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Supplement of

Carbon soil stock change in an intensive crop field near Paris reveals significant carbon losses over a decade

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Supplementary Material and Method

1 Spatial comparison between 2005 and 2019 sampling campaigns

To enable a reliable comparison between the 2005 and 2019 data and infer changes in SOC stocks, we minimised the effect of spatial heterogeneity in the 2019 sampling by subsetting the strata. To address this, we first employed a K-means-based clustering algorithm (MacQueen, 1967) to identify pedologically homogeneous zones. We used the 2019 dataset, which offered well-distributed coverage across the study area, with each sampling point characterised by its physical (clay and rock fragment contents, fine earth mass) and chemical properties (carbonates and SOC content). In addition, we extracted information from the soil descriptions of each 2019 SP-I (Table S2), including the maximum soil depth described, corresponding to the cumulative thickness of the described horizons (H1, H2, etc.) down to the upper boundary of the parent material (Figure S1) and clay content (%). These variables were aggregated to a depth of 60 cm using weighted mean (e.g., for carbonates) or summation (e.g., for soil mass) and then interpolated using Inverse Distance Weighting (IDW) of power 2 (Shepard, 1968), selected as the most suitable method for interpolation given the limited number of samples (n < 30). The resulting raster maps (Figure S3) were stacked in a single raster and resampled to a common resolution. Subsequently, K-means-based clustering algorithms were applied (with K = 4) using the stats::kmeans (R core team, 2005) to delineate zones with comparable pedological characteristics. The number of clusters (K) was defined using the elbow within-cluster sum of squares (Thorndike, 1953). This analysis resulted in the identification of four distinct clusters, hereafter, soil zones (Figure S4).

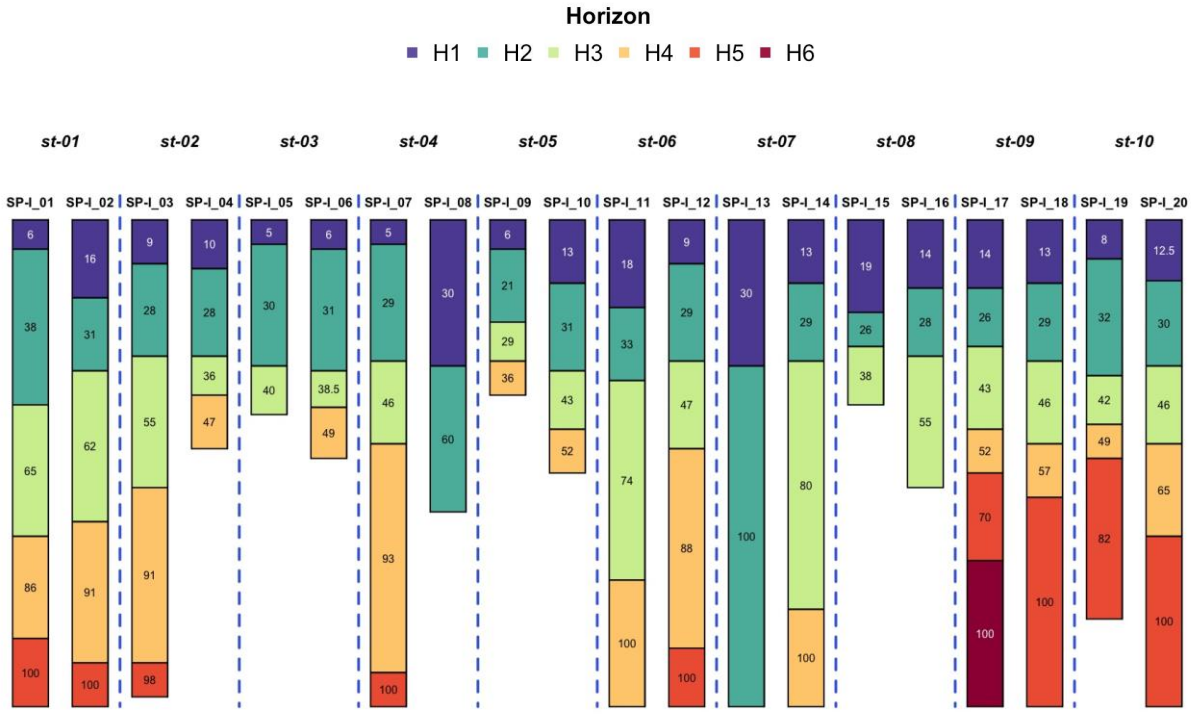

Figure S1. Maximum soil depth recorded for each SP-I plot during the pedological description in the 2019 sampling campaign within their respective stratum (st), grouped by stratum. The lower boundary of each horizon was inferred from soil core observations, including colour, texture, carbonate reaction, and coarse fragment content. Values shown within each horizon indicate the lower boundary depth (cm). The maximum description depth was 100 cm.

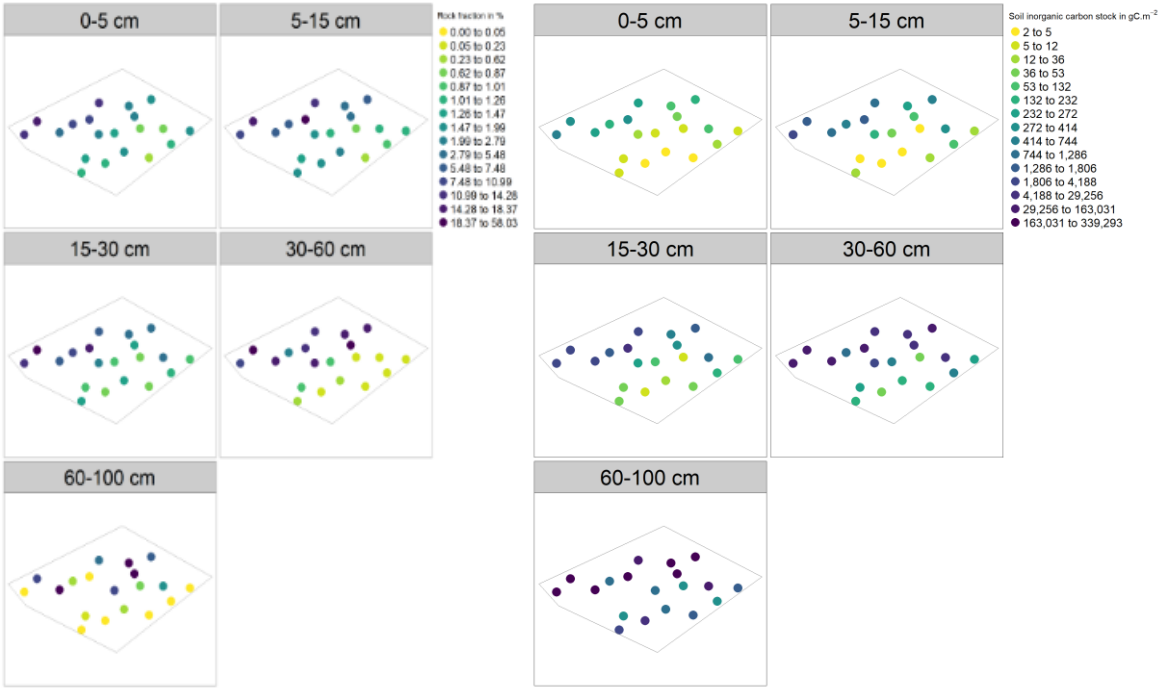

Figure S2. Rock fraction (left) and carbonates (right) spatial variability was measured in 2019 at the 20 spatial sampling points at several layers. In the 60-100 cm layer the SP-15 is missing as it was too stony to sample.

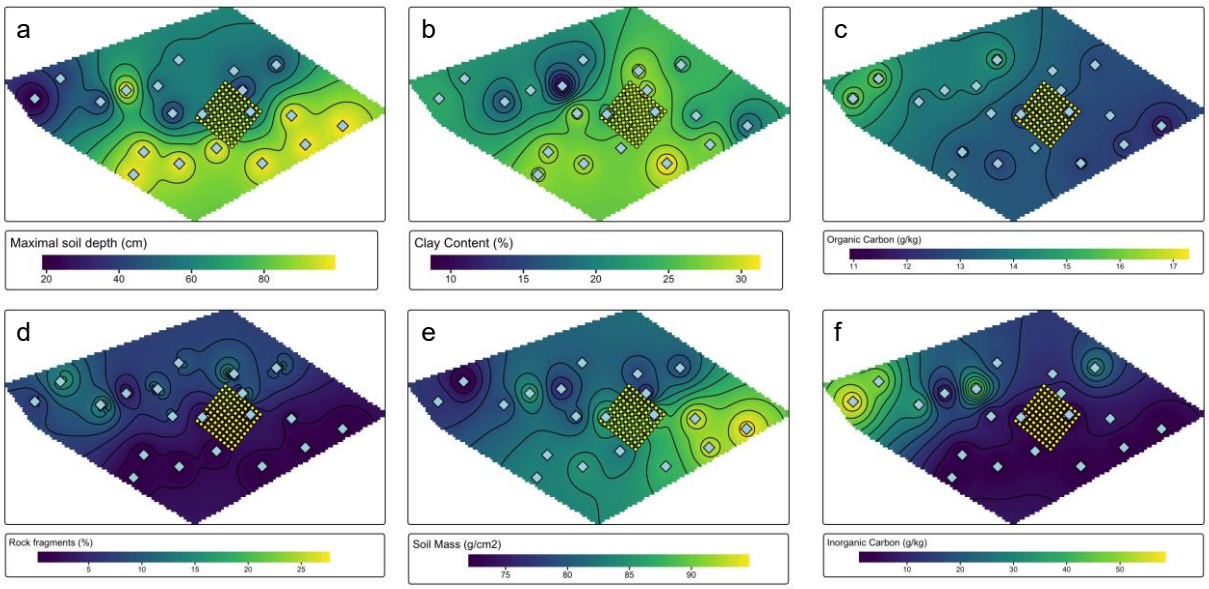

Figure S3. Interpolated 2019 soil properties used to construct the soil group map. Yellow circles indicate the 2005 sampling points, while blue diamonds represent the 2019 sampling locations. Maximum depth (cm) and clay content (%) were derived from the soil description report for the FR-Gri site according to WRB (2022). Clay content was measured in the diagnostic horizon and harmonized to the standard depth intervals (0–5, 5–15, 15–30, 30–60, and 60–100 cm) using cubic spline interpolation. All other variables were measured in the same five standardized layers.

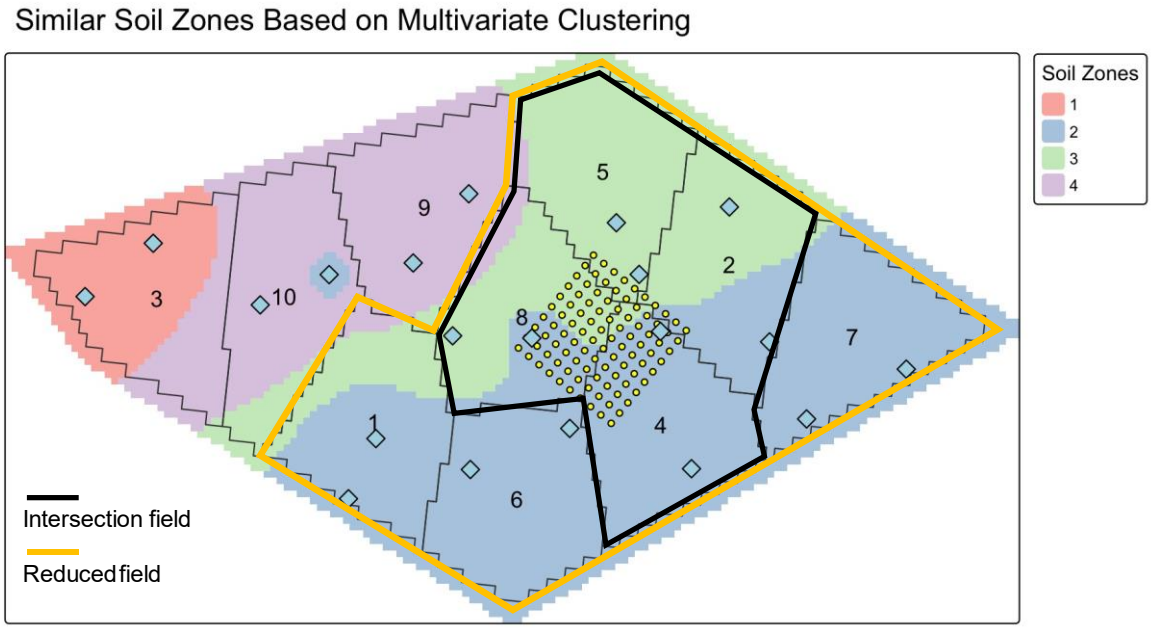

Figure S4. Map showing similar soil zones derived from multivariate clustering analysis. The study area is classified into four distinct soil zones (labelled 1–4), each representing regions with homogeneous soil properties based on statistical clustering of multiple variables (clay content, rock fragments, carbonates, organic carbon, fine earth mass, effective soil depth). The 2005 (yellow circles) and 2019 (blue diamonds) sampling points are superimposed together with the strata (numbered polygons) defined in the 2019 sampling. Yellow polygon represents the "Reduced field" and black polygon the "Intersection field".

Zone 2 is characterised by deep soils (> 100 cm) with low contents of rock fragments and inorganic carbon. Zones 1 and 4 are composed of shallow soils (20–50 cm) with high concentrations of rock fragments and carbonates, and with less than 20% clay content. Zone 3 presents intermediate soil properties: soils are moderately shallow (40–60 cm) with medium levels of rock fragments and carbonates. The 2005 sampling points are located within Zones 2 and 3. Based on the soil property map, the 2019 data was subset in three different ways: (1) Complete field = Including all the strata and corresponding SP-I plots. (2) Intersection field = Including the four strata of the 2019 campaign (Strata 8, 4, 2, and 5) that intersected the 2005 sampling area. (3) Reduced field = Including the strata within the same soil zones within the 2005 sampling area, that is, the strata 1, 2, 4, 5, 6, 7, and 8. The Intersection and Reduced fields were chosen to ensure similar pedological properties in both campaigns. The SP-I_19 plot intersected Zone 2, while SP-20 did not fall within any of the target zones. Since both samples are part of Stratum 10, they were excluded from the analysis. All these analyses were performed using a set of R packages. For vector and raster manipulation, we used sf (Pebesma, 2018; Pebesma and Bivand, 2023), raster (Hijmans, 2010), and stars (Pebesma and Bivand, 2023). For inverse distance weighting (IDW) interpolation, we used gstat (Gräler et al., 2016; Pebesma, 2004). Plotting was carried out using tmap (Tennekes, 2018), and multivariate clustering was performed using stats (R Core Team, 2025). Effect-size analysis comparing soil variables in 2019 across the original sampling layers revealed no significant differences between the Intersection field and Reduced field, as indicated by Hedges' g values close to zero and confidence intervals spanning zero (Figure S**2**). In contrast, the Complete field and Reduced field exhibited significant differences in several soil variables, such as SOC and SIC

content, SOC and SIC stocks, rock fraction percentage, total nitrogen content and stocks, and fine earth mass, with different differences pronounced up to 30 cm. Notably, SIC content and stocks differ consistently across all layers. Given these discrepancies in soil properties, the following sections focus on comparisons between the 2005 and 2019 campaigns within the Reduced field to explore the SOC changes due to its consistent soil properties.

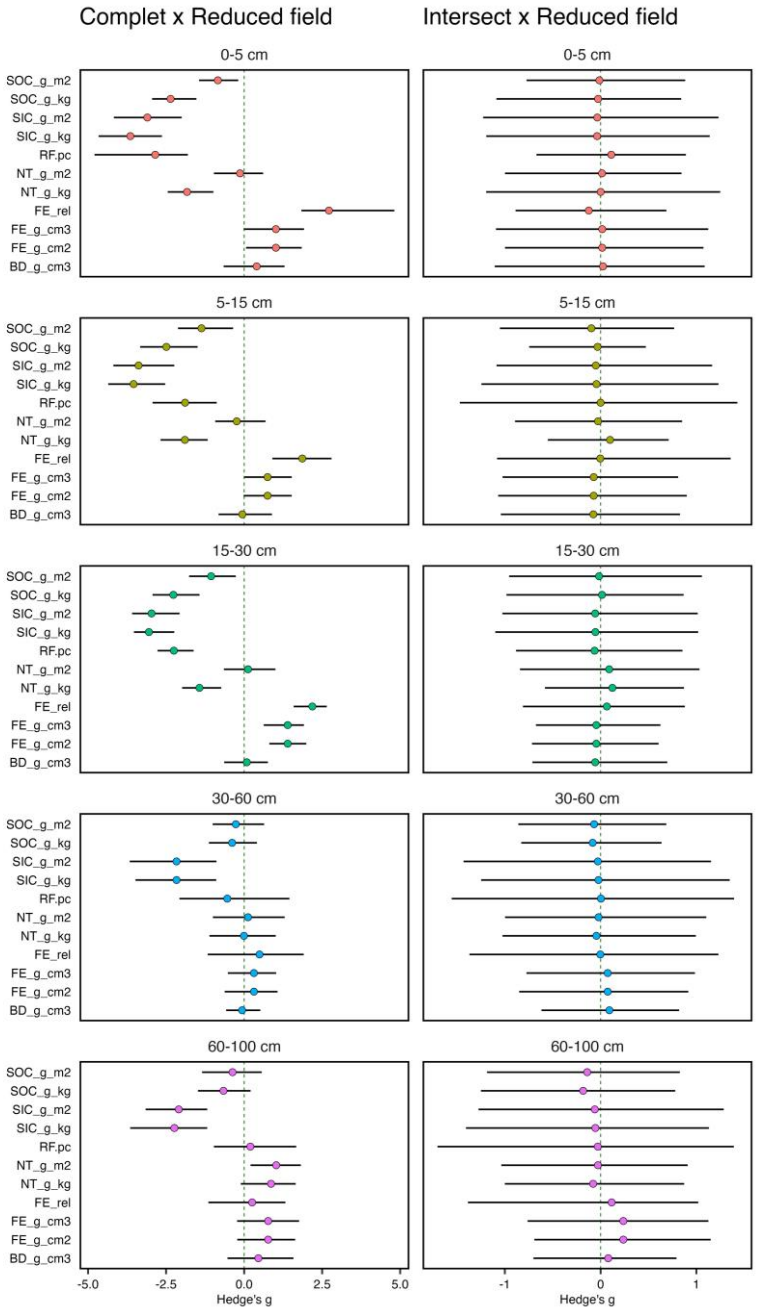

Figure S5. Magnitude of differences in soil variables between different subsets of the 2019 dataset, measured using Hedges' g effect size method (Hedges, 1981). Circles represent Hedges' g values, and error bars denote bias-corrected and accelerated (BCa) 95% confidence intervals based on 20,000 bootstrap resamples. The complete field includes 10 strata, the reduced field comprises 7 strata, and the intersection field comprises 5 strata. Variable codes are followed by their respective units: BD_g_cm3 – soil bulk density (g cm^{-3}); FE_g_cm2 – fine earth mass per area (g cm^{-2}); FE_g_cm3 – fine earth density (g cm^{-3}); FE_rel – proportion of fine earth mass (dimensionless, ratio); RF.pc – rock fragment content (%); SOC_g_kg – soil organic carbon concentration (g kg^{-1}); SIC_g_kg – soil inorganic carbon concentration (g kg^{-1}); NT_g_kg – total nitrogen concentration (g kg^{-1}); SOC_g_m2 – soil organic carbon stock (g m^{-2}); SIC_g_m2 – soil inorganic carbon stock (g m^{-2}); NT_g_m2 – total nitrogen stock (g m^{-2}).

2 Statistics of soil properties in the reduced and complete fields.

The field included a small section on the northeast side of the field with shallow (~40 cm depth) and calcareous soils, visible in **Figure S4.** The shallow soil zone (e.g., strata 3, 9, and 10 in **Figure S4**) shows high rock fractions (RF), ranging between 10% and 15%. In contrast, the deep soil zones (e.g., strata 1, 4, 6, 7 in **Figure S4**) have much lower RF, ranging from 0.6% to 2%. The distribution of RF and inorganic C per layer across the 2019 area can be found in **Figure S2-S3**. The area sampled in 2005 (**Figure S6**) showed a rock fraction smaller than a few per cent, as also reported by Schrumpf et al. (2011). The proportion of the fine earth (FE_{prop}) in the soil ranged from 0.92 to 0.99 after harmonising the data into three common depth intervals (**Table S4, Figure S7**). In the *Reduced field*, changes in the proportion of the fine earth between 2005 and 2019 were small and statistically non-significant (differences < 1%), which was not the case in the *Complete field*, which showed a significant difference of around 3% (**Table S5**). This confirms that the choice of the *Reduced field* sampling zone in 2019 allows comparison with the 2005 sampling.

3 Effect-size using BCa bootstrap

Hedges' g was computed as:

$$g = d\frac{\Gamma\left(\frac{df}{2}\right)}{\sqrt{\frac{df}{2}}\Gamma\left(\frac{df-1}{2}\right)}$$

$$d = \frac{\overline{X_1} - \overline{X_2}}{s} \quad \text{(s1)}$$

$$s = \sqrt{\frac{\sum(X_1 - X_1)^2 + \sum(X_2 - X_2)^2}{n_1 + n_2 - 2}}$$

Where d is the uncorrected effect size (Cohen's *d*), df represents the pooled degrees of freedom, Γ is the gamma function, s is the pooled standard deviation, X represents the individual observations in each group denoted by subscripts 1 and 2, $\bar{X}$ the sample mean in each group; n is the sample size in each group.

Confidence intervals for effect-size estimates were computed using 20000 nonparametric bootstraps with resampling and bias-corrected and accelerated (BCa) method (Canty et al., 2024; Efron, 1987; Kirby and Gerlanc, 2013). Negative values of Hedges' g indicate a reduction in SOC stocks from 2005 to 2019, while positive values indicate an increase. If the confidence intervals (CIs) include zero, it suggests that there is no significant difference in SOC stocks between the two sampling years. These analyses were performed using the R package "*bootES*" (Kirby and Gerlanc, 2013).

The bias-corrected and accelerated (BCa) bootstrap confidence interval is computed as follow:

$$\mathrm{CI}_{\mathrm{BCa}} = \left[\widehat{\theta^{(\alpha_1)}}, \widehat{\theta^{(\alpha_2)}}\right] \quad \text{(s2)}$$

where the adjusted quantiles α_1 and α_2 are calculated as:

$$\alpha_1 = \Phi\left(z_0 + \frac{z_0 + z_{\alpha/2}}{1 - \hat{a}(z_0 + z_{\alpha/2})}\right) \quad \text{(s3)}$$

$$\alpha_2 = \Phi\left(z_0 + \frac{z_0 + z_{1-\alpha/2}}{1 - a\left(z_0 + z_{1-\alpha/2}\right)}\right) \quad \text{(s4)}$$

Here, Φ is the of standard normal cumulative distribution, and $z_{\alpha/2}$ and $z_{1-\alpha/2}$ are the corresponding quantiles of the standard normal distribution.

The bias correction factor is computed as the inverse of standard normal cumulative distribution:

$$\boldsymbol{z_0 = \Phi^{-1}\left(\frac{\#\{\widehat{\theta_b^*} < \widehat{\theta}\}}{B}\right)} \quad \text{(s5)}$$

Where $\widehat{\boldsymbol{\theta}}$ is the observed statistic (e.g., mean, median, effect size), $\boldsymbol{\theta_b^*}$ are the bootstrap replications, $\#\{\widehat{\boldsymbol{\theta_b^*}} < \widehat{\boldsymbol{\theta}}\}$ counts the number of bootstrap replication smaller than $\widehat{\boldsymbol{\theta}}$, and $\boldsymbol{B}$ is is the number of bootstrap samples.

Supplementary tables

Table S1. Soil properties by horizon from two soil profiles at the FR-Gri site in 2006. UD and LD are the upper and lower depths of the soil horizon (cm). SOC is soil organic carbon content (%), NT is total nitrogen content (%), $CaCO_3$ is calcium carbonate content (%), Total C is total carbon content (%), C/N is the carbon-to-nitrogen ratio (unitless), pH (H_2O) is the pH measured in water (unitless), BD is bulk density (kg m^{-3}), SOC (kg m^{-3}) is soil organic carbon concentration by volume, NT (kg m^{-3}) is total nitrogen concentration by volume, SOC stock is soil organic carbon stock (kg m^{-2}), and NT stock is total nitrogen stock (kg m^{-2}).

Mean of soil properties

UD	LD	SOC	NT	$CaCO_3$	Total C	C/N	pH (H_2O)	BD	SOC	NT	SOC Stock	NT Stock
cm		%				-	-	kg m^{-3}	kg m^{-3}		kg m^{-2}	
0	15	1.84	0.176	2.95	2.189	10.6	7.95	1340	24.6	2.4	3.7	0.4
15	27	1.58	0.152	3.10	1.952	10.6	8.05	1440	22.8	2.2	6.3	0.6
27	35	1.56	0.147	4.15	2.053	10.7	8.05	1460	22.7	2.1	8.2	0.8
35	49	0.84	0.087	1.95	1.069	9.7	8.20	1470	12.3	1.3	9.6	0.9
49	70	0.62	0.066	10.15	1.838	9.5	8.35	1490	9.2	1.0	11.0	1.1
70	83	0.38	0.037	23.05	3.141	10.1	8.55	1500	5.6	0.6	11.8	1.2
83	120	0.28	0.024	23.10	3.052	11.7	8.60	1500	4.2	0.4	12.2	1.2
120	140	0.27	0.029	22.90	3.018	9.3	8.60	1500	4.1	0.4	12.6	1.2

Range (Max – Min) of soil properties

UD	LD	SOC	NT	$CaCO_3$	Total C	C/N	pH (H_2O)	BD	SOC	NT	SOC Stock	NT Stock
cm		%				-	-	kg m^{-3}	kg m^{-3}		kg m^{-2}	
0	15	0.25	0.04	2.85	0.59	0.71	0.35	13.40	3.5	0.5	0.5	0.1
15	27	0.19	0.03	3.00	0.55	1.06	0.15	14.40	3.0	0.5	0.9	0.1
27	35	0.30	0.03	3.75	0.75	0.46	0.15	14.60	4.5	0.5	1.3	0.1
35	49	0.09	0.01	1.15	0.05	1.76	0.00	14.70	1.4	0.1	1.4	0.1
49	70	0.25	0.03	9.15	1.35	0.02	0.05	14.90	3.8	0.4	2.0	0.2
70	83	0.08	0.00	22.05	2.72	2.03	0.15	15.00	1.2	0.0	2.2	0.2
83	120	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
120	140	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table S2. Horizon-based depth and soil properties from 20 SP-I plots at the FR-Gri site in 2019 during the ICOS soil sampling campaign. UD and LD are the upper and lower depths of the soil horizons (cm). Reported properties include clay content (%), carbonate presence (tested with 1 M HCl), and Munsell colour of moist soil (Hue, Value, Chroma). Notes: most soil profiles include parental material in their description. Maximum soil depths (A + B + C horizons; parent material not included) are shown in Figure S1 and represent the maximal value of LD per SP-I.

Point	UD	LD	Clay (%)	Carbonates	Hue	Value	Chroma
SP-I_01	0	6	28	0	10YR	3	2
SP-I_01	6	38	30	0.5	10YR	3	4
SP-I_01	38	65	30	0	10YR	3	4
SP-I_01	65	86	25	1	7.5YR	4	4
SP-I_01	86	100	26	1	7.5YR	4	4
SP-I_02	0	16	30	0	10YR	3	2
SP-I_02	16	31	30	0	10YR	3	3
SP-I_02	31	62	28	0.5	10YR	3	4
SP-I_02	62	91	30	1	10YR	3	6
SP-I_02	91	100	25	1	10YR	4	4
SP-I_03	0	9	22	1	10YR	3	3
SP-I_03	9	28	20	1.5	10YR	3	4
SP-I_03	28	55	22	2	10YR	4	4
SP-I_03	55	91	24	2	10YR	4	6
SP-I_03	91	98	14	2	10YR	4	6
SP-I_04	0	10	30	1.5	10YR	3	3
SP-I_04	10	28	30	1.5	10YR	3	2
SP-I_04	28	36	30	1.5	10YR	4	3
SP-I_04	36	47	30	2	10YR	4	4
SP-I_04	47	64	NaN	2	10YR	7	2
SP-I_04	64	73	NaN	2	2.5YR	8	2
SP-I_05	0	5	17	2	10YR	3	3
SP-I_05	5	30	23	2	10YR	3	3
SP-I_05	30	40	20	2	10YR	4	3
SP-I_06	0	6	29	2	10YR	3	2
SP-I_06	6	31	20	2	10YR	3	3
SP-I_06	31	38.5	25	2	10YR	3	3
SP-I_06	38.5	49	25	2	10YR	4	3
SP-I_06	49	58	27	2	10YR	8	2
SP-I_07	0	5	24	0	10YR	3	3
SP-I_07	5	29	28	0	10YR	3	3
SP-I_07	29	46	33	0	10YR	3	4
SP-I_07	46	93	33	0	10YR	4	4
SP-I_07	93	100	33	2	10YR	5	4
SP-I_08	0	30	23	0	10YR	3	3
SP-I_08	30	60	32	0	10YR	3	6
SP-I_09	0	6	30	0	10YR	3	3
SP-I_09	6	21	30	0.5	10YR	3	3
SP-I_09	21	29	30	1	10YR	3	4
SP-I_09	29	36	NaN	2	10YR	3	4

SP-I_10	0	13	30	0.5	10YR	3	3
SP-I_10	13	31	30	0.5	10YR	3	3
SP-I_10	31	43	28	0.5	10YR	3	4
SP-I_10	43	52	NaN	2	10YR	3	4
SP-I_11	0	18	19	0	10YR	3	3
SP-I_11	18	33	25	1	10YR	3	3
SP-I_11	33	74	30	1	10YR	3	4
SP-I_11	74	100	28	1	10YR	3	6
SP-I_12	0	9	35	0	10YR	3	4
SP-I_12	9	29	30	0	10YR	3	3
SP-I_12	29	47	35	0	10YR	3	6
SP-I_12	47	88	25	1	7.5YR	4	4
SP-I_12	88	100	25	2	10YR	5	4
SP-I_13	0	30	27	0.5	10YR	3	3
SP-I_13	30	100	15	2	10YR	4	4
SP-I_14	0	13	30	0.5	10YR	3	3
SP-I_14	13	29	28	0.5	10YR	3	3
SP-I_14	29	80	28	0	10YR	4	4
SP-I_14	80	100	25		10YR	3	4
SP-I_15	0	19	28	0.5	10YR	3	3
SP-I_15	19	26	30	0.5	10YR	3	3
SP-I_15	26	38	30	1	10YR	3	4
SP-I_16	0	14	16	0	10YR	3	3
SP-I_16	14	28	28	2	10YR	3	3
SP-I_16	28	55	25	0	10YR	3	4
SP-I_17	0	14	25	2.5	7.5YR	3	2
SP-I_17	14	26	20	3	10YR	3	2
SP-I_17	26	43	10	3	10YR	5	4
SP-I_17	43	52	10	3	10YR	5	4
SP-I_17	52	70	0	3	2.5YR	7	2
SP-I_17	70	100	0	3	2.5YR	7	2
SP-I_18	0	13	27	2.5	10YR	3	2
SP-I_18	13	29	30	2.5	10YR	3	3
SP-I_18	29	46	30	3	10YR	4	3
SP-I_18	46	57	25	3	10YR	3	4
SP-I_18	57	100	5	3	2.5YR	8	2
SP-I_19	0	8	25	2	10YR	3	3
SP-I_19	8	32	18	2	10YR	3	4
SP-I_19	32	42	16	2	10YR	4	4
SP-I_19	42	49	13	2	10YR	8	2
SP-I_19	49	82	13	2	10YR	8	1
SP-I_20	0	12.5	17	2	7.5YR	2.5	3
SP-I_20	12.5	30	28	2	7.5YR	2.5	3
SP-I_20	30	46	24	2	7.5YR	4	3
SP-I_20	46	65	22	1	10YR	4	6
SP-I_20	65	100	20	2	7.5YR	5	6

Table S3. Mean and standard error estimations from the 2005 campaign, the 2019 complete field, the 2019 reduced field, and the 2019 intersection field, reported according to their original layer intervals. Sample sizes (N) and number of strata (H) are: 2005 (N = 100, H = 50), 2019 complete field (N = 20, H = 10), 2019 reduced field (N = 14, H = 7), and 2019 intersection field (N = 10, H = 5). Means and standard errors were calculated using Equations (6) and (7). UD and LD are the upper and lower depths of the soil layer (cm). Variables include bulk density (BD), fine earth mass (FEM), fine earth density (FED), relative proportion of fine earth (FE_{rel}, 0–1), soil organic carbon concentration (SOC, g C kg^{-1}), and soil organic carbon stock (SOC stock, kg C m^{-2}).

UD	LD	BD	FEM	FED	FE_{rel}	SOC content	SOC stock
cm		g cm^{-3}	g cm^{-2}	g cm^{-3}	-	g C kg^{-1}	kg C m^{-2}
2005							
0	5	1.31 (0.02)	6.48 (0.10)	1.30 (0.02)	0.99 (0.00)	21.09 (0.23)	1.36 (0.03)
5	10	1.48 (0.01)	7.32 (0.07)	1.46 (0.01)	0.99 (0.01)	19.61 (0.18)	1.43 (0.02)
10	20	1.51 (0.01)	14.89 (0.10)	1.49 (0.01)	0.98 (0.00)	18.89 (0.19)	2.81 (0.04)
20	30	1.57 (0.01)	15.20 (0.13)	1.52 (0.01)	0.97 (0.01)	17.43 (0.25)	2.64 (0.04)
30	40	1.60 (0.01)	15.26 (0.22)	1.53 (0.02)	0.95 (0.01)	9.84 (0.39)	1.46 (0.05)
40	50	1.54 (0.01)	14.46 (0.26)	1.45 (0.03)	0.94 (0.02)	5.73 (0.29)	0.78 (0.03)
50	60	1.54 (0.01)	14.62 (0.22)	1.46 (0.02)	0.95 (0.01)	4.52 (0.21)	0.64 (0.02)
2019: Complete field							
0	5	1.00 (0.01)	4.76 (0.07)	0.95 (0.01)	0.95 (0.00)	25.75 (0.42)	1.21 (0.01)
5	15	1.36 (0.01)	12.96 (0.15)	1.30 (0.02)	0.95 (0.01)	21.76 (0.30)	2.80 (0.05)
15	30	1.52 (0.01)	21.61 (0.20)	1.44 (0.01)	0.95 (0.01)	17.06 (0.22)	3.65 (0.07)
30	60	1.59 (0.01)	43.79 (0.85)	1.46 (0.03)	0.92 (0.02)	6.82 (0.22)	2.95 (0.11)
60	100	1.59 (0.02)	59.89 (0.99)	1.50 (0.02)	0.94 (0.02)	3.38 (0.13)	2.02 (0.07)
2019: Reduced field							
0	5	1.02 (0.02)	5.01 (0.09)	1.00 (0.02)	0.98 (0.00)	23.28 (0.52)	1.16 (0.02)
5	15	1.36 (0.02)	13.28 (0.20)	1.33 (0.02)	0.98 (0.00)	20.04 (0.33)	2.66 (0.06)
15	30	1.52 (0.01)	22.33 (0.14)	1.49 (0.01)	0.98 (0.00)	15.49 (0.23)	3.46 (0.06)
30	60	1.58 (0.02)	44.66 (1.09)	1.49 (0.04)	0.94 (0.02)	6.56 (0.19)	2.89 (0.11)
60	100	1.60 (0.01)	61.21 (0.52)	1.53 (0.01)	0.96 (0.01)	3.21 (0.11)	1.97 (0.08)
2019: Intersection field							
0	5	1.01 (0.02)	4.94 (0.10)	0.99 (0.02)	0.98 (0.00)	23.56 (0.72)	1.16 (0.01)
5	15	1.37 (0.02)	13.41 (0.28)	1.34 (0.03)	0.98 (0.01)	20.04 (0.27)	2.69 (0.07)
15	30	1.53 (0.02)	22.41 (0.19)	1.49 (0.01)	0.98 (0.00)	15.55 (0.19)	3.48 (0.05)
30	60	1.57 (0.02)	43.22 (1.52)	1.44 (0.05)	0.92 (0.02)	6.78 (0.24)	2.90 (0.14)
60	100	1.60 (0.01)	59.88 (0.67)	1.50 (0.02)	0.94 (0.01)	3.26 (0.15)	1.97 (0.10)

Table S4. Summary statistics of soil variables measured during the 2005 and 2019 campaigns, reported by aggregated depth intervals (0–5 cm, 5–30 cm, 30–60 cm). The 60–100 cm layer from 2019 was excluded from analysis. Aggregated mean values were weighted by layer thickness. UD and LD are the upper and lower depths of the soil layer (cm). Variables include bulk density (BD), fine earth mass (FEM), fine earth density (FED), relative proportion of fine earth (FErel, 0–1), soil organic carbon concentration (SOC, g C kg^{-1}), and soil organic carbon stock (SOC stock, kg C m^{-2}). Means, standard errors (SE), and 95% confidence intervals (CI) were calculated using Equations (6)–(8). Sample sizes (N) and number of strata (H) per subset are: 2005 (N = 100, H = 50), 2019 complete field (N = 20, H = 10), 2019 reduced field (N = 14, H = 7), and 2019 intersection field (N = 10, H = 5).

UD	LD	Variable	Unit	Mean	SE	Lower CI	Upper CI
2005							
0	5	BD	g cm^{-3}	1.31	0.02	1.27	1.35
5	30	BD	g cm^{-3}	1.53	0.01	1.52	1.54
30	60	BD	g cm^{-3}	1.56	0	1.55	1.57
0	5	FED	g cm^{-3}	1.3	0.02	1.25	1.34
5	30	FED	g cm^{-3}	1.5	0.01	1.48	1.51
30	60	FED	g cm^{-3}	1.48	0.02	1.45	1.51
0	5	FEM	g cm^{-2}	6.48	0.1	6.27	6.68
5	30	FEM	g cm^{-2}	37.42	0.2	37.01	37.82
30	60	FEM	g cm^{-2}	44.35	0.46	43.42	45.27
0	5	FE_{rel}	0-1	0.99	0	0.98	1
5	30	FE_{rel}	0-1	0.98	0	0.97	0.99
30	60	FE_{rel}	0-1	0.95	0.01	0.93	0.97
0	5	SOC content	g C kg^{-1}	21.09	0.23	20.62	21.56
5	30	SOC content	g C kg^{-1}	18.45	0.15	18.15	18.76
30	60	SOC content	g C kg^{-1}	6.7	0.25	6.2	7.2
0	5	SOC stock	kg C m^{-2}	1.36	0.03	1.31	1.41
5	30	SOC stock	kg C m^{-2}	6.89	0.07	6.75	7.02
30	60	SOC stock	kg C m^{-2}	2.88	0.08	2.72	3.04
2019: Complete field							
0	5	BD	g cm^{-3}	1	0.01	0.97	1.03
5	30	BD	g cm^{-3}	1.46	0.01	1.43	1.48
30	60	BD	g cm^{-3}	1.59	0.01	1.56	1.62
0	5	FED	g cm^{-3}	0.95	0.01	0.92	0.98
5	30	FED	g cm^{-3}	1.38	0.01	1.36	1.41
30	60	FED	g cm^{-3}	1.46	0.03	1.4	1.52
0	5	FEM	g cm^{-2}	4.76	0.07	4.62	4.91
5	30	FEM	g cm^{-2}	34.57	0.28	33.94	35.2
30	60	FEM	g cm^{-2}	43.79	0.85	41.9	45.69
0	5	FE_{rel}	0-1	0.95	0	0.94	0.96
5	30	FE_{rel}	0-1	0.95	0.01	0.93	0.97
30	60	FE_{rel}	0-1	0.92	0.02	0.88	0.96
0	5	SOC content	g C kg^{-1}	25.75	0.42	24.82	26.68
5	30	SOC content	g C kg^{-1}	18.94	0.21	18.47	19.4
30	60	SOC content	g C kg^{-1}	6.82	0.22	6.33	7.31
0	5	SOC stock	kg C m^{-2}	1.21	0.01	1.18	1.24

5	30	SOC stock	kg C m^{-2}	6.45	0.1	6.22	6.69
30	60	SOC stock	kg C m^{-2}	2.95	0.11	2.7	3.21
2019: Reduced field							
0	5	BD	g cm^{-3}	1.02	0.02	0.98	1.07
5	30	BD	g cm^{-3}	1.45	0.01	1.43	1.47
30	60	BD	g cm^{-3}	1.58	0.02	1.55	1.62
0	5	FEM	g cm^{-2}	5.01	0.09	4.79	5.24
5	30	FEM	g cm^{-2}	35.61	0.26	34.99	36.24
30	60	FEM	g cm^{-2}	44.66	1.09	42.09	47.23
0	5	FED	g cm^{-3}	1	0.02	0.96	1.05
5	30	FED	g cm^{-3}	1.42	0.01	1.4	1.45
30	60	FED	g cm^{-3}	1.49	0.04	1.4	1.57
0	5	FE_{rel}	0-1	0.98	0	0.98	0.98
5	30	FE_{rel}	0-1	0.98	0	0.98	0.98
30	60	FE_{rel}	0-1	0.94	0.02	0.9	0.98
0	5	SOC content	g C kg^{-1}	23.28	0.52	22.05	24.51
5	30	SOC content	g C kg^{-1}	17.31	0.23	16.76	17.86
30	60	SOC content	g C kg^{-1}	6.56	0.19	6.11	7
0	5	SOC stock	kg C m^{-2}	1.16	0.02	1.13	1.2
5	30	SOC stock	kg C m^{-2}	6.11	0.09	5.91	6.32
30	60	SOC stock	kg C m^{-2}	2.89	0.11	2.64	3.14
2019: Intersection field							
0	5	BD	g cm^{-3}	1.01	0.02	0.96	1.06
5	30	BD	g cm^{-3}	1.46	0.01	1.43	1.5
30	60	BD	g cm^{-3}	1.57	0.02	1.51	1.63
0	5	FED	g cm^{-3}	0.99	0.02	0.94	1.04
5	30	FED	g cm^{-3}	1.43	0.01	1.4	1.47
30	60	FED	g cm^{-3}	1.44	0.05	1.31	1.57
0	5	FEM	g cm^{-2}	4.94	0.1	4.68	5.2
5	30	FEM	g cm^{-2}	35.82	0.37	34.88	36.76
30	60	FEM	g cm^{-2}	43.22	1.52	39.31	47.12
0	5	FE_{rel}	0-1	0.98	0	0.97	0.98
5	30	FE_{rel}	0-1	0.98	0	0.97	0.98
30	60	FE_{rel}	0-1	0.92	0.02	0.85	0.98
0	5	SOC content	g C kg^{-1}	23.56	0.72	21.72	25.4
5	30	SOC content	g C kg^{-1}	17.35	0.17	16.9	17.79
30	60	SOC content	g C kg^{-1}	6.78	0.24	6.18	7.39
0	5	SOC stock	kg C m^{-2}	1.16	0.01	1.13	1.19
5	30	SOC stock	kg C m^{-2}	6.17	0.08	5.96	6.38
30	60	SOC stock	kg C m^{-2}	2.9	0.14	2.55	3.26

Table S5. Welch's t-test statistics of soil properties measured during the 2005 and 2019 campaigns across both the reduced and complete field areas. Reported are mean values, mean differences between campaigns, standard errors of the differences (accounting for unequal sample sizes: N2005 = 100, N2019.complete = 20, N2019.reduced = 14), and two-sided P values. Variables include bulk density (BD), fine earth mass (FEM), fine earth density (FED), relative proportion of fine earth (FE_{rel}, 0–1), and soil organic carbon concentration (SOC, g C kg^{-1}).

UD	LD	Variable	Unit	Mean 2005	Mean 2019	Mean diff	SE diff	P value
2005 – 2019: Complete field								
0	5	BD	g cm^{-3}	1.312	1.002	-0.310	0.024	0.000
5	30	BD	g cm^{-3}	1.530	1.456	-0.074	0.013	0.000
30	60	BD	g cm^{-3}	1.559	1.587	0.027	0.013	0.054
0	5	FED	g cm^{-3}	1.295	0.953	-0.343	0.025	0.000
5	30	FED	g cm^{-3}	1.497	1.383	-0.114	0.014	0.000
30	60	FED	g cm^{-3}	1.478	1.460	-0.018	0.032	0.571
0	5	FEM	g cm^{-2}	6.477	4.764	-1.713	0.123	0.000
5	30	FEM	g cm^{-2}	37.417	34.571	-2.846	0.346	0.000
30	60	FEM	g cm^{-2}	44.347	43.793	-0.554	0.966	0.571
0	5	FE_{rel}	0-1	0.987	0.949	-0.037	0.005	0.000
5	30	FE_{rel}	0-1	0.978	0.950	-0.028	0.008	0.001
30	60	FE_{rel}	0-1	0.948	0.920	-0.028	0.019	0.147
0	5	SOC content	g kg^{-1}	21.090	25.750	4.660	0.479	0.000
5	30	SOC content	g kg^{-1}	18.451	18.935	0.484	0.256	0.066
30	60	SOC content	g kg^{-1}	6.697	6.821	0.124	0.332	0.710
2005 – 2019: Reduced field								
0	5	BD	g cm^{-3}	1.312	1.023	-0.289	0.027	0.000
5	30	BD	g cm^{-3}	1.530	1.452	-0.078	0.011	0.000
30	60	BD	g cm^{-3}	1.559	1.584	0.024	0.017	0.170
0	5	FED	g cm^{-3}	1.295	1.003	-0.292	0.028	0.000
5	30	FED	g cm^{-3}	1.497	1.424	-0.072	0.013	0.000
30	60	FED	g cm^{-3}	1.478	1.489	0.010	0.039	0.794
0	5	FEM	g cm^{-2}	6.477	5.015	-1.462	0.140	0.000
5	30	FEM	g cm^{-2}	37.417	35.611	-1.806	0.332	0.000
30	60	FEM	g cm^{-2}	44.347	44.660	0.313	1.182	0.794
0	5	FE_{rel}	0-1	0.987	0.980	-0.007	0.004	0.141
5	30	FE_{rel}	0-1	0.978	0.981	0.003	0.004	0.504
30	60	FE_{rel}	0-1	0.948	0.939	-0.008	0.020	0.679
0	5	SOC content	g C kg^{-1}	21.090	23.279	2.189	0.569	0.001
5	30	SOC content	g C kg^{-1}	18.451	17.309	-1.143	0.277	0.000
30	60	SOC content	g C kg^{-1}	6.697	6.557	-0.140	0.312	0.656

Table S6. Welch's t-test statistics of soil organic carbon stocks (SOC stock, kg C m^{-2}) measured during the 2005 and 2019 campaigns across the reduced and complete field areas. Reported are mean SOC stock values, mean differences between campaigns (SOC stock changes), and the standard errors of the differences, accounting for unequal sample sizes (N2005 = 100, $N2019._{complete}$ = 20, N2019.reduced = 14). Field refers to the 2019 strata subset. Soil layer (cm) indicates sampling depth; for the Equivalent Soil Mass (ESM) approach, layer thickness is adjusted per campaign (see Figure S5-B). Statistical comparisons used t-tests without assuming equal variances; degrees of freedom were estimated via the Welch–Satterthwaite approximation. The minimum detectable difference (MDD) is the smallest true difference detectable given variability and sample size. A significant SOC stock change is larger than the MDD is considered detectable (black); if SOC stock change is smaller than the MDD, the change is not statistically distinguishable (red). Large MDD values reflect high variability or low sensitivity, whereas small MDD values indicate greater precision in detecting SOC changes.

Equivalent soil mass (ESM)										
Field subset	**Reference Soil mass kg m^{-2} ***	**SOC Stock 2005 kg C m^{-2}**	**SOC Stock 2019 kg C m^{-2}**	**SOC Stock Change kg C m^{-2}**	**SOC Stock Change %**	**SE difference kg C m^{-2}**	**CI Lower kg C m^{-2}**	**CI Upper kg C m^{-2}**	***P value***	**MDD**
Complete field	62.5	1.31	1.54	0.23	+17.5	0.02	0.19	0.27	< 0.001	0.07
Complete field	372.6	6.83	6.42	-0.41	-6.0	0.11	-0.65	-0.18	0.001	0.39
Complete field	453.2	3.05	2.83	-0.22	-7.2	0.12	-0.47	0.03	0.09	0.41
Reduced field	62.5	1.31	1.41	0.10	+7.6	0.02	0.05	0.15	< 0.001	0.09
Reduced field	372.6	6.83	6.06	-0.77	-11.3	0.11	-0.99	-0.55	< 0.001	0.37
Reduced field	453.2	3.05	2.77	-0.28	-9.2	0.12	-0.52	-0.04	0.021	0.41
Cumulative SOC stocks (~0-60 cm)										
Complete field	887.6	11.19	10.79	-0.40	-3.6	0.22	-0.84	0.04	0.07	0.72
Reduced field	887.6	11.19	10.24	-0.95	-8.5	0.20	-1.37	-0.53	< 0.001	0.68

* The reference mass for each layer corresponds approximately to the 0–5 cm, 5–30 cm, and 30–60 cm depth intervals, with respective masses of 62.5, 372.6, and 453.2 kg m^{-2} (total for 0–60 cm: 887.6 kg m^{-2}). The adjusted depth intervals after the ESM calculation are shown in the table S7.

Fixed depth (FD)										
Field subset	**Layer cm**	**SOC Stock 2005 kg C m^{-2}**	**SOC Stock 2019 kg C m^{-2}**	**SOC Stock Change kg C m^{-2}**	**SOC Stock Change %**	**SE difference kg C m^{-2}**	**CI Lower kg C m^{-2}**	**CI Upper kg C m^{-2}**	***P value***	**MDD**
Complete field	0-5	1.36	1.21	-0.15	-11.0	0.03	-0.21	-0.10	< 0.001	0.09
Complete field	5-30	6.89	6.45	-0.43	-6.2	0.12	-0.68	-0.18	0.002	0.41
Complete field	30-60	2.88	2.95	0.08	+2.8	0.14	-0.20	0.36	0.58	0.46
Reduced field	0-5	1.36	1.16	-0.20	-14.7	0.03	-0.26	-0.14	< 0.001	0.10
Reduced field	5-30	6.89	6.11	-0.77	-11.2	0.12	-1.00	-0.55	< 0.001	0.37
Reduced field	30-60	2.88	2.89	0.01	+0.4	0.13	-0.25	0.28	0.92	0.44
Cumulative SOC stocks (0-60 cm)										
Complete field	0-60	11.12	10.62	-0.51	-4.6	0.24	-0.99	-0.03	0.04	0.79
Reduced field	0-60	11.12	10.17	-0.96	-8.6	0.22	-1.40	-0.51	0.00	0.73

Table S7. Summary statistics of cumulative soil mass and carbon measured during the 2005 and 2019 campaigns, reported by seven depth intervals and soil mass reference. UD and LD are the upper and lower depths of the soil layer (cm). Variables include reference soil mass (FE_{ref}) and soil organic carbon stock (SOC stock, kg C m^{-2}). Means, standard errors (SE), and 95% confidence intervals (CI) were calculated using Equations (6)–(8). Sample sizes (N) and number of strata (H) per subset are: 2005 (N = 100, H = 50), 2019 complete field (N = 20, H = 10) and 2019 reduced field (N = 14, H = 7).

UD	LD	FE_{ref}	SOC stock	SE	CI lower	CI upper
cm			kg m^{-2}			
2005						
0	4.9	62.5	13.12	0.14	13.40	12.84
4.9	9.9	135.7	27.45	0.18	27.82	27.08
9.9	19.9	285.3	55.67	0.39	56.45	54.90
19.9	30.1	438.7	81.92	0.64	83.21	80.62
30.1	40.5	595.8	97.34	1.00	99.35	95.33
40.5	50.8	744.7	105.37	1.13	107.64	103.09
50.8	61.5	893.4	112.14	1.26	114.68	109.60
2019: Complete field						
0	6.2	62.5	15.42	0.17	15.80	15.04
6.2	11.8	135.7	31.37	0.30	32.03	30.71
11.8	22.6	285.3	58.79	0.52	59.94	57.63
22.6	33.2	438.7	79.83	0.96	81.98	77.69
33.2	44.1	595.8	90.54	1.27	93.36	87.72
44.1	54.5	744.7	100.64	1.57	104.14	97.15
54.5	64.5	893.4	108.10	1.78	112.07	104.14
2019: Reduced field						
0	5.9	62.5	14.1	0.21	14.60	13.60
5.9	11.5	135.7	28.8	0.36	29.64	27.95
11.5	21.9	285.3	54.08	0.63	55.58	52.58
21.9	32.2	438.7	74.95	0.92	77.12	72.77
32.2	43.0	595.8	85.24	1.16	87.98	82.50
43.0	53.1	744.7	95.02	1.41	98.35	91.69
53.1	62.9	893.4	102.6	1.62	106.44	98.75

Supplementary figures

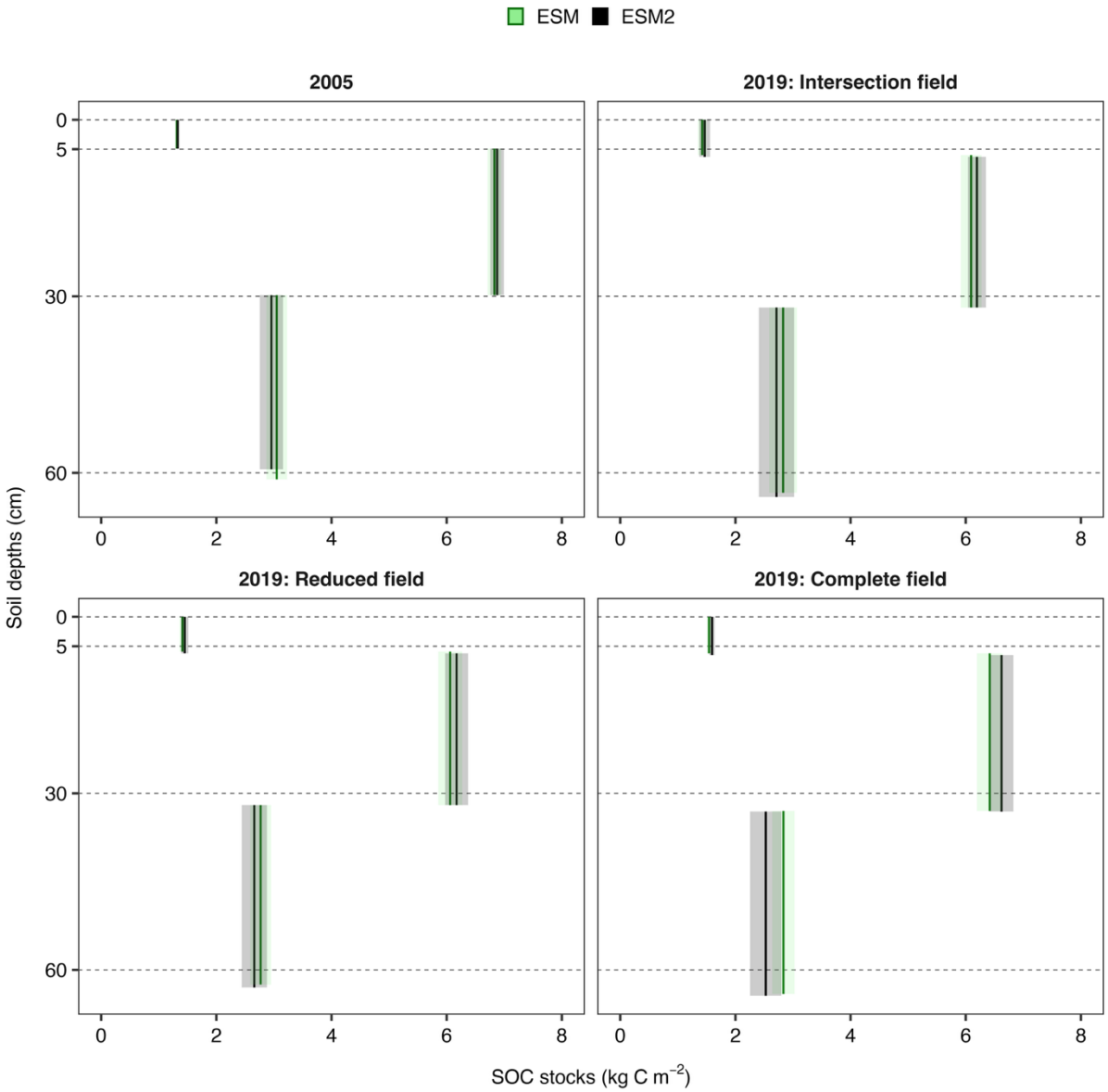

Figure S6. Soil Organic Carbon stocks (SOC stock, kg C m^{-2}) estimated using two Equivalent Soil Mass approaches for the 2005 and 2019 campaigns. ESM is the classical ESM method (Ellert and Bettany, 1995) and ESM2 is a model-based approach incorporating cubic splines (Wendt and Hauser, 2013). Solid lines (vertical) represent the mean SOC stocks across the entire depth range, while shaded ribbons indicate the upper and lower CIs. The dashed grey (horizontal) line represents the sampling soil depth aggregated into 0-5, 5-30, and 30-60 cm. If the thickness of the ESM-adjusted depth falls outside the upper or lower bounds of the sampling soil depth, it indicates that a depth adjustment was made during the ESM computation. The complete field includes 10 strata and the reduced field 7 strata.

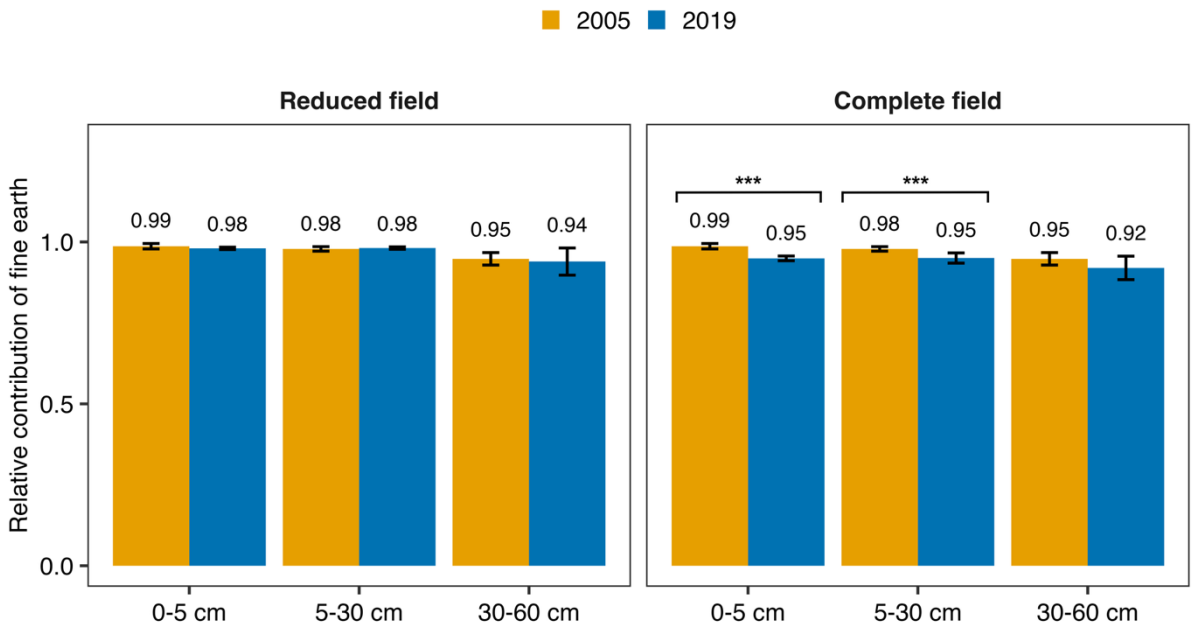

Figure S7. Means of the mass and relative contribution of fine earth across the soil layers, along with their corresponding confidence intervals (error bars) for the 2005 and 2019 campaigns. In the "Complete field" panel, all strata from 2019 were considered. In the "Reduced Field panel", seven strata from the 2019 dataset with similar pedological characteristics to the 2005 area were included. Asterisks denote significant differences between both campaigns: $P < 0.0001$ (***), $P < 0.001$ (**), $P < 0.05$ (*).

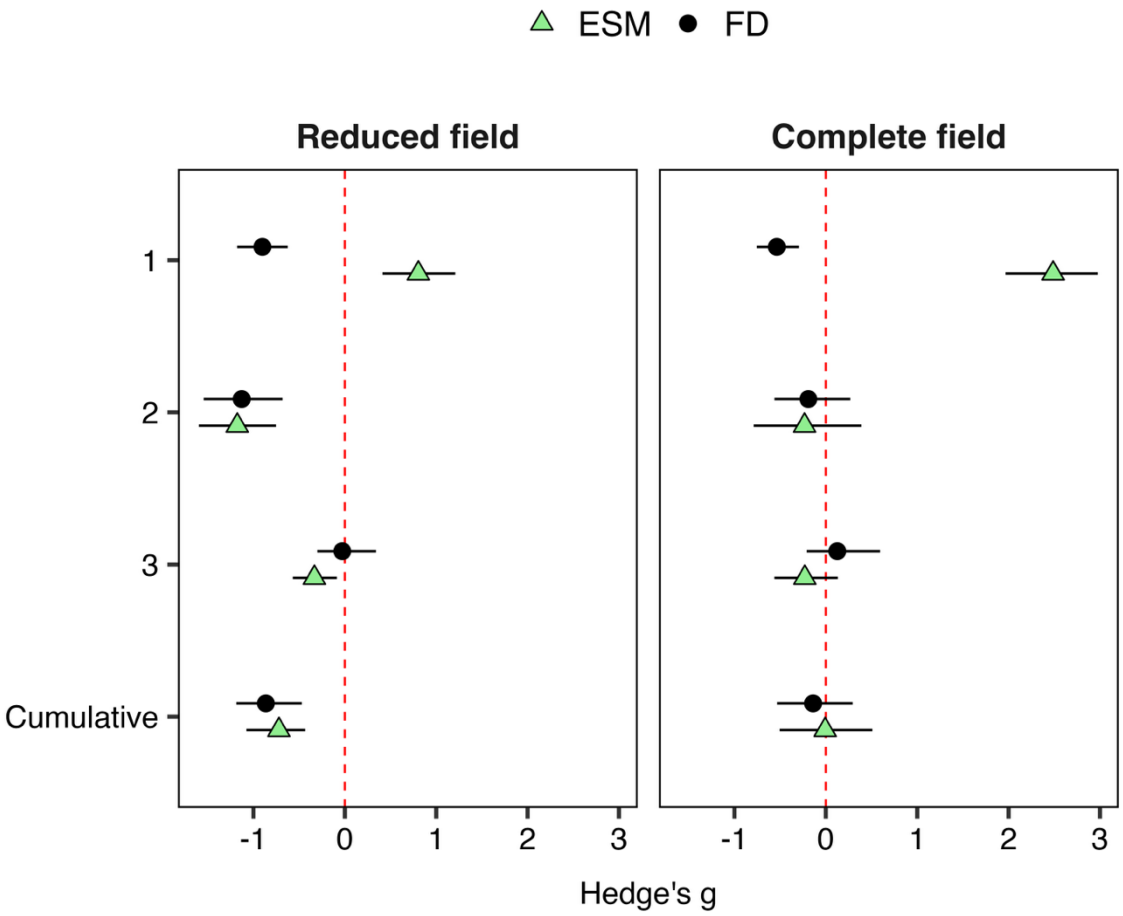

Figure S8. Magnitude of differences in soil organic carbon stock (SOC stock, kg C m^{-2}) between 2005 and 2019 across soil layers, quantified using Hedges' g effect size (Hedges, 1981). Points represent Hedges' g values; their sign indicates whether SOC stocks changes (kg C m^{-2}) in 2019 increased (positive) or decreased (negative) relative to 2005. Error bars show bias-corrected and accelerated (BCa) 95% confidence intervals, based on 20,000 bootstrap resamples. Confidence intervals that overlap zero indicate no statistically significant difference between the two campaigns for the corresponding variable. Soil layers 1, 2, and 3 correspond to sampling depth intervals of 0–5 cm, 5–30 cm, and 30–60 cm, respectively. The "Cumulative" category represents the full 0-60 cm soil profile for FD and 889 kg m^{-2} for ESM. The complete field includes 10 strata and the reduced field 7 strata.

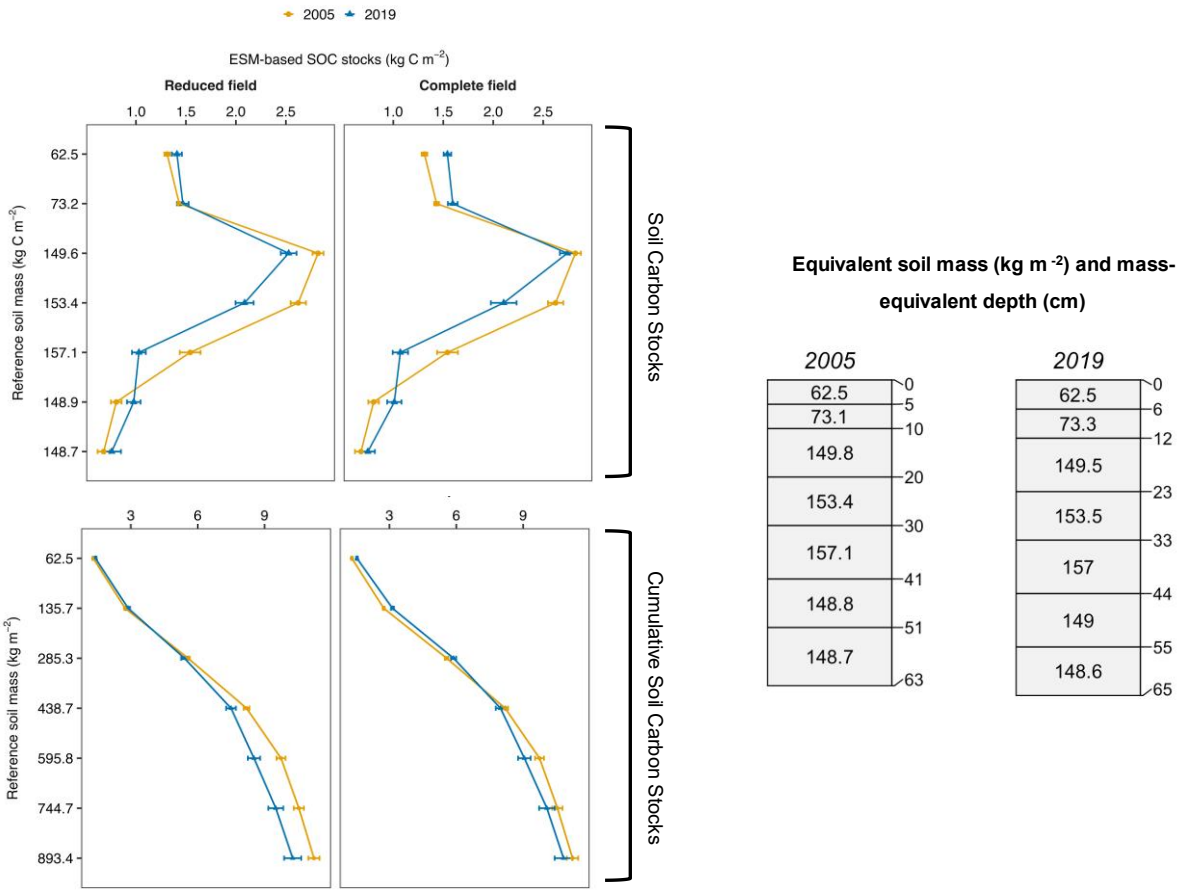

Figure S9. (A) Soil Organic Carbon stock (SOC stock, kg C m^{-2}) stocks and (B) Cumulative SOC stock (kg C m^{-2}) across seven reference soil masses (kg m^{-2}) using Equivalent Soil Mass (ESM) approach. C) Profile plot showing soil mass (kg m^{-2}, in boxes) and equivalent mass depth for the 2005 and 2019 campaigns. Dots represent the mean SOC stocks across soil mass; error bars denote 95% confidence intervals. The complete field includes 10 strata and the reduced field includes 7 strata.