang and J. Pan, 2003). In forest and agro-ecosystems, litter acts as an input-output system for nutrients and the rates at which the forest litter falls contribute to the regulation of nutrient cycling, fertility sustenance and primary productivity in forest and tree-based ecosystems (B. Berg,2000; J. Ranger *et al* ., 2003). Many studies have been carried out on litterfall and decomposition dynamics in both tropical and temperate forests and agro-forest systems (M.E. Issac *et al.*, 2005) Litterfall and decomposition can be impacted both by the structural and floristic changes that occur from secondary succession (R.L. Chazdon, 2003). Past research has demonstrated that structural variables such as canopy closure, basal area and stem density generally recover much faster than pre-disturbance species composition (R.L. Chazdon, 2003). More commonly, studies compare a secondary forest of a single age to plantations or to primary forest (Y. Li, 2005). or compare data worldwide across forests of different ages (S. Brown and A.E. Lugo, 1990)

Although, there have been studies on litterfall production and leaf litter decomposition (S.M. Sundarapandian and P.S. Swamy, 1999) in tropical forest ecosystems, information on litterfall production and leaf litter decomposition in natural forest and Para rubber tree plantation systems in lower Northern Thailand is limited. Para rubber tree plantations are a recent economic agricultural land use for the people in lower Northern Thailand. The Para rubber tree system is a simple system in upland areas and it is a nearly natural forest system; however, different systems could be expected to have different rates and amounts of nutrient cycling. Conversion of natural forest into Para rubber tree plantation affects the process of nutrient cycling due to the management practices involved. Thus, it would be important to study litterfall, litter decomposition and factors regulating the carbon and nitrogen return in these systems to improve recommendations for their management and conservation to mitigate the global greenhouse effect.

The present study was carried out to comparatively measure above ground biomass, litterfall production and litter decomposition in relation to carbon and nitrogen returns to the soil in an upland area of secondary mixed deciduous forest (SMDF) and Para rubber tree plantation (PAR) in Huai Lam Kra Don subwatershed, Phitsanulok province, Thailand. The aims of the work presented here were to investigate the litter dynamics, to understand decomposition in relation to the carbon and nitrogen returns to soil patterns following forest conversion to Para rubber tree plantation, and to use linear regression to analyze litterfall and climate data obtained from the study area. The aims of study they are1) measure carbon sequestration rate and aboveground biomass carbon potential 2) litter fall production in recently converted Para rubber tree plantations will be low compared to native forest, 3) forest litter decomposition rates in native forest will be more rapid than in Para rubber tree plantations and 4) carbon and nitrogen returns to the soil in Para rubber tree plantations will be low compared to native forest.

Material and methods

Site description

The study site was located in the Huai Lam Kradon subwatershed in the Wang Thong watershed in lower northern Thailand at an altitude of approximately 700–860 m above sea level. The study area covered forest in the Thung Salang Luang National Park and some adjacent Para rubber tree plantation. The geological formation of the study area is composed of sedimentary rock and metamorphic rock (Royal Forest Department, 1995). The climate is tropical and sub-tropical with three distinct seasons—winter, summer and monsoon. While the mean temperature is 22 °C, March to June are the hottest months with a mean maximum temperature of 29 °C, and November to February are the coldest months with a mean minimum temperature of 17 °C. The maximum rainfall occurs during the monsoon season from May to October with a mean annual rainfall of 1,300–1,700 mm (Fig. 1). Two major land uses—namely, mixed deciduous forest and Para rubber tree (*Hevea brasiliensis* Müll. Arg.) plantation—were selected as representative land uses for the study. The study was undertaken from April 2010 to March 2011.

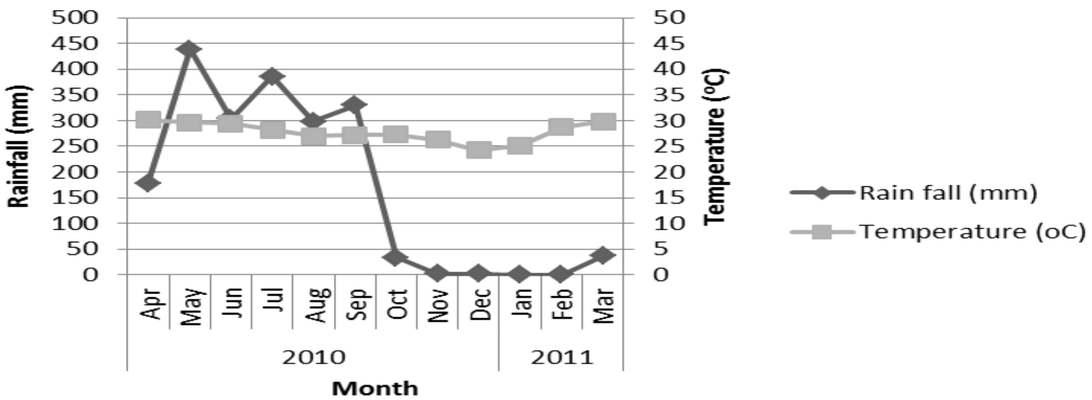

Fig. 1. Monthly rainfall (mm) and temperature (°C) from April 2010 to March 2011 at Protection Unit 12 of Thung Salang Luang National Park. Data from Royal Irrigation Department telemetering weather station

Aboveground biomass

The aboveground biomass in mixed deciduous forest was estimated by Equations 1-4 (Ogawa *et al.* 1965):

Ws	=0.02903(D2H) 0.9813	(1)
Wb	=0.0033487(D2H) 1.0270	(2)
Wl	=(28.0/Wtc+0.025)-1	(3)
WT	=Ws+Wb+Wl	(4)

Where

Ws, Wb, Wl = dry weight of stems, branches and leaves of a tree, total biomass aboveground biomass (kg)

Wtc = Ws + WbWT = obtained by summing by the partial biomass (kg)

In case, Para rubber plantation was estimated by Equations 5-8 (Yoosuk, 2005):

Stem =Log WS = 0.866 log D2H -1.255 (5)
Branch=Log WB=1.140 log D2H - 2.657 (6)
Leaf =Log WL=0.741 log D2H - 1.654 (7)
Root =Log WR=0.709 log D2H - 0.131 (8)
Where
WS =dry weight of stems biomass
WB =dry weight of branches biomass
WL =dry weight of leaves biomass
WR =dry weight of root biomass

Litterfall collection

Litterfall was collected monthly for one year at 1.30 m above ground level using nine litter traps (1 × 1 m) set up in each plot of 50 × 50 m, with four plots providing a total of 36 traps per land use. All accumulated litter in each trap was collected every month during the one-year period, and afterwards sorted into leaves, twigs, barks, reproductive, and other fractions; each fraction was oven dried at 80 oC for 24–48 hr and then weighed for analysis of the total carbon and total nitrogen content. Climatic variables (rainfall and maximum and minimum temperature) were also monitored on site during the study period, *using appropriate measuring equipment*.

Litter decomposition and calculation

Litter decomposition data were collected from a mix of leaves sampled from the five dominant species. The weight was calculated by the important value index (IVI) ratio using a 30 g subsample from each leaf sample. Each subsample was placed in a vinyl litter bag (30 × 30 cm) with 36 bags per plot of 50 × 50 m, so the four plots had a total of 144 bags per land use. Three bags were retrieved randomly from the field at one-month intervals for 1 yr. The contents were emptied and extraneous material, such as soil, visible animals and fine roots were removed. The remaining sample was oven dried at 80 oC for 24–48 hr to constant weight to determine the final weight of the sample and for analysis of the total carbon and total nitrogen content. A single exponential equation, according to an exponential decay model (J.S. Olson, 1988) was used to calculate the decomposition constant (k) and the rates of loss of carbon and nitrogen using Equation (9)

Ln (Xt / Xo) = -kt (9)
Where
Xo=the original weight of litter,
Xt=the final weight of litter,
k=decomposition constant,
t=the time,
Ln=natural logarithm.

Carbon and nitrogen analysis

The carbon and nitrogen analysis of plant litter was carried out at the Department of Silviculture, Faculty of Forestry, Kasetsart University using a CHN Analyzer (PerkinElmer 2400 series II CHNS/O).

Data analysis

Analysis of variance (ANOVA) was used to test for significant effects of land use on litterfall, the decomposition constant and the carbon and nitrogen content in the litter. The weight and the carbon and nitrogen content of the litterfall and of its decomposition were analyzed statistically using a one-way ANOVA with the Tukey test applied at a significance level of 0.05, while the Spearman correlation coefficient was used to analyze the litterfall and climatic data.

Result and Discussion

Aboveground biomass

The above ground biomass in the stems, branches and leaves of trees in each plot will be determined from a selection of five dominant species (highest IVI).The data collected from field observation using permanent plots of 50 x 50 m 4 quadrates in mixed deciduous forest and para rubber plantation.

In term mixed deciduous forest, the aboveground biomass of the tree such as stems, branches and leaves have been estimated using allometric equations by Ogawa *et al.* 1965 above ground biomass of different sections of the tree are presented in Table 1

Table 1. Total aboveground dry biomass of the tree in mixed deciduous forest (MDF).

Tree	Total dry weight (ton/ha)			
	stem	branch	leaves	biomass
Haldina cordifolia	5143.87	4224.96	334.60	9703.43
Albizia odoratissima	782.41	531.11	46.91	1360.43
Lagerstroemia duperreana	161.69	93.57	91.16	346.42
Fermandoa adenophylla	199.86	118.17	11.36	329.39
Croton roxburghii	78.76	42.38	4.33	125.47

In term para rubber plantation, The aboveground biomass of the tree such as stems, branches and leaves have been estimated using equations by Yoonsuk, 2005, and the dry biomass of different sections of the tree are presented in Table 2

Table 2. Total aboveground dry biomass of the tree in para rubber plantation (PAR)

Tree	Total dry weight (ton/ha)			
	stem	branch	leaves	biomass
Hevea brasilliensis	7.99	9.80	6.51	32.04

Litterfall production

Monthly patterns of litterfall production were similar among the eight sites, with a peak during the dry period and dips during the wet period (Figure. 2). Differences in the total annual litterfall production between the land use types are shown in Table 3. Annual litterfall production was higher in the forest (416.40 ± 13.54 g m-2 yr-1) than in the Para rubber plantation (137.69 ± 5.12 g m-2 yr-1). Differences in total annual litterfall production were significant ($P<0.05$) between the two land use types. Litterfall production is a major process by which carbon and nitrogen are transferred from vegetation to the soil. The total litterfall production showed a significant increase with time after forest conversion to rubber plantation. The litterfall pattern in land use types in tropical ecosystems is determined by various factors, including species composition, the successional stage in the development of the system and related microclimatic differences (S.M. Sundarapandian and P.S. Swamy, 1999). Therefore, variations in the litterfall patterns between land use types, especially forest and agriculture, were expected in this study. Comparable litterfall rates in secondary forest have been reported to average 1,040 ± 0.6 g m-2 yr-1 (Y. Li *et al.,* 2005) and observed aboveground inputs within a tropical forest have been reported to be between 880 and 1,000 g m-2 yr-1 (P.M. Vitousek, 1984).

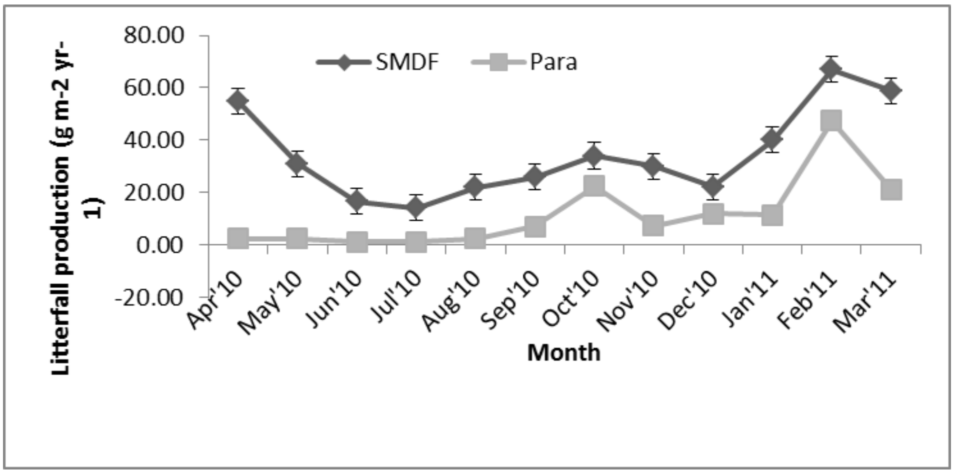

Fig. 2. Monthly variation in litterfall production (g m-2 yr-1) of secondary mixed deciduous forest (MDF) and Para rubber tree plantation (PAR) from April 2010 to March 2011. Vertical lines represent standard error from 36 replicated measurements

Table 3. Amount of litterfall (g m-2 yr-1) collected over 1 yr during two periods (wet and dry) under secondary mixed deciduous forest and para rubber plantation. The contribution of each fraction of litterfall to total litterfall production is also reported. Data are mean ± SE and lower case superscripts indicate significant differences ($p < 0.05$) between land use types.

Litterfall fraction/ periods	**Land use types**	
	MDF	PAR
Leaf		
Wet period	$54.13^{a} \pm 3.27$	$7.37^{b} \pm 0.92$
Dry period	$191.72^{a} \pm 13.42$	$66.39^{b} \pm 8.16$
Total	$245.85^{a} \pm 79.44$	$73.76^{b} \pm 41.74$
Twigs		
Wet period	$43.27^{a} \pm 4.39$	$2.37^{b} \pm 0.30$
Dry period	$90.42^{a} \pm 4.74$	$37.92^{b} \pm 7.71$
Total	$133.69^{a} \pm 33.35$	$40.29^{b} \pm 25.13$
Bark		
Wet period	$2.46^{a} \pm 0.57$	$0.12^{b} \pm 0.04$
Dry period	$2.70^{a} \pm 0.54$	$0.14^{b} \pm 0.04$
Total	$5.15^{a} \pm 0.17$	$0.26^{b} \pm 0.01$
Reproductive		
Wet period	$8.33^{a} \pm 0.93$	$2.80^{b} \pm 0.86$
Dry period	$12.28^{a} \pm 2.76$	$18.18^{b} \pm 6.82$
Total	$20.62^{a} \pm 2.79$	$20.97^{a} \pm 10.87$
Other fraction		
Wet period	$4.29^{a} \pm 0.82$	$1.12^{b} \pm 0.41$
Dry period	$6.81^{a} \pm 1.97$	$1.28^{b} \pm 0.45$
Total	$11.09^{a} \pm 1.78$	$2.40^{b} \pm 0.11$
Litterfall		
Wet period	$112.47^{a} \pm 24.31$	$4.04^{b} \pm 2.79$
Dry period	$303.97^{a} \pm 81.64$	$133.64^{b} \pm 27.87$
Total	$416.40^{a} \pm 19.35$	$137.69^{b} \pm 21.99$

Litterfall fraction

There were significant ($P<0.05$) differences in the litter fractions of leaves, twigs, bark and other fraction, whereas for the reproductive fraction there was no significant difference ($P > 0.05$) between the two land use types. Leaves always represented the largest fraction in both the secondary mixed forest and the Para rubber plantation (Table 4). For both land uses, mean litter fall production differed significantly between the wet and dry periods. Litterfall may be affected by physical factors such as the mechanical action of rainfall, the temperature and the wind or by the physical responses of the plants to environmental changes (L.S. Satiago and S.S. Mulkey, 2005). This study found a seasonal pattern of litterfall production which increased in the dry period (October–April) and decreased in the wet period (May–September) in both land use types. Most litterfall studies in tropical forests have demonstrated a strong seasonality of leaf litterfall, with the dry season producing the peak litterfall (R.K. Wieder and S.J. Wright, 1995) The pattern of litterfall in the current study was consistent with the seasonal patterns in vegetation forms in both land use types. The leaves fraction of litterfall was highest (over 50%) in both land use types.

Table 4. Amount of carbon return (g m-1 yr-1) collected over 1 yr under secondary mixed deciduous forest (MDF) and para rubber plantation (PAR). The contribution of each fraction of litterfall to total litterfall production is also reported. Lower case superscripts indicated significant differences ($p < 0.05$) between land use types

Month/ year	Leaves		Twigs		Bark		Reproductive		Other fraction		Total	
	SMDF	PARA	SMDF	PARA	SMDF	PARA	SMDF	PARA	SMDF	PARA	SMDF	PARA
Apr 10	12.09a	0.80b	7.11a	0.31b	0.75a	0.00b	3.68a	0.00b	2.50a	0.04b	27.23a	1.15b
May10	5.79a	0.74b	7.51a	0.34b	0.67a	0.00b	1.07a	0.00b	1.07a	0.03b	17.19a	1.11b
Jun 10	4.30a	0.41b	3.02a	0.14b	0.10a	0.04b	0.49a	0.00b	0.32a	0.04b	8.82a	0.63b
Jul 10	3.66a	0.40b	2.22a	0.15b	0.11a	0.00b	0.51a	0.00b	0.47a	0.00b	7.52a	0.55b
Aug 10	5.05a	0.72b	5.04a	0.11b	0.11a	0.01a	0.50a	0.33b	0.22a	0.01b	12.08a	1.18b
Sep 10	7.76a	1.58b	3.07a	0.44b	0.00a	0.00a	1.51a	0.99b	0.02a	0.48b	15.36a	3.49b
Oct 10	6.37a	1.44b	8.09a	0.20b	0.16a	0.00b	1.11a	9.83b	0.00a	0.58b	27.21a	12.05b
Nov10	11.64a	2.80b	2.38a	0.75b	0.02a	0.05a	0.26a	0.00b	0.00a	0.00a	17.90a	3.60b
Dec 10	5.10a	4.90a	4.47a	1.15b	0.08a	0.00b	0.25a	0.00b	0.00a	0.00a	15.96a	6.05b
Jan 11	14.56a	4.94b	4.54a	0.97b	0.08a	0.00b	0.17a	0.00b	0.00a	0.00a	25.25a	5.91b
Feb 11	24.12a	13.69b	6.16a	10.66b	0.05a	0.01a	0.22a	0.06b	0.00a	0.00a	54.96a	24.42b
Mar 11	19.62a	6.15b	8.63a	4.63b	0.13a	0.00a	0.14a	0.00a	0.05a	0.00a	39.35a	10.78b
Total	120.0a	38.56b	62.23a	19.85b	2.26a	0.11b	9.90a	11.21b	4.66a	1.18b	268.8a	70.91b

Litter decomposition

The decomposition of leaf litter under both land use types based on the results of the litter bag method was studied over about 12 months. The residual mass (% of the initial mass) of leaf litter differed significantly ($P < 0.05$) between the land use types, with the Para rubber tree plantation being significantly lower than the secondary mixed deciduous forest, though both land use types had lost about 50% of their initial litter mass after the wet period (Fig 3). The monthly decomposition coefficients (k) between the land use types ranged from 0.06 to 0.51 yr-1 in the secondary mixed deciduous forest and from 0.02 to 0.59 yr-1 in the Para rubber tree plantation (Fig. 4). The average annual decomposition constant (k) were 0.15 ± 0.04 yr-1 for the secondary mixed deciduous forest and 0.10 ± 0.01 yr-1 for the Para rubber tree plantation and were significantly different ($P < 0.05$). As would be expected, the pattern for the coefficients was highest in the wet period (May–September) and lowest in the dry period (October–April). Decomposition showed a decreasing trend from the secondary mixed deciduous forest to the Para rubber tree plantation. In this study, the significantly lower rates of decomposition in the Para rubber tree plantation compared to the secondary mixed deciduous forest suggest the possible effect of land use on the levels of carbon and nitrogen in the litter released to the soil with regard to the carbon balance in each land use system. Different species types in a land use system have been reported to have different nutrient release patterns, which are related to the litter quality and seasonal environmental factors (V.A. Kavvadias *et al* ., 2001)

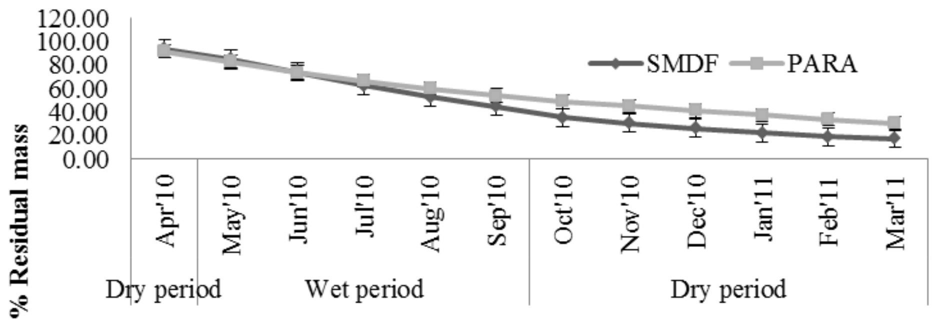

Fig.3. Residual mass (% of the initial) of secondary mixed deciduous forest (SMDF) and Para rubber tree plantation (PARA) from April 2010 to March 2011 and during the wet and dry periods. Vertical lines represent standard error from 12 replicated measurements

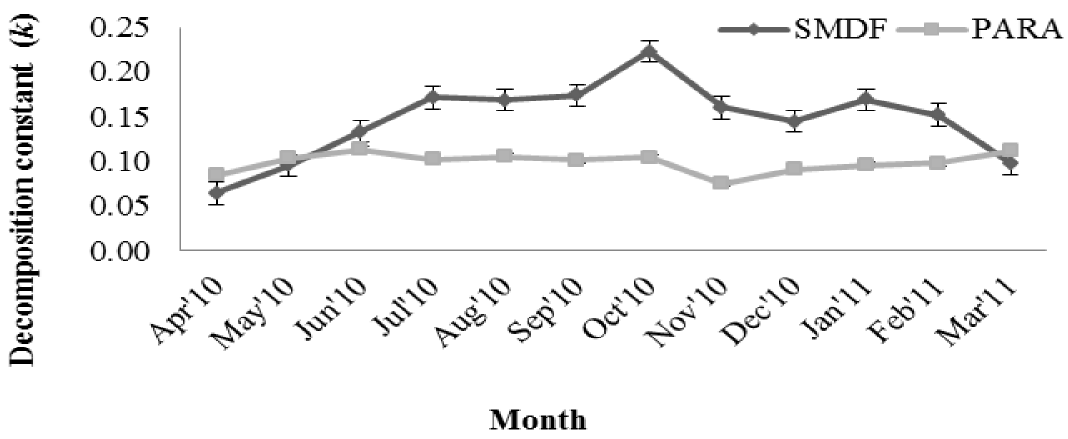

Fig. 4. Decomposition constant (k) of secondary mixed deciduous forest (SMDF) and Para rubber tree plantation (PARA) from April 2010 to March 2011. Vertical lines represent the standard error from 12 replicated measurements.

Aboveground biomass carbon

The aboveground biomass carbon of the tree such as stems, branches and leaves have been collected and dried at laboratory, and the dry biomass of different sections of the tree are presented in Table 5. The result of carbon analysis through CHN Analyzer is presented in Table 6. It is observed with mixed deciduous forest for Haldina cordifolia that average leaf, stem and branch contained 43.32, 47.49, and 46.01% carbon, respectively. For Albizia odoratissima, average leaf, stem and branch contained 46.34, 45.98 and 46.61 % carbon, respectively. For Lagerstroemia duperreana, average leaf, stem and branch contained 47.61, 47.96 and 46.88 %. For Croton roxburghii, average leaf, stem and branch contained 45.29, 47.53 and 45.68 %. It is observed in para rubber plantation for Hevea brasilliensis that average leaf, stem and branch contained 51.20, 50.66, 49.83 %. Carbon content of the tree was established by the works of different Scientists and Researchers, the carbon in plant was approximately 50% of dry matter (The world bank. 1998). The carbon concentration of different tree parts was rarely measured directly, but generally assumed to be 50% of the dry weight (Losi *et al.* 2003). Losi *et al.* (2003) obtained that measured carbon content of dry sample was 47.8% for Anacardium. excelsum and 48.5% for Dorstenia. panamensis. West (2003) reported in paper that "Extensive studies in Australia recently of a variety of tree species showed above ground dry biomass generally contain 50% carbon. These proportions of carbon in aboveground biomass agreed closely with values of 49 and 47% reported from other parts of the world for Pinus taeda (Kinerson *et al.* 1977). The total carbon content presented in Table 5 of Haldina cordifolia, Albizia odoratissima, Lagerstroemia duperreana, Fermandoa adenophylla and Croton roxburghii were 4,531.76, 629.05, 5.25, 5.25 and 58.76 kg, respectively. Negi *et al.* (2003) reported that carbon content in Shorea robusta tree was 46%.

Table 5 Average result of carbon analysis of different parts of the tree.

Land use types	Tree	Parts of the tree	Carbon (%)
Mixed deciduous forest (MDF)	Albizia odoratissima	Leaf	43.32
		Stem	47.49
		Branch	46.01
Mixed deciduous forest (MDF)	Croton roxburghii	Leaf	46.34
		Stem	45.98
		Branch	46.61
Mixed deciduous forest (MDF)	Fermandoa adenophylla	Leaf	47.61
		Stem	47.96
		Branch	46.88
Mixed deciduous forest (MDF)	Haldina cordifolia	Leaf	46.24
		Stem	47.46
		Branch	45.57
Mixed deciduous forest (MDF)	Lagerstroemia duperreana	Leaf	45.29
		Stem	47.53
		Branch	45.68
Para rubber plantation (PAR)	Hevea brasilliensis	Leaf	51.82
		Stem	48.91
		Branch	49.83

The carbon content of the whole tree (leaf, stem, branch) of Haldina cordifolia, Albizia odoratissima, Lagerstroemia duperreana, Fermandoa adenophylla, Croton roxburghii and Hevea brasilliensis is shown in Table 6.

Table 6. Carbon content of the aboveground biomass.

Tree	Parts of the tree	Carbon (%)	Total carbon content in tree species (kg ha-1)
Haldina cordifolia	Leaf	43.32	144.95
	Stem	47.49	2,443.03
	Branch	46.01	1,943.78
Total carbon content in tree		45.61	4,531.76
Albizia odoratissima	Leaf	46.34	21.74
	Stem	45.98	359.75
	Branch	46.61	247.55

Total carbon content in tree		46.31	629.05
	Leaf	47.61	43.40
Lagerstroemia duperreana	Stem	47.96	77.54
	Branch	46.88	43.86
Total carbon content in tree		47.49	5.25
	Leaf	46.24	94.85
Fermandoa adenophylla	Stem	47.46	53.84
	Branch	45.57	153.94
Total carbon content in tree		46.42	5.25
	Leaf	45.29	1.96
Croton roxburghii	Stem	47.53	37.44
	Branch	45.68	19.36
Total carbon content in tree		46.17	58.76
	Leaf	51.82	414.04
Hevea brasilliensis	Stem	48.91	479.32
	Branch	47.83	311.38
Total carbon content in tree		50.56	1,204.74

Factors correlated to litterfall production, carbon and nitrogen returns

Based on the data collected on the annual litterfall fractions (leaves, twigs, bark, reproductive, other fraction) and the total annual litterfall under both land use types, there were significant ($P < 0.05$) correlations with the climatic variables in this study based on values of the Spearman coefficient (Table 7). In the secondary mixed deciduous forest, strong correlations were found between rainfall and the twigs fraction, and between rainfall and the total litterfall, whereas in the Para rubber tree plantation most correlations were fewer correlations except between rainfall and the reproductive fraction, between rainfall and the other fraction and between temperature and the other fraction.

Table 7. spearman coefficients between annual litterfall production under secondary mixed deciduous forest (smdf) and para rubber tree plantation (para) and climatic variable data/

	Rainfall	Temperature
SMDF	0.024, (r = 0.622)	0.168, (r = 0.195)
Leaves	-0.112, (r = 0.249)	0.476, (r = 0.405)
Twigs	0.634, (r = 0.412)	0.685, (r = 0.556)
Bark	0.627, (r = 0.254)	0.287, (r = 0.423)
Reproductive	0.671, (r = 0.277)	0.547, (r = 0.518)
Other fraction	-0.550, (r = 0.532)	0.350, (r = 0.375)
Total litterfall	0.024, (r = 0.622)	0.168, (r = 0.195)
PAR		
Leaves	-0.785, (r = 0.642)	-0.203, (r = 0.080)
Twigs	-0.627, (r = 0.454)	-0.112, (r = 0.213)
Bark	-0.202, (r = 0.085)	-0.141, (r = 0.011)
Reproductive	0.145, (r = 0.202)	-0.062, (r = 0.095)
Other fraction	0.467, (r = 0.034)	0.284, (r = 0.083)
Total litterfall	-0.789, (r = 0.633)	-0.224, (r = 0.016)

Conclusion

This study demonstrated carbon sequestration rate and aboveground biomass carbon potential of five dominate species in mixed deciduous forest such as: *Haldina cordifolia, Albizia odoratissima, Lagerstroemia duperreana, Fermandoa adenophylla* and *Croton roxburghii* and in para rubber plantation such as: *Hevea brasilliensis*. The article concludes that carbon sequestration rate from the ambient air as obtained by secondary forest at Thung Salaeng Luang National Park. Percentage of carbon content in the aboveground biomass of *Haldina cordifolia, Albizia odoratissima, Lagerstroemia duperreana, Fermandoa adenophylla, Croton roxburghii* and *Hevea brasilliensis* were 45.61, 46.31, 47.49, 46.42, 46.17, 50.56 % respectively. Total aboveground biomass carbon stock per hectare for *Haldina cordifolia, Albizia odoratissima, Lagerstroemia duperreana, Fermandoa adenophylla, Croton roxburghii* and *Hevea brasilliensis* were 4,531.76 kg C ha^{-1}, 629.05 kg C ha^{-1}, 5.25 kg C ha^{-1}, 5.25 kg C ha^{-1}, 58.76 kg C ha^{-1} and 1,204.74 kg C ha-1, respectively. Analysis of the two different land use types and land use conversion between secondary mixed deciduous forest and Para rubber tree plantation in Huai Lam Kradon, lower northern Thailand showed there was a decrease in litterfall production and in the rate of decomposition and nutrient released which could impact on nutrient cycling in the land use especially the potential of each land use for balancing carbon for mitigating greenhouse gas effect in the local area.

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