SUPPLEMENTARY INFORMATION APENDIX

Negative effects of nitrogen override positive effects of phosphorus on grassland legumes worldwide

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SUPPLEMENTARY INFORMATION

Supplementary figures

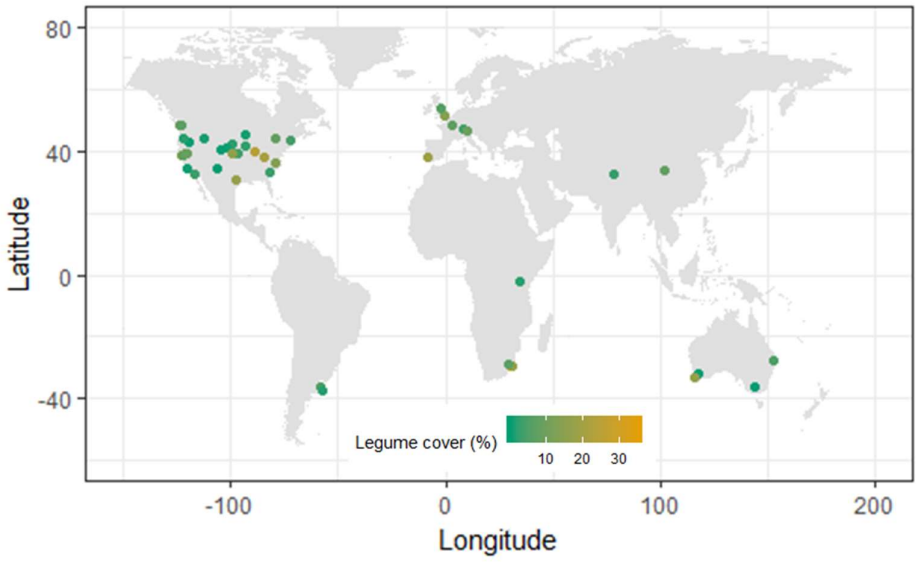
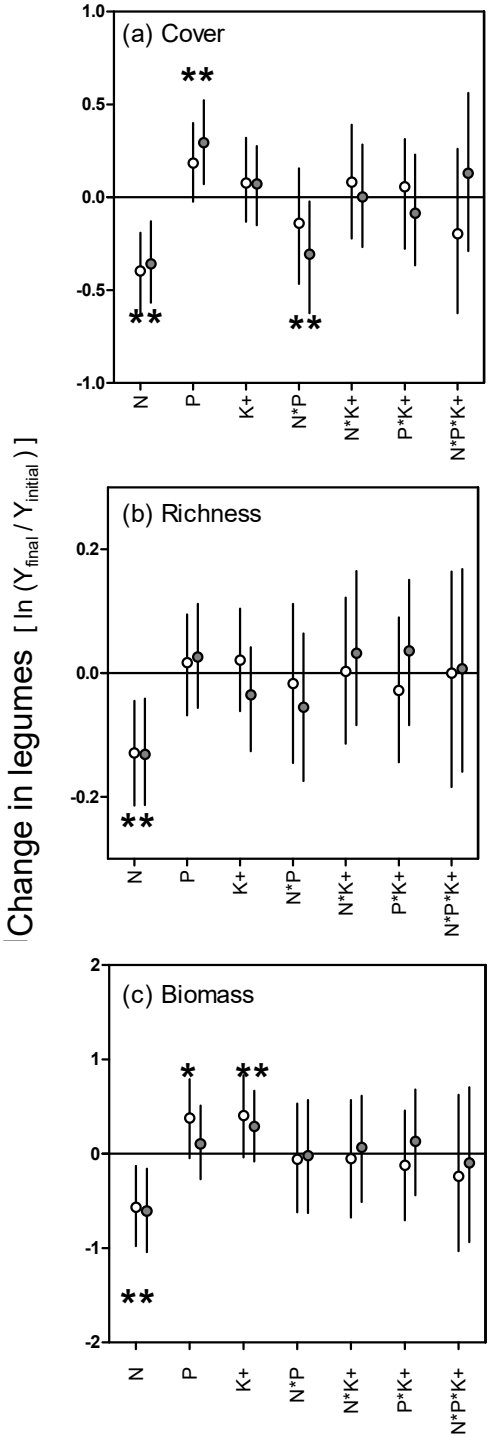


Fig. S1. Location of the 45 experimental sites. Colour scale represents the mean initial abundance of N-fixing legumes (%). See Table S1 for details about each site.



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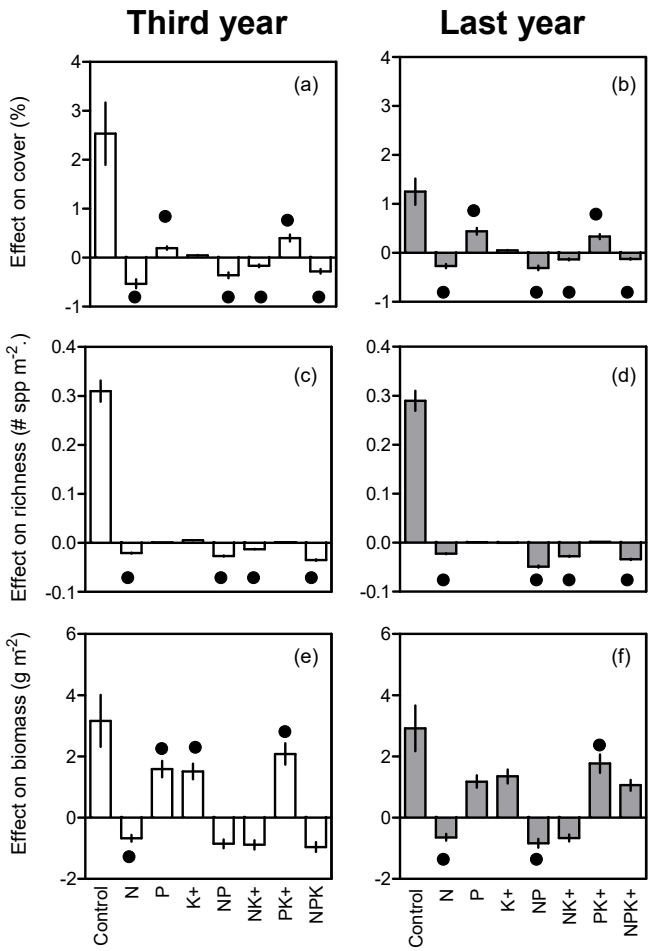
48 **Fig. S2**. Estimated effects of N, P, K+ from mixed models of change in cover (a), richness (b) and
49 biomass (c) of legumes by the 3rd year (open circles) and last year (filled circles) of the experiment.
50 Interactions (i.e. N*P, N*K+, P*K+, and N*P*K+) test for additivity, with significant positive or
51 negative values indicating positive or negative super-additivity, when compared with respective
52 individual nutrient effects (see Results). Symbols are the estimates ± bootstrapped 95% confidence
53 intervals for the model parameters of the complete model. Asterisks indicate significant terms
54 remaining in the reduced model (*P < 0.05 see Table S3).



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56 **Fig. S3.** Response of legume cover (a-b), richness (c-d) and biomass (e-f) for the third year (left
57 column) and last (third to sixth) year after initiation of the experiment (right column). Responses
58 were expressed in their original values after back transformations. Positive and negative values
59 indicate increases and decreases in relation to control (first bar; presented for reference),
60 respectively. Initial legume cover, richness and biomass covariable coefficients were all significant
61 and positive. Bars are means ± standard error of the means and dots (•) indicate treatment means
62 statistically differed from controls. Note the different Y-axis ranges. Cover and richness data were
63 available for 45 sites and biomass data for 26 sites. Simplified model in Table S4.

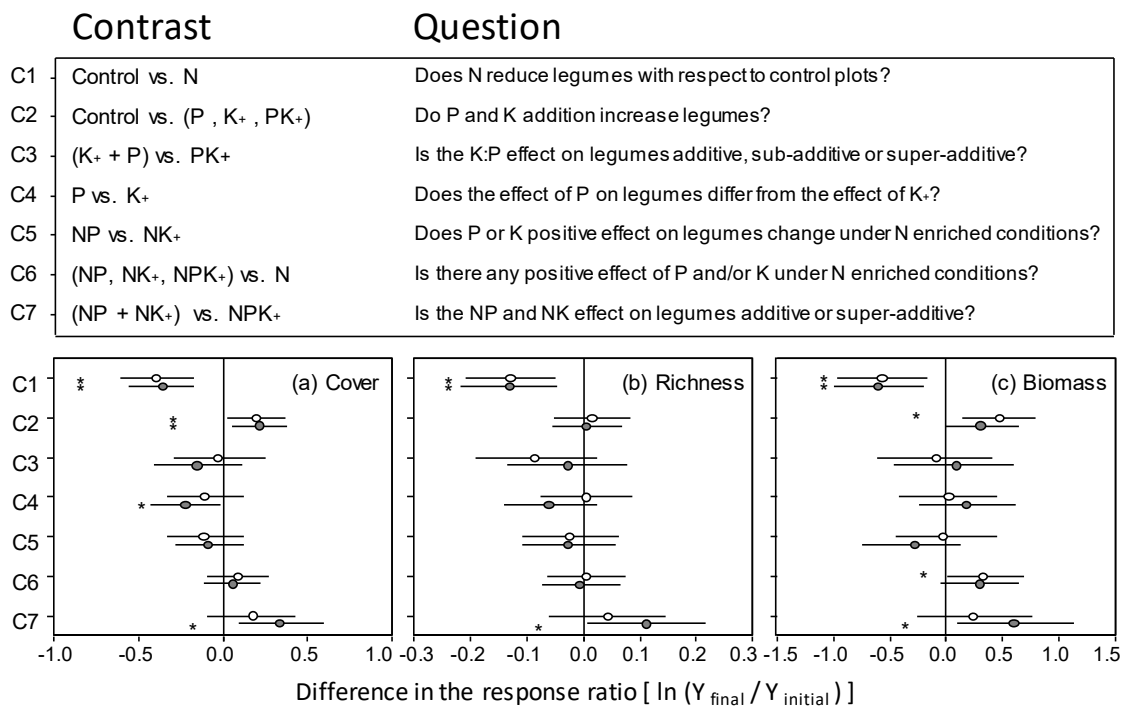


Fig. S4. Differences in the response ratio of legume cover (a), richness (b) and biomass (c) following planned contrasts (C1-C7; upper panel) for the 3rd year (open) and last year (filled). The '*comma*' indicates that the effects are averaged to test mean effect, whereas '*sum*' indicates that the effects are summed to test additivity. Symbols are the estimates ± bootstrapped 95% confidence intervals. Asterisks indicate that the contrast is different from zero (bootstrapped confidence intervals do not cross zero; see Table S5). Cover and richness data were available for 45 sites, and biomass data for 26 sites.

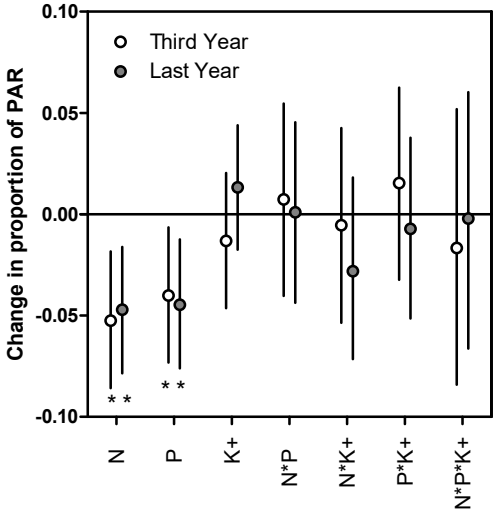


Fig. S5. Change in the proportion of PAR reaching the ground due to the addition of N, P, K+, and their interactions (i.e., N*P, N*K+, P*K+, and N*P*K+) for the 3rd (open) and last (filled) years. Symbols are estimates ± bootstrapped 95% confidence intervals. Asterisks indicate that the contrast differs from zero (i.e., bootstrapped confidence intervals do not include zero), where zero is the average proportion of PAR reaching the soil surface in control plots (0.375 and 0.387 for the 3rd and last year, respectively).

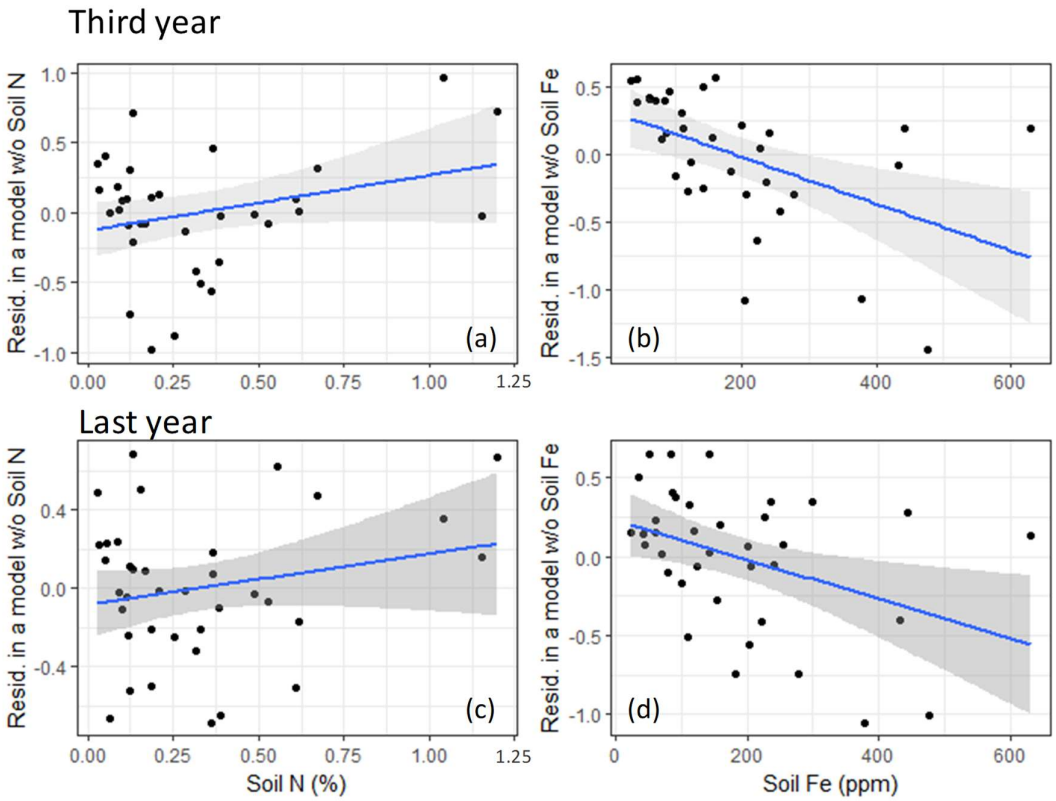
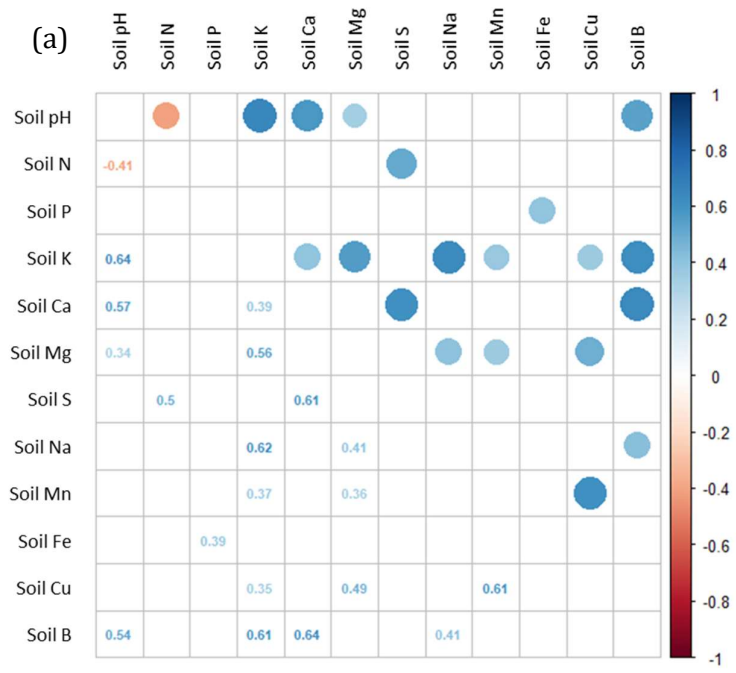


Fig. S6. Initial soil N (a, c) and soil Fe (b, d) predicted the effect of N addition on the change in legume cover by the third year (top row) and the last year (bottom row) of the experiment. In each graph, the Y-axis shows the residuals of the legume LR due to N addition; positive and negative values indicate increases and decreases, respectively. All trends shown are significant ($P < 0.05$). See Table S9 for complete results.



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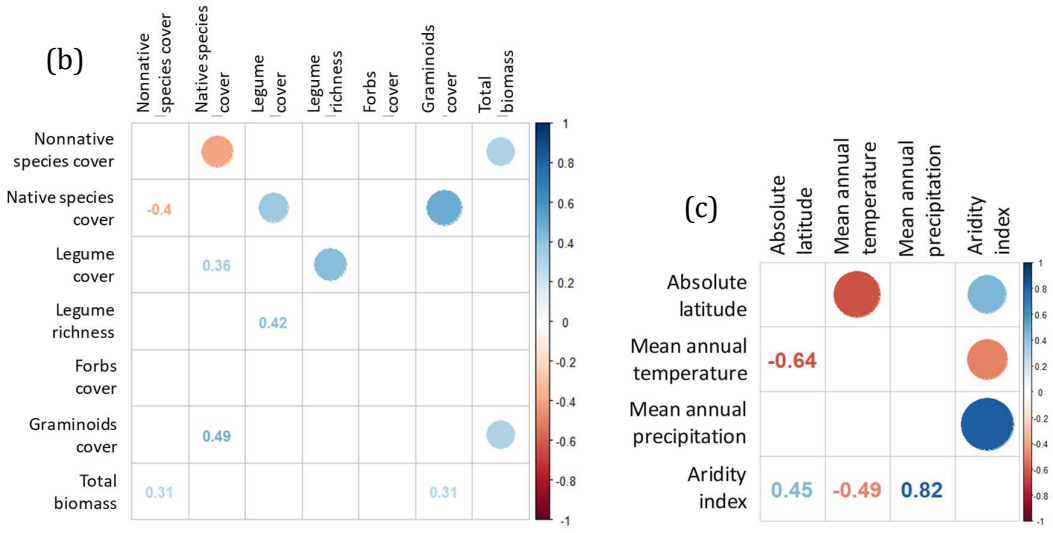

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90 **Fig. S7.** Correlation coefficients among site level soil (a), community (b) and climatic (c) predictors
91 used in the contingency regression analysis (Suppl. Tables S9, S10, S11). The circles above the
92 diagonal represent the strength (size) and direction (colour) of the significant (P<0.05) Pearson's
93 correlation coefficients; numbers below the diagonal show the corresponding correlation
94 coefficients.

Supplementary Tables

Table S1. List of sites included in the present study. Biomass indicated is the average live biomass across all experimental years for the control (unfertilized) plots. See details in the text for methods. Nat.=natural, Ant=anthropic, 'NA': data not available.

Id	Site	Country	Habitat	Natural Anthropic	Legume cover (%)	Legume richness (# spp.)	Exper. length (yr)	Blocks (#)	Lat-itude	Lon-gitude	Elev-ation (m.a.s.l.)	Mean Annual Temp. (*C)	Mean Annual Precip. (mm)	Biomass [cntrl plots] (g m^{-1})	Total soil N (%)	Extr. soil P (ppm)
1	azi.cn	China	Alpine grassland	Nat.	7.59	4	5	3	33.7	101.9	3500	2.0	667	361.2	0.554	70.50
2	barta.us	USA	Mixedgrass prairie	Nat.	2.05	1	4	3	42.2	-99.7	767	8.7	597	232.1	0.058	17.25
3	bnch.us	USA	Montane grassland	Nat.	18.47	3	6	3	44.3	-122.0	1318	5.5	1647	204.2	0.618	13.87
4	cbgb.us	USA	Tallgrass prairie	Ant.	1.90	2	6	6	41.8	-93.4	275	9.0	855	424.6	0.063	62.81
5	cdcr.us	USA	Tallgrass prairie	Nat.	0.75	1	6	5	45.4	-93.2	270	6.3	750	156.8	0.051	61.46
6	cdpt.us	USA	Shortgrass prairie	Nat.	0.50	2	6	6	41.2	-101.6	965	9.5	445	141.2	0.115	32.60
7	cereep.fr	France	Old field	Ant.	7.57	4	3	3	48.3	2.7	83	11.0	642	567.7	0.131	127.42
8	chilcas.ar	Argentina	Mesic grassland	Nat.	5.24	2	3	3	-36.3	-58.3	15	15.1	925	804.8	0.361	22.50
9	comp.pt	Portugal	Annual grassland	Ant.	18.80	7	3	3	38.8	-8.8	200	16.5	554	171.9	0.121	34.17
10	cowi.ca	Canada	Old field	Nat.	9.25	4	6	3	48.5	-123.4	50	9.8	764	530.3	0.391	40.13
11	elliot.us	USA	Annual grassland	Nat.	4.27	2	6	3	32.9	-117.1	200	17.2	331	244.2	0.156	16.46
12	frue.ch	Switz.	Pasture	Ant.	3.78	2	6	3	47.1	8.5	995	6.5	1355	837.5	0.367	69.79
13	gilb.za	S. Africa	Montane grassland	Nat.	35.14	5	3	3	-29.3	30.3	1748	13.1	926	221.9	1.155	17.67
14	hart.us	USA	Shrub steppe	Nat.	0.27	2	5	3	42.7	-119.5	1508	7.4	272	88.6	0.103	67.13
15	hero.uk	UK	Mesic grassland	Nat.	13.97	3	6	3	51.4	-0.6	60	9.9	692	508.9	NA	NA
16	hnvr.us	USA	Old field	Ant.	4.20	3	3	3	43.4	-72.1	271	6.4	1033	347.3	0.385	63.08
17	hopl.us	USA	Annual grassland	Nat.	11.29	8	6	3	39.0	-123.1	598	12.3	1127	186.6	NA	NA
18	kibber.in	India	Alpine grassland	Nat.	2.80	1	3	3	32.3	78.0	4241	1.1	504	34.8	NA	NA
19	kiny.au	Australia	Semiarid grassland	Nat.	0.22	2	6	3	-36.2	143.8	90	15.5	426	221.3	0.117	10.21
20	koffler.ca	Canada	Pasture	Nat.	7.62	1	6	3	44.0	-79.5	301	6.4	815	640.6	NA	NA
21	konz.us	USA	Tallgrass prairie	Nat.	3.69	3	6	3	39.1	-96.6	440	11.9	877	352.7	NA	NA
22	lancast.uk	UK	Mesic grassland	Nat.	5.82	2	6	3	54.0	-2.6	180	8.0	1322	121.9	1.039	33.48

Id	Site	Country	Habitat	Natural Anthropic	Legume cover (%)	Legume richness (# spp.)	Exper. length (yr)	Blocks (#)	Lat-itude	Lon-gitude	Elev-ation (m.a.s.l.)	Mean Annual Temp. (*C)	Mean Annual Precip. (mm)	Biomass [cntrl plots] (g m^{-1})	Total soil N (%)	Extr. soil P (ppm)
23	look.us	USA	Montane grassland	Nat.	1.65	1	6	3	44.2	-122.1	1500	4.8	1898	243.9	1.197	54.00
24	marc.ar	Argentina	Salt marsh grassland	Nat.	1.55	3	5	3	-37.7	-57.4	6	13.9	838	555.6	NA	NA
25	mcla.us	USA	Annual grassland	Nat.	6.57	5	6	3	38.9	-122.4	642	13.5	867	257.4	NA	NA
26	mtca.au	Australia	Savanna	Nat.	0.26	2	6	4	-31.8	117.6	285	17.3	330	134.2	0.092	9.25
27	ping.au	Australia	Old field	Ant.	16.51	2	3	3	-32.5	117.0	338	16.2	483	225.3	0.133	15.21
28	pinj.au	Australia	Pasture	Ant.	4.89	3	3	3	-27.5	152.9	38	20.3	1133	691.0	0.486	142.71
29	sage.us	USA	Montane grassland	Nat.	10.08	1	6	3	39.4	-120.2	1920	5.7	882	123.7	0.670	35.25
30	saline.us	USA	Mixedgrass prairie	Nat.	17.40	4	6	3	39.1	-99.1	440	11.8	607	240.6	NA	NA
31	sava.us	USA	Savanna	Nat.	3.14	4	5	2	33.3	-81.7	71	17.3	1194	85.4	0.027	45.94
32	sedg.us	USA	Annual grassland	Nat.	0.58	2	6	3	34.7	-120.0	550	14.9	521	281.1	0.188	66.13
33	sereng.tz	Tanzania	Savanna	Nat.	1.76	2	4	3	-2.3	34.5	1536	22.1	854	298.8	0.125	69.71
34	sevi.us	USA	Desert grassland	Nat.	0.08	1	6	5	34.4	-106.7	1600	12.6	252	59.6	0.032	33.53
35	sgs.us	USA	Shortgrass prairie	Nat.	0.33	1	6	3	40.8	-104.8	1650	8.4	365	101.9	0.085	64.23
36	shps.us	USA	Shrub steppe	Nat.	0.80	2	6	4	44.2	-112.2	910	5.5	262	127.8	0.207	37.63
37	sier.us	USA	Annual grassland	Nat.	9.68	4	6	5	39.2	-121.3	197	15.6	935	234.9	0.188	18.33
38	smith.us	USA	Mesic grassland	Nat.	6.87	5	6	3	48.2	-122.6	62	9.8	597	399.7	0.527	75.04
39	spin.us	USA	Pasture	Ant.	22.00	2	6	3	38.1	-84.5	271	12.5	1140	391.0	0.255	227.63
40	summ.za	S. Africa	Mesic grassland	Nat.	17.19	5	3	3	-29.8	30.7	679	18.2	939	365.9	0.330	12.16
41	temple.us	USA	Tallgrass prairie	Nat.	18.06	3	6	3	31.0	-97.3	184	19.1	871	517.0	0.366	20.60
42	trel.us	USA	Tallgrass prairie	Nat.	24.12	1	5	3	40.1	-88.8	200	11.0	982	1124.3	0.285	51.92
43	ukul.za	S. Africa	Mesic grassland	Nat.	6.98	5	6	3	-29.7	30.4	843	18.1	880	488.4	0.318	9.27
44	unc.us	USA	Old field	Ant.	13.22	3	4	3	36.0	-79.0	141	14.6	1163	330.6	0.169	21.71
45	valm.ch	Switz.	Alpine grassland	Nat.	7.57	5	6	3	46.6	10.4	2320	0.3	1098	218.4	0.610	46.00

Tables S2. List of genera of legume species included in the experiment. # Sites: number of sites where each genus is present. # Sp: Number of species considered in each genus. Mean: mean cover (visual percent scale; see Methods section for further details) across all plots where genus is present.

Genera	# Sites	# Species	Mean
Acacia	1	2	7.80
Acmispon	4	3	5.20
Adesmia	1	1	1.00
Aeschynomene	2	1	2.80
Alysicarpus	2	2	3.13
Amorpha	3	1	5.76
Anthyllis	1	1	1.88
Argyrolobium	2	4	1.54
Astragalus	8	12	1.57
Baptisia	1	2	3.07
Caragana	1	1	16.47
Centrosema	1	1	2.38
Chamaecrista	4	5	3.45
Crotalaria	4	4	5.68
Cytisus	1	1	30.00
Dalea	3	3	2.08
Desmanthus	1	1	25.40
Desmodium	4	5	2.66
Eriosema	3	4	9.31
Glycine	1	1	2.29
Gueldenstaedtia	1	1	2.19
Hippocrepis	1	1	4.21
Indigofera	5	7	4.67
Kummerowia	1	1	1.82
Lathyrus	5	7	3.58
Lespedeza	6	6	4.98
Lotononis	1	1	1.00
Lotus	8	6	4.95
Lupinus	10	11	5.15
Medicago	7	5	4.81
Melilotus	5	3	6.70
Mimosa	3	2	18.08
Neonotonia	1	1	9.00
Ornithopus	1	2	8.19
Oxytropis	3	3	2.21
Pearsonia	1	2	5.09
Pisum	1	1	1.00
Psoralea	5	3	4.24
Psoralidium	1	1	13.89
Rhynchosia	3	3	3.85
Schrankia	1	1	2.08
Swainsona	1	1	1.00
Syrmatium	1	1	10.80
Tephrosia	4	5	4.01
Thermopsis	1	1	2.37
Tibetia	1	1	1.59
Trifolium	21	25	4.47
Vicia	18	11	5.33
Vigna	1	1	4.80
Zornia	2	1	1.83
Unknown species	5	3	1.73

Table S3. Estimated means (Estim.) and bootstrapped 95% confidence intervals for the relative change in cover (a), richness (b), and biomass (c) of N-fixing legumes in the third and last years of the study. Variables shown are those retained in the reduced models after AIC elimination. Bold indicates that the confidence interval 95% does not include zero. 'n' indicates the number of sites included in the analyses. R^2 indicates the approximate proportion of variance explained by fixed / random model terms.

a) Cover

	Third year				Last year			
Coeff.	df	Estim.	2.5%	97.5%	df	Estim.	2.5%	97.5%
Intercept	1,56	0.229	-0.055	0.484	1,59	-0.026	-0.276	0.224
N	1,1018	**-0.353**	**-0.514**	**-0.191**	1,1055	**-0.356**	**-0.507**	**-0.200**
P	1,1018	**0.214**	**0.054**	**0.368**	1,1055	**0.253**	**0.113**	**0.387**
N:P	1,1018	**-0.240**	**-0.448**	**-0.017**	1,1055	**-0.243**	**-0.455**	**-0.049**
		n=43	R^2: 3.4/48.8			n=45	R^2:4.1/48.3	

b) Richness

	Third year				Last year			
Coeff.	df	Estim.	2.5%	97.5%	df	Estim.	2.5%	97.5%
Intercept	1,46	-0.026	-0.300	0.232	1,49	-0.034	-0.120	0.055
N	1,1019	**-0.356**	**-0.509**	**-0.214**	**1,1055**	**-0.140**	**-0.182**	**-0.097**
		n=43	R^2: 2.1/39.7			n=45	R^2:2.1/40.3	

c) Biomass

	Third year				Last year			
Coeff.	df	Estim.	2.5%	97.5%	df	Estim.	2.5%	97.5%
Intercept	1,30	0.217	-0.377	0.755	1,29	0.110	-0.413	0.604
N	1,593	**-0.683**	**-0.883**	**-0.475**	**1,602**	**-0.607**	**-0.816**	**-0.405**
P	1,593	**0.229**	**0.018**	**0.424**	---	---	---	---
K	1,593	**0.258**	**0.043**	**0.445**	**1,601**	**0.364**	**0.177**	**0.567**
		n=26	R^2: 3.7/52.3			n=26	R^2:3.4/47.9	

Table S4. Estimated means (Estim.) and bootstrapped 95% confidence intervals for the absolute change in cover (a), richness (b), and biomass (c) of N-fixing legumes in the third and last years of the study. Variables shown are those retained in the reduced models after AIC elimination. Bold indicates that the confidence interval 95% does not include zero. 'n' indicates the number of sites included in the analyses. R^2 indicates the proportion of variance explained by fixed / random model terms. sq.LEG0= Square root of initial legume cover; sq.RLEG0= square root of initial legume richness. ln.BLEG0= logarithm of initial legume cover.

a) Cover

	Third year				Last year			
Coeff.	df	Estim.	2.50%	97.50%	df	Estim.	2.50%	97.50%
Intercept	1, 64	**1.600**	**1.128**	**2.082**	1, 70	**1.165**	**0.767**	**1.566**
N	1, 1015	**-0.676**	**-0.919**	**-0.437**	1, 1050	**-0.553**	**-0.772**	**-0.335**
P	1, 1014	**0.432**	**0.197**	**0.677**	1, 1050	**0.509**	**0.295**	**0.722**
K	1, 1014	**0.200**	**0.028**	**0.372**	1, 1049	0.128	-0.025	0.277
N:P	1, 1014	**-0.428**	**-0.773**	**-0.090**	1, 1050	**-0.519**	**-0.823**	**-0.211**
sq.LEG0	1, 925	**0.336**	**0.265**	**0.405**	1, 1007	**0.340**	**0.279**	**0.402**
		n=43	R^2: 13.7/54.2			n=45	R^2:16.4/58.1	

b) Richness

	Third year				Last year			
Coeff.	df	Estim.	2.50%	97.50%	df	Estim.	2.50%	97.50%
Intercept	1, 65	**0.590**	**0.458**	**0.722**	1, 70	**0.532**	**0.399**	**0.661**
N	1, 1015	**-0.163**	**-0.228**	**-0.099**	1, 1050	**-0.151**	**-0.216**	**-0.087**
P	1, 1014	0.001	-0.063	0.065	1, 1050	0.045	-0.018	0.110
N:P	1, 1014	-0.049	-0.141	0.041	1, 1050	-0.089	-0.180	0.003
sq.RLEG0	1, 1060	**0.351**	**0.294**	**0.409**	1, 1097	**0.324**	**0.269**	**0.381**
		n=43	R^2: 17.9/58.2			n=45	R^2:16.1/58.1	

c) Biomass

	Third year				Last year			
Coeff.	df	Estim.	2.50%	97.50%	df	Estim.	2.50%	97.50%
Intercept	1, 32	**1.276**	**0.776**	**1.770**	1, 33	**1.059**	**0.584**	**1.538**
N	1, 593	**-0.581**	**-0.749**	**-0.409**	1, 601	**-0.503**	**-0.671**	**-0.338**
P	1, 593	**0.278**	**0.112**	**0.444**	1, 599	**0.177**	**0.005**	**0.347**
K	1, 593	**0.273**	**0.106**	**0.441**	1, 600	**0.359**	**0.192**	**0.529**
ln.BLEG0	1, 629	**0.192**	**0.106**	**0.276**	1, 639	**0.195**	**0.110**	**0.281**
		n=26	R^2: 6.8/57.9			n=26	R^2:6,4/53.0	

Table S5. Estimated means (Estim.) and bootstrapped 95% confidence intervals for the planned comparisons among specific treatments (contrasts; see Methods and Supplementary Fig. S3) of change in legume cover (a), richness (b) and biomass (c) in the third and last years of the study. The contrast treatments in the third and last experimental years of each site were estimated through a linear mixed effect model, with sites and blocks within sites as random effects. Bold indicates that 95% confidence intervals does not include zero. Intercepts were omitted as they are not informative for contrasts.

a) Cover	Third year				Last year			
Contrast	df	Estim.	2.50%	97.50%	df	Estim.	2.50%	97.50%
Control vs. N	1,1015	**-0.397**	**-0.606**	**-0.172**	1,1051	**-0.359**	**-0.554**	**-0.171**
Control vs (P, K, PK)	1,1016	**0.192**	**0.021**	**0.372**	1,1052	**0.216**	**0.051**	**0.381**
(K + P) vs KP	1,1013	-0.028	-0.296	0.252	1,1051	-0.154	-0.410	0.109
P vs. K	1,1013	-0.108	-0.330	0.124	1,1050	**-0.222**	**-0.429**	**-0.016**
NP vs. NK	1,1013	-0.114	-0.332	0.117	1,1051	-0.087	-0.280	0.121
(NP, NK, NPK) vs. N	1,1013	0.088	-0.092	0.270	1,1051	0.055	-0.118	0.218
(NK + NP) vs. NPK	1,1014	0.173	-0.095	0.426	1,1051	**0.335**	**0.095**	**0.592**

b) Richness								
Contrast	df	Estim.	2.50%	97.50%	df	Estim.	2.50%	97.50%
Control vs. N	1,1015	**-0.129**	**-0.210**	**-0.049**	1,1050	**-0.131**	**-0.217**	**-0.046**
Control vs (P, K, PK)	1,1016	0.016	-0.053	0.085	1,1051	0.006	-0.055	0.069
(K + P) vs KP	1,1013	-0.086	-0.191	0.024	1,1050	-0.026	-0.135	0.079
P vs. K	1,1013	0.005	-0.077	0.087	1,1049	-0.061	-0.140	0.024
NP vs. NK	1,1013	-0.025	-0.108	0.064	1,1050	-0.026	-0.109	0.058
(NP, NK, NPK) vs. N	1,1013	0.007	-0.063	0.075	1,1050	-0.007	-0.071	0.067
(NK + NP) vs. NPK	1,1013	0.044	-0.062	0.147	1,1050	**0.112**	**0.006**	**0.216**

c) Biomass								
Contrast	df	Estim.	2.50%	97.50%	df	Estim.	2.50%	97.50%
Control vs. N	1,589	**-0.569**	**-0.969**	**-0.164**	1,596	**-0.607**	**-0.995**	**-0.197**
Control vs (P, K, PK)	1,590	**0.480**	**0.147**	**0.800**	1,597	0.304	-0.010	0.652
(K + P) vs KP	1,589	-0.090	-0.610	0.416	1,598	0.091	-0.463	0.600
P vs. K	1,589	0.026	-0.414	0.452	1,595	0.185	-0.238	0.613
NP vs. NK	1,589	-0.031	-0.446	0.445	1,595	-0.273	-0.736	0.130
(NP, NK, NPK) vs. N	1,589	**0.324**	**0.004**	**0.692**	1,595	0.302	-0.048	0.640
(NK + NP) vs. NPK	1,590	0.239	-0.258	0.766	1,596	**0.600**	**0.098**	**1.131**

Table S6. Estimated means (Estim.) and bootstrapped 95% confidence intervals for changes in forb cover (a), grass cover (b) and forb+grass cover (c) in the third and last years of the study. Variables shown are those retained in the reduced models after AIC elimination. Bold indicates that confidence interval does not include zero. 'n' indicates the number of sites included in the analyses. R^2 indicates the approximate percentage of variance explained by fixed / random model terms.

a) Forbs	Third year				Last year			
Coeff.	df	Estim.	2.50%	97.50%	df	Estim.	2.50%	97.50%
Interc.	1,48	-0.082	-0.294	0.131	1,47	-0.018	-0.210	0.174
N	1,1017	-0.086	-0.175	0.003	----	----	----	----
P	1,1017	**-0.110**	**-0.198**	**-0.020**	1,1055	**-0.075**	**-0.140**	**-0.009**
N:P	1,1017	0.115	-0.009	0.243				
	n=43		R^2=0.2/61.2		n=45		R^2=0.2/55.8	

b) Grasses	Third year				Last year			
Coeff.	df	Estim.	2.50%	97.50%	df	Estim.	2.50%	97.50%
Interc.	1,63	-0.117	-0.280	0.044	1,50.7	-0.277	-0.524	-0.027
N	1,1018	**0.129**	**0.029**	**0.226**	1,1054	**0.137**	**0.029**	**0.245**
P	1,1018	**0.151**	**0.054**	**0.246**	1,1054	0.101	-0.007	0.210
N:P	1,1018	-0.129	-0.267	0.008	1,1054	-0.145	-0.299	0.007
	n=43		R^2=0.5/55.1		n=45		R^2=0.2/65.3	

c) Forbs + grasses	Third year				Last year			
Coeff.	df	Estim.	2.50%	97.50%	df	Estim.	2.50%	97.50%
Interc.	1,45	-0.060	-0.149	0.029	1,46	-0.084	-0.194	0.023
N	1,1019	**0.043**	**0.013**	**0.073**	1,1055	**0.039**	**0.009**	**0.070**
	n=43		R^2=0.3/58.1		n=45		R^2=0.2/66.9	

Table S7. Estimated means (Estim.) and bootstrapped 95% confidence intervals for changes in N-fixing legume cover in the third and last years of the study as a function of changes in community composition measures, soil N:P ratio, and N addition. Variables shown are those retained in the reduced models after AIC elimination; the initial model also included LR_{PAR} and $LR_{biomass}$. Bold indicates that the confidence interval does not include zero. 'n' indicates the number of sites included in the analyses. R2 indicates the approximate proportion of variance explained by fixed / random model terms.

	Third year				Last year			
	df	Estim.	2.50%	97.50%	df	Estim.	2.50%	97.50%
Intercept	1,39	0.151	-0.191	0.485	1,37	0.054	-0.309	0.416
N	**1,793**	**-0.293**	**-0.444**	**-0.139**	**1,763**	**-0.329**	**-0.493**	**-0.172**
LR_{F+G}	**1,857**	**-0.500**	**-0.710**	**-0.294**	**1,719**	**-0.406**	**-0.616**	**-0.197**
Soil N_P ratio	**1,140**	**0.240**	**0.118**	**0.363**	**1,142**	**0.188**	**0.061**	**0.308**
$Legumes_{initial\ site}$	**1,38**	**-0.037**	**-0.065**	**-0.009**	**1,36**	**-0.034**	**-0.063**	**-0.004**
$Legumes_{init.}$: N	**1,789**	**-0.015**	**-0.028**	**-0.002**	**1,758**	**-0.018**	**-0.032**	**-0.005**
	n=35		R2=17.3/50.7		n = 34		R2=15.2/49.5	

Table S8. Estimated means (Estim.) and bootstrapped 95% confidence intervals for the relative change in photosynthetically active radiation (PAR) interception with nutrient addition treatments in the third and last years of the study. Variables shown are those retained in the reduced models after AIC elimination. Bold indicates that the confidence interval does not include zero. 'n' indicates the number of sites included in the analyses. R2 indicates the approximate proportion of variance explained by fixed / random model terms.

	Third year				Last year			
Coeff.	df	Estim.	2.50%	97.50%	df	Estim.	2.50%	97.50%
Intercept	1, 33	-0.046	-0.102	0.009	1, 35	-0.006	-0.062	0.049
N	**1, 750**	**-0.044**	**-0.059**	**-0.029**	**1, 780**	**-0.050**	**-0.064**	**-0.036**
P	**1, 750**	**-0.035**	**-0.049**	**-0.020**	**1, 780**	**-0.046**	**-0.060**	**-0.032**
	n=32		R^2=3.2/68.8		n=34		R^2=2.1/68.4	

Table S9. Estimated means (Estim.) and bootstrapped 95% confidence intervals for the logits of colonization (a) and local extinction (b) of all legumes, perennials and annuals/biennials in the third and last years of the study. Colonization was calculated as the number of legume species that were absent initially but appeared in a plot in the 3rd or last year, divided by the total number of legume species present in the third or last year. Extinction was calculated as the number of legume species that were present initially but absent in the third or last year, divided by the total number of legume species present initially. Colonization and extinction were modelled as logits, though back-transformed probabilities are reported. Variables shown are those retained in the reduced models after AIC elimination; the initial models included all nutrient addition treatments and initial legume cover. The probability of colonization and extinction for the intercept (Int., -N) and nutrient addition treatments is provided. Bold indicates that the confidence interval does not include zero. Plot number varied among models, thus 'n' indicates the number of sites/blocks/observations included in the analyses. R^2 indicates the approximate proportion of variance explained by fixed / random model terms.

a) Colonization

		Third year				Last year			
	Coeff.	Estim.	2.5%	97.5%	Prob.	Estim.	2.5%	97.5%	Prob.
Total	Int.	-0.648	-1.775	0.299	0.343	-0.971	-2.537	0.155	0.275
	N	**-1.048**	**-1.623**	**-0.511**	0.155	**-1.230**	**-1.876**	**-0.645**	0.099
		n= 32/93/468		R^2=2.6/58.6		n= 33/96/479		R^2=2.8/68.2	
Perenn.	Int.	**-2.565**	**-5.965**	**-1.468**	0.055	**-3.182**	**-7.843**	**-1.971**	0.040
	N	**-0.866**	**-1.482**	**-0.319**	0.027	**-0.895**	**-1.614**	**-0.275**	0.017
		n= 35/113/674		R^2=1.3/62.2		n= 36/116/685		R^2=1.3/68.4	
Annual	Int.	-7.613	-11.874	-6.697	0.001	**-9.198**	**-12.470**	**-8.279**	0.000
	N	**-1.148**	**-2.352**	**-0.335**	0.001	**-2.026**	**-3.726**	**-1.139**	0.000
		n= 41/127/894		R^2=0.0/0.0		n= 43/133/936		R^2=0.0/0.0	

b) Extinction

		Third year				Last year			
	Coeff.	Estim.	2.5%	97.5%	Prob.	Estim.	2.5%	97.5%	Prob.
Total	Int.	**-1.063**	**-1.691**	**-0.449**	**0.257**	**-0.645**	**-1.265**	**-0.043**	**0.344**
	N	**0.905**	**0.516**	**1.317**	**0.461**	**0.936**	**0.567**	**1.330**	**0.572**
		n= 40/116/695		R^2=5.2/39.8		n= 42/122/726		R^2=4.3/37.8	
Perenn.	Int.	**-1.283**	**-2.348**	**-0.377**	**0.217**	**-0.670**	**-1.396**	**0.063**	**0.338**
	N	**0.697**	**0.189**	**1.219**	**0.358**	**0.607**	**0.172**	**1.070**	**0.484**
		n= 32/87/489		R^2=2.7/54.4		n= 34/93/520		R^2=3.8/39.0	
Annual	Int.	-0.185	-0.995	0.620	0.454	1.049	-0.074	2.375	0.741
	N	**1.169**	**0.561**	**1.844**	**0.728**	0.553	-0.402	1.602	0.832
	P					**-1.529**	**-2.616**	**-0.662**	**0.382**
	N:P					**1.461**	**0.112**	**3.002**	**0.823**
		n= 19/53/269		R^2=11.6/42.2		n= 19/53/269		R^2=6.9/56.9	

Table S10. Multiple regression results for the effect of initial soil (a), initial community (b) and climate predictors (c) on the predicted N addition effect at the site level for the third and last experimental year on legume cover. The predicted N-addition effect for each site was obtained from the N x Site interaction. Independent variables were standardized (Z-scores). Bold indicates terms consistently significant across third and last experimental year. Model fit and descriptors are below each table (R.S.E.: residual standard error; F-values and degrees of freedom; P-values; coefficients of determination).

a) Initial soil

	Third year				Last year			
Coeff.	Estim.	S.E.	t	P	Estim.	S.E.	t	P
Intercept	-0.36	0.068	-5.32	0.000	-0.96	0.301	-3.20	0.003
Soil N (%)	**0.23**	**0.086**	**2.69**	**0.012**	**0.16**	**0.070**	**2.36**	**0.025**
Soil Fe (ppm)	**-0.28**	**0.079**	**-3.51**	**0.002**	**-0.24**	**0.072**	**-3.26**	**0.003**
Soil K (ppm)	**0.31**	**0.106**	**2.93**	**0.007**	**0.25**	**0.075**	**3.42**	**0.002**
Soil S (ppm)	-0.16	0.100	-1.62	0.117				
Soil Na (ppm)	-0.17	0.093	-1.82	0.080				
Soil B (ppm)	-0.15	0.095	-1.61	0.118				
Soil Ca (ppm)					-0.30	0.070	-4.25	0.000
Soil Mn (ppm)					0.19	0.088	2.13	0.042
Soil Cu (ppm)					-0.26	0.084	-3.06	0.005
Years of treatment (#)					0.13	0.058	2.20	0.036
	R.S.E.=0.4; $F_{6,28}$=4.97; P=0.001				R.S.E.=0.36; $F_{7,29}$=7.12; P<0.001			
	R^2=0.52; $R^2_{Adj.}$=0.41				R^2=0.63; $R^2_{Adj.}$=0.54			

b) Initial community

	Third year				Last year			
Coeff.	Estim.	S.E.	t	P	Estim.	S.E.	t	P
Intercept	-0.42	0.073	-5.70	0.000	-0.36	0.062	-5.75	0.000
Non-native cover	**-0.23**	**0.076**	**-3.01**	**0.005**	**-0.16**	**0.063**	**-2.53**	**0.015**
Legume richness	**-0.18**	**0.082**	**-2.23**	**0.032**	**-0.20**	**0.069**	**-2.89**	**0.006**
Initial legume cover	**-0.19**	**0.079**	**-2.43**	**0.020**	**-0.15**	**0.069**	**-2.13**	**0.039**
Forb cover	0.13	0.075	1.74	0.090				
	R.S.E.=0.47; $F_{4,37}$=7.54; P<0.001				R.S.E.=0.41; $F_{3,40}$=10.51; P<0.001			
	R^2=0.45; $R^2_{Adj.}$=0.39				R^2=0.44; $R^2_{Adj.}$=0.39			

c) Climate

	Third year				Last year			
Coeff.	Estim.	S.E.	t	P	Estim.	S.E.	t	P
Intercept	-0.41	0.087	-4.66	0.000	-0.97	0.340	-2.85	0.007
Mean annual temp.	**-0.32**	**0.124**	**-2.55**	**0.015**	**-0.23**	**0.096**	**-2.43**	**0.019**
Latitude	-0.22	0.119	-1.88	0.068	-0.26	0.100	-2.59	0.013
Years of treatment (#)					0.12	0.064	1.85	0.071
	R.S.E.=0.57; $F_{2,40}$=3.26; P=0.048				R.S.E.=0.48; $F_{3,41}$=5.16; P=0.029			
	R^2=0.14; $R^2_{Adj.}$=0.10				R^2=0.19; $R^2_{Adj.}$=0.13			

Table S11. Multiple regression results for the effects of initial soil (a), initial community (b) and climate predictors (c) on the predicted P-addition effect at the site level for the third and last experimental year on legume cover. Predicted effect of P-addition for each site was obtained from the P x Site interaction. Independent variables were standardized (Z-scores). Bold indicates terms consistently significant across third and last experimental year. Model fit and descriptors are below each table (Estim.: estimated mean; R.S.E.: residual standard error; F-values and degrees of freedom; P-values; coefficients of determination). Stepwise elimination did not conserve any climatic predictor for the effect of P for the third year on legume cover.

a) Initial soil

	Third year				Last year			
Coeff.	Estim.	S.E.	t	P	Estim.	S.E.	t	P
Intercept	0.16	0.051	3.16	0.003	0.22	0.063	3.41	0.002
Soil Mn (ppm)	-0.19	0.065	-2.93	0.006	-0.16	0.081	-1.95	0.060
Soil Cu (ppm)	0.13	0.066	1.94	0.061	0.13	0.082	1.56	0.129
Soil Na (ppm)	0.10	0.053	1.98	0.057				
Soil Ca (ppm)					-0.13	0.065	-1.99	0.055
	R.S.E.=0.29; $F_{3,31}$=4.18; P=0.013				R.S.E.=0.38; $F_{3,33}$=2.14; P=0.084			
	R^2=0.28; $R^2_{Adj.}$=0.21				R^2=0.18; $R^2_{Adj.}$=0.10			

b) Initial community

	Third year				Last year			
Coeff.	Estim.	S.E.	t	P	Estim.	S.E.	t	P
Intercept	0.21	0.052	3.94	0.000	0.31	0.067	4.59	0.000
Native species cover	-0.09	0.054	-1.64	0.110	-0.07	0.070	-0.93	0.358
Legume richness	0.11	0.054	1.96	0.057	0.12	0.070	1.77	0.084
	R.S.E.=0.33; $F_{2,39}$=4.91; P=0.085				R.S.E.=0.44; $F_{2,41}$=1.69; P=0.196			
	R^2=0.11; $R^2_{Adj.}$=0.07				R^2=0.07; $R^2_{Adj.}$=0.03			

c) Climate

	Third year				Last year			
Coeff.	Estim.	S.E.	t	P	Estim.	S.E.	t	P
Intercept	0.20	0.054	3.73	0.001	0.30	0.066	4.52	0.000
Mean annual temp.					-0.10	0.067	-1.49	0.144
	R.S.E.=0.35 on 42 d.f.				R.S.E.=0.44; $F_{1,43}$=2.21; P=0.144			
					R^2=0.05; $R^2_{Adj.}$=0.02			

Table S12. Multiple regression results for the effects of initial soil (a), initial community (b) and climate predictors (c) on the K-addition effect at the site level for the third and last experimental year on legume cover. Predicted effect of K-addition for each site was obtained from the K x Site interaction. Independent variables were standardized (Z-scores). Bold indicated terms consistently significant across the third and last experimental year. Model fit and descriptors are below each table (R.S.E.: residual standard error; F-values and degrees of freedom; P-values; coefficients of determination). Stepwise elimination did not conserve any climatic predictor for the effect of K on legume cover.

a) Initial soil

	Third year				Last year			
Coeff.	Estim.	S.E.	t	P	Estim.	S.E.	t	P
Intercept	0.11	0.056	1.93	0.064	0.11	0.054	2.06	0.048
Soil P (ppm)	**0.22**	**0.062**	**3.53**	**0.001**	**0.20**	**0.063**	**3.20**	**0.003**
Soil K (ppm)	**-0.23**	**0.075**	**-3.10**	**0.004**	**-0.27**	**0.076**	**-3.59**	**0.001**
Soil Fe (ppm)	**-0.18**	**0.064**	**-2.77**	**0.010**	**-0.16**	**0.063**	**-2.50**	**0.018**
Soil Na (ppm)	0.13	0.076	1.74	0.092	0.13	0.074	1.82	0.079
Soil Mn (ppm)					0.14	0.061	2.25	0.032
	R.S.E.=0.33; $F_{4,30}$=5.07; P=0.003				R.S.E.=0.32; $F_{5,31}$=5.19; P=0.001			
	R^2=0.40; $R^2_{Adj.}$=0.32				R^2=0.45; $R^2_{Adj.}$=0.37			

b) Initial community

	Third year				Last year			
Coeff.	Estim.	S.E.	t	P	Estim.	S.E.	t	P
Intercept	0.08	0.058	1.40	0.169	0.07	0.062	1.14	0.263
Native species cover	-0.16	0.062	-2.64	0.012	-0.13	0.067	-1.87	0.068
Legume cover	0.14	0.061	2.31	0.026	0.09	0.066	1.42	0.162
	R.S.E.=0.37; $F_{2,39}$=4.53; P=0.017				R.S.E.=0.41; $F_{2,41}$=2.07; P=0.139			
	R^2=0.18; $R^2_{Adj.}$=0.14				R^2=0.09; $R^2_{Adj.}$=0.05			

c) Climate

	Third year				Last year			
Coeff.	Estim.	S.E.	t	P	Estim.	S.E.	t	P
Intercept	0.08	0.062	1.33	0.192	0.07	0.062	1.08	0.287
	R.S.E.=0.40 on 42 d.f.				R.S.E.=0.42 on 44 d.f.			