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Environmental drivers of wood-inhabiting, terricolous saprotrophic and ectomycorrhizal macrofungi

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Host, climate, substrate… What are important for macrofungi?

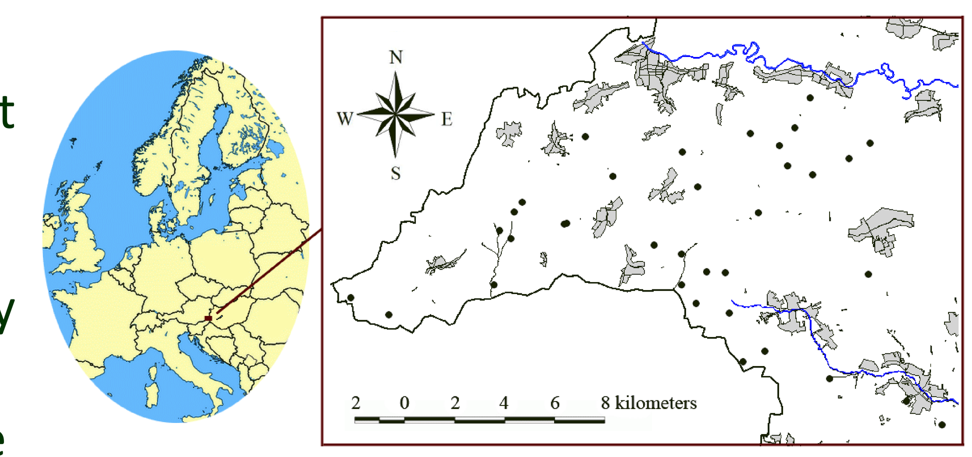
Introduction

This study has been carried out in Őrség National Park, West Hungary, Central Europe. We aimed to: (1) find the most influential environmental factors that are best able to explain the species composition (**SC**), species richness (**SR**) and fruiting performance (**FP**) of different functional groups of macrofungi; (2) highlight similarities and differences among the environmental drivers of these groups.

Results

- Identification of 245 wood-inhabiting, 290 EcM, and 127 terricolous saprotrophic macrofungi taxa;
- 13,396 fixed records.

Materials and methods

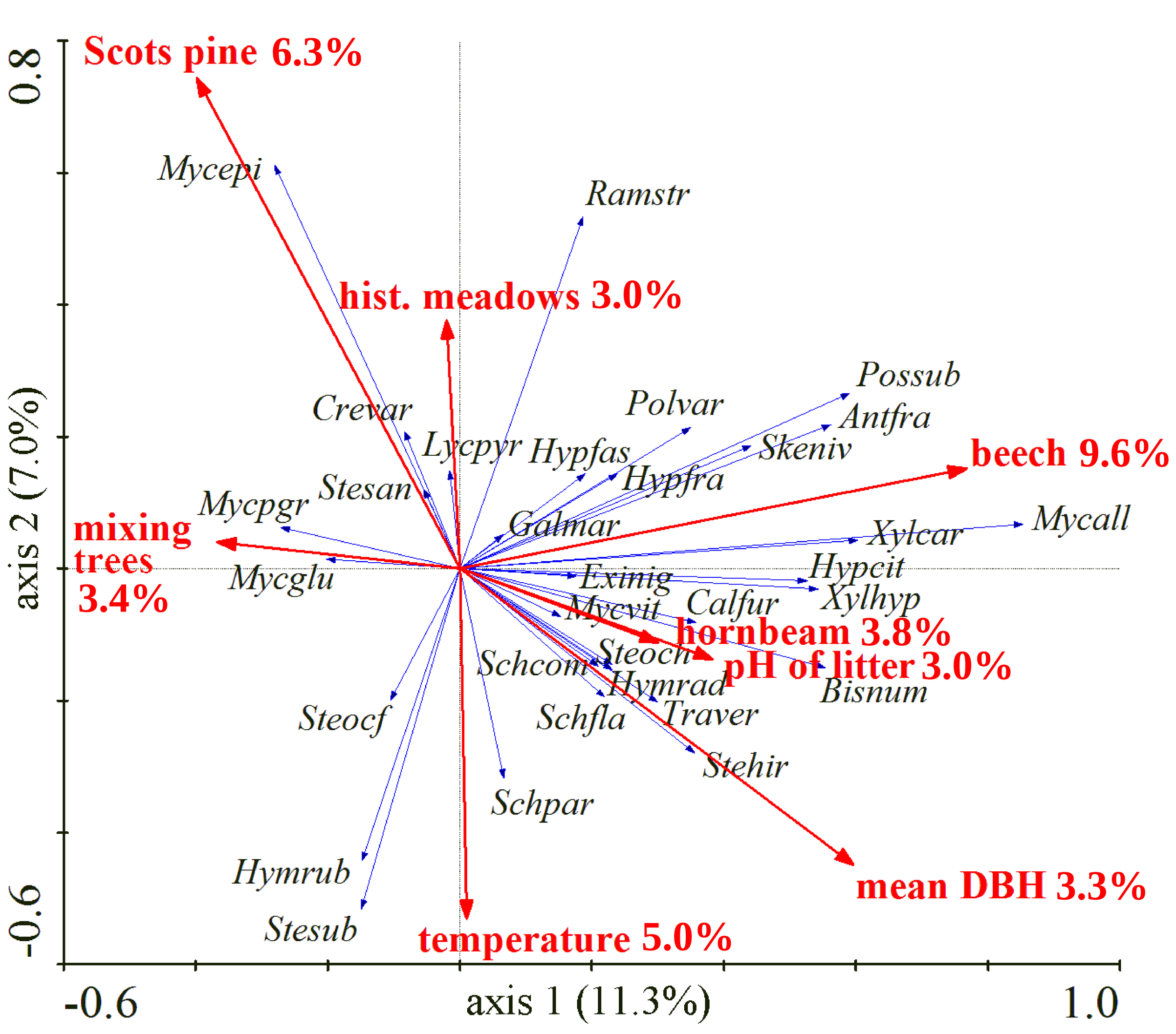


- Thirty-five, 70–100 years old, managed forest stands, 30 m × 30 m plots;
- Thirty-six, 5 m × 5 m quadrats within the plots;
- Three sporocarp surveys: in August and May 2009, and during autumn 2010;
- Fifty-one measured variables representing: tree species composition, stand structure, soil and litter conditions, microclimate, landscape structure and management history;
- Analyses of species compositions by ordination methods: PCA, DCA and RDA (based on local frequency data), of species richness and fruiting performance: linear regression models (using plot level number of species and summarized local frequency data, respectively).

Species compositions, redundancy analyses (RDAs)

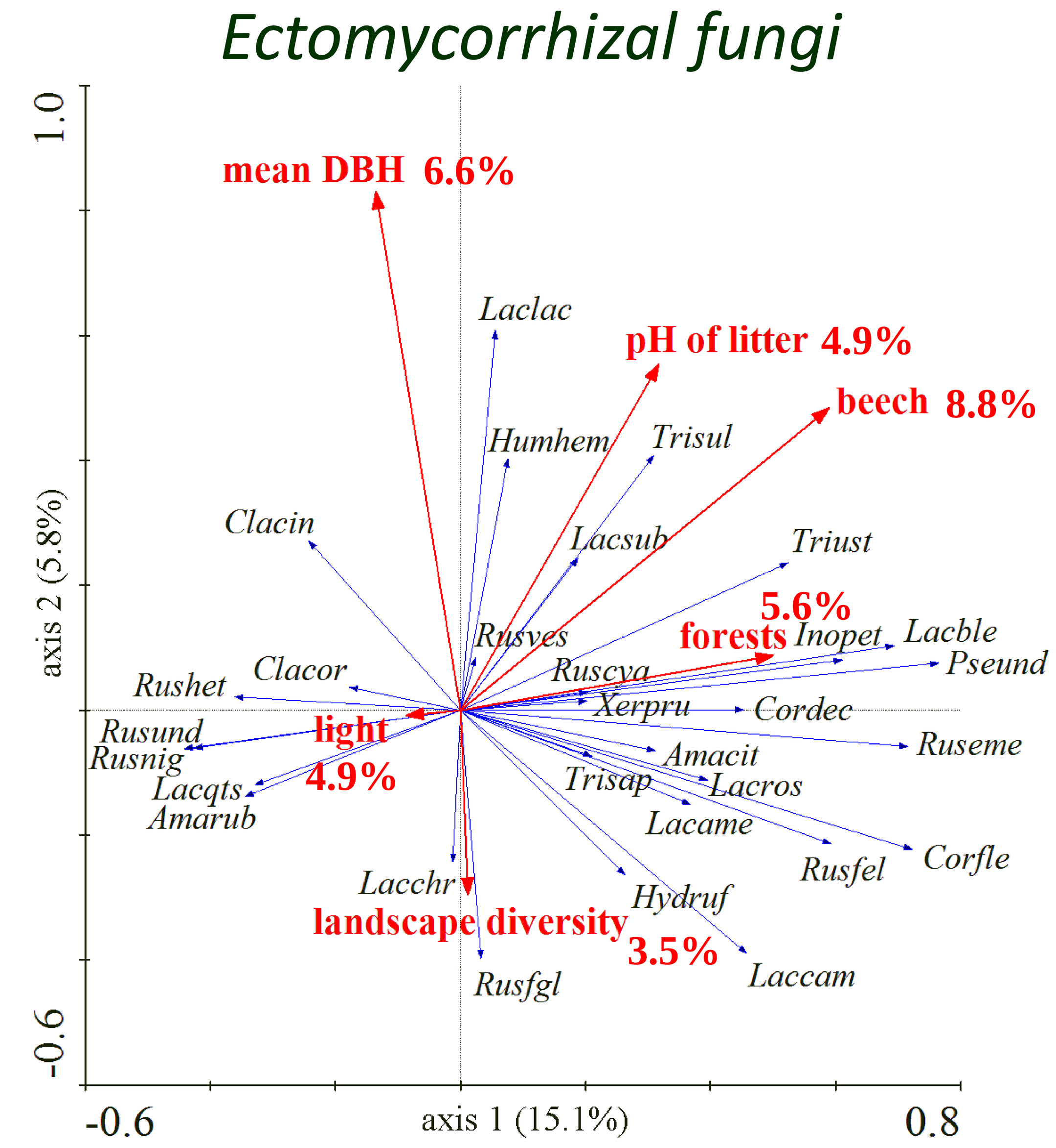
(the most frequent species are shown only)

Wood-inhabiting fungi



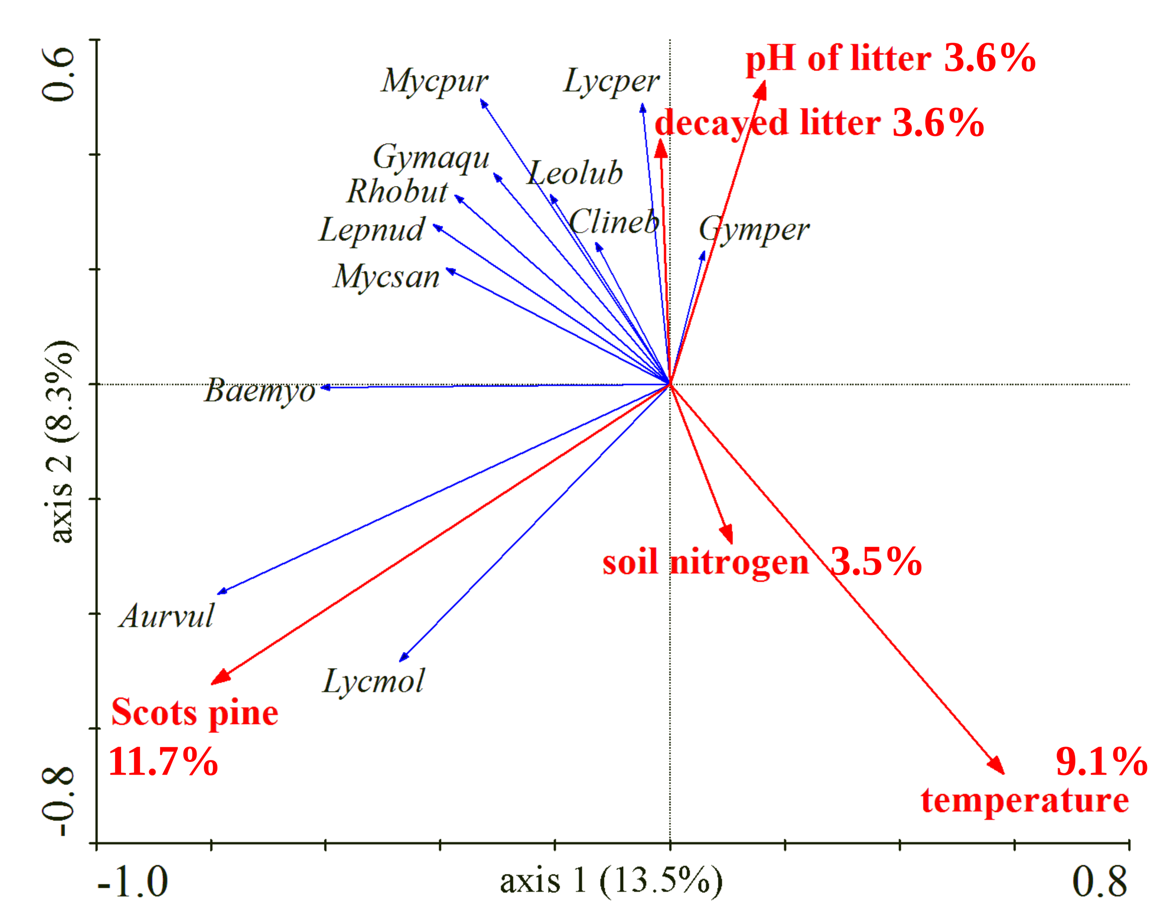
F = 2.279, p = 0.001

Ectomycorrhizal fungi



F = 2.652, p = 0.001

Terricolous saprotrophic fungi



F = 3.310, p = 0.001

Species richness, linear regression models

Variable	Effect	Variance (%)	p-value
pH of litter	+	24.79	2.17e-05
Cover of fine woody debris	+	19.40	0.00011
Relative volume of beech	+	11.91	0.00143
Relative volume of Scots pine	–	5.39	0.02408
Mass proportion of decayed litter	+	4.87	0.03121
Mean daily temperature difference	–	4.18	0.04472
Cover of bryophytes	–	4.00	0.04932

$R^2 = 0.6793$, $F_{(7,27)} = 11.29$, $p < 0.00001$

Variable	Effect	Variance (%)	p-value
Mean daily temperature difference	–	15.51	0.01181
Nitrogen content of soil	–	11.29	0.02947
Exchangeable acidity (y2)	+	6.02	0.10563

$R^2 = 0.2632$, $F_{(3,31)} = 5.05$, $p = 0.00579$

Variable	Effect	Variance (%)	p-value
Mean daily temperature difference	–	36.69	1.66e-05
Dry litter mass	+	9.77	0.01330
Basal area of trees	+	9.64	0.01385

$R^2 = 0.5185$, $F_{(3,31)} = 13.20$, $p = 0.00001$

Fruiting performance, linear regression models

Variable	Effect	Variance (%)	p-value
Relative volume of beech	+	25.04	4.423e-5
Cover of fine woody debris	+	12.36	0.00208
Mass proportion of decayed litter	+	10.13	0.00470
Mean daily temperature difference	–	8.70	0.00818
Cover of bryophytes	–	7.50	0.01333
Relative volume of Scots pine	–	6.20	0.02317

$R^2 = 0.6349$, $F_{(6,28)} = 10.85$, $p < 0.00001$

Variable	Effect	Variance (%)	p-value
Nitrogen content of soil	–	20.00	0.00709

$R^2 = 0.1756$, $F_{(1,33)} = 8.243$, $p = 0.00709$

Variable	Effect	Variance (%)	p-value
Mean daily temperature difference	–	45.50	4.225e-7
Dry litter mass	+	16.69	0.00054
Cover of fine woody debris	+	3.13	0.10448

$R^2 = 0.6195$, $F_{(3,31)} = 19.46$, $p < 0.00001$

Conclusions

We found slight, but general differences between the environmental drivers of **SR** and **FP**, and **SC** of each studied functional group: according to the regression models, microclimate and soil conditions were essential for **SR** and **FP**, while, based on the RDAs, tree species compositions were important for **SC** in the region. We revealed that functional groups have different environmental drivers that are confined mainly to the dissimilar roles of biotrophic and non-biotrophic fungi in nature.

This study was carried out in the frame of Őrs-Erdő Project (http://orserdo.okologia.mta.hu/), and supported by the Hungarian Scientific Research Fund (OTKA, K79158) and the Őrség National Park.

Appendix 1. Abbreviations of fungal names plotted in the RDA diagrams.

Abbreviation	Species name	Author	Functional group
Amacit	*Amanita citrina*	(Schaeff.) Pers.	EcM
Amarub	*Amanita rubescens*	Pers.	EcM
Clacin	*Clavulina cinerea*	(Bull.) J. Schröt.	EcM
Clacor	*Clavulina coralloides*	(L.) J. Schröt.	EcM
Cordec	*Cortinarius decipiens* s.l.	(Pers.) Fr.	EcM
Corfle	*Cortinarius flexipes* var. *flexipes*	(Pers.) Fr.	EcM
Humhem	*Humaria hemisphaerica*	(F.H. Wigg.) Fuckel	EcM
Hydruf	*Hydnum rufescens*	Pers.	EcM
Inopet	*Inocybe petiginosa*	(Fr.) Gillet	EcM
Lacame	*Laccaria amethystina*	Cooke	EcM
Laclac	*Laccaria laccata*	(Scop.) Cooke	EcM
Lacble	*Lactarius blennius*	(Fr.) Fr.	EcM
Laccam	*Lactarius camphoratus*	(Bull.) Fr.	EcM
Lacchr	*Lactarius chrysorrheus*	Fr.	EcM
Lacqts	*Lactarius quietus*	(Fr.) Fr.	EcM
Lacros	*Lactarius rostratus*	Heilm.-Claus.	EcM
Lacsub	*Lactarius subdulcis*	(Pers.) Gray	EcM
Pseund	*Pseudocraterellus undulatus*	(Pers.) Rauschert	EcM
Ruscya	*Russula cyanoxantha*	(Schaeff.) Fr.	EcM
Ruseme	*Russula emetica*	(Schaeff.) Pers.	EcM
Rusfel	*Russula fellea*	(Fr.) Fr.	EcM
Rusfal	*Russula fragilis*	Fr.	EcM
Rushet	*Russula heterophylla*	(Fr.) Fr.	EcM
Rusnig	*Russula nigricans*	Fr.	EcM
Rusund	*Russula undulata*	Velen.	EcM
Rusves	*Russula vesca*	Fr.	EcM
Trisap	*Tricholoma saponaceum*	(Fr.) P. Kumm.	EcM
Trisul	*Tricholoma sulphureum*	(Bull.) P. Kumm.	EcM
Triust	*Tricholoma ustale*	(Fr.) P. Kumm.	EcM
Xerpru	*Xerocomus pruinatus*	(Fr. & Hök) Quél.	EcM
Aurvul	*Auriscalpium vulgare*	Gray	t. sapr.
Baemyo	*Baeospora myosura*	(Fr.) Singer	t. sapr.
Clineb	*Clitocybe nebularis*	(Batsch) P. Kumm.	t. sapr.
Gymaqu	*Gymnopus aquosus*	(Bull.) Antonín & Noordel.	t. sapr.
Gymper	*Gymnopus peronatus*	(Bolton) Antonín, Halling & Noordel.	t. sapr.
Leolub	*Leotia lubrica*	(Scop.) Pers.	t. sapr.
Lepnud	*Lepista nuda*	(Bull.) Cooke	t. sapr.
Lycmol	*Lycoperdon molle*	Pers.	t. sapr.
Lycper	*Lycoperdon perlatum*	Pers.	t. sapr.
Mycpur	*Mycena pura*	(Pers.) P. Kumm.	t. sapr.
Mycsan	*Mycena sanguinolenta*	(Alb. & Schwein.) P. Kumm.	t. sapr.
Rhobut	*Rhodocollybia butyracea*	(Bull.) Lennox	t. sapr.
Antfra	*Antrodiella fragrans*	(A. David & Tortič) A. David & Tortič	wood-inh.
Bisnum	*Biscogniauxia nummularia*	(Bull.) Kuntze	wood-inh.
Calfur	*Calocera furcata*	(Fr.) Fr.	wood-inh.
Crevar	*Crepidotus variabilis*	(Pers.) P. Kumm.	wood-inh.
Exinig	*Exidia nigricans*	(With.) P. Roberts	wood-inh.
Galmar	*Galerina marginata*	(Batsch) Kühner	wood-inh.
Hymrub	*Hymenochaete rubiginosa*	(Dicks.) Lév.	wood-inh.
Hymrad	*Hymenopellis radicata*	(Relhan) R.H. Petersen	wood-inh.
Hypfas	*Hypholoma fasciculare*	(Huds.) P. Kumm.	wood-inh.
Hypcit	*Hypocrea citrina*	(Pers.) Fr.	wood-inh.
Hypfra	*Hypoxylon fragiforme*	(Pers.) J. Kickx f.	wood-inh.
Lycpyr	*Lycoperdon pyriforme*	Willd.	wood-inh.
Mycepi	*Mycena epipterygia*	(Scop.) Gray	wood-inh.
Mycgalu	*Mycena galericulata*	(Scop.) Gray	wood-inh.
Mycpar	*Mycena polygramma*	(Bull.) Gray	wood-inh.
Mycvit	*Mycena vitilis*	(Fr.) Quél.	wood-inh.
Mycall	*Mycetinis alliaceus*	(Jacq.) Earle ex A.W. Wilson & Desjardin	wood-inh.
Polvar	*Polyporus varius*	(Pers.) Fr.	wood-inh.
Possub	*Postia subcaesia*	(A. David) Jülich	wood-inh.
Ramstr	*Ramaria stricta*	(Pers.) Quél.	wood-inh.
Schcom	*Schizophyllum commune*	Fr.	wood-inh.
Schfla	*Schizopora flavipora*	(Berk. & M.A. Curtis ex Cooke) Ryvarden	wood-inh.
Schpar	*Schizopora paradoxa* s.l.	(Schrad.) Donk	wood-inh.
Skeniv	*Skeletocutis nivea*	(Jungh.) Jean Keller	wood-inh.
Steoch	*Steccherinum ochraceum*	(Pers.) Gray	wood-inh.
Stehir	*Stereum hirsutum*	(Willd.) Pers.	wood-inh.
Steocf	*Stereum ochraceoflavum*	(Schwein.) Sacc.	wood-inh.
Stesan	*Stereum sanguinolentum*	(Alb. & Schwein.) Fr.	wood-inh.
Stesub	*Stereum subtomentosum*	Pouzar	wood-inh.
Traver	*Trametes versicolor*	(L.) Pilát	wood-inh.
Xylcar	*Xylaria carpophila*	(Pers.) Fr.	wood-inh.
Xylhyp	*Xylaria hypoxylon*	(L.) Grev.	wood-inh.

Appendix 2. List of potential explanatory variables influencing the functional groups of macrofungi.

Variable	Unit	Mean (range)	Transformation
TREE SPECIES COMPOSITION			
Species richness of trees	pc/1600 m^2	5.63 (2–10)	ln
Shannon diversity of tree species	–	0.847 (0.097–1.802)	ln
Relative volume of beech	%	27.9 (0.0–94.4)	ln
Rel. vol. of hornbeam	%	3.9 (0.0–21.8)	ln
Rel. vol. of Scots pine	%	26.2 (0.0–76.9)	ln
Rel. vol. of oaks	%	36.4 (1.1–98.0)	ln
Rel. vol. of mixing trees	%	0.02 (0.00–0.17)	ln
STAND STRUCTURE			
Density of trees [diameter at breast height (DBH) > 5 cm]	stems/ha	593.39 (217.75–1392.75)	–
Density of shrubs and saplings (DBH = 0–5 cm)	stems/ha	952.14 (0.00–4706.25)	ln
Density of large trees (DBH > 50 cm)	stems/ha	17.14 (0.00–56.25)	ln
Basal area of trees	m^2/ha	32.87 (21.49–42.26)	–
Mean DBH of trees	cm	26.65 (13.70–40.75)	–
Coefficient of variation of DBH of trees (DBH > 5 cm)	–	0.480 (0.172–0.983)	–
Volume of snags	m^3/ha	8.99 (0.90–65.02)	ln
Volume of logs	m^3/ha	10.51 (0.17–59.48)	ln
Total volume of logs and snags (coarse woody debris, CWD)	m^3/ha	19.50 (1.93–73.37)	ln
Rel. vol. of decayed logs (decay stages 3–6)	%	54.86 (8.25–98.61)	–
Cover of fine woody debris	m^2/ha	261.57 (79.44–729.99)	ln
Cover of understory	m^2/ha	740.80 (19.19–4829.30)	ln
Cover of bryophytes	m^2/ha	247.37 (16.57–2201.59)	ln
SOIL AND LITTER * layer: 0–10 cm			
Cover of soil	m^2/ha	146.75 (8.56–472.22)	–
Cover of litter	m^2/ha	9367 (7815–9834)	–
pH of litter	–	5.29 (4.86–5.68)	–
pH of soil *	–	4.33 (3.96–4.84)	–
Dry litter mass	g/900 cm^2	147.66 (105.41–243.08)	–
Mass proportion of deciduous litter	%	14.71 (2.54–32.80)	–
Mass proportion of decayed litter	%	67.71 (51.58–84.16)	–
Hydrolytic acidity (y1) *	–	30.21 (20.68–45.22)	–
Exchangeable acidity (y2) *	–	15.27 (3.94–30.47)	–
Fine texture proportion (clay and silt) *	%	51.95 (27.60–68.60)	–
Carbon content of litter	%	65.69 (42.87–78.09)	–
Carbon content of soil *	%	6.45 (3.30–11.54)	–
Nitrogen content of litter	%	1.28 (0.83–1.84)	–
Nitrogen content of soil *	%	0.22 (0.11–0.34)	–
Phosphorus content of soil *	mg P_2O_5/100 g	4.29 (1.96–9.35)	–
Potassium content of soil *	mg K_2O/100 g	7.74 (4.00–13.10)	–
MICROCLIMATE			
Mean daily temperature difference	°C	–0.10 (–0.93–0.73)	–
Daily temperature range difference	°C	0.94 (–0.42–2.49)	–
Mean daily air humidity difference	%	0.84 (–1.83–3.32)	–
Daily air humidity range difference	%	1.89 (–2.27–6.58)	–
Mean relative diffuse light	%	2.93 (0.62–10.36)	ln
Coefficient of variation of relative diffuse light	%	0.51 (0.12–1.23)	ln
LANDSCAPE (r=300 m)			
Proportion of renewal patches	%	5.73 (0.00–23.03)	ln
Proportion of forests	%	89.80 (56.92–100.00)	–
Proportion of open areas (settlements, meadows, arable lands)	%	4.72 (0.00–45.25)	–
Shannon diversity of landscape elements	–	1.114 (0.108–1.858)	–
MANAGEMENT HISTORY			
Historical proportion of forests (r=300 m)	%	76.58 (24.03–100.00)	–
Historical proportion of meadows (r=300 m)	%	7.26 (0.00–40.73)	–
Historical proportion of arable lands (r=300 m)	%	16.16 (0.00–61.27)	–
Locality of forests	binary	0.800	–
Locality of arable lands	binary	0.171	–