

**Table S1.** Definitions for the symbols and abbreviations used to describe the TCF model components and required input information.

Model Component	Symbols	Definition	Units
General	$T_s$	Soil temperature	K
	$T_{min}$	Daily minimum air temperature	K
	$SW_{rad}$	Incident shortwave radiation	W/m <sup>2</sup>
	$VPD$	Vapor pressure deficit	Pa
	$APAR$	Absorbed photosynthetically active radiation	MJ m <sup>-2</sup>
	$FPAR$	Fraction photosynthetically active radiation	[ ]
	$\epsilon_{max}$	Maximum plant light use efficiency	mg C MJ <sup>-1</sup>
	$\epsilon$	Light use efficiency with environ. constraints	mg C MJ <sup>-1</sup>
	$\theta$	Volumetric water content	d <sup>-1</sup>
	$\theta_{opt}$	Soil moisture optimum	[ ]
	$\phi_s$	Saturated pore volume	m <sup>-3</sup> d <sup>-1</sup>
	$\phi_a$	Aerated pore volume	m <sup>-3</sup> d <sup>-1</sup>
CO <sub>2</sub> Model	$CUE$	Plant carbon use efficiency (NPP/GPP)	[ ]
	$C_{met}$	Metabolic carbon pool	g C m <sup>-2</sup>
	$C_{str}$	Structural carbon pool	g C m <sup>-2</sup>
	$C_{rec}$	Recalcitrant carbon pool	g C m <sup>-2</sup>
	$F_{met}$	Fraction of NPP into $C_{met}$	[ ]
	$F_{str}$	Fraction of $C_{met}$ allocated to $C_{str}$	[ ]
	$F_{rec}$	Fraction of $C_{str}$ allocated to $C_{rec}$	[ ]
	$R_a$	Autotrophic respiration	g C m <sup>-2</sup> d <sup>-1</sup>
	$R_h$	Heterotrophic respiration	g C m <sup>-2</sup> d <sup>-1</sup>
	$R_{eco}$	Ecosystem respiration	g C m <sup>-2</sup> d <sup>-1</sup>
	$K_p$	Potential soil decomposition rate	d <sup>-1</sup>
	$K_{met}$	Modified soil decomposition rate	d <sup>-1</sup>
	$T_{mult}$	Temperature multiplier for $K_p$	[ ]
	$T_{ref}$	Reference temperature for $T_{mult}$	K
	$W_{mult}$	Soil moisture multiplier for $K_p$	[ ]

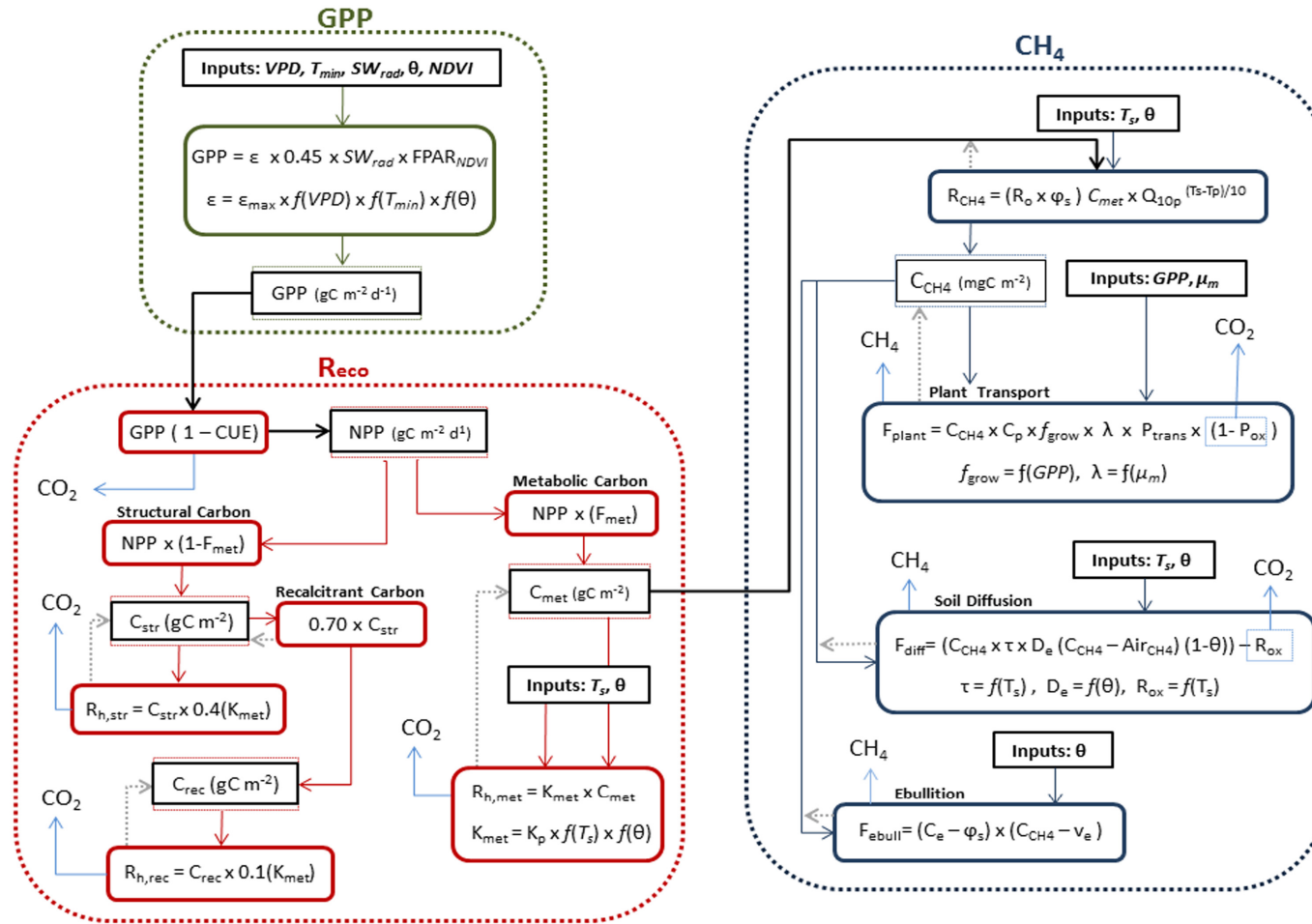
**Table S1 continued.**

Model Component	Symbols	Definition	Units
Soil CH <sub>4</sub> Production	$R_{CH4}$	Daily CH <sub>4</sub> production	mg C m <sup>-2</sup> d <sup>-1</sup>
	$C_{CH4}$	Total CH <sub>4</sub> storage	mg C m <sup>-2</sup>
	$R_o$	CH <sub>4</sub> production rate	μM CH <sub>4</sub> d <sup>-1</sup>
	$Q_{10p}$	Q <sub>10</sub> temperature modifier, CH <sub>4</sub> production	K
	$T_p$	Reference temperature, CH <sub>4</sub> production	K
	$F_{CH4}$	Total CH <sub>4</sub> emission	mg C m <sup>-2</sup> d <sup>-1</sup>
	$F_{plant}$	Plant CH <sub>4</sub> transport	mg C m <sup>-2</sup> d <sup>-2</sup>
	$F_{diff}$	Diffusion CH <sub>4</sub> transport	mg C m <sup>-2</sup> d <sup>-3</sup>
	$F_{ebull}$	Ebullition CH <sub>4</sub> transport	mg C m <sup>-2</sup> d <sup>-4</sup>
Plant Transport	$C_p$	Plant CH <sub>4</sub> transport rate	d <sup>-1</sup>
	$P_{trans}$	Transport modifier for C <sub>p</sub>	[ ]
	$f_{grow}$	Plant growth scalar, based on GPP	d <sup>-1</sup>
	$\mu_m$	Mean daily wind velocity	m s <sup>-1</sup>
	$g_a$	Aerodynamic conductance	m s <sup>-1</sup>
	$\lambda$	Aerodynamic modifier	d <sup>-1</sup>
	$k$	von Karman constant (for g <sub>a</sub> )	[ ]
	$z_m$	Anemometer height	m
	$d$	Zero-plane displacement height (for g <sub>a</sub> )	m
	$z_{om}$	Roughness length, momentum (for g <sub>a</sub> )	m
	$z_{ov}$	Roughness length, heat/vapor transfer (for g <sub>a</sub> )	m
	$P_{ox}$	Fraction oxidized during plant transport	[ ]
Diffusion And Ebullition	$P_{diff}$	Potential CH <sub>4</sub> diffusion	mg C m <sup>-2</sup> d <sup>-1</sup>
	$R_{ox}$	CH <sub>4</sub> oxidation	mg C m <sup>-2</sup> d <sup>-1</sup>
	$A_{CH4}$	Atmospheric CH <sub>4</sub>	μM CH <sub>4</sub>
	$D_e$	Effective soil diffusion rate	μM CH <sub>4</sub> d <sup>-1</sup>
	$D_{air}$	CH <sub>4</sub> diffusion rate, aerated fraction	μM CH <sub>4</sub> d <sup>-1</sup>
	$D_{water}$	CH <sub>4</sub> diffusion rate, saturated fraction	μM CH <sub>4</sub> d <sup>-1</sup>
	$\tau$	Soil tortuosity coefficient	[ ]
	$L_s$	Length of soil profile	m
	$V_{max}$	Maximum reaction rate,	μM CH <sub>4</sub> d <sup>-1</sup>
	$K_m$	Substrate conc. at 1/2 V <sub>max</sub>	μM CH <sub>4</sub>
	$Q_{10d}$	Q <sub>10</sub> temperature modifier, CH <sub>4</sub> diffusion	[ ]
	$T_d$	Reference temperature, CH <sub>4</sub> oxidation	K
	$v_e$	CH <sub>4</sub> threshold for ebullition	μM
	$C_e$	CH <sub>4</sub> ebullition transport rate	μM d <sup>-1</sup>

**Table S2.** Parameter values used for site-specific peatland (Biome 1) and wet tundra (Biome 2) TCF model CO<sub>2</sub> and CH<sub>4</sub> flux simulations.

TCF Component	Parameter	Tower Site:	SM	SK	LR	KY	ZK	BA
			Biome: 1	1	2	2	2	2
GPP	$e_{max}$	mg C MJ <sup>-1</sup>	0.82	0.82	0.82	0.82	0.82	0.82
	$\theta_{min}$	Fract.	0.15	0.15	0.15	0.15	0.15	0.15
	$\theta_{max}$	Fract.	0.75	0.72	0.75	0.70	0.75	0.75
$R_{eco}$	$CUE$	Fract.	0.45	0.35	0.55	0.55	0.5	0.5
	$K_p$	d <sup>-1</sup>	0.03	0.03	0.03	0.03	0.03	0.03
	$F_{met}$	Fract.	0.65	0.52	0.72	0.72	0.72	0.72
	$T_{ref}$	K	293	293	297	293	297	297
CH <sub>4</sub>	$\phi$	Fract.	0.75	0.75	0.70	0.70	0.70	0.70
	$R_o$	μM CH <sub>4</sub> d <sup>-1</sup>	22.4	15.4	9.2	10.8	10.8	10.8*
	$T_p$	K	287	288	289	287	287	287
	$Q_{10p}$	[ ]	3.5	3.5	4	3.9	3.5	3.8
	$P_{trans}$	[ ]	8	9	7	7	7	7
	$P_{ox}$	Fract.	0.8	0.8	0.7	0.7	0.7	0.7
	$A_{CH4}$	μM CH <sub>4</sub>	0.11	0.11	0.11	0.11	0.11	0.11
	$V_{max}$	μM CH <sub>4</sub> d <sup>-1</sup>	120	120	120	120	120	120
	$K_m$	μM CH <sub>4</sub>	1	1	1	1	1	1
	$T_d$	K	274	274	274	274	274	274
	$Q_{10d}$	[ ]	2	2	2	2	2	2
	$v_e$	μM	500	500	500	500	500	500
	$C_e$	μM d <sup>-1</sup>	3	3	3	3	3	3

\*A  $R_o$  value of 4.5 was used for BA 2007 to account for flooding disturbance impacts on substrate availability and methanogenesis.



**Fig. S1.** TCF model flow diagram for GPP (in green),  $R_{eco}$  (in red) and  $CH_4$  (in blue) modules. Rectangular boxes denote primary environmental inputs (single border) or model derived stored carbon pools (double border) including  $C_{met}$ ,  $C_{str}$ ,  $C_{rec}$  and  $C_{CH_4}$ . Rounded rectangles indicate major process calculations, and arrows show the direction of data flow. The dashed lines specify where pool updates occur at daily time steps to account for carbon losses.