Supplement of

Boreal-forest soil chemistry drives soil organic carbon bioreactivity along a 314-year fire chronosequence

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Table S1: Path coefficients and model-averaged estimators for each of the *a priori* hypothesized causal relationship among variables (arrows) for the O layer.

Direct causal effects

| Model | MAT | GDD5 | MAP | WB | Sand | Silt | Clay | TSF | pH | IMD | Mn |
|-------|-----|------|-----|----|------|------|------|-----|----|-----|----|
|       | ↓ C_loop | ↑ C_loop | ↓ C_loop | ↓ C_loop | ↓ C_loop | ↓ C_loop | ↓ C_loop | ↓ C_loop | ↓ C_loop | ↓ C_loop | ↓ C_loop |
| O1    | 0.02 | -    | -    | -   | -0.10 | -    | -    | 0.25 * | 0.36 ** | 0.09  | 0.35 ** |
| O1    | 0.03 | -    | -    | -   | -0.08 | -    | 0.25 * | 0.36 ** | 0.09  | 0.35 ** |
| O1    | 0.02 | -    | -    | -   | -    | 0.11 | 0.24 * | 0.36 ** | 0.08  | 0.34 ** |
| O1    | -    | -    | -    | -   | -    | -    | 0.25 * | 0.36 ** | 0.08  | 0.33 ** |
| O1    | -    | -    | -    | -   | 0.09 | -    | 0.25 * | 0.35 ** | 0.12  | 0.30 ** |
| O1    | -    | -    | -    | -   | -    | -    | 0.24 * | 0.35 ** | 0.06  | 0.31 ** |
| O1    | -    | -    | -    | -   | 0.17 | -    | 0.28 * | 0.34 ** | 0.00  | 0.35 *** |
| O1    | -    | -    | -    | -   | 0.16 | -    | 0.28 ** | 0.34 ** | 0.01  | 0.35 *** |
| O1    | -    | -    | -    | -   | 0.26 * | -    | 0.26 * | 0.33 ** | 0.00  | 0.34 ** |
| O1    | -    | -    | -    | -   | -    | 0.12 | 0.28 ** | 0.35 ** | 0.01  | 0.39 *** |
| O1    | -    | -    | -    | -   | 0.30 ** | -0.16 | -    | 0.28 ** | 0.35 ** | 0.00  | 0.38 *** |
| O1    | -    | -    | -    | -   | -    | 0.15 | 0.28 ** | 0.34 ** | 0.01  | 0.40 *** |
| O1    | -    | -    | -    | -   | 0.26 * | -    | 0.26 * | 0.34 ** | 0.00  | 0.38 *** |
| O2    | -    | -    | -    | -   | -    | -    | 0.25 * | 0.34 ** | 0.08  | 0.34 ** |
| O2    | -    | -    | -    | -   | -    | -    | 0.25 * | 0.34 ** | 0.08  | 0.34 ** |
| O2    | -    | -    | -    | -   | -    | -    | 0.25 * | 0.34 ** | 0.08  | 0.34 ** |
| O2    | -    | -    | -    | -   | -    | -    | 0.25 * | 0.34 ** | 0.08  | 0.34 ** |
| O2    | -    | -    | -    | -   | -    | -    | 0.25 * | 0.34 ** | 0.08  | 0.34 ** |
| O2    | -    | -    | -    | -   | -    | -    | 0.25 * | 0.34 ** | 0.08  | 0.34 ** |
| O2    | -    | -    | -    | -   | -    | -    | 0.25 * | 0.34 ** | 0.08  | 0.34 ** |

Model-averaged estimator

| Model | MAT | GDD5 | MAP | WB | Sand | Silt | Clay | TSF | pH | IMD | Mn |
|-------|-----|------|-----|----|------|------|------|-----|----|-----|----|
|       | ↓ C_loop | ↑ C_loop | ↓ C_loop | ↓ C_loop | ↓ C_loop | ↓ C_loop | ↓ C_loop | ↓ C_loop | ↓ C_loop | ↓ C_loop | ↓ C_loop |

Note: *Model*: model name; *MAT*: mean annual temperature; *GDD5*: growing degree-day above 5°C; *MAP*: mean annual precipitation; *WB*: water balance; *Sand*: sand content of the mineral soil; *Silt*: silt content of the mineral soil; *Clay*: clay content of the mineral soil; *TSF*: time since fire; *pH*: pH of the O layer; *IMD*: index of moss dominance; *Mn*: exchangeable manganese; *C_loop*: carbon bioreactivity of the O layer. The model that best fitted the data is highlighted by bold font. (*) p ≤ 0.05; (**) p ≤ 0.01; (***) p ≤ 0.001.

Indirect causal effects

| Model | TSF | IMD | MAT | GDD5 | MAP | WB | Sand | Silt | Clay |
|-------|-----|-----|-----|------|-----|----|------|------|------|
|       | ↓ pH | ↑ pH | ↓ IMD | ↓ IMD | ↓ IMD | ↓ IMD | ↓ IMD | ↓ IMD | ↓ IMD |
Direct causal effects

variables (arrows) for the mineral soil.

Note: Model: model name; MAT: mean annual temperature; GDD5: growing degree-day above 5°C; MAP: mean annual precipitation; WB: water balance; Sand: sand content of the mineral soil; Silt: silt content of the mineral soil; Clay: clay content of the mineral soil; TSF: time since fire; pH: pH of the O layer; IMD: index of moss dominance; C_{bioRx}: carbon bioreactivity of the O layer. The model that best fitted the data is highlighted by bold font. (*) p ≤ 0.05; (**) p ≤ 0.01; (***) p ≤ 0.001.

Table S2: Path coefficients and model-averaged estimators for each of the a priori hypothesized causal relationships among variables (arrows) for the mineral soil.

Direct causal effects

| Model | MAT ↓ C_{bioR} | GDD5 ↓ C_{bioR} | MAP ↓ C_{bioR} | WB ↓ C_{bioR} | Sand ↓ C_{bioR} | Silt ↓ C_{bioR} | Clay ↓ C_{bioR} | TSF ↓ C_{bioR} | pH ↓ C_{bioR} | Mpy ↓ C_{bioR} | Mn ↓ C_{bioR} | Al ↓ C_{bioR} |
|-------|---------------|-----------------|----------------|-------------|---------------|----------------|---------------|-------------|-------------|--------------|-------------|-------------|
| MIN1  | 0.24 *        | -               | -              | 0.23        | -             | -11            | -0.19         | -0.32 *     | 0.15        | -            | -           | -           |
| MIN1  | 0.21          | -               | -              | 0.21        | -             | -0.22          | -0.24         | -0.32 *     | -0.3         | -0.42 ***    | 0.14        | -           |
| MIN1  | 0.24 *        | -               | -              | -           | -             | -0.06          | -0.27 *       | -0.3         | 0.06        | -0.33 *      | -0.32 *     | -0.42 **    |
| MIN1  | 0.21          | -               | -              | -           | -             | 0.06           | -0.26 *       | -0.31 **    | -0.15       | -0.44 ***    | -0.32 *     | -0.42 **    |
| MIN1  | 0.23          | -               | -              | -           | -             | -0.15          | -0.11         | -0.25       | -0.3 *      | 0.17         | -           | -           |
| MIN1  | 0.18          | -               | -              | -           | -             | -0.02          | 0.06          | -0.31 *     | -0.29        | -0.42 **     | -0.32 *     | -0.42 **    |
| MIN1  | -             | 0.21            | -              | -           | *             | -              | -0.08         | -0.16       | -0.28 *     | 0.15         | -           | -           |
| MIN1  | -             | 0.18            | -              | 0.22        | -             | -              | 0.08          | -0.25 *     | -0.26 *     | -0.42 ***    | -0.26 *     | -0.42 ***    |
| MIN1  | -             | 0.2             | -              | -           | -11           | -0.08          | -0.15         | -0.28 *     | 0.14        | -           | -           | -           |
| MIN1  | -             | 0.17            | -              | -           | -             | 0.09           | -0.23         | -0.27 *     | -0.44 ***    | -0.32 *     | -0.42 **    |
| MIN1  | -             | 0.14            | -              | -           | -0.03         | 0.08           | -0.29 *       | -0.26 *     | -0.42 **    | -0.32 *     | -0.42 **    |
| MIN1  | -             | 0.24            | 0.25           | *           | -             | -0.09          | -0.2          | -0.33 *     | 0.13        | -           | -           | -           |
### Model-averaged estimator

| Model | MAT | GDD5 | MAP | WB | Sand | Silt | Clay | TSF | pH | Mpy | Mn | Al |
|-------|-----|------|-----|----|------|------|------|-----|----|-----|----|----|
|       | C_mnt | C_mnt | C_mnt | C_mnt | C_mnt | C_mnt | C_mnt | C_mnt | C_mnt | C_mnt | C_mnt | C_mnt |
| MIN1  | -    | 0.22 | -    | -   | -    | -    | 0.07  | -0.28 | -   | -0.31 | -   | -0.42 |
| MIN1  | -    | 0.25 | -    | -   | -    | -    | -0.26 | -0.09 | -   | -0.34 | 0.11 | -   |
| MIN1  | -    | 0.23 | -    | -   | -    | -    | 0.07  | -0.27 | -   | -0.33 | -   | -0.44 |
| MIN1  | -    | 0.18 | -    | -   | -    | -    | -0.12 | -0.09 | -   | -0.24 | -   | -0.3  | 0.14 |
| MIN1  | -    | 0.15 | 0.21 | -   | -0.23 | -    | 0.07  | -0.31 | -   | -0.3  | -   | -0.42 |
| MIN1  | -    | 0.17 | -    | -   | -    | -    | 0.08  | -0.27 | -   | -0.31 | 0.11 | -   |
| MIN1  | -    | 0.12 | -    | -0.11 | -0.11 | -0.08 | -0.22 | -0.3  | 0.14 | -   |
| MIN1  | -    | 0.11 | 0.01 | 0.01  | 0.08  | -0.5  | -0.3  | 0.08  | -0.28 | 0.12 | -   |
| MIN2  | -    | 0.09 | -    | -    | -    | -    | 0.09  | -0.27 | -0.3  | 0.12 |
| MIN2  | -    | 0.09 | -    | -    | -    | -    | -0.07 | -0.18 | -0.28 | 0.12 | -   |
| MIN2  | -    | 0.09 | -    | -    | -    | -    | -0.07 | -0.18 | -0.28 | 0.12 | -   |
| MIN2  | -    | 0.09 | -    | -    | -    | -    | -0.07 | -0.18 | -0.28 | 0.12 | -   |
| MIN2  | -    | 0.09 | -    | -    | -    | -    | -0.07 | -0.18 | -0.28 | 0.12 | -   |
| MIN2  | -    | 0.09 | -    | -    | -    | -    | -0.07 | -0.18 | -0.28 | 0.12 | -   |
| MIN2  | -    | 0.09 | -    | -    | -    | -    | -0.07 | -0.18 | -0.28 | 0.12 | -   |
| MIN2  | -    | 0.09 | -    | -    | -    | -    | -0.07 | -0.18 | -0.28 | 0.12 | -   |
| MIN2  | -    | 0.09 | -    | -    | -    | -    | -0.07 | -0.18 | -0.28 | 0.12 | -   |
| MIN2  | -    | 0.09 | -    | -    | -    | -    | -0.07 | -0.18 | -0.28 | 0.12 | -   |

Note: *Model*: model name; *MAT*: mean annual temperature; *GDD5*: growing degree-day above 5°C; *MAP*: mean annual precipitation; *WB*: water balance; *Sand*: sand content of the mineral soil; *Silt*: silt content of the mineral soil; *Clay*: clay content of the mineral soil; *TSF*: time since fire; *pH*: pH of the mineral soil; *Mpy*: pyrophosphate extractable metals; *Mn*: exchangeable manganese; *Al*: exchangeable aluminum; *C_BioR*: carbon bioreactivity of the mineral soil. The model that best fitted the data is highlighted by bold font. (*) *p* ≤ 0.05; (**) *p* ≤ 0.01; (***) *p* ≤ 0.001.

### Indirect causal effects
|    | MIN1 | MIN1 | MIN1 | MIN1 | MIN1 | MIN1 | MIN1 | MIN1 | MIN1 | MIN1 | MIN1 | MIN1 | MIN1 |
|----|------|------|------|------|------|------|------|------|------|------|------|------|------|
|    |      |      |      |      |      |      |      |      |      |      |      |      |      |
| MIN2 | 0.14 | -    | -    | -    | -    | -0.37** | -0.16 | -0.07 | -    | -    | -    | -    | -    | 0.23 |
| MIN2 | 0.14 | -    | -    | -    | -    | -0.37** | -0.16 | -    | 0.01 | -    | -7   | -    | -    | 0.24 *|
| MIN2 | 0.14 | -    | -    | -    | -    | -0.37** | -0.16 | -0.05 | -    | -    | -    | -    | 0.35 **|
| MIN2 | 0.14 | -    | -    | -    | -    | -0.37** | -0.16 | 0.21  | -    | -    | -    | -    | 0.27 *|
| MIN2 | 0.14 | -    | -    | -    | -    | -0.37** | -0.16 | -    | -    | -    | 0.24 *| -    | -    | 0.33 **|
| MIN2 | -    | -0.04| -    | -    | -    | -0.35** | -0.16 | -0.07 | -    | -    | -    | -    | 0.23 |
| MIN2 | -    | -0.04| -    | -    | -    | -0.35** | -0.16 | -    | 0.01 | -    | -    | -    | 0.24 *|
| MIN2 | -    | -0.04| -    | -    | -    | -0.35** | -0.16 | -0.05 | -    | -    | -    | -    | 0.35 **|
| MIN2 | -    | -0.04| -    | -    | -    | -0.35** | -0.16 | 0.21  | -    | -    | -    | -    | 0.27 *|
| MIN2 | -    | -0.04| -    | -    | -    | -0.35** | -0.16 | -    | -    | -    | 0.24 *| -    | -    | 0.33 **|
| MIN2 | -    | 0.18 | -    | -0.39** | -0.16 | -0.07 | -    | -    | -    | -    | 0.23 |
| MIN2 | -    | 0.18 | -0.39** | -0.16 | -    | -0.02 | -    | -    | -    | -    | 0.24 *|
| MIN2 | -    | 0.18 | -0.39** | -0.16 | -0.01 | -    | -    | -    | -    | -    | 0.24 *|
| MIN2 | -    | 0.18 | -0.39** | -0.16 | -    | -0.05 | -    | -    | -    | -    | 0.24 *|
| MIN2 | -    | 0.18 | -0.39** | -0.16 | 0.21 | -    | -    | -    | -    | 0.27 *|
| MIN2 | -    | 0.18 | -0.39** | -0.16 | -    | -    | -    | -    | 0.24 *| -    | -    | 0.33 **|
| MIN2 | -    | -    | 0.21 | -0.38*** | -0.16 | -0.07 | -    | -    | -    | -    | 0.23 |
| MIN2 | -    | -    | 0.21 | -0.38*** | -0.16 | -    | -0.02 | -    | -    | -    | 0.24 *|
| MIN2 | -    | -    | 0.21 | -0.38*** | -0.16 | -0.01 | -    | -    | -0.05 | -    | 0.35 **|
| MIN2 | -    | -    | 0.21 | -0.38*** | -0.16 | 0.21 | -    | -    | -0.01 | -    | 0.27 *|
| MIN2 | -    | -    | 0.21 | -0.38*** | -0.16 | -    | -    | -    | -    | 0.24 *| -    | 0.33 **|

Model-averaged estimator

|        | 0.01 | 0.00 | 0.03 | 0.11 | -0.34 | -0.15 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.17 | 0.05 | -0.24 |
Note: Model: model name; MAT: mean annual temperature; GDD5: growing degree-day above 5°C; MAP: mean annual precipitation; WB: water balance; Sand: sand content of the mineral soil; Silt: silt content of the mineral soil; Clay: clay content of the mineral soil; TSF: time since fire; pH: pH of the mineral soil; Mpy: pyrophosphate extractable metals; Mn: exchangeable manganese; Al: exchangeable aluminum; C_Bioreac: carbon bioreactivity of the mineral soil. The model that best fitted the data is highlighted by bold font. (*) p ≤ 0.05; (**) p ≤ 0.01; (***) p ≤ 0.001.
Figure S1: Diagram of the sampling plot.

- 20*20 cm template used for dominant mosses identification
- X Thicknes of the O layer measurement with a soil auger
- Brown: Sampling of the O layer and mineral soil from 0 to 15 cm
- Gray: Soil pit used for soil description and for sampling of the mineral soil from 15 to 35 cm and the top 15 cm of the B horizon

Figure S2: Cumulative specific respiration (Rs) as a function of the sampling Julian day. Boxplots represent the distribution of Rs values for each of the soil layers for each sampling day. Lines are drawn for each of the samples. FH (green): O layer; MIN015 (blue): mineral soil, top 15 cm; MIN1535 (salmon): mineral soil, from 15 to 35 cm.
Figure S3: Acid-insoluble soil carbon stock and fraction (a-c) and bioreactive soil carbon stock and fraction (d-f) as a function of time since fire for the O layer (a, d), the top 15 cm of the mineral soil (b, e) and the mineral soil from 15 to 35 cm (c, f). Stock: maroon dots; proportion relative to total soil carbon stock: green dots. Plain line and dashed lines: prediction with confidence interval, respectively. Dashed line only: mean, where linear relationship was found to be not significant (p < 0.05). See also Table 2.