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Invasion from the canopy: altered litterfall and nutrient input in European temperate forests

Supplementary Material

Table S1. Summary of linear mixedeffects models describing differences in particular components of litterfall mass (log-transformed), among studied forest types (fixed effects). Study year was considered as a random effect (RE). Abbreviations: SE – standard error; SD – standard deviation; RE – random effect; *RoPs – Robinia pseudoacacia*; *AcPl – Acer platanoides*; *AcPs – A. pseudoplatanus*; *PiSy – Pinus sylvestris*; *PrSe – Prunus serotina*; *QuRu – Quercus rubra*; *QuPe – Q. petraea*

Variable				Predictor	Estimate	SE	DFDen	t	Pr>|t|
bark				Intercept (*RoPs*)	4.7064	0.2552	5.1	18.44	<0.0001
AICc	69.407	AICc0	105.209	*AcPl+AcPs*	0.5869	0.2415	33	2.43	0.0207
R^2m	0.649	R^2c	0.777	*PiSy+AcPs*	1.7788	0.2415	33	7.36	<0.0001
F Ratio	16.078	Prob>F	<0.0001	*PiSy+AcPs+PrSe*	1.6049	0.2415	33	6.65	<0.0001
Year RE SD	0.3285	Residual RE SD	0.4183	*PiSy+PrSe*	1.7357	0.2415	33	7.19	<0.0001
Total RE SD	0.5319	Year RE pValue	0.37	*QuPe*	0.9488	0.2415	33	3.93	0.0004
				QuRu	0.6283	0.2415	33	2.60	0.0138
flowers				Intercept (*RoPs*)	3.9240	0.468	4.6	8.38	0.0006
AICc	116.381	AICc0	116.659	*AcPl+AcPs*	0.1446	0.42	33	0.34	0.73
R^2m	0.255	R^2c	0.557	*PiSy+AcPs*	1.4862	0.42	33	3.54	0.0012
F Ratio	3.178	Prob>F	0.0142	*PiSy+AcPs+PrSe*	0.5419	0.42	33	1.29	0.21
Year RE SD	0.6265	Residual RE SD	0.7274	*PiSy+PrSe*	0.7892	0.42	33	1.88	0.07
Total RE SD	0.96	Year RE pValue	0.36	*QuPe*	1.0689	0.42	33	2.55	0.0158
				QuRu	1.0148	0.42	33	2.42	0.0214
fruits/seeds				Intercept (*RoPs*)	6.8529	0.2036	3.6	33.66	<0.0001
AICc	36.106	AICc0	121.954	*AcPl+AcPs*	0.0355	0.1593	33	0.22	0.83
R^2m	0.867	R^2c	0.934	*PiSy+AcPs*	2.2684	0.1593	33	14.24	<0.0001
F Ratio	72.359	Prob>F	<0.0001	*PiSy+AcPs+PrSe*	2.2504	0.1593	33	14.13	<0.0001
Year RE SD	0.2938	Residual RE SD	0.2758	*PiSy+PrSe*	1.6277	0.1593	33	10.22	<0.0001
Total RE SD	0.403	Year RE pValue	0.35	*QuPe*	0.9856	0.1593	33	6.19	<0.0001
				QuRu	0.6702	0.1593	33	4.21	0.0002
remnants				Intercept (*RoPs*)	5.8153	0.1538	4.4	37.80	<0.0001
AICc	21.445	AICc0	14.630	*AcPl+AcPs*	0.2490	0.1354	33	1.84	0.075
R^2m	0.154	R^2c	0.509	*PiSy+AcPs*	0.0798	0.1354	33	0.59	0.56
F Ratio	1.735	Prob>F	0.14	*PiSy+AcPs+PrSe*	0.0304	0.1354	33	0.22	0.82
Year RE SD	0.2086	Residual RE SD	0.2344	*PiSy+PrSe*	0.0866	0.1354	33	0.64	0.53
Total RE SD	0.3138	Year RE pValue	0.36	*QuPe*	0.0191	0.1354	33	0.14	0.89
				QuRu	0.1789	0.1354	33	1.32	0.20
twigs				Intercept (*RoPs*)	6.2516	0.3515	2.5	17.79	0.0012
AICc	44.393	AICc0	51.526	*AcPl+AcPs*	0.3203	0.1685	33	1.90	0.07
R^2m	0.169	R^2c	0.808	*PiSy+AcPs*	0.8332	0.1685	33	4.94	<0.0001
F Ratio	4.846	Prob>F	0.0012	*PiSy+AcPs+PrSe*	0.3499	0.1685	33	2.08	0.0457
Year RE SD	0.5727	Residual RE SD	0.2919	*PiSy+PrSe*	0.5317	0.1685	33	3.16	0.0034
Total RE SD	0.6428	Year RE pValue	0.33	*QuPe*	0.6209	0.1685	33	3.68	0.0008
				QuRu	0.4778	0.1685	33	2.84	0.0078

Table S2. Mean (±SE) concentrations of elements (%) in freshly fallen leaves. Values are based on 12 autumnal collections over a three-year period (2019–2022), each conducted at the end of September, October, November, and December. For each species, concentrations were measured in composite leaf samples collected from 14 study plots

Element	*Acer platanoides*		*Acer pseudoplatanus*		*Pinus sylvestris*		*Prunus serotina*	
	Mean (±SE)	Min-Max	Mean (±SE)	Min-Max	Mean (±SE)	Min-Max	Mean (±SE)	Min-Max
C	44.62 (0.24)	43.01–46.02	44.57 (0.32)	42.5–48.09	49.63 (0.19)	47.96–51.52	45.41 (0.24)	43.64–47.24
N	1.89 (0.16)	0.97–3.63	1.95 (0.17)	1.22–4.22	0.93 (0.07)	0.53–1.5	1.56 (0.14)	0.74–2.79
Ca	1.82 (0.12)	1.07–2.69	2.21 (0.19)	1.06–4.07	0.98 (0.04)	0.73–1.29	1.85 (0.10)	1.39–2.70
K	0.43 (0.05)	0.2–1.01	0.44 (0.07)	0.14–1.05	0.19 (0.01)	0.13–0.33	0.31 (0.04)	0.07–0.69
Mg	0.17 (0.01)	0.13–0.26	0.15 (0.01)	0.06–0.22	0.06 (0.00)	0.05–0.1	0.29 (0.03)	0.13–0.52
P	0.09 (0.01)	0.04–0.14	0.09 (0.01)	0.03–0.15	0.05 (0.01)	0.02–0.09	0.09 (0.01)	0.04–0.14
Mn	0.19 (0.02)	0.08–0.34	0.18 (0.02)	0.07–0.33	0.16 (0.01)	0.09–0.21	0.26 (0.01)	0.15–0.37

Element	*Quercus petraea*		*Quercus rubra*		*Robinia pseudoacacia*	
	Mean (±SE)	Min-Max	Mean (±SE)	Min-Max	Mean (±SE)	Min-Max
C	46.19 (0.13)	44.95–47.31	46.46 (0.20)	44.92–48.39	44.76 (0.24)	43.02–47.08
N	1.48 (0.13)	0.75–2.71	1.15 (0.13)	0.48–2.32	2.1 (0.09)	1.56–3.03
Ca	0.9 (0.07)	0.52–1.36	0.98 (0.06)	0.44–1.37	3.01 (0.14)	2.22–4.06
K	0.33 (0.03)	0.14–0.58	0.37 (0.07)	0.09–1.05	0.3 (0.03)	0.17–0.57
Mg	0.16 (0.01)	0.13–0.25	0.13 (0.01)	0.09–0.18	0.18 (0.01)	0.11–0.28
P	0.08 (0.01)	0.02–0.15	0.08 (0.01)	0.01–0.16	0.08 (0.00)	0.05–0.11
Mn	0.27 (0.02)	0.11–0.41	0.41 (0.02)	0.22–0.58	0.04 (0.00)	0.01–0.08

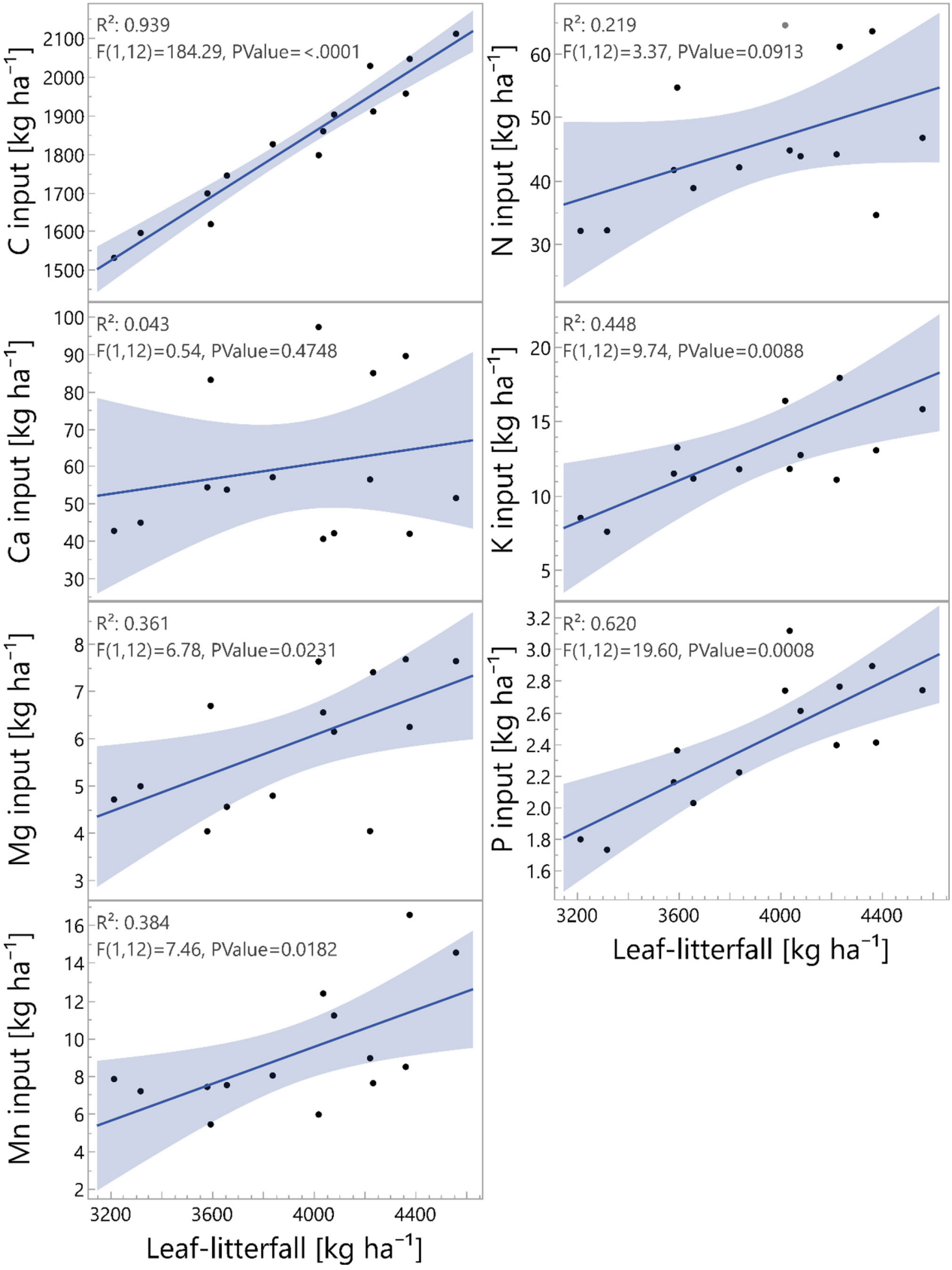

Fig. S1. Linear correlations between total annual leaf-litterfall and annual fluxes of selected elements (C, N, P, K, Ca, Mg, Mn) reaching the forest floor with freshly fallen leaves. Values represent averages from three study years across all forest types. Regression lines and corresponding R^2 and p-values are shown in each panel

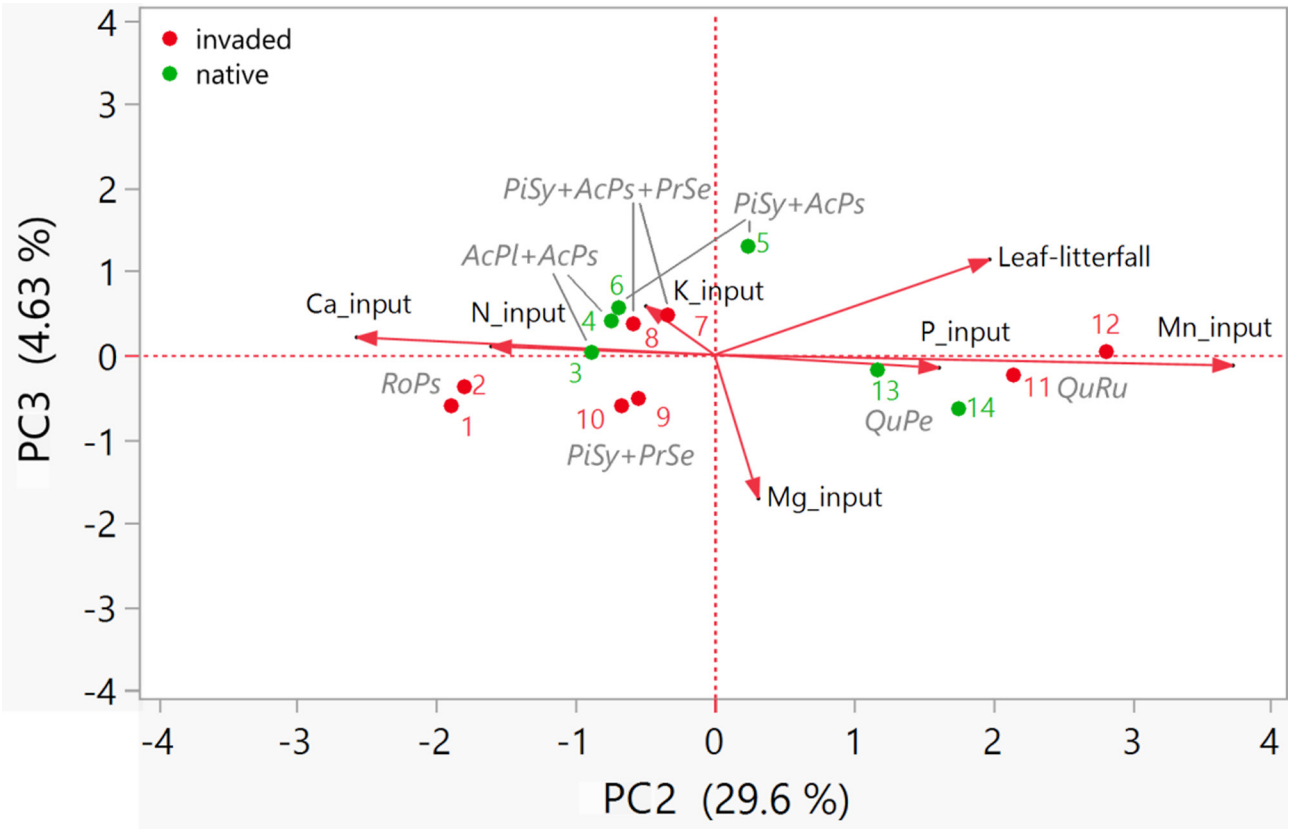

Fig. S2. Principal Components Analysis of mean annual leaf-litterfall and element inputs (N, Ca, K, Mg, P, Mn) across 14 study plots (kg ha^{-1}). All variables were standardized prior to analysis. Arrows indicate the direction and strength of variable loadings. Numbers represent individual plots grouped by forest type: 1–2 – *Robinia pseudoacacia* (*RoPs*); 3–4 – *Acer platanoides* and *A. pseudoplatanus* (*AcPl+AcPs*); 5–6 – *Pinus sylvestris* with *A. pseudoplatanus* undergrowth (*PiSy+AcPs*); 7–8 – *P. sylvestris* with *A. pseudoplatanus* and *Prunus serotina* undergrowth (*PiSy+AcPs+PrSe*); 9–10 – *P. sylvestris* with *P. serotina* undergrowth (*PiSy+PrSe*); 11–12 – *Quercus rubra* (*QuRu*); 13–14 – *Q. petraea* (*QuPe*)