Effect of native and invasive plant congeners on soil biotic and abiotic properties

Biological Invasions

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Supplementary Information

Table S1 Chemical composition of the soil before cultivation. Total nitrogen and carbon in %, exchangeable calcium, magnesium, potassium, phosphorus and total phosphorus in mg/1000 g. Soil is a mixture 1:1 of sand and common garden soil

Soil property	**Mean ± SD**	
	Year 2017	**Year 2018**
Active pH	7.77 ± 0.03	7.87 ± 0.03
Exchangeable pH	7.70 ± 0.01	7.62 ± 0.08
Total N	0.07 ± 0.02	0.07 ± 0.02
Total C	1.01 ± 0.20	0.91 ± 0.26
Exchangeable Ca	1259.35 ± 125.63	1691.77 ± 134.60
Exchangeable Mg	105.03 ± 11.53	117.11 ± 11.47
Exchangeable K	278.6 ± 21.61	272.91 ± 24.67
Exchangeable P	39.99 ± 1.12	35.99 ± 2.15
Total P	159.46 ± 46.7	204.98 ± 35.04

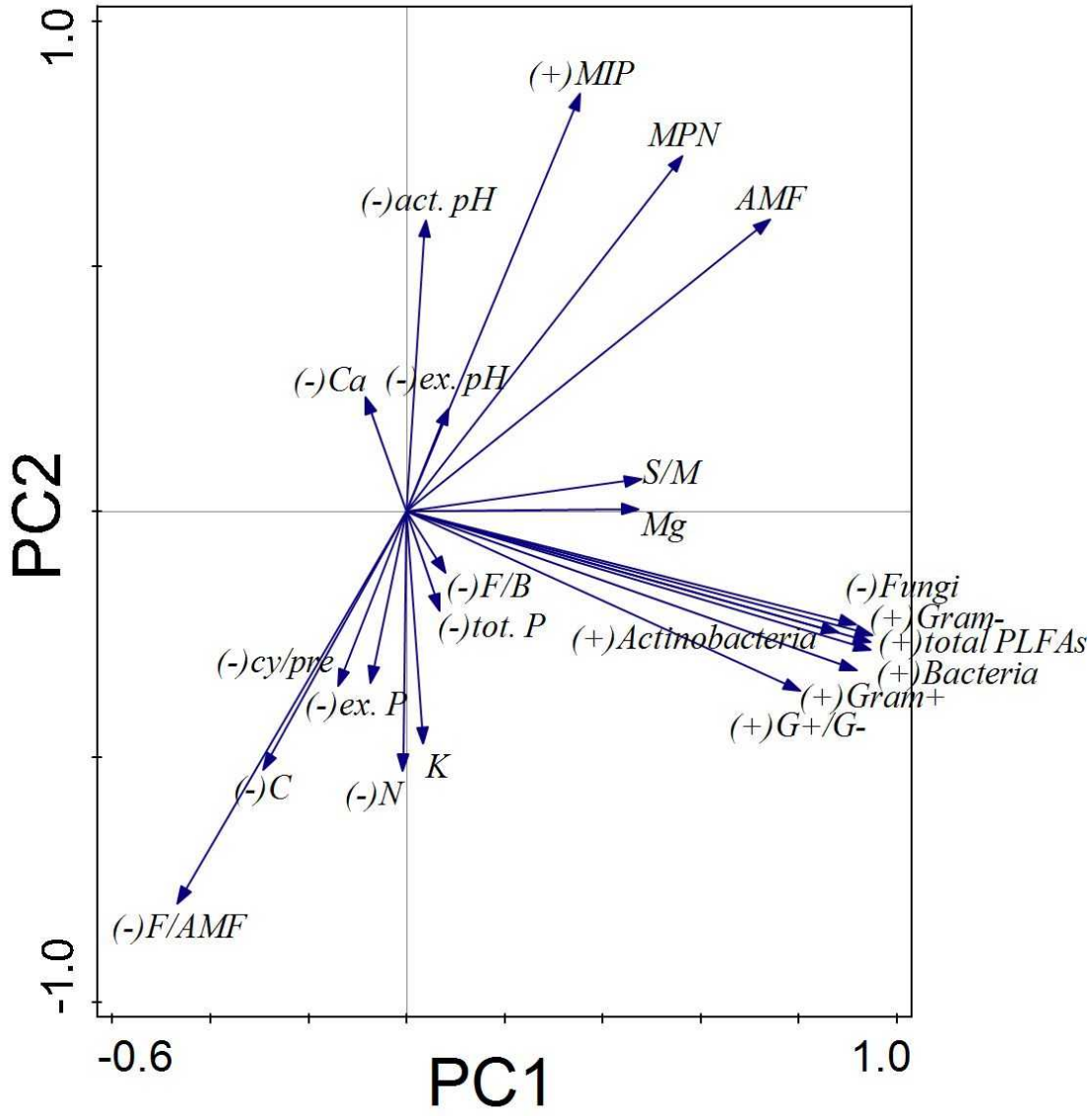
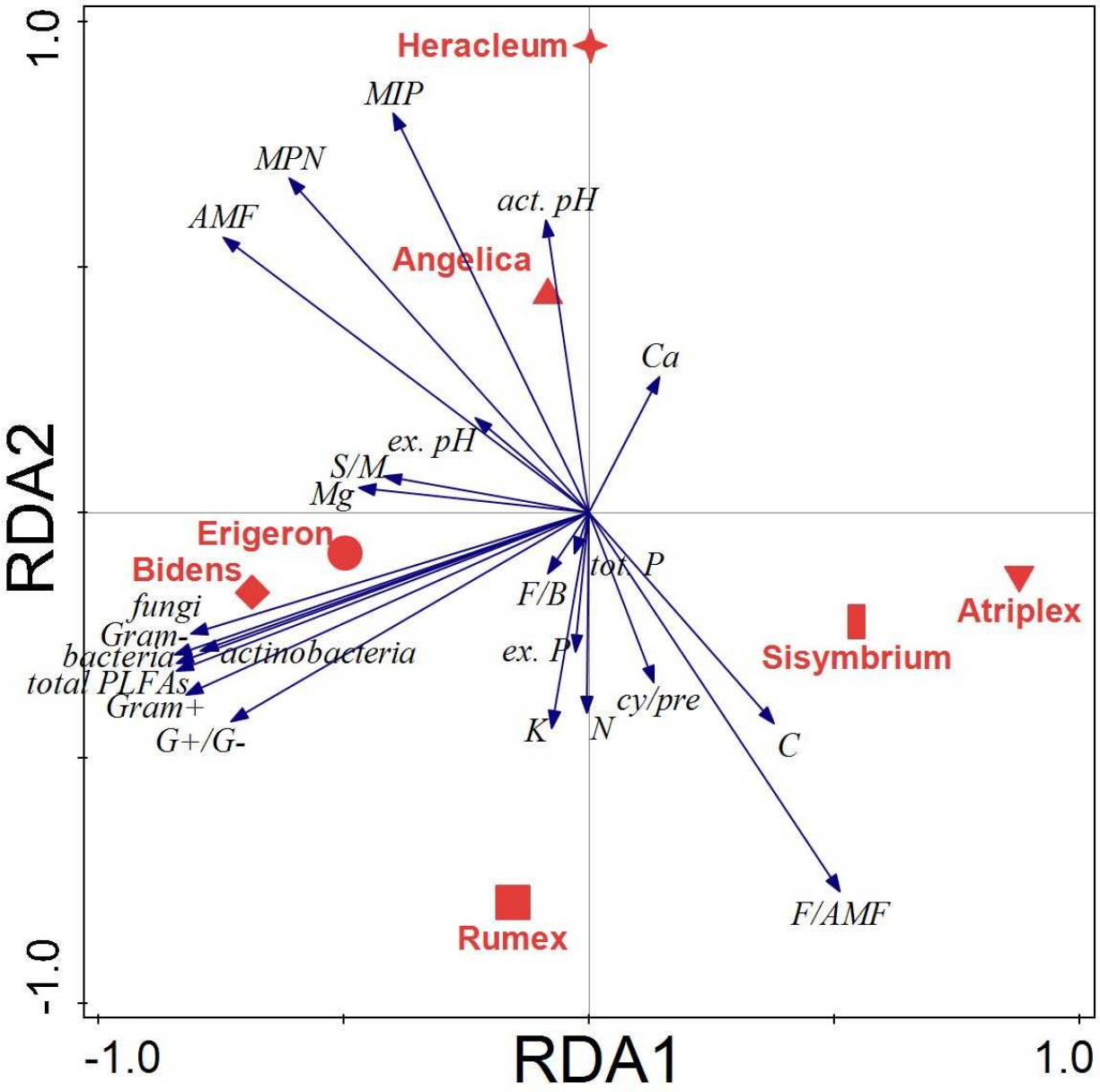


Fig. S1 PCA analysis of all the 23 soil properties (9 abiotic and 14 biotic) with the marked ratios of soil properties in cultivated to uncultivated soil (+ and -). Explained variation by axis 1 = 33.04 %, axis 2 = 18.9 %. It shows positive correlation of properties describing mycorrhiza (AMF, MPN and MIP) with soil acidity (both active and exchangeable pH) and calcium. Most other biotic properties clustered together (except ratios F/AMF and cy/pre) and they were also correlated with magnesium. The F/AMF and cy/pre ratios were correlated with total carbon, nitrogen and total and exchangeable phosphorus.

The ratios of soil properties in cultivated to control soil were significantly less than one (-) (i.e. lower in the cultivated soil) in 11 properties (active and exchangeable pH, total nitrogen, carbon and phosphorus, exchangeable calcium and phosphorus, fungi, F/B, F/AMF and cy/pre), significantly greater than one (+) in 7 (MIP, bacteria, Actinobacteria, Gram positive and Gram negative bacteria, total PLFAs and G+/G-) and not different from 1 in 5 properties (no sign) (exchangeable magnesium and potassium, MPN, AMF and S/M)



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34 **Fig. S2** Results of RDA analyses showing the effect of plant genus on all the 23 soil properties (9 abiotic and 14 biotic).
35 Pseudo-F = 25.60, p = 0.002, explained variation by axis 1 = 28.81 % and axis 2 = 17.50 %. All variables significantly
36 differ among genera when tested separately

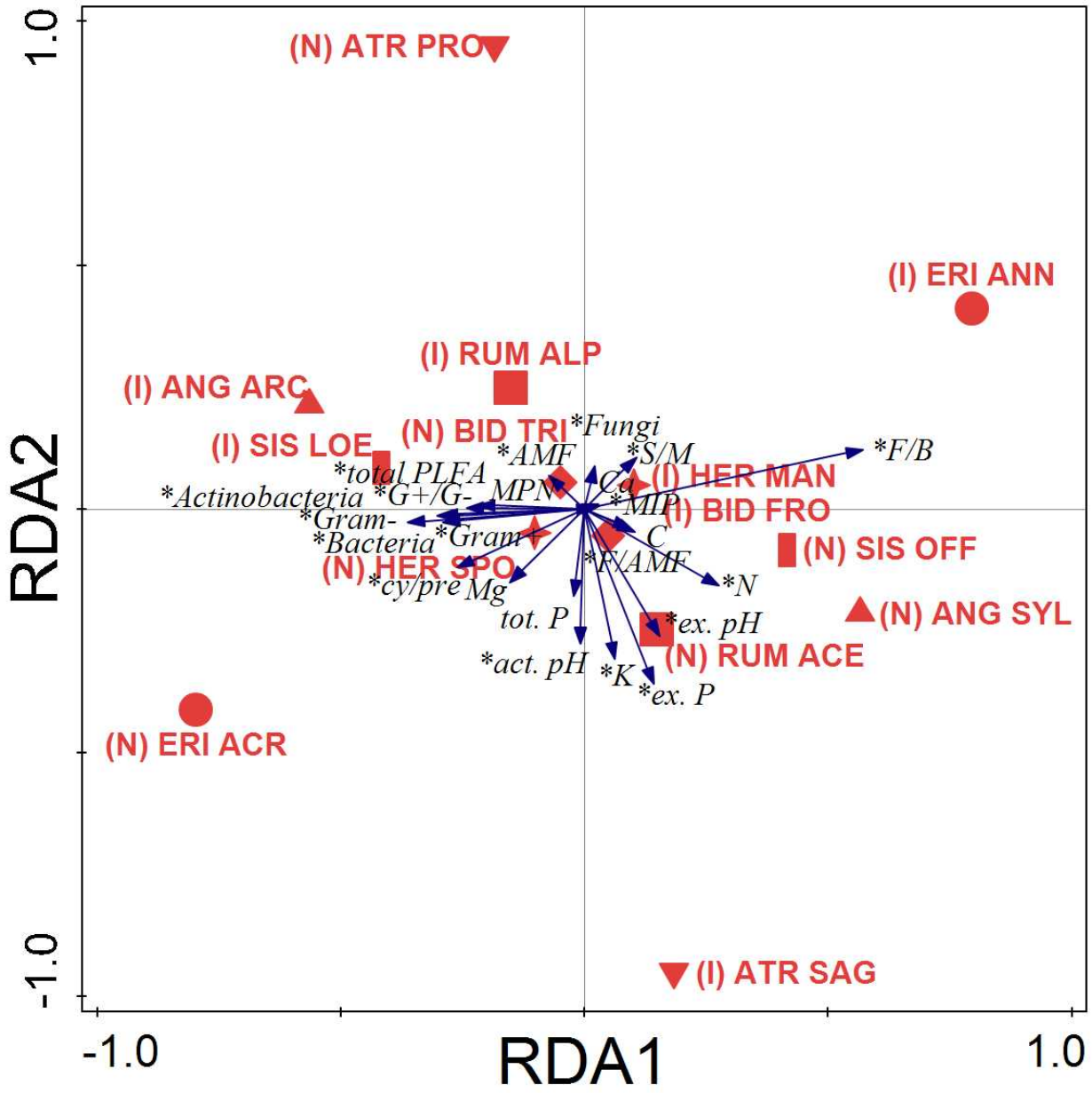


Fig. S3 Results of RDA analyses showing the effect of interaction of plant genus and invasion status on all the 23 soil properties (9 abiotic and 14 biotic). Pseudo- F = 4.40, p = 0.002, explained variation by axis 1 = 4.69 % and axis 2 = 2.20 %. Legend: (N) – native species, (I) – invasive species, asterisks – significant effect of interaction in ANOVA before Holm-Bonferroni correction, ANG ARC – Angelica archangelica, ANG SYL – Angelica sylvestris, ATR PRO – Atriplex prostrata, ATR SAG – Atriplex sagittata, BID FRO – Bidens frondosus, BID TRI – Bidens tripartitus, ERI ACR – Erigeron acris, ERI ANN – Erigeron annuus, HER MAN – Heracleum mantegazzianum, HER SPO – Heracleum sphondylium, RUM ACE – Rumex acetosa, RUM ALP – Rumex alpinus, SIS LOE – Sisymbrium loeselii, SIS OFF – Sisymbrium officinale

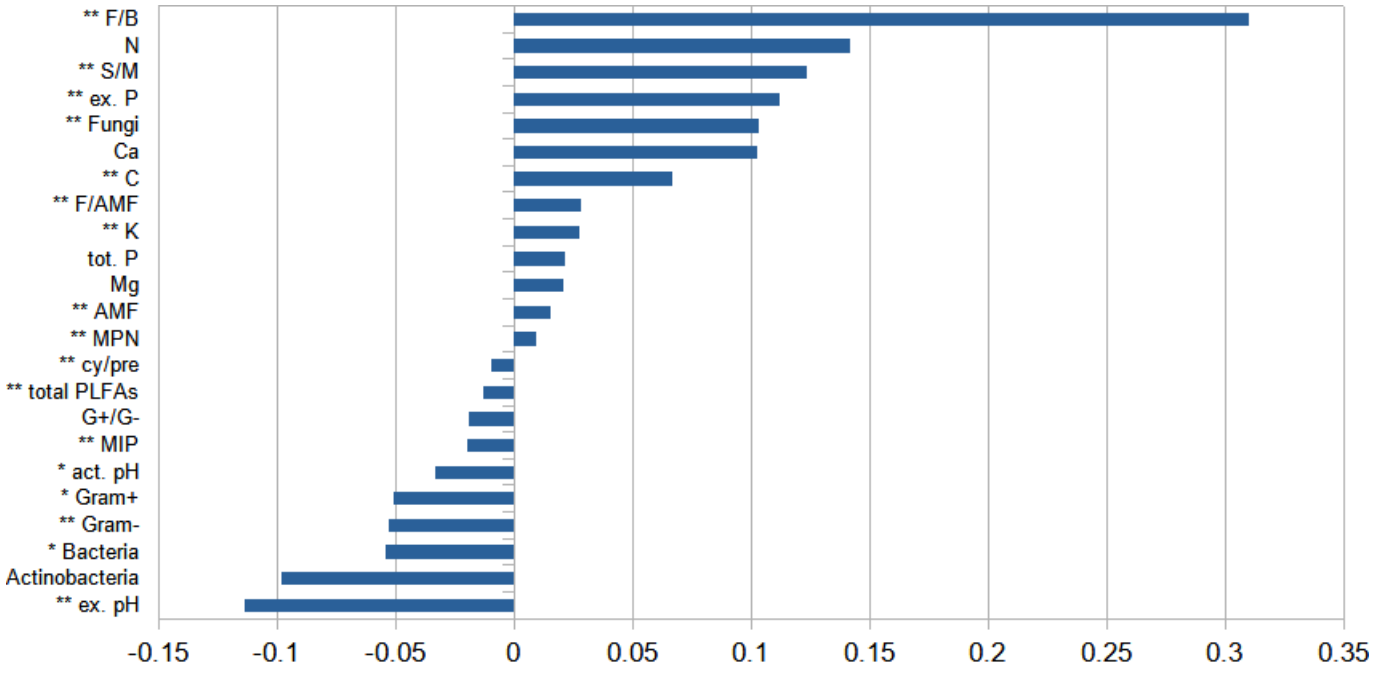


Fig. S4 Effect of plant aboveground biomass on all measured soil properties, based on axis 1 in RDA (pseudo- F = 2.10, p = 0.03, explained variation by axis 1 = 0.89 %), * - significant effect of biomass in ANOVA before Holm-Bonferroni correction, ** - significant effect on biomass after correction. Negative value indicates negative correlation with biomass whilst positive values indicate positive correlation with biomass

Table S2 Pearson correlation coefficient among studied soil properties. Act. pH and ex. pH represent the pH values. N, C and tot. P refer to total content of the nutrients, Ca, Mg, K and ex. P to content of exchangeable nutrients. MPN (most probable number) describes the amount of mycorrhizal fungi in the soil and MIP (mean infection percentage) describes the potential of AMF to colonize roots. AMF, Fungi, Bact. (Bacteria), Actin. (Actinobacteria), Gram+ (Gram-positive bacteria, G+), Gram- (Gram-negative bacteria, G-) and PLFAs (total microbial biomass) represent biomass of the individual groups of soil biota obtained by PLFA and NLFA analyses, and F/B, G+/G-, F/AMF their ratios. Cy/pre represents the ratio of cyclopropyl PLFAs to their monoenoic precursors and S/M is a ratio of saturated to monounsaturated PLFAs. Significant correlations ($p < 0.05$) are in bold, positive correlations are highlighted by blue and negative correlations by red colour. Soil properties not used in RDA analyses due to strong correlations ($r > 0.7$) are highlighted by grey colour

	act. pH	ex. pH	N	C	Ca	Mg	K	ex. P	tot. P	MPN	MIP	AMF	Fungi	Bact.	Actin.	Gram+	Gram-	PLFAs	F/B	G+/G-	F/AMF	Cy/pre	S/M
act. pH	1.00																						
ex. pH	**0.56**	1.00																					
N	-0.20	-0.04	1.00																				
C	**-0.45**	**-0.40**	**0.66**	1.00																			
Ca	-0.10	**-0.48**	-0.12	-0.04	1.00																		
Mg	-0.06	0.13	0.17	-0.17	**0.25**	1.00																	
K	-0.06	**0.37**	**0.23**	-0.11	**-0.31**	**0.38**	1.00																
ex. P	-0.02	**0.40**	**0.27**	0.06	**-0.38**	0.15	**0.49**	1.00															
tot. P	-0.06	-0.14	**0.46**	**0.36**	0.10	0.19	-0.03	0.09	1.00														
MPN	**0.45**	**0.27**	**-0.26**	**-0.47**	0.01	**0.28**	**-0.29**	-0.14	-0.08	1.00													
MIP	**0.59**	**0.29**	**-0.37**	**-0.51**	0.07	0.18	**-0.29**	**-0.25**	-0.19	**0.85**	1.00												
AMF	**0.29**	0.12	-0.19	**-0.37**	0.07	**0.38**	**-0.32**	-0.20	0.04	**0.87**	**0.77**	1.00											
Fungi	-0.15	-0.06	0.18	-0.08	-0.06	**0.32**	0.05	-0.04	0.09	**0.31**	0.12	**0.52**	1.00										
Bact.	-0.09	0.01	0.04	-0.17	-0.14	**0.37**	0.12	-0.03	0.06	**0.32**	0.10	**0.51**	**0.87**	1.00									
Actin.	-0.01	0.08	0.03	**-0.24**	-0.16	**0.40**	0.18	-0.02	0.03	**0.33**	0.13	**0.49**	**0.79**	**0.97**	1.00								
Gram+	-0.12	0.00	0.06	-0.14	-0.16	**0.34**	0.13	0.00	0.06	**0.26**	0.04	**0.46**	**0.85**	**0.99**	**0.95**	1.00							
Gram-	-0.09	0.00	0.05	-0.18	-0.13	**0.38**	0.11	-0.05	0.06	**0.33**	0.12	**0.52**	**0.88**	**1.00**	**0.97**	**0.98**	1.00						
PLFA	-0.14	-0.03	0.09	-0.14	-0.12	**0.37**	0.11	-0.05	0.09	**0.31**	0.09	**0.52**	**0.93**	**0.99**	**0.94**	**0.97**	**0.99**	1.00					
F/B	**-0.25**	-0.20	**0.34**	**0.24**	0.14	-0.01	-0.08	0.00	0.16	-0.03	-0.04	0.08	**0.47**	-0.01	-0.12	-0.03	0.02	0.14	1.00				
G+/G-	-0.11	0.04	0.04	-0.11	-0.20	**0.25**	0.14	0.09	0.00	0.18	-0.03	**0.35**	**0.74**	**0.89**	**0.83**	**0.94**	**0.87**	**0.85**	-0.11	1.00			
F/AMF	**-0.40**	-0.17	**0.30**	**0.39**	-0.11	**-0.30**	**0.39**	0.21	-0.01	**-0.87**	**-0.84**	**-0.93**	-0.16	-0.20	-0.21	-0.15	-0.21	-0.19	0.11	-0.07	1.00		
Cy/pre	0.09	**0.29**	-0.12	-0.08	**-0.39**	-0.16	**0.40**	**0.35**	**-0.29**	**-0.30**	**-0.22**	**-0.43**	-0.21	0.05	0.12	0.10	0.02	-0.04	**-0.52**	**0.22**	**0.40**	1.00	
S/M	**-0.22**	-0.14	**0.25**	0.07	0.03	**0.38**	-0.07	-0.12	**0.33**	**0.31**	0.16	**0.53**	**0.53**	**0.32**	**0.27**	**0.26**	**0.35**	**0.43**	**0.56**	0.08	**-0.37**	**-0.68**	1.00

Table S3 Effect of plant genus, invasion status, their interactions and aboveground biomass all the 23 soil properties (9 abiotic and 14 biotic), % = explained variability, P<0.05 in bold, RDA performed in CANOCO and the tests were done using permutation test with 499 permutations. The results are obtained using type III test, i.e. effect of each predictor is tested after controlling for all the other predictors

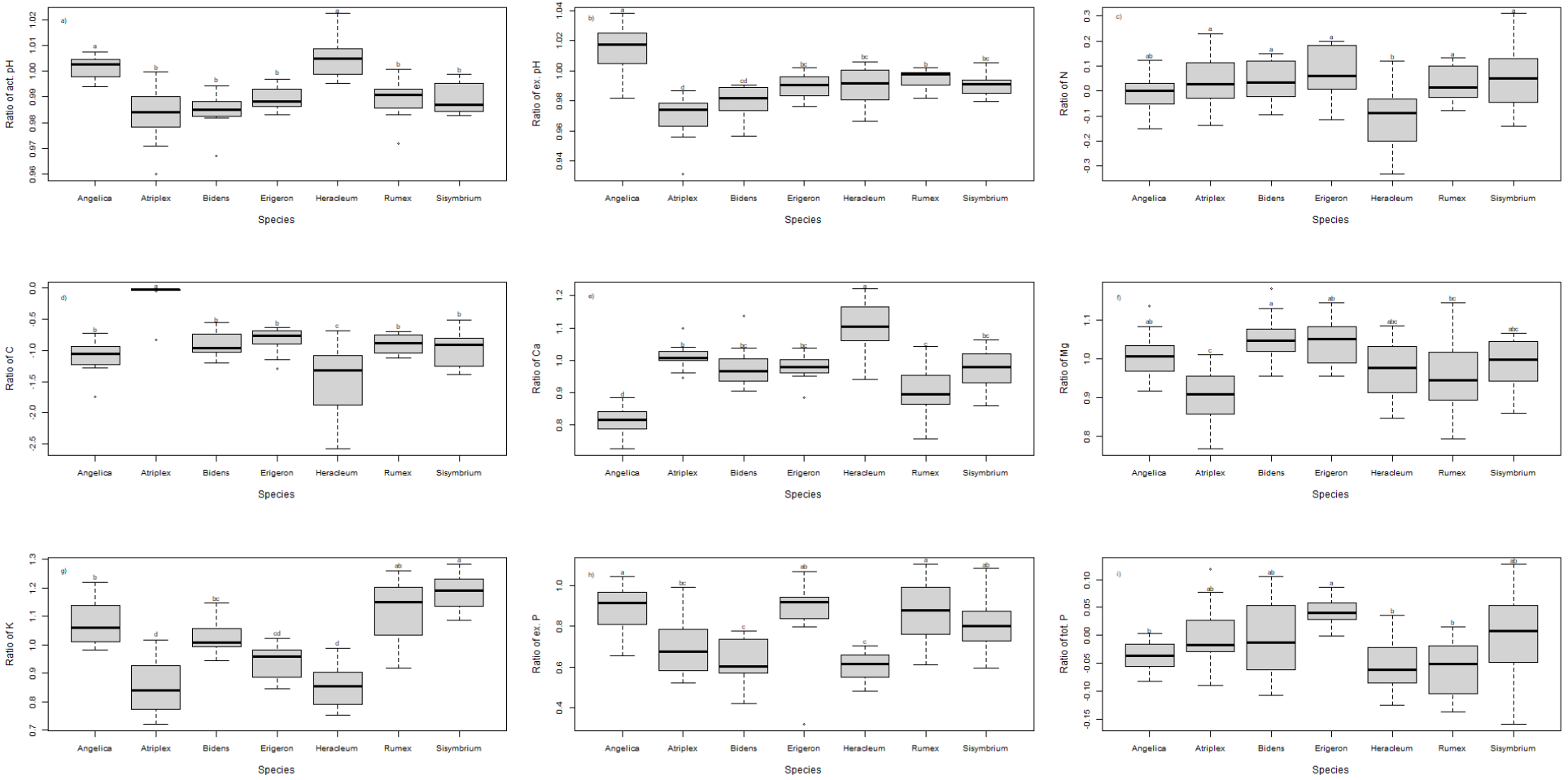
	Genus		**Invasion status**		**Genus*Invasion status**		**Aboveground biomass**	
	%	P-value	%	P-value	%	P-value	%	P-value
Abiotic properties	45.19	**0.002**	-	0.412	8.84	**0.002**	-	0.358
Biotic properties	75.85	**0.002**	-	0.486	8.44	**0.002**	9.45	**0.002**
Abiotic + biotic properties	63.85	**0.002**	-	0.518	8.60	**0.002**	0.89	**0.030**

Table S4 Transformation applied to improve normality and homogeneity of variance of different soil properties

Soil property	**Transformation**
ex. pH	none
act. pH	y ^ 2.25
N	log10(y)
C	((-1)*(y ^ -1.275))
Ca	y ^ 0.85
Mg	none
K	sqrt(y)
ex. P	y ^ 2.3
tot. P	log10(y)
MPN	log10(y)
MIP	none
AMF	log10(y)
Fungi	log10(y)
Bacteria	sqrt(y)
Actinobacteria	sqrt(y)
Gram+ bacteria	sqrt(y)
Gram- bacteria	sqrt(y)
PLFA_total	sqrt(y)
F/B	log10(y)
Gp/Gm	none
F/AMF	log10(y)
cy/pre	((-1)*(y ^ -2.125))
S/M	sqrt(y)

Table S5 Effect of genus, invasion status, interaction of genus and invasion status and biomass on soil properties. Comparison of p-values from ANOVA before and after Holm-Bonferroni correction. Significant p-values before correction in bold

Soil property	Genus, p-value	Significant after H-B correction	Invasion status, p-value	Significant after H-B correction	Genus*invasion status, p-value	Significant after H-B correction	Biomass, p-value	Significant after H-B correction
act. pH	**<0.001**	yes	0.315	no	**0.008**	no	**0.006**	yes
ex. pH	**<0.001**	yes	0.841	no	**0.003**	yes	**<0.001**	yes
N	**<0.001**	yes	0.880	no	**0.018**	no	0.159	no
C	**<0.001**	yes	0.856	no	0.521	no	**<0.001**	yes
Ca	**<0.001**	yes	0.369	no	0.720	no	0.577	no
Mg	**<0.001**	yes	0.252	no	0.198	no	0.746	no
K	**<0.001**	yes	0.231	no	**<0.001**	yes	**<0.001**	yes
ex. P	**<0.001**	yes	**0.032**	no	**<0.001**	yes	**0.004**	yes
tot. P	**<0.001**	yes	0.648	no	0.634	no	0.517	no
MIP	**<0.001**	yes	**0.001**	no	**0.004**	yes	**<0.001**	yes
total PLFAs	**<0.001**	yes	0.357	no	**<0.001**	yes	**<0.001**	yes
F/B	**<0.001**	yes	0.681	no	**<0.001**	yes	**<0.001**	yes
cy/pre	**<0.001**	yes	0.065	no	**<0.001**	yes	**<0.001**	yes
S/M	**<0.001**	yes	0.778	no	**0.019**	no	**<0.001**	yes


a)
Ratio of act. pH
Angelica
Atriplex
Bidens
Erigeron
Heracleum
Rumex
Sisymbrium
Species
b)
Ratio of ex. pH
c)
Ratio of N
d)
Ratio of C
e)
Ratio of Ca
f)
Ratio of Mg
g)
Ratio of K
h)
Ratio of ex. P
i)
Ratio of tot. P

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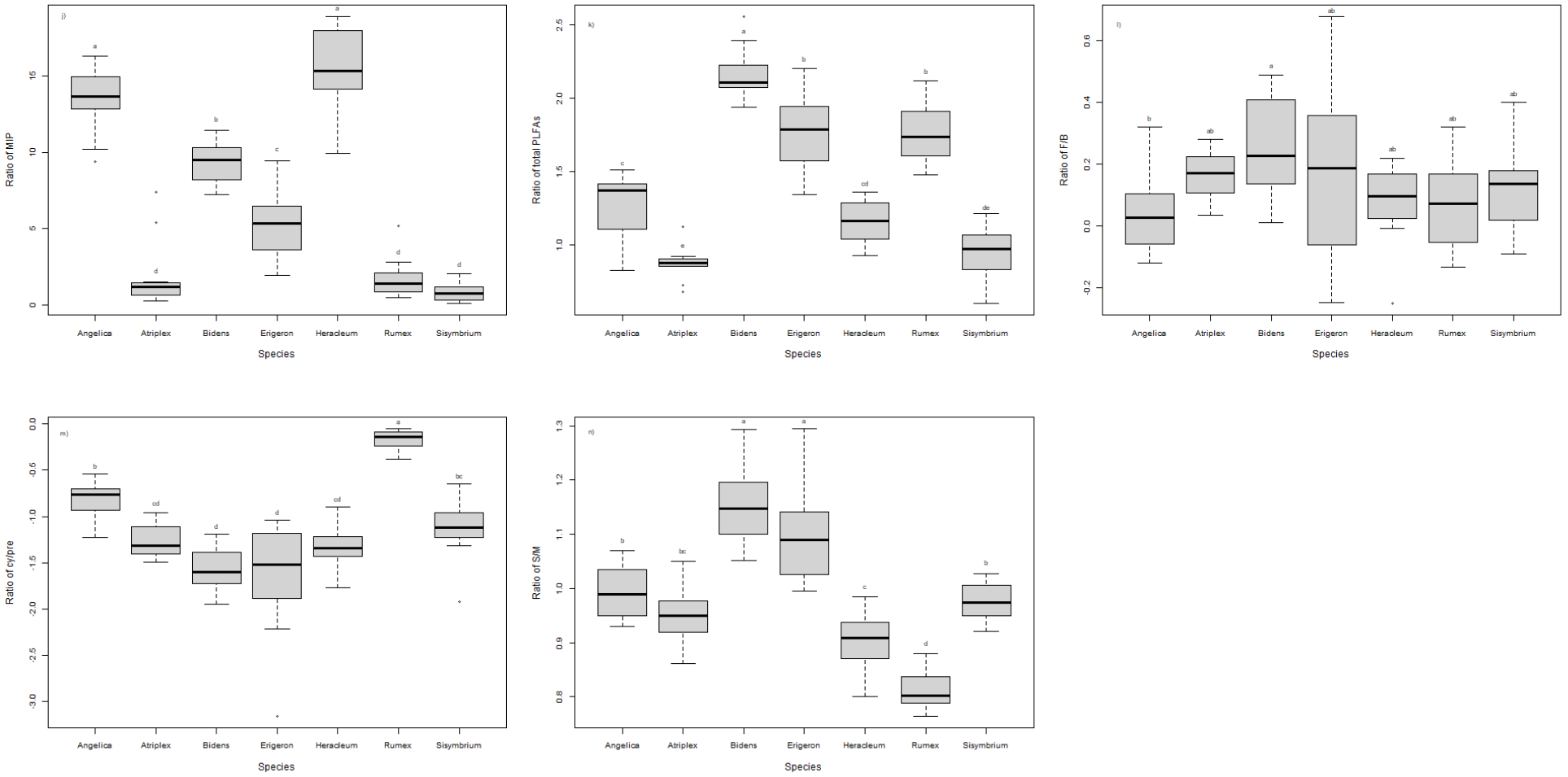
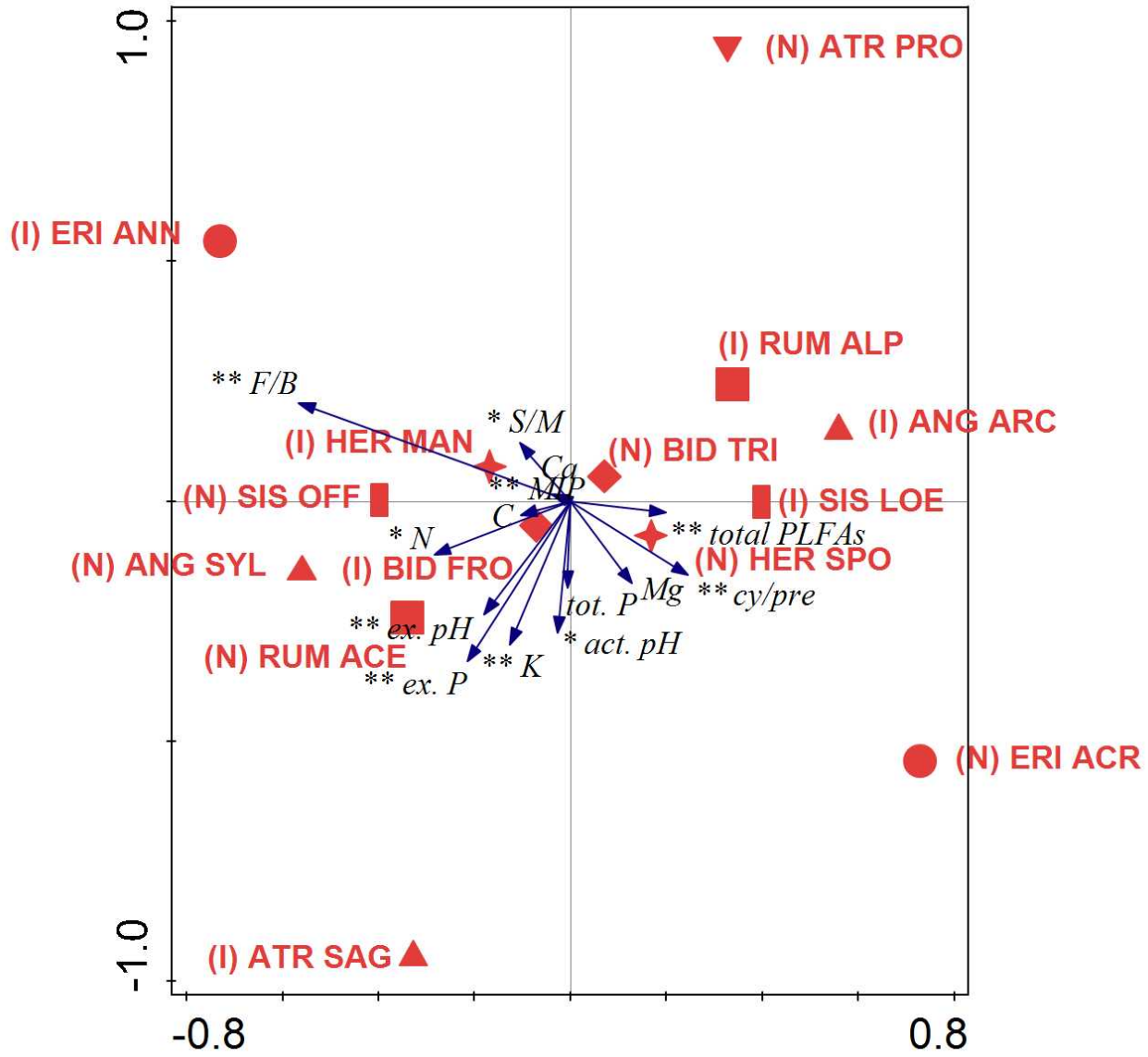


Fig. S5 Effect of individual genera on soil properties. Shown are soil properties identified as significantly different based on ANOVA. Genera not sharing any letter are significantly different from each other based on Tukey test



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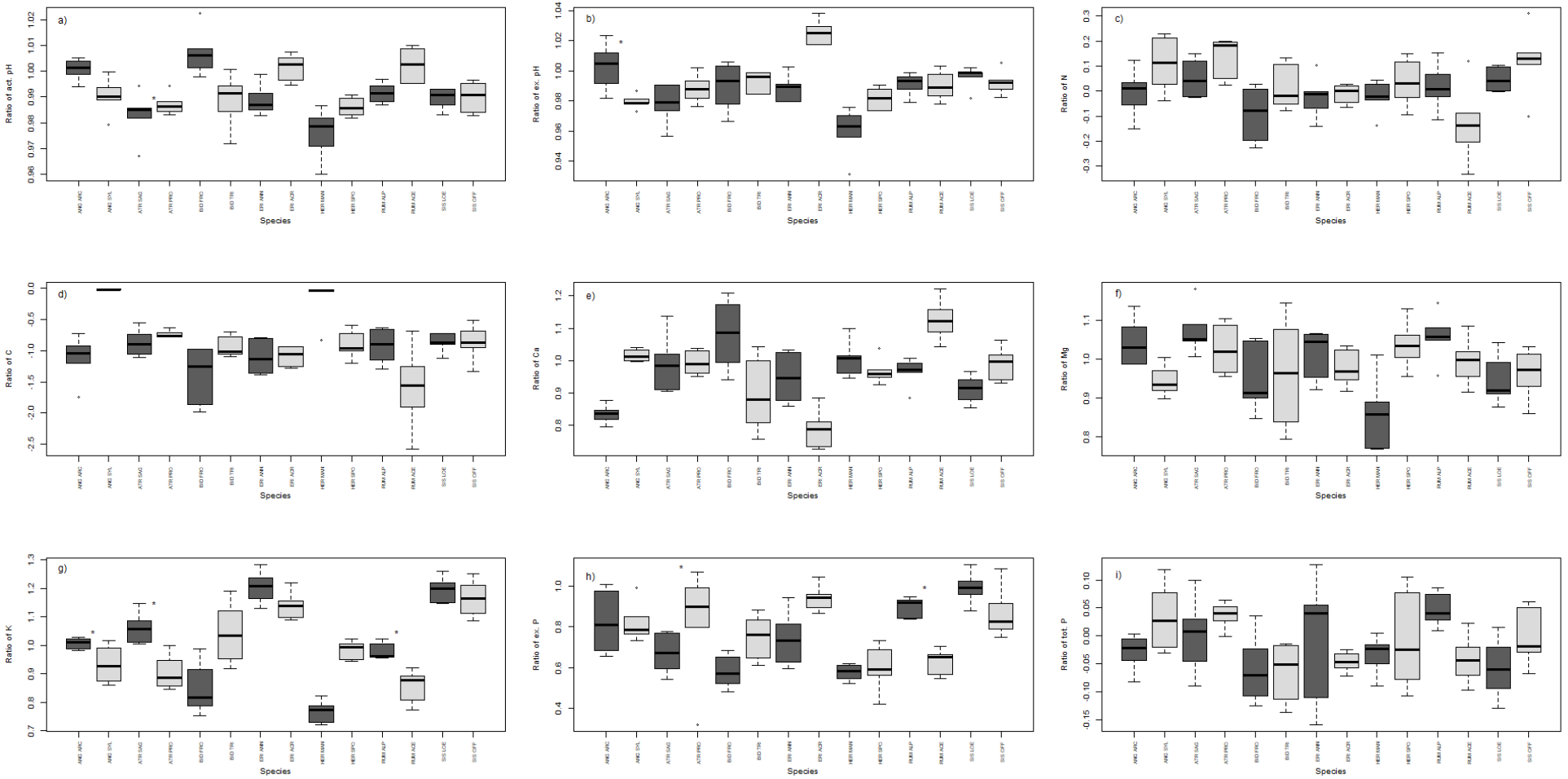
78 **Fig. S6** Effect of interaction of plant genus and invasion status on biotic and abiotic selected soil properties, pseudo- F =
79 3.60, p = 0.002, explained variation by axis 1 = 4.55 % and axis 2 = 3.49 %, RDA, legend: (N) – native species, (I) –
80 invasive species, * – significant effect of interaction in ANOVA before Bonferroni correction, ** – significant effect of
81 interaction in ANOVA after correction, ANG ARC – Angelica archangelica, ANG SYL – Angelica sylvestris, ATR PRO
82 – Atriplex prostrata, ATR SAG – Atriplex sagittata, BID FRO – Bidens frondosus, BID TRI – Bidens tripartitus, ERI
83 ACR – Erigeron acris, ERI ANN – Erigeron annuus, HER MAN – Heracleum mantegazzianum, HER SPO –
84 Heracleum sphondylium, RUM ACE – Rumex acetosa, RUM ALP – Rumex alpinus, SIS LOE – Sisymbrium loeselii,
85 SIS OFF – Sisymbrium officinale


a)
Ratio of act. pH
b)
Ratio of ex. pH
c)
Ratio of N
d)
Ratio of C
e)
Ratio of Ca
f)
Ratio of Mg
g)
Ratio of K
h)
Ratio of ex. P
i)
Ratio of tot. P
Species

86

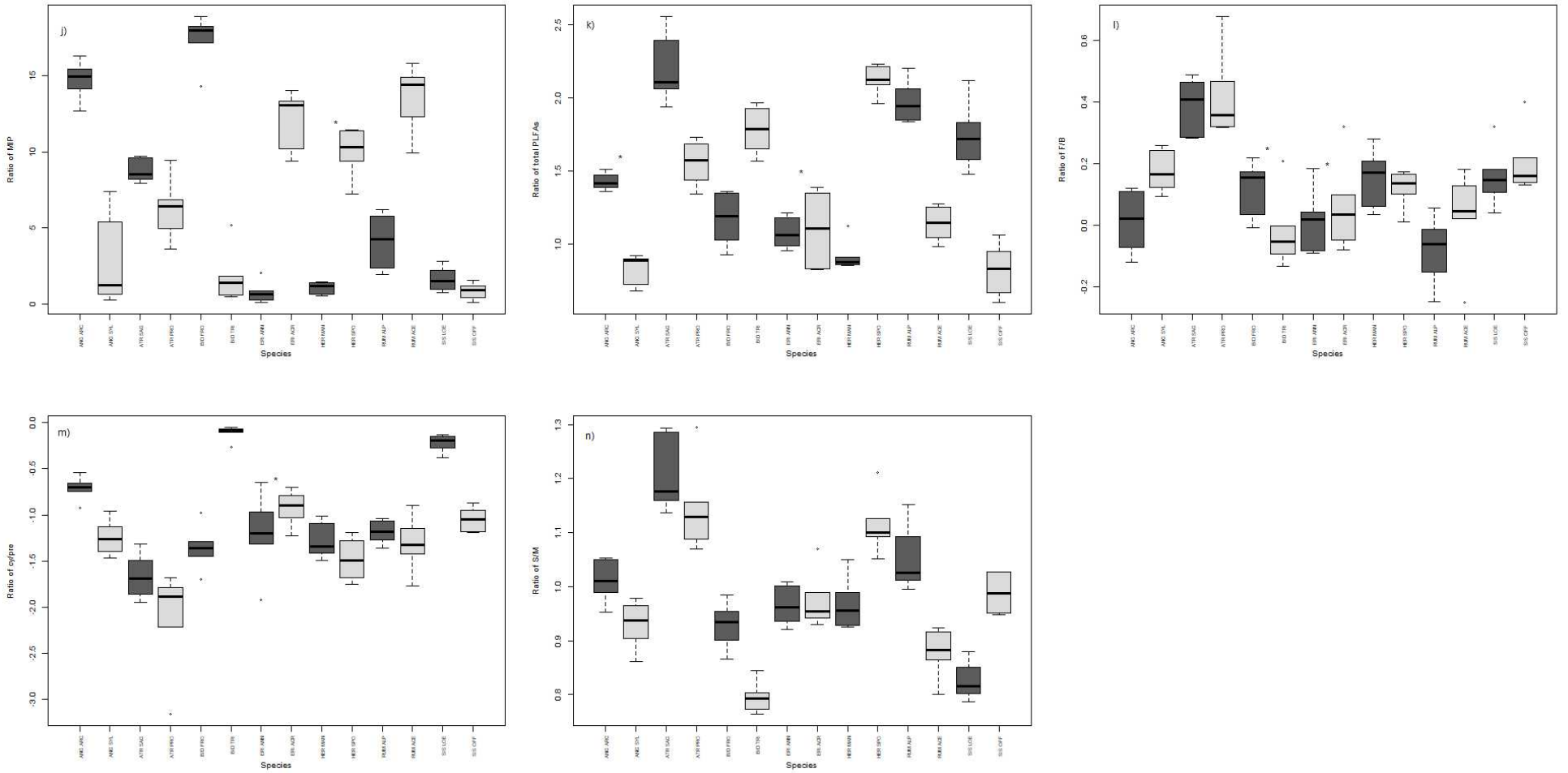


Fig. S7 Effect of individual species on soil properties. Shown are soil properties identified as significantly different based on ANOVA. Invasive species are highlighted by dark grey colour, native species by light grey. Asterisks – species with the significant differences within genera based on Tukey test