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ECOLOGICAL STUDIES OF TROPICAL SEMI-EVERGREEN RAIN FOREST AT SAKAERAT, NAKHON RATCHASIMA, NORTHEAST THAILAND, II. LITTERFALL

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ABSTRACT

Litterfall measurements were made from May 1985 to April 1989 for *Shorea henryana* type and from March 1987 to February 1990 for *Hopea ferrea* type of semi-evergreen rain forest at Sakaerat, Nakhon Ratchasima Province, in Northeast Thailand. The mean annual litterfall over a period of 48 months of *Shorea henryana* type was 6.8 t/ha/y, consisting of 70.3% leaves, 15.2% woody material, 5.0% reproductive structures and 9.5% unclassified. In the *Hopea ferrea* type, mean annual litterfall was 6.4 t/ha/y, comprising 73.5% leaves, 17.3% woody material, 3.0% reproductive structures and 6.2% unclassified. The year-to-year variation in total litterfall was significant for both types. Seasonality of litterfall was more marked in the *Shorea henryana* type than in the *Hopea ferrea* type.

The nutrient element concentrations in the litterfall were similar between the types. The concentrations of all elements were within the ranges reported for other tropical forests.

INTRODUCTION

Litterfall is the main pathway by which organic matter and chemical elements are transferred from the vegetation to the soil surface in the forest ecosystem. The amount and pattern of litterfall play an important role in soil formation and in maintaining its fertility. The rate of litterfall has been shown to vary according to stand structure, age, latitude, and seasonal climatic change (EWEL, 1976; TANNER, 1980). Climatic variation between years influences many ecosystem functions through changes in productivity (MURPHY & LUGO, 1986) and other pathways. Therefore, litterfall measurement should be extended over several years to improve our understanding of ecosystem characteristics (PROCTOR, 1983).

The first paper of this series (BUNYAVEJCHEWIN, 1986) has divided the semi-evergreen rain forest at Sakaerat into two distinct groups: *Hopea ferrea* type and *Shorea henryana* type. Previous studies of litterfall at Sakaerat have been conducted in the *Hopea ferrea* type for one year (CHUNKAO & BOONYAWAT, 1980; CHINSUKJAIPRASERT, 1984). The two previous studies differed in rate of litterfall and temporal variation. This study aims to clarify the rate of litterfall and its temporal distribution pattern for the semi-evergreen rain forest at Sakaerat. In addition to litterfall, the values for chemical composition of litterfall are reported. These values can be used for further studies on nutrient circulation.

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STUDY SITE

Two study sites were selected, one in the *Shorea henryana* type and the other in the *Hopea ferrea* type, 3 km apart, at Sakaerat Environmental Research Station, 60 km south of Nakhon Ratchasima City (14° 31' N, 101° 55' E). The forest structure, floristics, and environment of both dominance-types were given in the previous paper (BUNYAVEJCHEWIN, 1986).

METHODS

Two 100x100 m (1 ha) permanent plots were established, one in *Hopea ferrea* type, in a level area, and the other one in the *Shorea henryana* type on a 40% slope. Twenty-five 1x1 m litter traps were placed at the centres of twenty-five 20x20 m subplots inside the 100x100 m plot. Each trap consisted of a square wooden frame held about 1 m off the ground on four wooden legs. The wooden frame was 20 cm high and the bottom was 1-mm nylon mesh.

Litter was collected monthly from May 1985 until April 1989 in the *Shorea henryana* type and from March 1987 until February 1990 in the *Hopea ferrea* type. The material was sorted into (1) leaves; (2) fine woody material including twigs, fine branches (diameter <2.5 cm) and bark; (3) reproductive structures (flowers, fruits and seeds); and (4) unclassified (insects, frass and amorphous material), and then dried at 80°C for 48 hours. Over the time of study, only 10 litter traps in the *Hopea ferrea* type and 15 litter traps in the *Shorea henryana* type were not disturbed by humans. Only litter from the undisturbed traps was used for analysis.

For the analysis of chemical elements, sub-samples of the litterfall were ground up, re-dried at 105°C and digested in a mixture of H_2SO_4-$NaSO_4$-Se, 1000:100:1. Calcium and magnesium in the digest were determined by an atomic absorption spectrophotometer. Nitrogen was measured using the Kjeldahl method. Phosphorus was determined by the vanadomolybdate yellow color technique. A flame photometer was used to determine potassium.

RESULTS

Total Litterfall

Mean monthly total litterfall and its components for both dominance-types are presented in Figures 1 and 2. Annual input of litterfall for each type is given in Table 1. The 4-year mean total litterfall in the *Shorea henryana* type, 6.8 ± 0.19 (SE) t/ha/y, was similar to the three-year mean in the *Hopea ferrea* type, 6.4 ± 0.21 (SE) t/ha/y. Variation between years was significant for both dominance-types ($F = 10.28$, $P < 0.001$ for *Shorea henryana* type and $F = 6.90$, $P < 0.01$ for *Hopea ferrea* type).

Litterfall patterns over the period of study differed between the dominance types. For the *Shorea henryana* type, a yearly minimum of less than 0.3 t/ha/mo (1 g/m^2/day) occurred

Table 1. Annual accession of total litterfall and its components (t/ha/y) in the two dominance-types.

	Year	Leaves	Wood	Reproductive structures	Unclassified	Total
Shorea henryana type	1985–86	5.77	0.88	0.57	0.86	8.08
	1986–87	5.36	1.34	0.37	0.64	7.71
	1987–88	4.14	1.13	0.13	0.77	6.35
	1988–89	4.03	0.81	0.11	0.32	5.27
	mean	4.82	1.04	0.34	0.65	6.85
	%	70.36	15.18	4.96	9.49	100.0
Hopea ferrea type	1987–88	4.54	1.34	0.29	0.53	6.70
	1988–89	5.46	1.17	0.15	0.42	7.20
	1989–90	4.15	0.82	0.13	0.26	5.36
	mean	4.72	1.11	0.19	0.40	6.42
	%	73.52	17.29	2.96	6.23	100.0

from the mid-rainy season to the beginning of dry season (July-November). A maximum of 0.85–1.47 t/ha/mo (2.7–4.9 g/m^2/day) normally occurred in the dry season (January–March). For the *Hopea ferrea,* there were two peaks during the year, one in the late dry season (March) and the other in the late rainy season (October) except in 1989/90 when the maximum occurred in July. The second peak usually occurred in the month following the highest rainfall. The minimum of less than 0.3 t/ha/mo (1 g/m^2/day) occurred during the mid-to-late rainy season (August–December). Half of total annual litterfall in the *Shorea henryana* type was recorded during the dry season (duration 4 to 5 months) each year. It ranged over the study period from 43% to 53% of the annual litterfall (Table 2). The dry season litterfall in the *Hopea ferrea* type ranged from 33% to 47% of the total annual litterfall (Table 2). Differences in the mean total litterfall among seasons were not significant in the *Shorea henryana* type (t-test, $P > 0.05$), but significant in the *Hopea ferrea* type (t-test, $P < 0.05$).

Litterfall Components

Leaves constituted 70–73% of the litterfall in both dominance-types. The percentage of leaves in the litterfall for the *Shorea henryana* type was highest at the time of maximum litterfall. The maximum proportional contribution of leaves in the litterfall of the *Shorea henryana* type exceeded 90% during maximum total litterfall that occurred in January to February (except during May 1987 – May 1988). Woody material showed the inverse pattern. It constituted only 4% at the time of maximum total fall and ranged 31–40% during the rainy season (June–September).

In the *Hopea ferrea* type, the percentage of leaf litterfall was highest (80–90%) in the driest months (December–January), not during the period of maximum total litterfall.

Woody litterfall was lowest (4–10%) during December to February, and reached a maximum of 34–40% in the rainy season (July–September).

The fall of reproductive structures in each dominance-type made only a small contribution to total litterfall, averaging only 2–7%.

Comparisons of the total mass of leaves, wood, reproductive structures and unclassified (March 1987–February 1988 and March 1988 – February 1989) revealed no significant differences ($P > 0.05$) between dominance-types.

Nutrient Elements in Litterfall

Element concentrations in the litterfall were similar between dominance types except for higher calcium concentration in leaf litterfall in the *Shorea henryana* type (Table 3). The calcium concentration in leaf litterfall was probably enhanced by the effect of higher calcium concentration in the topsoil of *Shorea henryana* type (BUNYAVEJCHEWIN, 1986). The chemical composition of litterfall of both dominance-types falls within the ranges recorded for other tropical forests (PROCTOR 1984, cited in RAI & PROCTOR, 1986).The quantities of elements returned to the forest floor as litterfall in the *Shorea henryana* type were slightly higher than in the *Hopea ferrea* type (Table 4).

DISCUSSION

The mean annual mass of total litterfall estimated during the present study (6.4–6.8 t/ha/y) lies within those recorded from other tropical forests in Asia, 3.4–12.0 t/ha/y. (YAMADA, 1976; LIM, 1978; PROCTOR ET AL., 1983; RAI & PROCTOR, 1986). The total litterfall from both types was very similar to those of other forest formations that have

Table 2. Annual total litterfall and for the dry and wet season in the *Shorea henryana* type and *Hopea ferrea* type

Year	Total litterfall (t/ha)		
	Dry season	Wet season	Annual
		Shorea henryana type	
1985–1986	4.34 (Dec–Mar)	3.74 (Apr–Nov)	8.08
1986–1987	4.10 (Nov–Mar)	3.60 (Apr–Oct)	7.70
1987–1988	2.78 (Dec–Mar)	3.57 (Apr–Nov)	6.35
1988–1989	2.86 (Nov–Mar)	2.41 (Apr–Oct)	5.27
1985–89 (mean)	3.52 (51.4%)	3.33 (48.6%)	6.85
		Hopea ferrea type	
1987–1988	2.24 (Dec–Mar)	4.47 (Apr–Nov)	6.70
1988–1989	3.43 (Nov–Mar)	3.77 (Apr–Oct)	7.20
1987–89 (mean)	2.83 (40.7%)	4.12 (59.3%)	6.95

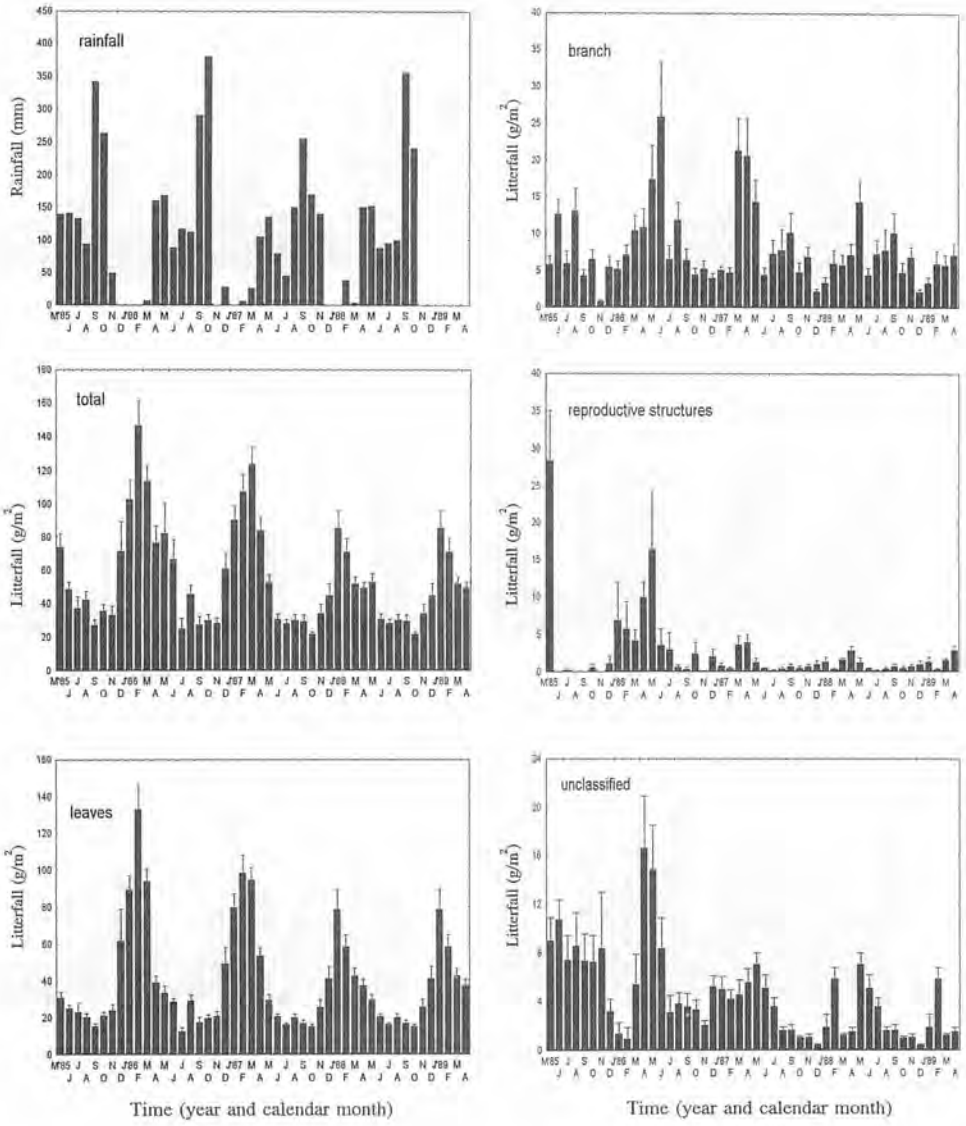

Figure 1. Temporal distribution of total litterfall and the fall of each component in the *Shorea henryana* type, and monthly rainfall. Bars indicate one-side of standard error of the mean. No rainfall data available after January, 1989.

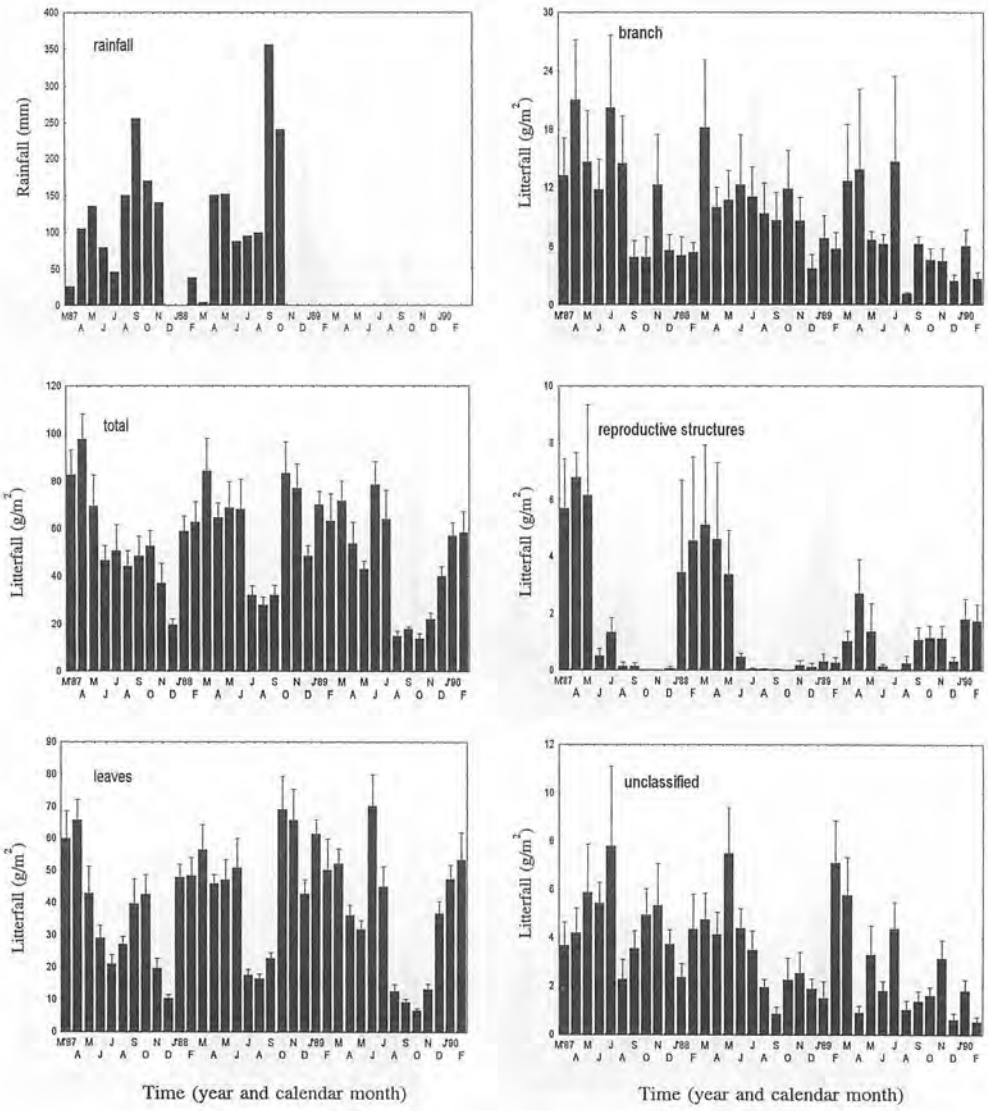

Figure 2. Temporal distribution of total litterfall and the fall of each component in the *Hopea ferrea* type, and monthly rainfall. Bars indicate one-side of standard error of the mean. No rainfall data available after January, 1989.

Table 3. Mean element concentrations (% dry weight) ± SE in litterfall component of *Shorea henryana* type and *Hopea ferrea* type at Sakaerat.

Component	n	N	P	K	Ca	Mg
Shorea henryana type						
Leaves	6	1.16±0.05	0.024±0.002	0.74±0.05	0.69±0.04	0.22±0.01
Wood	6	1.05±0.10	0.037±0.012	0.74±0.12	0.68±0.04	0.23±0.05
Reproductive structures	1	1.63	0.078	1.19	0.30	0.20
Unclassified	1	1.30	0.078	1.06	0.40	0.16
Hopea ferrea type						
Leaves	4	1.15±0.06	0.028±0.005	0.83±0.05	0.39±0.02	0.17±0.02
Wood	4	0.93±0.02	0.016±0.001	0.64±0.08	0.74±0.04	0.14±0.003
Reproductive structures	2	1.37	0.123	1.28	0.65	0.17
Unclassified	1	1.36	0.066	0.94	0.62	0.11

Table 4. The estimated rate of addition (kg/ha/y) of elements in the litterfall in *Shorea henryana* type and *Hopea ferrea* type at Sakaerat.

Component	N	P	K	Ca	Mg
Shorea henryana type					
Leaves	55.80	1.13	35.65	33.14	10.70
Wood	10.92	0.38	7.69	7.11	2.44
Reproductive structures	5.53	0.26	4.04	1.02	0.68
Unclassified	8.42	0.51	6.91	2.60	1.06
Total	80.67	2.28	54.29	43.87	14.88
Hopea ferrea type					
Leaves	54.50	1.34	39.09	18.29	8.27
Wood	10.34	0.18	7.12	8.26	1.60
Reproductive structures	2.61	0.23	2.43	1.24	0.33
Unclassified	5.46	0.26	3.75	2.50	0.45
Total	72.91	2.01	52.39	30.29	10.65

Table 5. Annual litterfall of different forest formations in Thailand.

Forest formation	Location	Total litterfall t/ha/y	Period of measure (y)	Reference
Lower montane forest	Doi Pui, Chiang Mai	6.8	5	Boonyawat & Ngampongsai, 1974
Primary peat swamp forest	Narathiwat	6.7	3	Bunyavejchewin & Nuyim, 1996
Semi-evergreen forest	Sakaerat			
Shorea henryana type		6.8	4	present study
Hopea ferrea type		6.4	3	present study

been studied in Thailand (Table 5): primary southern peat-swamp and lower montane forest. This reflects similar primary productivity of the three Thai forests. However, forests expected to have lower (e.g., deciduous forest) or higher (lowland rain forest) productivity have not yet been measured. JORDAN (1983) mentioned that net primary productivity in the tropics was about 1.3 times litterfall production.

Annual variation in the ratio of maximum to minimum litterfall in semi-evergreen rain forest, 1:1.53 over 4 years for the *Shorea henryana* type and 1:1.34 over 3 years for the *Hopea ferrea* type, was somewhat higher than reported for other tropical forests which was close to 1 (KUNKEL-WESTPHAL & KUNKEL, 1979; BRASELL ET AL., 1980; SPAIN, 1984; HERBON & CONGDON, 1993). Because of the high variability in annual litterfall, it is necessary to extend litter production measurement beyond a single year in order to get more precise estimates of mean annual litterfall and to study the long term dynamics of the system. The Dipterocarpaceae, especially *Shorea henryana,* will drop their fruits a few months after peak litterfall, usually during April–May. A high rate of litterfall may be effected on their regeneration. In some years after germination, a lot of young seedling die because their roots cannot penetrated through thick litter to soil (personal observation).

Annual variation in litterfall production was greater in the *Shorea henryana* type, probably because this dominance type occupied the slope area with shallow soil and less moisture holding capacity. The forest probably suffered more from drought during short dry periods during the rainy season.

The timing of maximum litterfall during the year differed between nearly adjacent study sites. The higher available soil moisture content in the *Hopea ferrea* type compared with the *Shora henryana* type (BUNYAVEJCHEWIN, 1986) may have delayed the responses of trees in the *Hopea ferrea* type to drought. Trees growing on soil with higher moisture content drop their leaves later in the dry season (MARTINEZ-YRIZAR & SARUKHAN, 1990).

The amount of litterfall in both dominance-types peaked in the drier months, as in many other tropical forests (HOPKINS, 1966; GONG & ONG, 1983; RAI & PROCTOR, 1986; SONGWE ET AL., 1988; MUOGHALU ET AL., 1993). This suggests that water deficit is a determinant of litterfall in many seasonal forests. Only a few studies have found peaks in both dry and wet seasons (CORNFORTH, 1970), as occurred in the *Hopea ferrea* type in this study. The cause of the bimodal pattern in the *Hopea ferrea* type was unclear, but may be related, at least in part, to a product of renewal continuous leaf replacement in some species (HERBON & CONGDON, 1993) and the washing down of litter retained in the canopy (EDWARD, 1977; BRASELL ET AL., 1980).

The proportion of leaves in litterfall at the present study sites was 70%–73% which was the same as the mean value (70%, range 48–96%) for 32 studies reported for tropical forest (SPAIN, 1984). The mean percentage of fine woody material in the present study (15.4–17%) was similar to those reported from other tropical forests in Australia (SPAIN, 1984), Papua New Guniea (EDWARDS, 1977), Java (YAMADA, 1976), and Panama (HAIENS & FOSTER, 1977). There was proportionally less reproductive material in the present study than in many other tropical forests studied. The mean percentage of reproductive material for the 22 studied was 8.2% (SPAIN, 1984).

The annual return of nutrients (except K) in litterfall at Sakaerat was generally lower than the mean levels found in other Asian rain forest. The means (and ranges) of annual nutrient content (kg/ha/y) in litterfall from Asian rain forests are N, 87.7 (44–110); P, 4.4 (1.2–7.0); K, 24.9 (17–33); Ca, 100.7 (13–290); and Mg, 17.9 (9–24) (DANTAS & PHILLIPSON, 1989, Table 1). Because of the low nutrient input from litterfall, and poor nutrients in soil (except K), the nutrients present in the system may recycle rapidly. Nutrients released from decomposing litter will be quickly absorbed by tree roots via fungal mycorrhiza. Most mineral nutrients may be pooled in the plant. This is probably a cause of the fact that crop fields around Sakaerat, where derived from semi-evergreen rain forest, cannot maintain high production for a long time.

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