EARTHWORM POPULATIONS OF HARDWOOD STAND IN NORTHERN BELGIUM

B. Muys (1)

Abstract

A comparative study of the earthworm populations in four different stands of broadleaved forest was made. Number, biomass and seasonal variation were studied.
Earthworms appeared to be abundant under poplar and ash and were found rarely under oak and beech.

(1) Research centre for Silviculture, Management and Forest Policy of the State University Ghent and I.W.O.N.L.

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I. INTRODUCTION

Many publications deal with the importance of earthworms for the conservation of soil fertility. Earthworms have indeed an important function in decay and recycling processes. They improve, in many respects the physical, chemical and biological soil characteristics : their galleries drain and aerate the soil, they mix up organic matter and mineral soil and contribute in this way to the recycling of biogene elements ; their excrements form stable, nitrogen enriched soil-aggregates and they stimulate the microbial life in soil.
As earthworms often represent the biggest portion in soil-fauna biomass, their activity is very intensive.

In the forest ecosystem, where normally no soil cultivation is executed and no fertiliser is used, unlike in arable soils, the earthworm activity seems to get an extraordinary ecological as well as economic significance. Therefore, it is necessary to acquire a profounder knowledge of the earthworm populations in different forest-types and a better understanding of the, possibly causal, relationship between different ecosystem-variables and the earthworm-abundance.

The here presented research-work was done between August 1984 and February 1986. A large amount of soil samples was taken under different forest-canopies in order to collect data about species composition, number and biomass of earthworms and seasonal variation of the populations. It was further tried to find out if essential differences, in this aspect, existed between forest-types and attention was paid to the causes of possible differences.

2. THE RESEARCH AREA

The research-area ' Aelmoeseneiebos ' is situated some 10 kilometers southward of Ghent (Northern Belgium).
The elevation varies between 11 and 20 metres above sea-level. The climate has a temperate Atlantic character (mean annual precipitation : 752 mm ; mean annual temperature : 9.6°C).

The geologic formations coming up to day are subhorizontal sediments of the Tertiary (clay and sand). The niveo-eolic upperlayer of the Quarternary is sandy-loam.
The water-economy is variable, depending on the elevation and on the texture and depth of the tertiary layer, but is never dry, even in summer.

The vegetation is typical of the Quercetum atlanticum LEMEE. 3 subassosiations can be distinguished.

The Quercetum atlanticum convallarietosum LEBRUN is found on the dryest sites. The tree layer is formed of oak and beech : herbal vegetation is scarce and shows little diversity. This subassociation can be regarded as

Table 2.1. Sylvicultural characteristics of the four research plots.

PLOT	Characteristics
A	Main species. poplar (*Populus x euramericana*) vegetation : *Q.atl.-Cirsietosum* stand type : stand of poplar mixed with ash and slightly mixed with oak and white poplar. Surface : 0.79 ha Number of stams/ha (d > 8 cm) = 451 Basal area/ha : 21.3 m^2 Mean diameter : 19,7 cm
B	Main species : ash (*Fraxinus excelsior*) vegetation : Q. atl. typicum stand type : stand of ash, mixed with oak and maple slightly mixed with poplar and beech. Surface : 0.73 ha Stems/ha : 341 Basal area/ha : 23,3 m^2 Mean diameter : 26.4 cm
C	Main species : oak (*Quercus robur*) vegetation : *Q. Atl. convallarietosum* stand type : stand of oak, mixed with american oak, beech and larch, slightly mixed with chestnut. Surface : 1.79 ha Stems/ha : 387 Basal area/ha : 31.1 m^2 Mean diameter : 20.2 cm
D	Main species : beech (*Fagus sylvatica*) Vegetation : *Q. Atl. Convallarietosum* Stand type :stand of beech mixed with american oak and slightly mixed with larch. Surface : 3.11 ha. Stem number/ha : 419 Basal area/ha : 30.7 m^2 Mean diameter : 27.8 cm

a degradation-phase due to the choice of tree species. Humus type is moder. On the more humid sites, the diverse Quercetum atlanticum typicum LEBRUN can be found. Main tree-species are oak, ash and poplar. Humustype is mull. On the extremely wet sites, this association is replaced by the Quercetum atlanticum cirsietosum LEBRUN.
The tree-layer is dominated by poplar and ash.

In the area described above, 4 research plots were chosen under 4 different forest canopies : dominated by respectively poplar, ash, oak and beech (table 2.1.).

In every plot a soil analysis showed the following parameters on different soil depths : pH, content of organic matter and C/N - ratio (fig.2.1,2.2 and 2.3).

Figure 2.1. pH value as a function of soil depth

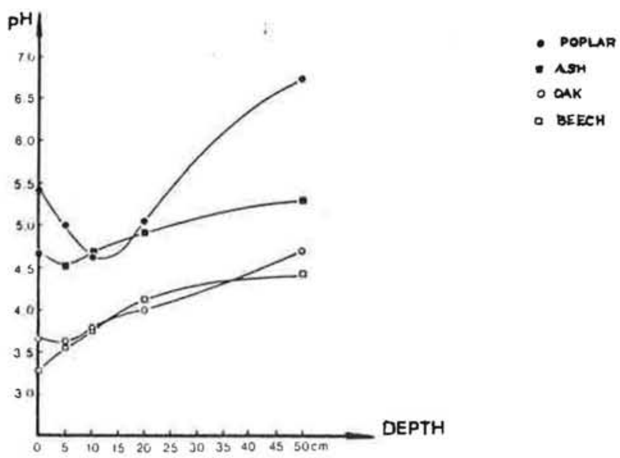


Figure 2.2. Organic matter content as a function of soil depth

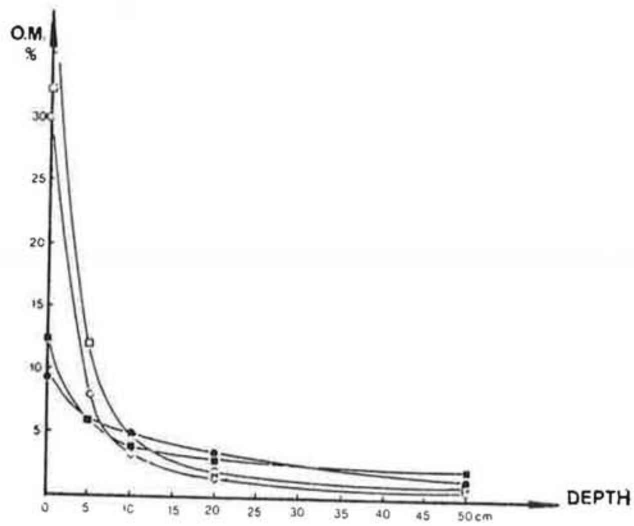
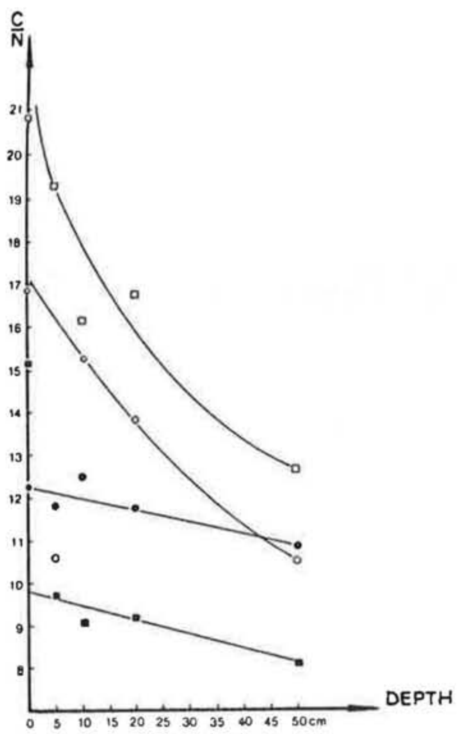


Fig. 2.3. C/N ratio as a function of soil depth.



The pH under ash and poplar is much higher than under oak and beech. The soil profile under ash and poplar is characterised by a moderate organic matter content, slowly decreasing with soil depth (typical for Mull humus type).
Under oak and beech, on the contrary, a superficial layer of raw organic matter can be found. The organic matter content is fastly tending to zero with increasing soil depth.

Humus quality, measured by means of the C/N ratio, shows that the superficial organic matter is badly demolished, which results in high C/N - values. The organic matter, being mixed with mineral soil shows good decay and is stable, as illustrated by the lower C/N-ratio.

3. METHODOLOGY

3.1. Sampling methods

Undoubtedly adequate sampling constitutes one of the most important problems in soil biology. Numerous methods for earthworm sampling have been established which do, however, lead to various results, strongly depending on the local situation and the specific perspectives of the research.

An extensive study of litterature was made in order to find the most accurate method for our own objectives.

In ethological methods, stimuli are used to drive the earthworms to the surface.
The most important methods of this type is the formalin method, as described for the first time by RAW in 1959.

This method is very practical for earthworm species with vertical gallery systems (anoecic species), but less attractive for horizontal digging species (endogeic species), and worms in resting conditions. Moreover, the research depth is unknown and the solution is introduced in soil, following preferential ways.

Other methods are using electricity, warmth, food, etc.

Physical methods are more frequently used. In these methods two actions mustbe distinguished soil sampling and the extraction of the worms from the soil sample.

The advantage of taking soil samples is, the certainty one haves of the investigated soil volume. The worms are extracted manually or mechanically. (by means of flotation and wet sieving) (BOUCHE 1972).
Handsorting is still the most currently applied extraction method because it can be done directly on the field with good results and without sophisticated expedients.
Disadvantages are the large input of labour and time requirement and an underestimation of small worms.

Combined methods try to unify the advantages of chemical and physical methods. In most cases however, these are rather complicated and accumulate a number of disadvantages.

3.2. Choice of the sampling method

In a preliminary research executed in september (low ground-water level), the formalin method and the handsorting method were compared in a homogeneous plot where, 8 pairs of samples were taken.

Every sample pair consisted of a 50 x 50 cm square treated with a formalin solution (16.6 m l formaldehyde 40 % solution in 3 l of water) and at a distance of 1 meter a square of the same dimensions was dug out to a depth of 20 cm and hand-sorted.
The results (table 3.1.) were compared (t'-test after a transformation (log x) of the data). This test differs from the t-test of Student as the amount of degrees of freedom (d.f.) is smaller and it is used in cases with a number of repetitions smaller than 15.

$$t' = \frac{\bar{x}_1 - \bar{x}_2}{\frac{S_1^2 + S_2^2}{n}} \qquad d.f. = \frac{(n-1)\, S_1^2 + S_2^2)^2}{S_1^4 + S_2^4}$$

Table 3.1. Number of collected earthworms

Sample	1	2	3	4	5	6	7	8	$\bar{x}$	s
Handsorting	35	48	12	7	7	90	17	25	30.1	28.1
Formalin	17	17	12	14	9	24	19	12	15.5	4.8

The t'-test showed no significant difference between the formalin and the handsorting method.
Therefore and in order to take a decision, concerning the method to be used, a list of factors, affecting the sampling accuracy was made up from data by BOUCHE (1972), SPRINGETT (1981) and our own experiences (table 3.2).

Table 3.2. Degree of influence on the sampling methods by different factors (x low xx medium xxx high)

FACTORS	METHODS : handsorting	formalin
1. Influence of human input (quality)	xxx	xx
2. Influence of human input (quantity)	xx	x
3. Importance of expedients		
4. Influence of the season	xx	xxx
5. Influence of the weather circumstances	xx	xx
6. Influence of the soil type	xx	xxx
7. Influence of tree roots	x	0
8. Influence of drainage class	xx	xxx
9. Inaccuracy of the treated volume	x	xxx
10.Low efficiency towards resting worms	x	xxx
11.Low efficiency towards small worms	x	xxx
12.Transport of material	xx	xx

The demands of the research proper were formulated as follows :

- The comparison between different tree-stands and different points of time requires constant efficiency and constant sample volume.
- Budget and labour input were restricted.
- Soils are not stony, but heavy and compact, with heigh groundwater levels during winter.
- The accessibility of the plots with expedients was difficult.

Under this circumstances, the handsorting method seemed to be the most suitable.

3.3. Applied methodology

In each of the 4 different plots, mentioned before, 6 soil samples were taken every month during one year (4 x 6 x 12 = 288 samples in total). The samples (25 x 25 x 25) cm^3 were taken by means of a steel-tray that was driven into the soil as fast as possible. The earthworms were hand-sorted on a white plastic film at the site or in the laboratory when it was too dark for efficient sorting. The soil was searched twice by two different persons. Extracted worms were conserved in 5 % formaldehyde and determined, measured and weighed after 1 month fixation.
Different authors mention an important loss of weight after conservation in formalin. In our research, 240 pigmented and non-pigmented worms of different length-classes were weighed fresh, after one month fixation and dried. The weighing method had to be strictly standardised. The t-test could establish no significant difference between fresh and fixed weight for all different classes.
The dry matter content was not constant for all classes. The analysis of variance showed a highly significant difference between pigmented (21 % dry matter) and non-pigmented (26 % dry matter) species. A possible explanation for this phenomenon is a bigger content of mineral particles in the intestines of non-pigmented endogeic species.

4. SPECIES COMPOSITION

4.1. Introduction

In the research area, a total number of 13 earthworm species were found. The number of species in the different stands is quite variable :

In the plots under poplar and ash, 12 species were gathered, under oak 7 and under beech only (table 4.1).

Table 4.1. Earthworm species of the different research plots

Species	Plot			
	poplar	ash	oak	beech
Lumbricus terrestris	+	+	-	-
Lumbricus rubellus	+	+	+	-
Lumbricus castaneus	+	+	-	-
Eisenia eiseni	-	+	+	+
Eiseniella tetraedra	+	+	-	-
Dendrobaena octaedra	+	+	-	-
Dendrobaena rubida	+	+	+	-
Dendrobaena mammalis	+	+	-	-
Allolobophora caliginosa	+	+	+	+
Allolobophora rosea	+	+	+	-
Octolasium cyaneum	+	+	-	-
Octolasium lacteum	+	-	+	-

4.2. Mean species composition

In each of the 4 stands, the population structure is quite similar, the genus Allolobophora is dominating number and biomass. It represents 74 %, 71 %, 86 % and 75 % of number under respectively poplar, ash, oak and beech, and, in the same sequence, 63, 54, 80 and 90 % of biomass.

Only under beech is the importance of the genus Allolobophora bigger for biomass than for number.
It depends on the size of the secondary species : under beech, mainly small species are found. In the other plots, on the contrary, the more heavy Lumbricus species are the main secundary species.
The genera Eiseniella, Dendrobaena and Octolasium are in all stands of relatively little importance.
Within the genus Allolobophora, A. caliginosa is by far the most important species, with exception of the plot under beech, where A. limicola dominates.

BOUCHE (1971) divides earthworm species in different ecological groups, corresponding to their ecological niche. This division is at least as important as the division in species, because each group has different effects on the soil characteristics.
The endogeic species are, because of their extensive horizontal gallery-systems, important for soil structure. The anoecic species build vertical galleries and are therefore important for drainage and aeration of the soil and for mixture of the organic material with the mineral soil. The epigeic species have a certain importance in litter decay. In a stable well-functioning ecosystem, all ecological groups occur in a well-balanced ratio (table 4.2).

Fig. 4.1. : Procentual importance in number and biomass of the different species in the 4 research plots.

Number code :

1. Lumbricus terrestris L.	10. Dendrobaena mammalis SAV.
2. Lumbricus rubellus HOFFN.	11. Dendrobaena juvenile
3. Lumbricus castaneus SAV.	12. Allolobophora caliginosa SAV.
4. Eisenia eiseni LEVINSON	13. Allolobophora limicola MICH.
6. Eiseniella tetraedra SAV.	14. Allolobophora rosea SAV.
7. Juvenile of the proceeding	15. Allolobophora juvenile
8. Dendrobaena octaedra SAV.	16. Octolasium cyaneum SAV.
9. Dendrobaena rubida SAV.	17. Octolasium lacteum OERLEY
	18. Octolasium juvenile

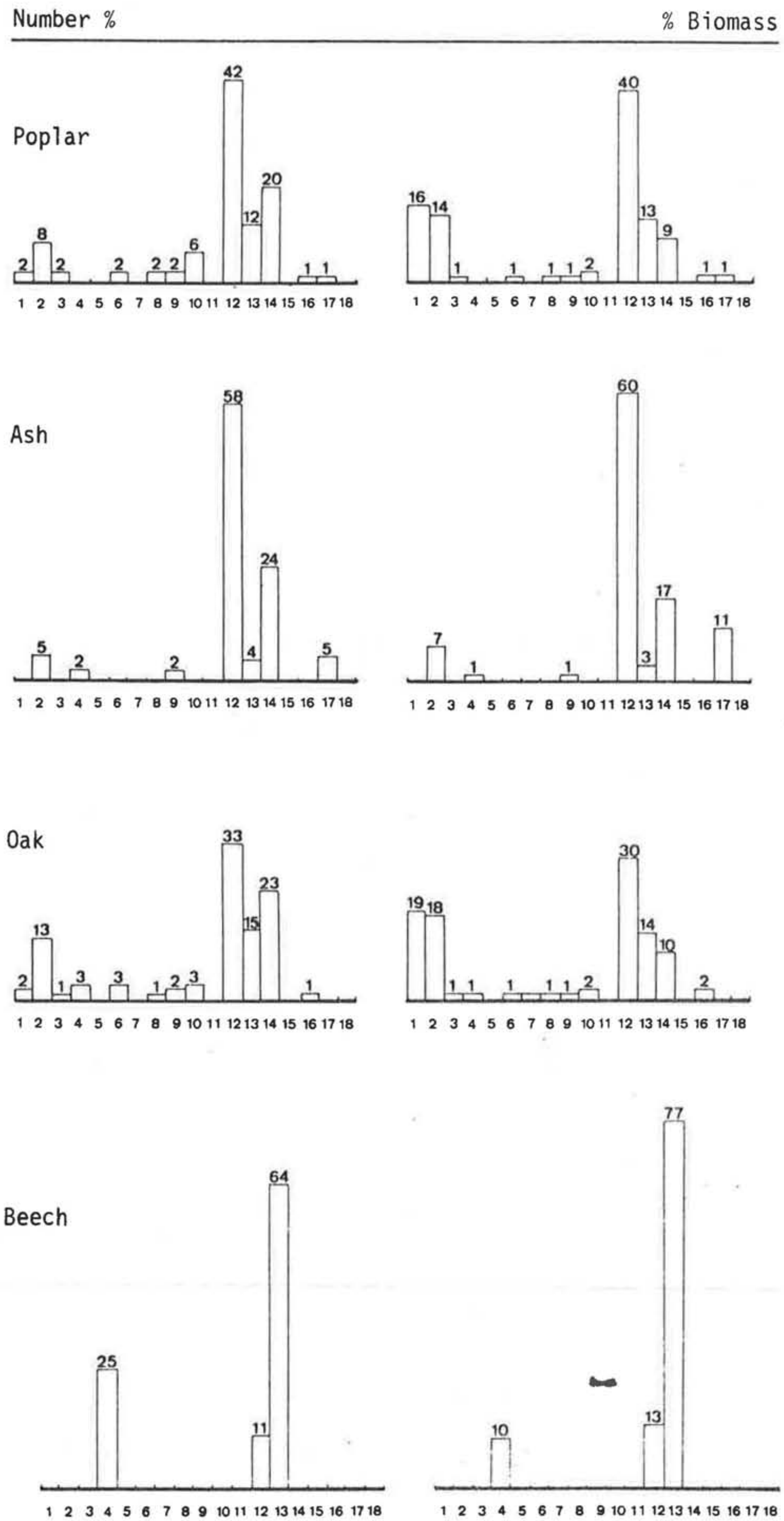

Number %
% Biomass
Poplar
2 8 2 2 2 2 6 42 12 20 1 1
16 14 1 1 1 1 2 40 13 9 1 1
Ash
5 2 2 58 4 24 5
7 1 1 60 3 17 11
Oak
2 13 1 3 3 1 2 3 33 15 23 1
19 18 1 1 1 1 1 2 30 14 10 2
Beech
25 11 64
10 13 77
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

Table 4.2. : classification of the earthworm species of the research area in ecologic groups

Epigeic	Endogeic	Anoecic
Dendrobaena octaedra Dendrobaena rubida Eisenia eiseni Eiseniella tetraedra Lumbricus rubellus Lumbricus castaneus	Octolasium cyaneum Octolasium lacteum Allolobophora Caliginosa Allolobophora rosea Allobophora limicola	Dendrobaena mammalis Lumbricus terrestris

The results of the research (fig. 4.2) show that all three ecologic groups are represented under poplar and ash. The situation under oak and beech is less favourable, because of the absence of anoecic species.

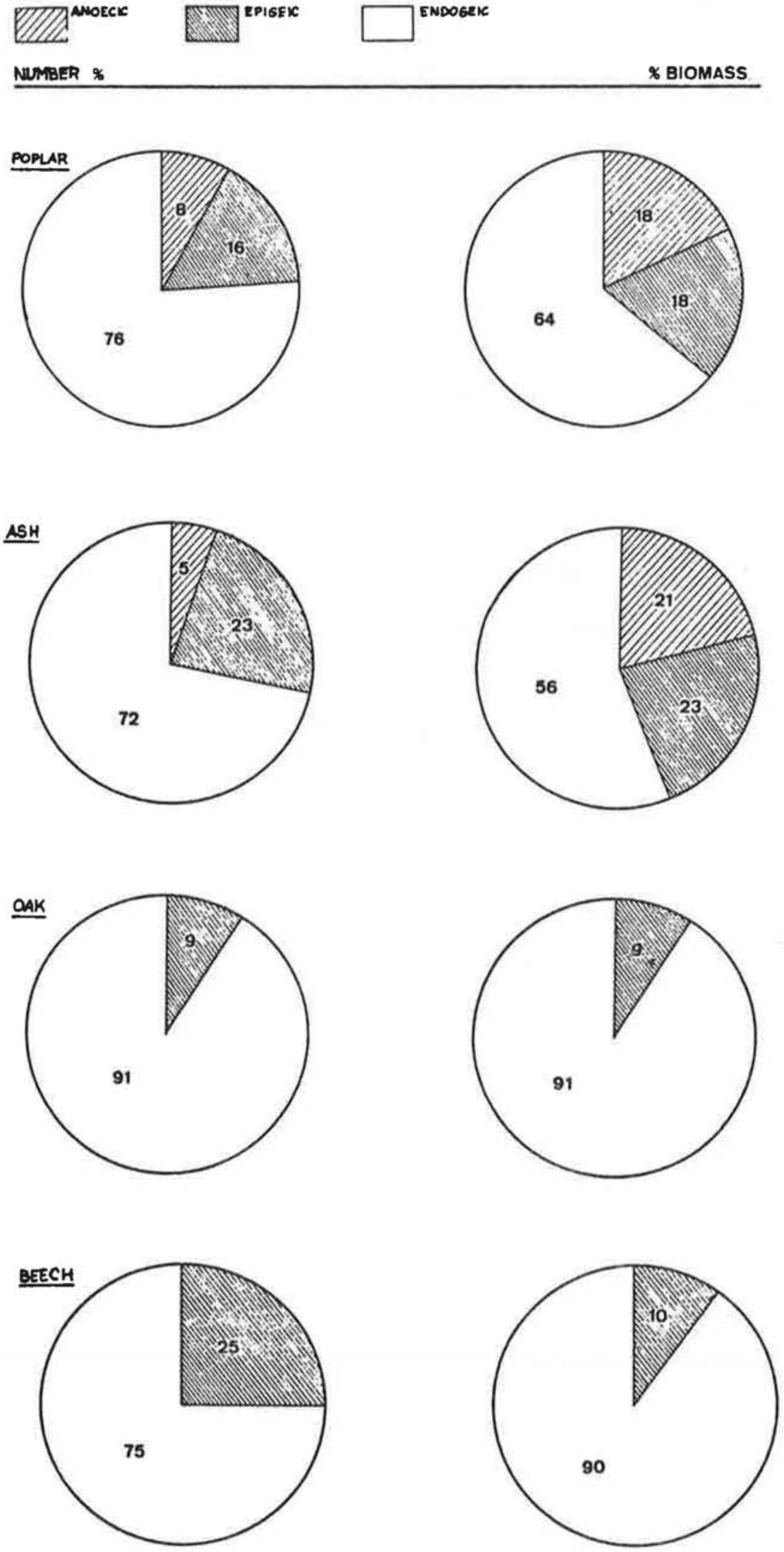
The situation under oak and beech needs a more detailed explanation.

After 6 months of sampling all samples in these two plots had been blank. As a consequence, the question was raised if earthworms actually would live under an oak or beech canopy ? In the following months, half of the samples were no longer taken at random, but more concentrated on sites, where earthworms were more likely to live : in ditches, on places with a rich soil vegetation, under solitary trees of other species with more easily decomposing litter (Acer pseudoplatanus), etc.
In some cases, a small solitary living individual of an epigeic species was collected, and in a few cases, only on the bed of the ditches, characterised by a humous, moist alluvial soil, important populations of endogeic species could be found. They provide the reason for the apparent dominance of endogeic species under these canopies, as seen in fig.4.2.
In reality, earthworms are extremely rare under oak and beech (respectivally 88 % and 96 % of all samples are blank).

4.3. Particularities in species composition

An interesting fact is, that the number of species found together at the same time is rather small. Under ash for example, an average of only 4 species a month are found, while the total number for the year is 12. Under poplar, it was only after 12 months, under ash after 9 months on a total of 12, that all species were found.
These may suggest that not all occuring species were found. It may also demonstrate on the other hand that the species aggregate as species associations. These findings have their consequence, concerning the sampling organisation : a sufficient amount of samples has to be taken and delayed in time. Indeed, some species were only found in certain periods of the year. This was very typical for the genus Dendrobaena. Dendrobaena mammalis was only found in spring, namely under poplar, from March till May. In summer, Dendrobaena octaedra was the only representative of the genus, under poplar from June till September. Dendrobaena rubida was only found in autumn and

Fig. 4.2. : Procentual importance of number and biomass of the different ecologic groups in the 4 research plots.



winter. (from October till february). For this reason research must necessarely cover all seasons.

Fig. 4.2. seems to suggest that the most evenly balanced ratio of the 3 ecological groups is found under ash. A glance at the separate samples learns that this figure is the result of the combination of samples containing only 1 or 2 ecological groups. It means that the ecological groups are spread in the horizontal level, which suggests, that the soil under ash is not homogeneously favourable for earthworms as it would seem. It consists however of a mosaic : places favourable for earthworms, where important populations of the exigent anoecic species can be found, and places, where almost no earthworms are found, except a few epigeic individuals, and of course all transitional soil situations between these two. The unfavourable situations are mostly found under solitary oak and beech trees, which are mixed in the ash stand.
Under poplar, on the contrary, homogeneously favourable conditions for an abundant endogeic population are present. The rather small importance of anoecic species under poplar is probably due to the high water-table and the very compact clay.

4.4. Species associations

As already mentioned species seem to occur in association. This was evaluated by a so-called average linking clustering. This method of classification is hierarchic, agglomerative and polythetic meaning that the agglomeration of species is done on the basis of more species at the same time. The calculation starts with the construction of a species-sampling matrix, being a n x n - matrix (n = total number of species), which gives for each couple of species the number of samples, whereby both species occur together (Table 4.3). On the diagonal, one can read the total number of positive samples for each species.

Table 4.3. : species - sampling matrix.

	1	2	3	4	6	8	9	10	12	13	14	16	17
1	11	2	0	0	0	2	1	3	5	7	6	0	0
2		38	0	0	0	3	3	3	22	9	16	1	1
3			6	0	1	1	0	2	6	3	4	0	0
4				3	0	0	0	0	1	2	1	0	0
6					6	0	0	5	4	6	4	1	0
8						10	0	1	6	6	4	0	0
9							12	0	4	2	2	0	0
10								16	10	11	7	0	0
12									70	26	38	1	2
13										40	25	1	0
14											51	1	1
16												2	0
17													3

Juveniles are not taken into account for this calculations. With these matrix-values, the similarity indexes of JACCARD are computed. This index is given by following formula :

$$SIab = Nab / (Na + Nb - Nab)$$

whereby SIab = similarity index of the species couple (a, b)

Nab = number of samples containing species a and b at the same time

Na = number of samples containing species a

Nb = number of samples containing species b

These indices form an n x n similarity matrix (Table 4.4). The highest similarity index indicates the 2 strongest associated species. These are taken together and get a new similarity index which is the average of the indexes of the two associated species. The matrix is recomputed and results in a new (n-1) x (n-1) matrix.
This is repeated until all species are associated and as a consequence, a 1 x 1 - matrix remains.

Table 4.4. : similarity-matrix

	1	2	3	4	6	8	9	10	12	13	14	16	17
1		043	0	0	0	105	045	125	066	159	107	0	0
2			0	0	0	067	064	059	258	130	219	026	025
3				0	091	067	0	100	086	087	075	0	0
4					0	0	0	0	014	049	019	0	0
6						0	0	313	056	150	075	143	0
8							0	040	081	138	070	0	0
9								0	051	040	033	0	0
10									132	244	117	0	0
12										310	458	014	028
13											379	024	0
14												019	019
16													0
17													

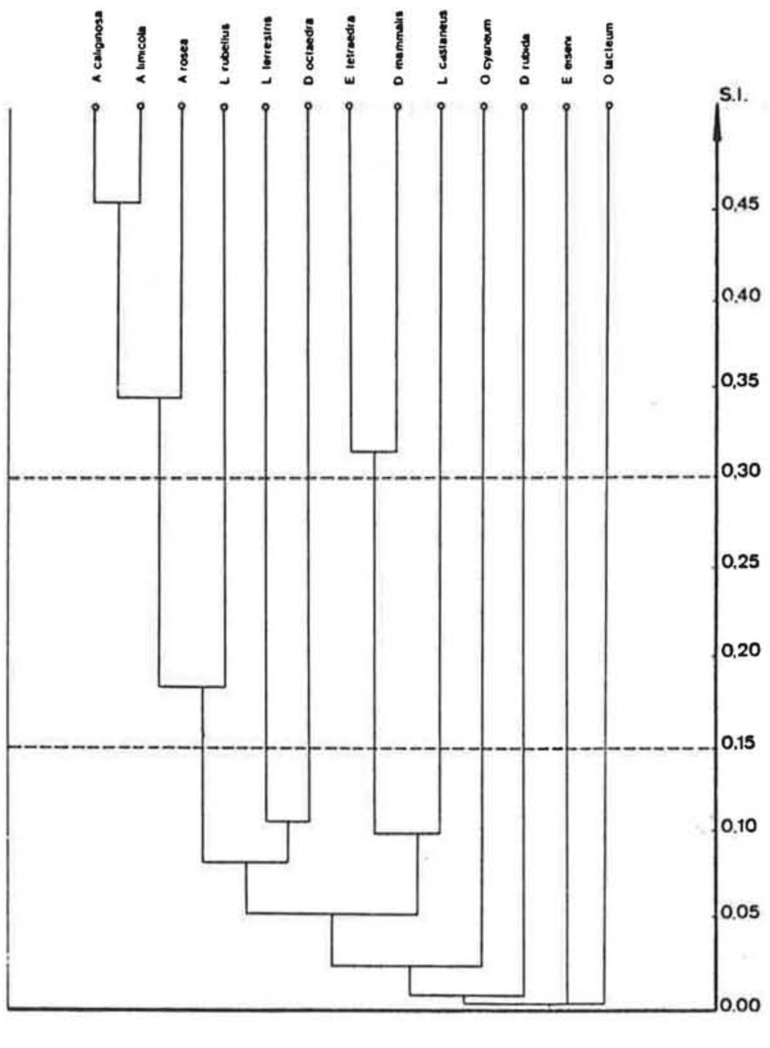
The results are represented in a dendrogram (fig.4.3). 3 classes are introduced :

SI < 0.15 : little or not associated

0.15 < SI < 0.30 : moderately associated

SI > 0.30 : strongly associated

Fig. 4.3 : species-association dendrogram



2 species associations can be distinguished : the Allolobophora-association. containing the 3 species of the genus Allolobophora and Lumbricus rubellus and the Eiseniella tetreaedra-Dendrobaena mammalis-association.

The other interspecific relations are too weak to evaluate them as not being casual. L. castaneus, O. cyaneum, O. lacteum, D. rubida and E. eiseni are very rarely associated with the other species and their reciprocal similarity is nil.

5. QUANTITATIVE STUDY OF THE EARTHWORM POPULATIONS

5.1. Mean individual weight (table 5.1).

The mean weight of an earthworm (after one month fixation in formalin) varies between 0,143 g in the beech and 0,176 g in the ash plot. The species can be divided in 4 classes, depending on their mean weight :

heavy species : 1 g and more
moderately heavy species 0.25 - 1 g
moderately light species 0.10 - 0,25 g
light species 0.10 g and less

Table 5.1. Mean individual weight (g) in the different plots

Species	PLOT			
	Poplar	Ash	Oak	Beech
L. terrestris	2.318	2.585	-	-
L. rubellus	0.536	0.408	0.390	-
L. castaneus	0.136	0.180	-	-
Eisenia eiseni	-	0.090	0.080	0.065
Eiseniella tetraedra	0.055	0.060	-	-
L. + E +. Juvenile	0.159	0.207	0.104	0.045
D. Octaedra	0.098	0.103	-	-
D. rubida	0.065	0.073	0.055	-
D. mammalis	0.090	0.123	-	-
D. juvenile	0.056	0.045	-	-
A. caliginosa	0.266	0.271	0.219	0.240
A. limicola	0.306	0.298	0.205	0.233
A. rosea	0.127	0.121	0.137	-
A. juvenile	0.097	0.079	0.091	0.086
O. Cyaneum	0.960	0.665	-	-
O. lacteum	0.317	-	0.370	-
O. juvenile	0.655	-	-	-
Not determined	0.399	0.072	-	-
Total	0.175	0.176	0.148	0.143

Lumbricus terrestris is the only heavy species. The presence of one single individual of this species in a sample causes an enormous increase of biomass.

- Moderately heavy are both Octolasium-species, L. rubellus, A. caliginosa and A. limicola.
- Moderately light are. L. castaneus and A. Rosea.
- The remaining species belong to the light class.

In terms of ecological groups, most epigeic species tend to be light. Endogeic species belong to the transition classes and the anoecic L. terrestris is a heavy one. This phenomenon is explained by the fact that heavy worms have a strongly developed muscular system, which enables them to build vertical galleries. The mean weight of earthworms of a certain species seems to be smaller in acid soils (oak and beech) than in neutral soils (poplar and ash). This was already stated by NORDSTRØM and RUNDGREN (1974).
It doesn't suggest that low pH is the fundamental cause of a lower weight. The nitricial value of the litter layer, expressed as the C/N-ratio and being pH correlated, can be of more importance.

5.2. Number of biomass of earthworms in the different plots

5.2.1. Results (fig. 5.1.).

The poplar stand has the biggest abundance of earthworms, with an annual average of 212 earthworms per sq.m. The population under ash represent 92 worms per sq. m. Populations under oak and beech are smaller : 25 worms per sq. m. under oak and 4 under beech.

In terms of biomass, this discrepancy is still more visible, since the mean individual weight under oak and beech is lower.

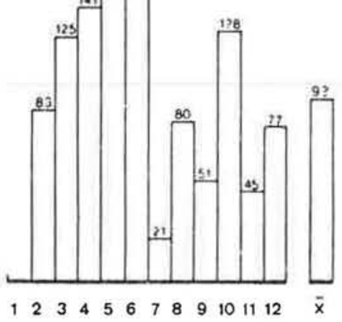
The mean biomass amounts to 37 per sq.m. under poplar; 17 g per sq.m. under ash, 4 g per sq.m. under oak and 0.5 g per sq.m. under beech.

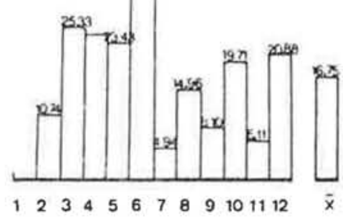
When comparing these measurements with the data found in litterature, number and biomass seem to be smaller (table 5.2.).

Fig. 5.1. Monthly and mean earthworm abundance and biomass per sq.m. in the different research plots (1 = january 1985 into 12 = december 1985).

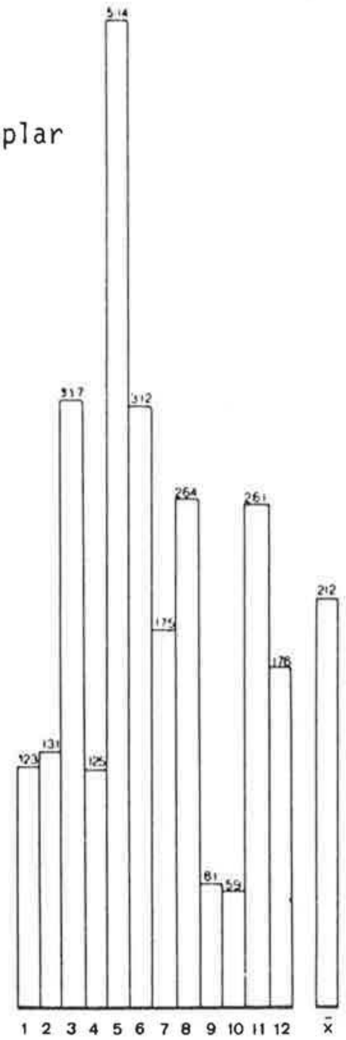
Number/m² g/m² Biomass

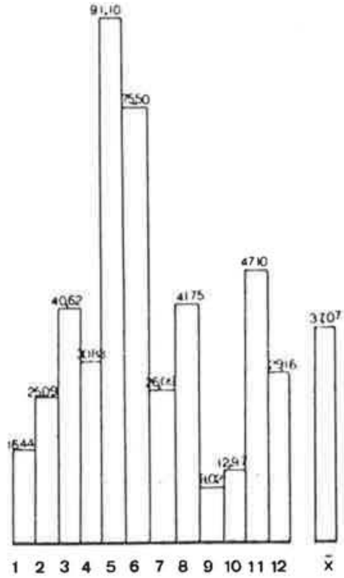
Ash



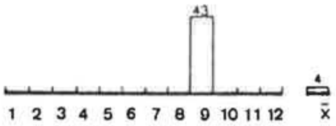


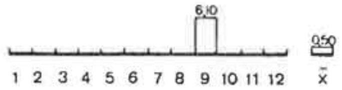
Poplar



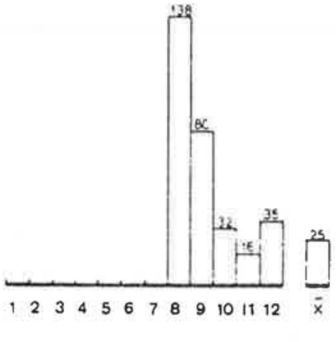


Beech





Oak



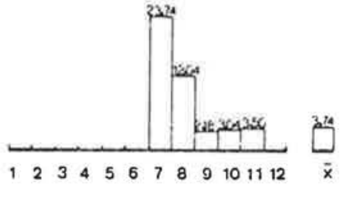


Table 5.2. Number and biomass of earthworms in different woodland types of the temperate zone per sq.m. (MUELLER 1965),(CUENDET 1974).

Forest type	Number/m^2	biomass g/m^2
Beech (Mull)	102	29
Beech (mor)	no data	3-6
Mixed forest (mull)	188 - 532	82-148
Conifers	no data	1-5

Even under poplar mull, our figures concerning biomass are inferior to the data of a mull broadleaved forest. Three possible causes for these differences can be considered (Tab.5.2.).

1. As the number of earthworms is relatively high, the mean individual weight is of decisive importance. As a consequence of the low pH-value (5.5 - acid mull), this individual weight is lower than normal.
2. Our research depth was limited to 25 cm. Literature data probably cover the whole profile.
3. Our figures are the average of a series of monthly taken samples ; literature data are mostly derived from instantaneous sampling in the favourable season.

Still the collected data seem to be strictly related with the measurements of the soil-parameters mentioned above. The measured values at 5 cm depth are examined on their correlation with the mean earthworm data (table 5.3., table 5.4.).

Table 5.3. Earthworms density and soil characteristics (5 cm depth) in the different plots.

Plot	Earthworms		Soil characteristics		
	Number (m^{-2})	Biomass ($g.m^{-2}$)	pH	C/N	% org.material
Poplar	212	37.07	4.93	12.00	6.46
Ash	92	16.75	4.56	9.78	6.18
Oak	25	3.74	3.60	16.74	7.92
Beech	4	0.50	3.52	19.43	12.36

Table 5.4. Matrix of the correlation coefficients (r)
(degrees of freedom : 2 ; * : significant at 0.05 level)

r	number	biomass	pH	C/N	% org. material
Number	1	1	0.950*	-0,717	-0.652
Biomass		1	0.953*	-0.645	-0.696
pH			1	-0.890	-0.774
C/N				1	0.897
% org.mat.					1

Acidity is significantly correlated with earthworm occurence : the higher the pH-value, the more earthworms occur.
The C/N-ratio and the organic matter content of soil which are rather good intercorrelated are both negatively correlated with the earthworm abundance: the higher the C/N-ratio and the higher the percentage of organic matter near the surface, the less earthworms occur. At low pH-values (5.5. - acid mull), the individual weight is lower than normal.

5.2.2. Analysis of variance

Table 5.5. : Analysis of variance for the number of species (transformation log (x+1)
** significant at 0.01 level.
* significant at 0.05 level.

Origin of variance		d.f.	Sum quadr.	Mean quadr.	F calculated
Objects		47	52.31908	1.11317	
-	plot	3	40.42228	13.47409	110.855 **
-	month	11	2.80201	0.25473	2.096 *
-	interaction	33	9.09439	0.27560	2.267 **
Residual error		240	29.17141	0.12155	
Total		287	81.49048		

Table 5.6. : Analysis of variance for the biomass (transformation log (x + 1))

** : significant at 0.01 level
* : sog,ofoca,t at 0.05 level

Origin of variance	d.f.	Sum quadr.	Mean quadr.	F calculated
Objects	47	1.67067	0.24831	
- plot	3	7.83956	2.61399	34.443 **
- month	11	1.07709	0.09792	2.977 **
- interaction	33	2.75402	0.08346	2.537 **
Residual error	240	7.89458	0.03289	
Total	287	19.56525		

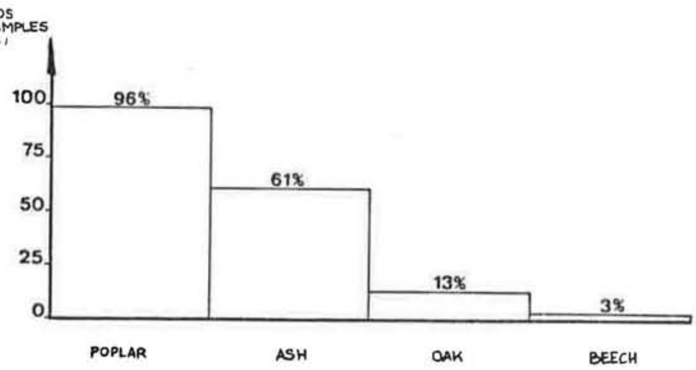
The analysis of variance showsvery significant differences in earthworm density and earthworm biomass between the stands. Moreover, number and biomass are significantly subject to time fluctuations.
The additional Duncan-tests showed that the populations under oak and beech do not differ significantly. As a consequence, the four examined woodland types can be redefined as three types : poplar woodland with abundant earthworm populations, ash woodland with moderately dense populations and oak-beech woodland with small populations.

The study of the seasonal variation within every plot leads to some interesting results : under oak and beech no significant seasonal variation can be observed : earthworms are constantly very rare. Under ash and poplar, on the contrary, significant seasonal variation is shown, more or less in the shape of a bimodal curve with maxima in spring and autumn, minima in winter and summer. These minima are caused by a combination of an effective decrease of the earthworm number due to mortality and migration towards deeper soil layers, away from drought or frost (physical drought). The summer minimum under poplar occurs sowewhat later than under ash. Water economy is an important factor : the very wet poplar site desiccates very slowly while the ash site, drains much faster, causing earlier vertical earthworm migration.

5.3. Final Evaluation of the sampling

In every plot, 72 soil samples were taken at random. The amount of samples, containing earthworms, is very dependent on the plot (Fig. 5.2.).

Fig.5.2. Relative amount of positive samples in the different plots (%).



Under poplar a blank sample is very exceptional ; earthworms occur almost everywhere.

A blank sample under ash, on the contrary, is no accidental phenomenon. Nearly every month, a third part of the taken samples was blank. This heterogenous earthworm density under ash is due to micro-ecological differences in this woodland, being not directly related with the water-economy, but with the humus quality, which depends directly on the tree species : the blank samples are almost always situated in parts of the plot, where ash is more or less mixed with Quercus robur, Q. rubra and Fagus sylvatica.In this cases, the absence of earthworms is even predictable with serious reliability by a simple observation of the soil vegetation : under ash and maple (Acer pseudoplatanus) a luxurious vegetation of Adoxa moschatellina, Anemone nemorosa, Ranunculus ficaria and Oxalis acetosella is found. This vegetation is abruptedly interrupted as soon as an oak or beech takes part in the canopy. The herbal vegetation is in this case much more modest : O. acetosella is found in association with ferns, grasses and mosses.

Under pure ash or mixed ash-maple canopy, even a thin layer of organic matter, covering the soil is totally absent. Indeed, oak and beech leaves need more than a year to decay. Ash, maple and poplar leaves are decomposed after half a year.

As mentioned above the water-economy doesn'tplay a direct role. Nevertheless, it can have its importance in this complex of ecological factors, because drought can always become a limiting factor. Under ash, the soil has a good crumby structure, but the soil under oak and beech show little cohesion when kneading between dumb and index : it is grinded to powder by lack of a collodial soil-humus complex. Though the soil is of the same texture as the one under ash, it is drier : the water retention is lower and the drainage faster. In this respect, earthworms restore their own living conditions : the better soil structure under ash is the consequence of intensive earthworm activity.
The ultimate cause for earthworm occurence seems to be the tree species, i.e. the constitution of the litter-fall : C/N value of ash leaves is about 20, of oak and beech about 50. These leaves of oak and beech, poor in nitrogen, enriched with tannines, are not attractive as nutrition for soil fauna, and form a sometimes thick, badly decomposing layer on the soil surface. Certain acids wash out and cause after a period of time a decrease of the pH-value towards a level below the tolerance-limits of most earthworm species.

6. CONCLUSION

In the experimental forest of the State University of Ghent, a study was made on earthworm populations to find an answer for the following questions.

- What earthworms species are living in the forest ?
- What abundance and biomass do they have ?
- Is there a difference between various forest-types as far as the occurence of earthworms is concerned and which factors play a role in this regard.
- Are earthworm populations subject to seasonal variation ?

Soil samples were taken over a period of one year in four different stands : oak, beech, ash and poplar. The soil samples measured (25 x 25 x 25 cm^3 and the earthworms were handsorted.
A big earthworm diversity was observed : in total, 13 earthworm species were found, meaning 60 % of the known Belgiam Lumbricid fauna. An important difference however exists between the stands : under poplar and ash, 12 species were found, under oak 7 and under beech only 3.
In all stands, the endogeic species Allolobophora caliginosa is dominating. Under beech and oak, none or little earthworms occur : respectively 4 and 25 per sp.m. Under ash 92 were found on average, under poplar 212 (research dept : 25 cm). Certain species frequently co-occur. Thus, it was possible by means of similarity indices, to establish 2 associations : the Allolobophora-association and the Eiseniella tetraedra-Dendrobaena mammalis - association.

Biomass also shows great variation. Under poplar, ash, oak and beech, a biomass of respectively 37, 17, 4 and 0,5 g/m^2 was found. These data were the result of weighing the worms after one month fixation in 5 % formaldehyde. Additional research showned that this weight is not significantly different from the fresh weight for respectively pigmented and non-pigmented species. Abundance and biomass show a maximum during spring and autumn, a minimum during summer and winter. This variation is due to activity-fluctuations as a consequence of humidity, temperature and food availability.
A possible explanation for the significant differences in abundance, biomass and number of species between stands was found through environment characterisation : pH, C/N-value, content of organic matter of the soil and the vegetation. Although all these factors interfere some precist conclusions could be drawn : earthworms are positively correlated with soil pH; less,but still clearly, negatively correlated with soil C/N value and organic matter content at a depth of 5 cm. Leaffall with a high C/N value (oak and beech) cause a bad demolition, storing of organic matter on the soil surface, acidification and finally absence of earthworms.

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