SITE CLASSIFICATION IN A MIXED HARDWOOD FOREST (HALLERBOS, BELGIUM) WITH A HOMOGENEOUS GROUND VEGETATION DOMINATED BY *HYACINTHOIDES NON-SCRIPTA* (L.) Chouard ex. Rothm.

D. MADDELEIN, B. MUYS, J. NEIRYNCK and G. SIOEN
Laboratory of Forestry - University of Ghent

ABSTRACT

The forest of Halle (560 ha), situated 20 km south of Brussels is covered by a beech (*Fagus sylvatica*) forest, locally mixed with secundary species (*Tilia, Fraxinus, Acer, Quercus,...)*. In almost all stands, herbal vegetation is dominated by Bluebell (*Hyacinthoides non-scripta*).

The research intended to classify 36 plots of different tree species composition according to their site quality. Three classification methods were compared : the first one based on the indicator value of the understorey vegetation, a second one on the humus morphology and a last one on some quantitative soil characteristics.

According to the plant sociological site classification, the plots have the same site quality. However, humus forms differ apparently and significant differences were found in pH value and base cation saturation of the soil, abundance and biomass of earthworms and biomass of the ectorganic horizon. Tree species proved to be the main cause of these differences.

The results illustrate that the herbal vegetation is not always a reliable indicator of site quality. In the case of a homogeneous vegetation dominated by one or more indifferent species, classification on humus morphology or soil analysis are more appropriate. In the forest of Halle, the tree species is probably the main cause of the observed differences in site quality.

Key words : site classification / forest floor / tree species / *Hyacinthoides non-scripta* / humus morphology

RESUME

La forêt de Halle (560 ha) est une hêtraie située 20 km au sud de Bruxelles, melangé localement avec des groupes d'essences secondaires comme le tilleul, le frêne, l'érable et le chêne. Dans presque tous les peuplements, la végétation est dominée par la Jacinthe des bois (*Hyacinthoides non-scripta*).

Cette recherche a essayé de classifier 36 placettes selon leur fertilité. Trois méthodes de classification ont été comparés : une première utilize la valeur indicatrice de la végétation herbacée, une deuxième la morphologie de l'humus et une dernière des caractéristiques chimiques du sol.
Selon la classification phytosociologique, toutes les placettes appartiennent à la même station. Par contre, la description morphologique des humus a montré des formes d'humus différentes et l'analyse quantitative a détecté également des différences significatives en ce qui concerne la valeur du pH, la saturation en bases, la densité et la biomasse des lombriciens, et la biomasse des horizons holorganiques. Les différences constatées sont attribuées en grande partie à l'essence forestière dominante.
Les résultats montrent que la végétation n'est pas toujours le meilleur indice de fertilité. Dans le cas d'une végétation homogène, dominée par une ou plusieurs espèces indifférentes, une classification à base de la morphologie de l'humus ou sur une analyse de sol est plus fiable. Dans la forêt de Halle, l'espèce est probablement la cause principale des différences observées dans la qualité de la station.

Mots clés : typologie des stations forestières / horizon holorganique / essence forestière / *Hyacinthoides non-scripta* / morphologie de l'humus

1. INTRODUCTION

The most classic and widespread site classification method of European forests is based on the indicator value of the understorey vegetation. This plant sociological approach was worked out by Braun-Blanquet (1952, 1964), Ellenberg (1974) and others. The effectivity of ground vegetation as an indicator for recognizing areas with contrasting humus form and site quality was frequently demonstrated (Rogister, 1978b, 1978c; Klinka et al, 1990). This method may become questionable in the case where the vegetation is dominated by one or more indifferent species with a broad range of presence.

Another approach is the site classification based on the morphological characteristics of the humus form, developed by Kubiena (1953), Delecour (1980), Klinka et al (1981) and Green et al (1993). Although very useful and reliable, the humus form is only a restricted component of the ecosystem's nutrient cycle. Therefore, it cannot be expected to be a faultless predictor of nutrient availability for trees (Klinka et al, 1990).

Undoubtedly, a quantitative physical, chemical and biological soil analysis provides the most objective dataset for the classification of forest stands according to site quality and nutrient availability. A disadvantage of this method is, however, that it is much more time and money consuming than both preceding methods.

The present study aims to compare the results of site classification following these three methods in a mixed broadleaved forest, characterized by a dominance of Bluebell (*Hyacinthoides non-scripta* (L.) *Chouard ex Rothm*) in the herbal layer. The study also examines the role of the tree species in eventual site differences found.

2. MATERIALS AND METHODS

The forest of Halle (560 ha) is situated 20 km south of Brussels on a plateau about 100 m above sea level and has a well drained loamy soil. The dominant tree species in this even-aged forest of about 70 years old is beech (*Fagus sylvatica*), locally mixed with groups of lime (*Tilia platyphyllos Scop.*), ash (*Fraxinus excelsior L.*), maple (*Acer pseudoplatanus L.*) and oak (*Quercus robur L.*). In this forest, 36 circular plots with a diameter of 10 m were established. In each plot, the basal area of each tree species present was measured. Most of the plots had a quite homogeneous tree species composition, some of them were more intensively mixed. In every plot, a plant sociological survey was performed by means of the method of Braun-Blanquet (1964).

The surveys were entered in Twinspan (Hill, 1979) for classification. Site quality was attributed to the formed groups by calculating their mean indicator values for humidity (mF), acidity (mR) and nitrification (mN) (Rogister, 1978a, 1978c, 1978d). These mean indicator values were calculated by averaging the indicator values of each species for humidity (F), acidity (R) and nitrification (N), weighed with their respective procentual coverage, using following formulas :

[illegible]

$$BC_i = \frac{\sum_j (A_{ij})}{n} \; x \; 100$$

with : BC_i = mean procentual cover of species i in the considered group of plots.
A_{ij} = procentual cover of species i in plot j
n = number of plots in the considered group

Ellenberg [illegible]

$$mF = \frac{\sum_i (BC_i \; x \; F_i)}{\sum_i (BC_i)}$$

$$mR = \frac{\sum_i (BC_i \; x \; R_i)}{\sum_i (BC_i)}$$

$$mN = \frac{\sum_i (BC_i \; x \; N_i)}{\sum_i (BC_i)}$$

The N values of the species were taken from the tables of Ellenberg (1974). The F and R values were found in Noirfalise and Dethioux (1970) and converted to the scale of Ellenberg with the method of Rogister (1978a).

The Ecological Affinity Coefficients EAC_{nm} (Rogister, 1978a) between the groups n and m were calculated using the mean indicator values for humidity, acidity and nitrification :

$$EAC_{nm} = \sqrt{(mR_n - mR_m)^2 + (mF_n - mF_m)^2 + (mN_n - mN_m)^2}$$

Afterwards, the product mR x mN was calculated. Rogister (1978c) found a very reliable positive relationship between this product and the humus form.

Humus profiles were described for the center of each plot following the taxonomic classification system of Green *et al* (1993). The biomass of the different ectorganic horizons was determined. Mineral soil samples were collected at 3 depths (0-5 cm, 5-20 cm, 20-40 cm) and taken to the laboratory for further analysis. Earthworm sampling using the combined method of Bouché & Aliaga (1986) was restricted to 28 plots with a homogeneous canopy.

Following analyses were performed on the mineral soil samples : pH_{H2O}, pH_{KCl}, effective CEC and exchangeable cations (ICP and flame photometry after 0.1 N $BaCl_2$ extraction). Exchangeable acidity, base cation saturation and molar (Ca+Mg)/Al ratio were calculated.
All data were listed in a datamatrix and processed with the statistical packages Biomeco (Groupe de biométrie, CNRS CEFE, Montpellier) and Canoco (Ter Braak 1988). A principal components analysis (PCA) was executed and the plots were classified on basis of their euclidian distance in the plane of the first and second principal axes. Then, it was tried to explain the datamatrix with the matrix of tree species composition using a redundancy analysis (RDA).

Finally, the plots were divided in 5 groups (oak, beech, lime, ash and maple), according to the main tree species. Plots where the basal area of the dominant tree species was less than 75 % of the total basal area, were excluded. The between tree species variability of chemical soil characteristics, biomass of earthworms and ectorganic horizons were tested with ANOVA's, using Statgraphics.

3. RESULTS

3.1. Plant sociological site classification

The Twinspan classification of the plots resulted in four groups (table 1). All four groups are characterized by an absolute dominance of *Hyacinthoides non-scripta*. Groups 1 and 2 have canopies of oak, lime, ash and maple. They are characterized by the appearance of *Lamium galeobdolon* L. and the absence of *Anemone nemorosa* L. Group 1 differs from group 2 by the presence of *Oxalis acetosella* L. and *Rubus fruticosus* L. Group two contains no differentiating species. The plots of groups 3 and 4 are found under beech canopy and are characterized by the absence of *Lamium galeobdolon* and the presence of *Anemone nemorosa*. In group 3, *Anemone nemorosa* is scarcely present, in group 4 codominant.

The calculated mF (mean humidity index) and mR x mN (mean humus quality) of the four groups is presented in an ecogram (fig. 1) and compared with some of the most important forest vegetation types of northern Belgium (Rogister, 1985). All of the four groups are mesophilous, have a mullmoder humus and are closely related to the *Endymio-Carpinetum*. Their Ecological Affinity Coefficients are less than 0.2, proving a very high ecological affinity (Rogister, 1978a).

Table 1 : Tree species composition, Twinspan vegetation group and humus form of the 36 plots (tree species codes and units are given in table 2)

PLOT	TREE SPECIES									TWINSPAN CLASS	HUMUS FORM
	TIL	ACE	FRA	QUE	FAG	SOR	LAR	ROB	CAS		
1	100	0	0	0	0	0	0	0	0	2	vermimull
2	100	0	0	0	0	0	0	0	0	2	vermimull
3	100	0	0	0	0	0	0	0	0	2	vermimull
4	100	0	0	0	0	0	0	0	0	2	vermimull
5	100	0	0	0	0	0	0	0	0	2	vermimull
6	0	0	0	100	0	0	0	0	0	2	mormoder
7	0	15	0	81	0	4	0	0	0	2	mullmoder
8	100	0	0	0	0	0	0	0	0	2	vermimull
9	0	7	0	5	0	0	0	89	0	2	vermimull
10	0	20	0	80	0	0	0	0	0	2	hemimor
11	0	0	0	32	0	0	0	0	68	2	mullmoder
12	0	3	0	17	0	0	80	0	0	1	mullmoder
13	34	1	0	64	0	0	0	0	0	2	mullmoder
14	0	0	0	100	0	0	0	0	0	2	mullmoder
15	0	0	0	0	100	0	0	0	0	4	mullmoder
16	0	0	0	0	100	0	0	0	0	4	mullmoder
17	0	100	0	0	0	0	0	0	0	2	vermimull
18	0	100	0	0	0	0	0	0	0	2	vermimull
19	0	100	0	0	0	0	0	0	0	2	vermimull
20	0	85	0	0	15	0	0	0	0	2	vermimull
21	0	80	0	0	20	0	0	0	0	2	hemimor
22	0	0	0	0	100	0	0	0	0	4	mullmoder
23	0	0	0	0	100	0	0	0	0	3	mullmoder
24	0	0	0	0	100	0	0	0	0	3	mullmoder
25	0	0	0	0	100	0	0	0	0	3	mullmoder
26	0	0	0	0	100	0	0	0	0	3	mullmoder
27	0	0	86	0	0	6	0	0	0	2	hemimor
28	0	1	83	0	0	4	0	0	0	2	vermimull
29	0	5	76	0	0	18	0	0	0	2	vermimull
30	0	0	87	0	0	9	0	0	0	1	vermimull
31	0	0	93	0	0	0	0	0	0	2	vermimull
32	0	15	0	73	0	11	0	0	0	2	mullmoder
33	0	10	0	25	0	64	0	0	0	1	mullmoder
34	0	8	0	77	0	10	0	0	5	2	mullmoder
35	0	2	0	8	0	0	90	0	0	1	mullmoder
36	0	7	0	93	0	0	0	0	0	1	mullmoder

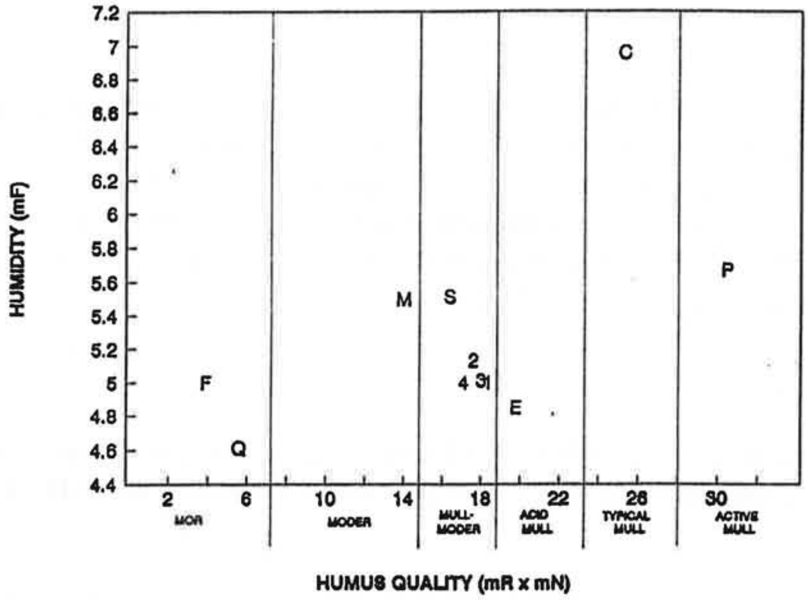

Fig. 1 : Humidity - humus quality ecogram. Position of the four vegetation groups in relation to seven main forest vegetation types of northern Belgium (C : *Carici-remotae Fraxinetum*, E : *Endymio-Carpinetum*, F : *Fago-Quercetum*, M : *Milio-Fagetum*, P : *Primulo-Carpinetum*, Q : *Querco-Betuletum*, S : *Stellario-Carpinetum*)

3.2. Humus morphological site classification

Humus classification on basis of the morphological description divided the 36 plots in four groups : hemimor (3 plots), mormoder (1 plot), mullmoder (17 plots) and vermimull (15 plots) (table 1). All plots with a lime or maple dominated canopy have a vermimull humus, except one hemimor (plot 21 with a consistent admixture of beech). Plots with a beech and ash canopy have a mullmoder humus and plots with an oak canopy have a humus ranging from mullmoder to hemimor.

Table 2 : Codes and units of the used variables

CODE	VARIABLE	UNIT	CODE	VARIABLE	UNIT
TIL	Basal area of Tilia platyphyllos	%	AC2	exchangeable acidity of the soil (5-20 cm)	meq/kg
ACE	Basal area of Acer pseudoplatanus	%	AC3	exchangeable acidity of the soil (20-40 cm)	meq/kg
FRA	Basal area of Fraxinus excelsior	%	CEC1	Effect. cat. exch. capacity of soil (0-5 cm)	meq/kg
QUE	Basal area of Quercus robur	%	CEC2	Effect. cat. exch. capacity of soil (5-20 cm)	meq/kg
FAG	Basal area of Fagus sylvatica	%	CEC3	Effect. cat. exch. capacity of soil (20-40 cm)	meq/kg
SOR	Basal area of Sorbus aucuparia	%	BA1	Base cation saturation of the soil (0-5 cm)	%
LAR	Basal area of Larix decidua	%	BA2	Base cation saturation of the soil (5-20 cm)	%
ROB	Basal area of Robinia pseudoacacia	%	BA3	Base cation saturation of the soil (20-40 cm)	%
CAS	Basal area of Castanea sativa	%	CAL1	Molar exch. (Ca+Mg)/Al ratio of soil (0-5 cm)	
PHH1	pH (H2O) of the soil (0-5 cm)		CAL2	Molar exch. (Ca+Mg)/Al ratio of soil (5-20 cm)	
PHH2	pH (H2O) of the soil (5-20 cm)		CAL3	Molar exch. (Ca+Mg)/Al ratio of soil (20-40 cm)	
PHH3	pH (H2O) of the soil (20-40 cm)		LF	Biomass of L and F ectorganic horizons	g/m^2
PHK1	pH (KCl) of the soil (0-5 cm)		H	Biomass of H ectorganic horizon	g/m^2
PHK2	pH (KCl) of the soil (5-20 cm)		LFH	Total biomass of ectorganic horizon	g/m^2
PHK3	pH (KCl) of the soil (20-40 cm)		EWB	Earthworm biomass	g/m^2
AC1	exchangeable acidity of the soil (0-5 cm)	meq/kg	EWD	Earthworm density	m^{-2}

3.3. Soil analytical site classification

The datamatrix (table 3) was used to calculate a PCA on basis of the correlation matrix of variables. The results are represented in table 4 and figures 2 and 3.

The first and second principal axes respectively account for 46 % and 12 % of total variability. The position of the variables in the correlation circle of these first two axes (fig. 2) clearly shows that the first axis is a soil fertility axis. Plots situated at its positive side are characterized by a high pH value, a high base saturation and a high (Ca+Mg)/Al ratio through the whole soil profile. Plots at the negative side are characterized by a thick ectorganic horizon, especially the presence of a H layer and a high exchangeable acidity of the soil. The second axis is formed by the cation exchange capacity. Plots situated at its negative side have a high cation exchange capacity, probably as a consequence of a higher humus content.

The classification divides the plots in two main groups (fig. 3), *grosso modo* a chemically poor group at the negative side of the first axis and a rich group at the positive side. Both groups can be split up in two subgroups, resulting in four site classes (fig. 3) : site A is a mull site. It has a thin ectorganic horizon almost without an H layer and is chemically rich; site B is an intermediary site between mull and moder. Ectorganic horizons are thin and the soil is fairly rich. Site C and D are moder sites. They are characterised by a thick ectorganic horizon with the presence of a pronounced H layer. They are chemically poor and acid. Site D is in general poorer than site C and has a higher CEC.

→ Cation Exchangeable Capacity

Table 3 : Datamatrix of the quantitative soil variables (variable codes and units are found in table 2)

PLOT	VARIABLE																				
	PHH1	PHH2	PHH3	PHK1	PHK2	PHK3	AC1	AC2	AC3	CEC1	CEC2	CEC3	BA1	BA2	BA3	CAL1	CAL2	CAL3	LF	H	LFH
1	5.26	4.28	4.38	4.00	3.51	3.72	11.88	31.20	25.84	74.20	39.20	31.64	83.35	20.40	18.33	8.93	0.65	0.40	406	0	406
2	4.68	4.21	4.41	3.64	3.56	3.86	26.80	35.12	34.96	61.35	43.20	38.20	53.70	15.47	8.49	1.74	0.29	0.12	194	0	194
3	4.46	4.35	4.54	3.62	3.70	3.87	35.68	26.40	29.84	66.76	33.25	36.25	46.56	20.60	17.68	1.76	0.57	0.38	98	0	98
4	4.50	4.27	4.33	3.58	3.53	3.79	32.24	28.72	24.92	60.90	37.96	31.82	47.06	22.28	21.68	1.92	0.45	0.63	105	0	105
5	4.78	4.58	4.32	3.76	3.67	3.65	23.76	31.28	35.04	74.68	42.30	39.07	68.19	26.05	10.31	4.75	0.53	0.18	131	0	131
6	3.84	3.77	4.14	2.98	3.10	3.67	57.68	63.20	45.64	80.35	73.52	49.97	28.21	14.04	8.66	0.78	0.39	0.16	1003	2058	3061
7	4.04	4.10	4.18	3.17	3.50	3.68	49.28	35.44	40.56	67.66	39.13	43.85	27.17	9.43	7.51	0.59	0.19	0.13	364	204	568
8	4.45	4.49	4.33	3.56	3.72	3.76	26.84	33.56	27.08	61.34	39.99	30.15	56.24	16.14	10.78	2.16	0.45	0.28	229	0	229
9	3.79	4.02	4.30	3.07	3.28	3.70	50.24	42.36	33.60	85.45	53.22	37.08	41.20	20.41	9.38	1.78	0.52	0.17	1332	1850	3182
10	3.90	4.14	4.34	3.13	3.53	3.80	47.44	38.88	33.60	60.89	44.19	37.08	22.09	12.02	9.38	0.53	0.27	0.17	1025	0	1025
11	3.86	4.23	4.20	3.09	3.58	3.61	52.72	17.56	43.60	66.30	51.36	49.54	20.48	13.37	12.00	0.43	0.19	0.18	1156	2394	3549
12	3.82	3.91	4.25	3.00	3.27	3.76	57.96	40.44	32.56	72.29	47.49	36.26	19.82	10.78	10.22	0.37	0.18	0.17	386	2037	2423
13	4.09	4.05	4.37	3.33	3.42	3.87	21.96	37.76	34.04	64.28	43.85	38.87	26.59	13.88	12.43	0.50	0.28	0.21	1732	373	2105
14	3.72	4.13	4.28	2.92	3.44	3.81	67.44	49.36	38.84	87.84	55.53	41.56	23.22	11.11	6.56	0.65	0.19	0.10	1302	6461	7763
15	3.84	4.00	4.26	3.11	3.44	3.86	51.44	38.00	34.92	59.84	42.40	38.87	14.03	10.39	10.15	0.35	0.21	0.20	920	1345	2265
16	3.28	3.74	4.23	2.78	3.16	3.73	59.32	49.16	49.44	72.47	53.71	57.67	18.15	8.48	8.73	0.85	0.21	0.17	841	1362	2202
17	3.84	4.14	4.25	3.19	3.40	3.58	41.08	38.16	35.76	67.57	43.98	38.97	39.20	13.24	8.24	1.11	0.24	0.14	666	377	1043
18	3.95	4.10	4.28	3.35	3.38	3.67	25.28	36.68	30.48	96.83	41.96	33.52	69.58	12.58	9.07	4.71	0.20	0.14	698	561	1259
19	3.93	4.04	4.22	3.23	3.27	3.56	36.36	46.20	39.32	82.14	52.48	43.64	55.73	11.96	9.90	2.49	0.21	0.20	909	0	909
20	4.00	4.17	4.42	3.37	3.45	3.78	27.04	34.00	29.24	74.73	46.82	31.32	63.82	27.37	6.65	3.99	0.71	0.14	2881	0	2881
21	3.73	4.10	4.20	3.09	3.41	3.66	46.24	45.52	46.36	60.62	50.97	49.24	23.72	10.70	5.86	0.59	0.22	0.11	3128	4560	7688
22	3.66	3.76	4.20	2.91	3.03	3.63	45.16	41.00	29.68	58.86	46.56	32.77	23.27	11.93	9.44	0.66	0.24	0.22	743	2024	2766
23	3.55	3.90	4.09	2.92	3.32	3.50	55.16	52.20	47.52	73.23	55.54	49.88	24.67	6.02	4.73	0.80	0.10	0.07	1011	4877	5888
24	3.98	4.21	4.17	3.20	3.49	3.59	34.84	35.76	39.16	52.67	38.95	42.24	33.86	8.20	7.29	1.16	0.16	0.12	844	1737	2580
25	3.72	4.16	4.23	3.01	3.52	3.76	47.48	33.40	28.56	55.34	35.31	29.84	14.20	5.40	4.30	0.35	0.10	0.10	1333	2307	3640
26	3.90	4.10	4.24	3.10	3.47	3.74	37.36	29.04	27.04	48.02	31.54	28.92	22.21	7.92	6.48	0.63	0.19	0.15	1035	1591	2626
27	3.65	3.95	4.19	3.04	3.32	3.51	54.56	43.24	51.68	76.32	50.14	55.72	28.51	13.76	7.25	1.44	0.35	0.11	348	3728	4076
28	3.84	4.09	4.20	3.24	3.43	3.56	38.60	31.44	40.52	68.50	32.01	41.28	43.65	1.80	1.85	1.55	0.04	0.03	672	1136	1808
29	3.80	4.01	4.23	3.23	3.39	3.66	41.68	38.92	33.40	54.19	42.91	35.56	23.09	9.30	6.08	0.77	0.22	0.10	353	1454	1807
30	3.75	3.98	4.27	3.16	3.33	3.75	42.24	34.40	31.24	62.39	51.24	31.61	32.30	32.86	1.16	1.54	1.40	0.03	294	1069	1363
31	3.74	3.92	4.28	3.18	3.20	3.82	46.72	44.52	30.84	74.37	49.84	31.25	37.18	10.67	1.32	1.31	0.22	0.02	277	215	492
32	3.49	3.81	4.09	2.79	3.06	3.41	54.60	42.64	37.44	60.67	43.13	37.85	10.00	1.14	1.08	0.39	0.03	0.03	692	2605	3297
33	3.70	4.00	4.10	3.07	3.37	3.50	49.44	40.04	39.12	53.45	40.52	40.22	7.51	1.18	2.74	0.18	0.02	0.03	762	2617	3379
34	3.50	3.90	4.20	2.81	3.12	3.55	61.84	49.80	39.00	72.73	51.22	41.28	14.97	2.77	5.52	0.74	0.08	0.11	926	3150	4076
35	3.46	3.69	3.94	2.82	3.10	3.34	34.16	45.92	38.40	47.85	49.90	40.03	28.61	7.97	4.08	0.90	0.15	0.06	1121	1586	2707
36	3.55	3.98	4.24	2.90	3.33	3.67	48.76	31.84	28.88	83.95	35.54	30.91	41.92	10.40	6.58	2.14	0.18	0.12	593	2797	3390

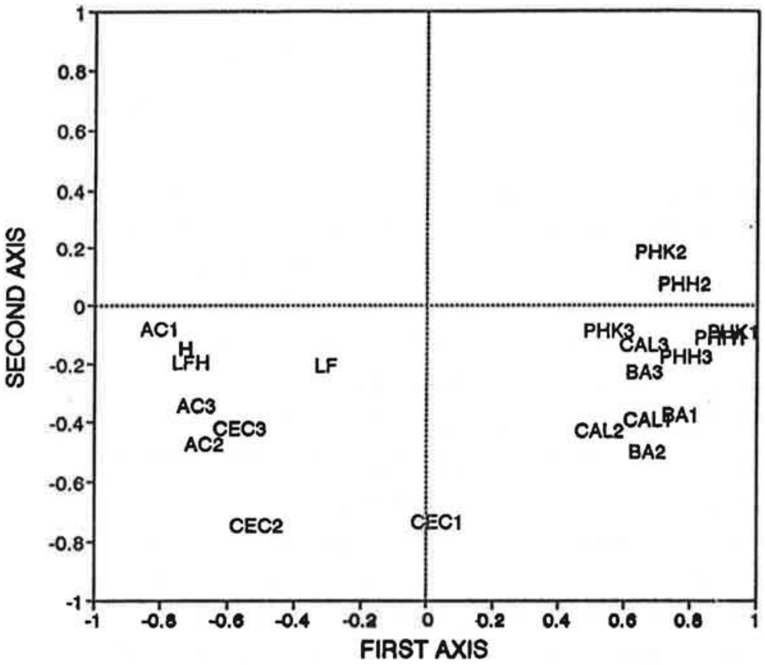

Fig. 2 : Position of the variables in the correlation circle of the first two principal axes (principle components analysis (PCA), variable codes and units are found in table 2)

Table 4 : Contribution of the first two principal axes to the explanation of the variables.

VARIABLE	AXIS 1	AXIS 2	SUM
PHH1	0.80	0.01	0.81
PHH2	0.62	0.01	0.63
PHH3	0.62	0.03	0.65
PHK1	0.87	0.01	0.88
PHK2	0.51	0.04	0.55
PHK3	0.31	0.01	0.32
AC1	0.64	0.01	0.65
AC2	0.45	0.22	0.67
AC3	0.48	0.12	0.60
CEC1	0.00	0.53	0.53
CEC2	0.26	0.55	0.81
CEC3	0.31	0.17	0.48
BA1	0.60	0.14	0.74
BA2	0.45	0.24	0.69
BA3	0.44	0.05	0.49
CAL1	0.46	0.15	0.61
CAL2	0.28	0.18	0.46
CAL3	0.44	0.02	0.46
LF	0.09	0.04	0.13
H	0.53	0.02	0.55
LFH	0.50	0.04	0.54

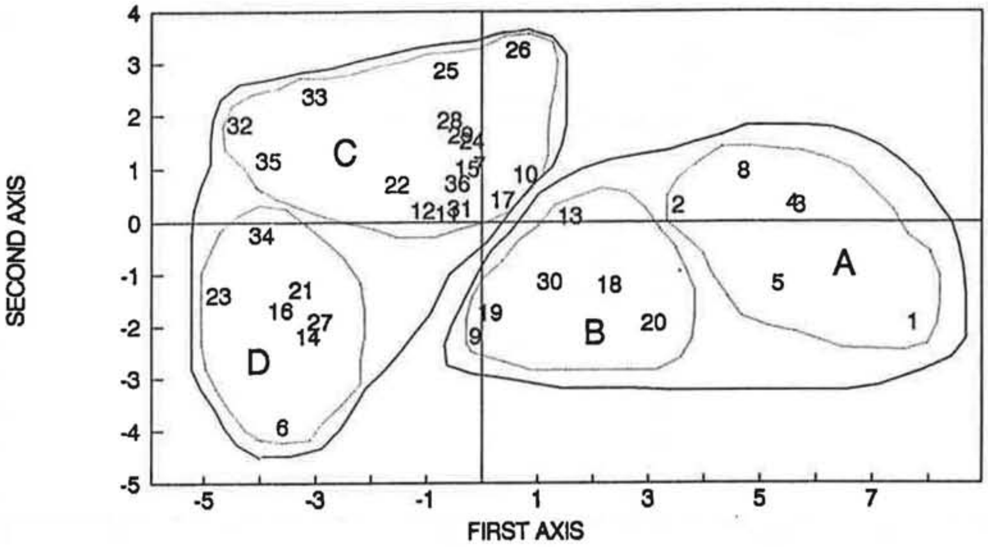

Fig. 3 : Principle components analysis (PCA) : representation and classification of the plots in the plane of the first two principal axes (tree species composition of the plots are found in table 1)

3.4. Effect of tree species on site quality

An RDA was used in order to explain these site differences by the species composition of the canopy. The first RDA axis is again a fertility axis and accounts for 67 % of the total eigenvalue of the ordination (fig. 4). Its reliability (monte Carlo permutation test : $P < 0.01$) proves that the tree species has a significant effect on site quality.

Plots with a dominance of Tilia and Acer are located at the positive side of the first axis and have a richer soil, characterized by mull humus. Plots with a dominance of *Quercus*, *Fagus*, *Sorbus* or *Larix* are located at the negative side of the first axis and are characterized by a poorer soil with moder humus. Fraxinus, *Robinia* or *Castanea* almost don't interfere on the first axis what could mean that plots dominated by these species occupy an intermediate position or that these plots can be either rich or poor. A series of monte Carlo permutation tests showed that the effect of lime ($P < 0.01$) and oak ($P=0.05$) on the soil variables is significant. For the other tree species, there can only be spoken of tendencies.

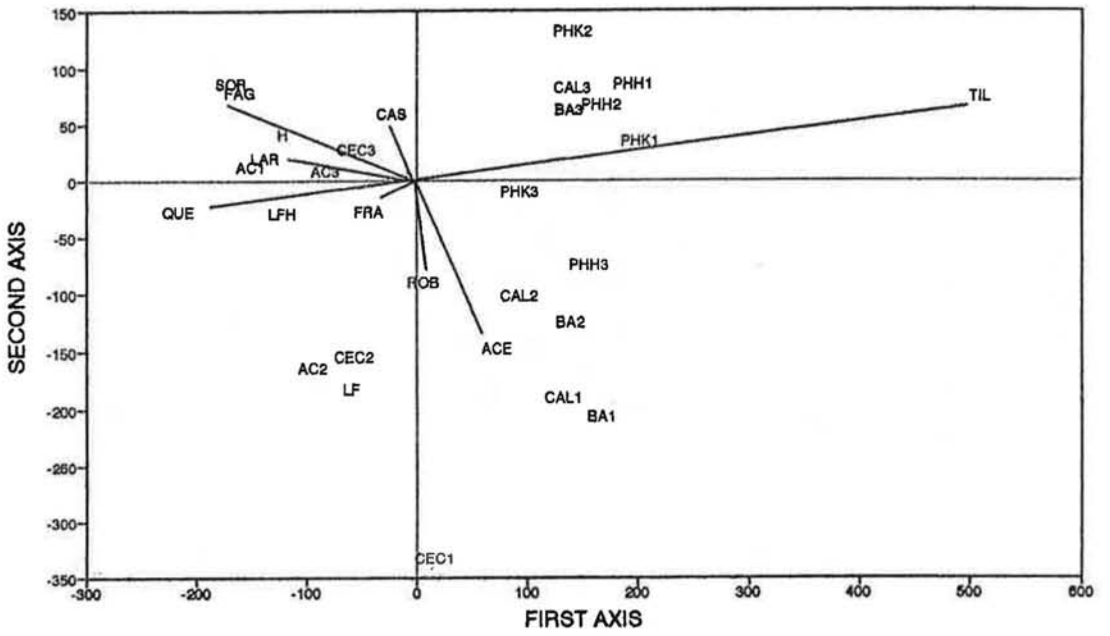

Fig. 4 : Position of soil variables and tree species composition in the plane of the first and second RDA axes (independent variables are represented as a vector; variable and tree species codes and units are found in table 2).

The effect of tree species on site quality, as detected in the RDA above, is tested more in detail by a series of ANOVA's (table 5).

The effect of the tree species is very significant for earthworm density and biomass and for the biomass of the ectorganic horizon. It is also significant for pH, base cation saturation and molar (Ca+Mg)/Al ratio on all depths, except for pH(KCl) on 20-40 cm and (Ca+Mg)/Al ratio on 5-20 cm. Differences in CEC are weak or not significant, expressing little differences in soil texture and humus content between plots.

Additional multiple range tests showed a significantly higher earthworm density under lime and maple than under the other species. The highest earthworm biomass was found under maple. The total biomass of the ectorganic horizon was significantly lower under lime than under other species. Under lime and to a lesser extent under maple, a significantly lower exchangeable acidity, higher (Ca+Mg)/Al-ratio, higher base cation saturation and higher pH are found compared to the other species. In most cases, soils under beech show the poorest conditions (table 5).

Table 5 : Unifactorial ANOVA's of 20 variables between homogeneous plots of 5 species (variable codes and units see table 2; Significance levels : $P < 0.001$ = ***, $P < 0.01$ = **, $P < 0.05$ = *, n.s. = not significant)

VARIABLE	PLOTS	Sig.level	Tilia	Acer	Fraxinus	Quercus	Fagus
EWB	28	***	10.58 ± 1.54	36.79 ± 5.82	11.65 ± 2.36	2.30 ± 1.22	0.23 ± 0.12
EWD	28	***	98.50 ± 11.18	128.6 ± 14.5	30.00 ± 7.75	8.25 ± 4.03	1.75 ± 0.88
LF	29	***	193.8 ± 47.4	1656 ± 553	388.9 ± 72.3	868.7 ± 137.2	960.9 ± 73.0
H	29	n.s.	0 ± 0	1100 ± 872	1520 ± 589	2445 ± 984	2177 ± 469
LFH	29	***	193.8 ± 47.4	2756 ± 1283	1909 ± 593	3314 ± 1052	3138 ± 492
CAL1	29	***	3.54 ± 1.17	2.58 ± 0.80	1.32 ± 0.15	0.89 ± 0.25	0.68 ± 0.11
CAL2	29	n.s.	0.49 ± 0.05	0.32 ± 0.10	0.44 ± 0.25	0.20 ± 0.04	0.17 ± 0.02
CAL3	29	***	0.33 ± 0.07	0.15 ± 0.02	0.06 ± 0.02	0.13 ± 0.01	0.15 ± 0.02
pHH1	29	***	4.69 ± 0.13	3.89 ± 0.05	3.76 ± 0.03	3.76 ± 0.09	3.70 ± 0.09
pHH2	29	***	4.36 ± 0.06	4.11 ± 0.02	3.99 ± 0.03	4.00 ± 0.06	3.98 ± 0.07
pHH3	29	***	4.39 ± 0.03	4.27 ± 0.04	4.23 ± 0.02	4.23 ± 0.03	4.20 ± 0.02
pHK1	29	***	3.69 ± 0.07	3.25 ± 0.05	3.17 ± 0.04	2.99 ± 0.06	3.00 ± 0.05
pHK2	29	***	3.62 ± 0.04	3.38 ± 0.03	3.33 ± 0.04	3.34 ± 0.08	3.35 ± 0.07
pHK3	29	n.s.	3.78 ± 0.03	3.65 ± 0.04	3.66 ± 0.06	3.70 ± 0.04	3.69 ± 0.05
AC1	29	***	26.20 ± 3.36	35.20 ± 4.02	44.76 ± 2.77	56.29 ± 3.03	47.25 ± 3.39
AC2	29	n.s.	31.05 ± 1.29	40.11 ± 2.44	38.50 ± 2.51	41.20 ± 6.59	39.79 ± 3.16
AC3	29	n.s.	29.61 ± 1.83	36.23 ± 3.12	37.54 ± 3.94	39.42 ± 2.37	36.62 ± 3.44
CEC1	29	*	66.54 ± 2.65	76.38 ± 6.25	67.15 ± 4.05	76.47 ± 3.63	60.06 ± 3.62
CEC2	29	n.s.	39.32 ± 1.45	47.24 ± 2.00	45.23 ± 3.62	51.05 ± 5.50	43.43 ± 3.42
CEC3	29	n.s.	34.52 ± 1.55	39.34 ± 3.28	39.09 ± 4.53	42.85 ± 2.85	40.03 ± 4.07
BA1	29	***	59.18 ± 5.80	50.41 ± 8.41	32.95 ± 3.53	26.00 ± 3.74	21.48 ± 2.61
BA2	29	*	20.16 ± 1.61	15.17 ± 3.08	13.68 ± 5.18	10.19 ± 1.65	8.34 ± 0.86
BA3	29	***	14.54 ± 2.19	7.94 ± 0.75	3.53 ± 1.30	7.80 ± 0.94	7.31 ± 0.86

4. DISCUSSION

On basis of the vegetation analysis, it was not possible to observe any detectable differences in site quality. This observation also affirms earlier authors who state that *Hyacinthoides non-scripta* is an indifferent species and consequently not useful for site description (Rogister, 1987 ; Keymeulen & Beeckman, 1990). Also, it illustrates that plant sociology, although useful in most cases, is unappropriate in cases where an indifferent species largely dominates the vegetation.

Classification on basis of humus morphology was more succesful and divides the plots basically in two main groups, vermimulls and mullmoders. Mormoder and hemimor are exceptionally found in this forest. A comparison between the classification after PCA of the quantitative variables and these morphological humus forms shows that plots of the mull group A and the intermediate group B all are morphologically a vermimull, except for plot 13, being a mullmoder. Plots of the moder group C are mullmoders, with the exception of plots 17, 20, 28 and 31 being vermimulls and 10 being hemimor. Plots of the moder group D are morphologically never a vermimull. In broad outline both methods result in a similar classification of the plots.

The effect of tree species on humus form and soil characteristics is clearly demonstrated. As the investigated area has a rather homogeneous loam soil, the 70 years lasting influence of the present tree species on the soil is probably the main cause of the observed differences in humus form and soil characteristics. Tree species influence on the soil is mainly a question of foliage composition and therefore decreases with soil depth (Page 1968). The results however show that the influence of lime and maple on pH and base saturation is significant up to a depth of 20-40 cm. The intermediate position of ash, generally known as a species with fast litter decomposition (Wittich 1948) is probably due to side effects caused by leaves of other species blown in by the wind. Also in plot 21 (hemimor under maple), the reason of a bad humus form is probably a relatively higher input of beech leaves than the 20 % contribution of beech in the basal area.

The observations show that the tree species can influence site quality within one rotation. Site quality and certainly humus type are dynamic properties of forest ecosystems that can rapidly modify in non-calcareous soils (Muys *et al*, 1992). In order to avoid soil deterioration, forest management should strive towards the continuous presence of secondary, soil ameliorating tree species over the whole forest area.

5. ACKNOWLEDGEMENTS

This research was financed by the Ministry of the Flemish Community and was executed in charge of the Minister of Environment of Flanders, Belgium.

6. REFERENCES

Bouché, M.B., Aliaga, R., 1986. Contre une dégradation physique et chimique des sols et pour leur optimisation économique, l'échantillonage des lombriciens : une urgente nécessité. *La défense des végétaux* 242, 30-36

Braun-Blanquet, J., 1952. Les groupements végétaux de la France Méditerranéenne. CNRS, Montpellier, 289 p.

Braun-Blanquet, J., 1964. Pflanzensoziologie. Grundzüge der Vegetationskunde. Springer Verlag, 865 p.

Delecour, F., 1980. Essai de classification pratique des humus. *Pédologie* 30, 225-241

Ellenberg, H., 1974. Zeigerwerte der Gefässpflanzen Mitteleuropas. Göttingen *Scripta geobotanica* IX, 122 p.

Green, R.N., Trowbridge, R.L., Klinka, K., 1993. Towards a taxonomic classification of humus forms. *Forest science*, Monograph 29, 49 p.

Hill, M.O., 1979. Twinspan, a Fortran program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes. Section of Ecol and Syst, Cornell University, New York, 49 p.

Keymeulen, R., Beeckman, H., 1990. Species-environment relationships in three woodlands using canonical correspondence analysis. Gent, Silva Gandavensis 55, 25-33.

Klinka, K., Green, R.N., Trowbridge, R.L., Lowe, L.E., 1981. Taxonomic classification of humus forms in ecosystems of British Columbia : first approximation. Ministry of Forests of British Columbia, 54 p.

Klinka, K., Wang, Q., Carter, R.E., 1990. Relationships among humus forms, forest floor nutrient properties, and understorey vegetation. *Forest science* 36, 564-581

Kubiena, W.L., 1953. Bestimmungsbuch und Systematik der Böden Europas. Ferdinand Enke Verlag Stuttgart, 392 p.

Muys, B., Lust, N., Granval, P., 1992. Effects of grassland afforestation with different tree species on earthworm communities, litter decomposition and nutrient status. *Soil Biol Biochem* 24, 1459-1466

Noirfalise, A., Dethioux, M., 1970. Répertoire écologique des espèces forestières de Belgique. *Notes techniques du centre d'écologie forestière (IRSIA)*, Gembloux, 10, 28 p.

Page, G., 1968. Some effects of conifer crops on soil properties. *Commonwealth forestry review* 47, 52-62.

Rogister, J.E., 1978a. Contribution to an ecological classification of forest plant associations (in Dutch with English summary). Proefstation van Waters en Bossen, Groenendaal, *Werken, Reeks A* 16, 157 p.

Rogister, J.E., 1978b. Contribution to a new eco-phyto-pedological classification of the *Luzulo-Fagetum* in Belgium (in Dutch with English summary). Proefstation van Waters en Bossen, Groenendaal, *Werken, Reeks A* 19, 51 p.

Rogister, J.E., 1978c. The ecological mR- and mN-values of the ground vegetation and the humus quality of forest plant associations (in Dutch with English summary). Proefstation van Waters en Bossen, Groenendaal, *Werken, Reeks A* 20, 29 p.

Rogister, J.E., 1978d. The site quality index for ash (*Fraxinus excelsior*) and beech (*Fagus sylvatica*) as a function of the calculated mean indicator values for soil acidity, humidity and nitrification (in Dutch with English summary). Proefstation van Waters en Bossen, Groenendaal, *Werken, Reeks A* 21, 28 p

Rogister, J.E., 1985. The main forest plant associations of Flanders (in Dutch with French summary). Rijksstation voor bos- en hydrobiologisch onderzoek, Groenendaal, *Werken, Reeks A* 29, 106 p.

Rogister, J.E., 1987. Ecology of the main forest ground vegetation species - ecograms. (in Dutch with French summary). Rijksstation voor bos- en hydrobiologisch onderzoek, Groenendaal, *Werken, Reeks A* 30, 104 p.

Ter Braak, C.J.F., 1988. CANOCO - A FORTRAN program for canonical community ordination by partial detrended canonical correspondence analysis, principal components analysis and redundancy analysis (version 2.1). Agricultural mathematics group, Wageningen, 95 p.

Wittich, W., 1948. Die heutigen Grundlagen der Holzartenwahl. Schaper Verlag Hannover, 67 p.