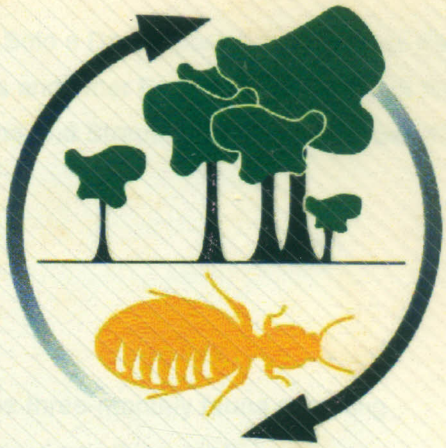

Soil Fauna and Litter Decomposition in Primary and Secondary Forests and a Mixed Culture System in Amazonia

Final Report 1996-1999

Project leadership:

Prof.Dr. Ludwig Beck (Staatliches Museum für Naturkunde, Karlsruhe, D)
Dr. Luadir Gasparotto (Embrapa Amazônia Ocidental, Manaus, BR)

Project coordination:

Dr. H. Höfer [4], Dr. C. Martius [1;6], Dr. W. Hanagarth [1], MSc. M. Garcia [2], Dr. E. Franklin [3], Dr. J. Römbke [5]

Further scientific collaborators:

Dr. B. Förster [5], Dr. T. Gasnier [7], Dipl. Biol. C. Hanne [6], Dr. F. Luizão [3], Dr. R. Luizão [3], MSc. L. Medeiros [3], Dr. W. Morais [3], MSc. R. Ott [3]

[1] Staatliches Museum für Naturkunde Karlsruhe (SMNK)
[2] Embrapa Amazônia Ocidental, Manaus
[3] Instituto Nacional de Pesquisas da Amazônia (INPA), Manaus
[4] II. Institute of Zoology, University of Göttingen
[5] ECT Oekotoxikologie GmbH, Flörsheim
[6] Center for Development Research (ZEF), Bonn
[7] Universidade do Amazonas, Manaus

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Litter production, litter stocks and decomposition coefficients in a central Amazonian rain forest, a secondary forest and agroforestry systems

Christopher Martius[1], Marcos Garcia[2], H. Hoefer[3,4], W. Hanagarth[4]

[1]Center for Development Research (ZEF), Bonn, Germany
[2]Embrapa Amazônia Ocidental, Manaus, Brazil
[3]Institute of Zoology, University of Göttingen, Germany
[4]Staatliches Museum für Naturkunde Karlsruhe (SMNK), Germany

Abstract

Fine litter fall and stocks were determined from July 1997 to March 1999 in an area of primary rain forest (FLO), a 13-year old secondary forest (SEC), and two polyculture culture systems (agroforestry; POA and POC) in Central Amazonia, Brazil. In 1998, the average annual litter production in the forest was 8.37 t ha^{-1} yr^{-1} (in the range of litter production in other rain forests in the region). This was similar to one plantation site (POC; 8.30 t ha^{-1} yr^{-1}), but higher than the secondary forest (SEC; 7.40 t ha^{-1} yr^{-1}) and POA (6.24 t ha^{-1} yr^{-1}). In FLO, leaf material accounted for 67% of the litter; leaf material was relatively more important in the other sites (76-82% of total litter fall), in which much less fine matter and almost no dead wood was recorded than in FLO. The negative linear regression between monthly rainfall and monthly litter fall was significant only for FLO (r^2 = 0.58; P=0.05). Litter production was higher in the one-year period 1997-98 (an El Niño year) than in 1998-99. The production of leaf litter had a much lower variability than that of wood, flowers and fine matter. Leaf litter production variability was also much lower in the plantation sites, indicating a much more homogenous stand structure.

Litter stocks on the forest floor were highest in SEC (24.70 t ha^{-1}), followed by POC and POA; they were lowest in the primary forest (FLO; 11.98 t ha^{-1}). The negative linear regression of litter stocks with rainfall was not significant.

From monthly values of litter stocks (X_{ss}) and total monthly litter production (L), the decomposition coefficient $k_e = L/X_{ss}$ was calculated for each month. It was, on average, highest for FLO (0,059), lower for POC (0,042) and POA (0,040), and lowest for SEC (0,024). Thus, the secondary forest site had the largest litter accumulations and a very low litter production; in short, very slow decomposition processes. In contrast, FLO had a high litter production but low stocks, and therefore, decomposition rates were high. The decay coefficients of the polyculture systems were between the primary forest and SEC.

Keywords: Rain forest, Agroforestry systems, Amazonia, Litter production, Litter stocks, Rainfall, Decomposition

1. Introduction

Litter is an important ecosystem resource. Litter feeds the decomposer food chain and thus initiates the nutrient cycles that are closed with the mineralization of the nutrients enclosed in the litter. Determining the dynamics of litter production and available litter stocks over time therefore is a central task in studies on decomposition on the ecosystem level. Here, we report on the assessment of litter dynamics in one natural and several man-managed ecosystems in central Amazonia, in the context of a study on soil fauna and litter decomposition (Beck et al. 1998a, b) that was initiated in 1996.

2. Material and Methods

Litter production was collected weekly with simple collectors of a basal area of 0.25m^2 (50x50 cm). A collector consisted of a wooden frame 8 cm high and a nylon screen mesh suspended to a height of 50 cm above ground. Twenty of such samplers were used in each of the primary (FLO) and secondary (SEC) forest areas, and 10 samplers in each of the areas of plantation system IV on block A and C (POA and POC). The collectors were distributed at random within the areas and their positions were maintained throughout the study. The collected litter was manually separated into fractions and oven-dried at 65°C for four days, then weighed (dry weight). For the preliminary analysis presented here, average weekly values were calculated and then multiplied with 52 to obtain the annual litter production at each site. The study lasted from 27.7.1997 to 29.3.1999 (608 days, 88 weeks).

Litter stocks were collected monthly with the soil core borers also used for the macrofauna assessment (21 cm diameter), at randomly chosen points in the study sites. Once every month between 26.8.1997 and 2.3.1999, 20 such samples were taken in FLO and SEC, and 10 samples in POA and POC. The collected litter was oven-dried at 65°C for four days, then weighed (dry weight). [Every three months, the material was manually separated into fractions (leaves, coarse wood, fine wood, flowers and seeds, fine matter, and roots). Roots were excluded from the total litter sample, as it was not possible to distinguish between live and dead roots. However, these data are not presented here.]

Data processing. The total study period was 88 months, and therefore the period of whole total data set includes two dry seasons but only one rainy season. As litter fall is related to rainfall, the data had to be adjusted to annual values based on true one-year seasonality (one rainy and one dry season). As inter-annual variation exists, several annual data sets have been produced referring to the periods 1997-98, 1998, and 1998-99.

Due to technical reasons, the sampling of litter fall took place in regular 1-week intervals, whereas stock sampling occurred in irregular intervals (2 to 5 weeks). For the correlation of litter production and stocks and the determination of decomposition coefficients, production data had to relate to the intervals of the stock assessments. Assuming that the litter stocks of a site are predominantly determined by the litter produced during the four weeks before the day of collection, we produced a data set using the production data of the last four-week interval before every stock sampling. In cases where stock sampling occurred in an interval of less than 4 weeks this led to an overlap (re-utilization) of the data of some weeks (Table 1).

3. Results

Litter production

The average weekly litter production (calculated on the basis of all weeks and all collectors, or 88x20 = 1760 data points for FLO and SEC, and 88x10 = 880 data points for POA and POC) was highest in FLO (17.18 ± 15.49 g m^{-2}), and decreased in the order POC > SEC > POA (Table 2). Annual litter fall was calculated for three different one-year periods (Table 3), in all of which the sequence was FLO > POC $\geq$ SEC > POA. Litter fall in FLO (7.93 - 9.50 t ha^{-1} yr^{-1}) was in the range of litter fall recorded in other sites (e.g. 7.1 ± 8.6 t ha^{-1} yr^{-1} in nearby Reserva Ducke; Martius in prep.).

Variability.

The highest litter fall and the highest variability were seen in the dry season of 1997 in all sites (Figure 1). Variation of litter fall in FLO was higher than in the other sites, due to the higher heterogeneity of stand structure. (One large peak in SEC at the end of 1998 (21.12.98) is due to the collection of 85.1 g/collector in collector AF08, much higher than the average production of 2.5 g/collector in this week).

Fraction distribution.

In all sites, leaves always represented the largest fraction, accounting for 67-82% of the litter. Fine wood (< 1cm diameter) was always the second largest fraction. Whereas large wood accounted for 2.8% of the litter in FLO, and 1.6% in SEC, almost none of it was found in POA and POC. Flowers and seeds had similar proportions in all sites, but fine matter (5 mm sieve) in FLO (9%) was two times higher than fine matter in the other sites (3-5%) (Table 4). The standard deviation as percent of the average (lower part of the table) indicates how steadily each fraction was produced. The leaf fraction was most predictably produced; this is more pronounced in the simply structured secondary forest and the plantations where cohorts of equally aged trees dominate. The coarse wood fraction was highly unpredictable; much more so in the plantations where dead wood rarely occurred (see above).

Seasonality and inter-annual variability. The highest litter falls were observed in October 1997 in all sites. Litter fall was lowest from February to March 1998, and increased again during the dry season (September) 1998. In FLO, annual litter fall was higher in 1997-98 than in 1998-99, but this trend was not observed in the other sites (Table 3). In FLO, monthly litter fall and monthly rainfall are correlated by a linear regression with an r^2-coefficients of 0.582, but in the other sites, the correlation is much weaker (Table 5).

Litter stocks

The largest stocks were found in SEC, followed by POC > POA > FLO (Table 6). This applies equally to the whole study period (averages from 88 weeks) and to the single annual periods. There are no significant differences of average litter stocks between the single annual periods, but in FLO, average monthly litter stocks are somewhat higher in the first year (97-98), and in SEC, they are lower in the first than in the other two annual periods. All this points to a difference between the El-Niño-year 1997 and the rest of the study period.

Stocks of large (coarse) dead wood in the study sites have been assessed on one occasion (the volume was assessed and converted to biomass; see subreport "Dead wood volume", following chapter). They follow the sequence FLO (24.5 t ha^{-1}) > POC (12.1 t ha^{-1}) > SEC (4.0 t ha^{-1}) > POA (2.4 t ha^{-1}). Thus, whereas leaf litter stocks were highest in SEC, large wood litter stocks were highest in FLO, and almost no large wood litter was found in the plantations. Wood biomass was roughly double that of small leaf litter biomass in FLO, but only about 15-75% of leaf litter in the plantations.

The coefficient of the linear regression of monthly litter stocks in the four sites and monthly rainfall is negative, but the correlations are weak (Table 7; however, the power of the performed tests (with alpha =0.05) generally is too low in order to not exclude a type II error, i.e. assuming no correlation where there actually is one).

4. Discussion

The decay coefficient. From monthly values of litter stocks (X_{ss}) and total monthly litter production (L), the decomposition coefficient $k_e = L/X_{ss}$ (Olson 1963) was calculated for each month (Figure 2). The average of the monthly values was highest for FLO (0,059), lower for POC (0,042) and POA (0,040), and lowest for SEC (0,024). Thus, the secondary forest site had the largest litter accumulations in spite of a relatively low litter production; and here decomposition processes were very slow. In contrast, FLO had a high litter production but low stocks, and therefore, decomposition rates were high. The decay coefficients of the polyculture systems were between the primary forest and SEC.

Acknowledgements

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5. References

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Tables

Table 1: Adjustment of sampling dates

How dates are distributed in Stocks assessm.				How dates should be distributed in Production assessment				
Stock dates	corresponds to weeks	n Weeks	n Days	What samples (weeks S...) to take for analysis	Start Date	End Date	n Weeks	n Days
26.08.97	S32-35	4	28	S32-35	29.07.97	25.08.97	4	27
09.09.97	S36-37	2	14	S34-37	11.08.97	08.09.97	4	28
03.10.97	S38-40	3	24	S37-40	01.09.97	29.09.97	4	28
07.11.97	S41-45	5	35	S42-45	06.10.97	03.11.97	4	28
03.12.97	S46-49	3	26	S46-49	31197	01.12.97	4	28
08.01.98	S50-98S01	5	36	S51-98S01	91297	06.01.98	4	28
02.02.98	S02-05	4	25	98S02-S05	60198	02.02.98	4	27
03.03.98	S6-S9	4	29	98S06-09	20298	02.03.98	4	28
07.04.98	S10-S14	5	35	98S11-14	09.03.98	60498	4	28
12.05.98	S15-19	5	35	98S16-19	13.04.98	110598	4	28
03.06.98	S20-22	5	22	98S19-22	04.05.98	10698	4	28
06.07.98	S23-27	3	33	98S23-27	08.06.98	60798	4	28
11.08.98	S28-32	5	36	98S29-32	14.07.98	100898	4	27
01.09.98	S33-35	3	21	98S32-35	03.08.98	310898	4	28
06.10.98	S36-S40	5	35	98S38-41	08.09.98	51098	4	27
05.11.98	S41-S44	4	30	98S41-44	05.10.98	31198	4	29
02.12.98	S45..S48	4	27	98S45-48	03.11.98	301198	4	27
06.01.99	S49..99S01	5	35	98S50-99S01	07.12.98	40199	4	28
05.02.99	S02-S05	4	30	99S02-05	04.01.99	10299	4	28
04.03.99	S06-S09	4	27	99S06-09	01.02.99	01.03.99	4	28

Table 2: Average weekly litter fall (dry weight, g m^{-2}) in the collectors of each site and calculated annual litter fall for 1998

System	Collector		Average	Std. Dev.	Average	Std. Dev.
FLO	Q 31		1779	1338	1718	1549
		AI 16	1751	1391		
		AF 08	1492	1218		
		F 34	1142	1009		
		AM 18	1470	1233		
		AK 20	1680	1215		
		Q 16	2192	1977		
		AJ 29	1536	900		
		AM 33	1346	850		
		P 10	2576	2108		
		H 25	1538	1673		
		H 15	1224	874		
		B 31	1861	2131		
		X 18	1687	1930		
		N 05	1836	1364		
		AD 13	1662	1488		
		AD 01	1152	909		
		AE 22	2099	1841		
		T 09	1730	1282		
		AI 38	2670	2087		
SEC	Q 31		1741	1404	1422	1543
		AI 16	1854	1409		
		AF 08	1536	3935		
		F 34	1489	1113		
		AM 17	1262	900		
		AK 20	1268	1004		
		Q 16	1616	1245		
		AJ 29	1751	1383		
		AM 33	1269	952		
		P 10	2242	2312		
		H 25	1161	1075		
		H 15	962	725		
		B 31	1134	1135		
		X 18	1565	1357		
		Q 06	1389	1195		
		AD 13	1465	1130		
		AD 01	784	712		
		AE 22	1589	1460		
		T 09	1322	1548		
		AI 38	1059	1094		
POA	R 19		1152	810	1265	884

		J 07	1347	998		
		M 25	1837	1198		
		W 26	1455	844		
		F 11	1122	676		
		G 02	847	661		
		S 23	1369	933		
		C 05	1109	762		
		AA 15	1187	649		
		B 07	1213	838		
POC	R 14		1578	932	1510	1165
		AC 21	1611	1454		
		K 05	1555	1417		
		N 15	1297	715		
		U 28	1498	1453		
		V 32	1757	1288		
		F 28	1430	826		
		G 18	608	448		
		S 12	1590	945		
		C 30	2171	1120		

Table 3: Average annual litter fall (dry weight, t ha^{-1} yr^{-1}) in each site, calculated for different periods out of the study period 1997-1999 (see text)

Area	1997-98		1998		1998-99	
	22.7.97-21.7.98		31.12.97-28.12.98		30.3.98-29.3.99	
	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.
FLO	950	881	837	682	793	659
SEC	719	776	740	763	757	764
POA	642	489	624	419	647	411
POC	719	619	830	616	872	603

Table 4: Percentage of fractions in litter production. Average of 10 (FLO, SEC) and 5 (POA, POC) collectors and 88 weeks.

	Area	Leaves	Wood >1cm	Wood <1cm	Flowers and Seeds	Fine Matter (5mm sieve)	Sum
Percentage of each Fraction	FLO	67.4	2,8	15.1	5,6	9,2	100
	SEC	80,2	1.6	9.4	5,6	3,2	100
	POA	75,7	0,1	10,8	8,5	4,9	100
	POC	81,9	0,1	9.4	5,0	3,7	100,0
Standard Deviation	FLO	15,1	6,6	11,4	6,2	6.6	0
	SEC	12,7	7,7	8,3	6.3	2,4	0

	POA	11,5	0,6	7.7	9.8	3	0
	POC	9,5	0,7	7,0	4,8	2.5	0
Standard Deviation as % of Average	FLO	22.4	239,7	75,5	109.7	72.2	0
	SEC	15,8	475,5	88,8	113.6	75.4	0
	POA	15,3	938,1	71,3	114,4	59.9	0
	POC	116	685,4	74,3	96,7	69.4	0

Table 5: Linear regressions (y =ax +b) of monthly litter fall (t ha^{-1} $month^{-1}$)and monthly rainfall (mm) for the study sites primary forest (FLO), secondary forest (SEC), and the plantation sites (POA and POC) (data set Aug 1997 - Feb 1999)

site	a	b	r^2
FLO	-17	1006	582
SEC	-14	844	299
POA	-6	640	224
POC	-9	775	176

Table 6: Average monthly litter stocks in the study sites during the study period (n= 20 months; August 1997-March 1999), and average stocks based on one-year periods

Area	Average stocks (t ha^{-1}) ± Std. Dev.	Std. Dev. as % of Average
FLO	11.98 ± 4.27	357
SEC	24.70 ± 3.43	139
POA	15.06 ± 3.03	201
POC	16.19 ± 4.12	255

Area	1997-98		1998		1998-99	
	22.7.97-21.7.98		31.12.97-28.12.98		30.3.98-29.3.99	
	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.
FLO	1268	446	1128	139	1090	142
SEC	2282	871	2522	886	2664	598
POA	1475	712	1355	560	1423	510
POC	1602	821	1511	544	1526	479

Table 7: Linear regressions (y =ax +b) of monthly litter stocks (t ha^{-1})and monthly rainfall (mm) for the study sites primary forest (FLO), secondary forest (SEC), and the plantation sites (POA and POC) (full data set; Aug 1997 - Feb 1999)

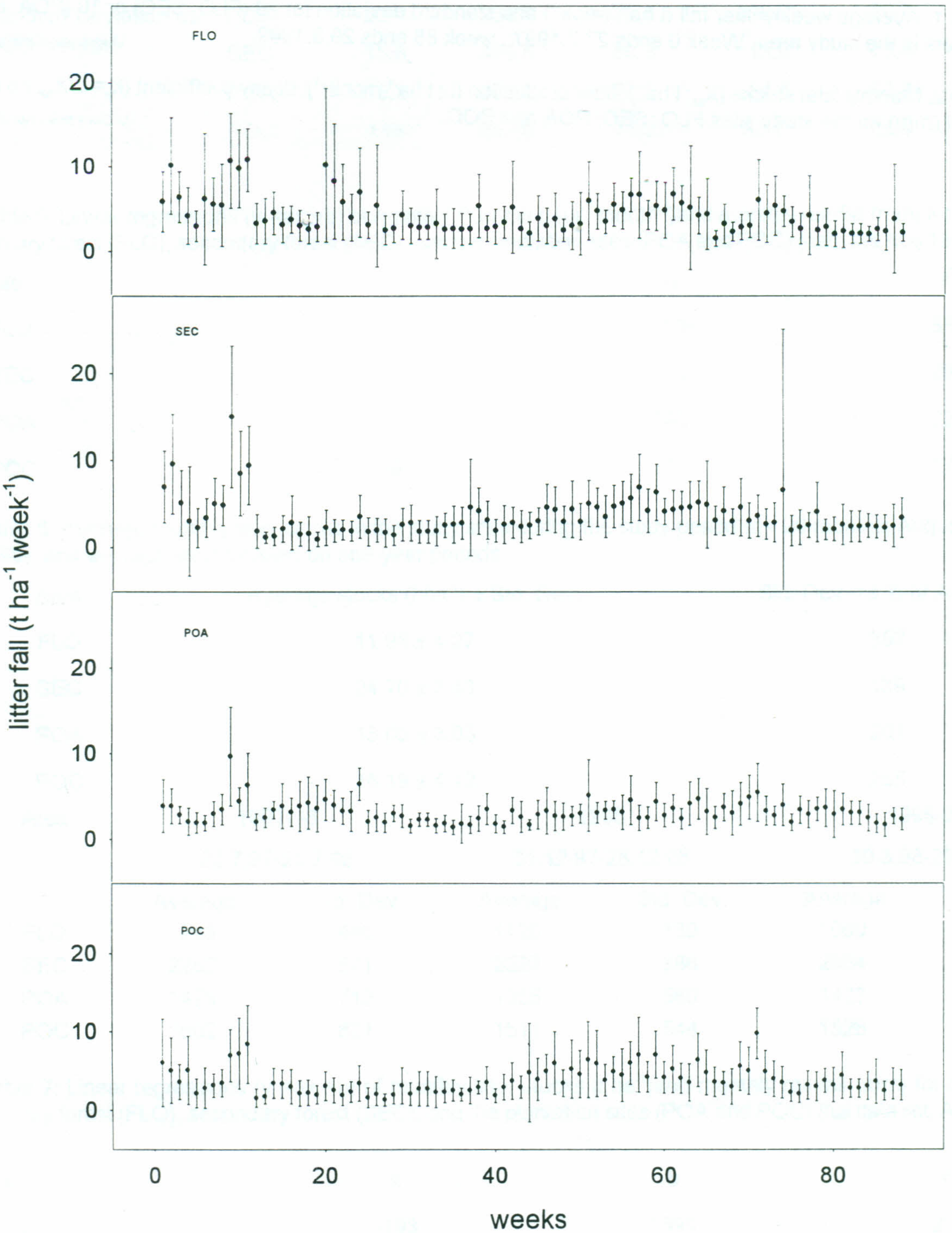
site	a	b	r^2
FLO	-193	1598	278
SEC	-250	2990	95
POA	-296	2121	238
POC	-265	2168	161

Legends to Figures

Figure 1: Average weekly litter fall (t ha^{-1} $week^{-1}$) and standard deviation for 20 (FLO, SEC) or 10 (POA, POC) litter samplers in the study area. Week 0 ends 27.7.1997 , week 88 ends 29.3.1999. Lit prod annual.JNB: graph page 3 ALL

Figure 2: Monthly litter stocks (X_{ss}; t ha^{-1}), litter production (L; t ha^{-1} $month^{-1}$), decay coefficient (k_e= L/X_{ss}; no units), and rainfall (mm) for the study sites FLO, SEC, POA and POC. Lit Stock prod L Xss.JNB graph page 1

Fig.1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POA
POC
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10
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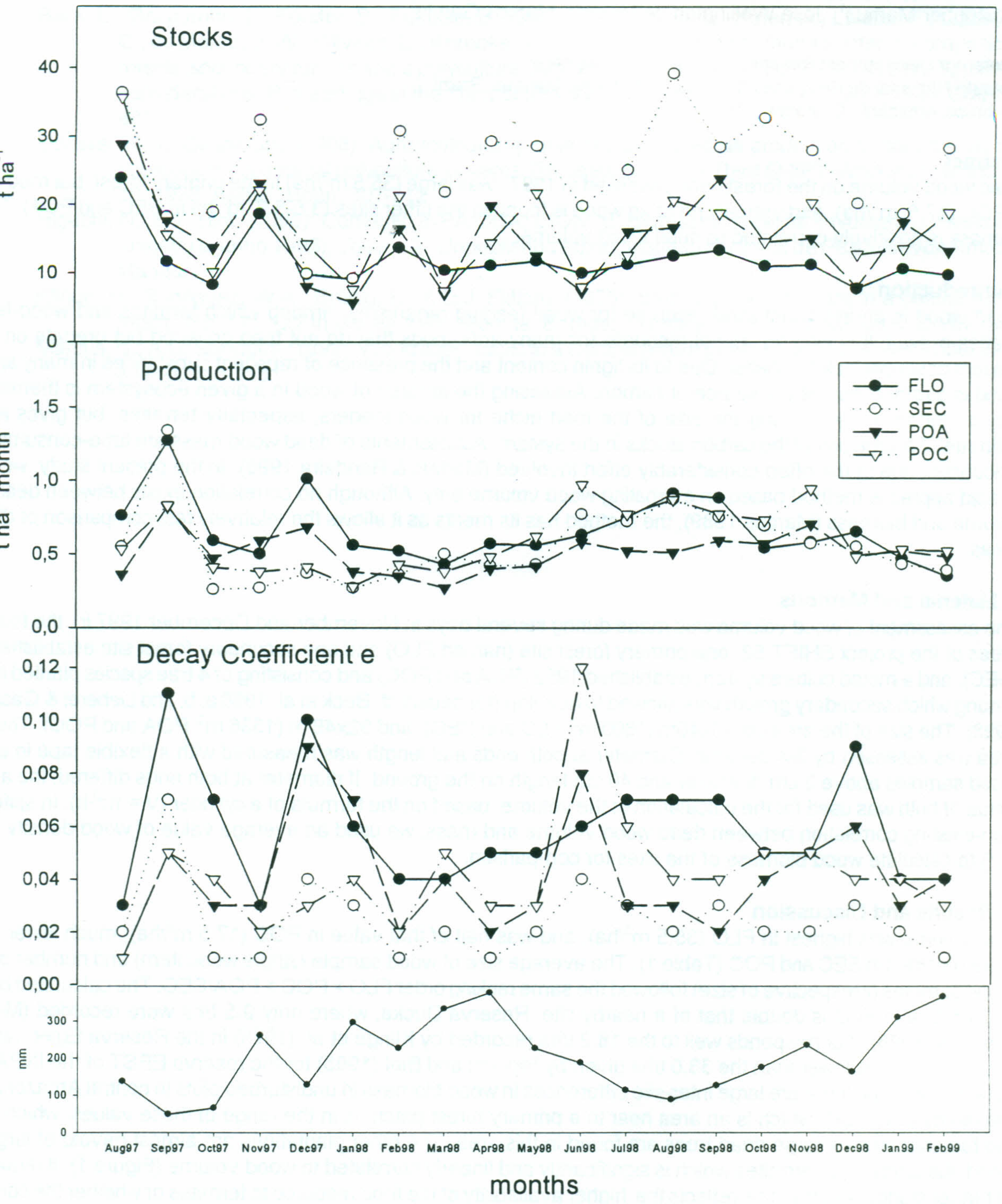
20
40
60
80
weeks

Fig. 2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t ha-1
40
30
20
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Production
t ha-1 month-1
1,5
1,0
0,5
0,0
FLO
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Decay Coefficient e
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0,12
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Aug97
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Nov98
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Jan99
Feb99
months

Dead wood volume in primary forest, secondary forest and an agroforestry plantation system in central Amazonia

Christopher Martius[1], José Wellington de Morais[2], Marcos Garcia[3]

[1]Center for Development Research (ZEF), Bonn, Germany
[2]Instituto Nacional de Pesquisas da Amazônia (INPA), Manaus, Brazil
[3]Embrapa Amazônia Ocidental, Manaus, Brazil

Abstract
Dead wood volume on the forest floor. assessed in 1997, was large (35.5 m^3/ha) in the primary forest, but much lower in POC (17.5 m^3/ha), and virtually no dead wood is found in the other sites (3.5-5.8 m^3/ha in SEC and POA). Termite biomass is positively correlated to dead wood volume.

1. Introduction

Dead wood is an important food resource for wood-feeding organisms, among which termites and wood-feeding beetles prevail. It is also an spatial resource for many arthropods that do not feed on wood but predate on wood-feeders or simply look for shelter. Due to its lignin content and the presence of repellent substances in many species, wood is a rather recalcitrant source of carbon. Assessing the amount of wood in a given ecosystem is therefore not only important for estimating the size of the food niche for wood-feeders, especially termites, but gives also an estimate of a large part of the carbon stocks in the system. Assessments of dead wood mass are time-consuming and labourious, due to the often considerably effort involved (Martius & Bandeira 1998). In the present study, we tested a rapid appraisal method based on estimating wood volume only. Although no correlation exists between dead wood volume and biomass (Martius 1989), the method has its merits as it allows the relatively fast comparison of different areas.

2. Material and Methods

The assessment of wood volume was made during several days in November and December 1997 in the four study areas of the project SHIFT 52: one primary forest site (named FLO) and one secondary forest site established 1984 (SEC), and a mixed culture system established 1992 (POA and POC) and consisting of 4 tree species planted in rows, among which secondary growth was allowed to develop (for details cf. Beck et al. 1998 a, b, and Lieberei & Gasparotto 1998). The size of the areas is 40x40m (1600 m^2, FLO and SEC), and 32x48 m (1536 m^2, POA and POC). The whole area was assessed by 3-4 persons. Diameter at both ends and length was measured with a flexible tape in all dead wood samples above 3 cm diameter and 40 cm length on the ground. If diameter at both ends differed, the average value of both was used for the calculation of the volume, based on the formula of a cylinder ($V = \pi r^2 \cdot h$). In spite of the non-existing correlation between dead wood volume and mass, we used an average value of wood density (0.69 g m^{-2}) to calculate wood biomass of the sites for comparison.

3. Results and Discussion

The volume was highest in FLO (35.5 m^3/ha), and was half of that value in POC (17.5 m^3/ha); much lower values were recorded in SEC and POC (Table 1). The average size of wood sample (single wood item) and number of single wood samples (irrespective of size) followed the same ranking order FLO > POC > POA/SEC. The calculated biomass of 24.5 t/ha in FLO is double that of a nearby site, Reserva Ducke, where only 9.5 t/ha were recorded (Martius & Bandeira 1998), it corresponds well to the 18.2 t/ha recorded by Klinge et al. (1975) in the Reserva Egler (about 40 km away), and is lower than the 33.0 t/ha given by Higuchi and Biot (1995) for the reserva EEST of the INPA; these data indicate that there are large inter-site differences in wood biomass in undisturbed plots in central Amazonia. Only the biomass in POC, which is an area near to a primary forest patch, is in the range of these values, which reflects the fact that several large dead trees are found in this area. The other plantations are almost devoid of large dead wood. the biomass of termites which is significantly and linearly correlated to wood volume (Figure 1). It remains pen to further studies whether this reflects the higher availability of the food resource to termites or whether the correlation is a coincidence, both factors being linked to some other characteristic of the sites.

Acknowledgements
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Tables

Table 1: Dead wood volume and biomass (calculated per ha); average size of wood samples and number of samples (per area)

	FLO	SEC	POA	POC
Volume (m^3/ha)	35.5	5.8	3.5	17.5
Calculated Biomass (t/ha)	24.5	4.0	2.4	12.1
Average (l per wood item) ± Std. Dev.	71.0 ± 86.3	49.2 ± 92.5	19.1 ± 16.8	49.9 ± 98.9
No. of samples in area	80	19	28	54
Size of area (m^2)	1600	1600	1536	1536

Figures

Figure 1: Linear regression showing the correlation between wood volume and termite biomass in the study plots