

FINE LITTER PRODUCTION AND NUTRIENT RETURN TO THE SOIL IN THREE NATURAL FOREST STANDS OF EASTERN AMAZONIA

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RÉSUMÉ.

Apports de menus éléments organiques à la litière et retour au sol des sels minéraux dans trois placeaux de forêt naturelle de l'Amazonie orientale.

Les apports organiques de faible dimension à la litière ont été mesurés pour trois stations en forêt naturelle près de Belém do Para. Les valeurs annuelles sont comprises entre 8 et 10 t/ha/an (exprimées en poids de matière sèche) et se situent dans la gamme des valeurs signalées pour d'autres forêts denses équatoriales. La périodicité saisonnière des apports est plus marquée en forêt située sur sols hydromorphes que pour la forêt de terre ferme, bien que pour cette dernière une périodicité existe toutefois près de Manaus. La teneur en sels minéraux des apports organiques à la litière est du même ordre de grandeur que celle signalée pour la forêt de terre ferme des environs de Manaus. Les valeurs des forêts amazoniennes sont plus faibles que celles des autres forêts équatoriales.

ABSTRACT.

Fine litter fall was measured in three natural forest stands near Belém do Para. Annual fine litter fall in the stands varies between 8 and 10 t/ha/year (oven-dry matter) and is therefore within the range of fine litter fall reported for other humid tropical forests. Fine litter fall is more seasonal in forest on wet ground than it is in the terra firme forest. Fine litter fall of a terra firme forest near Manaus however is also seasonal. Concentration of nutrients in fine litter fall is in the same order of magnitude reported for the terra firme forest near Manaus. Fine litter fall in Amazon forests returns smaller amounts of nutrients to the soil than do other tropical forests.

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INTRODUCTION

The term fine litter fall is used to refer to the fall of leaves, small flowers and fruits, and twigs (KLINGE 1974). It excludes by definition the fall of branches and stems (coarse litter fall). Thus, aboveground productivity of a given stand cannot be estimated by measuring its fine litter fall. If it is intended to estimate productivity by measuring litter fall, fall of both fine litter and coarse litter are to be recorded simultaneously.

Data on litter production of Amazon forests are scarce. There is a single study of fine litter fall in the seasonal evergreen rain forest on terra firme near Manaus, central Amazonia, by KLINGE & RODRIGUES (1968), and some additional information on fine litter fall in the same forest, in a paper by KLINGE (1973).

The present study was made possible by co-operation of J.M. PIRES, Belém who organized the respective field work.

METHODS AND MATERIALS

16 litter traps each were placed at the ground of the Belém forests, and emptied at fortnightly intervals, in the period May 1969 to March 1971. The trap area was 0.25 m².

The areas in which the fine litter fall was studied, measured 100 × 200 m in case of the varzea forest, and 160 × 230 m in case of the terra firme forest. The traps were spaced along the axis of a 960 m long transect traversing a low igapo-covered valley between terra firme outcrops.

Fine litter fall samples were dried and stored at Belém before the whole set of samples was shipped to Plön where in each two-week-sample leaves, small flowers + fruits, and twigs were separated by hand.

N, P, K, Ca, Mg, and Na in the samples were estimated separately for each fraction, by the Kjeldahl method (nitrogen), by flame photometry (sodium, potassium, magnesium), and by EDTA titration (calcium); phosphorus was determined colorimetrically (Anon. 1969).

THE FOREST STANDS

The stands occur in the vicinity of Belém do Para and belong according to PIRES (1973) and PRANCE (1973) to

- forest on terra firme (non-flooded ground), at Mocambo F.R.,
- varzea forest on temporarily flooded area, at Aura F.R.,
- water-logged rainwater igapo forest, at Catu F.R.

The tree vegetation of each stand will be discussed in a forthcoming paper (KLINGE & PIRES, in preparation).

FINE LITTER FALL

Average annual fine litter fall in the Belém forests was found to vary between 8 and 10 t/ha/ oven-dry matter (table 1). The terra firme forest near Manaus has a significantly lower fine litter production which is derived from a study of weekly fine litter fall during two consecutive years (KLINGE & RODRIGUES 1968).

Table 1. Average annual fine litter fall in Amazon forest stands

Stand	t/ha/yr. (oven-dry matter)			
	Leaves	Flowers + fruits	Twigs	Total
Mocambo	8.0	0.6	1.3	9.9
Aurà	7.5	0.7	0.8	9.0
Catú	6.7	0.4	0.7	7.8
Manaus	5.6	0.4	1.3	7.3

The contribution of leaves to the annual fine litter fall is between 80 and 86 %, at Belém, whilst at Manaus it is 77 %. The proportion of small flowers + fruits varies between 5 and 8 %, the proportion of twigs between 9 and 18 %. Both terra firme forests have a significantly higher proportion of twigs than have forests on wet ground. This feature is possibly due to different proportions of living twigs and branches in total aboveground living phytomass of dry land forests and wet ground stands. The respective proportion is however only known for the Manaus stand (FITTKAU & KLINGE 1973, KLINGE & RODRIGUES 1973, 1974).

A high decomposition rate of fine litter in terrestrial habitats of the Amazon region was reported by COUTINHO & LAMBERTI (1971), KLINGE (1973), and STARK (1971). These data make probable that at least in warm and rainy months appreciable fine litter amounts will have disappeared in the two weeks the freshly fallen fine litter remained in the traps, at Belém (KIRITA & HOZUMI 1969). Therefore actual litter fall in the Belém area is higher than indicated by the data given in table 1.

FINE LITTER FALL PATTERN

Lowest monthly leaf fall (42 g/m²/month) at Mocambo occurs in September, i.e. in the first month of the dry season (WALTER & LIETH 1960-67). Average leaf fall in the rainy season is 77 g/m²/month dry matter as opposed to an average of 65 g/m²/month dry matter in the dry season.

Cumulative leaf fall in July, October and November was greater in 1969 than in the following year, but for September and December the reverse is true. Total leaf fall in the period July + September to December varied in 1969 between 247 and 469 g/m², and in 1970 between 221 and 501 g/m². The 1969 average was 344 g/m². The 1970 average was 3 % greater (356 g/m²).

When monthly leaf fall is lowest in the dry season, a higher proportion of flowers + fruits, and twigs than in the rainy season is observed. Seasonal variation of fine litter fall composition between years however is also high.

Despite the spatial variation in fine litter fall a reduction of trap numbers from 16 (all traps) over 11 (each third trap) to 10 (omitting last 6 traps) does not change drastically the totals for leaves and twigs, whilst the proportion of flowers + fruits decreases sharply (table 2).

Table 2. Fine litter fall (air-dry matter) from May to December 1969 at Mocambo, computed for 16, 11, and 10 traps

Number of traps	%			
	Leaves	Flowers + fruits	Twigs	Total
16	100	100	100	100 (=6.31 t/ha/yr.)
11	96.1	126.5	93.8	98.6 (=6.22 t/ha/yr.)
10	98.1	39.5	92.9	92.0 (=5.80 t/ha/yr.)

At Aurà, lowest leaf fall (44 g/m²/month dry matter) also occurred in the dry season, whilst in the rainy season it was 72 g/m²/month. Corresponding data for flowers + fruits are 5 g/m² per month in dry season against 7 g/m² and month in rainy season, or for dry twigs 3 g/m²/month in dry season against 6 g/m²/rainy season month.

Fall of fine litter in 1970 (September till December) yielded only 84 % (leaves), 38 % (flowers + fruits), and 76 % (twigs) of corresponding 1969 amounts.

Average annual fine litter fall is given separately for both igapo portions near the terra firme and for its central portion, in table 3. Fall of leaves and twigs in the central portion is significantly lower than in the portions near the terra firme, but the reverse is true for flowers + fruits.

Table 3. Average annual fine litter fall (oven-dry matter), at Catù

Portion of transect	t/ha/year (oven-dry matter)			
	Leaves	Flowers + fruits	Twigs	Total
Near terra firme				
— western portion	6.9	0.3	0.7	7.9
— eastern portion	7.6	0.3	0.9	8.8
Average	7.3	0.3	0.8	8.4
Central portion	5.8	0.6	0.4	6.8

Highest leaf fall occurs when rainfall decreases. Leaf fall is again lowest in September. Generally, there is a more pronounced seasonality of fine litter fall in the ipapo forest than at Mocambo or at Aurà (fig. 1). Since no parameter governing the seasonal pattern of fine litter fall was monitored, differences between the stands cannot be analyzed critically.

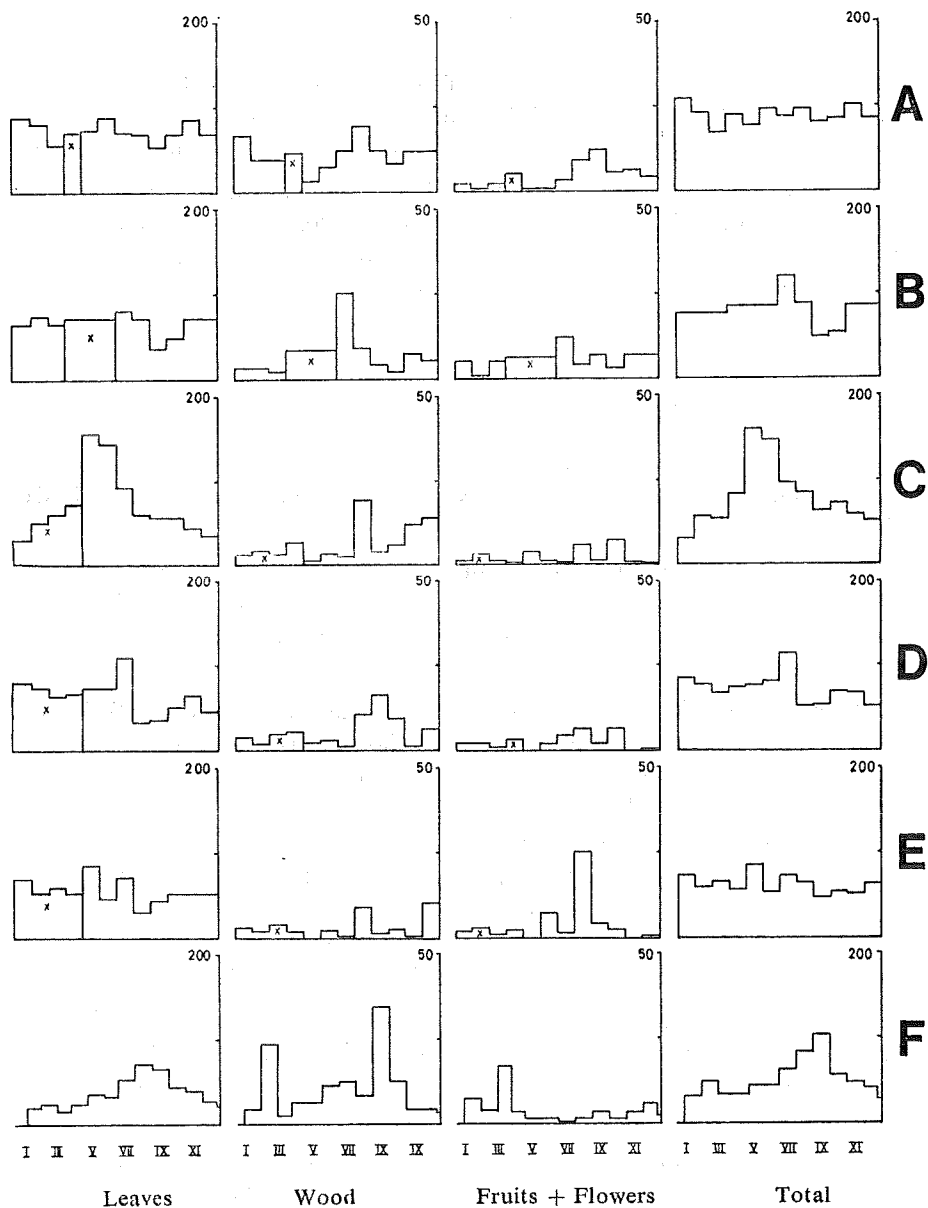


Fig. 1. Fine litter fall (g/m²/month) in Amazonian forests : A: Mocambo rain forest, 16 sites, 10.7 t/ha/yr.; B: Aurà várzea forest, 8 sites, 10.2 t/ha/yr; C: Catù igapoforest, 6 sites, eastern portion, 9.6 t/ha/yr; D: Catù igapã forest, 5 sites, western portion, 8.6 t/ha/yr; E: Catù igapô forest, 5 sites, central portion, 7.4 t/ha/yr; F: Manaus rain forest, 10 sites, 1964, 5.7 t/ha/yr (x calculated values/month).

FINE LITTER PRODUCTION IN HUMID TROPICAL FORESTS

In a literature survey on fine litter fall of forests in both tropical lowlands and uplands (KLINGE 1974) it was found that fine litter production in these forests is astonishingly equal. The data published so far are all around 10 t/ha/year or so.

If the small amounts of fine litter retained by the forest canopy (SOEPADMO 1974) are added to the data given in table 1 and if the loss due to decomposition prior to harvesting the litter fall samples could also be accounted for, the fine litter production of the Belém forests would come near to the above overall mean of fine litter production in humid tropical forests.

NUTRIENTS IN FINE LITTER FALL

The amounts of nutrients which in the four Amazon forests return annually via fine litter fall to the soil, are given on a kg/ha basis in table 4, and on a % basis in table 5.

Nitrogen concentration in leaves from the wet forests is lower than in leaves from the terra firme forests which have lower concentrations of potassium and calcium. Variation in the concentration of phosphorus, magnesium and sodium in leaves from the four stands is generally low.

Differences in nutrient concentrations between leaves and flowers + fruits are small for sodium and magnesium, but high for phosphorus. Calcium and potassium concentrations in flowers + fruits from the terra firme forests are lower than the concentration of these elements in flowers + fruits from the wet forests. No clear tendency is observed for nitrogen.

Twigs have lower concentrations in nitrogen, potassium and magnesium than leaves or flowers + fruits. Calcium concentrations in twigs are similar to those found in leaves. The wet forests have lower nitrogen and magnesium concentrations than the terra firme forests, but are richer in potassium and calcium.

Comparing the nutrient concentration in fine litter fall of Amazon and other tropical forests (KLINGE & RODRIGUES 1968) it is evident that the Amazon forests return considerably lower amounts of nutrients via fine litter fall to the soil, except for nitrogen.

In relation to the nutrient status of leaf litter fall at Mocambo it is interesting to refer to the results of a study on Mocambo leaf litter by HOWARD-WILLIAMS (1974). This author stated very low mineral ash and protein values but high amounts of undigestible cell-wall material, high caloric values, and, relatively high polyphenol concentrations in the leaf matter. These results are interpreted in terms of low quality forage of the leaf litter which is supposed to be related to the low animal biomass of the Amazon forests, stressed by FITTKAU & KLINGE (1973).

Table 4. Nutrients in annual fine litter fall in Amazon forests

Fine litter fraction	Stand	Nutrients (kg/ha/year, oven-dry matter)					
		N	P	K	Ca	Mg	Na
Leaves	Mocambo	134.0	3.24	13.8	25.0	22.1	5.9
	Catù	83.6	2.41	21.4	53.5	25.3	4.8
	Aurà	92.7	2.69	19.7	65.1	22.8	5.2
	Manaus	86.3	1.65	10.0	12.4	9.8	4.3
Flowers + fruits	Mocambo	9.1	0.44	1.8	2.0	1.5	0.5
	Catù	6.2	0.28	1.8	2.6	1.2	0.4
	Aurà	9.4	0.53	2.0	3.7	1.5	0.3
	Manaus	4.1	0.19	1.4	0.8	0.5	0.1
Twigs	Mocambo	13.4	0.43	1.4	5.8	3.2	0.6
	Catù	6.4	0.73	1.1	6.0	1.3	0.7
	Aurà	7.6	0.19	1.3	7.5	1.3	0.2
	Manaus	15.2	0.30	1.3	5.2	2.3	1.1
Total	Mocambo	156.5	4.1	17.0	32.8	26.8	7.0
	Catù	96.2	3.4	24.3	62.1	27.8	5.6
	Aurà	109.7	3.4	23.1	76.3	25.6	5.7
	Manaus	105.6	2.1	12.7	18.4	12.6	5.5

Table 5. Average nutrient concentration in fine litter fall of Amazon forests

Fine litter fall fraction	Stand	%					
		N	P	K	Ca	Mg	Na
Leaves	Mocambo	1.68	0.04	0.17	0.31	0.28	0.07
	Aurà	1.24	0.03	0.26	0.87	0.30	0.07
	Catù	1.25	0.04	0.32	0.80	0.38	0.07
	Manaus	1.54	0.03	0.18	0.22	0.18	0.08
Flowers + fruits	Mocambo	1.52	0.07	0.29	0.34	0.26	0.08
	Aurà	1.35	0.08	0.29	0.53	0.22	0.04
	Catù	1.55	0.07	0.45	0.65	0.31	0.09
	Manaus	1.00	0.05	0.35	0.20	0.13	0.03
Twigs	Mocambo	1.03	0.03	0.11	0.44	0.25	0.05
	Aurà	0.95	0.02	0.17	0.94	0.17	0.03
	Catù	0.91	0.10	0.15	0.86	0.19	0.10
	Manaus	1.17	0.02	0.10	0.40	0.18	0.08

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