ABUNDANCE OF FIVE DIFFERENT SOIL ARTHROPOD GROUPS IN CENTRAL JAVA IN RELATION TO CHEMICAL FACTORS

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VINK, K. & SOEJONO SASTRODIHARDJO, F.X. 1996. Abundance of five different soil arthropod groups in Central Java in relation to chemical factors. This study was aimed at revealing relationships between abundances of Acarina, Coleoptera, Collembola, Diplopoda, Isopoda and various soil chemical factors (C, N, Ca, Mg, Fe, Cu, Zn, Na concentrations, litter density and pH). Seven different forest sites distributed over Central Java (Indonesia) were sampled and soil fauna was extracted using Tullgren equipment. In addition, one of the sites was investigated in more detail during one year. The results demonstrated significant changes of both soil fauna and litter chemistry with the seasons. Most animal groups showed highest abundance in the wet season (October-March). Changes of Fe, Ca and C:N ratio with time may depend on leaf fall patterns and subsequent decomposition flushes. The comparison of sites revealed significant differences in both soil fauna and soil chemistry. One of the sites had exceptionally high abundance of soil fauna. The comparison of sites revealed some significant correlations between fauna and chemistry (Diploposa with Na, Zn and C, Isoposa with Na), but no consistent pattern emerged. It is concluded that the high abundance of soil fauna at one of the site was related to the microhabitat created by extensive formation of surface stolons of *Eupatorium riparium*, rather than by litter chemistry.

Key words: Abundance - chemical factors - soil fauna - tropical forest - Acarina - Coleoptera - Collembola - Diplopoda - Isopoda

VINK, K. & SOEJONO SASTRODIHARDJO, F.X. 1996. Kepadatan lima kumpulan artropod tanih berlainan di Jawa Tengah berasaskan faktor-faktor kimia. Kajian ini bertujuan untuk menunjukkan perhubungan di antara kepadatan Acarina, Coleoptera, Collembola, Diplopoda, Isopoda dengan pelbagai faktor kimia tanih (kepekatan C,N,Ca, Mg, Fe, Cu, Zn, Na, ketumpatan sarap dan pH). Tujuh tapak hutan yang

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berbeza yang bertaburan di Jawa Tengah (Indonesia) telah disampel dan fauna tanih telah diasingkan menggunakan peralatan Tullgren. Di samping itu, salah satu daripada tapak itu telah dikaji dengan lebih lanjut dalam masa satu tahun. Keputusan-keputusan menunjukkan perubahan-perubahan ketara bagi kedua-dua fauna tanih dan kimia sarap dengan musim. Kebanyakan kumpulan haiwan menunjukkan kepadatan tertinggi di musim hujan (Oktober-Mac). Perubahan-perubahan di dalam Fe, Ca dan kadar C:N dengan masa mungkin bergantung kepada pola keluruhan daun dan pereputan seterusnya. Perbandingan tapak-tapak menunjukkan korelasi ketara di antara fauna tanih dan kimia (Diploposa dengan Na, Zn dan C, Isopoda dengan Na), bagaimanapun pola yang tetap tidak wujud. Kepadatan fauna tanih yang tinggi pada salah satu tapak tersebut adalah berkaitan dengan mikrohabitat yang dihasilkan daripada pembentukan stolon permukaan yang berleluasa oleh *Eupatorium riparium* daripada disebabkan oleh kimia sarap.

Introduction

Soil fauna densities in tropical forests are low compared to temperate forests. Tropical arthropods usually belong to many taxonomic groups with a low abundance of each species present (Collins 1980, Pearson & Derr 1986). In a temperate forest soil invertebrates often are important decomposers. It is assumed that their tropical counterparts also contribute to decomposition of leaf litter. Litter input in a temperate forest is seasonal, with peaks at the beginning of autumn. Litter input to the tropical forest floor often takes place throughout the year (Brasell *et al.* 1980, Edwards 1982, Martinez-Yrizar & Sarukhan 1990). The high decomposition rate in the tropics can probably be explained by the environmental conditions, which usually are more optimal than in the cooler temperate forests (Swift *et al.* 1979).

Many studies have been conducted on soil fauna abundance and on nutrient cycling in tropical forests (Adis *et al.* 1987a, b, 1989 a, b, Bruijnzeel 1991, Burghouts *et al.* 1992). It is generally assumed that litter quality and nutrient content are regulating factors for soil fauna, but little information exists on this relationship.

The main question for the present research was: Are there relationships between the nutrient content of forest floor litter and other soil factors with the soil fauna present? To investigate this question, seven locations in Central Java were sampled once, while one of the locations was sampled throughout the whole year to analyse seasonal patterns of abundance and to determine sampling times associated with optimal densities of soil fauna. Five arthropod groups were selected based on their possible role in the decomposition process. Collembola and Acarina as mesoinvertebrates mainly affect the microbial community (Seastedt 1984). The orders Coleoptera, Diplopoda and Isopoda were representatives of the comminutors or litter shredders.

Material and methods

Site description

Seven locations were selected throughout Central Java are shown in Figure 1. Soil type classification was derived from the geological map of Central Java.

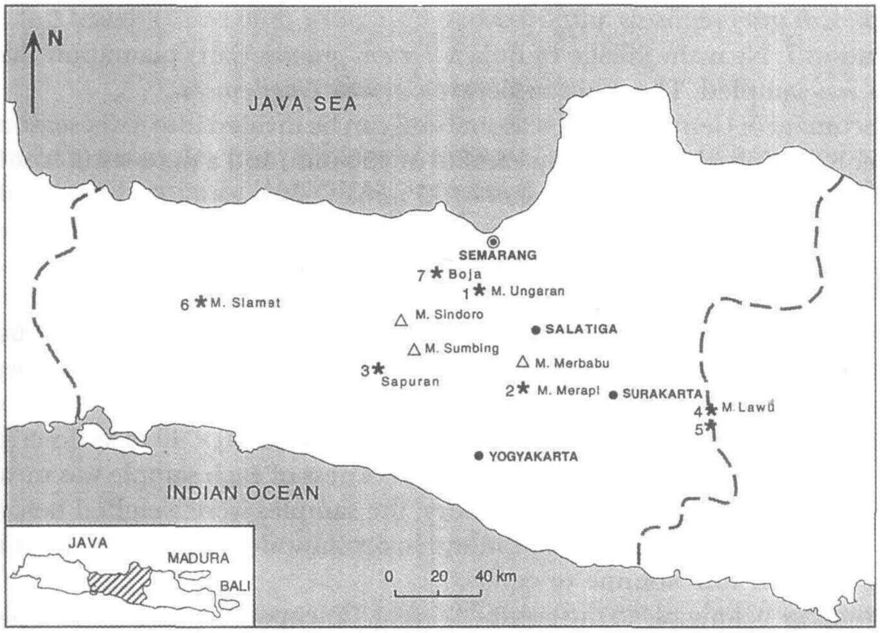

Figure 1. Map of Central Java, Indonesia, showing the locations of sampling sites (1 to 7) as well as some major towns/cities and volcanoes

Location 1: A *Pinus merkusii* (pine) forest at an altitude of 1200 m, on the southern slope of Mount Ungaran near the village of Gintungan. The main undergrowth was *Eupatorium riparium,* which covers the forest floor almost completely. The soil type is a brown andosol. A more detailed description of the location can be found in Vink & Purwanti (1994).

Location 2: A *P. merkusii* forest on the southwest slope of Mount Merapi (altitude 800 m). The location was described in detail by Gunadi (1993). The undergrowth is dominated by *Centotheca lappacea, Paspalum conjugatum, E. riparium* and *Lantana camara.* The soil type is a complex of grey regosol and lithosol.

Location 3: An *Agathis dammara* forest (altitude 700 m) on a slope of Mount Sumbing near the village of Sapuran. The undergrowth was a mixture of many different species such as *L. camara, Zingiberaceae, Chromolaena, Piperaceae* and *Araceae.* The soil is a brown latosol.

Locations 4 and 5: Two plots on the slope of Mount Lawu. A *P. merkusii* forest (altitude 700 m) with little undergrowth except for a few plants of *E. riparium*, and a secondary forest (altitude 550 m) with *Albizia* sp. *Quercus* sp. and *Castanea* sp. as the dominant tree species, and almost no undergrowth. The soil type is a complex of brown andosol.

Location 6: An *A. dammara* forest on the slope of Mount Slamet (altitude 800 m). The main ground vegetation is *Aracea, L. camara* and *Zingiberaceae*. The soil type is a complex of grey regosols and lithosols.

Location 7: Near the village of Boja a *Tectone grandis* (jati) plantation (altitude 200 m) was sampled. The main undergrowth was *Zingiberaceae*.

The climate in Central Java is seasonal and can be divided into a wet season from October to March with a monthly rainfall of 450 mm, and a dry season from April to September with a monthly rainfall of 75 mm.

Sampling methods for soil fauna and identification

At location 1 (Mount Ungaran) soil fauna were sampled in July, October and December 1990 and in February and April 1991. In the other locations, samples were taken only once in January - February 1992.

At each location, 32 samples were taken in a plot of 50 × 40 m as described by Vink and Purwanti (1994). The litter layer thickness of each sample was measured after opening the corer. At the laboratory, the samples were weighed before and after a 7- day Tullgren extraction. Litter density was calculated for each sample as the dry mass per unit volume (g cm^{-3})

Individuals belonging to the groups Acarina, Coleoptera, Collembola, Diplopoda and Isopoda were identified and counted. The abundance no. m^{-2} was calculated.

Chemical analyses

In location 1, the pine forest on Mount Ungaran, five litter samples were taken monthly from July 1990 until June 1991 and in the other six locations, in January-February 1992. These litter samples were taken in the same plot as the soil fauna samples were taken, by using a 25 × 25 cm quadrat. The samples were used for measuring litter pH, mineral nitrogen, total nitrogen, total carbon, organic matter contents and the total amount of Ca, Mg, Fe, Zn, Cu, Na and K.

Litter pH and mineral nitrogen

From each sample ca. 10 g fresh litter was shaken for 2 h at 75 rpm in 100 ml distilled water and ca. 10 g in 100 ml 0.1 M KCl. The samples were used to measure pH (water and KCl), soluble nitrogen (ammonium and nitrate) and exchangeable nitrogen (ammonium).

The measurements of ammonium and nitrate were done by colorimetric methods for routine analysis of waste water samples (APHA 1976). For detailed descriptions see Vink (1994).

Carbon, nitrogen and other elements

Part of the litter collected with the quadrat was air-dried. The total nitrogen and carbon were determined with an elemental analyser (Carlo Erba Strumentazione Model 1106). The organic matter content was estimated and the elements Ca, Mg, Fe, Zn, Cu, Na and K were measured as described by Burghouts *et al.* (1993), by atomic absorption spectrophotometry (AAS, Perkin-Elmer 4000). Standard reference olive leaves (CRM 062) were used to control the quality of the AAS analyses.

Statistical analyses

The data of samples from location 1 (Mount Ungaran) were subjected to a one-way analysis of variance (ANOVA), described by Sokal and Rohlf (1981), to examine the effects of time. The data from the seven locations were subjected to a similar one-way ANOVA to determine the differences between the locations. The ANOVA was followed by a multiple comparison among pairs of means (unplanned comparison) using the *t*-method as described by Sokal and Rohlf (1981). Since analysis of variance assumes homogeneity of variances, the data were log transformed where necessary.

Results

Soil fauna abundance at site 1

Figure 2 shows the abundance of the five dominant orders (Acarina, Coleoptera, Collembola, Diplopoda and Isopoda) in the pine forest of sampling site 1 (Mount Ungaran) throughout the year. The abundance of Acarina ranged from 6 000 m^{-2} during the dry season to 20 000 m^{-2} in the wet season; Collembola ranged from 2 500 m^{-2} at the end of the dry season to 50 000 m^{-2} at the end of the wet season and Isopod abundance was 300 m^{-2} in the dry season and 1 200 m^{-2} in the wet season.

The abundance changed significantly with the sampling times: $p< 0.001$ for the Acarina, Collembola, Diplopoda and Isopoda, and $p<0.01$ for the Coleoptera. These significant differences in abundance was caused by differences between the dry season (April - September) and wet season (October-March) (Figure 2). At the end of the wet season, in February, all groups reached their highest abundance. The Coleoptera, Diplopoda and Isopoda were fewest in the middle of the dry season while the Acarina and Collembola were least abundant just at the beginning of the wet season (October).

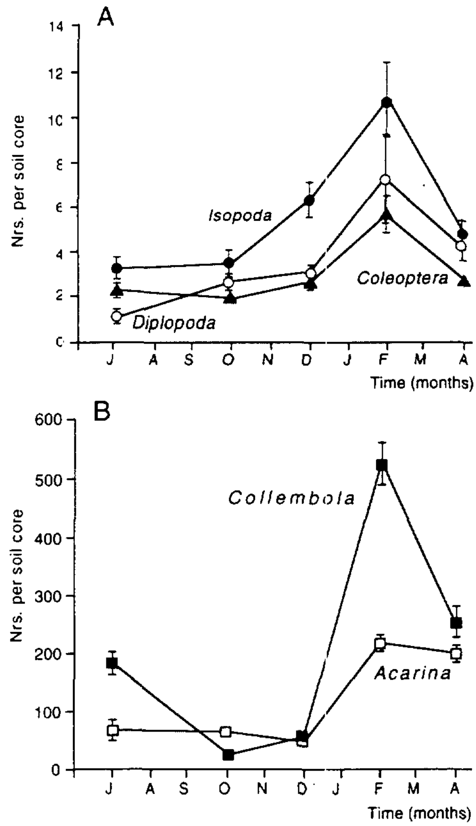

Figure 2. Abundances of five soil invertebrate groups as a function of time at site I (pine forest, Mount Ungaran); A: Coleoptera (▲), Diplopoda (O) and Isopoda (●); B: Acarina (□) and Collembola (■). Bars indicate standard errors of the mean.

The Ca, Fe and Mg concentrations in the litter of the pine forest on Mount Ungaran differed significantly between the sampling times at $p<0.001$. Ca decreased between July and September from 267 μmol g^{-1} to 155 μmol g^{-1} followed by an increase to 222 μmol g^{-1} in April (Figure 3A).

Iron reached high concentrations at the end of the dry season (Figure 3A). This may be due to a higher litter input at this time of the year. The decrease of iron during the first part of the wet season may be caused by greater leaching because of the rainfall. Magnesium was relatively constant compared to calcium and iron.

The nitrogen and carbon percentages fluctuated significantly throughout the year: $p<0.001$ for C, and $p<0.01$ for N and the C:N ratio (Figure 3B). During the wet season the carbon percentage was significantly higher and nitrogen percentage significantly lower than in the dry season. This may be caused by a higher litter input at the end of the dry season and higher activity by soil organisms in the course of the wet season.

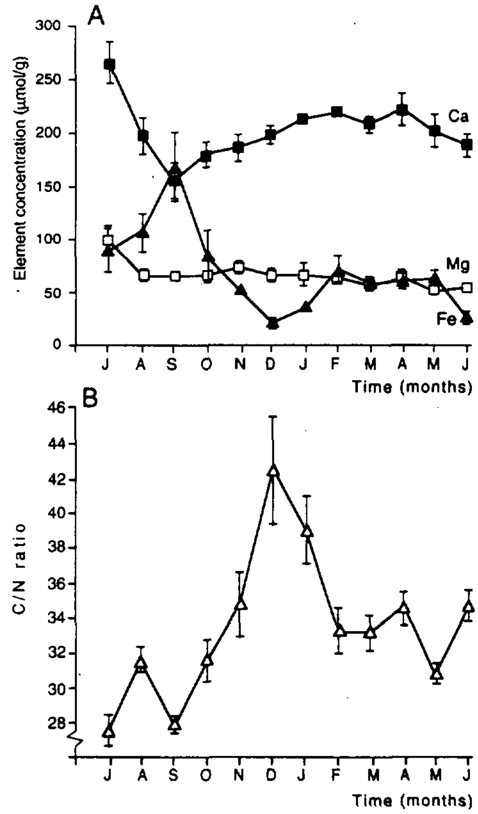

Figure 3. Concentrations of Ca (■), Mg (□), and Fe (▲) in litter (A) and C:N ratio of litter (B) as a function of time at site 1 (pine forest, Mount Ungaran). Bars indicate standard errors of the mean.

The ammonium concentration did not fluctuate significantly throughout the year but nitrate did at $p<0.001$. Although the fluctuations of ammonium were not significant, a closer look at the results showed that higher ammonium concentrations were followed by an increase in nitrate, which suggests that ammonification and nitrification take place alternatively.

Copper and zinc were measured in all the samples, but most of the concentrations measured were too close to the detection level of the analytical procedure to allow reliable calculations. The mean concentration found for copper was 0.11 $\mu mol\ g^{-1}$ and for zinc 0.9 $\mu mol\ g^{-1}$.

Fauna distribution in the seven locations

The mean abundance of Acarina, Collembola, Coleoptera, Diplopoda and Isopoda found in the seven locations are given in Table 1. The pine forest on Mount Ungaran is rather exceptional with its high numbers of Acarina, Collembola and Isopoda. High numbers for Coleoptera and Diplopoda were also found, but with less differences among the locations. The low litter density in this forest did not

Table 1. Litter properties and fauna abundance at the seven sampling locations. Means in the same column sharing a common letter (a, b, c, d, e) do not differ significantly from each other ($p < 0.05$).

Location	N %	C %	C:N	NH_4 (ug g^{-1})	NO_3 (ug g^{-1})	min N (ug g^{-1})	pH KCl
Ungaran	1.32 c	43.51 d	33.24 c,d	57.65 b	2.79 b, c	60.52 b	4.47 d
Merapi	1.12 d	51.88 a,b,c	57.89 b	34.45 b	0.07 a	34.81 b	7.76 c
Sapuran	1.12 c	53.35 a,b	41.56 c	35.24 b	0.38 c, d	36.38 b	4.27 a
Luwa 1	1.38 e	52.18 a,b,c	72.69 a	52.10 b	0.21 d	52.64 b	6.46 d
Lawu 2	2.45 a	50.75 b,c	20.58 e	44.00 b	3.53 b	53.88 b	5.13 b
Slamet	1.38 c	53.87 a	38.95 c	30.52 b	2.25 b,c,d	32.80 b	5.89 c
Boja	1.99 b	50.24 c	25.40 d,e	203.21 a	0.03 d	194.91 b,a	4.47 c

Location	Ca	Mg	Fe	Cu	Zn	Na	K
	(µmol g^{-1})						
Ungaran	219.90 c,d,f	64.88 c,e	71.52 c	0.07 c,d	0.82 a	8.26 a	15.80 c
Merapi	332.98 b,d,f	77.48 c,d	22.17 c	0.06 d,e	0.51 b,c	2.33 b,c	11.51 c
Sapuran	446.12 b	109.58 b,d	81.72 c	0.15 c	0.31 d	1.78 c	36.73 a
Luwa 1	144.96 c,e,g	85.00 c,d	22.36 a	0.05 d,e	0.52 b,c	0.64 c	12.08 c
Lawu 2	574.60 a	239.70 a	261.44 e	0.37 b	0.32 d	3.59 b,c	30.21 a,b
Slamet	344.82 b,d	132.90 b	25.40 c	0.11 c,d	0.44 c,d	4.37 b	19.87 b,c
Boja	217.29 c,e,f	123.90 b	609.28 a	0.62 a,b	0.70 a,b	1.37 c	35.60 a

Location	Acarina	Collembola	Coleoptera	Diplopoda	Isopoda	Litter density	Litter thickness
	(n m^{-2})					(g cm^{-3})	(cm)
Ungaran	61 945 a	148 599 a	938 a,b, c	1 326 a	3 565 a	0.11 c	4.55 d
Merapi	23 550 b	20 513 b	449 d	592 b,c	319 c	0.30 b	5.38 d
Sapuran	12 649 b,c	12 943 b	579 c,d	649 b,c	516 b	0.17 c	0.97 a
Luwa 1	619 e	2 831 c,d	1 053 a,b	449 c	355 c	0.15 c	4.33 c
Lawu 2	8 750 c	4 384 c	1 487 a	579 b,c	373 c	0.17 c	4.16 c
Slamet	4 187 d	1 180 e	695 b,c,d	634 b,c	528 b	0.13 c	2.55 b
Boja	9 163 c	2 051 d,e	564 c,d	834 a,b	355 c	0.42 a	1.31 a

differ significantly from the two Lawu plots, Sapuran and Slamet. The other two pine forests (Lawu and Merapi) had high numbers of Collembola and low numbers of Diplopoda. The same can be said for the agathis forests (Lawu & Sapuran). Isopoda and Diplopoda were rather scarce in the two other pine forests.

The differences in nutrient concentrations among the seven locations are less extreme between forests of the same type (Table 1) except for C:N, NO_3 and Na.

Significant correlations between soil fauna abundance and chemical variables were found with Na for Isopoda and Diplopoda and with carbon and zinc for Diplopoda (Table 2). High but not significant correlations were found with carbon for Acarina, Isopoda and Collembola; with sodium for Acarina; and with litter density for Coleoptera (Table 2).

Table 2. Correlation coefficients between soil fauna abundance and litter properties. Each correlation is based on seven data points, being means for the seven sampling sites.

	Acarina	Collembola	Coleoptera	Diplopoda	Isopoda
N	0.428	0.104	0.046	0.359	0.192
C	- 0.724	- 0.685	- 0.557	- 0.824**	- 0.677
C:N	- 0.623	0.003	0.056	- 0.567	0.378
NH_4	0.069	- 0.282	- 0.396	0.348	- 0.078
NO_3	0.408	0.132	0.646	0.336	0.542
min N	0.083	- 0.282	- 0.357	0.355	- 0.067
Ca	0.187	0.012	0.121	0.216	0.134
Mg	- 0.097	0.447	0.193	0.256	0.191
Fe	0.126	0.329	0.293	0.273	0.132
Zn	0.406	0.349	0.059	0.754*	0.440
Cu	0.083	- 0.409	- 0.288	0.180	- 0.179
Na	0.751	0.567	0.488	0.777*	0.812**
K	0.242	- 0.212	- 0.238	0.073	0.046
pH	0.205	0.074	0.387	0.115	0.258
Litter-density	0.067	0.245	- 0.679	0.067	- 0.563
Litter-thickness	- 0.056	0.364	0.509	- 0.043	0.126

* Significantly different from zero at the 5% level, ** 1% level.

Discussion

The abundances throughout the year of the five groups in location 1 undergo seasonal changes. Such seasonality was also found in a neotropical forest in Brazil (Adis *et al.* 1987 a,b, 1989 a,b) and in a pine forest in Central Java (Gunadi 1993). The seasonality can be explained by temperature, humidity and litter input. Brasell *et al.* (1980) and Edwards (1982) found a peak in litter input at the beginning of the wet season in montane and rain forests in Southeast Asia, followed by stable litter input and hardly no input during the dry season. The seasonality in litter input means a seasonality in available food for the soil fauna. Although there are no data available on litterfall during the sampling period for location 1, we could expect that litterfall will show a comparable seasonal distribution as found in two nearby pine forests at Mount Merapi and Mount Merbabu (Gunadi 1993). It was shown that the total amount of litter increased during the dry season with a maximum at the end (150 g m^{-2} per month) and a second maximum at the end of the wet season (70 g m^{-2} per month). The effect of time on the mineral content of the litter in location 1 (the Mount Ungaran site, Figure 3), could be explained by the seasonality of litter input.

The abundance of Collembola in location 2 (Merapi) is comparable with the results of Gunadi (1993) in the same plot as used in this research. Comparing the abundance of the five arthropod groups with literature data (Table 3), we can conclude in general that the numbers of Isopoda, Coleoptera and Diplopoda found in this research are comparable with those found in other studies done in the tropical forests in Asia and South America, except for location 1 (Mount Ungaran). The abundances found in location 1 are high compared with tropical forests in general (Table 3), but low when compared with pine forests in the temperate region where numbers of 50 000 to 100 000 m^{-2} are common (Peterson & Luxton 1982, Teuben & Smidt 1992).

The nutrient content of the available litter was low (Table 1) and lies in the range as found in other tropical forests in Asia (Brasell *et al.* 1980, Edwards 1982).

Paoletti *et al.* (1991) compared the abundance and diversity of invertebrate fauna with the nutrient content of arboreal and terrestrial soils and litters in a Venezuelan cloud forest. They found higher mineral concentrations in the arboreal than in the terrestrial soils. They also found high densities of arboreal soil fauna which may be much more concentrated than terrestrial soil fauna. Their findings suggest a correlation between the abundance of fauna and nutrients. Hagvar and Abrahamsen (1984) found correlations with Ca, Mg, and K for Collembola. Isopods and diplopods need great amounts of Ca for their exoskeleton and high concentrations are found in these animals. Correlations were expected between calcium and isopods and diplopods, and Cu and isopods. Isopods are known to contain extremely high amounts of copper (Hopkin 1989). For Collembola and Acarina pH is an important factor for their distribution (Hagvar & Abrahamsen 1984) which suggests a correlation as well. However, our results show no clear relationship between the abundance of soil fauna and forest type, soil type or nutrients.

The significant correlations found here with Na for Isopoda and Diplopoda and with C for Diplopoda cannot be easily explained . They are mainly due to the fact that only one location differed extremely from the other locations.

The significant positive correlation of Zn with diplopods suggests that in some sites Zn levels may be low enough to be limiting for this group. There is no evidence from other studies that soil fauna could be Zn-deficient. Zn concentrations in the litter were very low indeed and diplopods, like isopods, usually have high body burdens of Zn (Hopkin 1989). Although no correlations were found between soil fauna and nutrient content from the available litter, we conclude that the low concentrations found may lead to the low abundance of soil fauna.

Table 3. An overview of the mean densities (n m^{-2}) of Acarina, Coleoptera, Collembola, Diplopoda and Isopoda for several tropical and temperate forest ecosystems

Forest type	Acarina	Collembola	Coleoptera	Diplopoda	Isopoda	Reference
South America						
Venezuela						
Portachuelo	230	80	120	60	0	Paoletti *et al.* (1991)
Rancho Granda	220	20	70	40	0	
Brazil						
Neotropical forest	3 620 - 7 140	25 650 - 29 030	460 - 440	650 - 1 130	120 - 320	Adis *et al.* (1987 a, b)
Neotropical Camp. forest	21 980 - 31 960	7 570 - 10 930	1 210 - 810	1 040 - 808	100 - 140	Adis *et al.* (1989 a, b)
Asia						
Malaysia						
Primary forest	250	50	60	30	70	Burghouts *et al.* (1992)
Logged forest	180	30	80	30	70	
Mixed dipterocarp montane		4 - 110	1 - 40	1 - 50		Collins (1980)
Indonesia						
Pine forest		3 940 - 6 650				Gunadi (1993)
Japan						
Pine forest	3 300	31 400	8	14	1	Takeda 1988
Europe						
Scandinavia						
Spruce forest		150 - 244 000				Petersen & Luxton (1982)
Coniferous forest	275 - 79 200					
Evergreen forest		105 000				
Deciduous forest		40 - 70 100				
Netherlands						
Pine forest	42 380 - 48 950	28 700 - 46 910				Teuben & Smidt (1992)
Italy						
Agroecosystem			10 - 120	3 - 270	1 - 50	Paoletti *et al.* (1988)

No clear correlation was found between soil fauna abundance and vegetation; however, we assume that the vegetation structure is a prime factor influencing abundance. As mentioned earlier, location 1 (Mount Ungarian) had extremely high densities of the five soil fauna groups. At this location the undergrowth is a monoculture of *E. riparium* which includes extensive stolon formation above the soil and in the litter and may present many different micro-habitats and shelters horizontally and vertically where soil fauna can hide. According to Gibson and O'Sullivan (1984) and Rai and Tripathi (1984), *E. riparium* leaves contain toxic substances for fauna species, but this does not affect the soil fauna. *E. riparium* will not be the main food source of the litter fauna because the input of litter is not constant throughout the year. After the blooming period, which is different per location and year, the litter input of *E. riparium* leaves reaches its maximum (Soenarto pers. com.).

We must conclude that the interrelationships between soil fauna and soil factors are complicated and must involve not only the chemical composition of the litter, but also its three-dimensional structure and micro-habitat diversity.

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