

Ecosphere

Effect of forest management on temperate ant communities

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Appendix S1

Table S1. List of ant species found in each region including the number of plots where they occurred and their abundance as the number of times (month x trap) a species was caught in pitfalls.

Region	Species	No plots	Abundance
Alb	<i>Camponotus herculeanus</i>	2	3
	<i>Camponotus ligniperdus</i>	1	1
	<i>Formica (Serviformica) fusca</i>	5	7
	<i>Formica polyctena</i> *	1	1
	<i>Formica pratensis</i>	5	6
	<i>Formica rufa</i> *	1	1
	<i>Formica (Raptiformica) sanguinea</i>	4	4
	<i>Lasius niger</i>	3	3
	<i>Lasius platythorax</i>	10	16
	<i>Lasius psammophilus</i>	1	1
	<i>Leptothorax acervorum</i>	2	2
	<i>Myrmica rubra</i>	7	20
	<i>Myrmica ruginodis</i>	40	172
	<i>Temnothorax nylanderi</i>	1	1
Hainich	<i>Formica (Serviformica) fusca</i>	1	2
	<i>Formica polyctena</i>	1	4
	<i>Formica (Raptiformica) sanguinea</i>	1	1
	<i>Lasius platythorax</i>	7	14
	<i>Myrmica rubra</i>	2	2
	<i>Myrmica ruginodis</i>	27	86
	<i>Myrmica specioides</i>	1	1
Schorfheide	<i>Camponotus fallax</i>	1	1
	<i>Dolichoderus quadripunctatus</i>	1	1
	<i>Formica (Coptoformica) foreli</i>	1	1
	<i>Formica (Serviformica) fusca</i>	21	45
	<i>Formica polyctena</i> *	36	140
	<i>Formica rufa</i> *	25	66
	<i>Formica (Raptiformica) sanguinea</i>	3	4
	<i>Lasius alienus</i>	3	3
	<i>Lasius (Dendrolasius) fuliginosus</i>	12	21
	<i>Lasius niger</i>	1	1
	<i>Lasius platythorax</i>	31	136
	<i>Lasius psammophilus</i>	10	13

Table S1. Continuation

Region	Species	No plots	Abundance
Schorfheide	<i>Lasius (Chthonolasius) umbratus</i>	1	1
	<i>Leptothorax acervorum</i>	3	4
	<i>Myrmica lobicornis</i>	10	20
	<i>Myrmica rubra</i>	31	87
	<i>Myrmica ruginodis</i>	48	341
	<i>Myrmica sabuleti</i>	5	8
	<i>Myrmica scabrinodis</i>	10	26
	<i>Polyergus rufescens</i>	1	1
	<i>Stenamma debile</i>	37	115
	<i>Temnothorax crassispinus</i>	46	178
	<i>Tetramorium caespitum</i>	3	3

* Species can produce fertile hybrids. Percentage of assumed hybrids was < 10 %

Table S2. Ant species found at the Schorfheide with the trait values used for the calculation of FD_{LH}. Trait information marked with [#] are taken from Seifert (2007, 2017) and marked with ⁺ are taken from Arnan et al. (2017). Abbreviations: CS, colony size; WL, Weber's length; Zoo, assumed percentage animal diet of total food intake; Nectar, assumed percentage of nectar diet of total food intake; Troph, assumed percentage trophobiosis based diet of total food intake; Plant, assumed percentage plant based diet of total food intake; Dom, behavioral dominance, nQ, number of queens per nest, nN, number of nests per colony; CFT, colony foundation type. Data type and additional information on the traits are provided in Table S3.

Species	#CS	WL	#Zoo	#Nectar	#Troph	#Plant	+#Dom	+#nQ	+#nN	+#CFT
<i>Camponotus fallax</i>	5.70	2.42	0.58	0.13	0.21	0.08	0	0	0	1
<i>Formica (Serviformica) fusca</i>	7.31	1.96	0.5	0.1	0.35	0.05	0	1	1	1
<i>Formica polyctena</i>	12.20	2.40	0.3	0.03	0.65	0.02	1	1	1	0
<i>Formica rufa</i>	11.00	2.54	0.3	0.03	0.65	0.02	1	1	1	0
<i>Formica (Raptiformica) sanguinea</i> *	8.52	2.57	0.48	0.02	0.48	0.02	1	0.5	0	0.5
<i>Formica (Coptoformica) foreli</i> *	10.13	1.63	0.4	0.02	0.56	0.02	1	1	1	1
<i>Lasius (Dendrolasius) fuliginosus</i>	10.31	1.51	0.25	0.07	0.64	0.04	1	0	0	0
<i>Lasius niger</i>	8.52	1.37	0.34	0.05	0.56	0.05	1	0	0	1
<i>Lasius platythorax</i>	8.52	1.22	0.34	0.05	0.56	0.05	1	0	0	1
<i>Lasius (Chthonolasius) umbratus</i>	9.21	1.33	0.2	0	0.8	0	1	0.5	0	0
<i>Lasius alienus</i>	8.52	1.06	0.39	0.18	0.37	0.06	1	0	0	1
<i>Lasius psammophilus</i>	8.52	1.17	0.35	0.14	0.5	0.01	0	0	1	1
<i>Polyergus rufescens</i> *	7.31	2.41	0.5	0.1	0.35	0.05	1	0	0	0
<i>Leptothorax acervorum</i>	5.19	1.02	0.87	0.02	0.07	0.04	0	1	0	0
<i>Myrmica lobicornis</i>	5.63	1.40	0.72	0.004	0.2	0.04	0	0.5	0	0.5
<i>Myrmica rubra</i>	7.38	1.47	0.48	0.05	0.37	0.1	0	1	1	0.5
<i>Myrmica ruginodis</i>	6.68	1.57	0.53	0.02	0.3	0.15	0	0.5	0	0.5
<i>Myrmica sabuleti</i>	6.48	1.43	0.51	0.07	0.37	0.05	0	1	0	0.5
<i>Myrmica scabrinodis</i>	6.40	1.41	0.51	0.06	0.4	0.03	0	0.5	0	0.5
<i>Stenamma debile</i>	4.03	0.99	0.95	0	0.02	0.03	0	1	1	0
<i>Temnothorax crassispinus</i>	4.38	0.77	0.95	0.02	0.03	0	0	0	0	0.5
<i>Tetramorium caespitum</i>	9.62	1.03	0.26	0.04	0.35	0.35	1	0	0	1
<i>Dolichoderus quadripunctatus</i>	5.70	1.1	0.61	0.13	0.13	0.13	0	0	1	0

Table S3. Description of the different traits for the calculation of the FD_{LH}

Trait	Data type	States
CS	Continuous	Mean colony size (log transformed)
WL	Continuous	Mean Weber's length of worker (mm)
Zoo, Nectar, Troph, and Plant	Continuous	Assumed relative percentage of animal-, nectar-, trophobiosis- or plant-based diet. All summed to 100 %. Values are partly assumed by Seifert (2017), but also based on very detailed food analyses*
Dom	Binary	(0) Subordinate; (1) Dominant
nQ	Ordinal	(0) Monogyny; (0.5) Monogyny or polygyny; (1) Polygyny
nN	Ordinal	(0) Monodomy; (0.5) Monodomy or polydomy; (1) Polydomy
CFT	Ordinal	(0) Dependent colony founding; (0.5) Dependent and independent colony founding; (1) Independent colony founding

* detailed analyses are published in e.g. Wellenstein (1952, Adlung (1966) for *Formica rufa*, Horstmann (1970) for *F. polyctena*.

LITERATURE CITED

- Adlung, K. (1966) A critical evaluation of the European research on use of red wood ants (*Formica rufa* group) for the protection of forests against harmful insects. Zeitschrift für angewandte Entomologie 57:167–189.
- Horstmann, K. (1970) Investigation on the food consumption of red wood ants (*Formica polyctena* Foerster) in an oak forest. Oecologia 5:138–157.
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- Seifert, B. (2007) Die Ameisen Mittel- und Nordeuropas. Lutra Verlag-u. Vertriebsgesellschaft, Boxberg OT Klitten/Tauer, Germany
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Table S4. Number of ant species found in the different management types and the number of plots where the particular number of ant species was found for each management type and region (based on n = 150 plots).

Management type	Number ant species per plot	Alb	Hainich	Schorfheide
Beech even-aged	0	5	7	-
	1	13	8	-
	2	7	2	-
	3	5	2	-
	4	-	4	2
	5	2	-	5
	7	1	-	4
	8	-	-	1
	10	-	-	1
Beech uneven-aged	0	-	6	-
	1	-	6	-
	2	-	1	-
Beech unmanaged	0	-	10	-
	1	2	3	1
	2	1	-	1
	3	2	-	1
	5	-	-	2
	6	-	-	1
	7	-	-	1
Oak even-aged	3	-	-	1
	5	-	-	3
	6	-	-	1
	8	-	-	2
Pine even-aged	6	-	-	2
	7	-	-	1
	8	-	-	1
	9	-	-	4
	10	-	-	2
	11	-	-	2
	12	-	-	1
	13	-	-	1
	14	-	-	1
Pine-beech even-aged	4	-	-	1
	5	-	-	2
	6	-	-	1
	7	-	-	1
	8	-	-	2
Spruce even-aged	0	2	-	-
	1	8	1	-
	2	-	3	-
	3	2	-	-

Table S5. Result of the multi model averaging approach for FD_M . The relative importance values of each predictor variable are calculated as the sum of AICc weights over all models with $\Delta AICc < 2$ in which the variable appears and the number of models which contained the precise variable is stated.

Variable	Importance (%)	N containing models
<i>Leaf litter thickness</i>	92	19
<i>Deadwood volume</i>	75	16
<i>Dominant tree species</i>	40	8
<i>Tree species diversity</i>	39	7
<i>Arthropod biomass</i>	30	7
<i>Arthropod species richness</i>	28	6
<i>Tree species richness</i>	24	5
<i>Stand purity</i>	8	2
<i>Percentage harvested tree volume (Iharv)</i>	7	2
<i>Canopy cover</i>	3	1
<i>Temperature amplitude</i>	3	1

Table S6. Result of the multi model averaging approach for ant species richness with region as fixed factor. The relative importance values of each predictor variable are calculated as the sum of AICc weights over all models with $\Delta\text{AICc} < 2$ in which the variable appears and the number of models which contained the precise variable is stated.

Variable	Importance (%)	N containing models
<i>Canopy cover</i>	100	12
<i>Arthropod biomass</i>	100	12
<i>Arthropod species richness</i>	100	12
<i>Dominant tree species</i>	100	12
<i>Region</i>	100	12
<i>Temperature amplitude</i>	100	12
<i>Tree species richness</i>	100	12
<i>Stand age</i>	78	9
<i>Stand purity</i>	66	8
<i>Percentage harvested tree volume (Iharv)</i>	65	7
<i>Stand structural complexity</i>	46	5
<i>Soil moisture</i>	19	3
<i>Tree species diversity</i>	15	2

Table S7. Path coefficients of the significant unidirectional relationships among variables of Fig. S3. Due to the high complexity of Fig S3, the path coefficients are not included in the figure like it was done in Fig 2, 3 and Fig S5.

Predictor	Response	Coefficient	SE	P-value
<i>Ant abundance</i>	<i>Ant species richness</i>	1.05	9.36e-02	>0.001 ***
<i>Pine</i>	<i>Ant species richness</i>	1.34	4.16e-01	0.002 **
<i>Tree species richness</i>	<i>Ant species richness</i>	0.15	5.19e-02	0.006 **
<i>Arthropod species richness</i>	<i>Ant abundance</i>	0.02	4.36e-03	>0.001 ***
<i>Spruce</i>	<i>Ant abundance</i>	-1.09	3.42e-01	0.002 **
<i>Hainich (region)</i>	<i>Ant abundance</i>	-0.94	3.13e-01	0.003 **
<i>Temperature amplitude</i>	<i>Ant abundance</i>	0.01	4.39e-03	0.013 *
<i>Arthropod biomass</i>	<i>Ant abundance</i>	-0.05	2.32e-02	0.038 *
<i>Hainich (region)</i>	<i>Arthropod species richness</i>	22.74	6.12e+00	>0.001 ***
<i>Schorfheide (region)</i>	<i>Arthropod species richness</i>	49.72	1.57e+01	0.002 **
<i>Stand structural complexity</i>	<i>Arthropod species richness</i>	5.65	1.94e+00	0.004 **
<i>Arthropod biomass</i>	<i>Arthropod species richness</i>	1.31	4.62e-01	0.005 **
<i>Pine</i>	<i>Arthropod species richness</i>	22.03	7.99e+00	0.007 **
<i>Temperature amplitude</i>	<i>Arthropod species richness</i>	0.21	8.82e-02	0.019 *
<i>Canopy cover</i>	<i>Arthropod species richness</i>	-24.48	1.09e+01	0.027 *
<i>Tree age</i>	<i>Arthropod species richness</i>	-0.09	4.43e-02	0.043 *
<i>Hainich (region)</i>	<i>Arthropod biomass</i>	-6.74	1.02e+00	>0.001 ***
<i>Tree species richness</i>	<i>Arthropod biomass</i>	-0.47	1.94e-01	0.017 *
<i>Oak</i>	<i>Arthropod biomass</i>	-4.20	1.76e+00	0.019 *
<i>Canopy cover</i>	<i>Temperature amplitude</i>	-46.14	1.02e+01	>0.001 ***
<i>Tree age</i>	<i>Temperature amplitude</i>	-0.11	4.34e-02	0.009 **
<i>Leaf litter thickness</i>	<i>Temperature amplitude</i>	5.17	2.02e+00	0.012 *
<i>Oak</i>	<i>Temperature amplitude</i>	-20.78	9.02e+00	0.023 *
<i>Schorfheide (region)</i>	<i>Temperature amplitude</i>	-29.32	1.42e+01	0.041 *
<i>Hainich (region)</i>	<i>Soil moisture</i>	-7.73	1.38e+00	>0.001 ***
<i>Schorfheide (region)</i>	<i>Soil moisture</i>	-22.95	4.46e+00	>0.001 ***
<i>Pine</i>	<i>Soil moisture</i>	-5.11	2.33e+00	0.03 *
<i>Spruce</i>	<i>Canopy cover</i>	-0.28	5.60e-02	>0.001 ***
<i>Schorfheide (region)</i>	<i>Canopy cover</i>	-0.17	5.49e-02	0.002 **
<i>Pine</i>	<i>Canopy cover</i>	-0.19	6.29e-02	0.003 **
<i>Tree species richness</i>	<i>Canopy cover</i>	0.03	9.14e-03	0.003 **
<i>Stand purity</i>	<i>Canopy cover</i>	-0.12	4.25e-02	0.005 **
<i>Oak</i>	<i>Canopy cover</i>	-0.20	8.26e-02	0.019 *
<i>Schorfheide (region)</i>	<i>Leaf litter thickness</i>	6.28	4.01e-01	>0.001 ***
<i>Pine</i>	<i>Leaf litter thickness</i>	1.90	3.11e-01	>0.001 ***
<i>Canopy cover</i>	<i>Leaf litter thickness</i>	1.75	4.12e-01	>0.001 ***
<i>Hainich (region)</i>	<i>Leaf litter thickness</i>	-0.69	2.20e-01	0.002 **
<i>Tree age</i>	<i>Leaf litter thickness</i>	0.00	1.83e-03	0.031 *

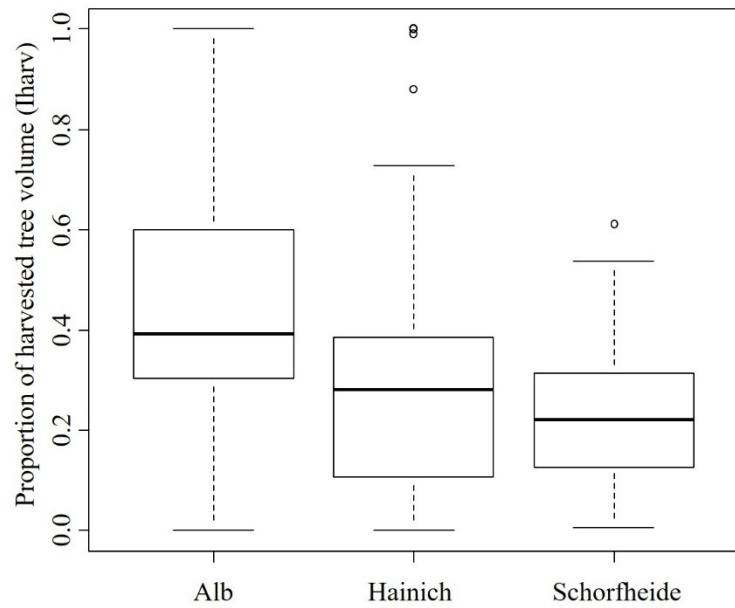


Fig. S1. Proportion of harvested tree volume (*Iharv*) between the different regions.

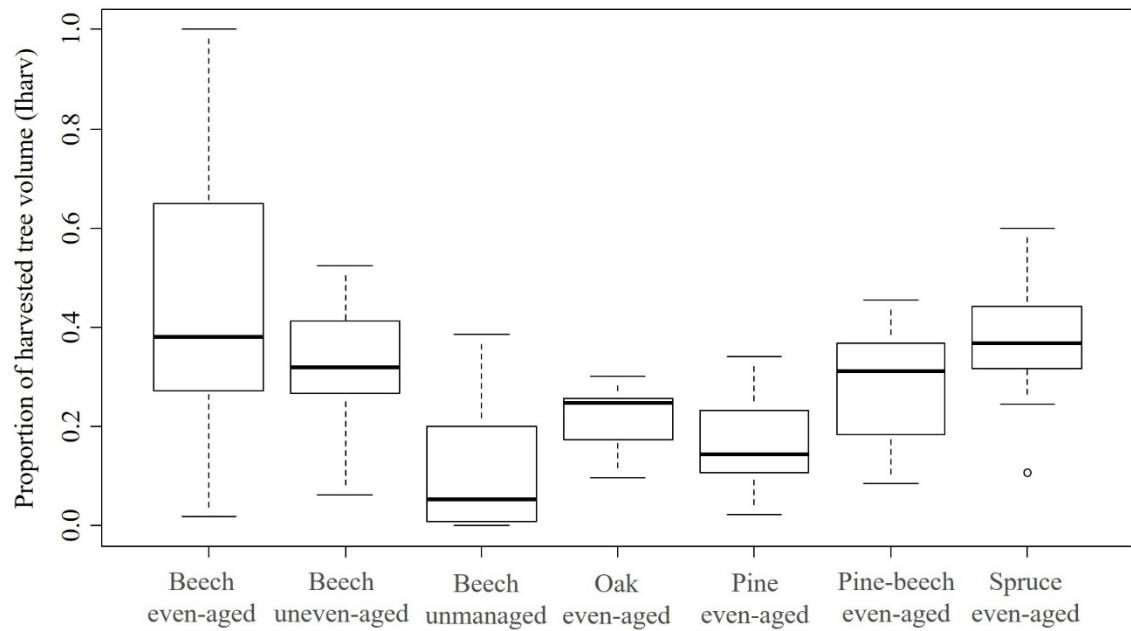


Fig. S2. Proportion of harvested tree volume (J_{harv}) between the different management types
(based on $n = 150$ plots)

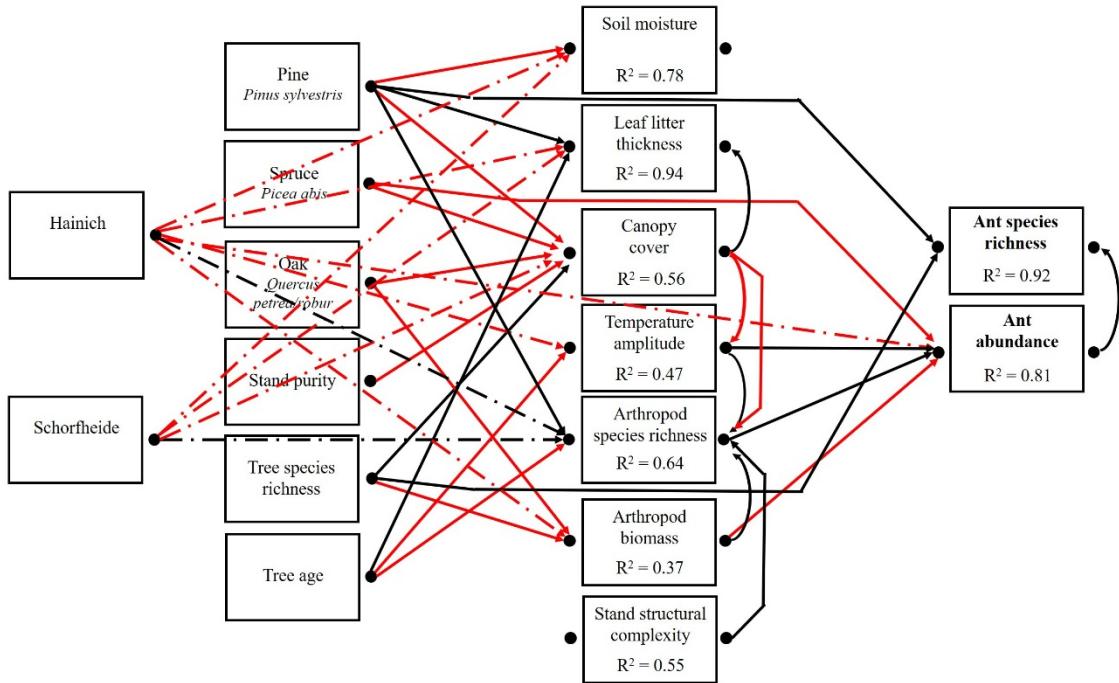


Fig. S3. Final piecewise structural equation model (based on $n = 141$ plots) exploring the direct and indirect effects of forest management on ant species richness with the region as fixed factor in the global model. Boxes represent measured variables. Arrows represent significant ($p < 0.05$), unidirectional relationships among variables. Black are positive and red are negative relationships. Dashed arrows are used to reduce the overlay. We report the path coefficients as standardized effect sizes in Table S7 to enhance the comprehensibility. R^2 values for component models are given in the boxes of their response variables.

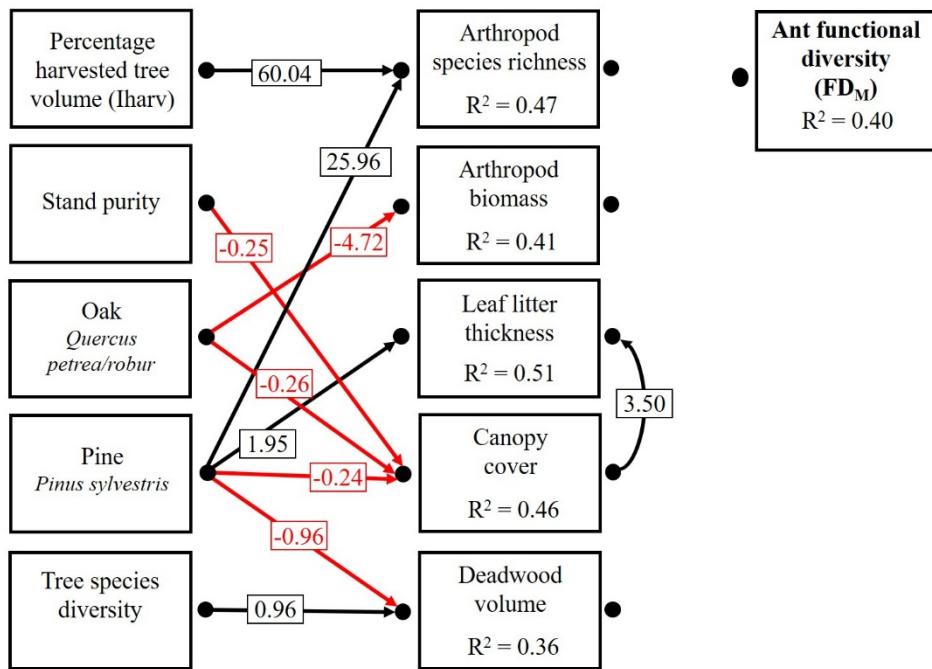


Fig. S4. Final piecewise structural equation model (based on $n = 44$ plots) exploring the direct and indirect effects of forest management on FD_M at the Schorfheide. Boxes represent measured variables. Arrows represent significant ($p < 0.05$), unidirectional relationships among variables. Black are positive and red are negative relationships.

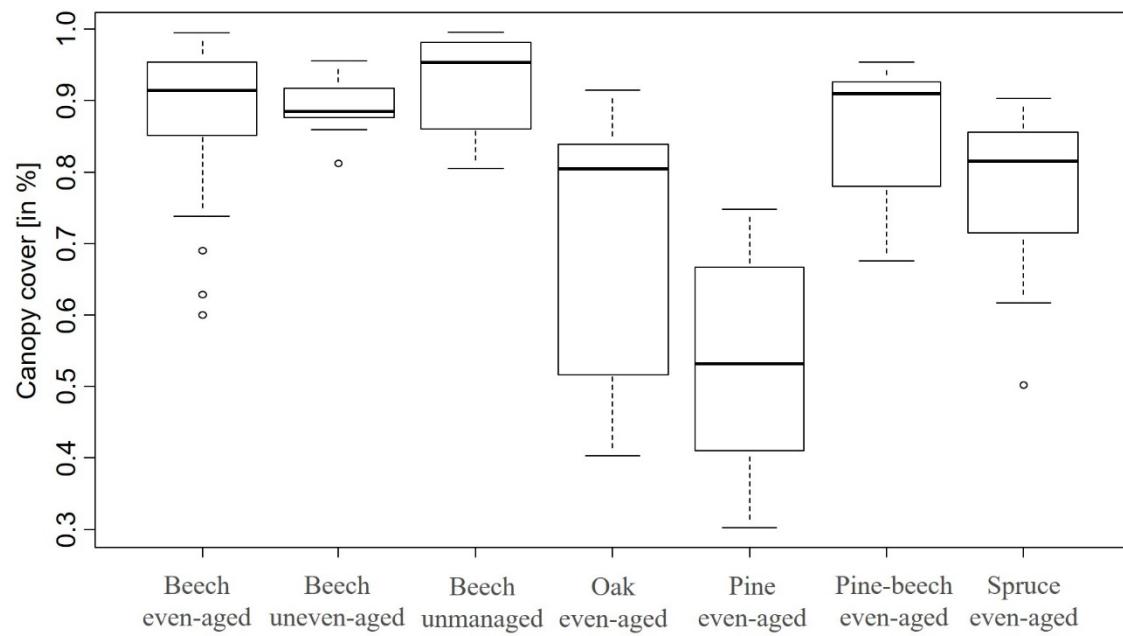


Fig. S5. Percentage of canopy cover of the different management types (based on $n = 150$ plots) assessed by airborne LiDAR in summer 2008 and 2009 during leaf-on condition.