Supplementary information for

Land use and mineral type determine stability of newly formed mineral-associated organic matter

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Supplementary methods

Supplementary methods 1: soil sampling and baseline characterisation of study sites

Mineral soil samples in each site were taken in May 2011 and 2017. In the forest, 14 core samples of the upper 10 cm of the mineral soil were also taken along two 40 m transects with a split tube auger (diameter of 5 cm). In grasslands, we also took 14 core samples at 10 cm depth along 20 m transects. One composite sample was prepared for each plot in forests and grasslands. These samples were air-dried and sieved to <2 mm after the removal of visible roots. Soil textural, using the air-dried samples, was performed using the pipette method (DIN ISO 11277, 2002) on samples collected in 2011 (see Herold et al., 2014[1] for more details). Potential soil OM mineralisation was also determined on fresh samples taken during the 2011 sampling campaign. To do so, samples (70 g for each plot) were filled in 250-ml glass beakers and placed in 1-l glass jars with airtight lids and two stopcocks. The samples were adjusted to 60% water holding capacity and then pre-incubated for 4 days. After pre-incubation, the CO_2 concentration in the jar headspace was determined and it was purged with CO_2 free air. The relative humidity in the CO_2 free air was adapted to an ambient level by adding 5 ml of deionized water to the bottom of the glass jars. Soil samples were then incubated for 14 days at a constant temperature of 20 °C. The CO_2 release from soil was measured after 14 days on 0.6-1 ml aliquots headspace air by a LI-6262 CO_2/H_2O infrared gas analyzer (LI-COR-Environmental, Lincoln, Nebraska USA). Soil OM mineralisability was calculated by normalizing the cumulative CO_2 released over the 14-day incubation to the concentration of OC in the soil sample. The pH of the mineral soil sample taken during the 2017 sampling campaign measured on 1:2.5 soil: 0.01 M $CaCl_2$ slurries using a calibrated pH meter (pH meter 538, WTW, Weilheim, Germany) after shaking for 1 h. The results of the soil textural anlysis, soil pH measurement, and potential soil OM mineralisation assessment are presented in Table S5.

Supplementary methods 2: characterisation of pristine minerals

Reactions

For pH determination, 10 g of pristine mineral was suspended in 25 ml of 0.01 M $CaCl_2$. The suspension was agitated for 1 hour on a horizontal shaker and centrifuged for 10 minutes at 2500 *g*, and the pH of the supernatant was then measured potentiometrically[2]. The concentration of acid oxalate extractable Al, Fe, Mn, and Si was determined according to Schwertmann (1964)[3] This entailed the extraction of 100 mg of material in 100 ml of 0.2 M NH_4 oxalate (pH 7) for 2 hours in the dark, followed by centrifugation at 2500 *g* for 20 minutes. The supernatants were passed through ash-free paper filters (Rotilabo 114A, Carl Roth GmbH, Karlsruhe, Germany), and Al, Fe, Mn, Si in the extracts were analysed by inductively coupled plasma−optical emission spectrometry (ICP−OES, Ultima 2, Horiba Jobin-Yvon, Longjumeau, France). The concentration of Al, Fe, and Mn in dithionite−citrate−bicarbonate extracts was also analysed by ICP-OES. For this extraction, 100 mg of material (for goethite 20 mg) was mixed with 40 ml 0.3 M Na citrate buffered to pH 8.3 with 10 ml 1 M $NaHCO_3$. One gram of $Na_2S_2O_4$ was then added to the suspension, before heating to 80 °C for 15 minutes. The suspension was centrifuged at 2500 *g* for 20 minutes and the supernatant was passed through an ash-free filter paper (Rotilabo 114A). The procedure was repeated with half the chemicals, and finally the residues (if any) were extracted with 25 ml of 0.05 M $MgCl_2$[4]. The specific surface area (SSA) of the minerals and quartz sand were calculated by applying the Brunnauer−Emmett−Teller (BET) to N_2 adsorption at 77 K at the relative pressure p/p_0 range of 0.05 to 0.35 (Autosorb IQ MP, Quantachrome Instruments, Boynton Beach, USA). Since N_2 gas cannot access the interlayer spaces of phyllosilicate clays, the BET method estimates the SSA of the external surfaces[5, 6]. The point of zero charge (isoelectric point) of goethite was estimated by determining the electrophoretic mobility of suspended minerals by dynamic light scattering at different pH (Zetasizer Nano ZS, Malvern Panalytical, Malvern, UK).

Element concentrations

Total carbon and nitrogen concentrations of 800 mg sample aliquots was determined by dry combustion elemental analyser (Vario Max Cube, Elementar Analysensysteme GmbH, Langenselbold, Germany). Samples were also tested for inorganic carbon by treating ground 200 mg sample aliquots with 50 ml 2 M HCl at 50 °C and subsequent detection of the released CO_2 (soliTIC modul interfaced to Vario Max Cube, Elementar Analysensysteme GmbH, Langenselbold, Germany). Since none of the samples had detectable contents of inorganic carbon, total carbon was considered to represent exclusively organic carbon (organic C). Total element concentrations were determined by sequential wave length-dispersive X-ray fluorescence spectroscopy (S8 Tiger Series 2, Bruker AXS, Karlsruhe, Germany) using fused beads prepared with 1 g sample aliquots ashed at 1000 °C; analyses were corrected for loss of ignition (including losses of organic C) during ashing.

Cation exchange capacity (CEC) and exchangeable cations

Total cation exchange capacity was determined according to Hendershot et al. (2008). All binding sites available to cations at pH 7 were saturated by equilibrating 500 mg aliquots in 20 ml of 1 M NH_4 acetate (pH 7) solution for 1 hour. Excess NH_4^+ was removed by rinsing with 20 ml of isopropanol. Ammonium ions bound to the mineral surfaces were then extracted by agitation for 1 hour with 20 ml 1 M KCl. Each of the aforementioned steps were repeated three times, with suspensions being centrifuged at 2500 *g* for 20 minutes, and supernatants passed through ash-free paper filters (Rotilabo 114A). The concentration of extracted NH_4^+ was determined photometrically with a continuous flow analyser (SANplus, Skalar Analytical B.V., Breda, The Netherlands). Exchangeable cations were extracted by suspending 1 g aliquots of mineral material in 100 ml 1 M NH_4Cl; shaking horizontally for 60 minutes; and centrifuging at 2500 *g* for 20 minutes. The supernatants were passed through ash-free paper filters (Rotilabo 114A), and Al, Fe, Mn, Ca,

Mg, K, Na in the extracts were analysed by inductively coupled plasma−optical emission spectrometry (ICP−OES, Ultima 2, Horiba Jobin-Yvon, Longjumeau, France). We calculated the Ca, Mg, K, Na saturation by dividing the sum of exchangeable Ca, Mg, K, Na by the total cation exchange capacity. Exchangeable ammonium was extracted by suspending 4 g aliquots of mineral material in 20 ml 1 M KCl; shaking horizontally for 60 minutes; and centrifuging at 2500 *g* for 20 minutes. The supernatants were then passed through ash-free paper filters (Rotilabo 114A), and NH_4^+ in the extracts was analysed photometrically with a continuous flow analyser (SANplus, Skalar Analytical B.V., Breda, The Netherlands).

DOC sorption capacity

Sorption of dissolved organic C (DOC) was tested with leachate solutions (membrane-filtered to <0.45 µm, SUPOR-450, Pall Corp., Port Washington, NY, USA) from different source material (i.e., spruce Oa DOC, beech litter DOC, and ryegrass DOC). Increasing amounts of mineral material were added to pH-adjusted 50 ml aliquots of leachate solutions, suspensions were horizontally shaken for 18 hours, centrifuged at 2500 *g* for 20 minutes, and then passed through 0.45-µm membrane filters (SUPOR-450). Solutions were analysed for DOC using a multi N/C 3100 analyser (Analytik Jena AG, Jena, Germany), and sorbed amounts were calculated by the difference in concentrations of initial and equilibrium solutions. The results of this sorption experiment are presented in Fig. S4. In a similar manner we determined the DOC sorption capacity to goethite and illite across a pH gradient by adding DOC (spruce Oa) solutions that were adjusted to different pH. These results are presented in Fig. S5.

X-ray diffraction (XRD)

Powder diffractograms were collected in Bragg-Brentano geometry on a Bruker D8 Advance instrument equipped with a LYNXEYE XE-T detector. Scans (q-q) were collected at 0.006°2θ step size and 0.9 s/step measuring time using Cu K_a radiation (tube settings: 40 kV and 20 mA for illite and goethite, and 40 kV and 40 mA for sea sand). Samples were rotated (30 rpm) during measurements to minimise preferential orientation effects. Prior to measurements, illite and sea sand samples were ground (10 min) to <5 mm particle size using a McCrone micronizing mill. Diffractograms were background-corrected, stripped of K_{a2}, and analysed by the Match! v. 3.12 software utilizing the crystallographic open database (COD). These results are presented in Fig. S6

Supplementary tables

Table S1: Concentration of carbon, nitrogen, and phosphorus and the C: N ratios and C: P ratios on the field-exposed minerals as affected by study region ('blocking factor'), land use, mineral type, and the interaction between land use and mineral type. Values are means with standard deviations. OC (organic C); TN (total nitrogen); TP (total phosphorus); NA (not applicable). Statistically significant effects ($P < 0.05$) are bold. Marginally significant effects ($0.05 > P < 0.1$) effects are in italics. Within each mineral type, different lowercase letters indicate significant differences ($P < 0.05$) between land use.

[§]A separate ANOVA was performed for each mineral. P values are quoted for goethite and illite, respectively.

Treatments		Parameter				
		g kg^{-1} dry sample				
Mineral	Land use	[#]OC	[#]TN	[#]TP	[#]C:N ratio	[#]C:P ratio
Goethite	Forest	2.51±1.2a	0.19±0.05b	0.13±0.03b	13.2±3.9a	19.4±8.5a[¥]
Goethite	Grassland mineral	2.31±0.6a	0.23±0.05a	0.17±0.07a	10.3±1.4b	14.4±3.5b
Goethite	Grassland organic	2.24±1.0a	0.22±0.07ab	0.14±0.03b	9.98±1.5b	15.9±6.0ab
Illite	Forest	0.74±0.3a	0.11±0.02b	0.12±0.01a	6.55±1.8a[¥]	6.20±2.2a
Illite	Grassland mineral	0.73±0.1a	0.13±0.02a	0.13±0.02a	5.79±0.7b	5.90±1.4a
Illite	Grassland organic	0.69±0.2a	0.11±0.02ab	0.13±0.01a	5.92±1.1b	5.52±1.9a
F-value						
Region		1.57	[§]1.032 & 0.487	9.92	[§]2.69 & 1.65	0.611
Land use (L)		1.63	[§]3.980 & 5.55	12.2	[§]11.3 & 3.60	2.35
Mineral (M)		368	NA	22.2	NA	288
L:M interaction		0.128	NA	2.68	NA	1.40
P-value						
Region		0.212	[§]0.362 & 0.617	**<0.001**	[§]*0.076* & 0.200	0.544
Land use (L)		0.200	**[§]0.024 & 0.006**	**<0.001**	**[§]<0.001 & 0.033**	*0.099*
Mineral (M)		**<0.001**	NA	**<0.001**	NA	**<0.001**
L:M interaction		0.880	NA	0.072	NA	0.251

[¥] Denotes a marginally significant effect ($0.05 > P < 0.1$)

[#]Variables were log transformed before running the ANOVA. Note, however, that the untransformed data are presented in the table.

Degrees of freedom for when minerals are analysed together—region: 2, land use (L): 2, Mineral (M): 1, L:M interaction: 2, Residuals: 128

Degrees of freedom for when minerals are analysed separately—region: 2, land use (L): 2, Residuals: 63

Means are quoted with standard devitations

It should be noted that unlike goethite, where the concentration of inorganic N was negligible, illite samples likely contained inorganic N in the form of NH_4^+ fixed in the mineral's interlayer. For this reason, we caution using the C:N ratio to indicate potential differences in the quality of OM that accumulated on the two minerals

Table S2: ANOVA F values, P values and effect sizes for the effects of region, land use, mineral type, and the interaction between land use and mineral type on various properties of the field-exposed mineral samples. Statistically significant effects ($P < 0.05$) are bold. Marginally ($0.05 > P < 0.1$) significant effects are in italics. MAOM-C (mineral-associated organic C); GP:GN ratio (gram-positive:gram-negative bacteria ratio); qCO_2 (PLFA-normalised CO_2 release; metabolic quotient).

	Factor											
	Region			Land use			Mineral			L:M interaction		
Parameter	F	*P*-value	Cohen's F	F	*P*-value	Cohen's F	F	*P*-value	Cohen's F	F	*P*-value	Cohen's F
MAOM-C accumulation	1.44	0.243	0.15	1.29	0.276	0.14	366	**<0.001**	1.69	0.317	0.718	0.07
Mineralisability	2.76	*0.067*	0.21	40.5	**<0.001**	0.80	117	**<0.001**	0.96	3.66	**0.028**	0.24
Extractability	43.9	**<0.001**	0.83	29.3	**<0.001**	0.68	40.5	**<0.001**	0.56	4.58	**0.012**	0.27
PLFA:MAOC	4.35	**0.015**	0.26	10.5	**<0.001**	0.41	87.1	**<0.001**	0.83	0.967	0.383	0.12
Fungi:bacteria	12.8	**<0.001**	0.45	9.53	**<0.001**	0.39	0.185	0.668	0.04	2.91	*0.058*	0.21
GP:GN bacteria	8.94	**<0.001**	0.37	26.9	**<0.001**	0.65	0.428	0.514	0.06	1.02	0.365	0.13
qCO2	1.41	0.249	0.15	50.7	**<0.001**	0.89	1.54	0.217	0.11	0.485	0.617	0.09
Vector length	0.038	0.963	0.02	70.9	**<0.001**	1.05	0.047	0.828	0.02	5.43	**0.005**	0.29
Vector angle	6.68	**0.002**	0.32	15.4	**<0.001**	0.49	58.6	**<0.001**	0.68	10.7	**<0.001**	0.41

Degrees of freedom—region: 2, land use (L): 2, Mineral (M): 1, L:M interaction : 2, Residuals: 128

Interpretation of Cohen's F (partial) effect sizes:

0.10 = Small effect size, 0.25 = Medium effect size, and 0.40 = Large effect size[7] .

[#]Variables were log-transformed before running the ANOVA.

Table S3: Extracellular enzyme activity on the field-exposed mineral samples as affected by study region, land use, mineral type, and the interaction between land use and mineral type. Statistically significant effects ($P < 0.05$) are bold. Values are means with standard deviations. Marginally significant effects ($0.05 > P < 0.1$) effects are in italics. Within each mineral type, different lowercase letters indicate significant differences ($P < 0.05$) between land use. BG (β-glucosidase); XYL (β-xylosidase); NAG (N-acetyl-β-glucosaminidase); AP (acid phosphatase).

Treatments		Parameter			
		nmol g^{-1} dry sample h^{-1}			
Mineral	Land use	#BG	XYL	#NAG	AP
Goethite	Forest	41.8±31b	19.4±17b	76.9±73a	629±268a
Goethite	Grassland mineral	84.5±60a	40.1±18a	71.6±57a	481±195b
Goethite	Grassland organic	87.7±42a	48.9±23a	72.0±32a	508±194b
Illite	Forest	10.3±5.5ab	1.52±1.3a	24.6±26a	75.5±38a
Illite	Grassland mineral	13.4±4.0a	3.37±2.2a	11.1±5.1b	39.7±25.2a
Illite	Grassland organic	11.0±17b	1.52±1.7a	6.24±2.4b	7.92±10.6a
F-value					
Region		1.31	2.88	2.71	0.106
Land use (L)		12.8	13.4	7.21	5.08
Mineral (M)		244	176	172	302
L:M interaction		7.66	13.0	6.53	1.65
P-value					
Region		0.273	*0.060*	*0.071*	0.899
Land use (L)		**<0.001**	**<0.001**	**0.001**	**0.008**
Mineral (M)		**<0.001**	**<0.001**	**<0.001**	**<0.001**
L:M interaction		**<0.001**	**<0.001**	**0.002**	0.197

Degrees of freedom—region: 2, land use (L): 2, Mineral (M): 1, L:M interaction : 2, Residuals: 128

#Variables were log transformed before running the ANOVA. Note, however, that the untransformed data are presented in the table.

Means are quoted with standard devitations

Table S4: Microbial biomass (PLFA) standardised extracellular enzyme activity on the field-exposed mineral samples as affected by study region, land use, mineral type, and the interaction between land use and mineral type. Values are means with standard deviations. Statistically significant effects ($P < 0.05$) are bold. Marginally significant effects ($0.05 > P < 0.1$) effects are in italics. Within each mineral type, different lowercase letters indicate significant differences ($P < 0.05$) between land use. BG (β-glucosidase); XYL (β-xylosidase); NAG (N-acetyl-β-glucosaminidase); AP (acid phosphatase); PLFA (phospholipid fatty acids)

Treatments		Parameter			
		h^{-1}			
Mineral	Land use	#BG:PLFA	#XYL:PLFA	#NAG:PLFA	AP:PLFA
Goethite	Forest	9.78±4.6c	4.70±3.2c	18.9±15b	431±171ab
Goethite	Grassland mineral	23.4±18b	11.4±8.5b	23.2±34ab	311±174b
Goethite	Grassland organic	64.4±59a	33.7±29a	50.6±47a¥	651±299a
Illite	Forest	4.43±2.2a	0.65±0.6a	10.0±9.2a	23.2±13.0a
Illite	Grassland mineral	5.82±2.3a	1.64±1.7a	4.64±2.3b	12.8±8.22a
Illite	Grassland organic	8.97±14a	1.25±1.3a	5.16±1.8ab	4.65±6.17a
F-value					
Region		4.04	3.19	5.85	2.04
Land use (L)		20.8	19.2	2.51	3.52
Mineral (M)		128	49.0	88.3	140
L:M interaction		9.76	20.1	7.83	5.46
P-value					
Region		**0.020**	**0.045**	**0.004**	0.135
Land use (L)		**<0.001**	**<0.001**	*0.085*	**0.033**
Mineral (M)		**<0.001**	**<0.001**	**<0.001**	**<0.001**
L:M interaction		**<0.001**	**<0.001**	**<0.001**	**0.005**

Degrees of freedom—region: 2, land use (L): 2, Mineral (M): 1, L:M interaction : 2, Residuals: 128

¥ Denotes a marginally significant effect ($0.05 > P < 0.1$)

#Variables were log transformed before running the ANOVA. Note, however, that the untransformed data are presented in the table.

Means are quoted with standard devitations

Table S5: Overview of climatic and pedo-geological properties of the three study regions (mean values across the plots with standard deviation). Abbreviations: MAT (mean annual air temperature in the years 2016–2020), MAP (mean annual precipitation in the years 2016–2020) grass.min (grasslands on mineral soils); grass.org (Schorfheide-Chorin grassland plots on organic soil); WRB (World Reference Base for Soil Resources)

	Study region		
Parameter	Schwäbische Alb	Hainich-Dün	Schorfheide-Chorin
Elevation (m a.s.l.)	460-860	258-500	3-140
MAT (°C)	8.2±0.7	9.2±0.7	9.7±0.6
MAP (mm)	902±49	485±48	581±29
Parent material	Jurassic shell limestone	Loess over triassic limestone	Glacial till covered by glacio-fluvial /aeolian sand
Typical soils (WRB)	Leptosols, Cambisols	Cambisols, Stagnosols Luvisols	Histo- and Luvisols in grasslands Cambisols in forest
#Clay (%)	48.7±10 (forest) 54.2±11 (grass.min)	31.8±12 (forest) 47.4±9.2 (grass.min)	5.28±10(forest) 12.2±6.1 (grass.min) 17.0±5.0 (grass.org
#Sand (%)	3.77±2.2 (forest) 6.63±5.5 (grass.min)	6.70±2.3 (forest) 5.34±1.4 (grass.min)	85.1±18(forest) 57.4±21.5 (grass.min 31.4±16 (grass.org)
Soil OC (g kg^{-1})	57.1±13(forest) 75.0±17 (grass.min)	37.6±17(forest) 40.9±12 (grass.min)	21.5±11(forest) 27.6±5.7 (grass.min) 152±103 (grass.org)
Soil C: N ratio (-)	13.5±1.4(forest) 10.5±1.2 (grass.min)	13.6±2.2(forest) 9.73±0.4 (grass.min)	18.5±2.8(forest) 10.5±0.5 (grass.min) 10.4±1.0 (grass.org)
#Soil pH	5.44±1.0(forest) 6.42±0.6 (grass.min)	5.1±0.8(forest) 6.87±0.5 (grass.min)	3.69±0.7(forest) 6.04±1 (grass.min) 7.19±0.7 (grass.org)
#Mineralisation (µg CO_2-C g^{-1})	72.9±24 (forest) 120±42 (grass.min)	51.4±23(forest) 112±38 (grass.min)	23.0 ± 2.1(forest) 46.7±18.6(grass.min) 150±57.3(grass.org)

[#]Mineralisability (mg CO_2-C g SOC^{-1})	1.12±0.2 (forest) 1.60±0.4 (grass.min)	1.31±0.4(forest) 2.62±0.9(grasss.min)	1.11±0.1(forest) 2.45±0.8 (grass.min) 1.0±0.2 (grass.org)

[#] See supplementary method 1 for details on the measurement of these properties

Means are quoted with standard deviations.

Table S6: Identification numbers and locations (latitude, longitude in decimal degrees) of plots from the *Biodiversity Exploratories* used in the current study

Study region	Land use	PlotID	Latitude	Longitude
ALB	Grassland	AEG1	48.39800501	9.34198675
ALB	Grassland	AEG2	48.37685727	9.47278412
ALB	Grassland	AEG3	48.40888148	9.53237875
ALB	Grassland	AEG4	48.38088845	9.41888912
ALB	Grassland	AEG5	48.39587586	9.43920071
ALB	Grassland	AEG6	48.40126215	9.44167811
ALB	Grassland	AEG7	48.39142098	9.37684713
ALB	Grassland	AEG8	48.42264028	9.49212459
ALB	Grassland	AEG9	48.39467093	9.50279238
ALB	Forest	AEW1	48.47807317	9.33441016
ALB	Forest	AEW2	48.37999048	9.35145064
ALB	Forest	AEW3	48.41226250	9.35559078
ALB	Forest	AEW4	48.39909865	9.24482734
ALB	Forest	AEW5	48.41961847	9.41468180
ALB	Forest	AEW6	48.39405132	9.44593671
ALB	Forest	AEW8	48.38258955	9.38238449
ALB	Forest	AEW9	48.36934576	9.41521762
ALB	Forest	AEW50	48.39211717	9.25444834
HAI	Grassland	HEG1	50.97164834	10.4053629
HAI	Grassland	HEG2	51.00074892	10.4300100
HAI	Grassland	HEG3	50.99809149	10.4329489
HAI	Grassland	HEG4	51.11336235	10.4361804
HAI	Grassland	HEG6	51.21493506	10.3912209
HAI	Grassland	HEG7	51.27358256	10.4104126
HAI	Grassland	HEG8	51.27125747	10.4179446
HAI	Grassland	HEG9	51.22389737	10.3807873
HAI	Grassland	HEG47	51.28420033	10.3719165
HAI	Forest	HEW1	51.18535508	10.3236211
HAI	Forest	HEW3	51.27164770	10.3107385
HAI	Forest	HEW4	51.36948156	10.5333275
HAI	Forest	HEW5	51.26387813	10.2409579
HAI	Forest	HEW6	51.26771983	10.2393783
HAI	Forest	HEW7	51.13109242	10.3854489
HAI	Forest	HEW8	51.35579218	10.5169674
HAI	Forest	HEW9	51.13024193	10.3811497
HAI	Forest	HEW10	51.08998735	10.4624339
HAI	Forest	HEW11	51.10283444	10.4008543
HAI	Forest	HEW12	51.10068810	10.4551830
HAI	Forest	HEW13	51.24264396	10.3129467
SCH	Grassland	SEG1	53.08742012	13.9696436
SCH	Grassland	SEG2	53.08930690	13.9800470

SCH	Grassland	SEG3	53.10283431	13.9856996
SCH	Grassland	SEG4	53.11375419	14.0018711
SCH	Grassland	SEG5	53.10745266	14.0005237
SCH	Grassland	SEG6	53.10349527	13.6228333
SCH	Grassland	SEG7	53.08838274	13.9770687
SCH	Grassland	SEG8	53.11397068	14.0170996
SCH	Grassland	SEG9	53.09818193	13.6125669
SCH	Grassland	SEG 18	53.13730516	13.8756098
SCH	Grassland	SEG 30	53.14814127	13.8306805
SCH	Grassland	SEG 31	53.14908648	13.8354379
SCH	Grassland	SEG 33	52.98578547	13.8425130
SCH	Grassland	SEG 37	53.13492781	13.8760305
SCH	Grassland	SEG 39	52.98092391	13.8232870
SCH	Grassland	SEG 42	52.87067320	13.9688289
SCH	Grassland	SEG 46	52.97843781	13.8263321
SCH	Grassland	SEG 48	53.09720511	13.6066414
SCH	Forest	SEW1	52.90084729	13.8463669
SCH	Forest	SEW2	52.95172886	13.7780281
SCH	Forest	SEW3	52.92070744	13.6430016
SCH	Forest	SEW4	52.91734663	13.8473114
SCH	Forest	SEW5	53.05703356	13.8853662
SCH	Forest	SEW6	52.90744279	13.8416880
SCH	Forest	SEW7	53.10734802	13.6944189
SCH	Forest	SEW8	53.19179716	13.9303379
SCH	Forest	SEW9	53.04453521	13.8103280
SCH	Forest	SEW10	53.09109594	13.6378431
SCH	Forest	SEW35	52.91126795	13.8534188

Schwäbische Alb (ALB), Hainich-Dün (HAI), Schorfheide-Chorin (SCH)

More information on these plots can be obtained from the Biodiversity Exploratories Information System, BExIS

(https://www.bexis.uni-jena.de/)

Table S7: Selected properties of pristine minerals goethite, illite, and sea sand: a) Reaction (pH in $CaCl_2$ solution); oxalate- and dithionite–citrate–bicarbonate (DCB)-extractable Al, Fe, and Mn (Al_o, Fe_o, Mn_o and Al_d, Fe_d, Mn_d, respectively), no oxalate-soluble Si and Mn detectable; specific surface area (SSA); point of zero charge (PZC); b) Element concentration (C:N analyser; X-ray fluorescence spectrometry), since no inorganic carbon was detectable, C represents organic C; c) Cation exchange capacity (CEC) and exchangeable cations; n.d. = not detectable; n.a.= not analysed.

a)

Sample	pH ($CaCl_2$)	Al_o g kg^{-1}	Fe_o g kg^{-1}	Al_d g kg^{-1}	Fe_d g kg^{-1}	Mn_d g kg^{-1}	SSA (N_2-BET) m^2 g^{-1}	PZC
Goethite	7.3	0.17	1.82	1.36	614.52	0.28	20.4	7.8
Illite	7.0	0.26	0.12	n.d.	0.25	n.d.	40.7	n.a.
Sea sand	6.7	n.d.	n.d.	n.d.	n.d.	n.d.	1.1	n.a.

b)

Sample	C g kg^{-1}	N g kg^{-1}	C:N	Fe g kg^{-1}	Mn g kg^{-1}	Al g kg^{-1}	Si g kg^{-1}	K g kg^{-1}	Mg g kg^{-1}	Ca g kg^{-1}	P g kg^{-1}
Goethite	0.40	0.19	2.1	613.49	0.46	2.15	0.24	1.00	0.28	0.36	0.12
Illite	0.42	0.38	1.1	4.07	0.07	149.33	265.58	70.24	7.50	2.31	0.21
Sea sand	0.10	0.04	2.5	n.d.	0.02	5.02	460.59	1.24	0.56	0.29	0.03

c)

Sample	CEC (pH 7) $mmol_c\ kg^{-1}$	Al^{3+} $mmol_c\ kg^{-1}$	Fe^{3+} $mmol_c\ kg^{-1}$	Ca^{2+} $mmol_c\ kg^{-1}$	Mg^{2+} $mmol_c\ kg^{-1}$	K^{+} $mmol_c\ kg^{-1}$	Na^{+} $mmol_c\ kg^{-1}$	NH_4^{+} $mmol_c\ kg^{-1}$	Ca, Mg, K, Na saturation of CEC (pH 7) %
Goethite	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Illite	165.5	<0.01	3.7	110.4	33.2	14.5	2.6	0.03	>97
Sea sand	4.8	n.d.	n.d.	3.5	0.4	0.5	0.4	n.d.	100

Supplementary figures

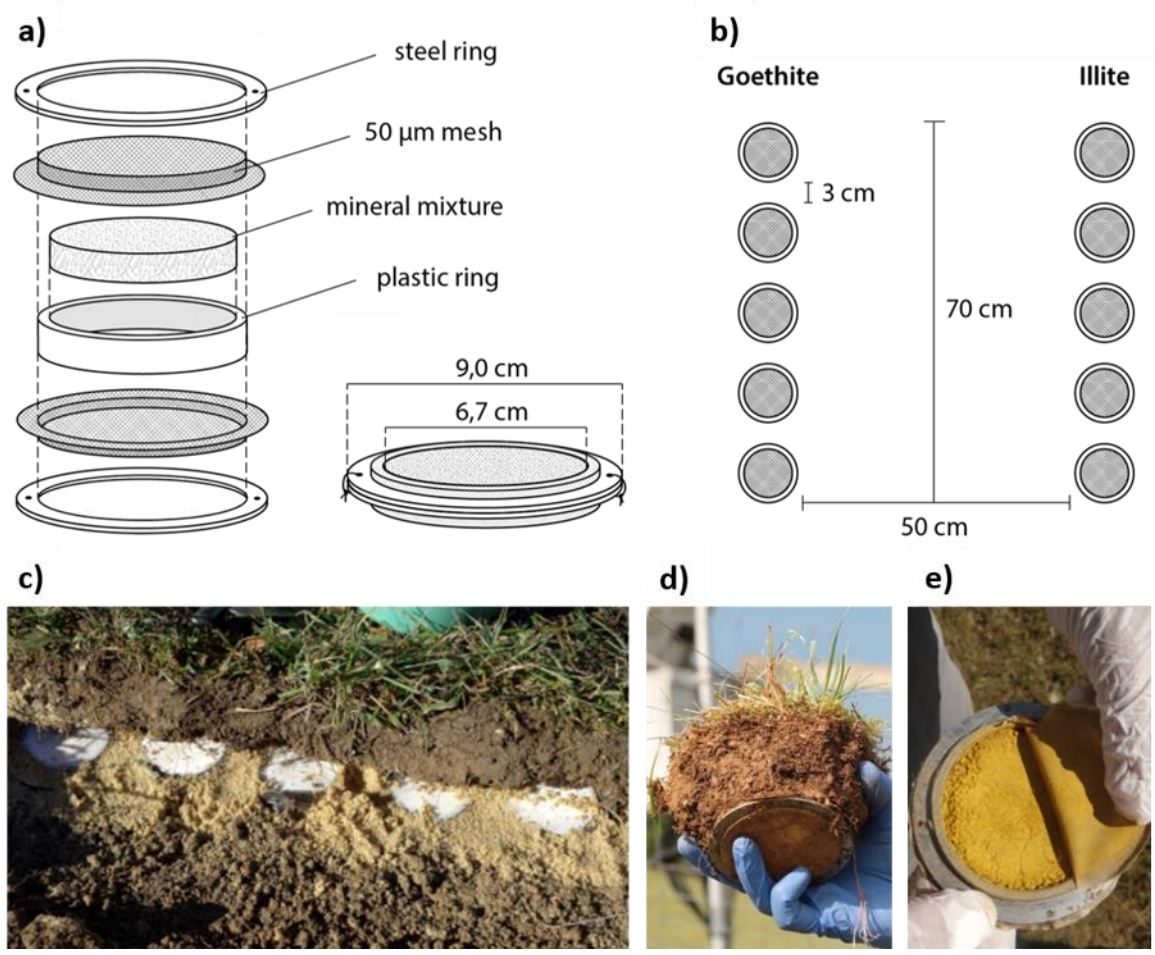

Fig. S1: (a) Setup and dimensions of a mineral container; (b) schematic top view of the mineral container placement in 5 cm soil depth; (c) photo of a row of minerals container on a sand bed during installation in 2015; (d) photo of sampling a mineral container and the surrounding soil; (e) photo of an opened mineral container (reprinted from Brandt et al., 2023[8] with the permission from Elsevier).

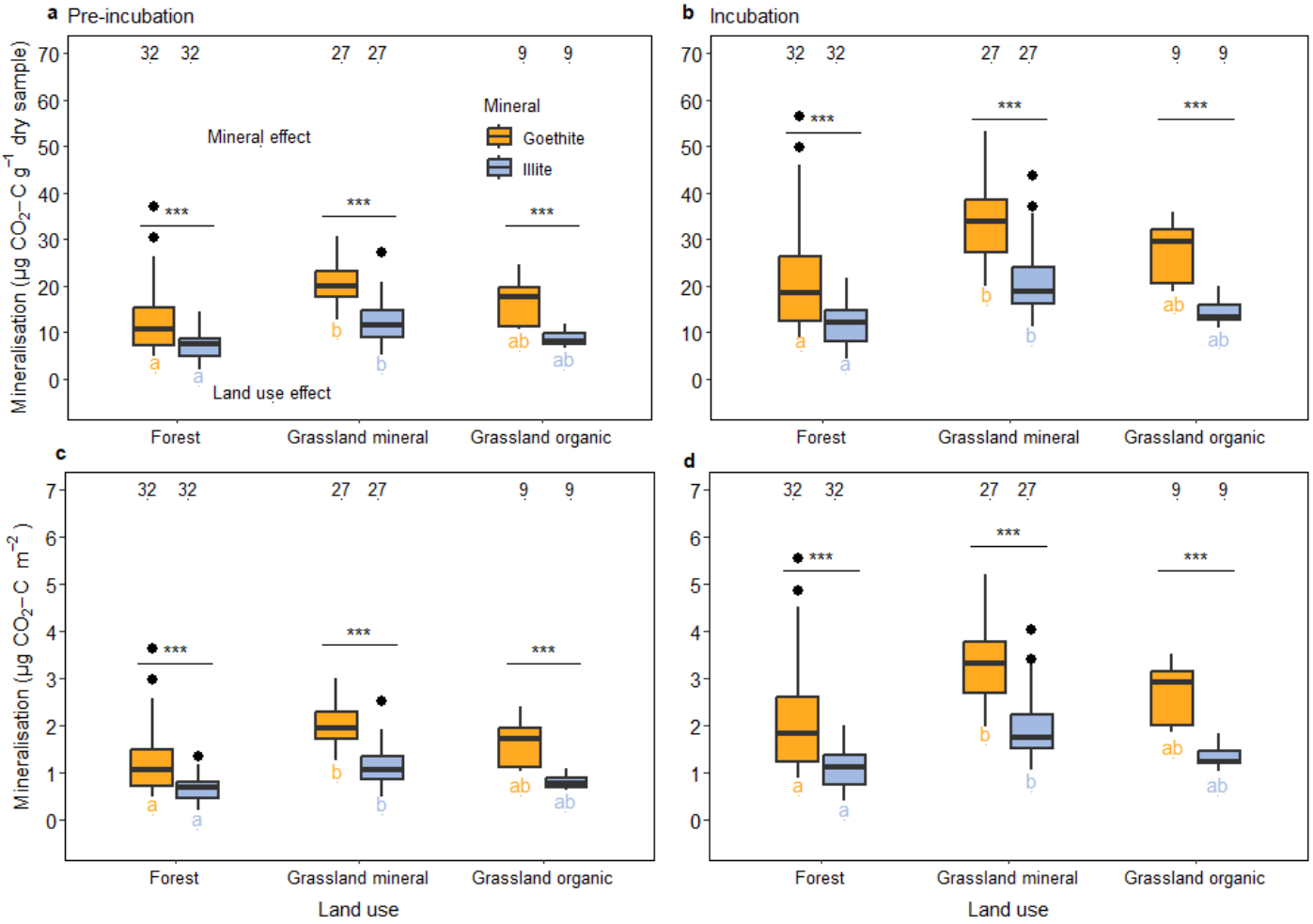

Fig. S2: Mineralisation of organic matter that accumulated on two different pristine minerals (goethite and illite) buried for five years at 5 cm depth in the topsoil of forests and grasslands in three regions across Germany. Values in Fig.s c and d are normalised to the specific surface area of the minerals. The number of replicates of independent samples is given at the top of each box plot. The horizontal line within the box plot represents the median. The ends of the boxes represent the first and third quartiles, and the whiskers show the interquartile range (IQR) from the first and third quartiles. Black dots outside the whisker (i.e., 1.5 × IQR) of the plot represent outliers. Statistical significance for the individual and interactive effect of land use and mineral type was tested using analysis of variance (ANOVA). Study region was considered as a 'blocking' factor in the ANOVA. ANOVA results : plot a) Region (df = 2), F = 2.00; Land use (df = 2), F = 22.7; Mineral (df = 1), F = 54.7; Land use:mineral interaction (df = 2), F = 0.894; residual df = 128; plot b) Region (df = 2), F = 2.18; Land use (df = 2), F = 24.5; Mineral (df = 1), F = 62.5; Land use:mineral interaction (df = 2), F = 0.427; residual df = 128; plot c) Region (df = 2), F = 1.95; Land use (df = 2), F = 22.4; Mineral (df = 1), F = 66.9; Land use:mineral interaction (df = 2), F = 1.13; residual df = 128; plot d) Region (df = 2), F = 2.17; Land use (df = 2), F = 23.9; Mineral (df = 1), F = 75.8; Land use:mineral interaction (df = 2), F = 0.625; residual df = 128. Statistical significance between means was determined using Tukey's honest significant difference test. *** denotes a significant ($P \leq 0.001$) difference between the two minerals with a given land use treatment. Within the same mineral type, different lowercase letters indicate a significant ($P < 0.05$) difference between land use treatments. Grassland mineral (grasslands on mineral soils); Grassland organic (grasslands on organic soils).

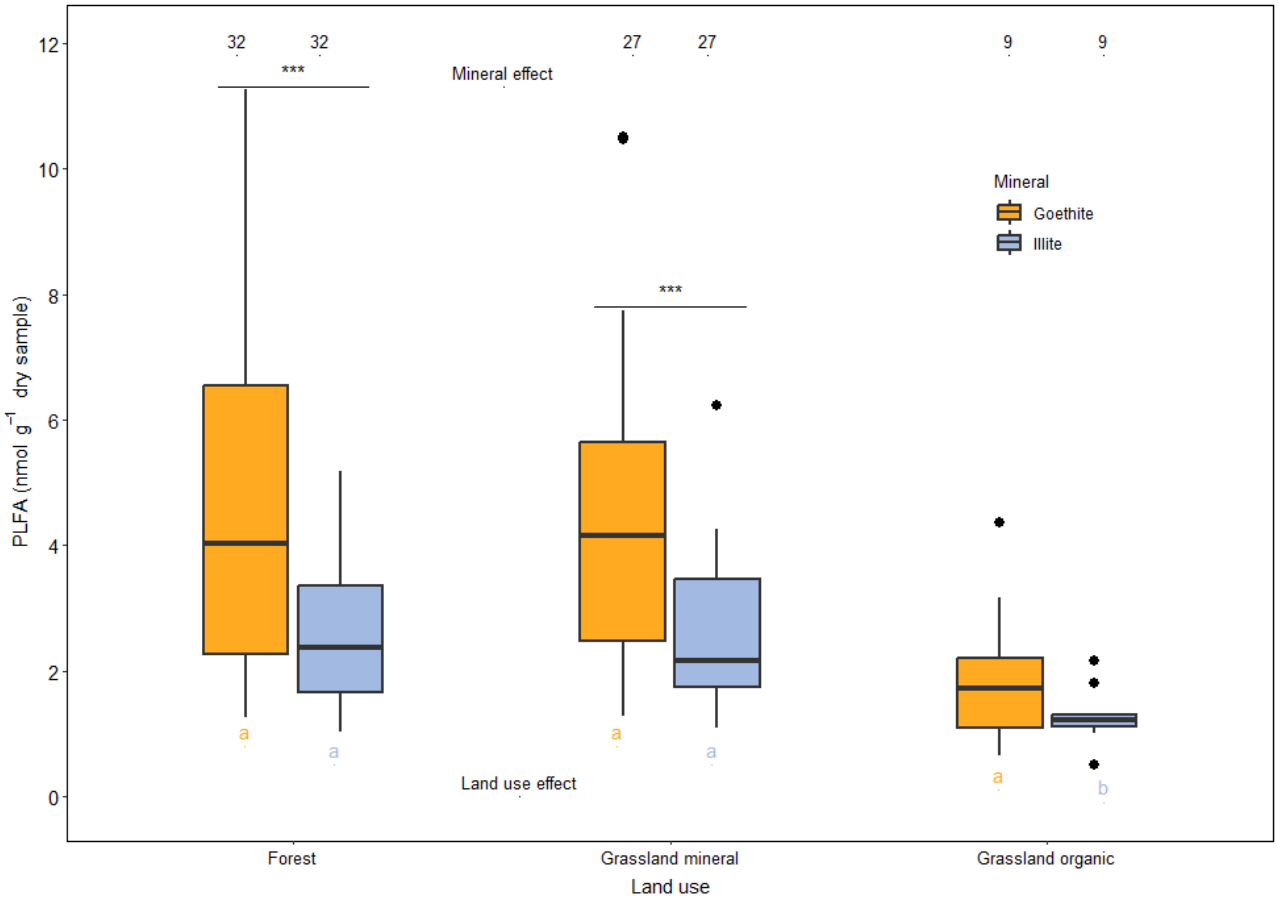

Fig. S3: Concentration of phospholipid fatty acids (PLFAs) on two different pristine minerals (goethite and illite) buried for five years at 5 cm depth in the topsoil of forests and grasslands in three regions across Germany. The horizontal line within the box plot represents the median. The ends of the boxes represent the first and third quartiles, and the whiskers show the interquartile range (IQR) from the first and third quartiles. Black dots outside the whisker (i.e., 1.5 × IQR) of the plot represent outliers. Statistical significance for the individual and interactive effect of land use and mineral type was tested using analysis of variance (ANOVA). Study region was considered as a 'blocking' factor in the ANOVA. ANOVA results : Region (df = 2), F = 1.08; Land use (df = 2), F = 15.9; Mineral (df = 1), F = 24.0; Land use:mineral interaction (df = 2), F = 0.169; residual df = 128 Statistical significance between means was determined using Tukey's honest significant difference test. *** denotes a significant ($P \leq 0.001$) difference between the two minerals with a given land use treatment. Within the same mineral type, different lowercase letters indicate a significant ($P < 0.05$) difference between land use treatments. Grassland mineral (grasslands on mineral soils); Grassland organic (grasslands on organic soils).

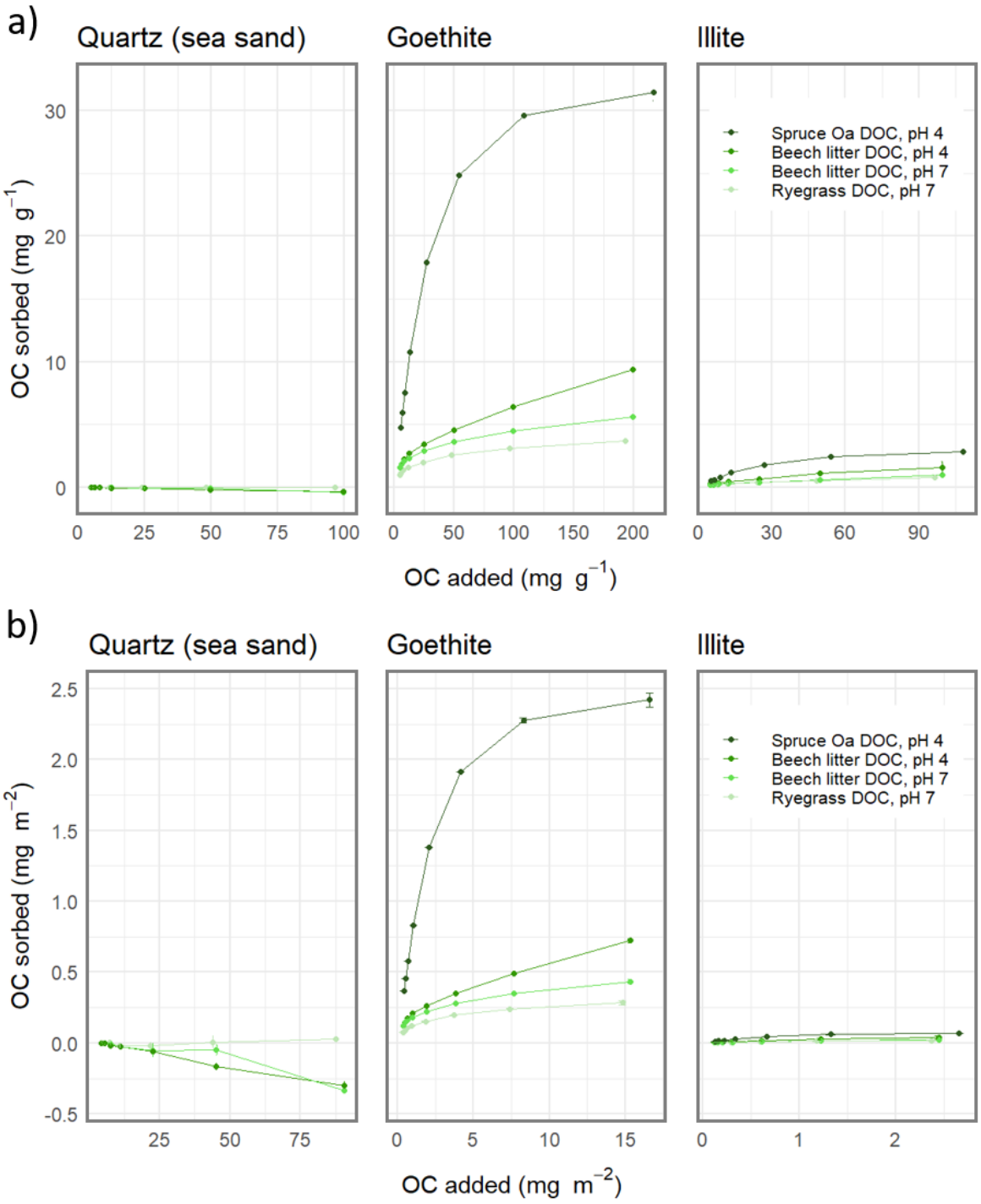

Fig. S4: Sorption of DOC from different sources to sea sand, goethite, and illite at different pH normalised to a) the weight, b) the specific surface area (SSA) of the respective mineral. Since the SSA of the sea sand is very small, values fluctuating around zero when normalised to the weight appear improbably large when normalised to the SSA.

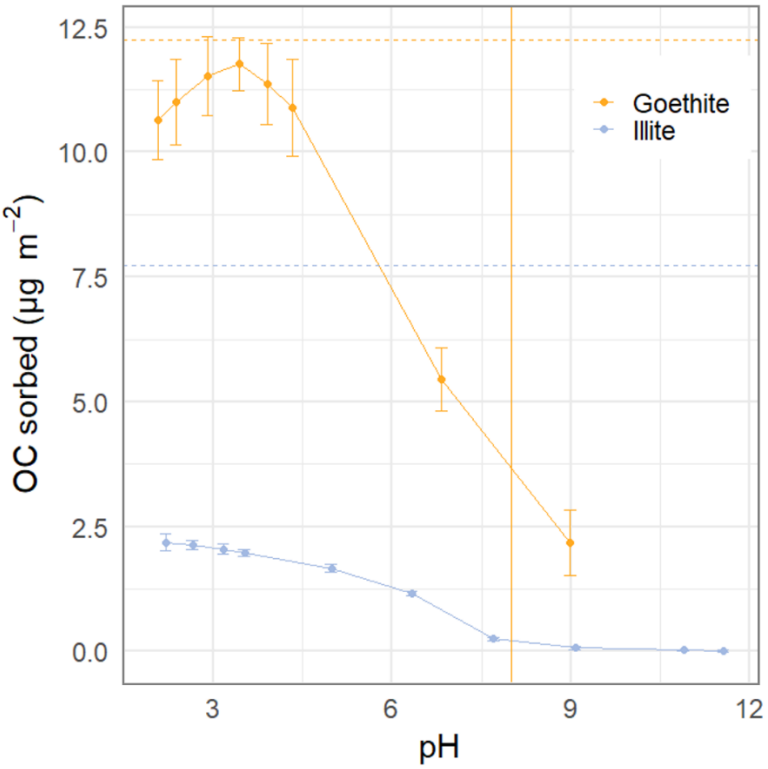

Fig. S5: Sorption of DOC from the Oa horizon of a spruce forest to goethite and illite at differing pH. The orange vertical line depicts the point of zero charge (PZC) of goethite.

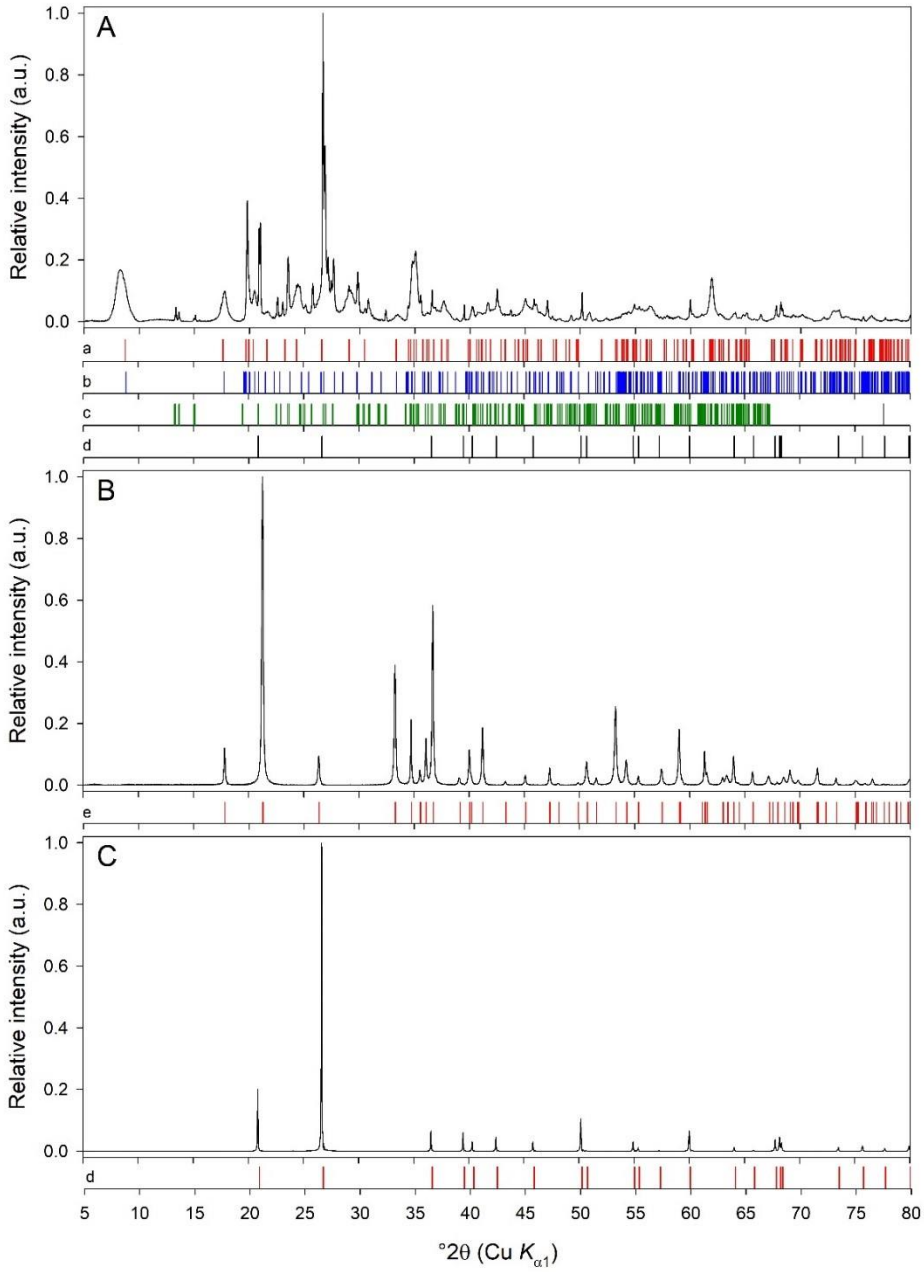

Fig. S6: Normalised and background-corrected powder X-ray diffractograms of (A) illite, (B) goethite, and (C) sea sand. Reference patterns are (a) illite (COD entry: 96-901-3720), (b) phengite (COD entry: 96-900-5488), (c) microcline (COD entry: 96-900-0702), (d) low-quartz (α-SiO2) (COD entry: 96-101-1098), and (e) goethite (COD entry: 96-221-1653). Goethite is phase pure and the sea sand is phase-pure α-quartz. The illite sample contains micaceous minerals (illite and phengite – a series between muscovite and caledonite; dioctahedral micas), K-feldspar (microcline), and α-quartz.

Supplementary references

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