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Original article

Aboveground Biomass and Litterfall of Natural Evergreen Forest in Eastern Region of Thailand

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ABSTRACT

The total aboveground biomass and net primary production (ΔPn) of natural evergreen forests in eastern region of Thailand were studied in moist evergreen forest (MEF), hill evergreen forest (HEF) at Khao Khitchakut National Park, and in dry evergreen forest (DEF) at Khao Soi Dao Wildlife Sanctuary, Chanthaburi province during January 2000 to January 2001. In addition, litterfall of these forests was studied during January 2001 to December 2001.

The results showed that the annual increment of aboveground biomass was estimated at 5.39, 20.08 and 2.58 ton ha^{-1} yr^{-1} for the MEF, DEF and HEF, respectively. The net primary production of the MEF, DEF and HEF were estimated to be 13.24, 28.91 and 7.46 ton ha^{-1} yr^{-1}, respectively. The annual litterfall of the MEF, DEF and HEF were estimated as 7.85, 8.83 and 4.88 ton ha^{-1} yr^{-1}, respectively. Litter was lowest in the rainy season (May-October), and highest in the dry season (November-April), this evidence related to water shortage, leading to leaf fall in dry season. In addition, litterfall showed clearly some evidence of a peak in early dry season (December), there were 1.73, 1.67 and 0.64 ton ha^{-1}, respectively.

Keywords: aboveground biomass, eastern region of Thailand, evergreen forest, litterfall, net primary production

INTRODUCTION

In forest ecosystems, forest trees require many chemical elements for their growth and biomass. The minerals that are taken up into forest trees are eventually returned to the surface of forest soil by litterfall and through the washing and leaching effects of rain on tree foliage and stems (Spurr and Barnes, 1986). Litterfall is the major pathway for the return of dead organic matter and many of its contained nutrient and non-essential elements from the aerial parts of the plant community to the surface of the soil. It is also a principal source of energy for the saprobiota of the forest floor and soil. However, the amount of nutrient elements supplied to the forest floor fluctuated seasonally, depending on the rate of litterfall and concentration of nutrient elements in the litterfall (Spain, 1984). From an ecological perspective, litter

means all of organic matter included dead parts of plant such as leaf, flower, fruit, branch, bark and stem or living part such as seeds and fresh leaf and animal body or insects which accumulate on the ground. However, in this study, litter covers only small amount of plant parts and leaf which accumulate as organic matter, while large pieces of plant such as branches, stems and fruits, with big size and heavy weight are not included. Furthermore, the aboveground biomass, annual increment of biomass and annual litterfall will affect the production efficiency of the forest, which were the valuable data for forest ecology study in the future.

In Thailand, many researchers have long attempted to quantify the aboveground biomass and rate of litter production in many types of forests. However, still few studies have been carried out in natural evergreen forest of eastern region. Therefore, it is necessary to examine aboveground biomass and litter production in order to get insight into the seasonal variation pattern of the litterfall and annual increment of aboveground biomass of natural evergreen forests in this region. The results should provided valuable data for sustainable forest management planning in this region of the country.

MATERIALS AND METHODS

Aboveground biomass and litterfall of natural evergreen forests were studied at Khao Khitchakut National Park and Khao Soi Dao Wildlife Sanctuary, Chanthaburi Province. Both sites are influenced by two monsoons, namely the northeast and southwest monsoons. The wettest period with surplus water or the rainy season occurs between November and February, while the period of moisture deficit or the dry season is between November and April (Figure 1).

A square permanent sample plot with the size of 100 m x 100 m (1 hectare) was set up in each forest type; the MEF, DEF and HEF. Each sample plot was further divided into 100 sub-plots of 10 m x 10 m. In each sub plot, all trees with DBH > 4.5 cm were mapped, species recorded, the label number tacked at the DBH level and botanical names identified. Species compositions were checked. Diameter at breast height (DBH) and total height (H) were also measured at the beginning of January 2000 and ending of the study in January 2001.

The total aboveground biomass (W_T), stem biomass (W_s), branch biomass (W_b) and leaf biomass (W_l) of tree with DBH > 4.5 cm in each sample plot were estimated by using the allometric relation proposed by Yamakura et al. (1986) for MEF, Ogawa *et al*. (1961) for HEF and Jamroenprucksa (1981) for DEF. The difference of biomass values at the two periods yielded an estimated biomass increment of the living plants (Δy).

Litterfall was observed for 1 year during January 2001 to December 2001. In order to collect litterfall, twenty-five circular litter traps with diameter of 60 cm were set up. The rims of all traps were set at 1.30 m above ground level. All accumulate litterfall in traps were collected every month. The collected litters were sorted into leaves, branches, and other components (barks, seeds, flowers, bud scales, insect bodies and feces and unidentified fractions). The sorted litters were weighed before and after oven drying. The oven temperature was set at 85^{o}C and the samples were dried to a constant weight. The monthly litterfall

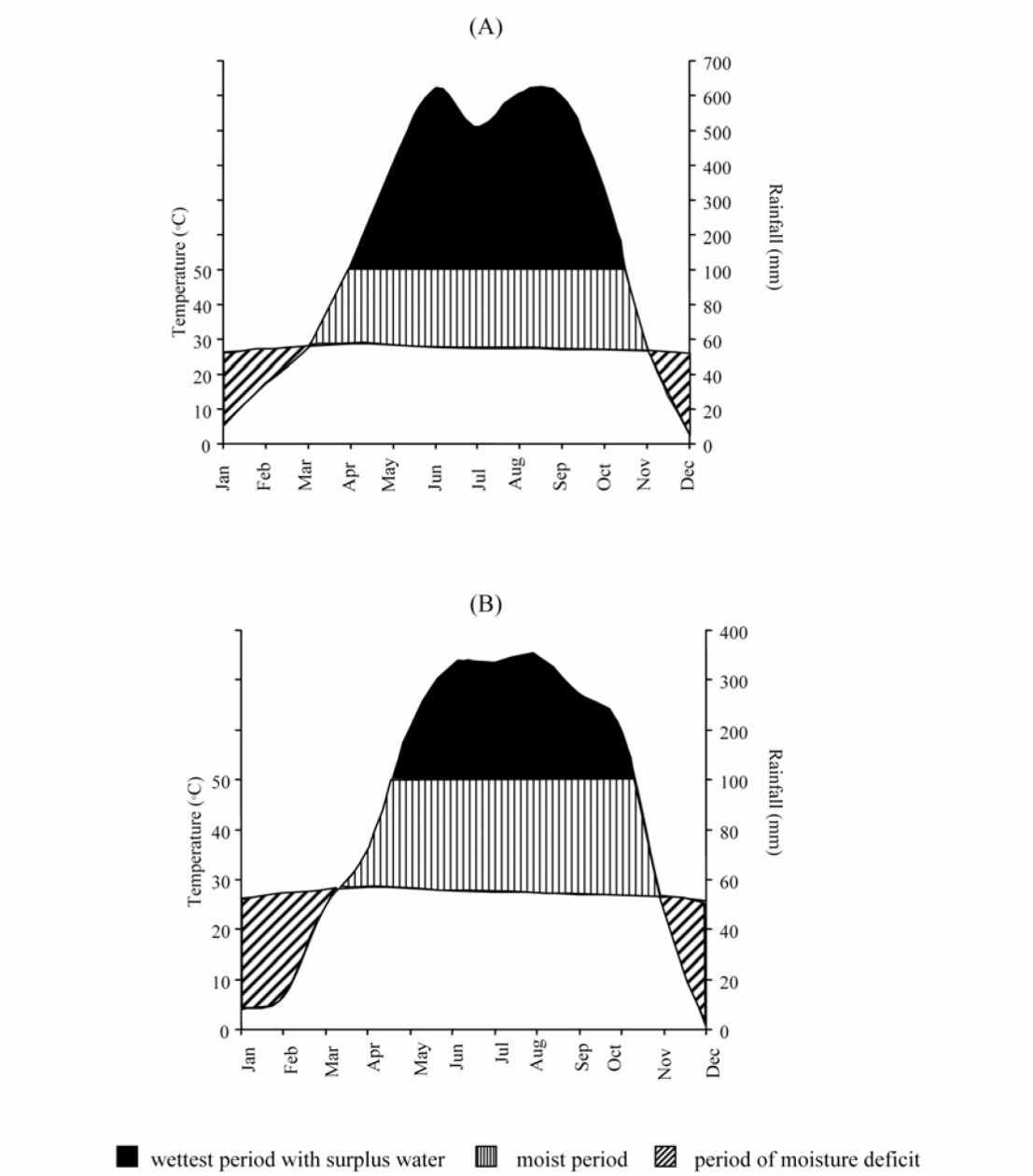

Figure 1. Walter's climatic diagrams of Chanthaburi station represented Khao Khitchakut National Park, (A), and Pong Nam Ron station represented Khao Soi Dao Wildlife Sanctuaty, (B), during 1981- 2000.

Table 1 Aboveground biomass and tentative estimation of annual dry matter production of tree with DBH ≥ 4.5 cm in moist evergreen forest (MEF), hill evergreen forest (HEF) at Khao Khitchakut National Park and dry evergreen forest (DEF) at Khao Soi Dao Wildlife Sanctuary, Chanthaburi Province

Plot		Year	Biomass (ton ha^{-1} yr^{-1})					
			Stem (W_s)	Branch (W_b)	Stem+Branch (W_{sb})	Leaf (W_l)	Others (W_o)	Total (W_t)
MEF	- Aboveground biomass	2000	365.76	68.94	-	5.28	-	439.98
		2001	367.98	70.72	-	6.67	-	445.37
	- Aboveground biomass increment (Δy)		2.22	1.78	-	1.39	-	5.39
	- Litterfall (ΔL)		-	1.59	-	4.59	1.67	7.85
	- Grazing (ΔG)*		-	-	-	-	-	-
	- Net primary production (ΔPn) = Δy + ΔL + ΔG		2.22	3.37	5.59	5.98	1.67	13.24
DEF	- Aboveground biomass	2000	282.98	53.50	-	4.08	-	340.56
		2001	298.80	56.57	-	5.27	-	360.64
	- Aboveground biomass increment (Δy)		15.82	3.07	-	1.19	-	20.08
	- Litterfall (ΔL)		-	1.52	-	5.93	1.38	8.83
	- Grazing (ΔG)*		-	-	-	-	-	-
	- Net primary production (ΔPn) = Δy + ΔL + ΔG		15.82	4.59	20.41	7.12	1.38	28.91
HEF	- Aboveground biomass	2000	-	-	94.32	10.52	-	104.84
		2001	-	-	96.15	11.27	-	107.42
	- Aboveground biomass increment (Δy)		-	-	1.83	0.75	-	2.58
	- Litterfall (ΔL)		-	3.26	-	0.87	0.75	4.88
	- Grazing (ΔG)*		-	-	-	-	-	-
	- Net primary production (ΔPn) = Δy + ΔL + ΔG		-	3.26	1.83	1.62	0.75	7.46

Remark: * Grazing consumption (ΔG) was assumed to be negligibly small as compared to other components of dry matter production.

Thai J. For. 26 : 70-81 (2007)

in each part was clarified and compared between each evergreen forest and other forests. The net primary production rate (ΔPn) in each evergreen forest was estimated by the summation method (Ogawa, 1977) as follows:

$(\Delta Pn) = \Delta y + \Delta L + \Delta G$

where

Δy = rates of biomass increment (ton ha^{-1} yr^{-1})

ΔL = loss of biomass due to the death of plant in the forms of litterfall (ton ha^{-1} yr^{-1})

ΔG = loss of biomass due to grazing which as assumed to be negligibly small as compared to other components of dry matter production (ton ha^{-1} yr^{-1})

RESULTS AND DISCUSSION

Aboveground Biomass

The The total aboveground biomass, stem biomass, branch biomass and leaf biomass of trees with DBH 4.5 ≥ cm in each sample plot are shown in Table 1. There were difference in total aboveground biomass. The MEF showed the highest total aboveground biomass in contrast with the HEF. Although the HEF had higher tree density, mean DBH and height were less than both in the MEF and the DEF. The small size of trees was contributed in this forest. Increment of total aboveground biomass of the DEF plot during studied period (January 2000-January 2001) showed the highest (20.08 ton ha-1 yr-1) while the MEF was 5.39 ton ha-1 yr-1 and the HEF was 2.58 ton ha-1 yr-1. Aboveground biomass of the DEF increased greatly when compareed to the HEF which increased slightly because many trees especially Fagaceae, died. Dead trees caused decreasing of biomass increment in this plot. This suggested that the HEF was grown in shallow soil and there were many larger rocks on the ground and less fertility than the other plots as showed in Glumphabutr (2004). From the results as suggested above, it is clearly indicated that the DEF could produce biomass higher than the MEF and the HEF because it is located on deeper soil site and less steep slope. These conditions were favorable for many tree species in the DEF than in the MEF and the HEF. Table 2 shows the total aboveground biomass in various forest types of Thailand. There was a clear indication that all plots in the present study were relatively dense and the total aboveground biomass were higher than other forests in Thailand.

Litterfall

The rate of litterfall (Δ) in various forest types of evergreen forests, the MEF, the DEF, and HEF are shown in Table 3 and Figure 2. The total litterfall (excluding big branches and trees) in the DEF, MEF and HEF were 8.83, 7.85 and 4.88 ton ha-1 yr^{-1}, respectively. The litterfall pattern throughoutt the year showed a marked seasonal distribution (Table 3 and Figure 2). The litters were lowest during the rainy season (May - October), and highest during the dry season (November - April), suggesting that the peak of litterfall may be related to the water shortage during dry season. However, litterfall pattern in these evergreen forests were similar to other forests in Thailand such as in the dry dipterocarp forest, Nakhon Ratchasima (Paovongsa, 1976), mixed deciduous forest with teak, Lampang (Thaiutsa et al., 1978) and hill evergreen forest, Chiang Mai (Boonyawat and Ngampongsai, 1974). In contrast, the results differed from dry evergreen forest, Sakaerat, Nakhon Ratchasima that total small litterfall

Table 2. The total aboveground biomass of various forest types in Thailand

Forest types	Tree Density (trees ha^{-1})	Total aboveground biomass (ton ha^{-1})	Reference
Moist evergreen forest , Khao Khitchakut National Park, Chanthaburi	1,510	439.99	Present study
Dry evergreen forest, Khao Soi Dao Wildlife Sanctuary, Chanthaburi	1,355	340.56	Present study
Hill evergreen forest , Khao Khitchakut National Park, Chanthaburi	2,513	104.84	Present study
Dry dipterocarp forest, Somdet, Kalasin	1,444	293.80	Kanzaki *et al*., (1991)
4 Sub-communities dry dipterocarp forest, Sakaerat, Nakhon Ratchasima	555-731	61.80-144.00	Nilroung (1986)
Dry dipterocarp forest, Ping Kong, Chiang Mai	1,488	49.60	Ogawa *et al*., (1961)
Mixed deciduous forest, Ping Kong, Chaing Mai	713	57.50	Ogawa *et al*., (1961)
Yang stand, Prachuap Khiri Khan	980	304.93	Watchrinrat *et al*., (1999)
Dry evergreen forest, Namprom dam, Chaiyaphum	1,088	281.67	Handechanon (1990)
Dry evergreen forest, Sakaerat, Nakhon Ratchasima	1,219	283.81	Kanzaki *et al.*, (1995)

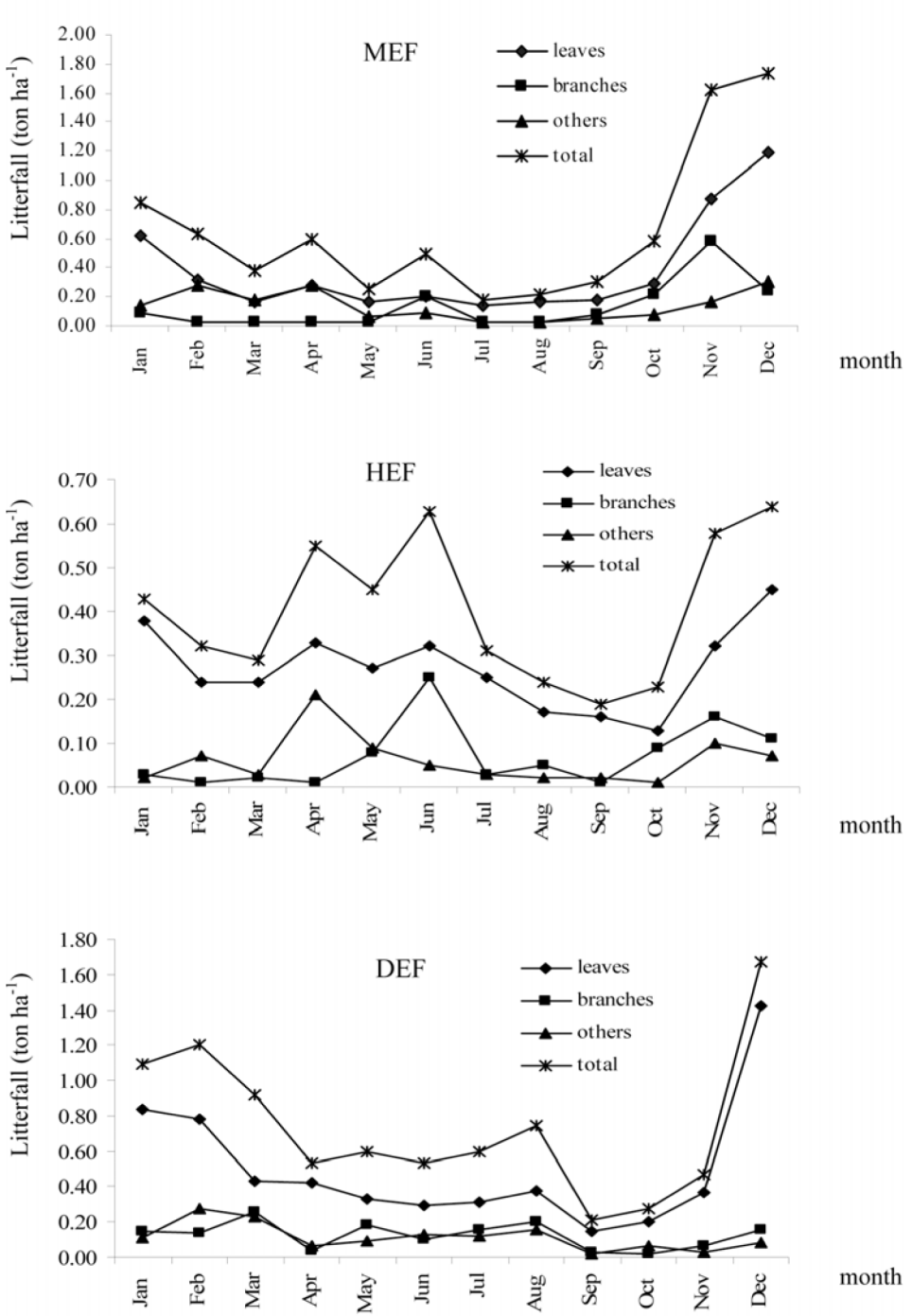

Figure 2. Monthly litterfall divided into leaves, branches and other fractions in moist ever green forest (MEF), hill evergreen forest (HEF) Khao Khitchakut National Park and dry evergreen forest (DEF) Khao Soi Dao Wildlife Sanctuary, Chanthaburi Province, in 2001.

Table 3. Seasonal litterfall in moist evergreen forest (MEF), hill evergreen forest (HEF) at Khao Khitchakut National Park and dry evergreen forest (DEF) at Khao Soi Dao Wildlife Sanctuary, Chanthaburi Province in 2001

Plot	Season	Litterfall (dry weight)							
		Leaf		Branch		Others		Total	
		(ton ha^{-1})	%	(ton ha^{-1})	%	(ton ha^{-1})	%	(ton ha^{-1})	%
MEF	Dry season[1]	3.45	75.06	1.01	63.62	1.36	81.43	5.82	74.10
	Rainy season[2]	1.14	24.94	0.58	36.38	0.31	18.57	2.03	25.90
	Total	4.59	100	1.59	100	1.67	100	7.85	100
DEF	Dry season	4.27	71.95	0.82	54.01	0.79	57.35	5.88	66.59
	Rainy season	1.66	28.05	0.70	45.99	0.59	42.65	2.95	33.41
	Total	5.93	100	1.52	100	1.38	100	8.83	100
HEF	Dry season	1.96	60.08	0.35	40.61	0.51	67.74	2.82	57.78
	Rainy season	1.30	39.92	0.52	59.39	0.24	32.26	2.06	42.22
	Total	3.26	100	0.87	100	0.75	100	4.88	100

Remark: [1] Dry season: November to April

[2] Rainy season: May to October

showed a marked peak in May which was the beginning of wet season (Sahunalu, 2004).

The leaf litterfall of the MEF was estimated to be 4.59 ton ha^{-1} yr^{-1} that constituted 58.46 % of total litterfall and 75.06% of leaf fall during dry season (November to April), and a peak of leaf fall was found in November (1.19 ton ha^{-1}). During March and April the raining started and some trees produced the new leaves in the study areas. Leaf litter of DEF and HEF were 5.93 and 3.26 ton ha^{-1} yr^{-1}, respectively. Therefore, leaf litter constituted 67.19 and 66.76% of total litterfall, respectively, and about 71.95 and 68.08% of leaf fell during the dry season (November - April), respectively. Both the DEF and the HEF had the peak of leaf fall in December, 1.42 and 0.46 ton ha^{-1}, respectively.

Branch fall pattern was also observed and it was estimated to be 1.59, 1.52 and 0.87 ton ha^{-1} yr-1 in the MEF, DEF and HEF, respectively. In each plot, pattern of branch fall showed fluctuation, the MEF showed a peak in November (0.58 ton ha^{-1}), while the DEF and HEF showed a peak in March and June, respectively. Actually, the branch fraction has been considered as the most variable fraction in litterfall studies (Proctor, 1983). Apparently, some factors could be explained for branch fall and leaf fall variation e.g. drought, low temperature, elevation and winds.

In case of other fraction, these fractions were composed of reproductive and unclassified parts of litterfall. This fraction showed the peak in December, February and April in the MEF, DEF and HEF, respectively. However, they fell in large amount at the end of dry season because most of this fraction composed of reproductive fractions (flower, fruit and seeds) that have fallen down to forest floor and will be germinated in the rainy season, these results reflect to the life cycle of trees in the evergreen forests in these areas.

Total amount of litterfall of the three evergreen forest types, ranged from 4.88 - 8.83 ton ha^{-1} yr^{-1} and lied within the range of 3.40 to 12.0 ton ha^{-1} yr^{-1} in the various types of Thailand and other tropical forests in Asia (Rai and Proctor, 1986). Compared to other forest types in Thailand (Table 4), it seemed to be comparable. The MEF and DEF tended to have the amount of total small litterfall higher than those type of forests in Thailand. In contrast, litterfall of the HEF

showed lower than that of those forests. However, compared to the several forests in other countries, the amount of small litterfall of all plots in the present study were lower than those of the forests

Table 4. Litterfall in various forest types of Thailand and other countries

Forest types	Site	Total litterfall (ton ha^{-1} yr^{-1})	Leaf litterfall (ton ha^{-1} yr^{-1})	Source
	Thailand			
Moist evergreen forest	Chanthaburi	7.85	4.59	Present study
Dry evergreen forest	Chanthaburi	8.83	5.93	Present study
Hill evergreen forest	Chanthaburi	4.88	3.26	Present study
Moist evergreen forest	Trang	23.22	-	Kira *et al.,* (1967)
Seasonal rain forest	Northeast	8.17	5.65	Sahunalu (2004)
Hill evergreen forest	Chiang Mai	6.90	-	Thaiutsa *et al.,*(1978)
Mixed deciduous forest with teak	Lampang	7.92	-	Thaiutsa *et al.,* (1978)
Dry dipterocarp forest	Nakhon Ratchasima	4.66	3.44	Paovongsa (1976)
Peat forest	Narathiwat	6.70	4.08	Bunyavejchewin and Nuyim (1996)
Mangrove forest	Ranong	8.93	-	Kooha (1983)
	Other countries			
Evergreen rain forest	Maraca Island, Roraima, Brazil	9.30	6.30	Scott *et al.,*(1992)
Rain forest	Pin Gin Hill, NE, Queensland, Australia	9.61	4.83	Spain (1984)
Lowland dipterocarp Forest	Pasoh, W. Malaysia	10.60	6.30	Ogawa (1978)
Dry deciduous forest	Varanasi, India	7.70	6.20	Bandhu (1973)

Net Primary Production (∆Pn)

The total net primary production (∆Pn) of each sample plot are shown in Table 1. The DEF showed the highest total net production (28.91 ton ha^{-1} yr^{-1}), while the MEF was 13.24 ton ha^{-1} yr^{-1} and the HEF was 7.46 ton ha^{-1} yr^{-1}. Compared to other forest types, the net primary production of a tropical evergreen forest in Peninsular Thailand to be 28.60 ton ha^{-1} yr^{-1} (Ogawa *et al.*,1961). Furthermore, the net primary production in a huge tropical rain forest in Peninsular Malaysia amounted to 27.20 ton ha^{-1} yr^{-1} (Kira, 1974). In addition, Whittaker and Likens (1973) estimated mean net productivity of various ecosystems; 20 ton ha^{-1} yr^{-1} for tropical rain forest, 15 ton ha^{-1} yr^{-1} for tropical seasonal forest, 13 ton ha^{-1} yr^{-1} for temperate evergreen forest, 12 ton ha^{-1} yr^{-1} for temperate deciduous forest, and 8 ton ha^{-1} yr^{-1} for subarctic forest. The net production of the DEF seemed comparable to the values for tropical rain forest in southern region of Thailand and Peninsular Malaysia, while the MEF and the HEF seemed comparable to temperate evergreen forest and subarctic forest, respectively.

CONCLUSION

The annual increment of total aboveground biomass and net primary production of trees was highest in the DEF followed by the MEF and lowest in the HEF, respectively.

The total small litterfall (excludeng big branchs and standing dead and fallen stem of trees) was highest in the DEF followed by the MEF and the HEF, respectively. The total amount of litterfall of the three evergreen forest types ranged from 4.88-8.84 ton ha^{-1} yr^{-1}. In addition, the total litterfall and each kind of litterfall throughout the year showed a marked seasonal distribution. Litters were lowest in the rainy season (May-October), and highest in the dry season (November-April), suggesting that the peak fall may be related to water shortage during dry season.

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