soil systems

MDPI

Supplementary material

Hot spots and hot moments of soil moisture explain fluctuations in iron and carbon cycling in a humid tropical forest soil

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15 FIGURES AND TABLES

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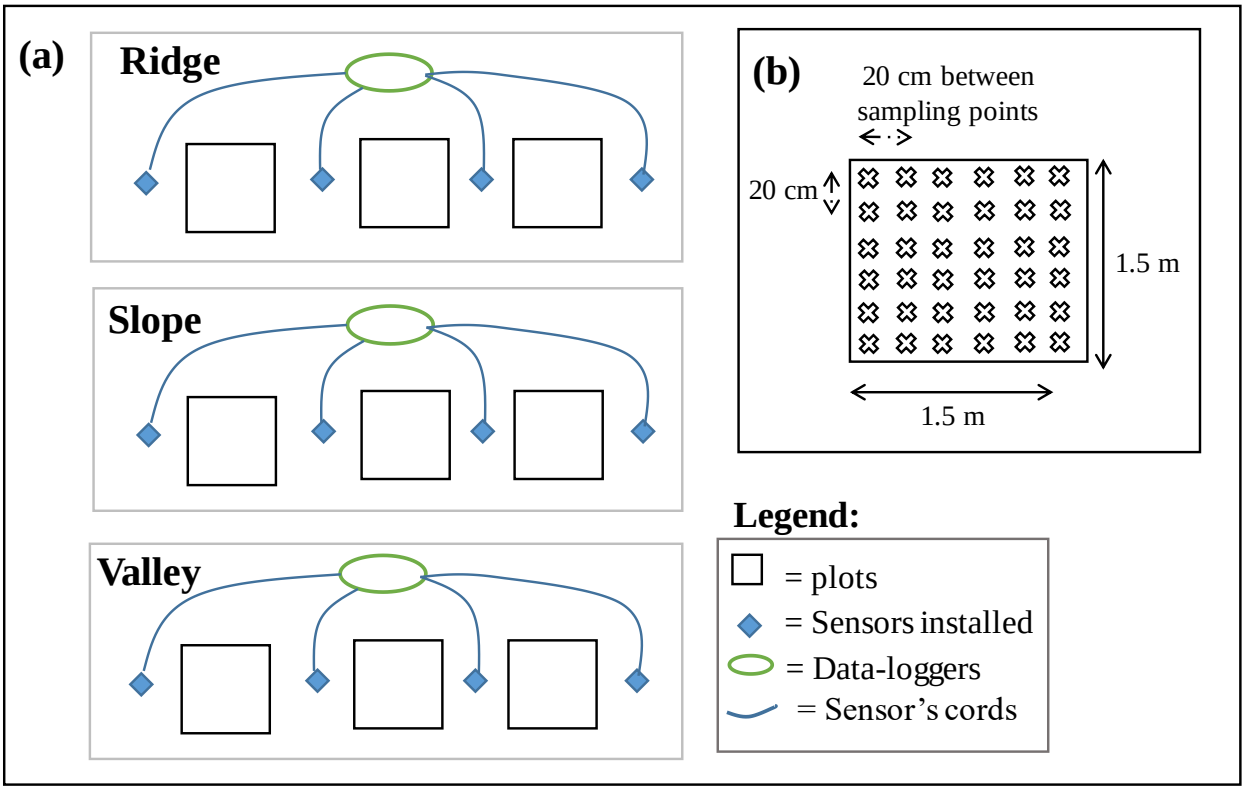

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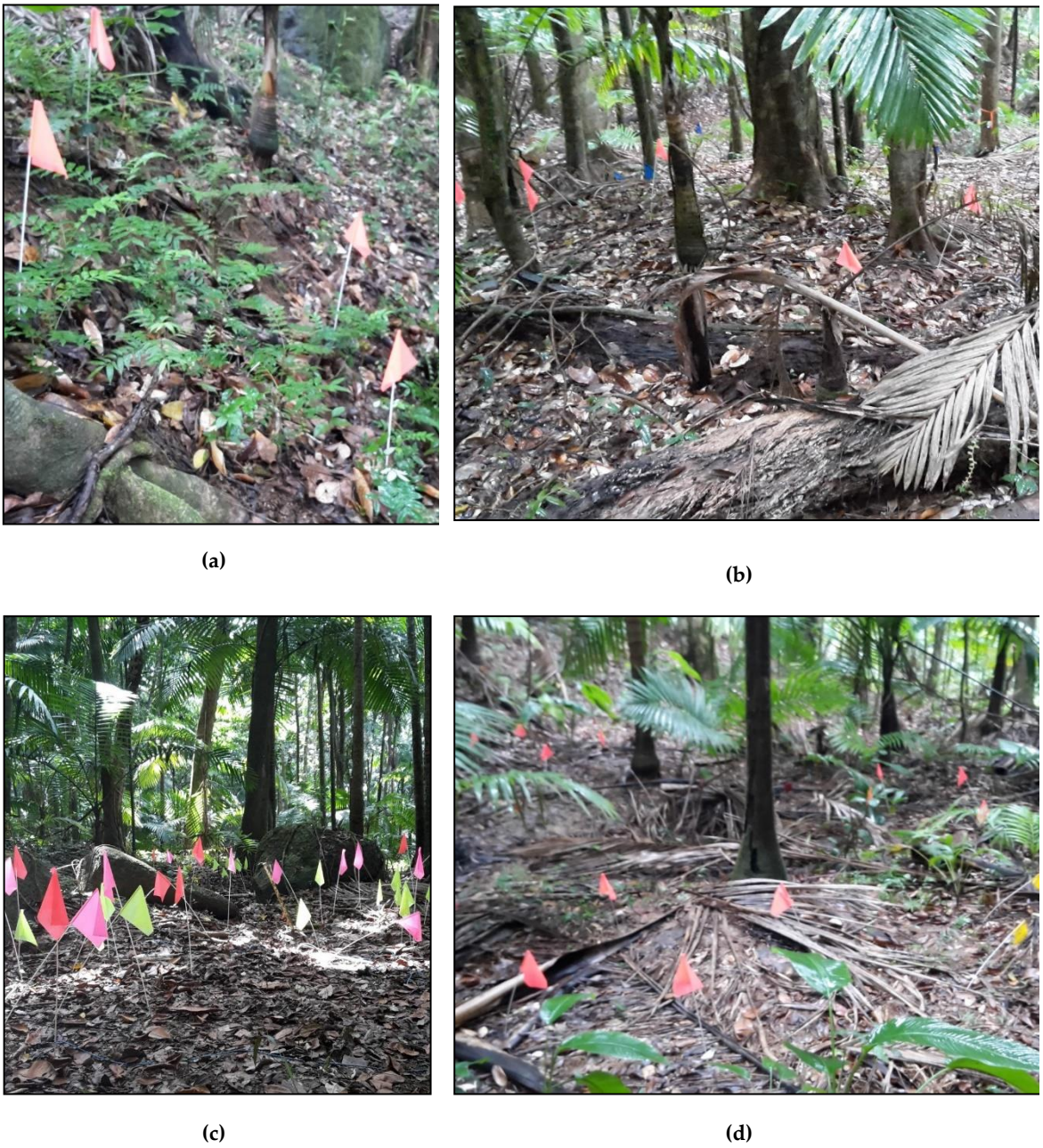
18 **Figure S1.** Illustration of sampling design at one of the catenas: **(a)** showing ridge, slope, and valley
19 topographic positions, the 3 plots allocated within each site, the sensors distributed within the plots, and **(b)**
20 example of a subplot of 1.5 m x 1.5 m, sampled at 0-15 cm depth with sampling points randomly located at
21 least 20 cm apart. Luquillo CZO, Puerto Rico (2016).



(a) **(b)**

(c) **(d)**

Figure S2. Visualization of subplots in Catena-2: **(a)** slope, **(b)** ridge, and **(c)** valley; and **(d)** valley in Catena-3. Luquillo CZO, Puerto Rico (2016).

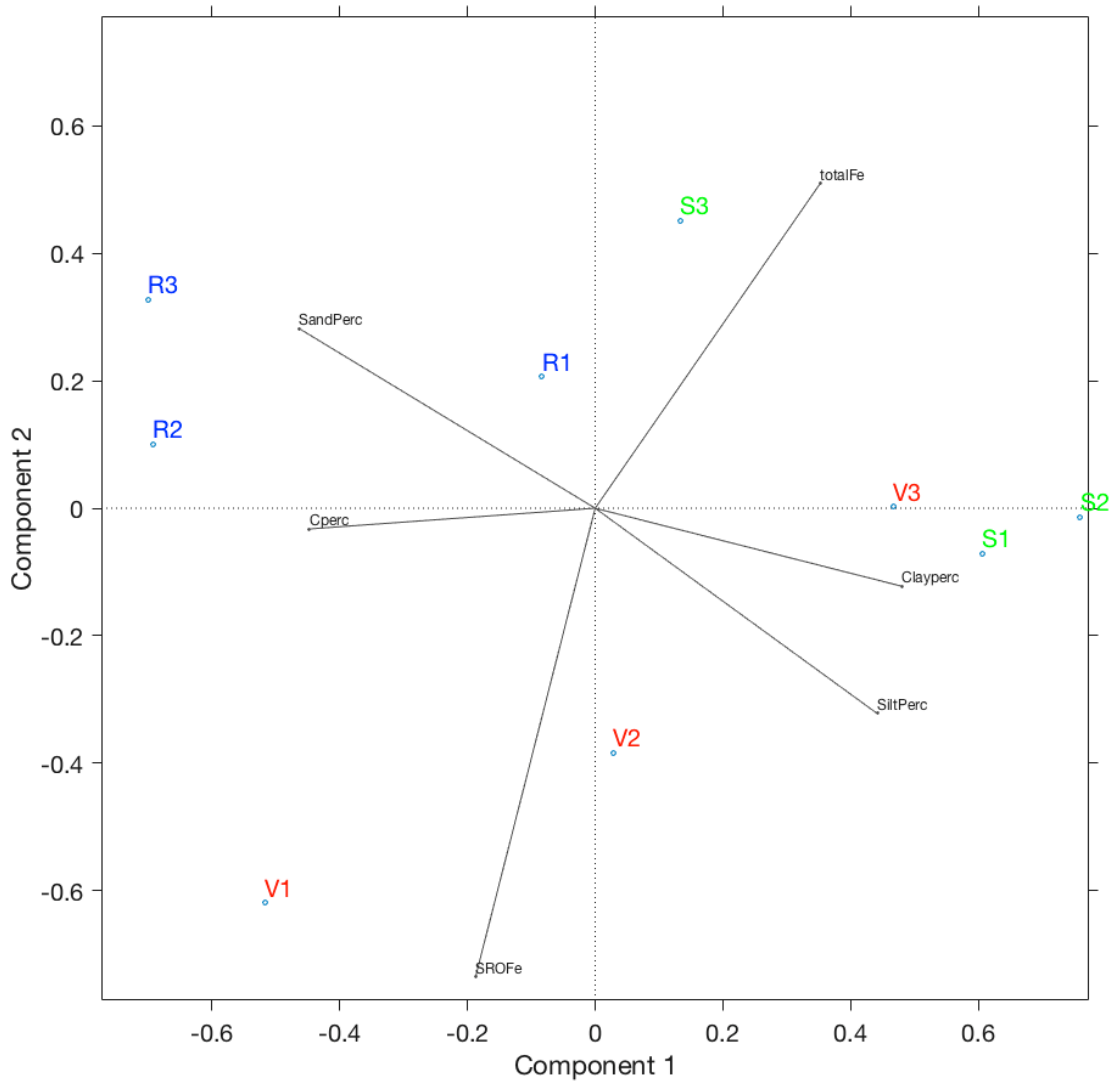


Figure S3. Principal Component Analysis (PCA) for the 9 sites, valleys (V1, V2, V3), slopes (S1, S2, and S3), and ridges (R1, R2, R3) based on the following soil characteristics: Total-Fe, SRO-Fe, Total-C, Sand, Silt, and Clay content. Soils from Luquillo CZO, Puerto Rico, sampled in 2016.

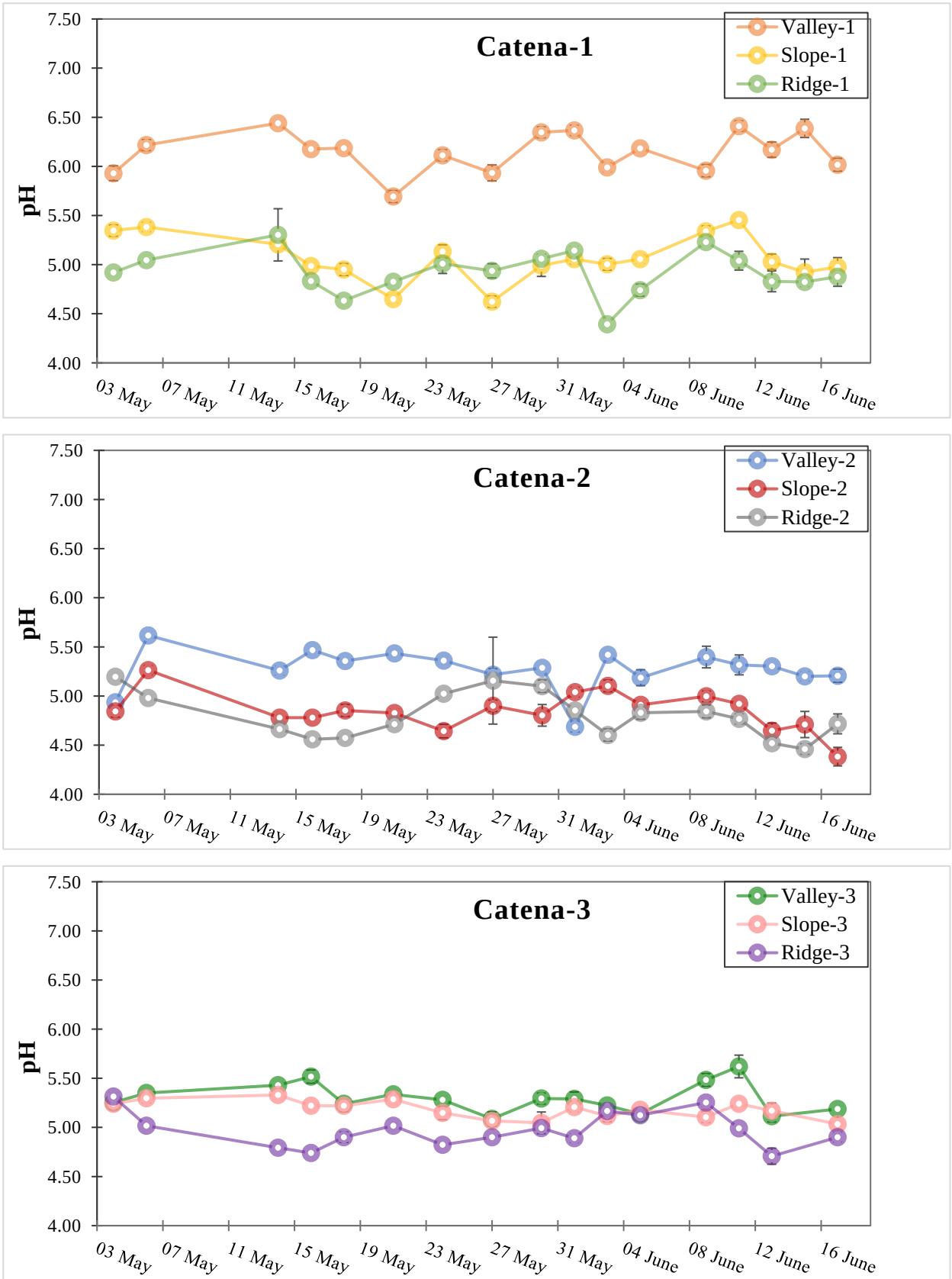


Figure S4. Soil pH (1:1 soil:water). Soils from Luquillo CZO, Puerto Rico (2016). Error bars are ± 1 SD.

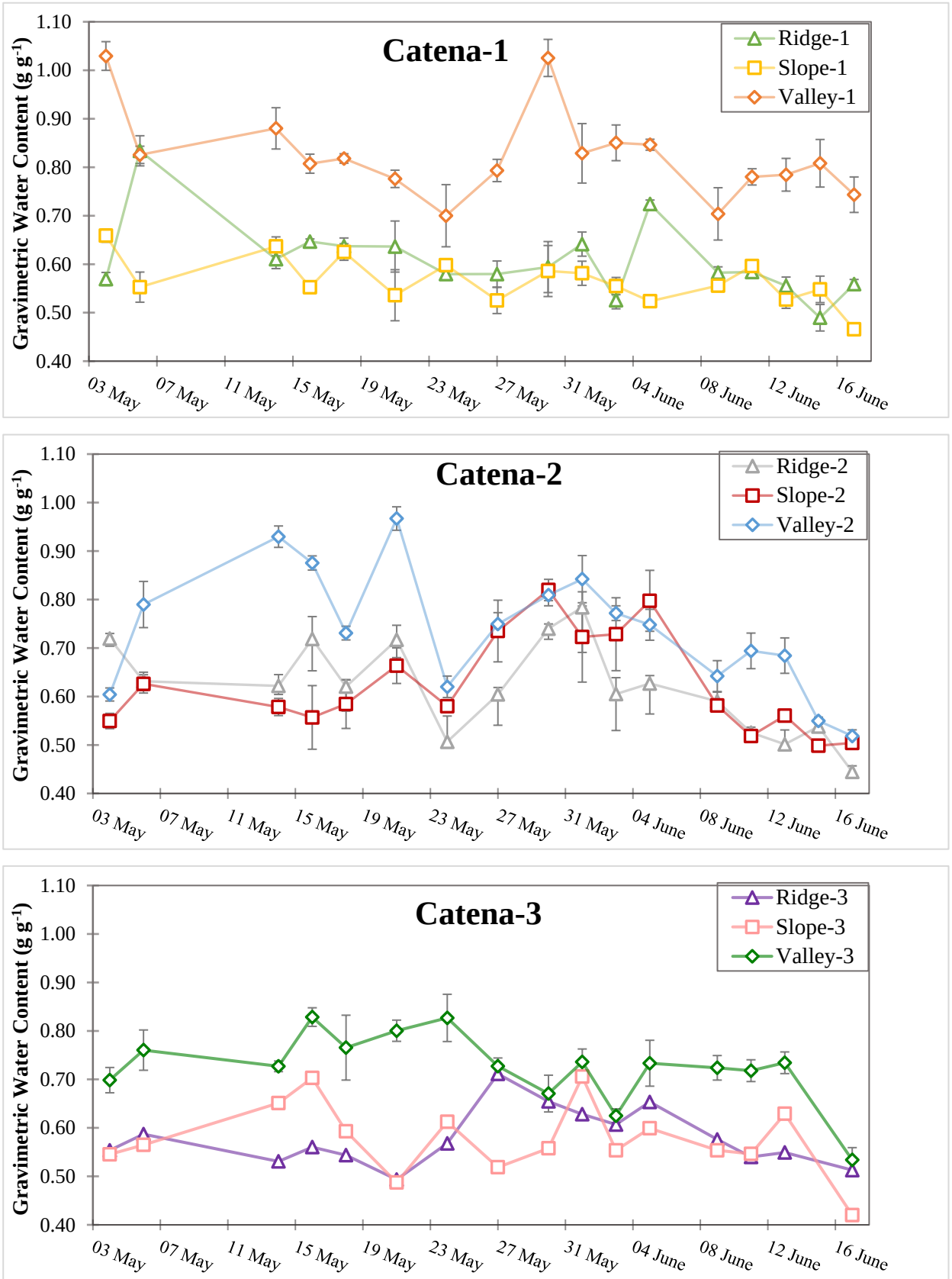


Figure S5. Gravimetric Water Content. Soils from Luquillo CZO, Puerto Rico (2016). Error bars are ± 1 SD.

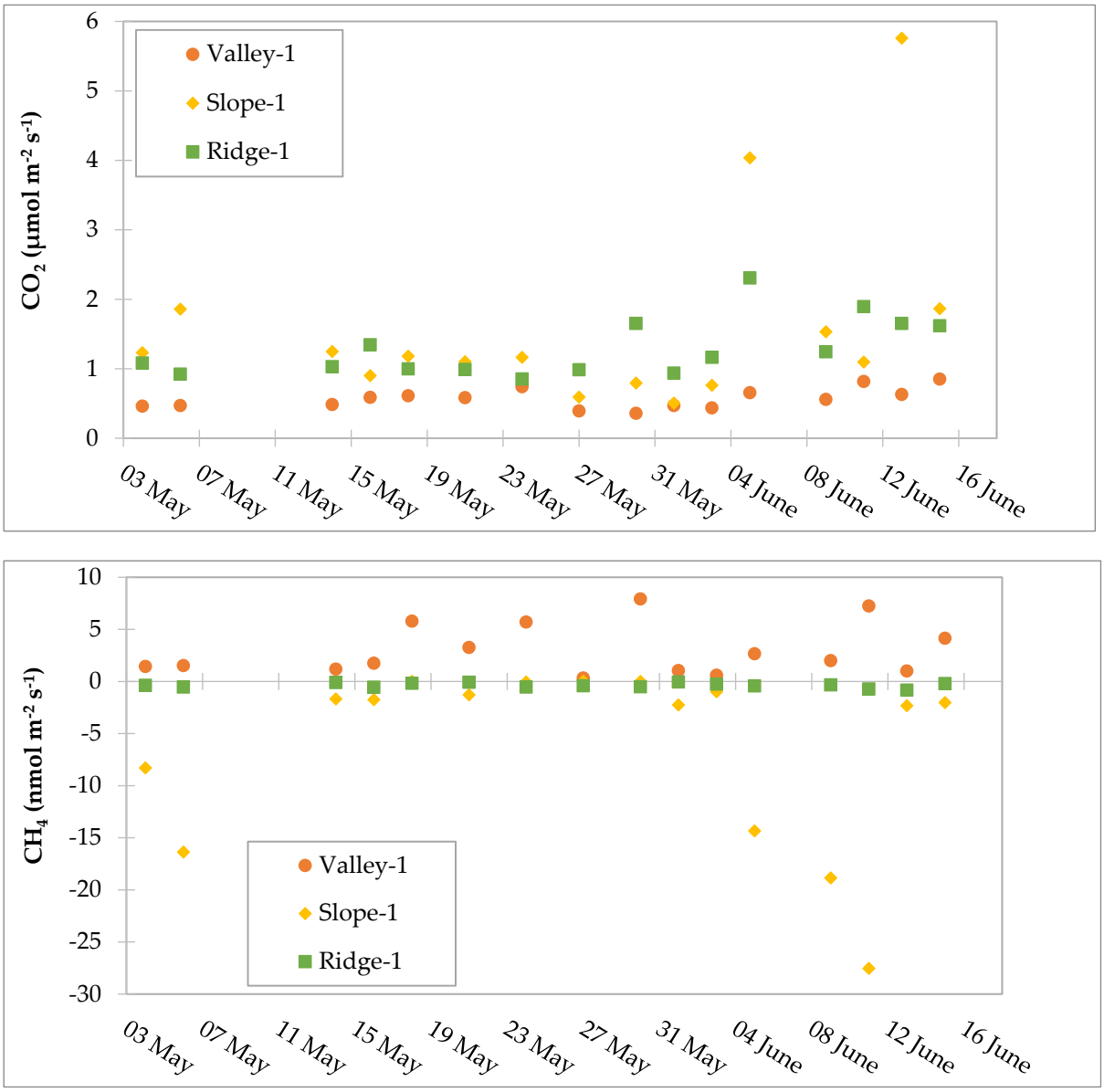
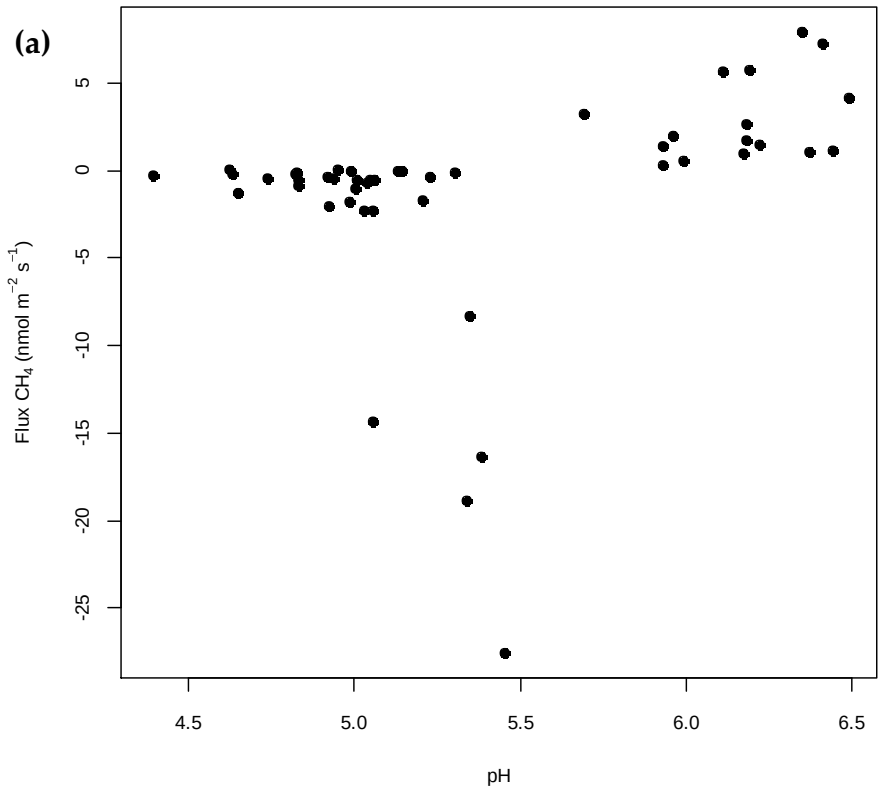


Figure S6. Soil CO_2 and CH_4 emissions. Soils from Luquillo CZO, Puerto Rico (2016).



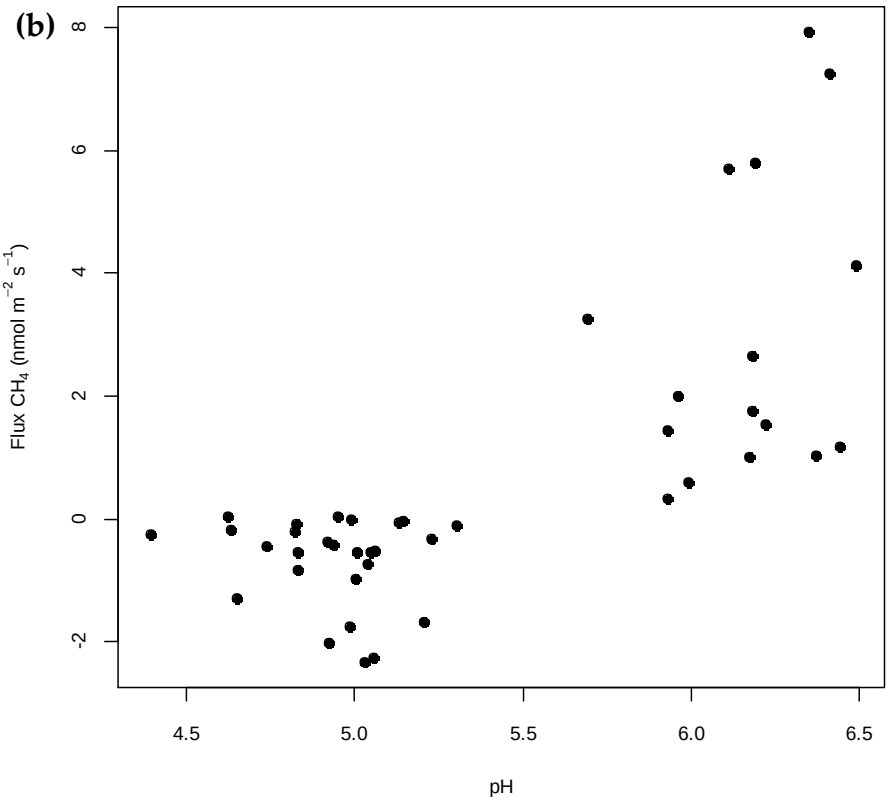


Figure S7. Values for pH and CH_4 fluxes **(a)** with and **(b)** without the outliers.

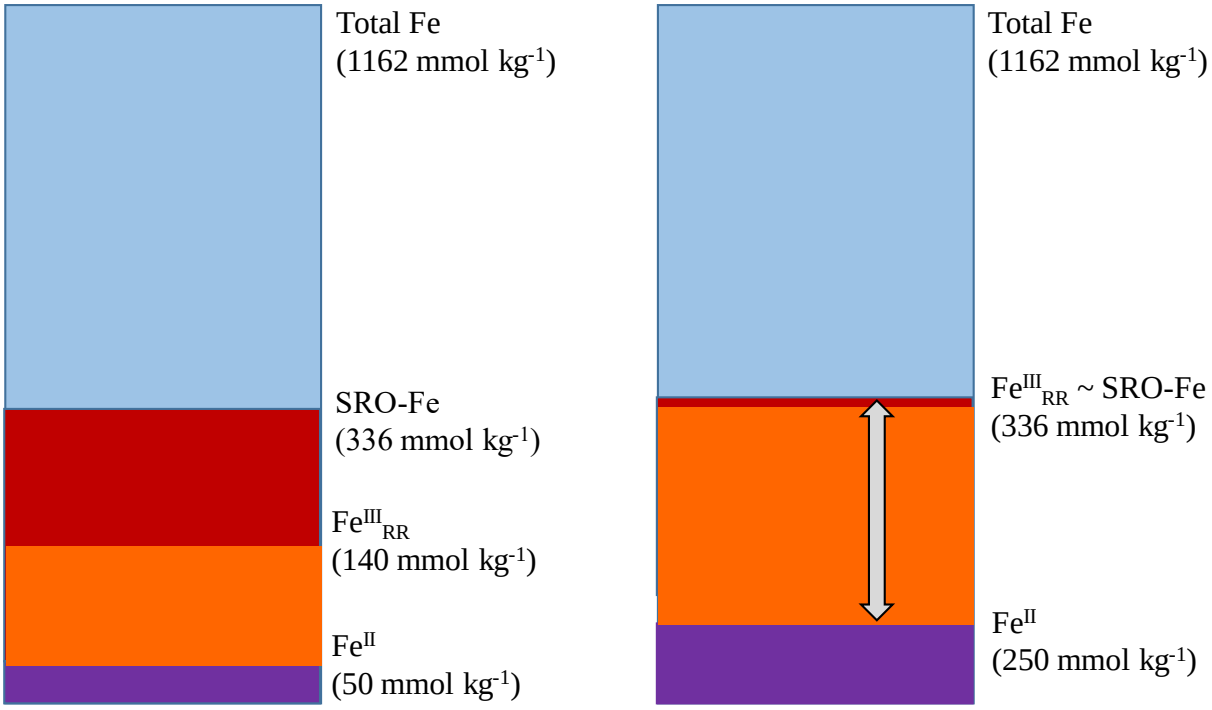


Figure S8. Pools of Total-Fe, SRO-Fe, Fe^{III}_{RR}, and Fe^{II} for two given sampling days (left and right) for valley-1. The pool of Fe^{III}_{RR} is dynamic and can be as high as the SRO-Fe pool. Soils from Luquillo CZO, Puerto Rico, sampled in 2016.

52 **Table S1.** GPS coordinates of the studied site.

Catena	Topographic position	Latitude	Longitude	Altitude (m)
1	Ridge	N 18.32092°	W 65.81729°	414
	Slope	N 18.32077°	W 65.81736°	415
	Valley	N 18.32087°	W 65.81700°	411
2	Ridge	N 18.32143°	W 65.81770°	400
	Slope	N 18.32156°	W 65.81793°	392
	Valley	N 18.32191°	W 65.81818°	379
3	Ridge	N 18.32121°	W 65.81736°	407
	Slope	N 18.32142°	W 65.81754°	401
	Valley	N 18.32141°	W 65.81754°	399

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Table S2(a). Total elemental analysis (concentrations in %). Soils from Luquillo CZO, Puerto Rico, sampled in 2016.

Site	Si	Al	Fe	Ca	Mg	Na	K	Ti	Mn
Valley-1	27.44	12.35	6.43	0.14	0.21	0.06	0.09	0.61	0.06
Valley-2	29.62	10.85	7.55	0.40	0.446	0.23	0.18	0.67	0.170
Valley-3	26.44	12.91	7.87	0.10	0.241	0.05	0.07	0.62	0.085
Slope-1	26.63	13.02	7.83	0.07	0.181	0.05	0.08	0.65	0.062
Slope-2	26.31	12.75	8.39	0.04	0.211	0.04	0.07	0.66	0.031
Slope-3	26.37	12.17	8.01	0.09	0.543	0.05	0.08	0.61	0.271
Ridge-1	24.97	12.95	8.02	0.05	0.20	0.04	0.08	0.63	0.04
Ridge-2	25.16	12.01	7.45	0.04	0.217	0.05	0.08	0.62	0.046
Ridge-3	26.37	12.17	7.48	0.08	0.229	0.06	0.08	0.62	0.101

Table S2(b). Total elemental analysis (concentrations in ppm). Soils from Luquillo CZO, Puerto Rico, sampled in 2016.

Site	Ba	Ce	Cr	Cs	Dy	Er	Eu	Ga	Gd	Hf	Ho	La	Lu	Nb	Nd	Pr	Rb	Sm	Sn	Sr	Ta	Tb	Th	Tm	U	V	W	Y	Yb	Zr
Valley-1	111	24.6	150	0.4	2.68	1.54	0.96	24.7	2.84	3.4	0.56	10.1	0.24	4.5	12.8	2.97	3.2	2.98	2	52.8	0.3	0.44	1.89	0.21	0.89	297	1	12.9	1.58	126
Valley-2	137	20.3	180	0.7	1.84	1.11	0.65	23.1	1.98	3.5	0.39	7.5	0.19	4.5	8.8	2.09	5	2.04	1	85.4	0.3	0.31	1.98	0.17	0.89	342	1	9.3	1.16	129
Valley-3	119	14.3	130	0.5	1.37	0.79	0.42	26.8	1.24	3.6	0.27	5.9	0.15	4.2	6.2	1.45	2.8	1.39	3	26.5	0.3	0.2	1.84	0.14	0.9	311	1	6.9	0.97	127
Slope-1	80	9.7	130	0.7	0.9	0.61	0.27	26.6	0.86	3.7	0.2	5.7	0.14	5.1	4.6	1.18	3.8	1.01	1	28.6	0.3	0.14	2.29	0.1	0.99	317	1	5.0	0.78	136
Slope-2	99	8.4	130	0.6	0.79	0.53	0.23	26.7	0.75	3.6	0.18	4.1	0.11	4.4	3.5	0.85	3.2	0.78	1	19.9	0.3	0.11	2.00	0.1	0.82	334	1	4.1	0.67	125
Slope-3	316	22.6	150	0.3	3.37	1.90	1.11	24.4	3.32	2.8	0.7	8.6	0.3	3.2	12.7	2.72	1.9	3.42	1	19.1	0.2	0.53	0.95	0.29	0.56	309	1	18.5	1.98	102
Ridge-1	97	13.4	120	0.6	1.06	0.64	0.36	26.4	1.00	3.5	0.23	5.5	0.14	4.3	5.4	1.3	3.3	1.18	2	24.9	0.3	0.18	2.00	0.14	0.9	331	1	5.5	0.91	123
Ridge-2	72	9.5	120	0.6	0.94	0.65	0.27	24.5	0.85	3.3	0.22	4.7	0.12	4.5	4.2	1.05	3.6	1.02	1	20.8	0.3	0.15	1.98	0.1	0.85	291	1	4.8	0.76	121
Ridge-3	96	10.1	120	0.6	1.00	0.68	0.29	25.0	0.87	3.5	0.23	5.1	0.13	5.0	4.4	1.12	3.4	0.97	2	23.9	0.3	0.15	2.04	0.12	0.96	301	1	5.2	0.85	127

Table S3. Turnover Times for HCl-extractable Fe^{II} Production and HCl-extractable Fe^{II} Consumption: highest frequency, median and mean.

Sites	Fe^{II} Production			Fe^{II} Consumption		
	Highest frequency	Median	Mean	Highest frequency	Median	Mean
	---------- *days* ----------					
All Sites	4	7	23	3 to 4	8	36
Valley-1	3	5	12	4	8	15
Valley-2	5 to 10	25	23	6	8	40
Valley-3	5 to 10	9	10	3 to 11	28	55
Slope-1	8	6	8	5 to 6	12	96
Slope-2	5 to 10	16	16	4	8	15
Slope-3	4	2	10	3 to 4	8	22
Ridge-1	4	5	38	3	10	86
Ridge-2	4 to 18	16	46	4	3	8
Ridge-3	3	2	4	4	4	17

62 **Table S4.** Parameters used for each variable studied before stepwise backward elimination.

Catenas	Initial Model (before stepwise backward elimination)
All	Eh ~ Precipitation, O_2, θ_V
1	O_2 ~ Precipitation, θ_V
1	θ_V ~ Precipitation
All	Fe^{II} ~ DOC, Media-Fe^{III}_{RR}, pH, θ_G, Precipitation_48h
1	Fe^{II} ~ DOC, Media-Fe^{III}_{RR}, pH, Precipitation_48h, O_2_48h, θ_V_12h
All	DOC ~ Fe^{II}, Media-Fe^{III}_{RR}, pH, θ_G, Precipitation_48h, Eh_2h
1	DOC ~ Fe^{II}, Media-Fe^{III}_{RR}, pH, Precipitation_48h, Eh_48h, O_2_48h, θ_V_36h
All	Media-Fe^{III}_{RR} ~ Fe^{II}, DOC, pH, θ_G, Precipitation_48h, Eh_6h
1	Media-Fe^{III}_{RR} ~ Fe^{II}, DOC, pH, Precipitation_48h, Eh_6h, O_2_6h, θ_V_24h
All	Shewa-Fe^{III}_{RR} ~ Fe^{II}, DOC, pH, θ_G, Precipitation_48h, Eh_6h
1	Shewa-Fe^{III}_{RR} ~ Fe^{II}, DOC, pH, Precipitation_48h, Eh_6h, O_2_3h, θ_V_12h
1	F(CO_2) ~ Fe^{II}, Media-Fe^{III}_{RR}, DOC, pH, Precipitation_48h, Eh_12h, O_2_48h, θ_V_24h, F(CH_4)
1	F(CH_4) ~ Fe^{II}, Media-Fe^{III}_{RR}, DOC, pH, Precipitation_48h, Eh_1h, O_2_48h, θ_V_1h, F(CO_2)

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Table S5. Number of hours before soil sampling the environmental factors are averaged that yielded the lowest AIC (best model). It represents the best averaging window to predict each variable in the mixed linear models (from 1 to 48 h of soil sampling).

Variable modeled	Eh	θ_V	O_2
Fe^{II}	-	12	48
DOC	2	36	48
Media-Fe^{III}_{RR}	6	24	6
Shewa-Fe^{III}_{RR}	6	12	3
$F(CO_2)$	12	24	48
$F(CH_4)$	1	1	48

Table S6. Comparison of reactive iron pool (SRO-Fe) extracted by Citrate-Ascorbate and the Fe reduced within 7 days by incubations with Shewa-Fe^{III}_{RR} and Media-Fe^{III}_{RR}: **(a)** for the actual values in mmol kg^{-1} for the 7 day-incubation, and **(b)** for ratio between Fe^{III}_{RR} pool and the SRO-Fe pool (in percent).

Table 4 (a)

Site	SRO-Fe	Shewa-Fe^{III}_{RR}				Media-Fe^{III}_{RR}			
		Min	Mean	(St Error)	Max	Min	Mean	(St Error)	Max
	mmol kg⁻¹								
Valley-1	336	140	221	(19)	344	128	214	(17)	342
Valley-2	305	8	80	(13)	139	6	73	(12)	120
Valley-3	195	8	63	(11)	113	3	60	(11)	104
Slope-1	178	3	53	(12)	144	3	33	(6)	68
Slope-2	213	5	52	(9)	89	6	34	(8)	76
Slope-3	131	3	35	(8)	81	5	20	(5)	62
Ridge-1	190	4	49	(7)	87	5	33	(7)	88
Ridge-2	227	8	49	(7)	95	12	34	(4)	51
Ridge-3	206	5	36	(6)	91	4	24	(4)	49

Table 4 (b)

Site	SRO-Fe	Shewa-Fe^{III}_{RR}				Media-Fe^{III}_{RR}			
		Min	Mean	(St Error)	Max	Min	Mean	(St Error)	Max
	mmol kg⁻¹	% (Fe^{III}_{RR} / SRO-Fe)							
Valley-1	336	42	66	(6)	102	38	64	(5)	101
Valley-2	305	3	26	(4)	46	2	24	(4)	39
Valley-3	195	4	32	(6)	58	1	31	(5)	53
Slope-1	178	2	30	(7)	81	1	18	(3)	38
Slope-2	213	2	24	(4)	42	3	16	(4)	36
Slope-3	131	3	27	(6)	62	4	16	(4)	47
Ridge-1	190	2	26	(4)	46	3	17	(4)	46
Ridge-2	227	3	21	(3)	42	5	15	(2)	22
Ridge-3	206	2	17	(3)	44	2	12	(2)	24