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Earthworms and litter decomposition in the forests of the Flemish region

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Abstract

The present contribution aims to evaluate the litter decomposition in 25 forest stands, representative of the forests of the Flemish region, and to assess the share of earthworms in litter breakdown.

Key-words : Earthworms, Litter decomposition, Forest soil.

Samenvatting

Deze bijdrage evalueert de strooiselafbraak in 25 bosbestanden, representatief voor het Vlaamse gewest en bestudeert daarbij de rol van de regenwormen.

Trefwoorden : Regenwormen, Strooiselafbraak, Bosbodem.

Introduction

Acidification is an important destabilizing factor in the forest ecosystem. It is a natural process in soils under forest cover of the temperate climates, but it is strongly increased by human interference (DEVRIES & BREEUWSMA 1985). For centuries, several management practices have contributed to the internal acidification (REHFUESS 1974) but recently, external acidification as a consequence of air pollution also affects the forest soil. These antropogenous proton-loads undermine the buffering capacity of the soil (ULRICH 1987). As a consequence, practically all forest soils in Flanders, regardless of the soil texture, are extremely acidified.

With regard to this problem, soils are often physically and chemically evaluated, meanwhile however neglecting the biological changes, in spite of the fact that biological processes of litter decomposition and humus formation are an essential link in the mineral cycle of the forest. Particularly the earthworms have an important function in many ecosystems, highly depending however on the presence of the different ecological groups : epigeic worms are rather unimportant litterdwellers, endogeic worms are borrowing humus-eaters and anecic earthworms are highly active decomposers and burrowers (BOUCHE 1977).

In this contribution, we investigate the consequences of soil acidity for the earthworm communities and the litter decomposition in 25 forest stands, representatively chosen among the forests of the flemish region (figure 1, table 1).

Materials and methods

In all forest stands, 10 earthworm samples were taken, 5 in april 1988, 5 in november 1988. In April, earthworms were sampled with the hand-sorting method in soil samples of (25 x 25 x 25) cm^3. In november, two methods were used : in stands where the sampling of april detected epigeic worms (table 2) only, handsorting was used in soil samples with a surface of (30 x 30) cm^2 and a depth, according to the thickness of both holorganic and first hemi-organic horizon ; in stands also containing endogeic or anecic worms, the combined method of BOUCHE & ALIAGA (1986) was used : the formalin application was carried out on a surface of (50 x 100) cm^2 and the soil sample for wet washing-sieving, taken in the middle of the formalin applicated surface, had a surface of (30 x 30) cm^2 and a depth of 20 cm. Together with all earthworm samples, a soil sample was taken for analysis. Sampled earthworms were preserved during 2 months in a 5% formalin solution before being identified and weighed.

Litter decomposition was studied with litterbags. In every stand, leaf litter of the dominant tree species was sampled in autumn, directly after abscission. In the forest of Gontrode, reference litter of two tree species was sampled as well : cherry (*Prunus avium*)-litter from stand n° 9 and oak (*Quercus robur*)-litter from stand n° 13. All litter was chemically analysed. In each litterbag, 20 discs with a diameter of 20 mm, cut out of the center of a leaf (for pine 20 needle pieces with a length of 20 mm) and with known weight, were incubated. The litterbags were positioned on the forest floor between the freshly fallen leaves. The experiment introduced four sources of variation between litterbags : (1) 25 forest stands ; (2) 2 different mesh sizes : fine mesh of 1.5 mm excluding earthworm decomposition and coarse mesh of 8 mm permitting earthworm decomposition (MALDAGUE 1970) ; (3) 3 different litter types incorporated : local leaf litter and two reference leaf litters, cherry and oak from the forest of Gontrode and (4) 4 spaces of decomposition time : 1, 2.5, 6 and 12 months. The experiment started in November 1987. Decomposition was characterized by mass loss. As a matter of fact,

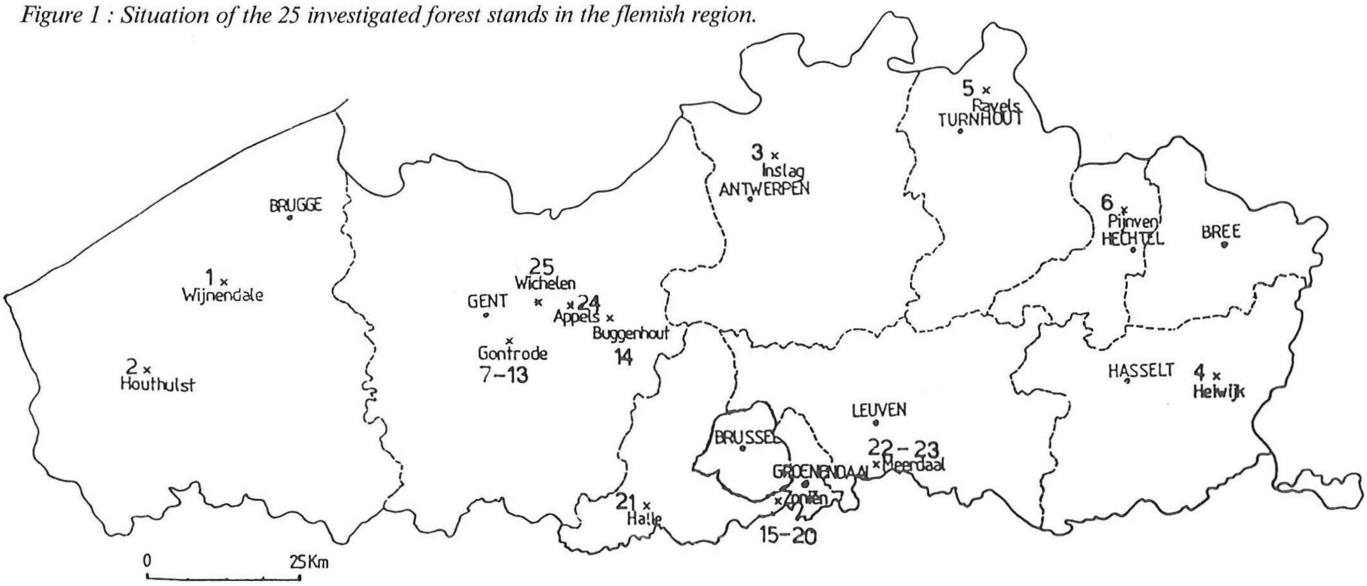

Figure 1 : Situation of the 25 investigated forest stands in the flemish region.

the ingestion of litter by soil animals doesn't give certainty about the degree of decomposition. It is however known that the organic material ingested by anecic worms is several times reingested until the nutrients become available for plant nutrition (BOUCHE, FERRIERE & SOTO 1987).

Results and discussion

1. Earthworms

In comparing the investigated forest stands, a considerable difference in earthworm biomass can be noticed, going from 2 kg.ha^{-1} in a pine forest on sandy soil to 1470 kg.ha^{-1} in a cherry forest stand on sandy loam soil (table 3).

Table 1 : Locality, soil texture, dominant tree species and humus type of the investigated forest stands.

FOREST STAND	LOCALITY	SOIL TEXTURE	MAIN TREE SPECIES	HUMUS TYPE
1	WIJNENDALE	SAND	FAGUS SYLVATICA	dysmoder
2	HOUTHULST	SAND	QUERCUS ROBUR	moder
3	BRASSCHAAT	SAND	PINUS SYLVESTRIS	mor
4	ZUTENDAAL	SAND	PINUS SYLVESTRIS	mor
5	RAVELS	SAND	PINUS NIGRA CALABRICA	mor
6	HECHTEL	SAND	PINUS NIGRA CALABRICA	mor
7	GONTRODE	SANDY LOAM	QUERCUS PALUSTRIS	mull
8	GONTRODE	SANDY LOAM	TILIA PLATYPHYLLOS	mull
9	GONTRODE	SANDY LOAM	PRUNUS AVIUM	mull
10	GONTRODE	SANDY LOAM	ALNUS GLUTINOSA	mull
11	GONTRODE	SANDY LOAM	FRAXINUS EXCELSIOR	mull
12	GONTRODE	SANDY LOAM	FRAXINUS EXCELSIOR	mull
13	GONTRODE	SANDY LOAM	QUERCUS ROBUR	moder
14	BUGGENHOUT	SANDY LOAM	FAGUS SYLVATICA	moder
15	HOEILAART	LOAM	ACER PSEUDOPLATANUS	moder
16	HOEILAART	LOAM	QUERCUS ROBUR	moder
17	HOEILAART	LOAM	FAGUS SYLVATICA	moder
18	HOEILAART	LOAM	FAGUS SYLVATICA	moder
19	HOEILAART	LOAM	FAGUS SYLVATICA	moder
20	HOEILAART	LOAM	FAGUS SYLVATICA	mull
21	HALLE	LOAM	FAGUS SYLVATICA	moder
22	SINT-JORIS WEERT	LOAM	QUERCUS ROBUR	moder
23	SINT-JORIS WEERT	LOAM	QUERCUS ROBUR	moder
24	APPELS	CLAY	POPULUS EURAMERICANA	mull
25	WICHELEN	CLAY	POPULUS EURAMERICANA	mull

It is known that the establishment of a mull humus type highly depends on the presence of a sufficient earthworm density (TOUTAIN 1981). We have found for the forests in the Flemish region that an earthworm biomass of about 150 kg.ha^{-1} is the lower limit for having a mull humus (figure 2). Most important, as BOUCHE (1981) states, is the presence of anecic earthworms. However, in the 9 forest mulls we investigated, only one anecic species (*Nicodrilus longus*) was found in some stands only and even then very rarely. Their function is replaced by the so-called epi-anecic species (table 2), mainly *Lumbricus terrestris.* Very interesting is the asessment that the normally epigeic species *Lumbricus rubellus* obtains epi-anecic morphological characteristics (flattened tail and hooked, strongly developed setae) when food supply has a richer composition. This was observed in different mull stands. In the limed beech stand n° 20, mull was exclusively obtained due to the epi-anecic *Lumbricus rubellus* and the endogeic *Allolobophora limicola.* The original moder however has only partly evolved to a mull-humus, according to a mosaic pattern. Since the liming was executed egally, we suppose that the mosaic pattern is the consequence of an originally unequally-spread earthworm community.

All oak, beech and pine forest stands investigated, with the exception of the above mentioned limed stand and a recent oak stand on former meadow, possess only epigeic earthworms with a biomass of less than 150 kg.ha^{-1} and are consequently characterised by a moder or mor humus form, irrespective of the soil texture. Since mulls were found under *Prunus avium, Tilia platyphyllos, Fraxinus excelsior, Alnus glutinosa* and *Populus sp.*, it is suggested that in the Flanders area, where climatic variability is small and parent rocks are never calcareous, the influence of the tree species is more important than the soil texture in determining the earthworm biomass and the humus form, with the exception however of poor sandy soils.

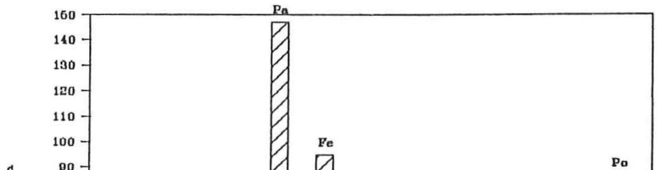

Figure 2 : Confrontation of fresh earthworm biomass (g.m^{-2}) with pH (H_2O) of the soil (0-5 cm) in the 25 forest stands (legend table 1) with abbreviated indication of the tree species and the critical values between mull and moder humus.

As was mentioned in the introduction, most forest soils in Flanders are extremely acidified. The soil acidification is partly due to slow litter decomposition causing the production of strong organic acids (DEVRIES & BREEUWSMA 1985). The soil acidity leads to the disappearance of active earthworms because they are not acidotolerant. As a matter of fact, we obtained a positive correlation between the topsoil pH(H_20)-value (0-5 cm) and the earthworm biomass (g.m^{-2}) (r= 0.85**). The calculated regression line of earthworm biomass on pH follows the equation $y = -107.209 + 31.0564x$. The pH-values obtained for the different forest stands show that the lower limit for having a mull humus type is a pH-value of 4 (figure 2). When putting this value in the calculated regression equation, we obtain an earthworm biomass limit of 170 kg.ha^{-1}, which is very close to the value of 150 kg.ha^{-1} which was put forward.

The ecological meaning of this critical values between mull humus type and moder-mor humus-types is twofold : first, the pH-value of 4 is the limit for endogeic and epi-anecic earthworms to survive. Below this limit, only acidotolerant litter-dwellers, like *Dendrobaena octaedra* do occur ; mixing of mineral soil and organic matter is inhibited by lack of borrowing soil fauna. This leads to compaction, decreased water-storage, retarded nutrient cycling, acidification and leaching ; secondly, the pH-value of 4 is about the limit between the exchange buffer range and the aluminium buffer range (ULRICH 1983). Below this value, leaching protons are exchanged with Al- and Fe-ions. These become mobile and cause toxicity for plants and podsolisation respectively.

Near to this limit of 4, big differences in humus type do occur (figure 2) : ash stand 12 has a pH-value of 4.09 and is a real mull with 400 kg earthworms.ha^{-1} ; maple stand 15 has a pH-value of 4.04 but it shows an earthworm biomass of only 50 kg.ha^{-1}. It is a stand, planted 80 years ago on former beech woodland. Phytosociological classification (ROGISTER 1975), as well as humus microstratigraphy (TANGHE, oral information) found evidence of the earthworm community and the humus from itself (the transition between holorganic and hemiorganic layer is not sharp) indicate that it still concerns a moder. RACKHAM (1980) shows that the critical pH-value between mull and moder is slightly dependent on the tree species. For the maple stand in concern however, we explain the moder humus as a consequence of the absolute dying out of the appropriate earthworm species in the former and the nowadays still surrounding beech woodland.

2. Litter decomposition

In order to obtain a first impression of the litter decomposition in the investigated forest stands and the importance of measured variables thought to be

Table 2 : Ecological groups and species of earthworms in the forests of the flemish region.

epigeic	endogeic	anecic
Lumbricus castaneus SAV.	Allolobophora rosea SAV.	Nicodrilus longus UDE
Lumbricus rubellus HOFFM.	Allolobophora limicola MICH.	
Eisenia eiseni LEV.	Allolobophora chlorotica SAV.	
Eiseniella tetraedra SAV.	Allolobophora muldali OMODEO	epi-anecic
Dendrobaena octaedra SAV.	Nicodrilus caliginosus SAV.	
Dendrobaena pygmea cognettii MICH.	Octolasium cyaneum SAV.	Lumbricus terrestris L.
Dendrobaena attemsi MICH.	Octolasium lacteum OERLEY	Lumbricus rubellus HOFFM.
Dendrobaena mammalis SAV.		
Dendrobaena rubida SAV.		

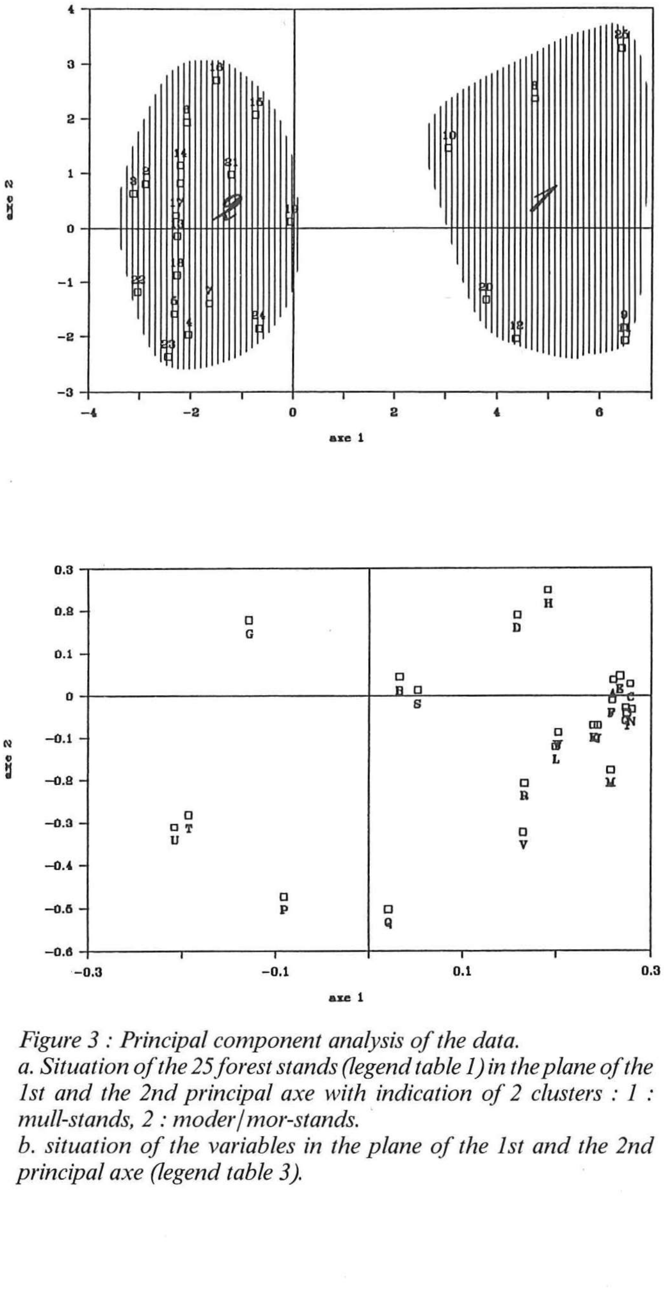

Figure 3 : Principal component analysis of the data.
a. Situation of the 25 forest stands (legend table 1) in the plane of the 1st and the 2nd principal axe with indication of 2 clusters : 1 : mull-stands, 2 : moder/mor-stands.
b. situation of the variables in the plane of the 1st and the 2nd principal axe (legend table 3).

relevant, we opted for a principal component analysis. We started from a matrix, containing values for 23 variables in each of the 25 stands (table 3). The variables used are the following :

- pH(H_2O) of the hemi-organic horizon between 0 and 5 cm.
- mineral content (ppm) of local leaf litter, originating from the dominant tree species, directly after abscission (Al, Ca, Fe, K, Mg, Mn and P ; C/N-ratio was not yet available for publication).
- fresh earthworm biomass (g.m^{-2}) for the total earthworm community, for the (epi-)anecic species and for the epigeic species.
- procentual mass loss after 1 ; 2.5 ; 6 and 12 months of decomposition for local, *Prunus arium* (cherry) and *Quercus robur* (oak) leaf litter in coarse litterbags (mesh size 0.8 cm).

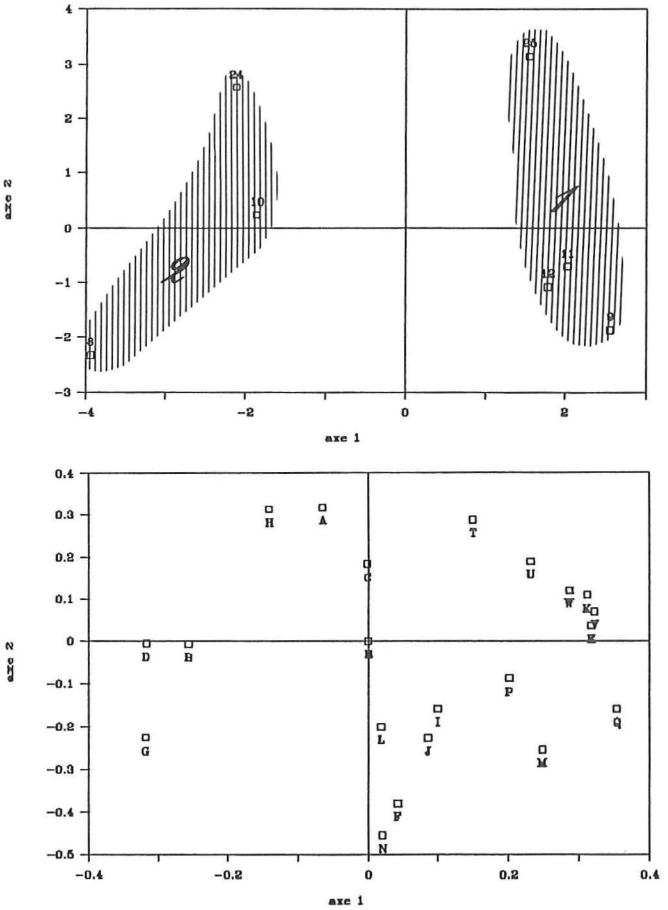

Figure 4 : Principal component analysis of the first cluster (stands with mull-humus).
a. situation of the stands (legend table 1) in the plane of the 1st and 2nd principal axe with indication of 2 clusters.
b. situation of the variables in the plane of the 1st and 2nd principal axe (legend table 3).

After ordination, the first and second principal axes account for 43% and 13% respectively of the total variance. The situation of the variables in the plane of the principal axes (figure 3b) shows that the formation of the first axe is mainly due to the variables soil pH, Ca-, K- and Mg-content of the local leaf litter, earthworm biomass and decomposition of the local leaf litter. These variables are mutually very well correlated.

As far as the position of the forest stands in the plane of the two principal axes is concerned, two clearly separated clusters can be defined (figure 3a) : a first cluster, related with fast litter breakdown, chemically rich leaf composition, big earthworm concentrations, contains precisely the forest stands with a mull humus-form, except again for those two forest stands showing moderaffections : stand n° 7 of *Quercus palustris* on former meadow, where the mull humus-form evolves to a moder under influence of the very poor leaf litter and stand n° 20 of *Fagus sylvatica*, where a moder is partly evolved to a mull humus after liming.

The second cluster with negative values on the first axe

CODE	FOREST STAND	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	SOIL ANALYSIS																									
A	pH(H2O) 0-5 cm	3.37	3.37	3.42	3.69	3.45	3.57	4.97	5.26	5.54	5.51	6.09	4.09	3.38	3.37	4.04	3.69	3.8	4	3.61	4.29	3.79	3.65	3.53	7.03	6.26
	LEAF ANALYSIS (ppm) (freshly fallen)																									
B	Al	124	92	156	138	221	381	60	285	60	60	92	188	92	124	60	156	60	124	60	124	124	60	124	317	60
C	Ca	51	89	62	110	31	53	81	460	370	237	510	304	100	72	168	131	144	145	146	206	136	130	130	510	520
D	Fe	138	88	87	99	108	117	17	357	38	136	161	167	105	117	87	74	94	97	74	84	85	10	42	275	139
E	K	81	108	105	40	76	42	40	241	307	207	281	304	139	82	221	96	64	95	72	71	50	98	62	261	309
F	Mg	656	1394	584	435	357	232	607	3859	3031	2451	3915	3887	1411	700	798	1141	1607	839	1188	1116	1210	1765	2067	2314	2177
G	Mn	110	273	120	214	120	115	182	416	147	245	68	77	350	650	645	783	959	720	689	604	844	645	487	129	61
H	P	721	665	777	342	536	188	548	1134	481	1565	1827	1304	709	752	1173	1245	690	752	771	727	721	784	853	4087	1572
	EARTHWORM BIOMASS (g.m-2)																									
I	total	1.2	0.4	0.2	2.1	0.5	0.7	36.3	75.2	147.1	54.6	95.1	39.8	2.4	0.4	5.3	4	0.1	3.1	0.9	15.2	0.4	6.6	1.1	86.5	53.4
J	anecic	0	0	0	0	0	0	23.5	53.4	91	11.6	33.8	20.8	0	0	0	0	0	0	0	2.5	0	0	0	30.5	30.7
K	epigeic	1.2	0.4	0.2	2.1	0.3	0.7	3.4	2.2	12	9.3	9.6	8.7	2.2	0.4	5.2	3.2	0.1	3	0.9	10	0.4	6.2	4	8	9.5
	LOCAL LEAF LITTER DECOMPOSITION (%)																									
L	1 month	0	0	4.6	14.6	0	35.5	13.9	47.2	36.8	22.2	81.3	22.3	22.4	4.6	17.8	0	12.8	0	27.5	30	8.2	0	48.4	35.6	12.7
M	2.5 months	7	19	27	20.2	6.9	39.3	15.1	65.2	100	28.5	100	94.4	24	10.1	21.6	24.4	10.2	10.2	30	40.8	35.6	12.5	54.6	58.2	51.6
N	6 months	13.6	26.4	31.1	39.1	7	47.1	24.6	100	100	94.6	100	96.5	24.6	15.5	50.1	45.2	23	23	33.4	43.8	40.3	47.3	57.9	83.2	79.1
O	12 months	44	59.1	41.5	59.8	40	73.9	47.6	100	100	100	100	100	50.2	32	76	58.1	51.8	51.8	47.7	78.2	58.6	49.4	70.7	100	100
	CHERRY LEAF LITTER DECOMPOSITION (%)																									
P	1 MONTH	76.6	41.8	59.1	78.4	51.8	64.2	59.9	40	36.8	49.1	56.5	69.3	49.7	48.4	37.4	13.5	51.9	57.4	46.2	40	70.6	36.2	66.9	8.1	62
Q	2.5 MONTHS	79	65.8	74.5	93.9	63.9	84.7	95.8	61.6	100	60.5	98.1	100	74.1	70.5	72.2	46.6	70	97.7	63.4	55.9	94.4	87.9	96	47.5	87
R	6 MONTHS	92.8	78.8	98.3	96.2	91.5	95.7	100	100	100	100	100	100	83.3	92.4	87.2	94.5	90	87.7	82.6	100	98.8	96.8	100	100	100
S	12 MONTHS	100	100	100	100	100	97.4	100	100	100	100	100	100	99.7	100	100	99.4	100	100	100	100	100	97.5	100	100	100
	OAK LEAF LITTER DECOMPOSITION (%)																									
T	1 month	48	0	18.5	54.6	31.2	45.6	29.6	0	0	0	7.1	1.1	22.4	23.7	5.7	20.9	29.3	40.1	32.5	40	45.1	0	30.4	0	24.6
U	2.5 months	50.2	24.9	40.7	54.7	34.5	59.6	39.1	0	0	0	24.1	21.5	24	39.8	17.7	28.2	53.4	53.4	39.7	42.2	54.4	11.5	41.7	0	39.1
V	6 months	54.2	31.6	43	56.3	45.7	62	42.3	8.1	100	33.7	100	100	24.6	43.8	21.9	40.9	55.6	55.6	43.9	43.5	52	31.5	52	85.9	71.2
W	12 months	71.3	73.8	63.8	74.6	61.6	73.5	63.2	82.2	100	92	100	100	50.2	74.5	56.1	66.7	95.3	95.3	80.4	96.5	69.4	80.5	63.2	100	94.5

and consequently to be translated in slow decomposition processes, contains all stands with moder- and mor-humus, including the two transitory stands mentioned above.
Both clusters are separated and the principal components analysis is recomputed for both of them.

In the principal components analysis of the first cluster (the mullstands), the variables which contibute most to the formation of the first axe (figure 4b), are on the one hand the biomass of epigeic earthworms, the K-content of local leaf litter, the decomposition of cherry leaves after 2.5 months and the decomposition of oak leaves after 6 months on the positive side of the axe, and, on the other hand, the Al-, Fe and Mn-content of the local leaf litter on the negative side of the axe.

These assessments can be interpreted as follows :

1. Litter decomposition in earthworm-dense soils seems to be dependent on the share of epigeic earthworms, which is in contradiction with the results of STOUT & GOH (1980). The relationship between decomposition and total earthworm biomass is found weaker. This is quite normal, because of the important share of humus-eating endogeic species, that do not contribute to the litter breakdown. The somewhat weaker relationship between decomposition and anecic earthworms, however, is strange. According to litterature (SHAW & PAWLUK 1986), they are the most active decomposers. The mesh size of litterbags (0.8 mm) might not allow big anecic worms to take out the leaf material easily.
2. Fast earthworm-dependent litter breakdown is established for cherry and local leaf litter after 2.5 months ; for oak only after 6 till 12 months. This delay in time seems to be logical : the cherry as well as the local leaf litter of mull-stands have a rich composition (table 3) and decompose quickly, while oak leaf litter with a lower ash-content, is believed to be attacked by earthworms starting as soon as lack of better food appears.
3. Starting from a certain pH-value (>4) and a certain Ca-content of the leaves (about 200 ppm), both factors are not longer determining factors for litter decomposition speed. Under these conditions, K-content seems to stimulate litter breakdown, while Fe, Mn and Al decrease it.

The situation of the forest stands in the plane of both the principal axes allows to distinguish two groups (figure 4a). The second group has negative values on the first axe and contains stand nº 8 of lime, stand nº 10 of alder and stand nº 24 of poplar. These are stands where a slow initial decomposition was observed. This could be explained by a high Al-content (285 ppm in lime and 317 ppm in poplar instead of 152 ppm on an average) or a high Fe-content (357 ppm in lime and 275 in poplar instead of 182). Another, equally plausible explanation, even though not measurable with the applicated variables is the lack of a humid forest microclimate in these stands without shrub understorey.

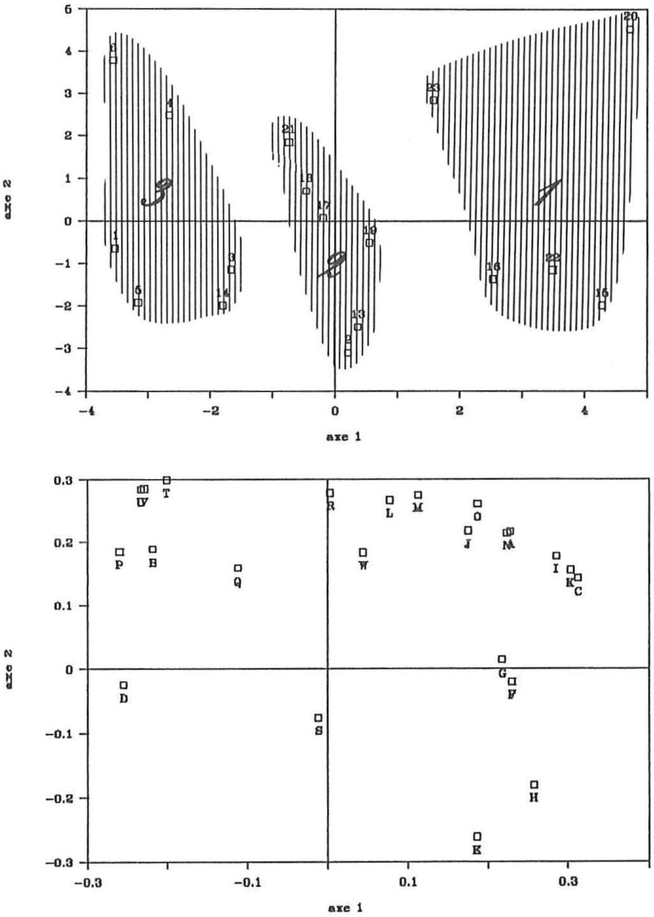

Figure 5 : Principal component analysis of the second cluster (stands with moder and mor-humus).
a. situation of the stands (legend table 1) in the plane of the 1st and 2nd principal axe with indication of 3 clusters.
b. situation of the variables in the plane of the 1st and 2nd principal axe (legend table 3).

In the principal component analysis of the second cluster (the moder- and mor-stands), the first axe is, on the positive side, mainly formed by the ash-content of the local leaf litter in general and the Ca-content in particular and also by the earthworm biomass and the soil pH (figure 5b). The decomposition speed of local leaf litter is quite well correlated with these parameters. On the negative side, the Fe- and Al-content of the local leaf litter strongly contribute to the formation fo the first axe. Contrary to the mull soils, the Mn-content seems to stimulate decomposition. The decomposition of cherry as well as oak leaves is situated on the negative side of the axe. It is explained by the fact that introducing leaves of high quality in relation with the local leaf litter leads to a big concentration of decomposing organisms on this introduced leaf : in stands with mor-humus, we detected very slow decomposition rates for local leaf litter and on the other hand, very quick decomposition rates for richer, introduced leaf material.

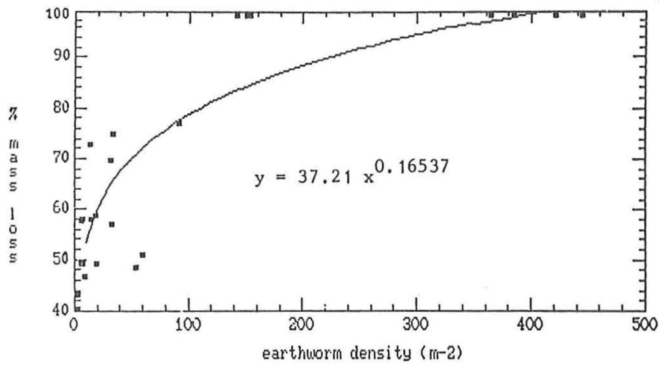

Figure 6 : Regression of procentual litter mass loss after 12 months decomposition on earthworm density (m^{-2}).

As far as the position of the forest stands in the plane of the first and second axe is concerned (figure 5a), 3 clusters can be distinguished, being very conform to humus quality :

1. mull-moder : oak (stands 16, 22, 23), maple (stand 15) and limed beech (stand 20) on loamy soil.
2. moder : oak on sand and sandy-loam (stands 2;13) and beech on loam (stands 17, 18, 19, 21).
3. dysmoder and mor : beech on sand and sandy loam (stands 1, 14) and pine on sand (stand 3, 4, 5, 6).

3. *Earthworms and litter decomposition*

The principal components analysis showed a strong interrelation between earthworms and chemical composition of the local litter. More evidence for a significant relationship between litter decomposition and earthworms was also obtained. The positive correlation between earthworm biomass and procentual mass loss of the local litter after 12 months (this is the time limit from where litter accumulation and soil degradation starts) is very strong (r = 0.85**) and the relation with eartworm density even stronger (r = 0.87**) (figure 6). In order to investigate the causality of this relationship, we confronted the decomposition results of the coarse litterbags (8 mm) used here-above with the results of the fine litterbags (1.5 mm) where earthworms do not participate in litter breakdown.
In order to obtain a synthesis with general validity for the forests of the Flemish region, average composition results were calculated for on the one hand the forest stands with mull-humus (9 repetitions) (figure 7a) and on the other hand for the forest stands with moder- and mor-humus (16 repetitions) (figure 7b). In these very different environments, the decomposition was followed for the well-palatable cherry leaves and for the relatively unpalatable oak leaves.

The results can be summarized as follows :

- In mulls as well as in moders, the decomposition of cherry leaves is much faster than oak leaves.
- In the initial phase of decomposition, mainly controlled by leaching and micro-organisms, earthworms do not play a substantial role : their populations are small at the end of summer and they await an increasing palatibility by preliminary microbial incubation. Later on, their role stays very modest in moders (a maximum share of 15% in decomposition), but is really essential in mulls (up to 40% of decomposition).
- The earthworms are most successful when other decomposers fail : not in the initial phase but in the end, when only unpalatable leaves or refractory veins remain, provided of course that they are numerous and well-fed before. Anyway, all decomposer organisms, even those adapted to unpalatable food resources, always prefer the best food available. The decomposition of oak leaves in mull forests by earthworms does not start before most well-palatable leaf litter has disappeared (compare curves A & C).
- When comparing the B and D curves (fine litterbags) of both mull and moder/ mor humus forms, they are practically similar. This means that the superiority of mull-humus for decomposition can be totally attributed to earthworms.

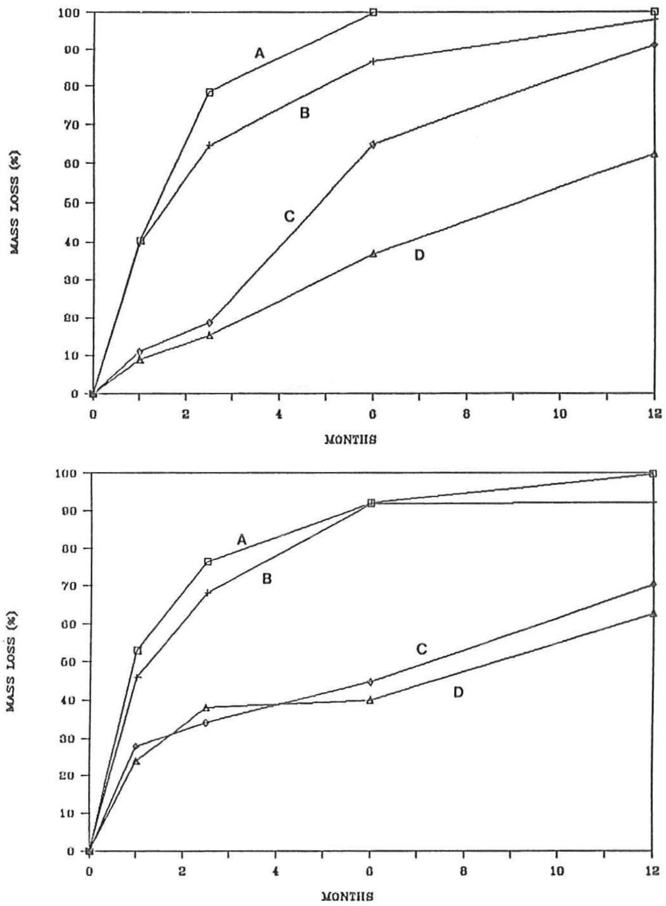

Figure 7 : Litter decomposition (procentual mass loss) as a function of time for cherry litter (curves A & B) and for oak litter (curves C & D) in litterbags with coarse mesh (8 mm) (curves A & C) and in litterbags with fine mesh (1.5 mm) (curves B & D).
a. forest stands with mull-humus.
b. forest stands with moder/mor-humus.

Conclusions

Most forest soils in the Flemish region are extremely acidified. Once the superficial soil pH sinks below 4, earthworm communities' biomass is situated below 150 kg.ha^{-1}. As a consequence, litter decomposition decelerates and causes holorganic humus types as moder and mor. Air pollution can affect these forests causing mineral deficiencies in soil and tree leaves.

For the land area which was investigated, the tree species seems to be the most explicative factor for humus formation, due to the different chemical composition of the leaf litters. This assessment is important for silviculture. It can contribute to a less soil degrading policy of tree species composition and mixture. It is shown that soil amelioration in extremely acidified monospecific forests is possible by means of enrichment with secondary tree species having palatable leaves or by sanitary liming, but only if enough burrowing earthworms are available. If not, we suggest to reintroduce them.

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