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The impact of spontaneous and induced afforestation on spider diversity in the 'Voeren'-region

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Summary

The effect of conversion of former arable lands with different historical use (grasslands versus arable lands) on spider diversity and composition was evaluated using several sampling techniques in the 'Voeren' region. More than 16000 adult spiders were caught belonging to 201 species. One species out of five is represented on the red list of spiders of Flanders making the region very interesting and vulnerable. Analysis of the diversity reveals the importance of forest expansion treatment. Ancient forest sites and old spontaneous afforestation/plantations sites share more common species than with younger sites. We found no significant differences between intensively used arable lands and extensively used grasslands. The choice of a certain silvicultural practice in achieving an extension of forest cover depends highly on the demands of the policy makers in which nature restoration is primordial.

Résumé

L'extension des forêts dans la région des Fourons (ce sont soit des plantations, soit des forêts à développement spontané) a été évaluée par l'étude de la diversité des araignées. Plus de 16.000 spécimens ont été capturés et 201 espèces ont été recensées. Une espèce sur cinq est reprise dans la Liste Rouge de la Flandre, ce qui reflète la valeur biologique de cette région et révèle son intérêt. L'analyse de la diversité en araignées démontre l'importance de la politique d'extension des forêts. Les vieux bois et les anciennes plantations à développement spontané possèdent plus d'espèces en commun que les peuplements plus jeunes. Toutefois, aucune différence significative n'a été observée entre les terres intensivement labourées par le passé et les pâturages anciens. Les mesures de gestion à prendre en vue de favoriser l'extension des forêts dépendent de la politique à mener pour revaloriser la nature au niveau régional.

Samenvatting

Bosuitbreiding (spontane ontwikkeling versus aanplantingen) in de Voeren regio werd geëvalueerd aan de hand van de diversiteit en het voorkomen van spinnen. Meer dan 16000 volwassen spinnen en 201 soorten werden gevangen. Eén soort op vijf is aanwezig op de Rode Lijst van spinnen in Vlaanderen wat deze regio zeer interessant en waardevol maakt. Analyse van de diversiteit onthult het belang van de gevoerde bosuitbreidingspolitiek. Oude bossites en oude spontaan geëvolueerde verbossingen en aanplantingen delen meer gemeenschappelijke soorten dan dat ze dit met jonge sites doen. Er werden geen significante verschillen waargenomen tussen voormalig intensief bewerkt akkerland en extensief gebruikte graslanden. Het gebruik van één of ander bosbeheersmaatregel met het oog op bosuitbreiding is afhankelijk van de gevoerde politiek waarin natuurherstel moet primeren.

Key words: spiders, afforestation, Araneae, Flanders, Voeren, diversity.

Introduction

The effect of afforestation (either spontaneously or man-induced (plantations)) on arthropod biodiversity has never been investigated before in Belgium and even literature in other European countries are scarce (PAJUNEN *et al.*, 1995; FINCH, 2005; OXBROUGH *et al.*, 2005). Belgium (and Flanders in particular) is poorly forested; less than 7% of the area in Flanders is covered with little, often fragmented and disturbed forests (DUMORTIER *et al.*, 2003). An agreement on the future increase of forest cover as a result of conversion of former arable lands was implemented by the governments (for a good theoretical background of the conversion policy see DEKONINCK *et al.* 2005, this volume). This is the first attempt to evaluate the effect of both silvicultural practices on spider diversity and to compare communities found in these recent forests with those in nearby ancient forests (i.e. sites that were already forest since 1778).

Material and Methods

A total of 15 sites belonging to 3 forest complexes were sampled using several sampling techniques including pitfall trapping, Malaise traps and white pan traps. All traps were filled with a 4% formaldehyde solution as killing and preservative agent together with some detergent to reduce surface tension. More details on the used sampling techniques, sampling dates and characterisation of the chosen sites in 3 forest complexes (Altenbroek, Alserbos and Veursbos) are discussed in detail in DEKONINCK *et al.* (2005, this volume). All analyses (except when stipulated) are based on data from the 3 pitfalls in each site which were emptied each fortnight from begin April until begin October.

Results and Discussion

General diversity and Red list species

A total of 16 053 adult spiders were caught during the sampling campaign belonging to 201 species covering all

Table 1 — List of all caught spider species with their numbers per site. Families are ordered according to PLATNICK, 2005.

Species	Voer 1	Voer 2	Voer 3	Voer 4	Voer 5	Voer 6	Voer 7	Voer 8	Voer 9	Voer 10	Voer 11	Voer 12	Voer 13	Voer 14	Voer 15	Total
Family Segestriidae																
Segestria senoculata (LINNAEUS, 1758)												1				1
Family Dysderidae																
Harpactea hombergi (SCOPOLI, 1763)	1															1
Family Mimetidae																
Ero cambridgei KULCZYNSKI, 1911											1					1
Ero furcata (VILLERS, 1789)	1						1		3	1	2		1			9
Family Theridiidae																
Achaearanea simulans (THORELL, 1875)							1	2	1		1					5
Anelosimus vittatus (C.L. KOCH, 1836)			1	1			1									3
Enoplognatha latimana HIPPA & OKSALA, 1982		4	1	8				1								14
Enoplognatha ovata (CLERCK, 1757)	16	1	1		38	2	9	17	6	5	8	5		5		113
Episinus angulatus (BLACKWALL, 1836)							1	2	1					1		5
Keijia tincta (WALCKENAER, 1802)	2						1									3
Neottiura bimaculata (LINNAEUS, 1767)										4						4
Paidiscura pallens (BLACKWALL, 1834)	2				1			1	1	2						7
Robertus lividus (BLACKWALL, 1836)				1	7			1	10	4	1				3	27
Robertus neglectus (O.P.-CAMBRIDGE, 1871)								1								1
Theridion impressum L. KOCH, 1881							1									1
Theridion mystaceum L. KOCH, 1870	2						1					1				4
Theridion varians HAHN, 1833	1	1			2				1	4	1	2				12
Family Anapidae																
Comaroma simoni BERTKAU, 1889													1			1
Family Linyphiidae																
Agyneta cauta (O.P.-CAMBRIDGE, 1902)											1					1
Agyneta decora (O.P.-CAMBRIDGE, 1870)	1	45	29	1			1				4					81
Asthenargus paganus (SIMON, 1884)	1						1								8	10
Bathyphantes gracilis (BLACKWALL, 1841)		40	40	48	3	7	3	1			3	2	9	6		162
Bathyphantes parvulus (WESTRING, 1851)						1				12	2					15
Centromerita bicolor (BLACKWALL, 1833)		2	5	1												8
Centromerus brevivulvatus DAHL, 1912	6						8									14
Centromerus leruthi FAGE, 1933		1					2									3
Centromerus sylvaticus (BLACKWALL, 1841)	7			2			1	1	2	4	4	3	9	9	2	44
Ceratinella brevipes (WESTRING, 1851)				1									3	7		11
Ceratinella brevis (WIDER, 1834)	9							2	26	50	15	11		4		117
Ceratinella scabrosa (O.P.-CAMBRIDGE, 1871)				1		3	1	5	20					3		33
Cnephalocotes obscurus (BLACKWALL, 1834)				2						1						3
Collinsia inerrans (O.P.-CAMBRIDGE, 1885)		41	34	1								1		1		78
Dicymbium nigrum (BLACKWALL, 1834)		15	17	2				2		2	5					43
Dicymbium nigrum brevisetosum LOCKET, 1962		10	25	4												39
Dicymbium tibiale (BLACKWALL, 1836)		75	68	17		2	1	29	34	6	79	1	42	64	1	419
Diplocephalus latifrons (O.P.-CAMBRIDGE, 1863)					4	3	5	91	179		74	2	16	42		416
Diplocephalus picinus (BLACKWALL, 1841)	2			1		34	101		1			1	29	23	3	195
Diplostyla concolor (WIDER, 1834)		20	17	45		38		4	54	10	61	73	93	22		437
Dismodicus bifrons (BLACKWALL, 1841)		5	7	18	1		2	1	1		2	1				38
Drapetisca socialis (SUNDEVALL, 1832)	1				1		1		2		4	1				10

Species	Voer 1	Voer 2	Voer 3	Voer 4	Voer 5	Voer 6	Voer 7	Voer 8	Voer 9	Voer 10	Voer 11	Voer 12	Voer 13	Voer 14	Voer 15	Total
Entelecara erythropus (WESTRING, 1851)									3							3
Eperigone trilobata (EMERTON, 1882)		1														1
Erigone atra (BLACKWALL, 1841)	3	264	140	91	14	2	1	2	6	11	5	8	11	10		568
Erigone dentipalpis (WIDER, 1834)		62	21	5	1		1			1	1	1				93
Floronia bucculenta (CLERCK, 1757)				1			1	1	2	1	2					8
Gnathonarium dentatum (WIDER, 1834)													1			1
Gonatium rubellum (BLACKWALL, 1841)							15								1	16
Gonatium rubens (BLACKWALL, 1833)							3		1							4
Gongylidiellum latebricola (O.P.-CAMBRIDGE, 1871)				2	4			3	1	7	4	3				24
Gongylidiellum vivum (O.P.-CAMBRIDGE, 1875)	1	32	19	21	2		1	1	3	6	1	1				88
Gongylidium rufipes (SUNDEVALL, 1829)				3	10		3		6				1	4		27
Helophora insignis (BLACKWALL, 1841)													1			1
Lepthyphantes leprosus (OHLERT, 1865)	1														1	2
Leptorhoptrum robustum (WESTRING, 1851)		30	27	14												71
Linyphia hortensis SUNDEVALL, 1829	7				1		9	6	5		7	4	3	1	12	55
Linyphia triangularis (CLERCK, 1757)	11			3	11		22	17	22	1	15	5	1	1	1	110
Macrargus rufus (WIDER, 1834)	12						2	1					1	6	7	29
Maso sundevalli (WESTRING, 1851)	2					7	13				1	2	1	2	1	29
Meioneta rurestris (C.L. KOCH, 1836)		1						1			1					3
Meioneta saxatilis (BLACKWALL, 1844)	4						35	1	1	111	5	9	20	5		191
Micrargus herbigradus (BLACKWALL, 1854)	22	2	5	1	2	19	25	7	10	19	25	16	26	26	16	221
Micrargus subaequalis (WESTRING, 1851)		10	5													15
Microneta viaria (BLACKWALL, 1841)	13				1			2		3	4	7	1		13	44
Minyriolus pusillus (WIDER, 1834)									1		1					2
Monocephalus fuscipes (BLACKWALL, 1836)				2	61	1	6	32	28		27		45	12		214
Neriene clathrata (SUNDEVALL, 1829)	7			1	1	1	5	1	5	1	3	2	3	2		32
Neriene montana (CLERCK, 1757)							1	1	3			1				6
Neriene peltata (WIDER, 1834)							1	1	1			3		1		7
Obscuriphantes obscurus (BLACKWALL, 1841)								1								1
Oedothorax fuscus (BLACKWALL, 1834)	1	63	107	22	10	2	4	3	3	2	2	6	15	3		243
Oedothorax retusus (WESTRING, 1851)		860	144	107	2			1		1		1	1	1		1118
Palliduphantes ericaeus (BLACKWALL, 1853)								2	1	3	4	1				11
Palliduphantes pallidus (O.P.-CAMBRIDGE, 1871)	3		1	2	1	1		1	9	3	3	3	1	6	1	35
Pelecopsis radicicola (L. KOCH, 1875)		1					2	7	8				7	11		36
Pocadicnemis juncea LOCKET & MILLIDGE, 1953			1	3						6		1				11
Pocadicnemis pumila (BLACKWALL, 1841)	2	1	1	2			1		4			1	2			14
Porrhomma convexum (WESTRING, 1861)										1						1
Porrhomma egeria SIMON, 1884	1		1									4			1	7
Porrhomma microphthalmum (O.P.-CAMBRIDGE, 1871)			1													1
Porrhomma pallidum JACKSON, 1913													1	2	1	4
Prinerigone vagans AUDOUIN, 1826													1			1
Saaristoa abnormis (BLACKWALL, 1841)	8				7	1	2	8	9	8	7	8	1		9	68
Stemonyphantes lineatus (LINNAEUS, 1758)										4						4
Tallusia experta (O.P.-CAMBRIDGE, 1871)	1															1
Tapinocyba insecta (L. KOCH, 1869)								2	3							5
Tapinopa longidens (WIDER, 1834)							1							1		2

Species	Voer 1	Voer 2	Voer 3	Voer 4	Voer 5	Voer 6	Voer 7	Voer 8	Voer 9	Voer 10	Voer 11	Voer 12	Voer 13	Voer 14	Voer 15	Total
Tenuiphantes alacris (BLACKWALL, 1853)									4	1						5
Tenuiphantes cristatus (MENGE, 1866)						2	1	3	8		10	1				25
Tenuiphantes flavipes (BLACKWALL, 1854)	146	4	1	1	9	58	125	82	23	1	25	91	12	12	22	612
Tenuiphantes mengei (KULCZYNSKI, 1887)	5		1			1	2	23	58	36	8	4				138
Tenuiphantes tenebricola (WIDER, 1834)	1						2	11	31		19	2	1	7	18	92
Tenuiphantes tenuis (BLACKWALL, 1852)	1	9	5	8	3	3	1	18	6	5	7	6	7	7		86
Tenuiphantes zimmermanni (BERTKAU, 1890)	15			1	1	17	51	81	26	1	49	10	10	16		278
Tiso vagans (BLACKWALL, 1834)		4	1	4							1					10
Trematocephalus cristatus (WIDER, 1834)					1					2	1					4
Troxochrus scabriculus (WESTRING, 1851)		4	3	122												129
Walckenaeria acuminata BLACKWALL, 1833					3			6	5	4	4	1			1	24
Walckenaeria antica (WIDER, 1834)										2						2
Walckenaeria atrotibialis (O.P.-CAMBRIDGE, 1878)		1	1	1	5			4	3	6	3		1			25
Walckenaeria corniculans (O.P.-CAMBRIDGE, 1875)	5														3	8
Walckenaeria cucullata (C.L. KOCH, 1836)						1	1									2
Walckenaeria cuspidata (BLACKWALL, 1833)		1							3							4
Walckenaeria dysderoides (WIDER, 1834)													1	3		4
Walckenaeria furcillata (MENGE, 1869)	6				1									1	4	12
Walckenaeria mitrata (MENGE, 1868)						1	1									2
Walckenaeria monoceros (WIDER, 1834)						1									1	2
Walckenaeria nudipalpis (WESTRING, 1851)					3						7					10
Walckenaeria vigilax (BLACKWALL, 1833)		1														1
Family Tetragnathidae																
Metellina mengei (BLACKWALL, 1869)	15				2		44	14	27	6	32	8	2	1	6	157
Metellina merianae (SCOPOLI, 1773)														1		1
Metellina segmentata (CLERCK, 1757)	6		1		1			3	2		2	1	3	1		20
Pachygnatha clercki SUNDEVALL, 1823	1	59	176	68								1	1			306
Pachygnatha degeeri SUNDEVALL, 1830	4	13	148	2	1				1	74			2	1		246
Pachygnatha listeri SUNDEVALL, 1830															1	1
Tetragnatha montana SIMON, 1874	1				5		2	2	7	2	9	5				33
Tetragnatha nigrita LENDL, 1886															1	1
Tetragnatha pinicola L. KOCH, 1870			1													1
Family Araneidae																
Araneus diadematus CLERCK, 1757	3		2	3	3		6		3	4	9	7				40
Araneus quadratus CLERCK, 1757			6													6
Araneus triguttatus (FABRICIUS, 1757)	1															1
Araniella cucurbitina (CLERCK, 1757)					3						1					4
Araniella opistographa (KULCZYNSKI, 1905)	1		1									2				4
Argiope bruennichi (SCOPOLI, 1772)		3	16													19
Larinioides cornutus (CLERCK, 1757)		1	5	1												7
Mangora acalypha (WALCKENAER, 1802)		2														2
Zygiella atrica (C.L. KOCH, 1845)			1													1
Family Lycosidae																
Alopecosa cuneata (CLERCK, 1757)		3	20													23
Alopecosa pulverulenta (CLERCK, 1757)	1	46	255	16				8	4	72		4		1		407
Arctosa leopardus (SUNDEVALL, 1833)		1	8	1												10

Species	Voer 1	Voer 2	Voer 3	Voer 4	Voer 5	Voer 6	Voer 7	Voer 8	Voer 9	Voer 10	Voer 11	Voer 12	Voer 13	Voer 14	Voer 15	Total
Aulonia albimana (WALCKENAER, 1805)	3									51						54
Pardosa amentata (CLERCK, 1757)	55	465	549	1206	145	2		252	16	3	3	141	12	40	2	2891
Pardosa hortensis (THORELL, 1872)	2															2
Pardosa lugubris (WALCKENAER, 1802)	44	3	31	1	10		13	21	31	9	36	13	4	7	1	224
Pardosa nigriceps (THORELL, 1856)		6	13							3	1	2				25
Pardosa palustris (LINNAEUS, 1758)		29	725	2									2			758
Pardosa prativaga (L. KOCH, 1870)		6	4													10
Pardosa proxima (C.L. KOCH, 1847)			7													7
Pardosa pullata (CLERCK, 1757)	1	149	232	6				1		73	1	5				468
Pardosa saltans TPFER-HOFMANN, 2000	40				2			1	2	8	10	1	1	2	1	68
Pirata hygrophilus THORELL, 1872		1	1							1			1			4
Pirata latitans (BLACKWALL, 1841)		156	52	33				1		34		1				277
Pirata uliginosus (THORELL, 1872)		1		1			4	10	10	26	40	9		5		106
Trochosa ruricola (DEGEER, 1778)		11	26	1										1		39
Trochosa terricola THORELL, 1856	3	16	21	5	2		4	18	21	49	16	38	7	10		210
Family Pisauridae																
Pisaura mirabilis (CLERCK, 1757)		4		15	2					3		1				25
Family Zoridae																
Zora spinimana (SUNDEVALL, 1833)					1		1	1		29	2	3				37
Family Agelenidae																
Histopona torpida (C.L. KOCH, 1834)	85	5			3	7	30		3	4		7	21	32	124	321
Tegenaria picta SIMON, 1870	8						3			14	1			2	3	31
Family Hahniidae																
Hahnia candida SIMON, 1875															1	1
Hahnia helveola SIMON, 1875															2	2
Hahnia montana (BLACKWALL, 1841)	2	1				2	3								11	19
Hahnia nava (BLACKWALL, 1841)	2															2
Hahnia ononidum SIMON, 1875															7	7
Hahnia pusilla C.L. KOCH, 1841	19	1				8	12						5	2	77	124
Family Dictynidae																
Cicurina cicur (FABRICIUS, 1793)									1	1		4	1		1	8
Lathys humilis (BLACKWALL, 1855)							2									2
Nigma flavescens (WALCKENAER, 1825)	4						1			1						6
Family Amaurobiidae																
Eurocoelotes inermis (L. KOCH, 1855)	8				3	3	18		1		3	1	14	9	11	71
Coelotes terrestris (WIDER, 1834)	63		1	1	6	35	40	2	36	6	1	12	67	83	105	458
Family Anyphaenidae																
Anyphaena accentuata (WALCKENAER, 1802)	12			1	16		9	2	2	1		11		1		55
Family Liocranidae																
Agroeca brunnea (BLACKWALL, 1833)	8				5	1	2	5	7	5	14	20		1		68
Agroeca cuprea MENGE, 1873												2				2
Apostenus fuscus WESTRING, 1851	4	1					8						1	1	22	37
Phrurolithus festivus (C.L. KOCH, 1835)										16		1				17
Family Clubionidae																
Clubiona brevipes BLACKWALL, 1841	2						5	1				1				9
Clubiona comta C.L. KOCH, 1839	4				17		17		2	4	1	26	1	6	4	82

Species	Voer 1	Voer 2	Voer 3	Voer 4	Voer 5	Voer 6	Voer 7	Voer 8	Voer 9	Voer 10	Voer 11	Voer 12	Voer 13	Voer 14	Voer 15	Total
Clubiona corticalis (WALCKENAER, 1802)	1															1
Clubiona diversa O.P.-CAMBRIDGE, 1862										18						18
Clubiona lutescens WESTRING, 1851	4	1	3	1	5		6	18	35	7	18	11	3	3		115
Clubiona neglecta O.P.-CAMBRIDGE, 1862		1	7							5						13
Clubiona pallidula (CLERCK, 1757)	4				1		1	1		5	1	17	1			31
Clubiona phragmitis C.L. KOCH, 1843							1									1
Clubiona reclusa O.P.-CAMBRIDGE, 1863		39	41	15	7	1		5	3	5	3					119
Clubiona terrestris WESTRING, 1862	20		2	2	7	2	5		2	4		6		1	3	54
Family Corinnidae																
Cetonana laticeps (CANESTRINI, 1868)	3															3
Family Gnaphosidae																
Drassodes cupreus (BLACKWALL, 1834)										4		1				5
Drassyllus pusillus (C.L. KOCH, 1833)		4	2	1				1		1						9
Haplodrassus silvestris (BLACKWALL,1833)	1									1						2
Micaria pulicaria (SUNDEVALL, 1831)		1														1
Trachyzelotes pedestris (C.L. KOCH, 1837)		1								1			1			3
Zelotes latreillei (SIMON, 1878)										8						8
Zelotes subterraneus (C.L. KOCH, 1833)				1	1					1						3
Family Philodromidae																
Philodromus albidus KULCZYNSKI, 1911	2											1				3
Philodromus aureolus (CLERCK, 1757)												1				1
Philodromus cespitum (WALCKENAER, 1802)		1								1						2
Philodromus dispar WALCKENAER, 1825	2				1		11					5				19
Philodromus praedatus O.P.-CAMBRIDGE, 1871	1															1
Family Thomisidae																
Ozyptila praticola (C.L. KOCH, 1837)	20	1		1	2	1	29	7	27		19	10	6	15		138
Ozyptila simplex (O.P.-CAMBRIDGE, 1862)			1													1
Ozyptila trux (BLACKWALL, 1846)			1	1			1	5	1	1		5	10	14	2	41
Xysticus acerbus THORELL, 1872		2														2
Xysticus audax (SCHRANK, 1803)		3	5													8
Xysticus cristatus (CLERCK, 1757)		52	109	40				1		1		1				204
Xysticus ferrugineus MENGE, 1875		1	6													7
Xysticus kochi THORELL, 1872		6	28	2												36
Xysticus lanio C.L. KOCH, 1824	8	1	2	2	4		7	2		3	1	4		1	1	36
Xysticus ulmi (HAHN, 1832)	2	5	3	20							2	1				33
Family Salticidae																
Ballus chalybeius WALCKENAER, 1802	1										1			1		3
Euophrys frontalis (WALCKENAER, 1802)					1				2	2	1					6
Neon reticulatus (BLACKWALL, 1853)										2					1	3
Synageles venator (LUCAS, 1836)		9	4	1												14
Total	801	2722	3246	2021	467	270	766	873	890	921	748	697	545	569	517	16053
Number of species	80	72	70	68	58	34	78	71	73	84	74	81	58	61	45	201

sampling techniques (for a complete list of the captured spiders in all sites, see Table 1). This is about one third of the total number of known species in Belgium, which is estimated at 701 species (BLICK *et al.*, 2004). If we look at the capture-rate between sampling techniques, we see that pitfall trapping is the most effective method of catching epigaeic spiders. Nevertheless, it is clear from the amount of species that is exclusively caught with the other techniques (white water pans 32% and Malaise traps 16% of all species) that the use of multiple sampling techniques is recommended in inventory-based samplings (Fig. 1). If we have a closer look at these species, we see that these are mainly species that inhabit higher strata (herbs, schrubs, trees) and which are often rarely caught with pitfall traps.

A total of 41 species (= 20.4% of all the catches) are mentioned on the Red list of spiders of Flanders (MAELFAIT *et al.*, 1998, Table 2). Among these, the capture of *Cetonana laticeps* is remarkable. This is the first corinnid spider even found in our country. The biology and distribution in Europe of this rarely caught species is further discussed in DEKONINCK *et al.* (2005). Furthermore, the anapid *Comaroma simoni* was also caught which is only known from a few localities, all situated in the southern part of Belgium despite intensive large sampling campaigns in Flanders in the past. Only recently the first males of this species could be recorded for our country (KEKENBOSCH, pers. comm.). The presence of some rare species like the wolf spiders *Aulonia albimana* and *Pirata uliginosus* and the crab spider *Xysticus robustus* (critically endangered with extinction in Flanders), indicates that the region holds a lot of potential for spiders. Also, the presence of the flamboyant spider *Argiope bruennichi* which is in serious expansion in the whole region (BOSMANS, 2002), is promising although expected.

For the analyses discussed further, we excluded the spider data from white water pans and Malaise traps. Furthermore, for our own convenience, we grouped species together according to their preference for either forests (without distinction between dry, wet and/or marshy forests) or open landscapes (e.g. all kinds of grasslands, heathland) since this is the most important issue in the goals of the project (Fig. 2).

We observe indeed that the ancient forest sites (OF-sites) in all forest complexes harbour species which are abundant in forested sites. The plantation site in Alten-

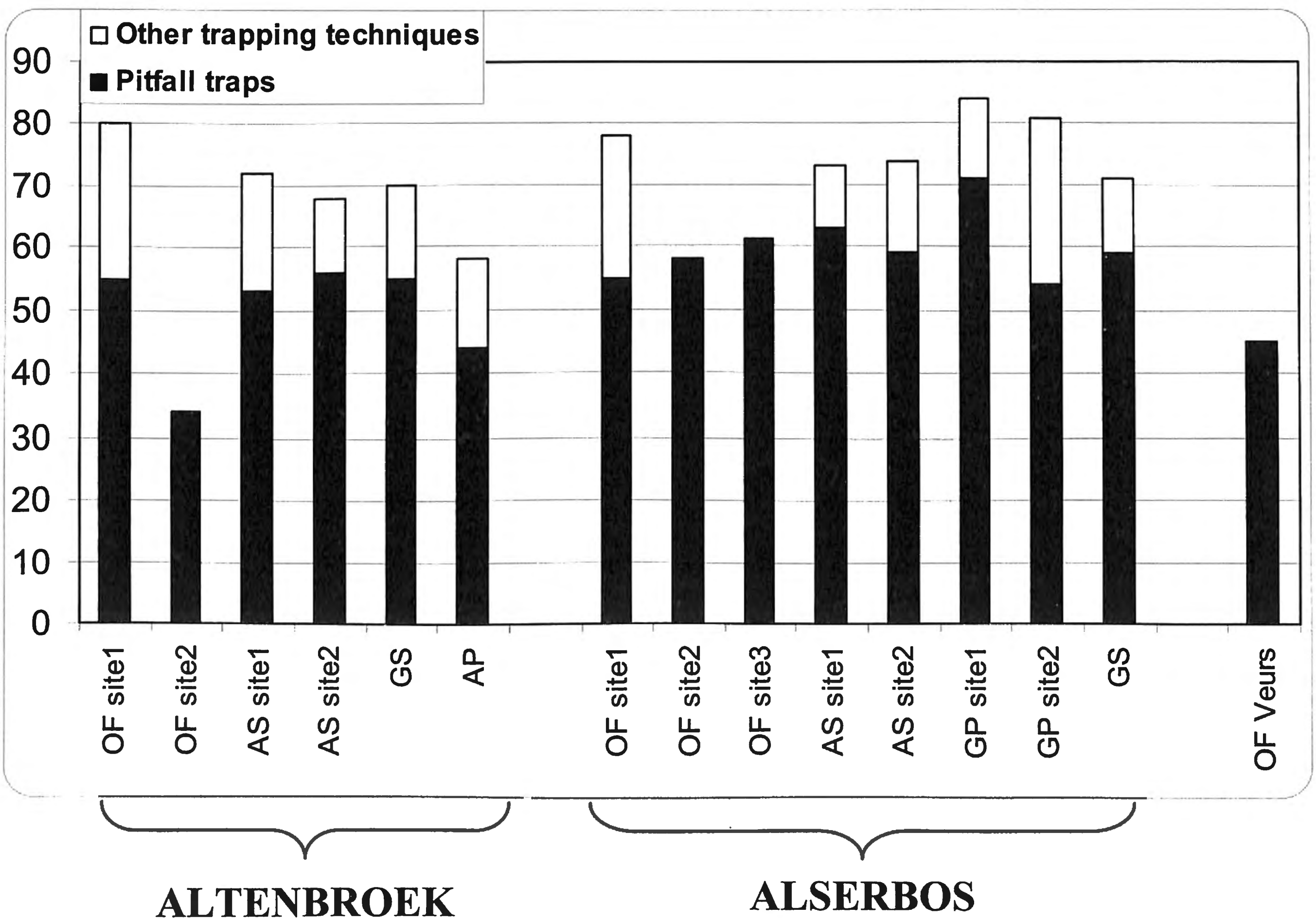


Fig. 1 — Number of found species in each site indicating the number of species caught exclusively with pitfall traps and with the other trap techniques used (white water pans and Malaise traps). Used abbreviations are explained as follows: OF= Ancient forest, AP= Arable land, plantation, AS= Arable land, spontaneous development, GS= Grassland, spontaneous development, GP= Grassland, plantation.

Table 2 — List of all caught Red list species with indication of their Red list status and habitat specificity (after MAELFAIT *et al.*, 1998).

Red list species	**Red list Category**	**Preferential habitat**	**Voer 1**	**Voer 2**	**Voer 3**	**Voer 4**	**Voer 5**	**Voer 6**	**Voer 7**	**Voer 8**	**Voer 9**	**Voer 10**	**Voer 11**	**Voer 12**	**Voer 13**	**Voer 14**	**Voer 15**	**Total**
Agroeca cuprea MENGE, 1873	Endangered	Dry oligotrophic grasslands with tussocks												2				2
Agyneta cauta (O.P.-CAMBRIDGE, 1902)	Endangered	Wet open deciduous forests											1					1
Alopecosa cuneata (CLERCK, 1757)	Vulnerable	Dry oligotrophic grasslands with bare ground		3	20													23
Apostenus fuscus WESTRING, 1851	Endangered	Dry deciduous forests with large amounts of dead wood	4	1					8						1	1	22	37
Arctosa leopardus (SUNDEVALL, 1833)	Vulnerable	Wet oligotrophic grasslands with tussocks		1	8	1												10
Argiope bruennichi (SCOPOLI, 1772)	Geographically restricted	Northern limit of distribution		3	16													19
Asthenargus paganus (SIMON, 1884)	Indeterminate		1						1								8	10
Aulonia albimana (WALCKENAER, 1805)	Extinct	Dry oligotrophic grasslands with rough vegetation	3									51						54
Centromerus leruthi FAGE, 1933	Geographically restricted	Northern limit of distribution		1					2									3
Cetonana laticeps (CANESTRINI, 1868)	Indeterminate	New for Belgium	3															3
Coelotes terrestris (WIDER, 1834)	Vulnerable	Dry deciduous forests with large amounts of dead wood	63		1	1	6	35	40	2	36	6	1	12	67	83	105	458
Comaroma simoni BERTKAU, 1889	Indeterminate	New for Flanders!													1			1
Eperigone trilobata (EMERTON, 1882)	Indeterminate	Exotic species		1														1
Eurocoelotes inermis (L. KOCH, 1855)	Vulnerable	Dry deciduous forests with large amounts of dead wood	8				3	3	18		1		3	1	14	9	11	71
Hahnia candida SIMON, 1875	Geographically restricted	Northern limit of distribution															1	1
Hahnia helveola SIMON, 1875	Vulnerable	Dry deciduous forests with large amounts of dead wood															2	2
Hahnia nava (BLACKWALL, 1841)	Endangered	Dry oligotrophic grasslands with rough vegetation	2															2
Hahnia ononidum SIMON, 1875	Indeterminate																7	7
Hahnia pusilla C.L. KOCH, 1841	Indeterminate		19	1				8	12						5	2	77	124
Haplodrassus silvestris (BLACKWALL,1833)	Endangered	Dry deciduous forests with large amounts of dead wood	1									1						2
Harpactea hombergi (SCOPOLI, 1763)	Endangered	Dry deciduous forests with large amounts of dead wood	1															1
Histopona torpida (C.L. KOCH, 1834)	Geographically restricted	Northern limit of distribution	85	5			3	7	30		3	4		7	21	32	124	321
Leptorhoptrum robustum (WESTRING, 1851)	Vulnerable	Riparian habitat with patches of bare ground		30	27	14												71
Pachygnatha listeri SUNDEVALL, 1830	Vulnerable	Open marsh-like forests															1	1
Pardosa hortensis (THORELL, 1872)	Geographically restricted	Northern limit of distribution	2															2
Pardosa lugubris (WALCKENAER, 1802)	Vulnerable	Verges of dry deciduous forests	44	3	31	1	10		13	21	31	9	36	13	4	7	1	224
Pardosa prativaga (L. KOCH, 1870)	Vulnerable	Mires with sedges (*Carex* sp.)	.	6	4													10
Pardosa proxima (C.L. KOCH, 1847)	Geographically restricted	Northern limit of distribution			7													7
Pardosa saltans TÖPFER-HOFMANN, 2000	Vulnerable	Verges of dry deciduous forests	40				2			1	2	8	10	1	1	2	1	68
Pelecopsis radicicola (L. KOCH, 1875)	Indeterminate			1					2	7	8				7	11		36
Philodromus albidus KULCZYNSKI, 1911	Endangered	Verges of dry deciduous forests	2											1				3
Philodromus praedatus O.P.-CAMBRIDGE, 1871	Endangered	Verges of dry deciduous forests	1															1
Pirata uliginosus (THORELL, 1872)	Critical	Wet heathland with vegetation of sedges (*Carex* sp.)		1		1			4	10	10	26	40	9		5		106
Robertus neglectus (O.P.-CAMBRIDGE, 1871)	Vulnerable	Verges of wet deciduous forests								1								1
Trachyzelotes pedestris (C.L. KOCH, 1837)	Endangered	Dry oligotrophic grasslands with tussocks		1								1			1			3
Trematocephalus cristatus (WIDER, 1834)	Vulnerable	Verges of dry deciduous forests					1					2	1					4
Walckenaeria corniculans (O.P.-CAMBRIDGE, 1875)	Vulnerable	Wet open deciduous forests	5														3	8
Walckenaeria mitrata (MENGE, 1868)	Endangered	Dry deciduous forests with large amounts of dead wood						1	1									2
Xysticus acerbus THORELL, 1872	Critical	Dry heathland with patches of bare ground		2														2
Xysticus ferrugineus MENGE, 1875	Geographically restricted	Northern limit of distribution		1	6													7
Zygiella atrica (C.L. KOCH, 1845)	Indeterminate				1													1
Number of Red list species			**17**	**16**	**10**	**5**	**6**	**5**	**11**	**6**	**7**	**9**	**7**	**8**	**10**	**9**	**13**	**41**

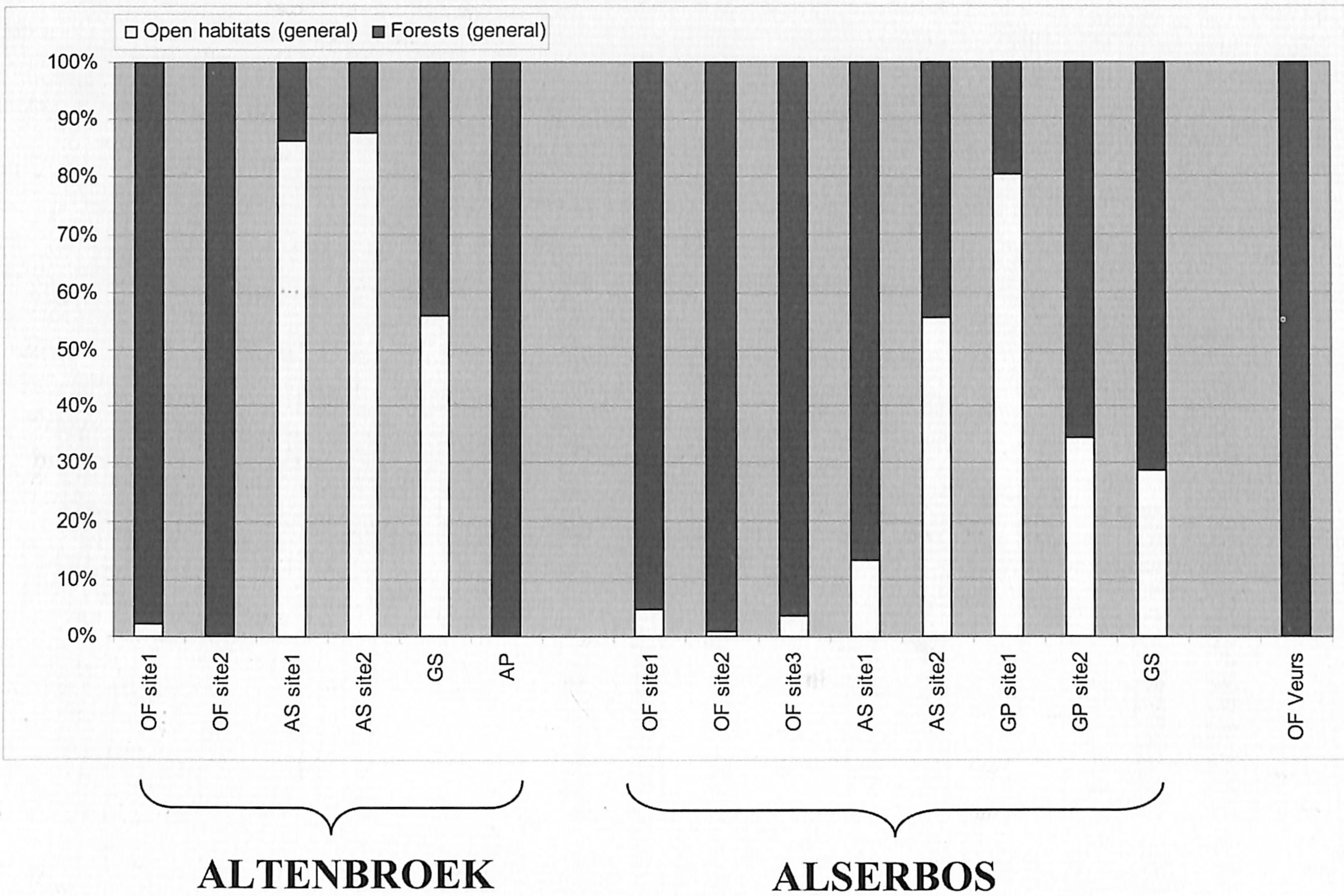


Fig. 2 — Relative percentage of the occurrence of Red list species per site indicated by their habitat specificity. Used abbreviations are explained as follows: OF= Ancient forest, AP= Arable land, plantation, AS= Arable land, spontaneous development, GS= Grassland, spontaneous development, GP= Grassland, plantation.

broek (AP) has even no open landscape species in contrast with the spontaneous developing sites (AS and GS-sites). For the Alserbos, the case is somewhat different, but nevertheless similar. Some spontaneous developing sites in this complex also display a high amount of forest species and this is due to the longer abandonment of the sites making it possible for forest species to migrate into these habitats if the right conditions are met. On the other hand, even young plantations (GP site 1) still do not harbour a forest fauna directly. This is a special case in the Alserbos in this matter that this site still displays an open structure on nutrient poor soil indicated by the presence of heath (*Calluna vulgaris*). This is clearly illustrated by the presence of *Pirata uliginosus*, a species indicative for wet heathland, which is present in high numbers in almost all sites of the Alserbos. This might be an indication the former land use was rather extensive, since agricultural activities did not have a serious effect on the survival and presence of this species unless the species should have survived in small remaining remnants. This species is, strangely enough, not recorded for the 'Altenbroek' area. The fact that the old plantation sites of the 'Altenbroek' is characterized by species of 'ancient' forests is a clear evidence that afforestation due to the plantation of trees rapidly (positively) effects species composition resulting in a higher degree of forest species. The younger afforested sites in this forest have a more heterogeneous composition while the sites in the Alserbos already display a more developed forest fauna since these sites were already longer abandoned or planted (20-25 years).

As a conclusion, we can state that the observed general patterns on spider diversity and composition are not a reflection of the former (arable) land use. Like in the ancient forests, all older plantations and/or spontaneously afforested sites already display a higher amount of species typical for old forest sites compared to young sites. This evolution takes place in a short time span as can be seen at the sites of Altenbroek and Alserbos which only differ in a restoration time of 10 years, but which differ already significantly in the number of typical eurytopic forest species. This is congruent with earlier, large scale research in forests all over Flanders which showed that older forest sites have indeed a lower diversity on spiders, but have a higher amount of eurytopic forest species (De Bakker *et al.*, 2000).

For each site, the Shannon-Wiener diversity index was calculated. As we can see in Fig. 3, no clear differences can be observed between and within forest sites and between young and older sites and between spontaneous and induced afforestation sites.

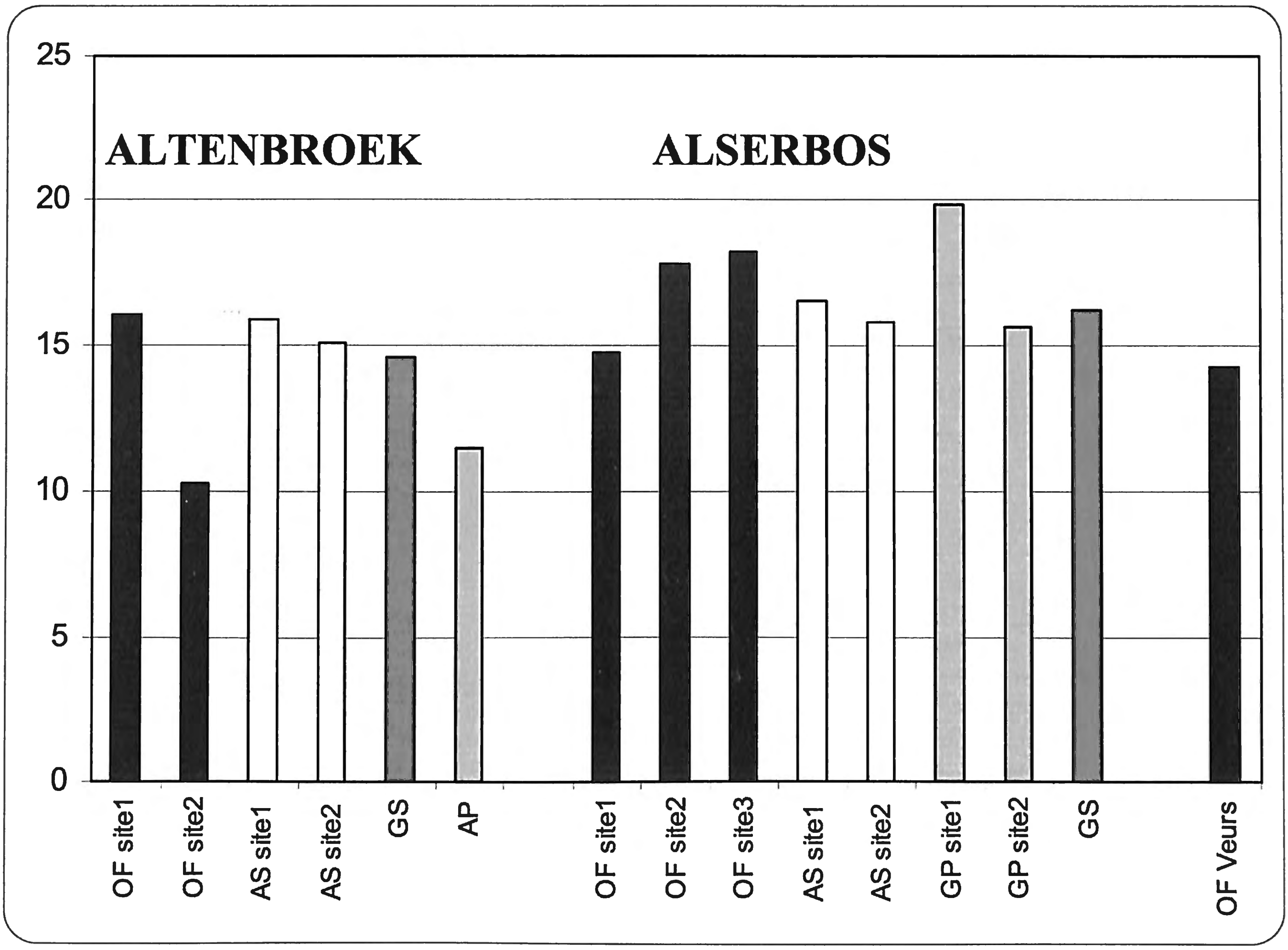


Fig. 3 — Value of Shannon-Wiener diversity index per site. Used abbreviations are explained as follows: OF= Ancient forest, AP= Arable land, plantation, AS= Arable land, spontaneous development, GS= Grassland, spontaneous development, GP= Grassland, plantation.

This is even better illustrated when we calculate the mean average indices for the concerning sites and situations. No clear differences can be observed between the mean Shannon-Wiener diversity index of the ancient forests (n=6, H=15.2), spontaneous afforestation sites (n=6, H=15.73) and that of the plantations (n=3, H=15.65). We see that the spontaneous afforestation sites have the highest species richness, (without being significantly higher than the other situations). This could indicate that although different biotopes display a different fauna, this is not reflected in a biased (lesser) diversity. Also, the former land use does not provide a clear pattern: mean index ancient forest sites (n=6, H=15.62), former grasslands (n=5, H=15.56) and former arable lands (n=4, H= 15.88).

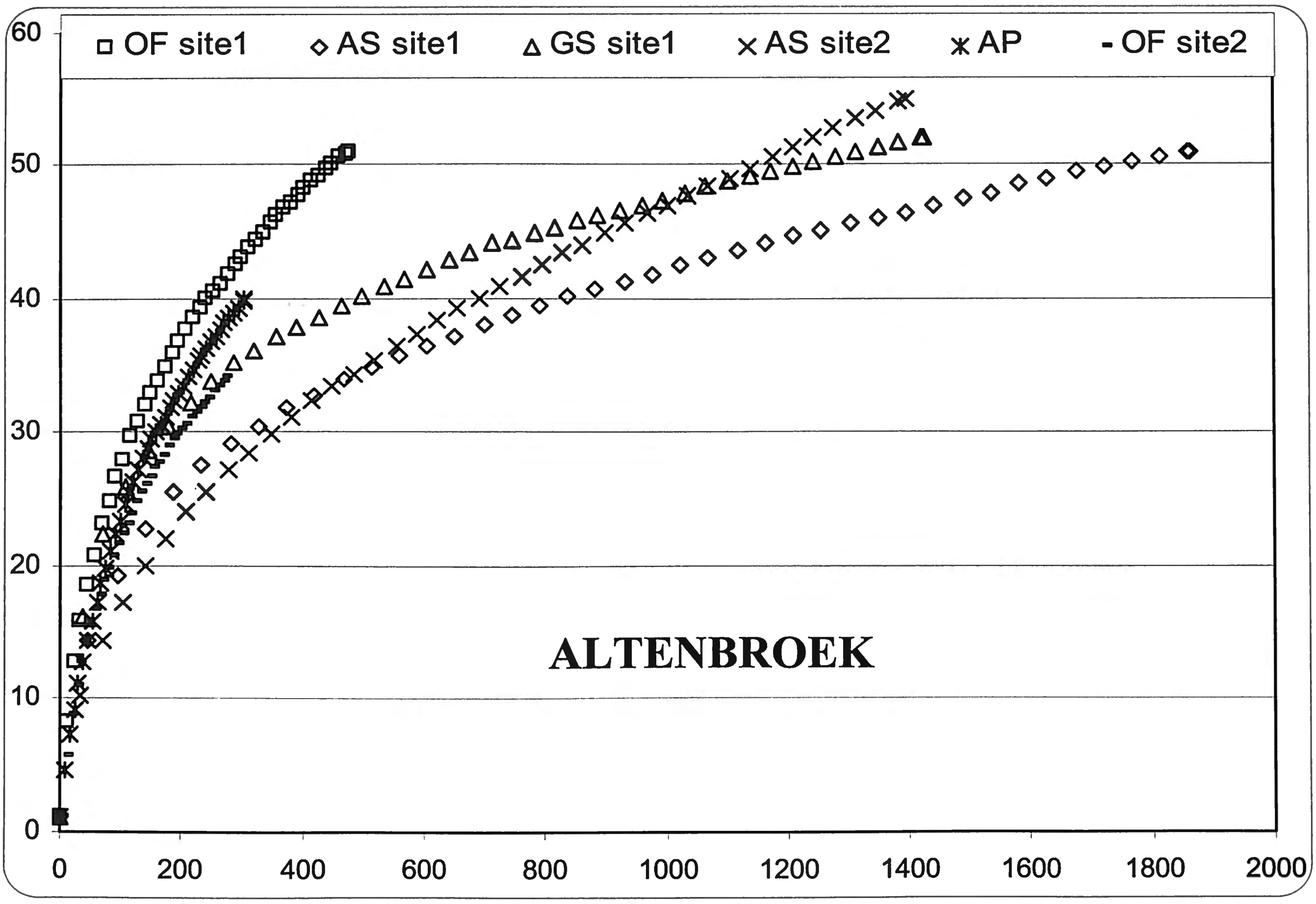
Rarefaction

Rarefaction (individual-based) curves per site provide an unclear pattern (Fig. 4).

The difference between the different types of forests is best illustrated in the 'Altenbroek'. There, it is obvious that for given number of caught individuals, the ancient forest sites, and the plantations are richer in species compared to the spontaneous afforestation sites. It is furthermore obvious that all curves do not reach an asymptote which indicates a lower bound biased sampling effort. For the 'Alserbos', the patterns are not that clear. Older spontaneous sites and plantations display a pattern similar to that of old forest sites and a clear distinction in this complex is harder to proof.

Cluster Analysis

In the Cluster Analysis (Sørenson, group average) the former history of the sites is very distinctive (Fig. 5). The ancient forest sites (independent off the location within the forest complexes) are separeted from the rest of the sites. It is clear that the young afforestation sites and the plantations show a larger difference in species composition than the older afforestation and plantation sites with the ancient forest sites which were more similar. It is once more clear that the ancient abandoned sites display a more forest fauna already. More strikingly is the fact that most sites (with exception of the ancient forest sites) are more or less grouped according to the forest complex they belong too while this is less the case for other analyses (see further).



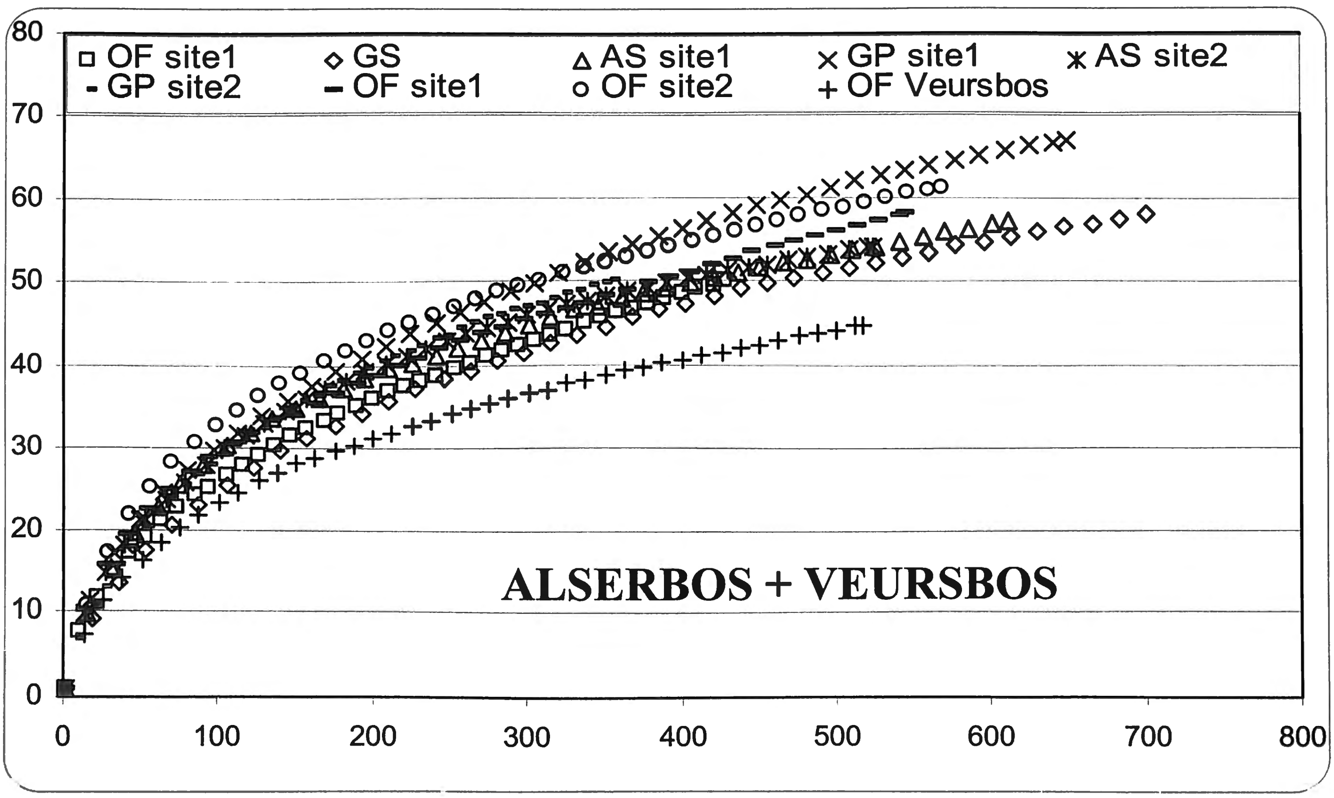


Fig. 4 — Rarefaction curve (1000 randomizations, random seed number generator) for sites in the Altenbroek and the Alserbos forest complex. Used abbreviations are explained as follows: OF= Ancient forest, AP= Arable land, plantation, AS= Arable land, spontaneous development, GS= Grassland, spontaneous development, GP= Grassland, plantation.

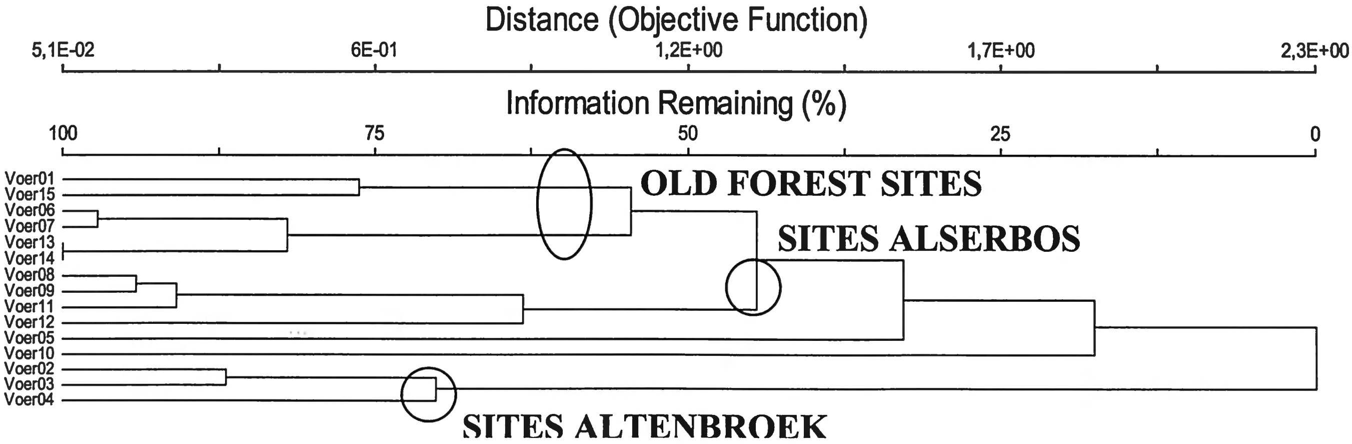


Fig. 5 — Cluster dendrogram (average Sorenson, nearest group) for all sample sites.

***Community Analysis through Indirect Gradient Analysis* (DCA, Jongman et al., 1995).**

Fur this analysis; we only used the most abundant species to avoid the biased effect of accidental immigrants and vagrants from other neighbouring, non-representative habitats (Desender, 1995). This means that 41 species were held for further analysis (being the number of spiders from which more than 45 specimens were caught (this equals the number of pitfall traps used in the sampling campaign). The relative abundances were calculated (percentage of abundance) to give each species the same weight.

The eigenvalues of the axes are respectively 0.76, 0.31 and 0.12. The third axis does not provide a significant higher explained variance, so the distribution along this axis is not discussed further. We see the ancient, closed forest sites on the right of the ordination diagram while the more open, younger sites (young spontaneous afforestation sites on former grasslands and arable lands) are

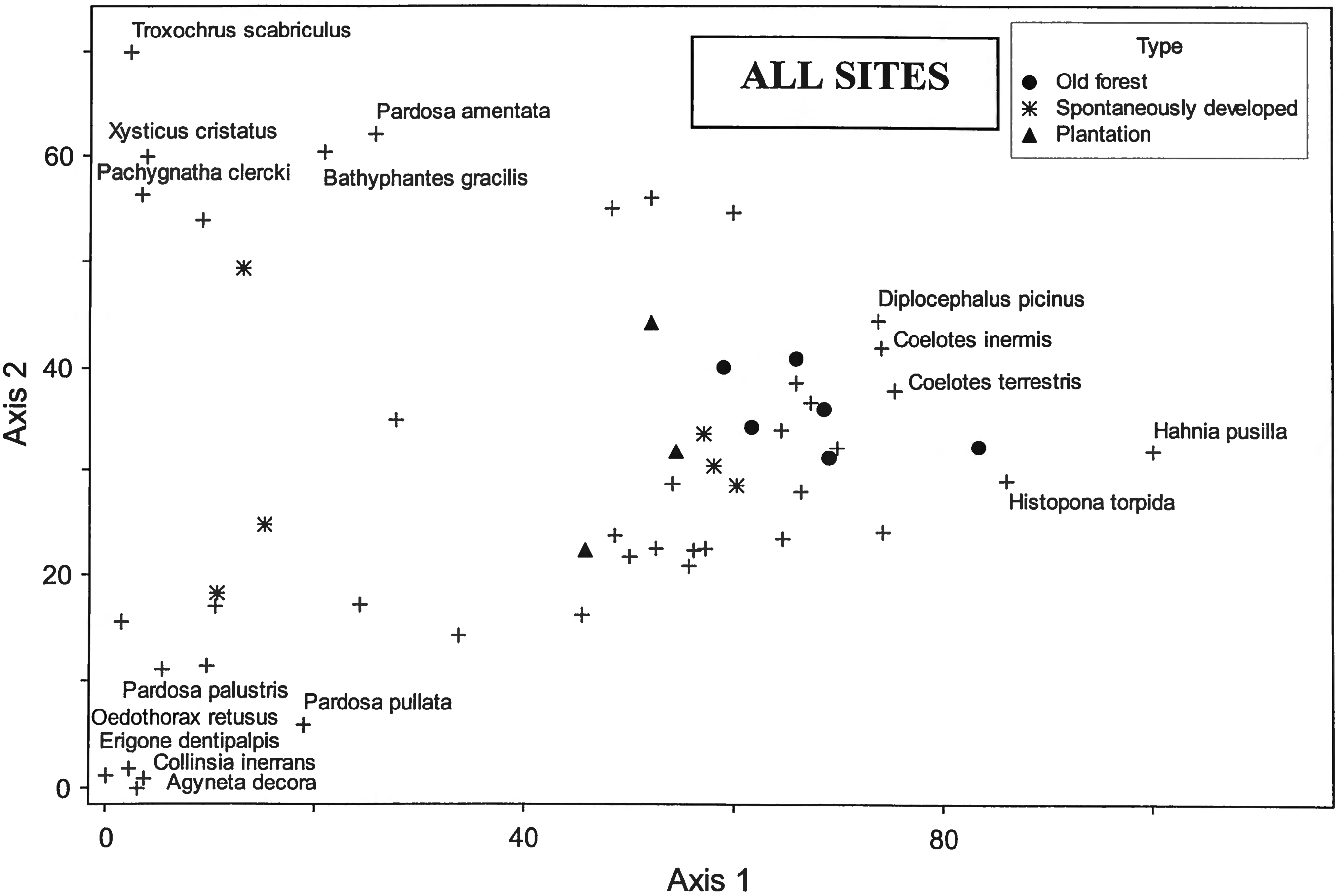


Fig. 6 — DCA-biplot-graph of all sites with indication of indicator species.

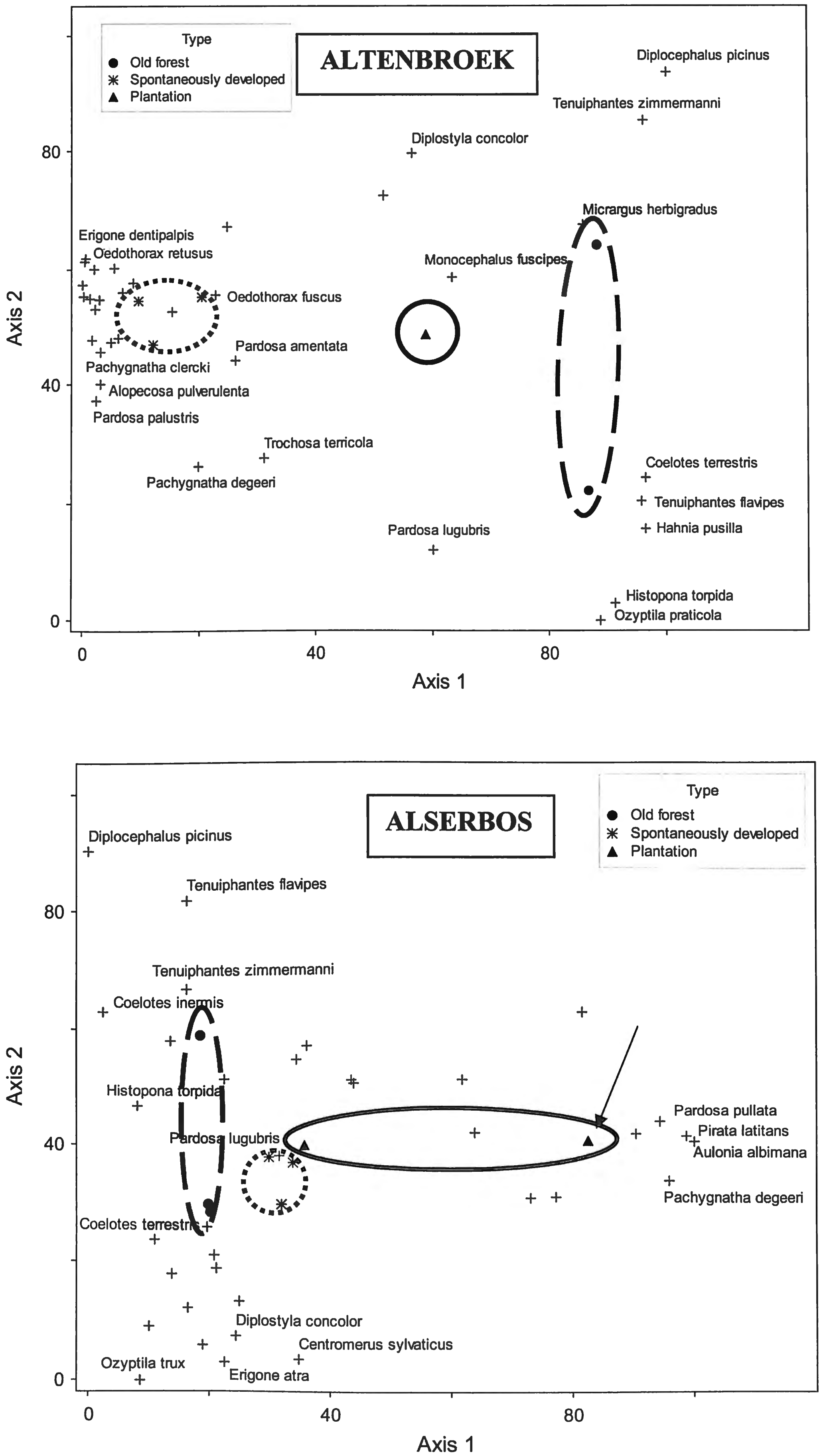


Fig. 7 — DCA-analysis based on the most abundant species of the sites of the Altenbroek and Alserbos forest complex.

on the left (Fig. 6). This separation becomes even more clearly when we look at the indicator species respectively. On the right we see true stenotopic forest species abundant in woodlands with a well developed litter layer (mostly beech and oak stands) like *Coelotes terrestris*, *Eurocoelotes inermis*, *Histopona torpida* and *Hahnia pusilla*. On the left side, we observe species typical for pioneer situations (*Erigone*-species), of different grasslands (*Pardosa palustris*, *P. pullata*, *Xysticus cristatus*) or from rough vegetations (*Pardosa amentata*). Furthermore, we can see that the older spontaneous developing sites and the plantations are situated more to the right indicating that these faunas are more similar to the one found in ancient forest sites as environmental conditions change (starting to have a litter layer) and probably migration takes place from neighboring source populations. It was already clear from other earlier studies that spider diversity and composition is influenced by the presence or absence of structural parameters in habitats and that they respond very quickly to environmental changes (UETZ, 1991; WISE, 1993). Using overlay figures of the most discriminating environmental categorical parameters, reveals that indeed the presence of dead wood, the amount of light reaching the forest floor and the type of forest expansion seem to be responsible for explaining most of the spreading over both axes of the ordination.

To see if the same patterns were observed within each forest as in the general analysis, we also performed the same analysis of the sites within each forest complex (Fig. 7). This was the case, so making the latter pretty solid for interpretation. Nevertheless, spontaneous developing sites of the Alserbos are more similar to the ancient forest sites than the ones of the Altenbroek. Apparently, the spontaneous developing sites of the Alserbos are older and display already a more similar patterns as found in ancient forest sites. Only site 10 (which is a plantation site on nutrient poor soil) displays a different fauna compared to the rest. Although it is planted with trees, still a more or less dry grassland fauna is present (with species like *Pachygnatha degeeri*, *Pardosa pullata* and *Aulonia albimana* as indicative) probably due to the open character of the site and the presence of a grassland/dry heathland vegetation which is still present.

Community Analysis through Direct Gradient Analysis (CCA, JONGMAN et al., 1995).

This analysis allows comparison between environmental data and the relative abundance of the most common species. It was observed that a lot of parameters were correlated with each other (DEKONINCK 2005, this volume), so the amount of parameters used for the analysis was redefined. Almost half of the observed variation in the analysis was explained (cumulative percentage explained variance is 44.9%).

With the CCA-biplot-overlay (Fig. 8), we see that the most explaining variables along the first axis (eigenvalue 0.664) are the presence of a litter layer, the amount of coverage by forest (combined in one factor VEG1) and the soil nutrient richness (measured as the nitrogen content of the soil, SoilVar2). In lesser degree (and along both axes), the presence of bare ground and presence of a humus layer (combined in one factor VEG2) are also important. This is more or less the same pattern observed as in the Indirect gradient Analysis; differences in spider communities can be explained by general differences in site characteristics (forest and old spontaneous/old plantation versus young plantations and spontaneous afforestation sites).

Indicator species Analysis (IndVal, DUFRENE & LEGENDRE, 1997).

In order to find suitable indicator species for each type of forest, an IndVal analysis was performed. This analysis permits a search for indicator species for a posteriori defined groups. For this analysis, we wanted to look which species were indicative for recent abandoned grasslands and arable lands, longer abandoned grasslands and arable lands and ancient forests. For good interpretation of the results, species with an Indval-value lower than 50 and a p-value higher than 0.05 were discarded. This ensures us that the species appointed by the analysis are very good indicators for the a posteriori defined groups.

When we look at the results (Table 3), we see that the species indicative for ancient forest sites are indeed the ones that prefer good forest conditions, mainly the presence of a large amount of dead wood and a well developed litter layer (e.g. *Coelotes terrestris*, *Histopona*

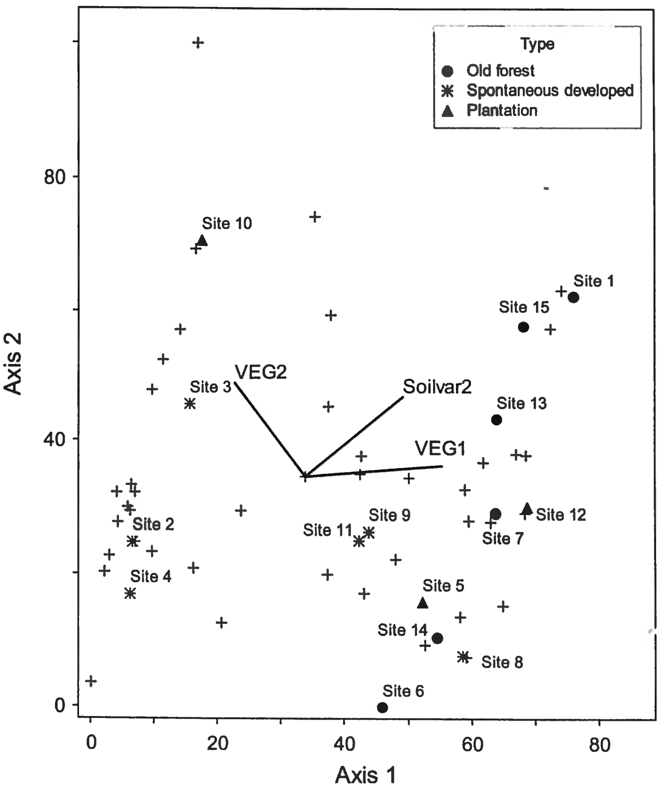


Fig. 8 — CCA-biplot-graph of all sites.

Table 3 — List of indicator species assigned by the IndVal-analysis with indication of their Indval-value, mean, standard deviation (SDev) and p-value.

Species	Type	IndVal-value	Mean	Sdev	p-value
Histopona torpida	Old forest	85.3	29.0	7.44	0.0010
Eurocoelotes inermis	Old forest	80.6	26.1	6.62	0.0010
Coelotes terrestris	Old forest	81.4	34.7	6.13	0.0010
Diplocephalus picinus	Old forest	87.8	22.9	7.03	0.0010
Micrargus herbigradus	Old forest	55.3	35.6	4.67	0.0010
Hahnia pusilla	Old forest	93.7	25.5	7.96	0.0010
Macrargus rufus	Old forest	53.1	17.3	6.57	0.0020
Tenuiphantes flavipes	Old forest	56.1	35.7	5.94	0.0050
Apostenus fuscus	Old forest	54.1	17.7	6.92	0.0030
Dicymbium nigrum	Spontaneous	62.7	20.0	7.40	0.0020
Dicymbium tibiale	Spontaneous	68.2	32.7	6.04	0.0010
Erigone atra	Spontaneous	67.8	35.8	8.48	0.0040
Erigone dentipalpis	Spontaneous	53.8	18.5	7.29	0.0020
Gongylidiellum vivum	Spontaneous	53.4	21.1	6.87	0.0020
Oedothorax fuscus	Spontaneous	50.7	35.1	7.70	0.0380
Oedothorax retusus	Spontaneous	55.2	22.4	8.42	0.0050
Leptoroptrum robustum	Spontaneous	50.0	15.3	6.27	0.0010
Pardosa amentata	Spontaneous	72.1	41.1	7.71	0.0010
Gongylidiellum latebricola	Plantation	53.6	20.0	6.14	0.0030
Zora spinimana	Plantation	59.6	15.8	6.57	0.0010

torpida). The fact that the recent abandoned sites do not possess a forest fauna yet is clearly demonstrated by the presence of indicator species as *Erigone* and *Oedothorax*-species which are good ballooners, often colonizing newly created (pioneer) habitats very fast. The species indicative for the longer abandoned, spontaneous developing sites are indeed species which can sometimes already be found in well developed forested sites (e.g. *Diplocephalus latifrons* and *Tenuiphantes zimmermanni*) emphasizing the already thorough transformation of a pioneer community towards a forest community. For recent plantations only *Monocephalus fuscipes* is really indicative (*Enoplognatha ovata* is more a higher strata inhabiting species which is occasionally found in pitfall traps) and can also be found regulary already in developed forest sites. For older plantations, the situation is not totally clear. The indicative species are certainly not specific for old forest sites, but mainly present in open, younger forests and/or clear cuts and verges of forests. However, some of the species indicated are not abundantly caught (e.g. *Zelotes latreillei*, *Phrurolithus festivus*, *Zora spinimana*). Why no real species for more forest conditions were appointed for these sites is not clear to us yet and should be investigated further.

General conclusions

This was the first thorough study in Belgium on the effect of spontaneous and induced afforestation on spider communities. This campaign yielded a large amount of species (in a hitherto never intensively sampled region) of which many are faunistically very important and only scarcely recorded in the past.

It was clear that, taking into account only the pitfall data, no significant differences could be observed between and within forest sites for what concerns species diversity. Furthermore, the general diversity results do not provide a clear pattern except the fact that the oldest abandoned sites (either spontaneous or plantations) already contain more or less a well-defined forest fauna. This was also clear from the Indirect gradient Analysis (DCA) where the oldest abandoned sites almost grouped together with the ancient forest sites and even shared common forest indicator species with them. The clustering further refined the difference by giving a distinction between older abandoned sites and the recently abandoned ones, but the general pattern remains the same.

Correlation with abiotic paramaters yielded the importance of the parameters linked with tree coverage, presence of a well developed litter layer, mineral content and the evolution towards a typical forest floor (indicated by the development of a well defined humus layer).

Similar pattern with the indicator species were assigned by the IndVal method. The former land use plays an important role even within older afforestation sites and plantations. The species indicative for ancient forest sites are species to monitor in future research. It is clear that these species are lacking in young and even older afforestation sites (both spontaneous and plantation). This clearly states that even for long abandoned sites, the presence of a typical forest fauna is not obvious. Nevertheless, we suspect that the planting of (preferably indigenous) trees will give a quicker evolution towards a forest fauna since conditions for such a fauna (presence litter layer, suitable structural parameters, high coverage) are created instantly and migration from neighbouring source populations could be rapid compared to spontaneous afforestation were migration could take longer. Everything depends on the demands and wishes of the policy makers. If a rapid conversion towards a forest fauna is pursued, than we suggest plantation as a suitable measure. If spontaneously afforestation is preferred (in many cases it is since this implements all stages of a natural succession), then it could take longer before a suitable forest fauna is present.

As similar to other studied arthropod groups in this campaign, we emphasize that all conclusions in this part are based on the given dataset for spiders and can not be extrapolated to other groups and other regions.

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