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*Supplement of*

## **Back to the future? Conservative grassland management can preserve soil health in the changing landscapes of Uruguay**

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# SUPPLEMENTARY

**Figure S1.** Variables examination: In addition to normality and homogeneity of variances tests, the 16 variables from topsoil samples were analyzed graphically by means of its distribution (mean depicted in dashed line) both overall and by main land use (AC, GL, NF, TP), and QQ-plot.

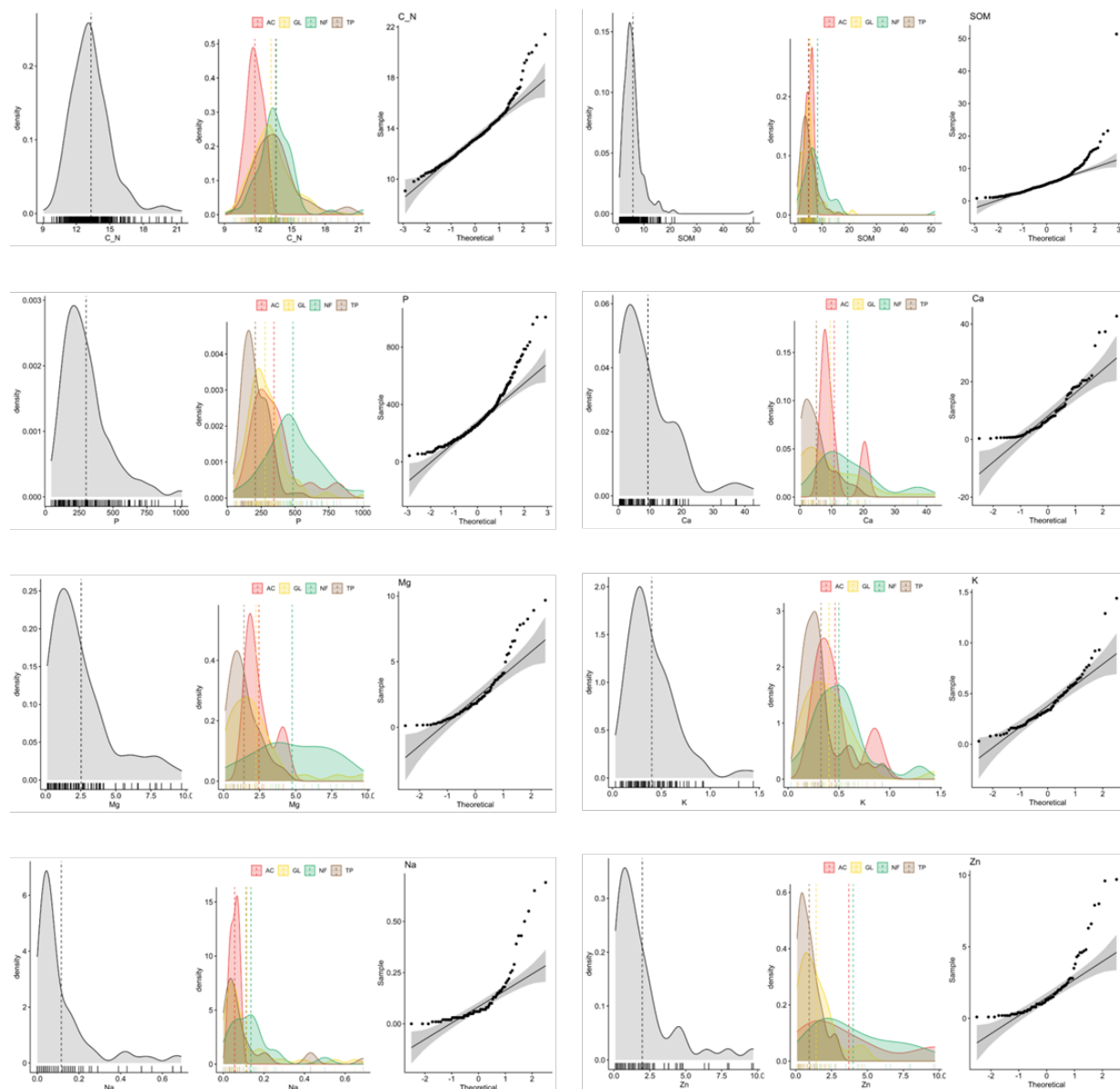
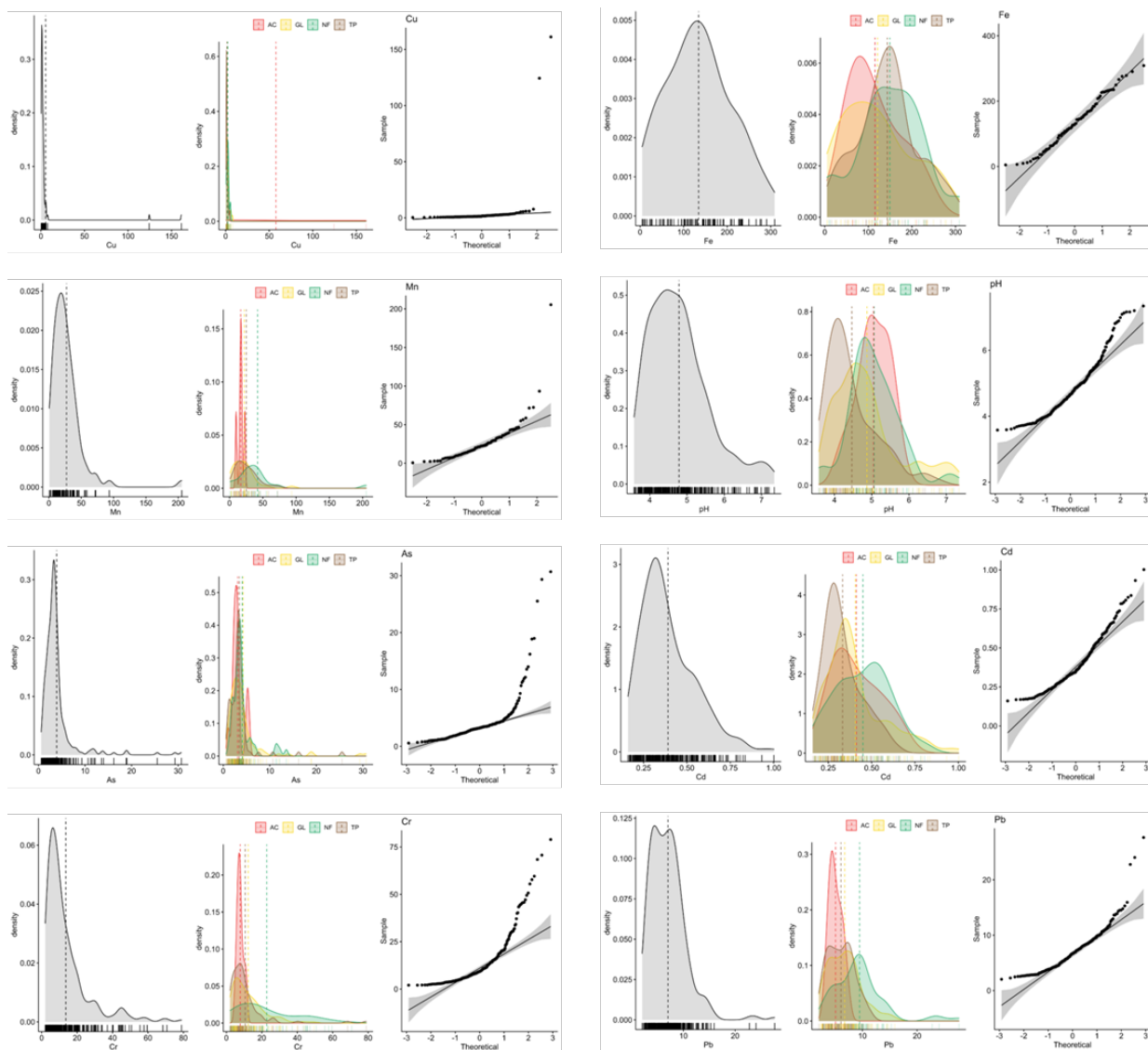


Figure S1. Continuation

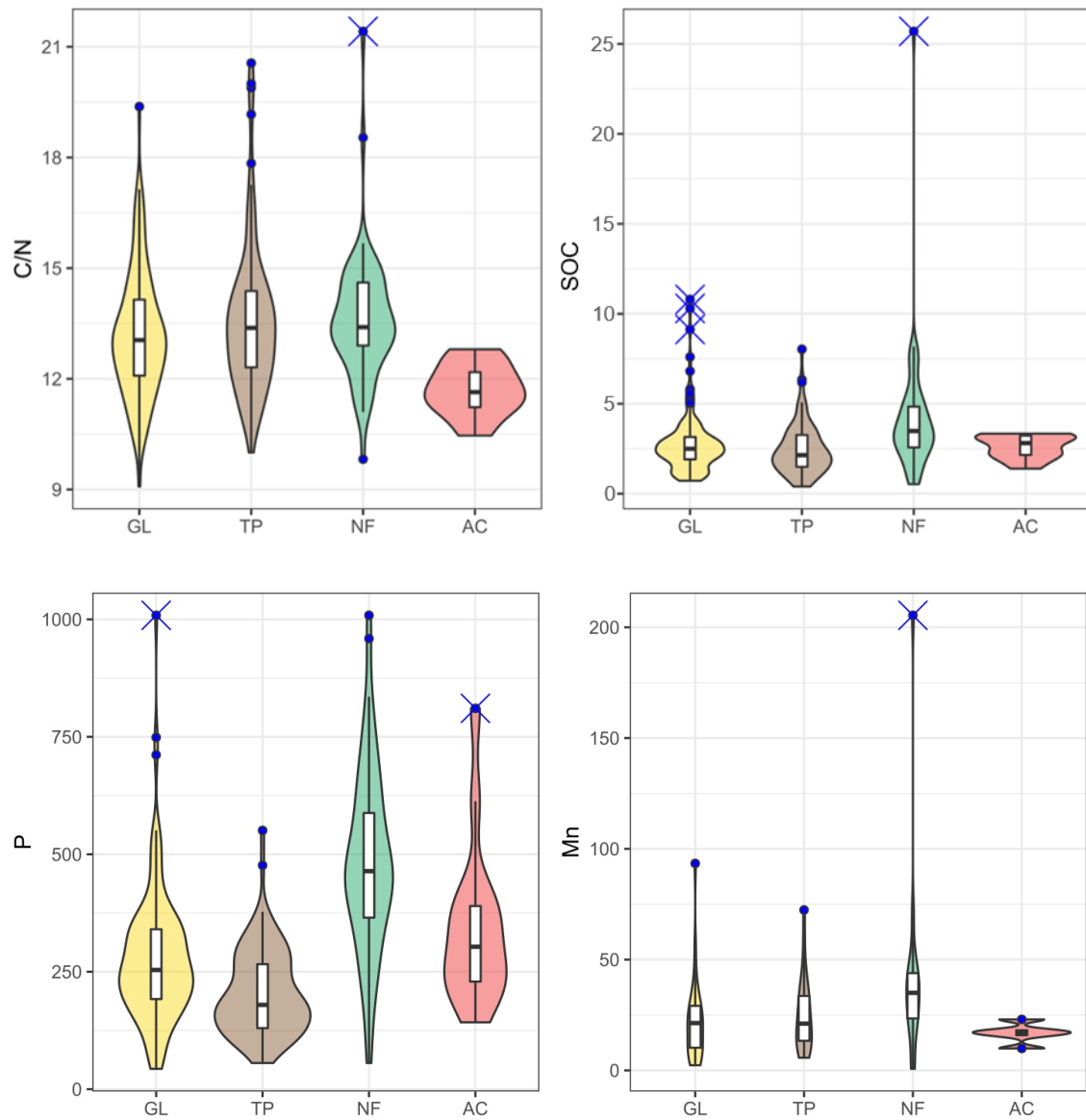


**Table S1.** Shapiro-Wilk normality test and Fligner-Killeen test of homogeneity of variances by land use

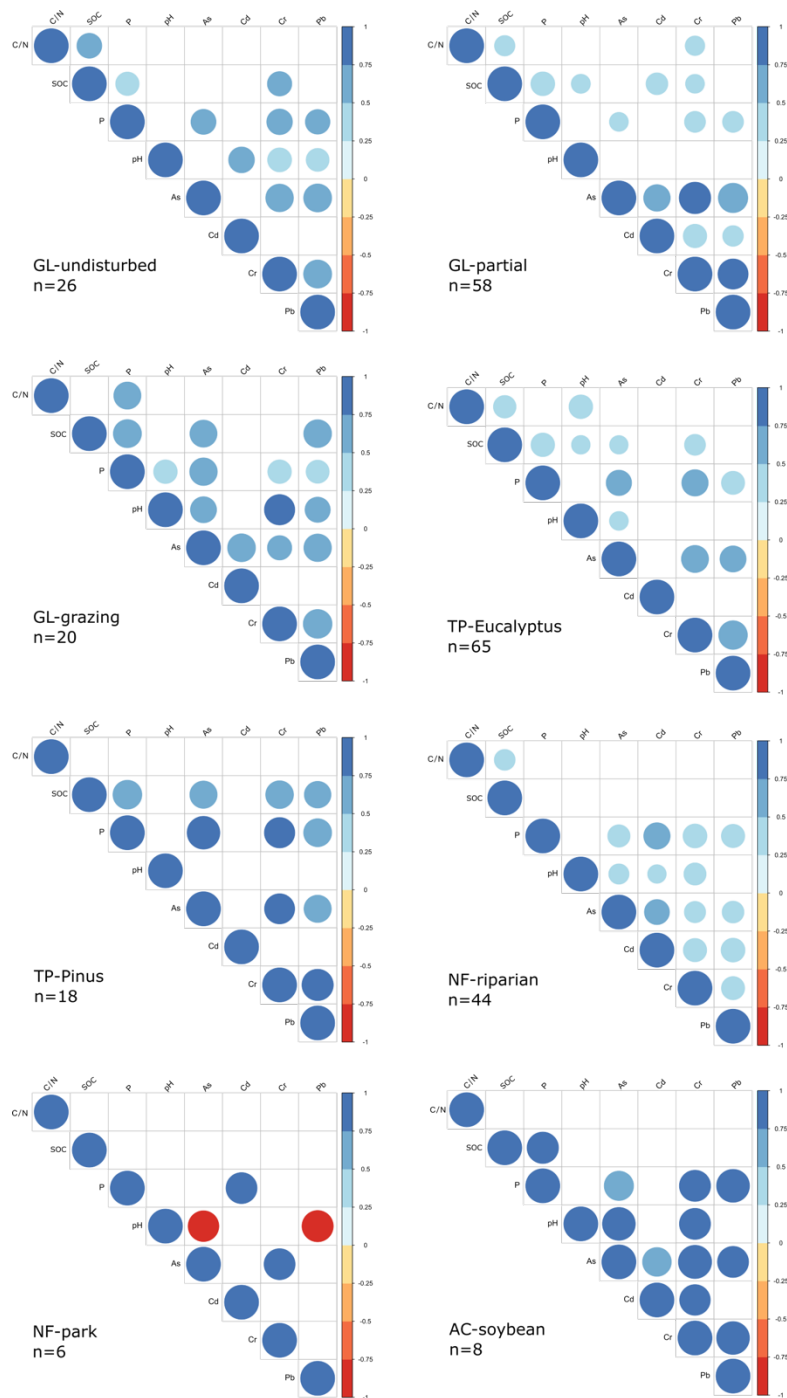
Variable	Shapiro-Wilk normality test		Fligner-Killeen test of homogeneity of variances by land use		
	W	p-value	med chi-squared	df	p-value
C/N ratio	0.93349	6.831e-10	9.2971	3	0.02559
SOC	0.67602	< 2.2e-16	13.82	3	0.003161
Ca	0.83698	4.563e-08	7.5164	3	0.05714
Mg	0.84532	8.56e-08	15.602	3	0.001368
K	0.88327	2.01e-06	2.5556	3	0.4653
Na	0.68901	6.875e-12	3.3219	3	0.3446
Zn	0.75882	2.775e-10	22.615	3	4.858e-05
Cu	0.18589	< 2.2e-16	9.0525	3	0.0286
Fe	0.97861	0.1876	1.7833	3	0.6186
Mn	0.65658	1.496e-12	5.9795	3	0.1126
pH	0.93056	3.828e-10	7.6001	3	0.05504
As	0.54474	< 2.2e-16	10.733	3	0.01326
Cd	0.93222	7.127e-10	9.4819	3	0.02352
Cr	0.74825	< 2.2e-16	49.433	3	1.055e-10
Pb	0.87683	3.161e-14	16.773	3	0.0007868

**Table S2.** Spatial autocorrelation of soil samples. P-values > 0.05 indicate the pattern does not appear to be significantly different than random. Moran's Index was calculated using ArcGIS 10.3 (ESRI, 2018).

Variable	Moran's Index	z-score	p-value
Humidity (%)	0.565	3.693	0.0002
N_total (%)	0.209	1.407	0.1593
C_total (%)	0.147	1.050	0.2935
C/N ratio	0.004	0.049	0.9609
SOC (%)	0.232	1.407	0.1594
P (mg kg <sup>-1</sup> )	0.470	3.071	0.0021
Ca (cmol kg <sup>-1</sup> )	-0.002	0.012	0.9904
Mg (cmol kg <sup>-1</sup> )	0.037	0.060	0.9520
K (cmol kg <sup>-1</sup> )	-0.114	-0.125	0.9003
Na (cmol kg <sup>-1</sup> )	0.043	0.069	0.9448
Zn (mg kg <sup>-1</sup> )	0.172	0.228	0.8193
Cu (mg kg <sup>-1</sup> )	0.046	0.099	0.9212
Fe (mg kg <sup>-1</sup> )	-1.288	-1.533	0.1253
Mn (mg kg <sup>-1</sup> )	-0.067	-0.066	0.9474
ph (all soil types)	0.479	3.127	0.0018
pH - Argiudolls	-0.184	-0.486	0.6271
pH - Argiudolls_Hapluderts	0.144	1.373	0.1699
pH - Hapludalfts_Hapludults	0.674	5.873	0.0000
As (mg kg <sup>-1</sup> )	0.686	4.694	0.0000
Cd (mg kg <sup>-1</sup> )	0.464	3.229	0.0012
Cr (mg kg <sup>-1</sup> )	0.557	3.680	0.0002
Pb (mg kg <sup>-1</sup> )	0.832	5.495	0.0000
CEC (cmol kg <sup>-1</sup> )	0.013	0.031	0.9750
K <sup>+</sup> /(Ca <sup>2+</sup> +Mg <sup>2+</sup> )	0.048	0.077	0.9388
K <sup>+</sup> /(Ca <sup>2+</sup> +Mg <sup>2+</sup> +Na <sup>+</sup> )	0.051	0.080	0.9360



**Figure S2.** Outliers detection: Variables were analyzed in the context of the sites, replicates and land use and soils classifications with violin/box plots, with emphasis on the identification (depicted as blue points) and extraction (marked as blue X) of outliers ( $> 1.5$  IQR, extreme outliers  $> 3$  IQR), as shown below for cases with an outlier removal.



**Figure S3.** Spearman's rank correlations for variables related to the quality of topsoils in country-wide samples according to its main land use sub-classification (GL: grassland; TP: timber plantation; NF: natural forest, AC: agriculture). Samples from timber plantation land use types of *Salix* and *Populus* species, as well as hill natural forest, and citrus agriculture plantations were too few for the analysis. Colour intensity and the size of the circle are proportional to the correlation coefficients ( $\rho$ ). Slots are shown empty for correlations with  $p > 0.05$ ;  $n$  is the number of observations used in the analysis.

**Table S3.** Permutational multivariate analysis of variance (PERMANOVA) of across and between grasslands (GL), timber plantation (TP) and native forest (NF) land uses (9999 permutations), using all the variables. df = degrees of freedom, SS = sum of squares, MS = mean square, P-adj = adjusted P with Benjamini & Hochberg correction. See NDMS in Fig. 3a.

	df	SS	MS	<i>F</i>	R <sup>2</sup>	P	P-adj
<i>Country-wide</i>							
Land use (GLxTPxNF)	2	156.22	78.111	5.5442	0.14573	1.00E-04	
Residuals	65	915.78	14.089		0.85427		
Total	67	1072			1.00000		
<i>Pairwise</i>							
Land use (GLxTP)	1	48.01	48.015	3.1187	0.05557	9.30E-03	9.30E-03
Residuals	53	815.99	15.396		0.94443		
Total	54	864			1.00000		
Land use (GLxNF)	1	63.3	63.296	4.2633	0.09419	2.10E-03	3.15E-03
Residuals	41	608.7	14.846		0.90581		
Total	42	672.00			1.00000		
Land use (TPxNF)	1	133.01	133.01	10.432	0.22467	1.00E-04	3.00E-04
Residuals	36	458.99	12.75		0.77533		
Total	37	592.00			1.00000		

**Table S4.** Permutational multivariate analysis of variance (PERMANOVA) between *Eucalyptus* and *Pinus* (9999 permutations), using C/N ratio, SOM, P, pH, As, Cd, Cr and Pb. df = degrees of freedom, SS = sum of squares, MS = mean square. See NDMS in Fig. 3b.

	df	SS	MS	<i>F</i>	R <sup>2</sup>	P
<i>Country-wide</i>						
Land use ( <i>Eucalyptus</i> , <i>Pinus</i> )	1	37.18	37.176	4.8661	0.05667	0,0007
Residuals	81	618.82	7.640		0.94333	
Total	82	656.00			1	



**Table S5.** Permutational multivariate analysis of variance (PERMANOVA) across Argiudolls and between grasslands (GL), timber plantation (TP), native forest (NF) and Agriculture (AC) land uses (9999 permutations), using all variables. df = degrees of freedom, SS = sum of squares, MS = mean square, P-adj = adjusted P with Benjamini & Hochberg correction. See NDMS in Fig. 3c.

	df	SS	MS	<i>F</i>	R <sup>2</sup>	P	P-Adj
<i>Country-wide</i>							
Land use (AC, GL, NF, TP)	3	79.87	26.6225	3.7087	0.14061	0.0004	
Residuals	68	488.13	7.1784		0.85939		
Total	71	568.0			1		
<i>Pairwise</i>							
Land use (GL, TP)	1	5.2	5.2020	0.64565	0.01301	0.6798	0.68910
Residuals	49	394.8	8.0571		0.98699		
Total	50	400			1		
Land use (GL, NF)	1	51.582	51.582	7.5975	0.17426	0.0002	0.00060
Residuals	36	244.418	6.789		0.82574		
Total	37	296			1		
Land use (GL, AC)	1	17.93	17.9324	2.3152	0.05604	0.0407	0.05556
Residuals	39	302.07	7.7453		0.94369		
Total	40	320.00			1		
Land use (TP, NF)	1	29.765	29.7562	4.1044	0.12398	0.003	0.00780
Residuals	29	210.244	7.2498		0.87602		
Total	30	240.000			1		
Land use (TP, AC)	1	19.876	19.8764	2.6054	0.07529	0.0236	0.03360
Residuals	32	244.124	7.6289		0.92471		
Total	33	264.000			1		
Land use (NF, AC)	1	33.412	33.412	5.015	0.20883	0.0028	0.00660
Residuals	19	126.588	6.663		0.79117		
Total	20	160.00			1		

**Table S6.** Permutational multivariate analysis of variance (PERMANOVA) across Argiudolls & Hapluderts and between grasslands (GL), timber plantation (TP) and native forest (NF) land uses (9999 permutations). df = degrees of freedom, SS = sum of squares, MS = mean square, P-adj = adjusted P with Benjamini & Hochberg correction. See NDMS in Fig. 3d.

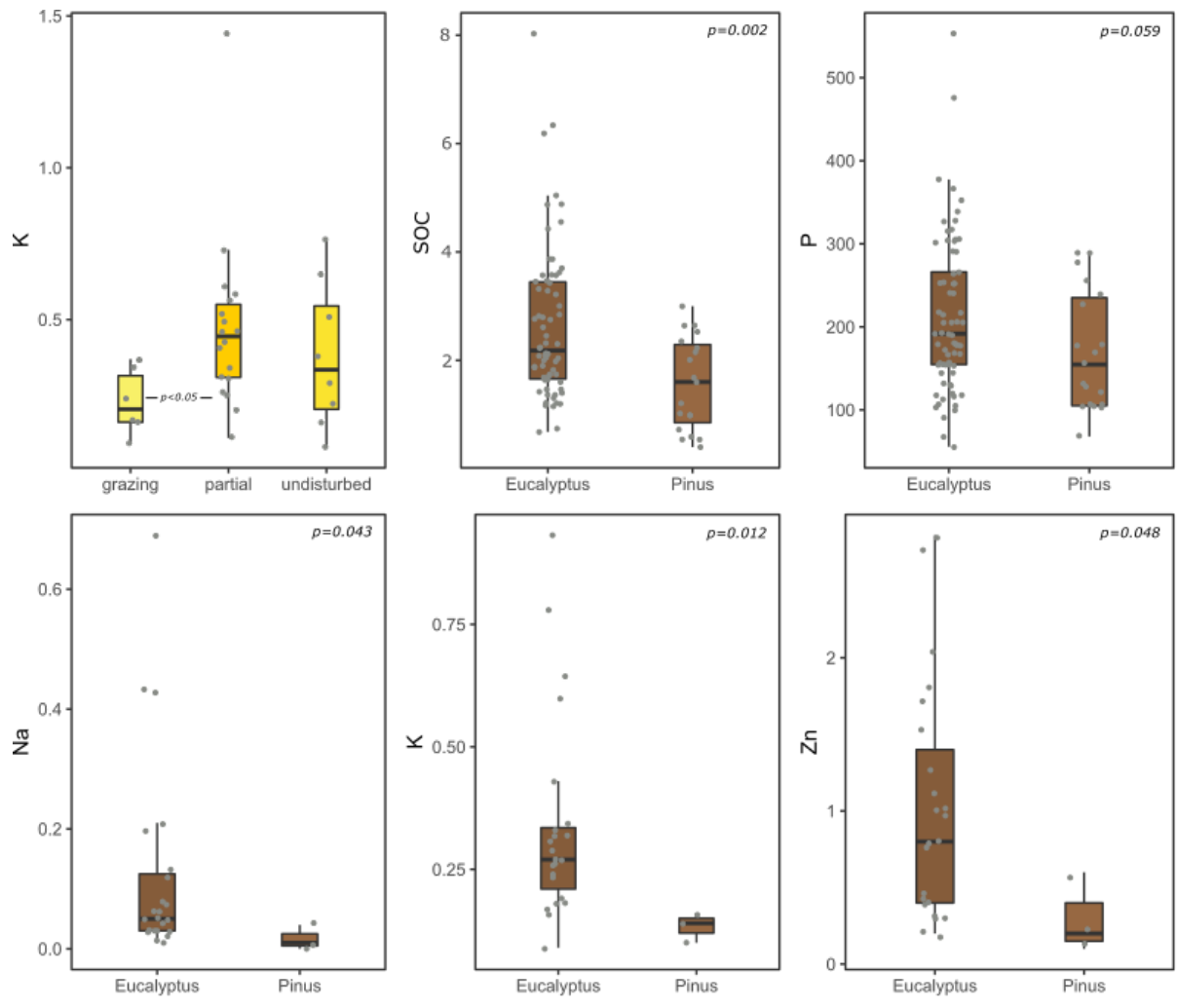
	df	SS	MS	F	R <sup>2</sup>	P	P-Adj
<i>Country-wide</i>							
Land use (GL, TP, NF)	2	53.71	26.85	3.80	0.15986	0.0009	
Residuals	40	282.29	7.0572		0.84014		
Total	42	336.00			1		
<i>Pairwise</i>							
Land use (GL, TP)	1	34.006	34.006	4.6727	0.11489	0.0015	0.00345
Residuals	36	261.994	7.278		0.88511		
Total	37	296.000			1		
Land use (GL, NF)	1	10.931	10.9307	1.3867	0.05255	0.2181	0.21290
Residuals	25	197	7.8828		0.94745		
Total	26	208.000			1		
Land use (TP, NF)	1	41.557	41,557	6,6663	0,25973	0,0008	0.00090
Residuals	19	118,443	6,234		0,74027		
Total	20	160,000			1		

**Table S7.** Permutational multivariate analysis of variance (PERMANOVA) across Argiudolls, Hapudolls & Hapludalf and between grasslands (GL), timber plantation (TP) and native forest (NF) land uses (9999 permutations). df = degrees of freedom, SS = sum of squares, MS = mean square, P-adj = adjusted P with Benjamini & Hochberg correction. See NDMS in Fig. 3e.

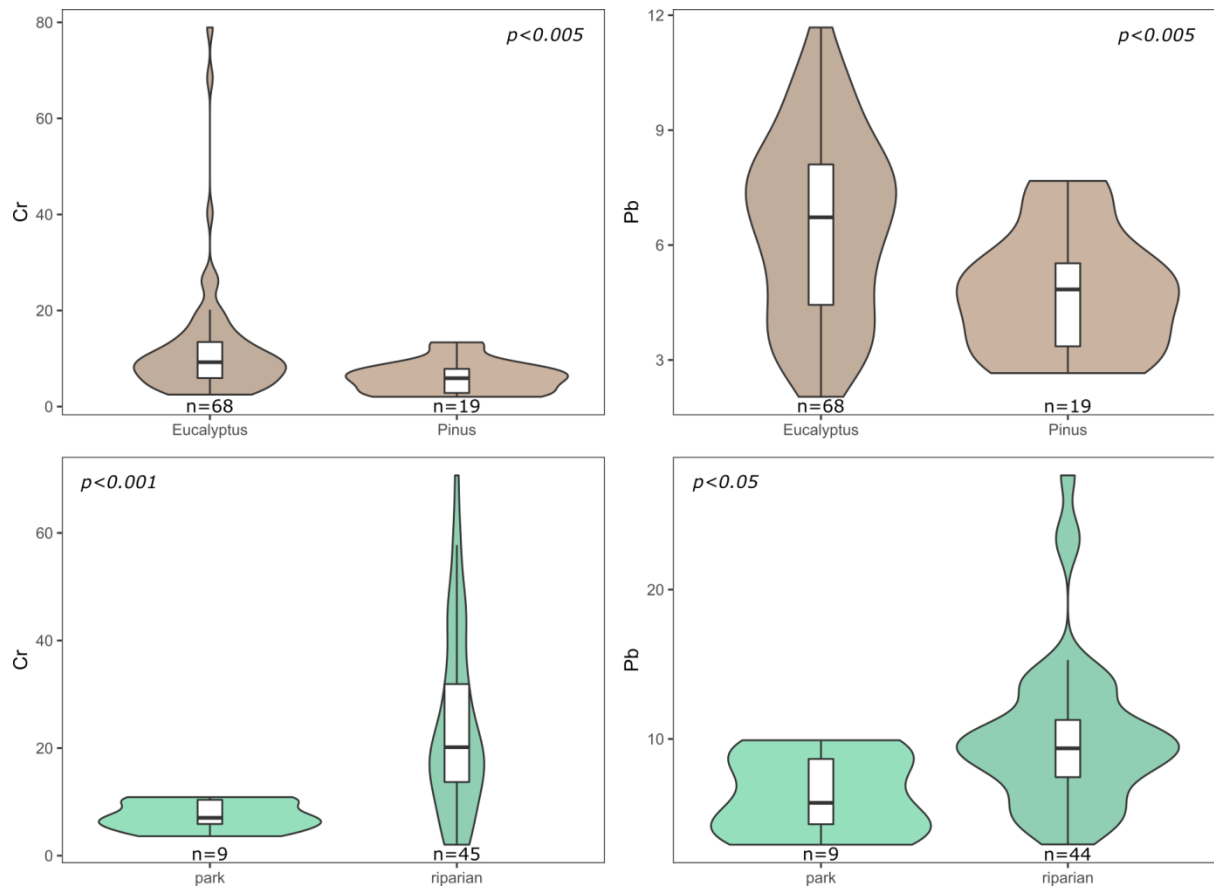
	df	SS	MS	F	R <sup>2</sup>	P	P-Adj
<i>Country-wide</i>							
Land use (GL, TP, NF)	2	32,874	16,4369	2,21	0,12841	0,0284	
Residuals	30	223,126	7,4375		0,87159		
Total	32	526,000			1		
<i>Pairwise</i>							
Land use (GL, TP)	1	21,044	21,0439	2,8774	0,13152	0,0285	0.0438
Residuals	19	138,956	7,3135		0,86848		
Total	20	160,000			1		
Land use (GL, NF)	1	08,259	10,2588	1,2998	0,05829	0,246	0.2537
Residuals	21	165,741	7,8924		0,94171		
Total	22	176,000			1		
Land use (TP, NF)	1	21,218	21,2184	2,8912	0,1263	0,0162	0.0438
Residuals	20	146,782	7,3391		0,8737		
Total	21	168,000			1		

**Table S8.** Permutational multivariate analysis of variance (PERMANOVA) across Hapludalfs & Hapludults and between grasslands (GL), timber plantation (TP) and native forest (NF) land uses (9999 permutations). df = degrees of freedom, SS = sum of squares, MS = mean square, P-adj = adjusted P with Benjamini & Hochberg correction. See NDMS in Fig. 3f.

	df	SS	MS	<i>F</i>	R <sup>2</sup>	P	P-Adj
<i>Country-wide</i>							
Land use (GL, TP, NF)	2	132,25	66,123	12,341	0,35936	0,0001	
Residuals	44	235,75	5,358		0,64064		
Total	46	368,00			1		
<i>Pairwise</i>							
Land use (GL, TP)	1	21,251	21,2510	2,7845	0,07179	0,0325	0.0342
Residuals	36	274,749	7,6319		0,92821		
Total	37	296,000			1		
Land use (GL, NF)	1	65,392	65,392	11,464	0,31439	0,0001	0.0006
Residuals	25	142,608	5,704		0,68561		
Total	26	208,000			1		
Land use (TP, NF)	1	98,911	98,911	21,349	0,4157	0,0001	0.0003
Residuals	27	125,089	4,633		0,55843		
Total	28	224,000			1		



**Figure S4.** Box Plots for significant Kruskal-Wallis Tests across soil categories of GL and TP land uses for fertility variables. Plots were classified in more specific subcategories: GL in ‘undisturbed’, ‘partially grazed’ and ‘highly grazed’ plots; TP in ‘*Eucalyptus*’ or ‘*Pinus*’ plots; NF in ‘park’ or ‘riparian’ plots; and AC plots in ‘orchards’ or ‘crops’.



**Figure S5.** Violin/Box Plots for significant Kruskal-Wallis Tests across evaluated country-wide land uses sub-classifications for trace metals variables. Sample number is depicted in each case.