Supplementary Material

1 Supplement

1.1 Description of sites and data used

We used data from two forest sites in Southern Finland (Table S1). Both sites are close, on drained peat soil, but have contrasting soil fertility. The nutrient-poor site, Kalevansuo, (60°38' N, 24°21' E, 123 m a.s.l.), and the nutrient-rich site, Lettosuo (60°38' N, 23°57' E; elevation 111 m a.s.l), have the same long term annual mean precipitation of 722 mm and annual mean air temperature of 5 ˚C.

Lettosuo was partly drained already during the 1930s by manually dug, widely spaced ditches. In 1969, the site was more effectively drained by 1 m deep ditches spaced 45 m apart, and the site was fertilized with phosphorus and potassium. Two years later, in 1971, Kalevansuo was drained by similar methods. Several ditches have been cleaned at Lettosuo during the 1990s, but at Kalevansuo, ditches have not been cleaned since 1971. Ditches at both sites are still functional but are now partly overgrown with *Sphagnum* mosses. Kalevansuo, was before drainage, classified an ombrotrophic dwarf-shrub pine bog. Following drainage, the trees have grown bigger, and mire species coverage has decreased while common forest species have taken over in the field and bottom layers. Scots pine (*Pinus sylvestris*), on average 120 years old in 2008, dominates the tree stand by 98% of the stand volume, and small pubescent birch (*Betula pubescent*) trees grow alongside ditches (Lohila et al., 2011). The stand has a total basal area of 18.4 m^2 ha^{-1} and tree carbon stock of 4600 g C m^{-2}. The field layer is dominated by *Ledum palustre*, *Vaccinium uliginosum*, *V. vitis-idaea*, *V. myrtillus*, *Empetrum nigrum*, *Calluna vulgaris*, *Eriophorum vaginatum,* and *Rubus chamaemorus*. The bottom layer covers approximately 90% of the land surface and is dominated by forest mosses *Pleurozium schreberi*, *Dicranum polysetum*, *Aulacomnium palustre,* and *Polytrichum strictum* with several peat mosses including *Sphagnum angustifolium*, *S. medium,* and *S. russowii* on the wetter spots. Before drainage, Lettosuo was a minerotrophic, mesotrophic herb-rich birch-pine fen. It was, like Kalevansuo, dominated by Scots pine with some pubescent birch. After drainage, Scots pine and pubescent birch dominate the canopy, with an understory of small-sized Norway spruce (*Picea abies*) and pubescent birch. The total basal area of trees was 27.5 m^2 ha^{-1} and tree carbon stock of 8000 g C m^{-2}; thus, the forest floor is more shaded and has patchy vegetation. The field layer consists of *Dryopteris carthusiana*, *Trientalis europaea,* and *Vaccinum myrtillus*. In the patchy bottom layer, *Pleurozium schreberi* and *Dicranum polysetum* dominate and in moist patches *Sphagnum girgensohnii*, *S. angustifolium* and *S. russowii* dominate. (Bhuiyan et al., 2017)

The topsoil at Kalevansuo is *Sphagnum*-dominated peat with a mixture of *Eriophorum vaginatum* and shrub constituents, while fen peat (i.e., sedges and herbs) is present in the deep layers (Mathijssen et al. 2017). Remains of earlier forest fires (charcoal particles) can be found, especially at a depth of 30–50 cm. After drainage, the toxic peat layer approximately 10–30 cm below the surface has decomposed to a high degree. In the top 10 cm of the soil, remnants of forest mosses and woody roots can be observed. The peat soil at Lettosuo is sedge-peat with a mixture of *Sphagnum* and wood, namely, typical peat for a treed fen. The peat in the topsoil is more decomposed than at Kalevansuo.

The coefficients of water retention characteristics were derived using a least-square fitting technique from the measured water content/pressure head points for the upper 5 soil layers with 0.1 m depth for each layer. Data used for deriving pF curves were measured by testing soil core samples to a pressure gradient of 0.1, 3, 10, 50, 100, 336.5, and 1000 cm water, and the recorded corresponding water content varied from 95% to 23%. No water recharge or discharge from nearby water bodies were considered in this study except horizontal water loss owing to drainage. Overall, the soil physical characteristics of the two sites were similar.

Table S1 Brief site characteristics of Kalevansuo and Lettosuo

Characteristics	*Kalevansuo*	*Lettosuo*	*References*
Peatland type	Bog forest	Fen forest	Laine and Vasander (1996)
Stand basal area, pine, m^2 ha^{-1}	17.6	17.4	Bhuiyan et al. (2016)
Stand basal area, spruce, m^2 ha^{-1}	<0.1	6.1	Koskinen et al. (2014)
Stand basal area, birch, m^2 ha^{-1}	0.7	4	
Forest understorey %, dwarf shrubs	29.1	4	
Forest understorey %, herbs	<0.5	10.6	
Forest understorey %, peat/forest mosses	2.9/87.7	11.3/24.9	
Bulk density, 0-0.6 m, g cm^{-3}	0.11 (±0.03)	0.13 (±0.02)	Lohila et al. (2011)
Tree C stock at 2005, g C m^{-2}	4600	8000	Minkkinen et al. (2018)
Peat depth, m	2.2 (±0.5)	2.6 (±0.2)	Lohila et al. (2011)
Soil C/N, 0-0.2 m	36	26	Linkosalmi et al. (2015)
Soil pH	5.0	4.4	Pihlatie et al. (2010)
Drainage depth	-0.8 m	-0.9 m	
Drainage space	40 m	40 m	

1.2 Basic Description of Model

A complete description of the model and the software for using the model is available at http://www.coupmodel.com. The complete set of input and output files with all the detailed information for running the model are also available at the same domain. This will allow any reader to download the model with the complete set of files to rerun the model or check detailed outputs. The complete set of input/output also includes an alternative setup of the model with respect to the assumed range for the selected parameters concerning the differences in rate coefficients for the three organic soil substrates. Here we present the most important equation that are of direct importance for the current application only (Table S2).

Table S2. List of main equations used in this study.

Equation	No.	Definition
Plant biotic processes		
$$C_{Atm\rightarrow a} = \varepsilon_L \cdot \eta \cdot f(T_l) \cdot f(T_{sum}) \cdot f(CN_l) \cdot f(E_{ta}/E_{tp}) \cdot R_{s,pl}$$ where ε_L is the radiation use efficiency, η is the conversion factor from biomass to carbon and $R_{s,pl}$ is the global radiation adsorbed by the plant.	(1)	Rate of photosynthesis (g C m^{-2} day^{-1})
$$f(T_l) = \begin{cases} 0 & T_l < p_{mn} \\ \frac{(T_l - p_{mn})}{(p_{o1} - p_{mn})} & p_{mn} \le T_l \le p_{o1} \\ 1 & p_{o1} < T_l < p_{o2} \\ 1 - \frac{(T_l - p_{o2})}{(p_{mx} - p_{o2})} & p_{o2} \le T_l \le p_{mx} \\ 0 & T_l > p_{mx} \end{cases}$$ where p_{mn}, p_{o1}, p_{o2} and p_{mx} are parameters.	(2)	Response function for leaf temperature
$$f(T_{sum}) = \begin{cases} 0 & T_{sum} \\ p_{fracTsum} + (1 - p_{fracTsum})\left(\frac{T_{sum}}{p_{tsumrange}}\right) & T_{sum} \\ 1 & T_{sum} \end{cases}$$ where $p_{fracTsum}$ and $p_{tsumrange}$ are parameters.	(3)	Seasonal acclimation
$$f(CN_l) = p_{photofactor}$$ where $p_{photofactor}$ is a parameter.	(4)	Response function for fixed leaf C:N ratio
$$f(E_{ta}/E_{tp}) = \frac{E_{ta}}{E_{tp}}$$ where E_{ta} is actual transpiration and E_{tp} is potential transpiration.	(5)	Response function for transpiration
$$C_{a\rightarrow Leaf} = p_{cal} \cdot C_a$$ where p_{cal} is a parameter.	(6)	Allocation of new assimilates to the leaves
$$C_{a\rightarrow Root} = p_{car} \cdot C_a$$ where p_{car} is a parameter.	(7)	Allocation of new assimilates to the roots
$$C_{respleaf} = k_{mrespleaf} \cdot f(T) \cdot C_{leaf} + k_{gresp} \cdot C_{a\rightarrow Leaf}$$ where $k_{mrespleaf}$ is the maintenance respiration coefficient for leaves, k_{gresp} is the growth respiration coefficient, and $f(T_a)$ is the temperature. The equation calculates respiration from stem, roots, and grains by exchanging $k_{mrespleaf}$ to $k_{mrespstem}$, $k_{mresproot}$, $k_{mrespgrain}$, and using the corresponding storage pools. Respiration from the old carbon pools is estimated with the same maintenance respiration coefficients as for respiration from new carbon pools.	(8)	Plant growth and maintenance respiration from leaves (g C m^{-2} day^{-1})
$$f(T) = t_{Q10}^{\frac{(T - t_{Q10bas})}{10}}$$	(9)	Temperature response function for

where t_{Q10} and t_{Q10bas} are parameters. maintenance respiration (–)

$$C_{Leaf\rightarrow LitterSurface} = p_{leafl} \cdot C_{Leaf} \quad (10)$$

Leaf C entering the surface litter pool

Where p_{leafl} is a parameter. The same first order rate equation is used for also stem using p_{steml} as a parameter

$$C_{Root\rightarrow Litter} = p_{rootl} \cdot C_{Root} \quad (11$$

Root C entering the soil litter pool

Where p_{rootl} is a paramter.

$$C_{Leaf\rightarrow Mobile} = C_{Leaf\rightarrow LitterSurface} \cdot m_{retain} \quad (12)$$

Allocation to the mobile C pool for developing new leaves during litter fall

where m_{retain} is an allocation coefficient.

$$C_{Mobile\rightarrow Leaf} = C_{Mobile} \cdot m_{shoot} \quad (13)$$

Allocation from the mobile C pool at leafing (between GSI 1 and 2)

where m_{shoot} is an allocation coefficient.

Plant abiotic processes

$$R_{s,pl} = (1 - e^{-k_{rn}\frac{A_l}{f_{cc}}}) \cdot f_{cc}(1 - a_{pl})R_{is} \quad (14)$$

Plant interception of global radiation (MJ m^{-2} day^{-1})

where k_{rn} is the light use extinction coefficient given as a single parameter common for all plants, f_{cc} is the surface canopy cover, and a_{pl} is the plant albedo.

$$f_{cc} = p_{cmax}(1 - e^{-p_{ck}A_l}) \quad (15)$$

Degree of plant cover

Where p_{cmax} is a parameter that determines the maximum surface cover and p_{ck} is a parameter that governs the speed at which the maximum surface cover is reached. A_l is the leaf area index of the plant.

Surface canopy cover (m^2 m^{-2})

$$L_v E_{tp} = \frac{\Delta R_n + \rho_a c_p \frac{(e_s - e_a)}{r_a}}{\Delta + \gamma\left(1 + \frac{r_s}{r_a}\right)} \quad (16)$$

Potential transpiration (mm day^{-1})

where R_n is net radiation available for transpiration, e_s is the vapour pressure at saturation, e_a is the actual vapour pressure, ρ_a is air density, c_p is the specific heat of air at constant pressure, L_v is the latent heat of vaporisation, Δ is the slope of saturated vapour pressure versus temperature curve, γ is the psychrometer 'constant', r_s is 'effective' surface resistance and r_a is the aerodynamic resistance.

$$r_s = \frac{1}{max(A_l g_l, 0.001)}$$ (17) Canopy resistance (s m^{-1})

where g_l is the leaf conductance.

$$g_l = \frac{R_{is}}{R_{is} + g_{ris}} \frac{g_{max}}{1 + \frac{(e_s - e_a)}{g_{vpd}}}$$ (18) Stomatal conductance per leaf area (m s^{-1})

where g_{ris}, g_{max} and g_{vpd} are parameter values, g_{maxwin} corresponds to g_{max} in winter.

$$E_{ta} = E_{ta}^{*} + f_{umov}(E_{tp}^{*} - E_{ta}^{*})$$ (19) Actual Transpiration (mm day^{-1})

where f_{umov} is the degree of compensation, E_{ta}^{*} is the uptake without any account for compensatory uptake and E_{tp}^{*} is the potential transpiration with eventual reduction due to interception evaporation.

$$E_{ta}{}^{*} = E_{tp}{}^{*} \int_{z_r}^{0} f(\psi(z))(T(z))r(z)\,\partial z$$ (21) Integration of water uptake from various layers

where $r(z)$ is the relative root density distribution, z_r is root depth and $f(\psi(z))$ and $f(T(z))$ are response functions for soil water potential and soil temperature.

$$f(\psi(z)) = min\left(\left(\frac{\psi_c}{\psi(z)}\right)^{p_1 E_{tp} + p_2}, f_\theta\right)$$ (22) Response to water potential of a specific layer

Where $\psi_c, p_1\ and\ p_2 are\ parameters\ and\ f_\theta$ is a function of water content (optionally used to reduce uptake close to saturation).

Soil carbon and nitrogen processes

$$C_{DecompL} = k_{org} \cdot f(T) \cdot f(\theta) \cdot C_{org}$$ (23) Decomposition of a C Org pool (g C m^{-2} day^{-1})

where k_{org} is a parameter. The same first order rate equation is applied for all organic soil pools (Org1, Org2 and Org3), by using the parameters k_{org1}, k_{org2}, or k_{org3}

$$C_{Org \rightarrow CO_2} = (1 - f_e) \cdot C_{Decomp}$$ (24) Respiration rate (g C m^{-2} day^{-1})

where f_e is a parameter

$$C_{Litter \rightarrow Humus} = f_e f_h C_{Decomp}$$ (25) Humification rate (g C m^{-2} day^{-1})

where $f_{h,l}$ is a parameter.

$$f(T) = \left(\frac{T - t_{min}}{t_{max} - t_{min}}\right)^2$$ (26) Response function for soil temperature (–)

where t_{min} and t_{max} are parameters. At temperature below t_{min} the function is 0 and above tmax the function is 1.

$$f(\theta) = min\begin{cases} p_{\theta satact} & \theta = \theta_s \\ \left(\left(\frac{\theta_s - \theta}{p_{\theta Upp}}\right)^{p_{\theta p}}(1 - p_{\theta satact}) + p_{\theta satact}, \left(\frac{\theta - \theta_{wilt}}{p_{\theta Low}}\right)^{p_{\theta p}}\right) & \theta_{wilt} \le \theta \le \theta_s \\ 0 & \theta < \theta_{wilt} \end{cases} \quad (27)$$

Response function for soil moisture (–)

where $p_{\theta Upp}$, $p_{\theta Low}$, $p_{\theta Satact}$, and $p_{\theta p}$ are parameters and the variables, θ_s, θ_{wilt}, and θ, are the soil moisture content at saturation, the soil moisture content at the wilting point, and the actual soil moisture content, respectively.

Soil water processes

$$q_w = -k_w\left(\frac{\partial\psi}{\partial z} - 1\right) - D_v\frac{\partial c_v}{\partial z} + q_{bypass} \quad (28)$$

Vertical water flow rate

where k_w is the unsaturated hydraulic conductivity, □ is the water tension, z is depth, c_v is the concentration of vapour in soil air, D_v is the diffusion coefficient for vapour in the soil and q_{bypass} is a bypass flow in the macropores described below. The total water flow, q_w, is thus the sum of the matrix flow, q_{mat}, the vapour flow, q_v, and the bypassflow, q_{bypass}.:

$$\frac{\partial\theta}{\partial t} = -\frac{\partial q_w}{\partial z} + s_w \quad (29)$$

Conservation assumption

where □ is the soil water content and s_w is a source/sink term. Under over saturated periods

$$q_{wp} = \int_{z_p}^{z_{sat}} k_s\frac{(z_{sat} - z_p)}{d_u d_p}\partial z \quad (30)$$

Drainage Rate equation

where d_u is the unit length of the horizontal element i.e. 1m, z_p is the lower depth of the drainage plane i.e. the drainage level, z_{sat} is the simulated depth of the ground water table and d_p is a characteristic distance between drain ditches/pipes.

1.3 Model set-up

The meteorological data was obtained from the ICOS (site code: FI-LET) and was used for both sites. Some precipitation data from the Jokioinen observatory (31 km NW from Lettosuo) was used to gap fill some of the data from the ICOS site. Hourly values of precipitation, global radiation, air temperature, relative humidity and wind speed was used.

Three vegetation layers were constructed for the model to represent the major differences in light, water, and nitrogen availability: Vegetation1 consisted of the coniferous tree canopy, Vegetation2 of deciduous trees of all sizes and smaller evergreen vascular plants, and Vegetation3 the bottom layer of only moss plants. The vegetation in the model can be understood as three big leaves allowing the partitioning of competition for light, water, and nutrients. A big leaf can intercept light from a certain height down to the soil surface. The interception of light follows the exponential Beers law as a function of the Leaf Area Index (LAI) and a corresponding uniform distribution of leaves with the height. The light extinction coefficients were assumed to be the same for the vascular plants, 0.5, but for the mosses, the coefficient of 2 was used, a number often used for field layer plants. The vegetation of each layer share light-regulated both by the degree of cover and LAI. The LAI, maximal height, and degree of soil cover were estimated for K and L (Table S3). The model calculates photosynthesis to be proportional to the global radiation absorbed by the canopy, however, it is limited by unfavorable temperature, water conditions, and lack of nitrogen in the leaf. Of the total incoming global radiation, on average, 92% was intercepted by vegetation at K and 93% at L. The conifers (Vegetation1) of the poor scenario intercepted only 53% of the light, while they intercepted 88% at L. At K, Vegetation2 plant types were composed mainly of dwarf shrubs, while at L deciduous trees dominated. The mosses (Vegetation3) differed most, intercepting 35% of the light at K but only 2% at L.

Vascular plants access water through roots in the uppermost soil 50 cm, with most roots in the surface 20 cm according to the measured root biomass data from Bhuiyan et al. (2017). Conversely, mosses access only water in the soil surface and lose water by evaporation from the leaf regulated by resistance between soil and atmosphere. The resistance can be described as similar to vascular plants but with the conceptual difference that stomata are missing, thus the only control is moisture availability.

Table S3 Vegetation characteristics as described by parameters of the modelled K and L system based on Kalevansuo and Lettosuo characteristics.

System	*Layer*	*LAI (m^2/m^2)*	*Height (m)*	*Degree of cover (m^2/m^2)*	*Average Light Interception (%)*	*Lowest root depth (m)*
K	1	2.8	0-14	0.55	53	-0.5
	2	1.2	0-0.3	0.1	3	-0.1
	3	2.5	0-0.05	0.9	35	-0.05
L	1	4.5	0-20	0.95	88	-0.5
	2	1.0	0-18	0.3	3	-0.5
	3	1.2	0-0.05	0.4	2	-0.05

The main aim for the pool separation was to link the soil processes to the plant origin. This model set-up assumes a soil structure with three soil organic matter components and 10 soil layers to describe the differences down to 2.5 m depth, focusing on the uppermost 50 cm of the soil profile (Table S4). The soil of the top 5 cm was assumed to be composed mostly of litter besides living mosses. The soil organic carbon (*SOC*) component design was: two litter pools *SOC1* and *SOC2*, originating from vascular plants and mosses, respectively. The third pool *SOC3*, was produced from decomposed *SOC1* and *SOC2*. The initial soil organic C of each layer was divided into *SOC1*, *SOC2*, and *SOC3*, by assuming a C/N of 45 for *SOC1*, 65 for *SOC2* (Kuhry and Vitt, 1996), and 20 for *SOC3* (Svensson et al., 2008).

Table S4. Initial soil C pools, Tot-C, g C m^{-2}, and C/N from measured data. *SOC* distributed by assuming a C/N of 45 for *SOC1*, 65 for *SOC2*, and 20 for *SOC3*.

	K					**L**				
SOIL DEPTH (M)	Tot-C g m^{-2}	C/N	*SOC1* % of Tot-C	*SOC2* % of Tot-C	*SOC3* % of Tot-C	Tot-C g m^{-2}	C/N	*SOC1* % of Tot-C	*SOC2* % of Tot-C	*SOC3* % of Tot-C
0-0.05	1600	41	33	47	20	1800	33	26	37	38
0.05-0.15	4100	34	27	38	35	7400	25	13	18	69
0.15-0.25	5400	38	30	44	26	11200	24	10	15	75
0.25-0.35	6800	34	26	38	36	8400	25	12	17	70
0.35-0.5	9500	53	40	58	2	9900	29	19	28	53
0.5-0.7	9900	37	29	42	28	20800	34	26	38	36
0.7-1.0	13900	46	36	53	11	20800	34	26	38	36
1.0-1.5	24900	53	40	58	2	27800	34	26	38	36
1.5-2.0	27400	47	37	54	9	34700	34	26	38	36
2.0-2.5	27400	47	37	54	9	34700	34	26	38	36

Soil water retention was described with the Brooks & Corey option of the model and estimated from measurements for the two systems (Table S5) (Juha Heiskanen *pers.com*). The hydraulic conductivity was assigned from similar peat soils in the soil database of the CoupModel.

Table S5. Soil physical properties for water retention and hydraulic conductivity.

	K				**L**			
Soil depth, (m)	*Porosity (vol %)*	*Pore size distribution index (-)*	*Air Entry (cm water)*	K_{sat} *(mm/day)*	*Porosity (vol %)*	*Pore size distribution index (-)*	*Air Entry (cm water)*	K_{sat} *(mm/day)*
0-0.05	93.2	.56	1.38	10000	93.2	0.56	1.23	8900
0.05-0.15	92.1	.43	1.52	7857	92.1	0.33	0.90	5800
0.15-0.25	90.7	.19	4.04	3657	90.7	0.11	1.37	5275
0.25-0.35	91.2	.10	12.6	1202	91.2	0.10	1.72	3914
0.35-0.5	92.6	.09	12.3	560	92.6	0.06	1.23	1275
0.5-0.7	93	.09	8.8	500	93	0.06	1.22	1032
0.7-1.0	93	.09	8.8	500	93	0.06	1.22	1032
1.0-1.5	93	.09	8.8	500	93	0.06	1.22	1032
1.5-2.0	93	.09	8.8	500	93	0.06	1.22	1032
2.0-2.5	93	.09	8.8	500	93	0.06	1.22	1032

Many parameters were assigned to values based on previous applications of the model and to a common value for both systems (Table S6). Attempts were also made to calibrate parameters, but we finally removed such parameters that we could not constrain by the measurements of the sites. The basic strategy was to try to use the same value for both systems when we did not have any strong evidence for assuming differences between the sites. The final selection of candidates for calibration was made to a few parameters (Table S7).

Table S6. Most important parameters with constant values. Index within parentheses for a name refer to the three plant layers.

Symbol	Name	unit	Eq.	Definition	Value
ε_L	*PhoRadEfficiency*	gDw MJ^{-1}	(1)	Radiation use efficiency for photosynthesis at optimum temperature, moisture and C-N ratio.	4.0
η	*Biomass to carbon*	mol C g^{-1} dw	(1)	conversion factor from biomass to carbon	0.45
p_{mn}	*T LMin(1)*	°C	(2)	Minimum mean air temperature for photosynthesis	-4
p_{mx}	*PhoTempResMax*	°C	(2)	Maximum mean air temperature for photosynthesis.	35
p_{o1}	*PhoTempResOpt1*	°C	(2)	Lower limit mean air temperature for optimum photosynthesis	15
p_{o2}	*PhoTempResOpt2*	°C	(2)	Upper limit mean air temperature for optimum photosynthesis	25
p_{cal}	*Leaf c1(1-2)*	day^{-1}	(5)	Allocation fraction to the leaves	0.3
p_{cal}	*Leaf c1(3)*	day^{-1}	(5)	Allocation fraction to the leaves	0.4
p_{car}	*Rootc1(1-2)*	day^{-1}	(5)	Allocation fraction to the Roots	0.3
p_{car}	*Rootc1(3)*	day^{-1}	(5)	Allocation fraction to the Roots	0.
k_{gresp}	*GrowthCoef(1-3)*	-	(7)	growth respiration coefficient	0.21
$k_{mrespleaf}$	*MCoefLeaf(1-3)*	day^{-1}	(7)	maintenance respiration coefficient for leaves	0.005
$k_{mresproot}$,	*MCoefRoot(1-3)*	day^{-1}	(7)	maintenance respiration coefficient for root	0.002
$k_{mrespstem}$	*MCoefStem(1-3)*	day^{-1}	(7)	maintenance respiration coefficient for stem	2.E-5
p_{leafl}	*LeafRate1(1-2)*	day^{-1}	(10)	Rate coefficient for the litter fall from leaves	0.0015
p_{leafl}	*LeafRate1(3)*	day^{-1}	(10)	Rate coefficient for the litter fall from leaves	0.005
p_{rootl}	*RootRate1(1-2)*	day^{-1}	(10)	Rate coefficient for the litter fall from roots	0.001
p_{rootl}	*RootRate1(3)*	day^{-1}	(10)	Rate coefficient for the litter fall from roots	0.0015
p_{steml}	*StemRate1(1-2)*	day^{-1}	(10)	Rate coefficient for the litter fall from stem	1.E-5
p_{steml}	*StemRate1(3)*	day^{-1}	(10)	Rate coefficient for the litter fall from stem	0.005
m_{retain}	*Mobile Allo Coef*	-	(12)	Coefficient for retaining N to mobile pool during litterfall	0.001
m_{shoot}	*Shoot Coef*	-	(13)	Coefficient for determining allocation from the mobile pool to the leaf at leafing.	0.1
g_{maxwin}	*CondMaxWinter*	$m^2\ s^{-1}$	(18)	The maximal conductance of fully open stomata.	.002
g_{max}	*CondMax*	$m^2\ s^{-1}$	(18)	The maximal conductance of fully open stomata.	0.02
g_{ris}	*CondRis*	J m^{-2} day^{-1}	(18)	The global radiation intensity that represents half-light saturation in the light response.	$5 \cdot 10^6$

g_{vpd}	*CondVPD*	Pa	(18)	The vapour pressure deficit that corresponds to a 50 % reduction of stomata conductance.	100
$p_{\theta Low}$	*ThetaLowerRange*	vol %	(31)	Water content interval in the soil moisture response function for microbial activity, mineralisation−immobilisation, nitrification and denitrification.	13

Table S7. Parameters defined by an uncertainty range used for calibration. Index within parentheses for a name refer to the three plant layers.

Symbol	Name	unit	Eq.	Definition	Value
$F(CN_l)$	*N_PhotoFactor(1-3)*	-	(4)	Degree of N stress	0.3-0.6
$p_{fractsum}$	*TF SumStart(1-3)*	-	(3)	Fraction of full efficiency at start of growing season	0.01-1.0
ψ_c	*CriticalThresholdDry(1-3)*	cm water	(22)	Threshold of pressure head where reduction starts	200-2000
k_{org1}	*RateCoefSOC1*	day^{-1}	(23)	First order rate coef, *SOC1*	5.E-4 – 4.E-3
k_{org2}	*RateCoefSOC2*	day^{-1}	(23)	First order rate coef, *SOC2*	5.E-5 – 2.E-4 (5.E-4 – 4.E-3)*
K_{org3}	*RateCoefSOC3*	day^{-1}	(23)	First order rate coef, *SOC3*	1.E-5 – 2.E-4
$p_{\theta p}$	*ThetaPowerCoef*	-	(27)	Power coefficient	0.2 – 2.2
$p_{\theta Upp}$	*ThetaUpperRange*	vol %	(27)	Water content range	3. – 20.

*) optional range for optional calibration of model

1.4 Statistical performance indicators

The CoupModel is software that enables the flexible selection of accepted candidates from a MonteCarlo based simulation approach. The model also allows for various methods and has many statistical performance indicators. Tutorials for learning those methods and testing various assumptions are available on the home page. All files will be archived as templates for future applications of the model.

Yearly cumulated *NEE* (g C m^{-2}) and *TotalDiffCPlant* (g C m^{-2}) were used to reduce the uncertainty of the prior distribution (n = 15000) to a posterior distribution (n = 100) by three criteria. First, the *TotalDiffCPlant* was a constraint to 1400–2000 and 2400–3000 to correspond to the observed value of 170 and 270 for the respective systems (K and L). Second, a combination of RMSE and ME was applied by iteration between criteria for the lowest possible RMSE and by rejecting the high or low candidates of mean errors (ME). The iteration was made until 100 candidates remained.

The difference in the prior and the posterior performance is the result of the application of those criteria (Table S8).

Table S8. Performance indicators and in the total change of plant biomass for the prior and posterior representation.

Variable	Indicator	Representation	K-prior	L-prior	K-post	L-post
NEE	R2	Mean	0,65	0,75	0,86	0,69
		CV	0,41	0,20	0,04	0,03
		Min	0,00	0,00	0,80	0,64
		Max	0,97	0,89	0,93	0,75
	Mean Error	Mean	0,159	-0,732	0,007	0,000
		CV	4,54	-0,86	17,83	258,58
		Min	-2,15	-2,69	-0,27	-0,04
		Max	2,90	0,97	0,21	0,08
	RMSE	Mean	153	3631	62	1290
		CV	0,361	0,578	0,074	0,050
		Min	46	814	48	1121
		Max	450	11858	68	1377
TotalDiffCPlant	Simulated Value	Mean	2562	3276	1731	2643
		CV	0,25	0,297	0,09	0,06
		Min	1092	1331	1403	2400
		Max	4320	5616	1994	2759

1.5 Estimated carbon flux and change of state variables

The posterior distributions can be understood as a description of how the model estimates all components of the model. In the section below, one table is for the fluxes (Table S9), and one is for the change of several major state variables from the start of the simulation to the end of the simulation (Table S10). Both Tables are split into a version (a) and (b) representing the main assumptions on differences between the prior distribution of the parameters for *SOC2*.

Table S9-a Selected carbon flux outputs with uncertainty range of the two systems L and K, g C m^{-2} d^{-1}.

	K				L			
Variable	Mean	StdDev	Min	Max	Mean	StdDev	Min	Max
NEE	-0,61	0,08	-0,75	-0,44	0,05	0,04	-0,03	0,15
Heterotrofic Soil respiration	1,10	0,08	0,88	1,31	1,59	0,08	1,43	1,81
SoilRespiration	1,39	0,08	1,18	1,63	2,08	0,10	1,90	2,35
Ecosystem respiration	1,85	0,09	1,61	2,11	2,88	0,13	2,66	3,24
GPP(1-3)	2,47	0,09	2,26	2,67	2,83	0,12	2,67	3,18
GPP(1)	1,39	0,09	1,25	1,59	2,51	0,11	2,34	2,82
GPP(2)	0,13	0,01	0,12	0,15	0,27	0,02	0,24	0,31
GPP(3)	0,94	0,09	0,76	1,21	0,05	0,01	0,03	0,08
SOC1 Respiration (1)	0,27	0,03	0,19	0,31	0,33	0,03	0,28	0,38
SOC1 Respiration (2)	0,26	0,02	0,20	0,29	0,24	0,02	0,21	0,27
SOC1 Respiration (3)	0,29	0,02	0,23	0,33	0,23	0,01	0,21	0,26
SOC1 Respiration (4)	0,06	0,03	0,01	0,15	0,13	0,01	0,10	0,14
SOC1 Respiration (5)	0,04	0,02	0,00	0,13	0,11	0,02	0,07	0,15
SOC1 Respiration (6)	0,00	0,00	0,00	0,02	0,11	0,02	0,07	0,18
SOC1 Respiration (7)	0.00	0,00	0,00	0,00	0,02	0,01	0,01	0,06
SOC2 Respiration (1)	0,01	0,00	0,01	0,02	0,01	0,00	0,01	0,02
SOC2 Respiration (2)	0,06	0,01	0,04	0,08	0,03	0,00	0,02	0,04
SOC2 Respiration (3)	0,03	0,00	0,02	0,04	0,03	0,00	0,02	0,03
SOC2 Respiration (4)	0,00	0,00	0,00	0,01	0,01	0,00	0,01	0,01
SOC2 Respiration (5)	0,00	0,00	0,00	0,01	0,01	0,00	0,01	0,01
SOC2 Respiration (6)	0,00	0,00	0,00	0,00	0,01	0,00	0,00	0,01
SOC2 Respiration (7)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
SOC3 Respiration (1)	0,01	0,00	0,00	0,01	0,02	0,00	0,01	0,02
SOC3 Respiration (2)	0,03	0,01	0,02	0,04	0,10	0,02	0,07	0,13
SOC3 Respiration (3)	0,02	0,00	0,01	0,03	0,13	0,01	0,10	0,17
SOC3 Respiration (4)	0,00	0,00	0,00	0,01	0,05	0,00	0,03	0,06
SOC3 Respiration (5)	0.00	0,00	0,00	0,00	0,02	0,00	0,01	0,02
SOC3 Respiration (6)	0,00	0,00	0,00	0,00	0,01	0,00	0,00	0,01
SOC3 Respiration (7)	0.00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Table S9-b Selected carbon flux outputs with uncertainty range of the two systems L and K when using optional assumptions on prior range for decomposition of *SOC2*, g C m^{-2} d^{-1}.

	K-optional				**L-Optional**			
Variable	Mean	StdDev	Min	Max	Mean	StdDev	Min	Max
NEE	-0,48	0,12	-0,73	-0,26	0,07	0,06	-0,05	0,21
Heterotrofic Soil respiration	1,34	0,16	0,96	1,67	1,72	0,10	1,51	1,92
SoilRespiration	1,65	0,17	1,26	2,01	2,24	0,11	2,00	2,48
Ecosystem respiration	2,14	0,18	1,70	2,52	3,09	0,14	2,80	3,38
GPP(1-3)	2,61	0,12	2,31	2,92	3,01	0,12	2,82	3,24
GPP(1)	1,46	0,11	1,24	1,66	2,47	0,10	2,29	2,67
GPP(2)	0,14	0,01	0,12	0,16	0,50	0,03	0,43	0,58
GPP(3)	1,01	0,12	0,76	1,30	0,05	0,01	0,03	0,08
SOC1 Respiration (1)	0,18	0,07	0,07	0,32	0,29	0,06	0,12	0,39
SOC1 Respiration (2)	0,19	0,06	0,08	0,29	0,21	0,04	0,10	0,27
SOC1 Respiration (3)	0,17	0,06	0,05	0,32	0,17	0,03	0,09	0,23
SOC1 Respiration (4)	0,02	0,01	0,00	0,06	0,08	0,02	0,04	0,12
SOC1 Respiration (5)	0,01	0,01	0,00	0,04	0,05	0,02	0,02	0,10
SOC1 Respiration (6)	0,00	0,00	0,00	0,01	0,05	0,02	0,02	0,11
SOC1 Respiration (7)	0,00	0,00	0,00	0,00	0,01	0,01	0,00	0,03
SOC2 Respiration (1)	0,09	0,03	0,04	0,14	0,09	0,02	0,04	0,13
SOC2 Respiration (2)	0,41	0,13	0,19	0,75	0,20	0,05	0,09	0,30
SOC2 Respiration (3)	0,20	0,07	0,06	0,34	0,16	0,04	0,09	0,23
SOC2 Respiration (4)	0,02	0,01	0,00	0,07	0,07	0,02	0,03	0,11
SOC2 Respiration (5)	0,01	0,01	0,00	0,04	0,05	0,02	0,02	0,08
SOC2 Respiration (6)	0,00	0,00	0,00	0,01	0,05	0,02	0,02	0,09
SOC2 Respiration (7)	0,00	0,00	0,00	0,00	0,01	0,00	0,00	0,02
SOC3 Respiration (1)	0,02	0,01	0,00	0,04	0,09	0,03	0,02	0,13
SOC3 Respiration (2)	0,01	0,01	0,00	0,03	0,09	0,04	0,02	0,19
SOC3 Respiration (3)	0,00	0,00	0,00	0,02	0,03	0,02	0,01	0,08
SOC3 Respiration (4)	0,00	0,00	0,00	0,00	0,01	0,01	0,00	0,03
SOC3 Respiration (5)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02
SOC3 Respiration (6)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
SOC3 Respiration (7)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Table S10-a Carbon state outputs with uncertainty range of the two systems during 10 years, g C m^{-2}.

	K				**L**			
Variable	Mean	StdDev	Min	Max	Mean	StdDev	Min	Max
ΔEcosystem	2312	284	1645	2822	-176	148	-556	108
ΔPlant	1587	131	1403	1872	2422	166	2201	2907
ΔSoil	724	282	4	1305	-2598	233	-3168	-2139
ΔSOC1	-1567	246	-2105	-815	-2074	176	-2704	-1714
ΔSOC2	2121	212	1687	2727	-282	25	-351	-233
ΔSOC3	166	21	130	237	-259	95	-440	-28

Table S10-b Carbon state outputs with uncertainty range of the two systems during 10 years when using optional range for decomposition of *SOC2*, g C m^{-2}.

	K-optional				**L-optional**			
Variable	Mean	StdDev	Min	Max	Mean	StdDev	Min	Max
ΔEcosystem	1790	449	969	2759	-278	214	-777	198
ΔPlant	1717	171	1405	1984	2673	164	2402	2986
ΔSoil	72	495	-971	1108	-2951	286	-3515	-2288
ΔSOC1	-27	812	-1663	1424	-555	628	-1933	1292
ΔSOC2	-257	929	-1902	2006	-2647	623	-3960	-1249
ΔSOC3	352	109	55	536	235	434	-835	1048

Obtained calibrated parameter with uncertainty range

The posterior distribution of the calibration parameters (Table S11) can be compared with the prior distributions (Table S7). The prior distribution is a uniform distribution for all parameters within the range (max-min). For the posterior distribution, we can study the change of mean value, min, max, and standard deviation and the results obtained with the optional assumptions of the prior distribution for the organic substrates *SOC2* (S11a and S11b).

Table S11-a Posterior parameters with uncertainty range for the two systems K and L.

	K				**L**			
Parameter	Mean	StdDev	Min	Max	Mean	StdDev	Min	Max
N_PhotoFactor(1-2)	0,35	0,03	0,30	0,42	0,36	0,03	0,32	0,43
N_PhotoFactor(3)	0,34	0,03	0,30	0,44	0,44	0,08	0,30	0,60
TF SumStart(1-3)	0,30	0,20	0,01	0,85	0,56	0,23	0,10	0,99
CriticalThresholdDry(1-2)	1044	529	210	1989	1218	500	202	1984
CriticalThresholdDry(3)	1074	529	219	1969	966	509	219	1995
RateCoefSOC1	3,2E-03	5,4E-04	1,8E-03	4,0E-03	3,2E-03	4,9E-04	2,3E-03	4,0E-03
RateCoefSOC2	1,6E-04	2,3E-05	1,1E-04	2,0E-04	1,6E-04	2,1E-05	1,3E-04	2,0E-04
RateCoefSOC3	1,6E-04	2,9E-05	8,0E-05	2,0E-04	1,6E-04	2,6E-05	1,1E-04	2,0E-04
ThetaPowerCoef	1,30	0,50	0,32	2,18	1,18	0,57	0,21	2,20
ThetaUpperRange	13,3	3,8	5,7	19,8	12,1	3,7	3,2	19,8

Table S11-b Posterior parameters with uncertainty range for the two systems K and L when using optional assumptions on decomposition of *SOC2*.

	K				**L**			
Parameter	Mean	StdDev	Min	Max	Mean	StdDev	Min	Max
N_PhotoFactor(1-2)	0,36	0,03	0,30	0,43	0,39	0,03	0,33	0,46
N_PhotoFactor(3)	0,36	0,04	0,30	0,48	0,46	0,08	0,30	0,60
TF SumStart(1-3)	0,38	0,22	0,01	0,99	0,52	0,25	0,03	1,00
CriticalThresholdDry(1-2)	1130	501	205	1994	1076	530	201	1955
CriticalThresholdDry(3)	1014	532	209	1998	1127	533	253	2000
RateCoefSOC1	1,8E-03	9,2E-04	5,2E-04	3,8E-03	2,5E-03	7,9E-04	7,3E-04	3,9E-03
RateCoefSOC2	1,5E-03	6,2E-04	5,0E-04	3,1E-03	1,7E-03	7,1E-04	5,4E-04	3,9E-03
RateCoefSOC3	1,0E-04	5,7E-05	1,0E-05	2,0E-04	1,3E-04	4,7E-05	3,1E-05	2,0E-04
ThetaPowerCoef	1,63	0,38	0,76	2,19	1,37	0,48	0,26	2,20
ThetaUpperRange	15,2	3,5	4,2	19,9	15,1	4,3	3,3	20,0

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