Ekológia (Bratislava) Vol. 19, Supplement 3, 45-58, 2000

A FIRST ANALYSIS ON THE RELATIONSHIP BETWEEN FOREST SOIL QUALITY AND SPIDER (ARANEAE) COMMUNITIES OF FLEMISH FOREST STANDS

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Abstract

De Bakker D., Maelfait J.-P., Hendrickx F., Van Waesberghe D., De Vos B., Thys S., De Bruyn L.: A first analysis on the relationship between forest soil quality and spider (Araneae) communities of Flemish forest stands. In Gajdoš P., Pekár S. (eds): Proceedings of the 18th European Colloquium of Arachnology, Stará Lesná, 1999. Ekológia (Bratislava), Vol. 19, Supplement 3/ 2000, p. 45-58.

A project aiming at the development of a practical bio-indication system for evaluating forest soil quality was recently started up. The project is funded by the Flemish Forestry Administration responsible for the protected Flemish forests and is managed by the Institute for Forestry and Game Management (IBW). In the project the arthropod fauna of fifty forest stands distributed all over the Flemish Region was sampled by traps operative from spring 1997 till spring 1998. All these plots were also investigated in relation to the physical and chemical properties of their soil and litter layers. The variation of the composition of the spider communities of these stands is unclear when we compare it with the most important litter and soil parameters, but future investigations with more (structural) parameters will hopefully give a good explanation. On a subregional scale, in forests on the same soil type (loam), spider community composition seems to be determined by humidity and density of tree coverage. Spider species forwhich abundance correlates with these major environmental factors are candidate bio-indicators to monitor forest soil quality.

Introduction

Flemish forests have been fragmented and degraded during several centuries. It is a safe assumption that, at the beginning of the Holocene, there was more woodland in Flanders than there is now. However, the history of woodlands in Flanders cannot be described by a simple model of linear decline, but is characterised by periods of regression and expansion (Tack et al., 1993; Tack, Hermy, 1998). Woodlands in Flanders can be described by three basic factors: deforestation events, changes in dimensions resulting in actual size, and exploitation history (Desender et al., 1999). Forest covers nowadays only about 8% of the total area in Flanders (Hermy, 1989). Communities of organisms bound to the forest are exposed to population dynamic and population genetic effects (e.g. Desender et al., 1999) due to fragmentation and a higher level of pollution derived from industry and agriculture (Maelfait, Hendrickx, 1998). Therefore a project was started up in 1997 to evaluate forest soil quality by means of soil-living arthropods.

A selection of 50 forests was chosen from 400 sampling points of the forest-inventory grid of Flanders. These forests were chosen to represent the full range of forest types found in Flanders.

Different arthropod groups were included in this study: spiders (Araneae), pseudoscorpiones, harvestmen (Opiliones), ground beetles (Coleoptera: Carabidae), other beetle-families (Coleoptera: Chrysomelidae, Staphylinidae, Curculionidae,…), millipedes (Diplopoda), centipedes (Chilopoda), woodlice (Isopoda), certain families of flies (Diptera: Syrphidae, Empididae, Sphaeroceridae, Dolichopodidae, Phoridae,…), plant-parasitic nematodes (Nematoda) and springtails (Collembola).

Material and methods

Pitfall traps were used in this project. These were glass vessels (9.5 cm diameter) placed into the ground so that the top of the trap was level with the soil surface. The traps were filled with a 4% formaldehyde solution in which we added a little detergent to reduce the surface tension. Also salt was added in the winter to prevent the solution from freezing. The advantages of this method can be summarised as follows (Maelfait, Baert, 1975; Maelfait, 1996): (1) the method is standardised, inexpensive and labour-effective, (2) large numbers of animals are caught which allows statistical analysis, (3) the method is commonly used, which allows comparison with earlier sampling campaigns, (4) nocturnal and diurnal animals are caught, (5) the distribution of catches of males and females during short, continuous periods (every fortnight during a complete year cycle is reasonable) allows a good reconstruction of the life cycle of the most abundant species and (6) the catches of a certain species in different types of habitats shows clearly the preference of a certain species for the sampled habitats (see also Obrtel, 1971; Uetz, Unzicker, 1976). The disadvantage of the method is that catches of different species which occur in the same habitat cannot be used to calculate the relative density of these species. This is because species vary in level of activity, which affects their probability of capture (see also Greenslade, 1964; Luff, 1975; Curtis, 1980; Desender, 1984; Desender, Maelfait, 1986).

We placed 3 pitfall traps in one row (approximately 3 meters apart). This gave a total of 150 pitfall traps emptied every fortnight (and every three weeks in the winter). Animals were sorted in the laboratory and preserved in 70% alcohol, to be identified later.

The location of the 50 forest stands is shown in Fig. 1. The list of names of the forests used in this figure is explained in Table 1. Spiders which were caught in May 1997 were identified for all 50 stations, (Table 2). For

8 stands in the region of the Flemish Ardens, the spider fauna was determined (for a graduate thesis) for the whole year cycle (Van Waesberghe, 1998). Due to the large sorting effort, we can only present these preliminary results. In a future contribution, the results of the analysis of the complete data will be displayed. For determination of species we used Locket, Millidge (1951, 1953), Locket et al. (1974) and Roberts (1987, 1998).

Furthermore, some parameters of the soil and litter layer were measured: acidity (pH), electrical conductivity, weight (DS) and the concentration of several mineral elements (Ca, N, S, P, Mg and K). Values for these parameters are shown in Table 3.

Ordinations and classifications were done with the programmes PC-ORD (McCune, Mefford, 1995) and CANOCO for Windows. Statistical tests were performed with the program STATISTICA.

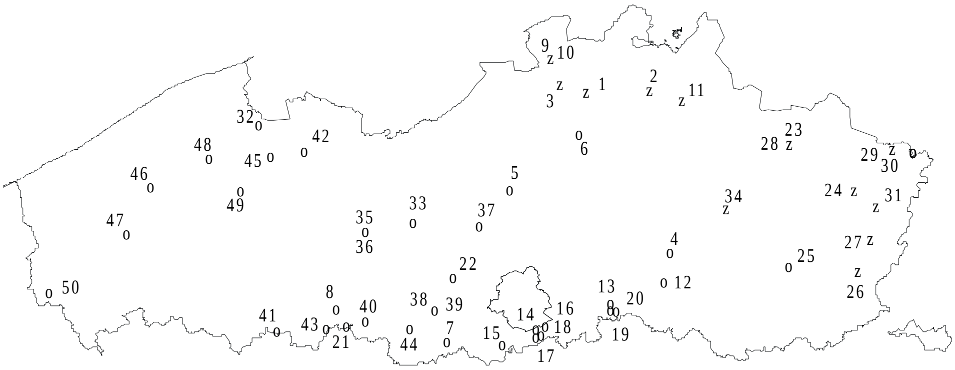

Fig. 1. Position of the sampled forest stands in Flanders (o- forests on sandy loam /loam soil, z- forests on sandy soils). Numbers of forest stands are explained in Table 1.

Results and discussion

The spiders captured during May 1997 were determined for all 50 forest stands (see Table 2). This revealed 9677 adult individuals belonging to 161 species. The complete year cycle of the 8 forest stands in the Flemish Ardens revealed 8 217 adult individuals belonging to 118 species (Van Waesberghe, 1998). 45 species, which have been determined for the 50 forest stands and the 8 stands of the Flemish Ardens, belong to the Red List of spiders of Flanders (Maelfait et al., 1998).

The species used in the analysis were the most abundant ones. In the case of the 50 forest stands we took 50 individuals for analyses. This is equivalent to one capture in every plot during the month of May 1997. We have 30 species that fulfil this condition. The quantitative data of these most abundant species were transformed to percentage distributions per species over the 50 forest stands as a measure of habitat preference (within the available data). Such a transformation ensures that each species (used in the analysis) receives an equal weight. This explains why less abundant species (with strong random variation in numbers, and often also possible accidental immigrants from other environments) are not used in the analysis. The results are used in an indirect gradient-analysis (DCA= Detrended

T a b l e 1. List of sampled forest stands with number, abbreviation, soil type on which the forest is situated, name and dominant tree species occurring in the stand. Forests in bold are the 8 forests with a complete dataset.

No.	Abbr.	Soil type	Forest stand	Main tree species
1	KAMP	Sand	Het Kamp	*Pinus silvestris*
2	BEER	Sand	Beerse Heide	*Pinus silvestris*
3	BRAS	Sand	Inslag	*Pinus silvestris*
4	WALE	Sandy loam	Walenbos	*Quercus robur, Q. petraea*
5	KOOL	Sandy loam	Koolhembos	*Alnus glutinosa*
6	MUIZ	Sandy loam	Muizenbos	*Fraxinus excelsior*
7	**EDIL**	**Loam**	**Bos Ter Rijst Edingen**	*Fraxinus excelsior, Quercus robur*
8	**BURR**	**Loam**	**Burreken**	*Quercus robur*
9	KAL9	Sand	Withoefse Heide	*Pinus silvestris*
10	KA10	Sand	Withoefse Heide	*Pinus silvestris*
11	SEVE	Sand	Sevendonck	*Fagus sylvatica*
12	BINK	Sandy loam	Kapellebos	*Quercus robur*
13	MELE	Sandy loam	Meerdaalwoud level-plot	*Quercus robur*
14	ZO14	Loam	Zoniën 14	*Fagus sylvatica*
15	HALL	Loam	Hallerbos	*Fagus sylvatica*
16	ZO16	Loam	Zoniën bestand 23	*Quercus robur, Carpinus betulus*
17	ZO17	Loam	Zoniën bestand 24	*Quercus robur, Carpinus betulus*
18	ZO18	Loam	Zoniën bestand 25	*Fagus sylvatica*
19	MEDR	Sandy loam	Meerdaalwoud drie eiken	*Betula* sp.
20	MEKO	Sandy loam	Meerdaalwoud grote konijnenpijp	*Fagus sylvatica*
21	**BRDR**	**Loam**	**Brakelbos**	*Fagus sylvatica*
22	RTTD	Sandy loam	RTT-domein	*Quercus robur, Betula* sp.
23	HE23	Sand	Pijnven	*Pinus silvestris*
24	HEID	Sand	Heiderbos	*Pinus silvestris*
25	WIMM	Sandy loam	Oude Mombeek	*Populus x canadensis*
26	GELL	Sand	Gellikerheide	*Pinus silvestris*
27	HECH	Sand	Heiwijk	*Pinus silvestris*
28	HE28	Sand	Pijnven	*Pinus silvestris*
29	BR29	Sand	Grootbroek-Bree I	*Quercus robur, Betula* sp.
30	BR30	Sand	Grootbroek Bree II	*Betula* sp., *Alnus glutinosa*
31	LANK	Sand	Lanklaarderbos	*Betula* sp.
32	PADD	Sandy loam	Paddepoelebos	*Quercus robur, Fraxinus excelsior*
33	SERS	Sandy loam	Zandputten	*Quercus robur*
34	KENI	Sand	Kenisberg-Kruisberg	*Pinus silvestris*
35	GONA	Sandy loam	Aelmoeseneie I	*Quercus robur, Fagus sylvatica*
36	GONB	Sandy loam	Aelmoeseneie II	*Fraxinus excelsior*
37	BUGG	Loam	Buggenhoutbos	*Fagus sylvatica*
38	**NEI7**	**Loam**	**Neigembos - bestand 7**	*Fagus sylvatica*
39	**NE7B**	**Loam**	**Neigembos - bestand 7bis**	*Betula* sp.
40	**PARI**	**Loam**	**Parikebos (Parike)**	*Populus x canadensis*
41	KLUI	Loam	Kluisbos	*Fagus sylvatica*
42	LEEN	Sandy loam	Het Leen	*Quercus robur*
43	**SCNA**	**Loam**	**Bos Terrijst Schorisse**	*Fraxinus excelsior, Alnus glutinosa*
44	**RASP**	**Loam**	**Raspaillebos**	*Quercus rubra, Castanea sativa*
45	DRON	Sandy loam	Drongengoed	*Fagus sylvatica*
46	WIJL	Sandy loam	Wijnendalebos	*Fagus sylvatica*
47	HOUT	Sandy loam	Houthulstbos	*Quercus robur*
48	NIEU	Sandy loam	Nieuwenhoven	*Quercur robur, Fagus sylvatica*
49	RUIG	Sandy loam	Vorte bossen	*Quercus rubra, Fraxinus excelsior*
50	HELL	Sandy loam	Helleketelbos	*Quercus robur, Acer pseudoplatanus*

T a b l e 2. Number of species caught in May 1997 for all 50 forest stands.

Species	No.
AMAUROBIIDAE	
Amaurobius fenestralis (STRO.)	1
DICTYNIDAE	
Cicurina cicur (FABR.)	3
Lathys humilis (BL.)	2
DYSDERIDAE	
Dysdera erythrina (WALC.)	3
GNAPHOSIDAE	
Haplodrassus silvestris (BL.)	74
Haplodrassus umbratilis (L. K.)	1
Micaria fulgens (WALC.)	6
Micaria pulicaria (SUND.)	5
Phaeocedus braccatus (L. K.)	1
Zelotes latreillei (SIMON)	1
Zelotes subterraneus (C. L. K.)	31
CLUBIONIDAE	
Clubiona brevipes BL.	1
Clubiona compta C. L. K.	11
Clubiona corticalis (WALC.)	1
Clubiona lutescens WEST.	9
Clubiona pallidula (CL.)	2
Clubiona reclusa O. P.-C.	4
Clubiona terrestris WEST.	40
LIOCRANIDAE	
Agroeca brunnea (BL.)	126
Apostenus fuscus WEST.	43
Phrurolithus festivus (C. L. K.)	7
Scotina celans (BL.)	1
ZORIDAE	
Zora spinimana (SUND.)	43
ANYPHAENIDAE	
Anyphaena accentuata (WALC.)	20
THOMISIDAE	
Coriarachne depressa (C. L. K.)	2
Ozyptila praticola (C. L. K.)	23
Ozyptila trux (BL.)	149
Xysticus audax (SCH.)	1
Xysticus erraticus (BL.)	1
Xysticus lanio C. L. K.	40
Xysticus ulmi (HAHN)	1
PHILODROMIDAE	
Philodromus aureolus (CL.)	1
Philodromus dispar WALC.	3
SALTICIDAE	
Ballus chalybeius (WALC.)	1
Euophrys frontalis (WALC.)	22

Species	No.
Euophrys petrensis C. L. K.	2
Evarcha falcata (CL.)	1
Marpissa muscosa (CL.)	2
Neon reticulatus (BL.)	11
LYCOSIDAE	
Alopecosa cuneata (CL.)	1
Alopecosa pulverulenta (CL.)	10
Hygrolycosa rubrofasciata (OHLE.)	3
Pardosa amentata (CL.)	50
Pardosa lugubris (WALC.)	306
Pardosa prativaga (L. K.)	2
Pardosa pullata (CL.)	2
Pardosa saltans TÖP.-HOF.	402
Pirata hygrophilus TH.	3106
Pirata latitans (BL.)	11
Pirata piraticus (CL.)	1
Pirata uliginosus (TH.)	98
Trochosa spinipalpis (O. P.-C.)	1
Trochosa terricola TH.	146
Xerolycosa nemoralis (WEST.)	4
PISAURIDAE	
Pisaura mirabilis (CL.)	2
AGELENIDAE	
Coelotes inermis (L. K.)	50
Coelotes terrestris (WIDER)	20
Histopona torpida (C. L. K.)	136
Tegenaria picta SIMON	258
Tegenaria silvestris L. K.	2
HAHNIIDAE	
Antistea elegans (BL.)	1
Hahnia helveola SIMON	8
Hahnia montana (BL.)	36
Hahnia nava (BL.)	1
Hahnia pusilla C. L. K.	109
MIMETIDAE	
Ero furcata (VILL.)	2
THERIDIIDAE	
Anelosimus vittatus (C. L. K.)	1
Crustulina guttata (WIDER)	2
Enoplognatha thoracica (HAHN)	23
Episinus angulatus (BL.)	2
Euryopis flavomaculata (C. L. K.)	81
Robertus lividus (BL.)	120
Theridion bimaculatum (L.)	3
Theridion pallens BL.	4
Theridion varians HAHN	1

T a b l e 2. (cont.)

Species	No.
THERIDIOSOMATIDAE	
Theridiosoma gemmosum (L. K.)	4
METIDAE	
Metellina mengei (BL.)	17
TETRAGNATHIDAE	
Pachygnatha clercki SUND.	23
Pachygnatha degeeri SUND.	2
Pachygnatha listeri SUND.	180
ARANEIDAE	
Cercidia prominens (WEST.)	5
Cyclosa conica (PALL.)	1
LINYPHIIDAE (ERIGONINAE**)**	
Ceratinella brevis (WIDER)	7
Ceratinella scabrosa (O. P.-C.)	57
Dismodicus bifrons (BL.)	10
Dicymbium nigrum (BL.)	1
Dicymbium tibiale (BL.)	33
Diplocephalus latifrons (O. P.-C.)	7
Diplocephalus picinus (BL.)	1329
Erigone atra (BL.)	3
Erigone dentipalpis (WIDER)	5
Erigonella hiemalis (BL.)	2
Glyphesis servulus (SIMON)	14
Gnathonarium dentatum (WIDER)	1
Gonatium rubellum (BL.)	20
Gongylidiellum latebricola (O. P.-C.)	8
Gongylidiellum vivum (O. P.-C.)	3
Gongylidium rufipes (SUND.)	87
Hypomma cornutum (BL.)	1
Leptorhoptrum robustum (WEST.)	1
Maso sundevalli (WEST.)	7
Micrargus herbigradus (BL.)	84
Minyriolus pusillus (WIDER)	36
Monocephalus fuscipes (BL.)	31
Oedothorax fuscus (BL.)	1
Oedothorax gibbosus (BL.)	4
Oedothorax retusus (WEST.)	2
Pocadicnemis pumila (BL.)	182
Saloca diceros (O. P.-C.)	8
Tapinocyba insecta (L. K.)	23
Tapinocyba praecox (O. P.-C.)	1
Tiso vagans (BL.)	2
Walckenaeria acuminata BL.	76
Walckenaeria alticeps (DENIS)	3
Walckenaeria atrotibialis (O. P.-C.)	13
Walckenaeria corniculans (O. P.-C.)	58
Walckenaeria cucullata (C. L. K.)	37
Walckenaeria cuspidata (BL.)	2
Walckenaeria dysderoïdes (WIDER)	32
Walckenaeria furcillata (MENGE)	19
Walckenaeria mitrata (MENGE)	2
Walckenaeria monoceros (WIDER)	1
Walckenaeria nudipalpis (WEST.)	6
Walckenaeria obtusa BL.	9
Walckenaeria unicornis O. P.-C.	1
(LINYPHIINAE)	
Agyneta ramosa JACK.	170
Agyneta subtilis (O. P.-C.)	18
Bathyphantes nigrinus (WEST.)	31
Bathyphantes parvulus (WEST.)	8
Centromerita concinna (TH.)	1
Centromerus aequalis (WEST.)	44
Centromerus dilutus (O. P.-C.)	6
Centromerus leruthi FAGE 1933	2
Centromerus pabulator (O. P.-C.)	1
Centromerus prudens (O. P.-C.)	5
Centromerus serratus (O. P.-C.)	5
Centromerus sylvaticus (BL.)	18
Diplostyla concolor (WIDER)	127
Lepthyphantes cristatus (MENGE)	36
Lepthyphantes ericaeus (BL.)	4
Lepthyphantes flavipes (BL.)	226
Lepthyphantes mengei KULC.	37
Lepthyphantes pallidus (O. P.-C.)	42
Lepthyphantes tenebricola (WIDER)	21
Lepthyphantes tenuis (BL.)	4
Lepthyphantes zimmermanni BERT.	70
Linyphia hortensis SUND.	37
Macrargus rufus (WIDER)	155
Meioneta saxatilis (BL.)	13
Microneta viaria (BL.)	268
Nereine clathrata (SUND.)	119
Nereine montana (CL.)	4
Nereine peltata (WIDER)	3
Poeciloneta globosa (WIDER)	4
Porrhomma convexum (WEST.)	1
Porrhomma egeria SIMON	10
Porrhomma pallidum JACK.	1
Porrhomma pygmaeum (BL.)	3
Saaristoa abnormis (BL.)	20
Sintula cornigera (BL.)	1
Total	9677

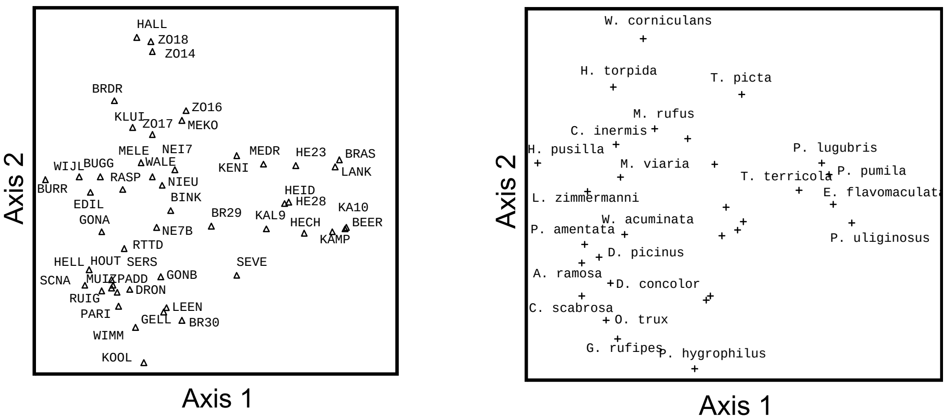

Fig. 2. DCA-ordination of the 50 forest stands on the basis of the most abundant spider species caught in may 1997 (left) and distribution of corresponding indicator spider species (right).

Correspondence Analysis; Ter Braak, 1988, Jongman et al., 1995) and a TWINSPAN (Two Way Indicator Species Analysis; Hill, 1979) which performs a two way-divisive and hierarchical classification where, at every level, the original group of samples and species are divided on the basis of indicator species. For the 8 forest stands of the Flemish Ardens, the number of individuals, to be incorporated into the analysis, was taken at 33. 44 species fulfilled this condition.

Indirect gradient analysis of the stands (DCA) on the basis of the most abundant spider species

The results of the DCA-analysis for the 50 forest stands are shown in Fig. 2 (axis 1 and 2). The eigenvalues of these axes are respectively 0.655 and 0.578 and the total variance explained by the first two axes is 26.7%. The following axes (axes 3 and 4) have eigenvalues which are lower than 0.3 and further increase in variance is minimal. The forests with a more sandy soil (with pine (*Pinus sylvestris*) as the main tree species) are found at the right. We also draw attention to a concentration of deciduous forests in the lower left corner. It consists mainly of more humid forests on loam /sandy loam soils (e.g. Koolhembos, Bos ter Rijst Schorisse, Wimmertingen, Parikebos, Vorte Bossen and Muizenbos). If we look at the corresponding species then we note the following indicator species for the forests on sandy soils: *Pardosa lugubris* (Walckenaer), *Trochosa terricola* Thorell, *Pocadicnemis pumila* (Blackwall), *Euryopis flavomaculata* (C. L. Koch) and *Pirata uliginosus* (Thorell). These are all species which prefer open, dry habitats. For deciduous forests we note the following indicator species: *Ozyptila trux* (Blackwall), *Pirata*

T a b l e 3. Values of the physico-chemical parameters of litter and soil for the 50 forest stands (DS- percent of total weight of soil sample that remains after drying at 105 degrees Celsius, concentrations are expressed in parts per million).

Forest Stand	**Litter - parameters**								**Soil - parameters**							
	DS (%)	**pH**	N (%)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	S (ppm)	DS (%)	**pH**	N (%)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	S (ppm)
KAMP	44.6	3.6	1.29	372	152	1702	268	2565	89.0	3.8	0.07	77	241	571	109	68
BEER	58.7	3.6	1.16	324	196	2101	391	1188	90.1	3.6	0.14	146	314	562	162	280
BRAS	54.2	3.5	1.40	399	174	2606	348	2279	90.8	4.0	0.08	46	208	426	105	107
WALE	36.9	4.6	1.74	596	1158	8383	1009	2454	51.8	3.7	0.89	495	2898	1599	1815	1094
KOOL	33.6	5.8	1.78	588	1265	6714	1543	1575	45.9	4.1	0.97	759	2102	3682	2480	1493
MUIZ	56.3	5.0	1.06	386	1789	14884	1068	916	83.5	6.1	0.24	285	2025	6686	2034	483
EDIL	40.5	5.5	1.18	656	2334	7472	1841	867	310	4.1	0.21	536	2433	1546	2192	368
BURR	40.3	4.1	1.33	529	2640	13048	2605	1317	67.5	4.2	0.37	358	5626	2775	4862	437
KAL9	48.3	3.7	1.47	424	147	3035	410	1667	87.5	4.0	0.11	29	153	250	84	99
KA10	39.9	3.7	1.43	434	202	2936	480	1440	85.4	3.9	0.06	42	156	405	87	141
SEVE	31.0	3.9	1.91	559	529	2954	571	1860	64.3	3.8	0.27	193	634	695	680	787
BINK	45.1	4.1	1.62	652	864	6041	961	1511	76.0	3.8	0.19	195	1826	1068	1439	308
MELE	46.4	4.7	1.57	704	1373	8094	1181	1316	71.9	3.9	0.52	626	2166	1816	2003	728
ZO14	36.5	4.2	1.66	615	481	6567	805	1965	67.0	3.8	0.36	717	1695	1712	1376	664
HALL	34.5	4.4	1.79	655	790	7302	972	1526	72.0	3.8	0.21	617	2248	1633	1686	515
ZO16	44.1	3.9	1.54	608	552	6015	803	1519	63.7	3.6	0.38	645	1692	1698	1244	542
ZO17	44.5	4.2	1.59	632	1049	6174	1113	1295	65.4	3.5	0.51	730	1952	1698	1499	737
ZO18	45.2	4.3	1.59	618	657	6576	897	1385	75.1	3.8	0.28	445	1824	1553	1343	384
MEDR	55.7	3.9	0.96	300	637	2599	724	792	84.3	3.6	0.20	201	959	775	771	360
MEKO	57.5	4.3	1.50	502	704	5244	909	1076	78.2	3.7	0.67	345	1486	1376	1173	511
BRDR	28.3	3.9	1.69	427	637	4853	681	2016	67.9	3.7	0.36	249	4862	1038	3666	527
RTTD	41.4	3.6	1.35	456	598	2698	725	1909	65.8	3.6	0.43	482	1647	1314	1250	693
HE23	43.9	3.6	1.29	417	165	2927	401	1426	89.2	3.7	0.09	182	249	329	160	197
HEID	53.5	3.8	1.36	398	275	3091	394	1476	86.5	3.7	0.08	116	306	353	58	240
WIMM	28.8	2.7	1.33	1216	3985	19228	2255	1177	62.0	5.9	0.50	930	5135	6943	4681	908
GELL	46.7	3.9	1.28	367	288	5135	465	1449	85.2	3.9	0.09	91	286	521	150	222
HECH	34.6	3.7	1.62	386	362	3121	335	1471	78.1	3.6	0.49	221	342	550	214	469
HE28	47.4	3.5	1.35	436	188	3150	393	1587	92.0	3.7	0.08	112	248	332	133	197
BR29	35.9	4.1	2.12	658	411	8876	682	3383	58.0	4.1	0.79	489	779	3256	822	2110
BR30	29.3	4.1	2.06	613	584	9361	711	1940	53.2	4.4	0.78	533	1593	4233	1522	2909
LANK	52.5	4.5	1.35	436	684	4464	811	1323	88.3	4.1	0.15	114	360	407	202	250
PADD	40.0	3.8	1.95	545	517	5327	645	2887	79.0	3.7	0.61	316	568	1242	629	573
SERS	37.3	3.8	1.59	396	626	4636	834	1381	71.1	3.6	0.35	276	1218	1244	958	589
KENI	65.2	4.2	1.17	572	1600	4376	801	1105	93.7	3.8	0.06	452	5915	358	2800	501
GONA	37.5	3.8	1.49	421	1017	3877	977	1869	68.5	3.5	0.29	318	2672	1089	2112	449
GONB	40.1	3.0	1.39	695	5575	10519	1443	1026	79.0	4.2	0.20	372	2760	1971	2843	327
BUGG	40.4	3.6	1.28	355	477	2648	550	1465	79.8	3.5	0.31	343	1294	1025	1011	397
NEI7	46.0	3.9	1.01	361	1518	3507	1204	1301	74.3	3.7	0.25	347	3934	636	2967	430
NE7B	51.1	4.1	1.06	341	1212	2974	1194	1381	73.9	3.7	0.28	324	3020	961	2299	396
PARI	40.9	6.3	1.37	787	3040	18183	1792	1045	74.1	6.5	0.55	716	3226	7803	3178	841
KLUI	42.3	3.8	1.31	491	798	3053	751	1981	64.2	3.6	0.39	518	2359	1295	1845	489
LEEN	28.8	3.5	1.73	353	306	3609	602	2713	70.2	3.4	0.30	358	1549	1183	1149	530
SCNA	47.0	5.3	1.36	655	1650	13427	1632	1261	70.2	3.9	0.37	403	3131	1931	2658	477
RASP	38.6	3.8	1.06	423	1184	3140	1291	878	69.6	3.8	0.21	430	2617	1481	2230	383
DRON	33.3	3.7	1.62	344	1060	5751	1286	1423	75.2	3.7	0.22	200	4364	649	3855	380
WIJL	36.1	3.4	1.81	301	134	1923	447	2599	78.8	3.5	0.18	299	1275	761	1006	330
HOUT	29.1	3.4	1.54	332	736	3763	812	1393	64.7	3.4	0.62	376	1486	1198	1111	580
NIEU	33.9	3.8	1.70	432	386	4772	637	1314	85.0	3.8	0.07	145	918	720	704	156
RUIG	57.3	4.4	1.14	386	1240	4260	1584	1028	69.1	4.0	0.43	410	2226	3412	3002	623
HELL	35.1	3.8	1.61	430	639	3799	922	1623	66.6	3.5	0.35	265	2284	1214	1616	734

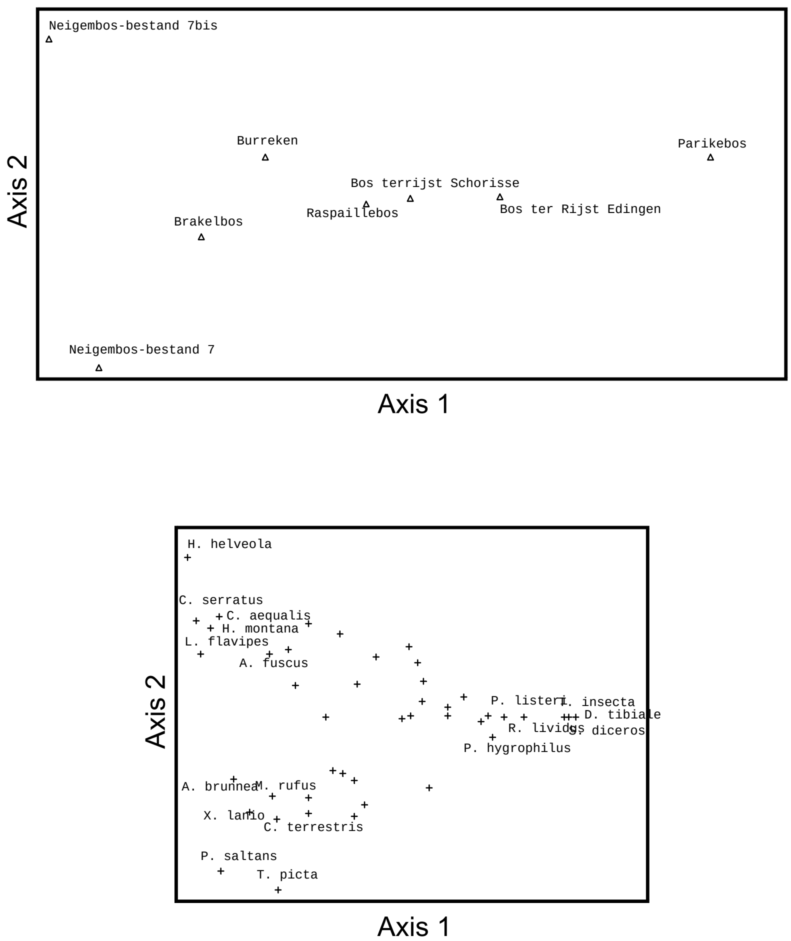

Fig. 3. DCA-ordination of the 8 forest stands of the Flemish Ardens based on the most abundantly caught spider species during a complete year cycle (1997-1998): distribution of the forest stands (above) and distribution of the specific indicator species (below).

hygrophilus Thorell, *Ceratinella scabrosa* (O. P.-Cambridge), *Gongylidium rufipes* (Sundevall) and *Diplostyla concolor* (Wider). These are all species which prefer more humid environments. At the top we see large and/or old forests (Zoniënwoud, Hallerbos and Meerdaalwoud) with beech (*Fagus sylvatica*) as the dominant tree species. The indicator species for these forests are *Walckenaeria corniculans* (O. P.-Cambridge), *Tegenaria picta* Simon, *Macrargus rufus* (Wider) and *Histopona torpida* (C. L. Koch). These are species which mostly prefer beech-woods with a large quantity of dead wood. We have the impression that, according to the first axis, soil texture is the most important parameter. In the future it would be useful to do research on deciduous forests with the same vegetation type and soil type and compare them with other results to reach a better conclusion on the reason why these forests are separated or grouped together from the rest. The second axis is probably a humid-dry gradient: dry forest stands mainly on top (e.g. Meerdaalwoud and Zoniënwoud) and more humid environments beneath (e.g. Koolhembos, Sevendonck and Bree), each associated with typical indicator species. Further analysis on a broader range of structural and other parameters should explain which parameter is most important for the division of the forest stands.

TWINSPAN-analysis yielded the same picture with the same indicator species. Habitat preferences of most of these indicator species, which appeared in the DCA-ordination as well as in the TWINSPAN-analysis, are similar to those generally found in the literature. Detailed information about distribution, phenology and habitat preferences of these species are discussed in ALDERWEIRELDT (1985), SEYS (1985), SEGERS (1986), DE KNIJF (1993), DE BAKKER (1995), VAN WAESBERGHE (1998), DE COCK (1999) and D'HERT (1999).

When we look at the indicator species for dry forest stands on sandy soils, we note that almost all of them are not really typical (stenotopic) woodland species. They are, on the contrary, all species which prefer open, dry and exposed habitats like heathland and all kinds of grassland (e.g. *E. flavomaculata*, *T. terricola* and *P. uliginosus*). Indicator species which belong to forest stands on sandy loam /loam soils (e.g. *Coelotes terrestris* (WIDER), *H. torpida*, …) are more typical (and stenotopic) woodland species in Belgium. Therefore it is difficult to interpretate the results obtained from the DCA-ordination. The difference between the two types of forest stands (sandy versus sandy loam /loam soils) can be the result of other reasons than those we have investigated here. Soils in the Campine Region (which are mostly dry, sandy and nutrient poor) were mostly planted with pine in the past, probably because this species is best adapted to this kind of soil and because pine wood was also frequently used in the mining industry. Pine forest stands have a more open vegetation, the soils are more exposed to the sun, are therefore warmer and all this resembles conditions of open habitats. This could explain the occurrence of several species that are not really bound to forests for their life-cycle. Comparison of these results with ordinations based on the most important litter and soil parameters strengthens our earlier findings. The ordination obtained based on the soil parameters seems to be similar to the one we derived on the basis of the most abundant species, but both ordinations (soil and litter) have very low eigenvalues and can therefore not be interpreted as being responsible for the difference. A Mann-Whitney U test between the litter and soil parameters of these two kinds of forest types confirmed the results already obtained, i.e. no significant difference between the two types of forest stands based on these parameters. The same result was obtained when using a (more formal) direct Canonical Correspondence Analysis (CCA) between litter and soil parameters and species frequencies: very low eigenvalues prohibits us to use even this ordination to explain the observed differences.

It can be concluded that the presented parameters are insufficient to explain the difference between the two kinds of forest stands. Other parameters, which are not available up to now, should give a clear picture of why these forests are separated. It is important in the future that we also investigate deciduous forest stands in the Campine region on sandy, nutrient poor soils to explain the difference between these forests and those on nutrient rich sandy loam /loamy soils. We also remark that these results are based on only one month of data and that in the future, with a complete set of data, we will be able to make conclusions about the division of the stands and find suitable bio-indicators.

We can conclude that different spider communities are present in forests on nutrient-poor sandy soils (with mainly pine and birch (*Betula* sp.) as dominant tree species) and forests on nutrient-rich loam/sandy loam soils (oak (*Quercus robur*/*Q. petraea*), beech and mixed deciduous forest stands). This is also reflected in different main tree species and other vegetation which cannot be investigated up to now. It is important to emphasise that we are not dealing with a zoogeographical phenomenon because the species used in the analyses are the most abundant ones and are very common in the whole region.

Analysis of 8 forest stands from the region of the Flemish Ardens

Forests on the same soil type (loam) were compared with each other for the complete set of data (whole year cycle) with the most abundant species. The DCA-ordination of the 8 forest stands and distribution of the most important indicator species are shown in Fig. 3. The axes have eigenvalues of respectively 0.554 (axis 1) and 0.123 (axis 2) with a total explained variation of 35% (for both axes). The following axes (axis 3 and 4) have very eigenvalues so that further explained variation is minimal.

We see that Parikebos, Bos terrijst Edingen and Bos ter Rijst Schorisse are on the right while the other forest stands Neigembos, Brakelbos and Burreken are on the left. Indicator species on the right are *Robertus lividus* (BLACKWALL), *Pachygnatha listeri* SUNDEVALL, *Saloca diceros* (O. P.-CAMBRIDGE), *Dicymbium tibiale* (BLACKWALL) and *Tapinocyba insecta* (L. KOCH). These are species which prefer more humid environments (with a very thin litter layer) according to most literature. Detailed information about most of these species can be also found in the above-mentioned literature. Indicator species on the left are *Pardosa saltans* TÖPFER-HOFMANN, *Centromerus serratus* (O. P.-CAMBRIDGE), *Apostenus fuscus* WESTRING and *Lepthyphantes flavipes* (BLACKWALL). These are species which (according the literature) prefer dry forest stands with a very well developed litter layer. The difference along the first axis could thus be explained as a humid-dry gradient. The division based on the second axis is probably due to an open or closed type of vegetation (with corresponding main tree species). Neigembos 7bis (birch stand) and Neigembos 7 (beech stand) are the two extremes of this axis. That is explained by the fact that the beech stand is a lot more open (and it was also situated on a south directed slope) and receives more sunlight than the birch stand that has a more closed vegetation. Both stands were only a few meters apart. This is also shown in the indicator species. Species which appears more in the beech stand are *P. saltans*, *T. picta* and *Xysticus lanio* C. L. KOCH (species which prefer open, dry habitats) and indicator species for the birch site are *C. serratus*, *Hahnia helveola* SIMON and *Centromerus aequalis* (WESTRING) (which can also be found in dry forest stands with a more dense vegetation).The results of the TWINSPAN-analysis confirms these results (VAN WAESBERGHE, 1998).

These results were compared with ordinations based on the most important litter and soil parameters. The ordination obtained based on the litter parameters seems to be similar to the one we derived on the basis of the most abundant species, but both ordinations (soil and litter) have very low eigenvalues and can therefore not be interpreted as being responsible for the difference. The same conclusion can thus be made as for the 50 forest stands. A Mann-Whitney U test between the litter and soil parameters of these 8 forest stands was done. Most significantly different values were seen within the litter parameters while only two parameters of the soil seemed to be significantly different, but these results were not sufficient to explain the difference between the forest stands. The analysis of other parameters (structural, vegetational,…) could not be done for the same reason as for the 50 forest stands (see above). The same results were obtained when using a (more formal) direct Canonical Correspondence Analysis (CCA) between litter and soil parameters and species frequencies: very low eigenvalues also prevented us from using this ordination to explain the observed differences. So differences in distribution of the forest stands in the ordination were mainly based on known habitat preferences of indicator species. Future investigations on other (probably more important) parameters should provide a more profound explanation of the observed differences.

As a conclusion the ordination of the spider communities that revealed the important character of a humid-dry gradient (along the first axis) is similar with the ordination of the litter parameters. This means that spider community composition on a subregional scale, with forests on the same soil type, correlates strongly with the abiotic characteristics of the litter layer, but because ordination based on the characteristics of the litter and soil layer could not give sufficient explanation (due to low eigenvalues) these conclusions still remain hypothetical and should be discussed more in detail in future when more information of other parameters becomes available.

Conclusions

We can conclude that the composition of soil-inhabiting spider communities on a Flemish scale seems to differ according to the soil type on which the forest is situated. They differ from nutrient-poor sandy and nutrient-richer sandy loam/loam soils. Other parameters which need further envestigation than these obtained from soil and litter seem to be responsible for the difference in species abundance. On a subregional scale, in forests which are situated on the same soil type, spider communities seem to vary mainly with the chemical and physical properties of the litter layer. That means that they are good indicators for the rate of litter breakdown. These first results indicate that, in the future, probably we will have to create two separate indicator-systems for the two most important soil types in Flanders. It will also be possible to evaluate forest soil quality on the basis of the spider communities if several types of forests on a same soil type are investigated. The low eigenvalues of certain analyses contradict these results. In the future the same analyses will be performed with a more complete set of parameters (structural, biotic and abiotic characters) to give a clearer understanding of why these forests separate and to give a better indication of soil quality and the use of spiders as bio-indicators in forests.

Acknowledgements

I (D. De Bakker) thank the Administration responsible for the Flemish Forests (AMINAL) for the great opportunity to work in the forests of Flanders. Konjev Desender, Dries Bonte, Shirley Gurdebeke and Bart Neirynck are acknowledged for all their help in this large project. Also acknowledged are the forest-engineers and technicians of the Institute of Forestry and Game Management (IBW) for their enormous help (providing abiotic data concerning the soil and litter layer, maps,…) and especially Ir. Kris Vandekerkhove and Ir. Diego Van Den Meersschaut. This project was funded by the Flemish Government responsible for the Flemish Forests (AMINAL, no. B&G/15/96 and continuing in project no. B&G/29/98).

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