

1 **Supplementary material**

2 Table S1: Variables considered in this study.

Variable	Description
Regional variables	
Climate variables	
MAP	Mean Annual Precipitation, mm.
MSP	Mean Summer Precipitation, mm.
MAT	Mean Annual Temperature, °C.
MST	Mean Summer Temperature, °C.
TSIS	MST-MAT.
Bedrock	3 categories : Basic (marls and calcareous rocks), Acidic (mostly sandstones and slates) or Mixed.
Landscape variables	
Topographical variables	
Slope	Pendent, °.
Aspect	Cos(°)
Macrotopography	Protected; north-facing slopes; Exposed, south-facing slopes.
Microtopography	Flat areas, convexities or mounds, and concavities, convexities or smooth areas.
Soil type variables	
Sand10	Percentage of sands in the 10 cm upper layer (%).
Clay	Percentage of clays in the 10 cm upper layer (%).
Loam	Percentage of loams in the 10 cm upper layer (%).
pH	pH value in soil 10 cm upper layer.
Management variables	
Management	Grazer type : Cattle, Sheep, Mixed
Grazing	Grazing intensity, (units of big grazer (UBG ha-1) low (1; lower than 0.2 UBG ha-1), medium (2; between 0.2-0.4 UBG ha-1) and high (3; up to 0.4 UBG ha-1).

Soil nutrient variables

Soil N	N in soil 20 cm upper layer. (%)
C/N	Soil C/N ratio
P10	Cations of P10 in soil 10 cm upper layer. (ppm).
K10	Cations of K10 in soil 10 cm upper layer. (ppm).

Herbage

Abiom	Avoveground biomass in g/m ²
ADL	Lignin concentration by the acid detergent lingin method (%/DM).
ADF	Fiber concentration by the acid detergent fiber method (%/DM).
NDF	Fiber concentration by the neutro detergent fiber method (%/DM).
NH	Nitrogen in the herbage (%/DM).
CH	Carbon in the herbage (%/DM)
CH/NH	CH/NH
ADL/N_NS	ADL/NH
NDF/CP	NDF/CP (CP: crude protein)
SOC20	Soil Organic Carbon stocks in the 20 cm upper layer (kg m ⁻²).

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5 Table S2: Minimum, maximum, median and mean values of the continuous predictors of this

6 study. Units are shown in Table S1.

	Minimum	Maximum	Median	Mean
MAT	1.08	9.90	4.72	4.96
MST	7.88	16.93	12.23	12.47
TSIS	6.80	7.80	7.58	7.51
MAP	964	1586	1252	1242.91
MSP	169.00	258.00	235.00	228.90

Slope	0.00	35.00	16.50	16.88
Aspect	1.00	3.00	1.84	2.05
Sand	3.10	72.20	32.80	32.67
Loam	13.60	73.50	38.60	39.80
Clay	2.90	68.60	27.25	27.53
pH	3.90	7.80	5.47	5.74
Soil N	0.11	1.10	0.46	0.47
P	4.00	54.00	11.00	12.98
C/N	4.13	41.60	12.47	13.39
Mg	2.89	5.99	4.99	4.92
K	3.40	6.84	4.99	5.03
NDF	31.20	78.90	52.45	52.08
ADF	17.70	46.60	29.55	30.07
ADL	1.16	12.72	6.32	6.63
NH	0.48	3.03	1.66	1.63
CH	22.60	49.10	45.15	44.53
CH/NH	13.90	97.20	26.60	31.14
Abiom	64.52	1224	308.32	341.91
NDF/CP	2.15	17.20	4.77	5.71
ADL/NH	0.50	14.02	3.92	4.78

7 Table S3: Chemical composition of herbage samples used for NIRS calibration

Parameter, %	N	Min.	Max.	Mean	SD
DM	67	91.60	96.73	93.48	1.39
Ash	67	3.58	19.73	10.10	3.98
CP	67	5.50	14.67	9.29	1.90

NDF	67	36.82	73.11	55.42	9.27
ADF	67	21.95	41.97	30.00	4.70
ADL	67	3.35	12.52	6.18	2.08
N	55	0.75	2.10	1.44	0.31
C	55	36.83	51.13	45.10	2.99

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9 Table S4: Calibration and cross validation statistics for predicting the chemical composition
10 parameters in herbage samples by NIRS analysis

Parameter	Math ^a treatment	Scatter ^b correction	R ²	r ²	SEC	SECV	RPD
DM	2,4,4,1	DT	0.92	0.85	0.392	0.539	2.58
Ash	2,4,4,1	MSC	0.83	0.70	1.583	0.830	4.80
CP	2,4,4,1	SNV	0.97	0.94	0.331	0.451	4.21
NDF	2,4,4,1	DT	0.83	0.72	3.756	4.728	1.96
ADF	2,4,4,1	DT	0.81	0.70	2.031	2.548	1.84
ADL	2,4,4,1	MSC	0.80	0.66	0.900	1.178	1.77
N	2,4,4,1	MSC	0.97	0.95	0.055	0.068	4.56
C	2,4,4,1	MSC	0.97	0.95	0.422	0.581	5.15

11 ^aDesignations: derivate order, gap, first smoothing, and second smoothing; ^bStandard Normal
12 Variance (SNV), Detrend (DT) and Multiplicative Scattering Correction (MSC) transformations.

13 R² = coefficient of determination for calibration. r² = coefficient of determination for cross
14 validation. SEC = standard error of calibration. SECV = standard error of cross validation. RPD = ratio
15 of performance to deviation (RPD=SD/SECV).

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18 Table S5: Variance inflation values for the continuous predictors included in the GLMs. Values
19 under 5 are considered non-problematic (Heiberger, 2017)

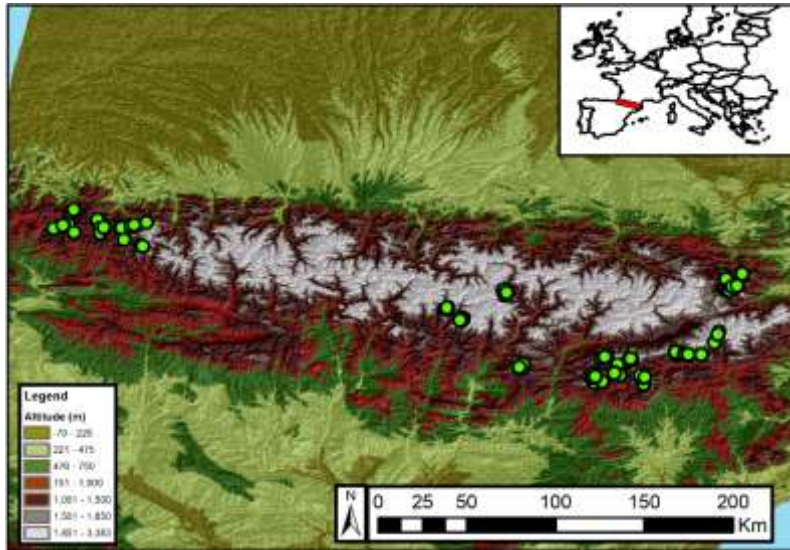
Predictor	MAP	MMT	Slope	Clay	Log(C/N)	N	NDF	ADL/NH
Abiotic model	1.26	1.16	1.27	1.22	-	-	-	-
Full model	-	1.26	1.32	-	1.58	1.82	1.32	1.67

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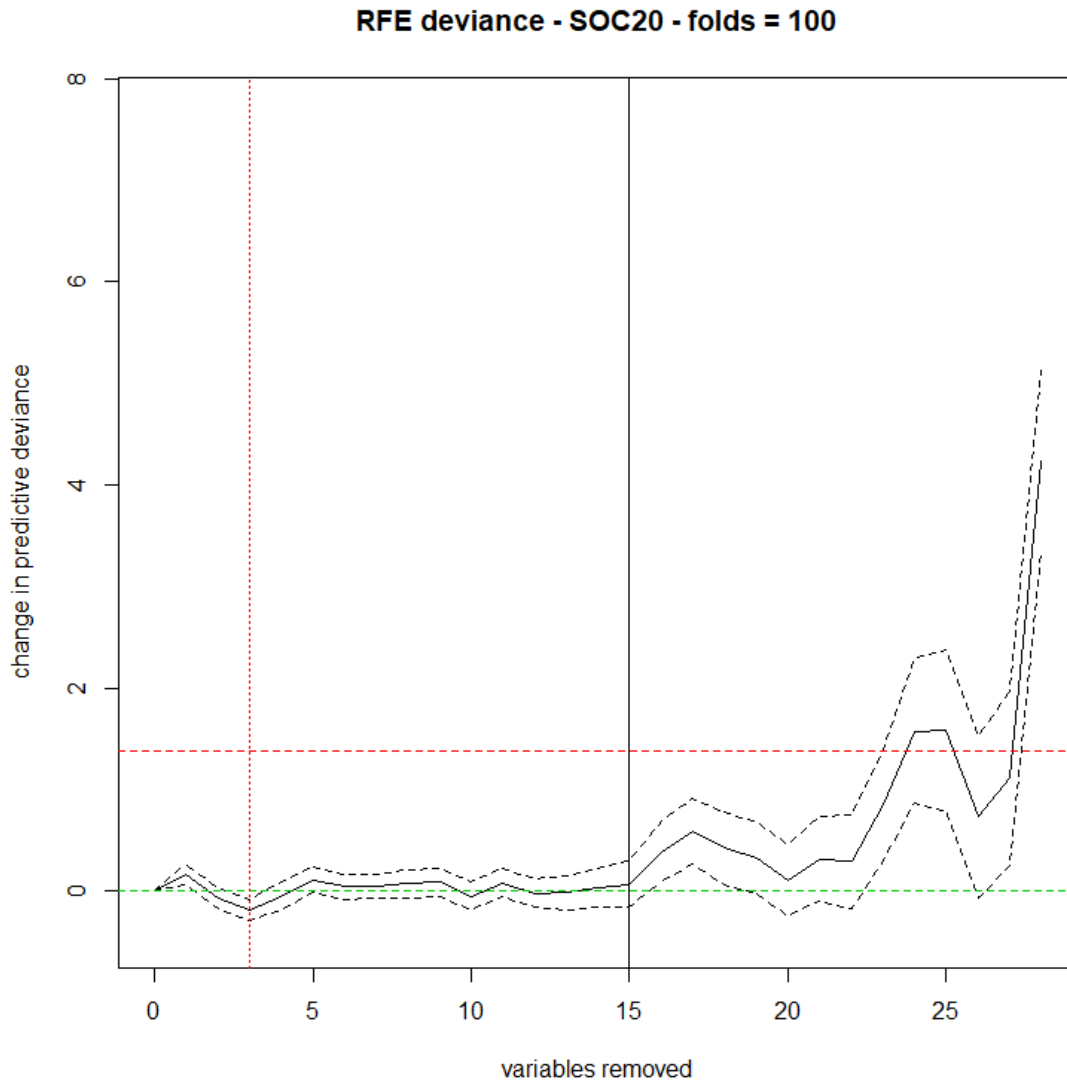
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25 Figure S1: Map of the study area. Points indicate sampling locations.

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27 Figure S2: Changes in the predictive deviance of BRT models by backward removal of its
 28 predictors. The solid line indicates the mean change in predictive deviance, and the dotted line
 29 the standard error, calculated over the 10 folds of the cross-validation. Solid vertical line
 30 indicates the variables removed for the second fit. Dotted vertical line indicates minimum
 31 change in predictive deviance. Dotted horizontal line indicates mean change in predictive
 32 deviance.

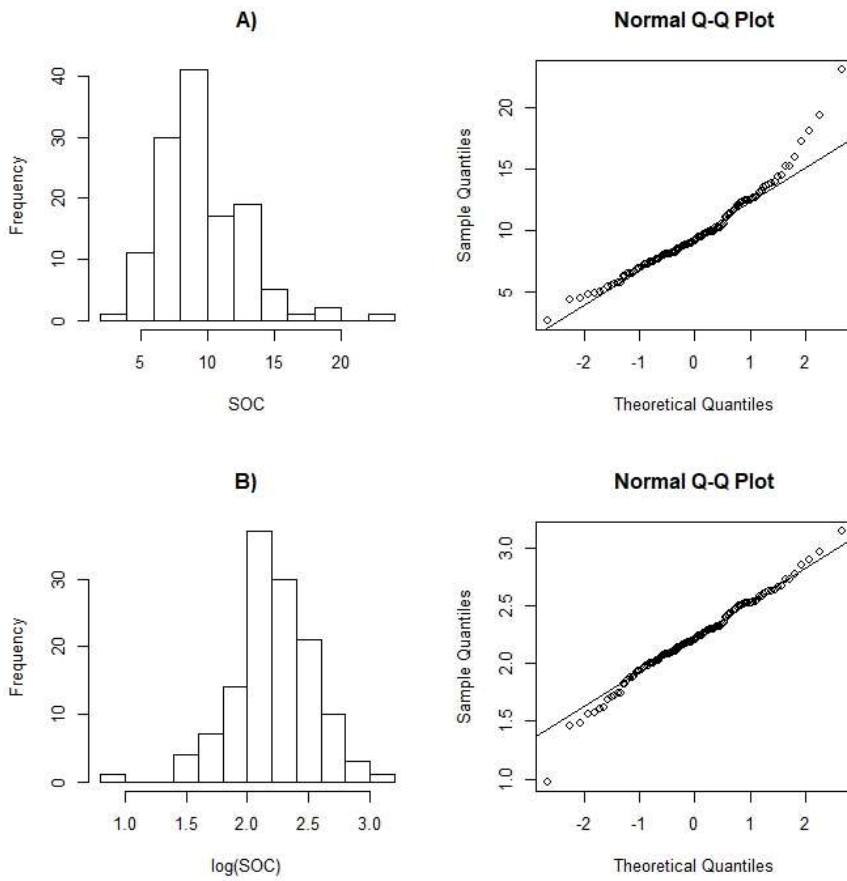
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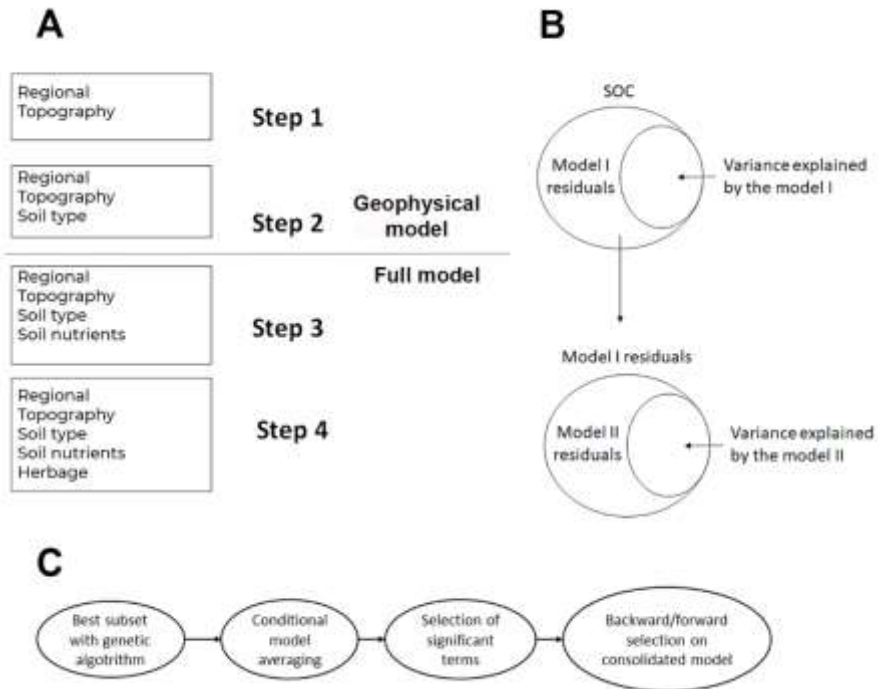
39 Figure S3: Histogram and normal Q-Q plot of A) SOC and B) log(SOC). Result of Shapiro Wilk W

40 test result were $W = 0.948$; $p\text{-value} < 0.001$ and $W = 0.99$; $p\text{-value} = 0.18$ respectively.

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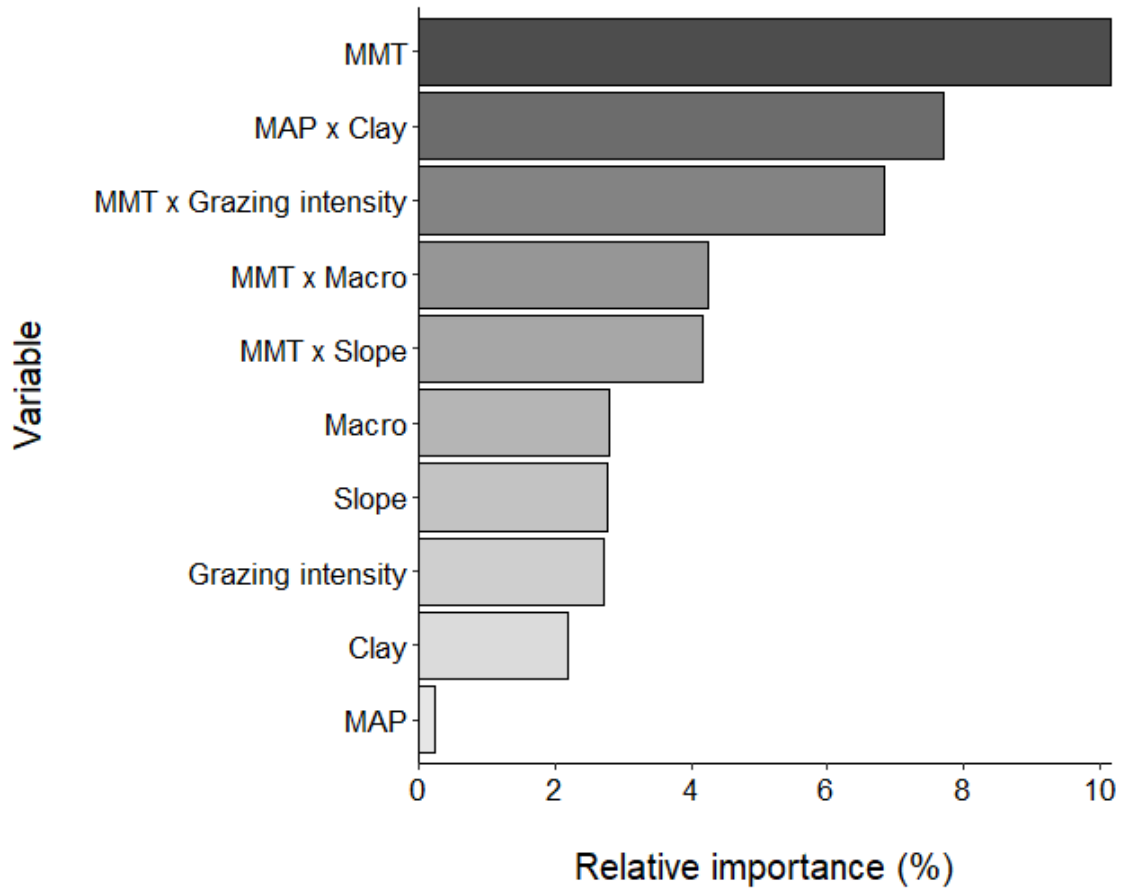


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45 Figure S4: Linear modelling procedure. A) Variables introduced in each step. The first linear
46 model (Geophysical model) is fitted until Step 2 and the second linear model (Complete
47 Model) is fitted until Step 4. B) For selecting the candidate predictor terms on each step,
48 residuals of the model obtained in the previous step are used as response variables in C. C)
49 Procedure to select candidate terms on each step. First, genetic algorithm was used to obtain a
50 set of best models. Second, these models were averaged and the significant terms were
51 selected as candidates for backward forward selection in the main/consolidated model.

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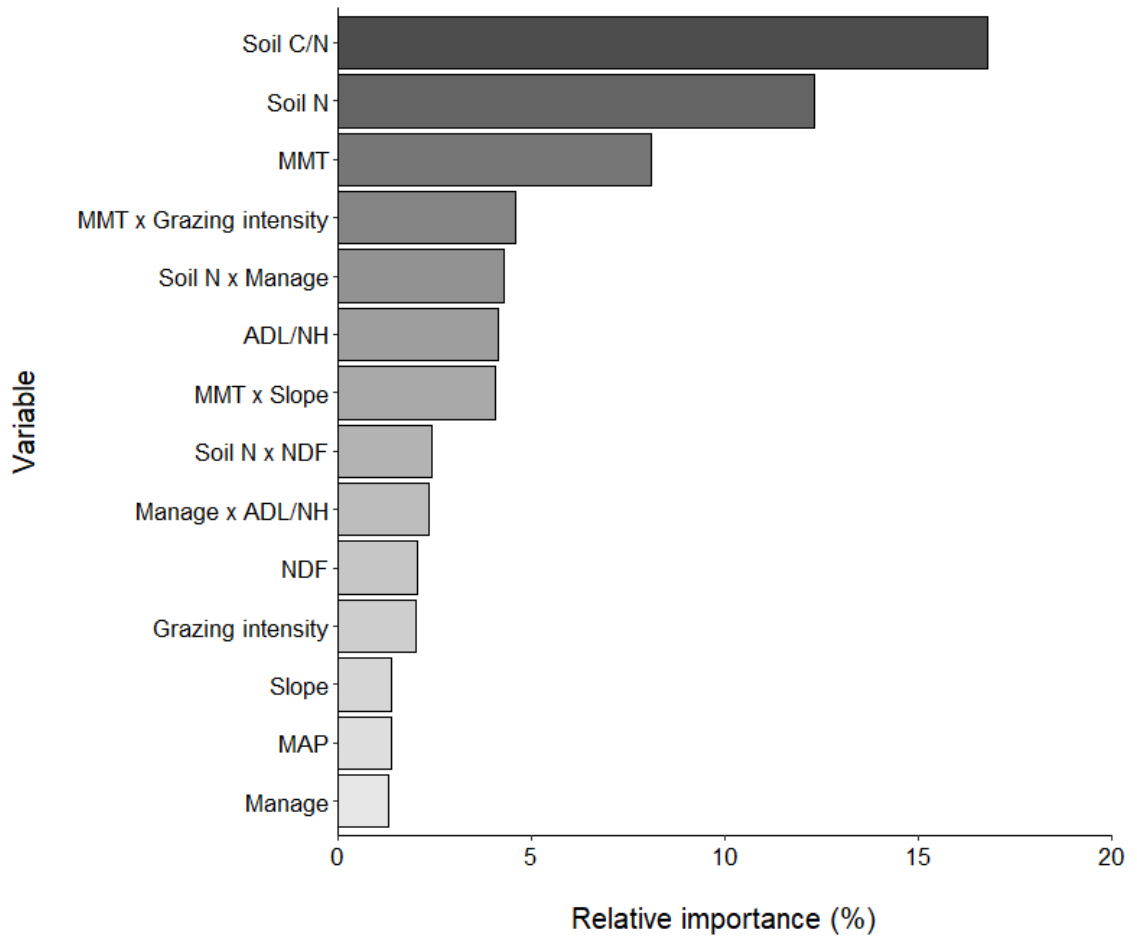


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55 Figure S5: Relative contributions of variable groups in the linear model explaining Soil Organic

56 Carbon, using regional, landscape and management predictors.

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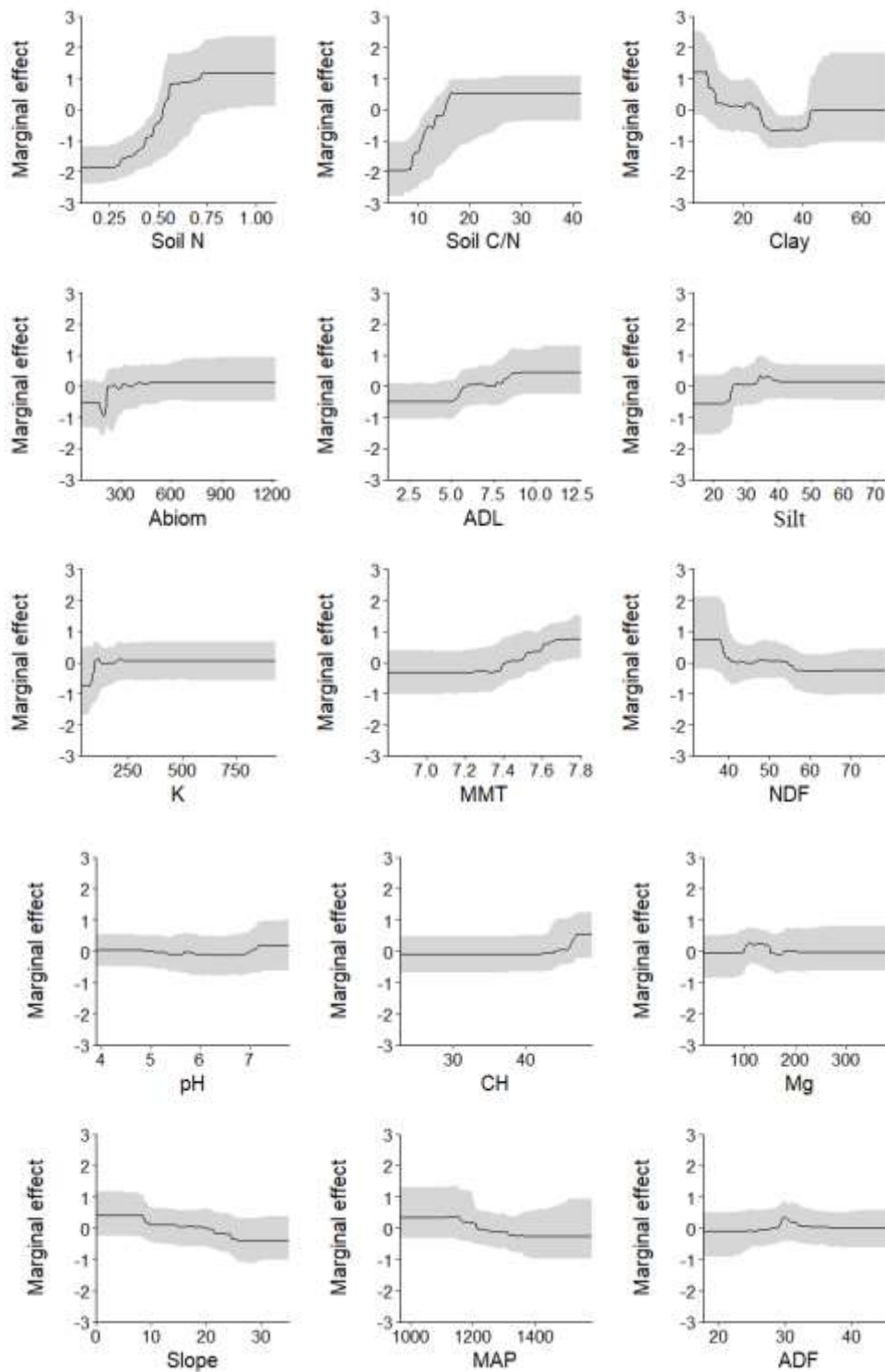


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59 Figure S6: Relative contributions of variable groups in the linear model explaining Soil Organic

60 Carbon using regional, landscape, management and biochemical predictors.

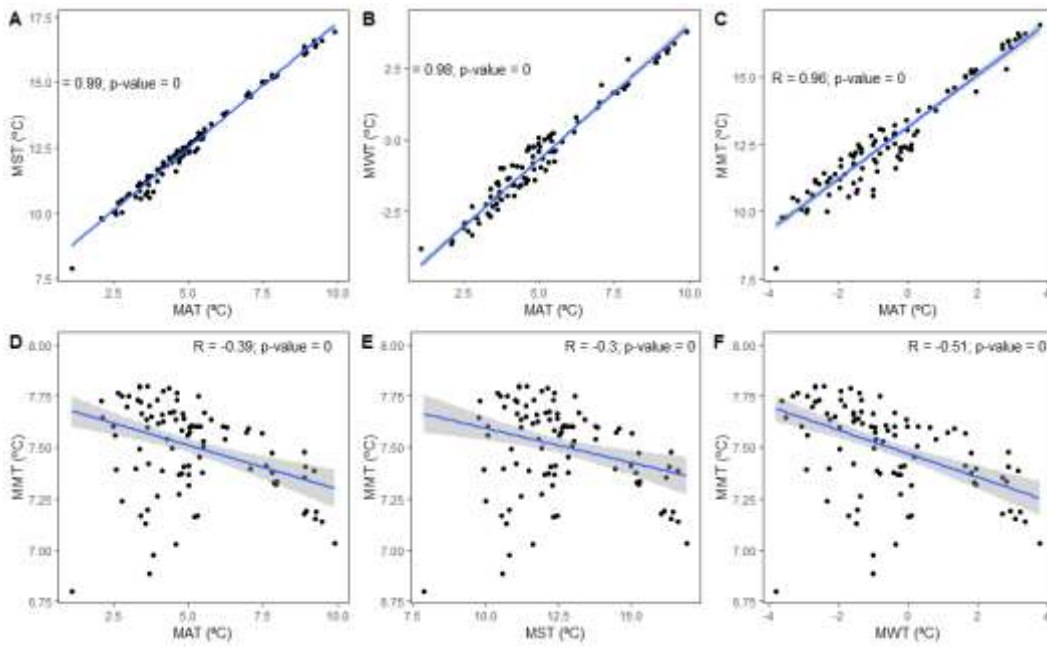
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63 Figure S7: Partial dependence plots for the 15 selected predictors in the BRT model. Y axes are
 64 centred to have zero mean over data distribution. Values (solid lines) are predictions of the
 65 model across the predictor's range maintaining the rest of the predictors at their average
 66 values. Grey areas around prediction lines indicate 95% bootstrap confidence intervals.

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69 Figure S8: Pairwise Pearson's correlations between climate variables. MST: mean summer
 70 temperature; MWT: mean winter temperature; MAT: mean annual temperature; MMT: inter-
 71 annual seasonality measured as MST-MAT.

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