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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Microclimate 1997- 1999 in primary forest, secondary forest and agroforestry systems in central Amazonia

Christopher Martius[1], Marcos Garcia[2], Hubert Höfer[3,4], Werner 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
Rainfall, average maximum and minimum air temperature, and relative air humidity as measured at the Embrapa wheather station all show that 1997 was a strong El Niño (ENSO) year. The same is true for the microclimate of the study sites (a primary forest (FLO), a 12-year old secondary forest (SEC), polyculture system (sites POA, POC, PolyIIB), and a peach palm monoculture (PupC), where maximum and average air temperature and soil temperature were all highest in September and October 1997. Minimum air temperatures were elevated in the subsequent period, from October 1997 to May 1998. Relative air humidity was extremely low in September 1997; and evapotranspiration and calculated saturation deficit were very high.
Litter temperatures in FLO, SEC, POC, and PupC were very similar; in POA they were consistently higher at about 2 degrees, and in PolyIIB they were about 4 degrees higher. The highest maxima were recorded in POA and PolyIIB, showing that microclimatic conditions are much more variable and unpredictable than in the other sites.
Soil temperatures were lowest in FLO, higher in SEC, and even higher in POA. In FLO, the soil temperature almost equalled the temperature in the litter layer, whereas soil temperatures in POA were considerably lower than the litter temperatures. Air humidity in all sites was lowest in September/October 1997. In the other months, it almost always stayed near 100% in FLO, SEC, POC, but was much lower in POA. In conclusion, the microclimate in the litter and soil layer of polyculture sites can be much harsher than in secondary forest and primary forest in Amazonia, but the mimicking of natural forest structure can be used for the management of microclimatic conditions that affect decomposer fauna.

1. Introduction

The record of microclimatic data is an essential basic task in a study aimed at analyzing differences in soil fauna abundance and performance in differently managed sites. In this project, small data loggers were used to record and store microclimatic data in the litter and soil layer of the studied plots; namely primary forest (FLO), secondary forest (SEC), and two plantations (polyculture system 4; POA and POC; for details cf. Lieberei & Gasparotto 1998, Beck et al. 1998a, b). Additionally, in May to November 1998, the litter layer temperature at two sites was recorded: the Pupunha monoculture in block C (PupC) and the polyculture system "II" in block B (PolyII-B), the sites where the study of Kurzatkowski (see separate subreport) was carried out. Here, we report on the recordings of the Embrapa whether station during the study period which are used as a reference against which to calibrate the data from the study sites; and on the microclimate recordings from the data loggers. An additional analysis of the data is presented in the following report ("Microclimate data that influence the 3-monthly fauna sampling").

2. Material and Methods

The study site located in central Amazonia has been described in detail elsewhere (Lieberei & Gasparotto 1998, Beck et al. 1998a, b). One data set containing daily values for maximum, minimum, and average soil temperature, air humidity, evapotranspiration and rainfall was obtained from the climatic station of the Embrapa Amazônia Ocidental for January 1996 through April 1998. This station is a standard climate station. Monthly averages were computed on the basis of daily values. Saturation deficit was calculated from air temperature and relative air humidity according to the "Magnus formula" (D'Ans-Lax 1967).
The microclimate was measured with data loggers in 6 different sites (Table 1). Due to technical reasons (battery life duration), data were obtained in three subsets: August 1997 to March 1998, May 1998 to November 1998, and November 1998 to April 1999 (details in Table 2).

Using small data loggers (Stowaway XTI Internal/External Temperature Logger", range -39 to 122 °C; storage capacity 32K, in air-tight "submersible" cases with silicagel to prevent damage due to humidity; "Stowaway RH Relative Humidity Logger"; storage capacity 8K; software for data transfer from logger and graphical analysis "Logbook for Windows V.2.0+"; all manufactured by Onset Computer Corporation, Porasset, MA, USA), we recorded temperature in the litter layer above the soil and in the soil at a depth of 5 cm, and relative air humidity at about 10 cm above the soil (somewhat above the litter layer).
Before being used in the field, all loggers were tested in a solution of water/ice in a styrofoam box for 24h; differences between individual loggers were <0.5°C. In the field, the temperature logger were conditioned in transparent water-tight submersible plastic cases supplied by the manufacturer and positioned on the forest floor, buried in the litter layer to avoid direct exposition to sunlight.
In the first recording phase (August 1997-February 1998), the loggers were on the soil surface and the soil temperature had been measured with an external sensor (the loggers used to record soil temperature were equipped with external sensors which ran through a hole in the case sealed with silicone and which were inserted 5 cm deep into the soil - a hole was made with a knife in order not to destroy the natural soil layering). This procedure led to humidity damage in some cases. Therefore, later the loggers used to record the soil temperature were buried directly in the soil in their cases to a depth of 5 cm.
The loggers were programmed to record air temperature at 10 minute intervals but store only average values calculated by the logger every two hours. Thus, there are 12 data points stored every day (00:00, 02:00, 04:00...22:00).
The humidity loggers were enclosed in bags made of 20 µm nylon mesh in order to hold soil fauna off the sensor; the openings of the mesh allowed the air to enter. The humidity loggers were suspended in a plastic holder with open sides at a height of approximately 5 cm from the ground, in the litter layer; they were protected from direct rain drops by a small roof and from rain water splashing off the ground by the sides of the plastic holder. Air could flow freely through this holder. Table 1 shows the exact distribution of all loggers in the field between May and November 1998. Logger positioning is detailed in the Tables 3 to 5.
(Technical information: All files were successfully retrieved from the loggers and exported from the Logbook-Software format (*.dtf) to *.txt format, using "Tab" as column separator and the "Mon/Day/Yr Hr:Min:Sec" format for time and date. We used "find..replace" to replace . with , and ' with <nothing>, to obtain numbers instead of labels in the spreadsheet).
Monthly data analysis (monthly averages) are calculated on a calender month basis, i.e., for the second measurement period, the averages for May and November refer to the periods of 26.-31.5. and 1.-19.11., respectively, whereas the other data refer to the whole months of June to October.

3. Results

Embrapa wheather station. Figure 1 shows the rainfall 1996-1999 (data in Table 6). The year 1996 was included for a better understanding of 1997, a strong El Niño year. While 1996 was a relatively normal, moist year (average monthly rainfall 215mm, no month below 100 mm), 1997 was extremely dry (average rainfall only 186mm; 4 months below 100 mm). Rainfall in 1998 returned to normal conditions (average 217mm; only August below 100 mm).
Figure 2 shows that maximum and average air temperature and soil temperature were all highest in September and October 1997. Minimum air temperatures were elevated in the subsequent period, from October 1997 to May 1998. Relative air humidity was extremely low in September 1997; whereas evapotranspiration showed a prominent peak in the same period. The saturation deficit also reached a extreme peakin September 1997. All this shows that 1997 was, in fact, an extreme El Niño year (ENSO event), which has consequences for the interpretation (generalization) of all project data from this year.

Microclimate at the sites (Data loggers). To check the performance of the data loggers, they were checked against the Embrapa wheather station data. Figure 3 shows that the air temperature in the litter layer always stays below the air temperature at the Embrapa site (a standard wheather station), whereas the temperature in the litter layer of the plantation sites POA and, particularly, PolyIIB, is much higher than at the Embrapa station. Another check of logger performance was made in the last measurement period where 4 loggers were placed under similar conditions in POC (Figure 4). It confirms that logger differed not more than 0.5°C from each other, after two years of use.
Litter temperatures in FLO, SEC, POC, and the Pupunha monoculture PupC were very similar, whereas they were consistently higher (on average about 2 degrees) in POA. In the plantation PolyIIB (=grass-covered bare soil) they were much (almost 4 degrees) higher than in FLO (Table 7, Figure 5). The highest maxima were

recorded in POA and PolyIIB, although the minima recorded here (probably at night) do not differ from those at the other sites. The recorded maxima (Table 7) are almost certainly artifacts, because the temperature was measured in loggers enclosed in tranlucent plastic cases, but the information shows that sun light is much more likely to hit the litter and soil surface in these openly-structured sites than under closed canopy, and that, therefore, microclimatic conditions are much more variable and unpredictable in POA and PolyIIB than in the other sites.
Soil temperatures were lowest in FLO (although no difference to SEC was recorded in September 1997), higher in SEC, and even higher in POA (POC not recorded; Figure 6 and Table 7). In FLO, the soil temperature almost equalled the temperature in the litter layer, whereas soil temperatures in POA were considerably lower than the litter temperatures (harsher conditions for the soil fauna in the litter layer; Figure 8).
Air humidity in all sites was lowest in September/October 1997. In the other months, it almost always stayed near 100% in FLO, SEC, POC, but was much lower in POA (Figure 7, Table 7).

We conclude that the microclimate can be much harsher in the litter and soil layer of polyculture sites than in secondary forest and primary forest in Amazonia, but a better developed canopy as in the 12 year old secondary forest (SEC) or the vicinity to closed forest as in POC are factors that offer protection from high variation and high temperature peaks. These results indicate that the mimicking of natural forest structure (closed canopy; mosaic landscape of intermittent ecosystem types instead of large-scale clearcutting) can be succesfully used for the management of microclimatic conditions that affect the important decomposer fauna and microflora of the soil.

4. References

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Tables

Table 1: Sites and periods of microclimatic measurements during the project SHIFT 52

Site Code	Description	Measurement Periods
FLO	primary rain forest	Aug 1997 - Mar 1998 May 1998 - Nov 1998 Nov 1998 - Apr 1999
SEC	secondary forest established in 1984	Aug 1997 - Mar 1998 May 1998 - Nov 1998 Nov 1998 - Apr 1999
POA	polyculture system consisting of 4 commercial wood species planted in rows, between which secondary growth was allowed (established in 1992)	Aug 1997 - Mar 1998 May 1998 - Nov 1998 Nov 1998 - Apr 1999
POC	idem	Aug 1997 - Mar 1998 May 1998 - Nov 1998 Nov 1998 - Apr 1999
PolyIIb	another mixed culture system consisting of 4 native Amazonian fruit trees planted in rows, between which only annual plants were admitted (established 1992; the logger was placed between two rows)	May 1998 - Nov 1998
PUP	a monoculture of peach palm (*Bactris gasipaes*; "pupunha" in Brazil). (established in 1992)	May 1998 - Nov 1998

Table 2: Data sets from loggers used for the analyses

	Start	End	Total number of measurements per logger	Days of periods
Aug 1997 - Mar 1998	22.7.1997, 00:00	4.2.1998, 16:00	2372	198
May 1998 - Nov 1998	26.5.1998, 02:00	19.11.1999, 12:00	2130	177
Nov 1998 - Apr 1999	20.11.1999, 20:00	9.4.1999, 10:00	1676	140

Table 3: Logger positioning during the first measurement period (07/97 - 04/98). HUM = humidity loggers; T = temperature loggers; Numbers = logger identification number (serial number). Daily Temp.: values taken all 10 minutes (two loggers set up for comparison).

Stratum	FLO	SEC	POA	POC
Litter layer L	HUM 966	HUM 970	HUM 973	-
	T 109 case	T 110 case	T 111 case	T 118 case
Soil S 0-5 cm	T 112*) & ext. sensor	T 114*) & ext. sensor	T 115*) & ext. sensor	T 116 case**)
Daily Temperature	T 98570 case	-	T 98572 case	-

*) in the lack of original submersible cases, loggers were placed in silicone-sealed plastic flasks, from July 1997 to April 1998

**) no external sensor was available and the logger in the case was buried into the ground to a depth of approx. 5 cm; from July 1997 to April 1998

Table 4: Logger positioning in the second measurement period (05/98 - 11/98). T = Temperature, HUM = humidity logger

	FLO	SEC	POA	POC	Pup-C	PolyII-B
Litter	T 109	T 110	T 111	T 112	T 570	T 572
Soil	T 114	T 115	T 118	T 569	-	-
Rel. Humidity	HUM 966	HUM 970	HUM 973	HUM 767	-	-

Table 5: Logger positioning in the third measurement period (11/98 - 04/99). Notes: In POC, loggers were exposed at 4 points, one in each of the secondary growth strips, approximately at 15 m from "0", to detect small-scale variation. The humidity loggers stopped recording before retrieval, between December and February

	FLO	SEC	POA	POC	POC	POC	POC
Litter	T 109	T 110	T 111	T 112	T 116	T 570	T 572
Soil 5 cm	T 114	T 115	T 118	T 569			
RH	HUM 966	HUM 970	HUM 973	HUM 973			

Table 6: Rainfall data of the station at the Embrapa Amazônia Ocidental (monthly sums) during the study period of the project SHIFT 52. (cf. Figure 1)

	1996	1997	1998	1999
Jan	291,7	251,7	296,5	310,4
Feb	276,0	319.2	226,1	366,1
Mar	385,5	464,1	333,1	290,5
Apr	366,5	271,0	377,3	425,2
May	144,6	177,2	226,2	
Jun	212,8	69,8	187,6	
Jul	133,5	44,9	113,1	
Aug	200,5	137,1	87,9	
Sep	110,4	48,4	125,9	
Oct	116,7	65,6	174,7	
Nov	178,6	261,3	234,4	
Dec	168,2	127,7	162,6	
Total/Year	**2585**	**2238**	**2545.4**	
Average/Month	**215.4**	**186.5**	**212.1**	

Table 7: Litter (L) and soil (S) temperature and relative air humidity (RH) in the study sites (for codes, see Table 1). Averages, Standard Deviations, medians, maxima and minima recorded in each of the three study periods (see Table 2).

1997-98

	109 FLO L	112 FLO S	66 FLO RH	110 SEC L	114 SEC S	70 SEC RH	111 POA L	115 POA S	73 POA RH	118 POC L
Average	26.4	26,1	96,6	26,4	26,1	90,5	28,4	26,6	86,9	26.6
Std.Dev.	1.8	0.7	8,6	1,9	0,8	15,7	5,5	1,0	20,0	2.1
Median	26,2	26,2	100	26,0	25,9	100,0	25.8	26.6	100	26,1
Maxima	34,7	27,7	100	32.6	32.6	32,6	50,9	29,9	100	36.5
Minima	22,6	23,7	43,6	22,8	22.8	22.8	22.2	23.1	20.6	22.8

1998-98

	109 FLO L	114 FLO S	66 FLO RH	110 SEC L	115 SEC S	70 SEC RH	111 POA L	118 POA S	73 POA RH	112 POC L	569 POC S	73 POC RH	570 PupC L	572 PolyII-B L
Average	25,6	25,7	96,9	25,7	25,9	99,3	26,8	26,3	92,5	25,8	25,6	99,3	25,6	29.7
Std.Dev.	1,3	0,5	16,1	1,2	0,4	3,2	3,2	0,9	17,4	2,4	0,6	2,7	2,5	7,3
Median	25,4	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Maxima	30,1	27,0	100,0	28,9	27,0	100,0	46,0	28,9	100,0	30,1	27,1	100,0	36,2	55,7
Minima	22,9	24,5	0,5	23,2	24,9	72,6	22,9	24,3	0,0	22,0	23,9	76,1	21,9	22,2

1998-99

	FLO L109	FLO S114	SEC L 110	SEC S 115	POA L111	POA S118	POC L112	POC S569	POC L116	POC L570	POC L572

Average	25,2	24,9	25,3	25,4	26	25,9	25.3	25,2	25,0	24,9	25,0
Std.Dev.	0,6	1,1	1,2	0,6	2,9	0,7	2,0	0,7	1,4	1,3	1,4
Median	25,1	24,5	25,0	25,2	25,0	25,7	24,5	25,0	24,7	24,7	24,7
Maxima	27,2	28,5	30,4	27,4	39,0	28,2	35,6	27,8	30,8	30,1	31,2
Minima	24,0	22,7	23,2	24,1	22,2	24,3	22,3	23,5	22,6	22,2	22,6

Table 8: Monthly average values of litter (L) and soil (S) temperature and relative air humidity (RH) in the study sites (for codes, see Table 1).

Period		109 FLO L	112 FLO S	66 FLO RH	110 SEC L	114 SEC S	70 SEC RH	111 POA L	115 POA S	73 POA RH	118 POC L
97-98	Aug-97	25,7	25,3	98,8	25,6	25,3	92,3	27,9	25,9	87,6	25,6
	Sep-97	26,8	26,1	92,7	26,9	26,1	83,7	29,5	26,8	79,5	26,8
	Oct-97	27,4	26,7	91,2	27,3	26,7	83,4	30,4	27,4	79,6	27,7
	Nov-97	26,4	26,3	97,7	26,4	26,3	91,3	28,3	26,7	88,5	26,7
	Dec-97	26,5	26,3	99,1	26,4	26,3	93,6	28,1	26,7	90,6	26,7
	Jan-98	25,9	25,9	100,0	25,9	25,9	98,9	26,9	26,1	96,1	26,1
	Feb-98	26,5		99,8	26,3	26,3	98,3	27,6	26,6	95,4	
	Mar-98	26,2		100,0	26,1	26,2	99,9	27,1	26,5	97,6	

Period		109 FLO L	114 FLO S	66 FLO RH	110 SEC L	115 SEC S	70 SEC RH	111 POA L	118 POA S	73 POA RH	112 POC L	569 POC S	73 POC RH	570 PupC L	572 PolyII-B L		570 PupC L	572 PolyII-B L
98-98	May-98	26,0	26,0	100,0	26,2	26,4	100,0	26,3	26,5	97,6	25,9	26,0	100,0	25,6	28,8		25,6	28,8
	Jun-98	25,3	25,5	100,0	25,6	25,8	100,0	25,7	25,9	97,5	25,3	25,4	99,9	25,1	28,3		25,1	28,3

	Jul-98	25,2	25,3	100,0	25,3	25,7	99,9	25,8	25,7	95,3	25,2	25,2	99,8	25,0	28,9		25,0	28,9
	Aug-98	25,9	25,7	100,0	25,6	25,8	98,4	26,8	26,2	83,8	26,0	25,6	98,8	25,9	30,2		25,9	30,2
	Sep-98	25,7	25,7		25,8	26,0		27,0	26,4		25,8	25,7		25,7	30,3		25,7	30,3
	Oct-98	25,9	25,9		25,9	26,1		28,2	26,7		26,4	25,9		26,3	31,4		26,3	31,4
	Nov-98	25,9	26,0		26,0	26,2		27,7	26,7		26,1	26,0		25,9	29,2		25,9	29,2
		FLO L109	FLO S114		SEC L 110	SEC S 115		POA L111	POA S118		POC L112	POC S569		POC L116	POC L570	POC L572		
98-99	Nov-98	25,5	25,1		25,5	25,7		26,1	26,1		25,5	25,5		25,2	25,1	25,2		
	Dec-98	25,8	25,5		26,1	26,0		27,1	26,5		26,2	25,8		25,8	25,6	25,8		
	Jan-99	25,1	24,6		25,1	25,3		25,6	25,6		25,0	25,0		24,8	24,7	24,8		
	Feb-99	25,1	24,6		25,1	25,2		25,7	25,6		25,1	25,1		24,8	24,7	24,7		
	Mar-99	25,0	24,7		25,1	25,2		25,8	25,6		24,9	24,9		24,8	24,6	24,8		
	Apr-99	25,1	24,6		25,0	25,2		25,5	25,6		24,8	25,0		24,7	24,5	24,7		

Figures

Figure 1: Monthly rainfall (y-axis; monthly sums) of the station at the Embrapa Amazônia Ocidental . (cf. Table 5 for raw data)

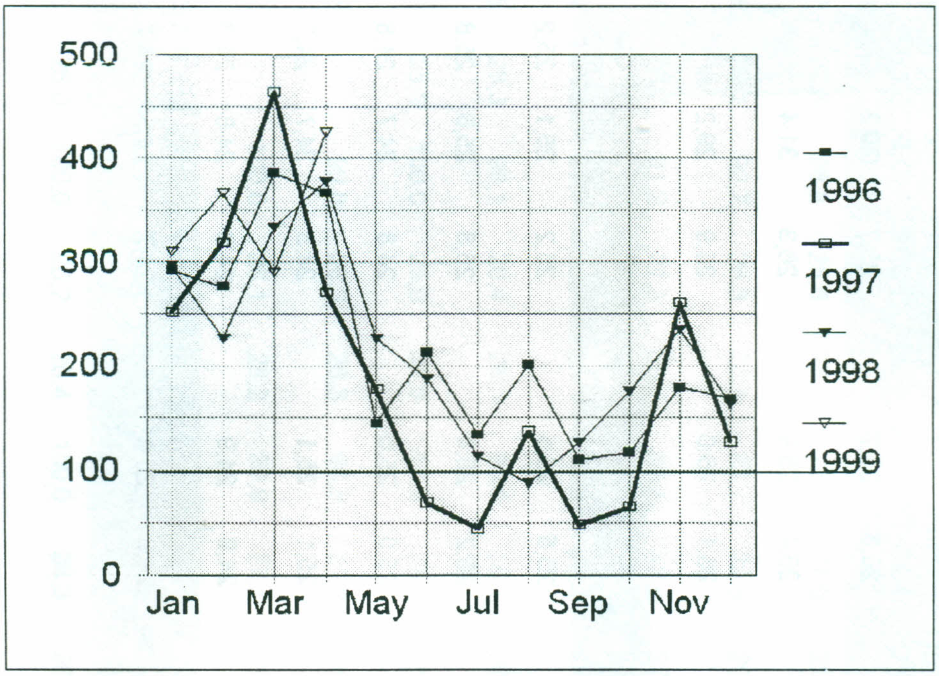

Figure 2: Climatic data as recorded by the Embrapa's wheather station (based on daily readings)

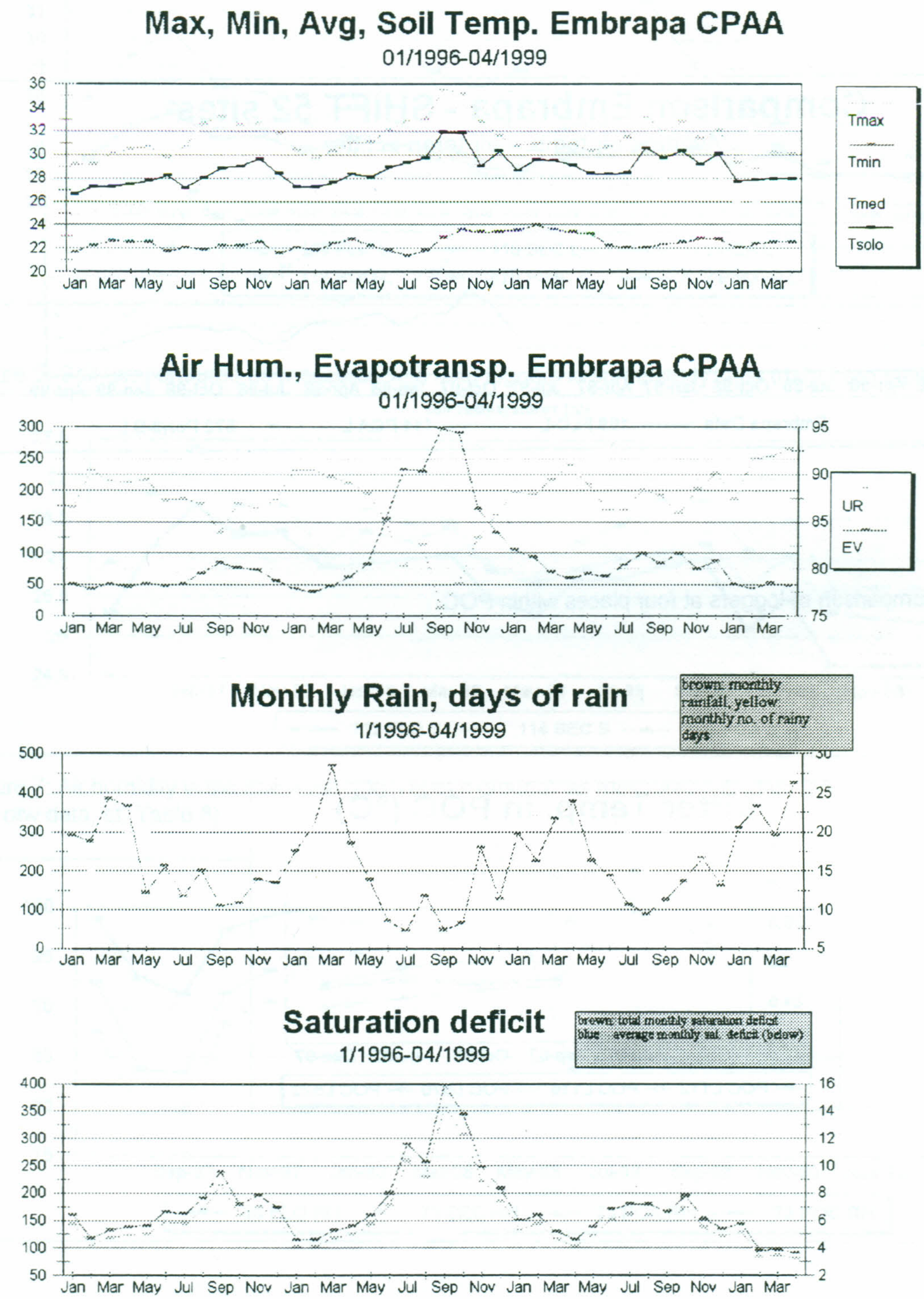

Figure 3: Comparison of air temperatures at the Embrapa's wheather station with the air temperature in the litter layer of the sites FLO, Polyllb, and POC

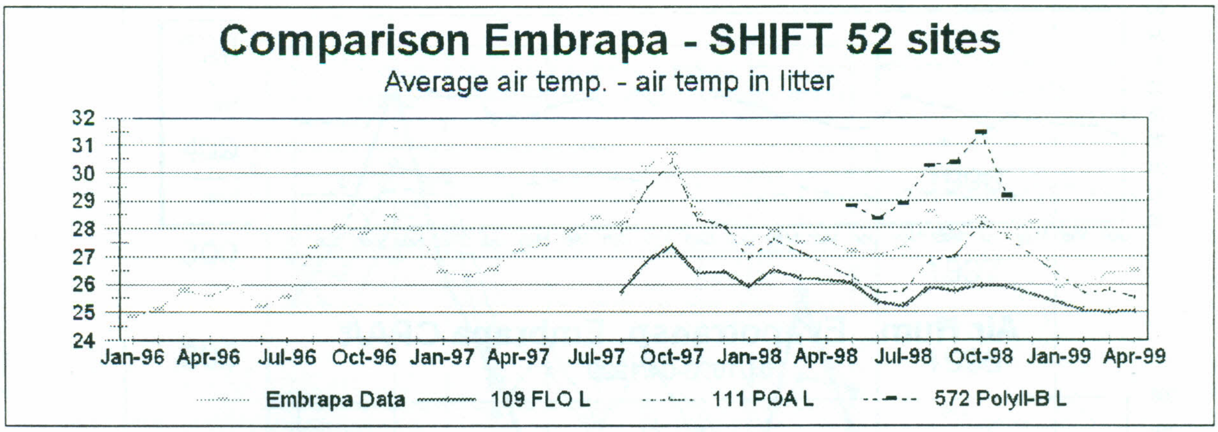

Figure 4: A comparison of loggers at four places within POC

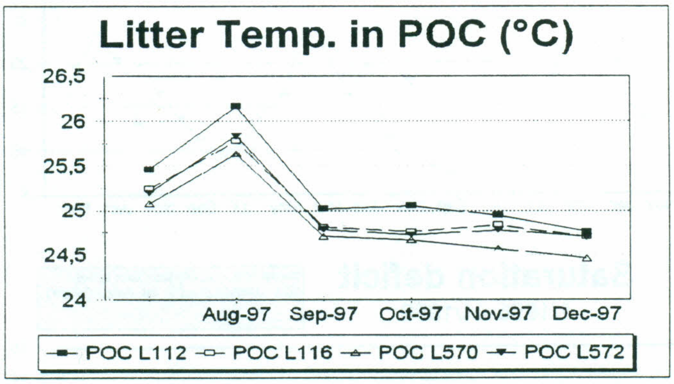

Figure 5: Litter temperatures as measured with data loggers in the study sites (for raw data, cf. Table 8)

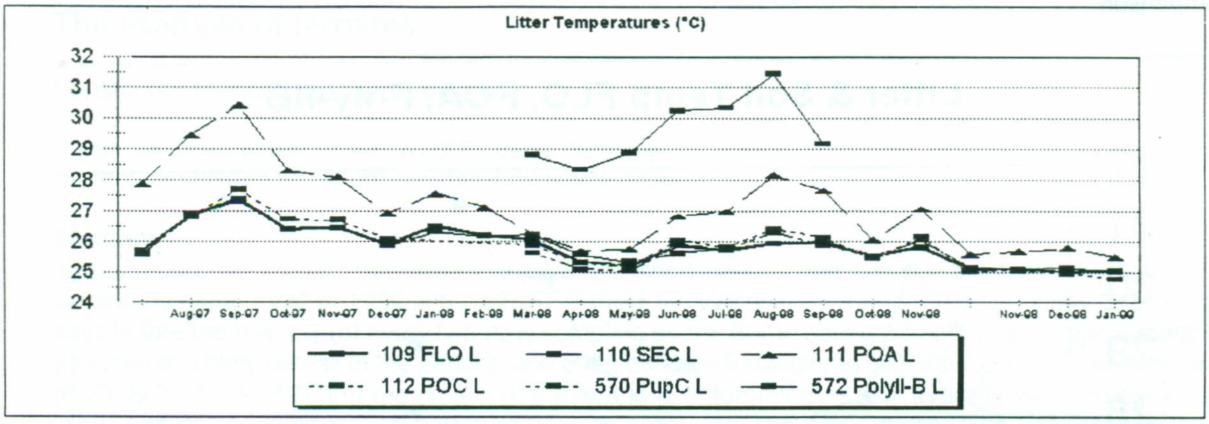

Figure 6: Soil temperatures as measured with data loggers in some study sites (data from table 8)

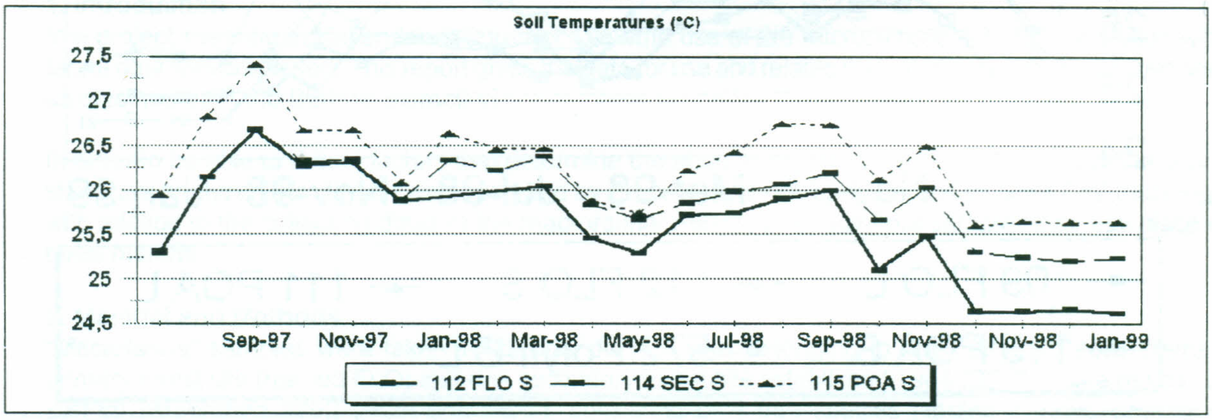

Figure 7: Air humidity in the litter layer (10cm above ground) as measured with data loggers in the study sites (for raw data, cf. Table 8)

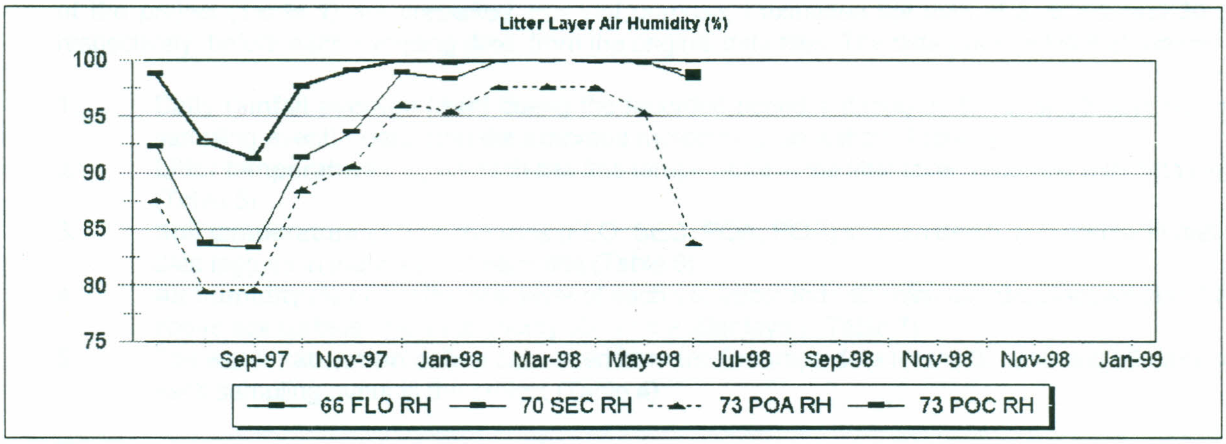

Figure 8: A comparison of litter (L) and soil (S) temperatures in FLO anbd POA. PolyIIB is shown for comparison.