Table 1: Mass balance equations for the carbon pools in the model, calculated for each vertical layer (subscript dropped from equations for readability). Units; $FC_{donor,reciver}$: $gCm^{-3}h^{-1}$. Details about the fluxes are found in Table A1.

Eqn	Stores	Growth rates	Sources	Sinks
(a)	Metabolic litter	$dC_{LITm}/dt =$	$FC_{Veg,LITm}$	$-FC_{LITm,SAPb} - FC_{LITm,SAPf}$
(b)	Structural litter	$dC_{LITs}/dt =$	$FC_{Veg,LITs}$	$-FC_{LITs,SAPb} - FC_{LITs,SAPf}$
(c)	Saprotrophic bacteria	$dC_{SAPb}/dt =$	$CUE_b(FC_{LITm,SAPb} + FC_{LITs,SAPb} + FC_{SOMa,SAPb})$	$-FC_{SAPb,SOMp} - FC_{SAPb,SOMa} - FC_{SAPb,SOMc}$
(d)	Saprotrophic fungi	$dC_{SAPf}/dt =$	$CUE_f(FC_{LITm,SAPf} + FC_{LITs,SAPf} + FC_{SOMa,SAPf})$	$-FC_{SAPf,SOMp} - FC_{SAPf,SOMa} - FC_{SAPf,SOMc}$
(e)	Ectomycorrhiza biomass	$dC_{EcM}/dt =$	$CUE_{EcM} \cdot FC_{Veg,EcM}$	$-FC_{EcM,SOMp} - FC_{EcM,SOMa} - FC_{EcM,SOMc}$
				$-FC_{enzEcM,SOMa}$
(f)	Arbuscular mycorrhiza biomass	$dC_{AM}/dt =$	$CUE_{AM} \cdot FC_{Veg,AM}$	$-FC_{AM,SOMp} - FC_{AM,SOMa} - FC_{AM,SOMc}$
(g)	Physically protected SOM	$dC_{SOMp}/dt =$	$FC_{Veg,SOMp} + FC_{SAPb,SOMp} + FC_{SAPf,SOMp}$	
			$+FC_{EcM,SOMp} + FC_{AM,SOMp}$	$-FC_{SOMp,SOMa} - FC_{EcMdecompSOMp}$
(h)	Chemically protected SOM	$dC_{SOMc}/dt =$	$FC_{Veg,SOMc} + FC_{SAPb,SOMc} + FC_{SAPf,SOMc}$	
			$+FC_{EcM,SOMc} + FC_{AM,SOMc}$	$-FC_{SOMc,SOMa} - FC_{EcMdecompSOMc}$
(i)	SOM available	$dC_{SOMa}/dt =$	$FC_{SAPb,SOMa} + FC_{SAPf,SOMa}$	
			$+FC_{EcM,SOMa} + FC_{AM,SOMa}$	
			$+FC_{SOMp,SOMa} + FC_{SOMc,SOMa} + FC_{enzEcM,SOMa}$	
			$+FC_{EcMdecompSOMc} + FC_{EcMdecompSOMp}$	$-FC_{SOMa,SAPb} - FC_{SOMa,SAPf}$
	Net Carbon change:	$dC/dt =$	$FC_{Veg,LITm} + FC_{Veg,LITs} + FC_{Veg,SOMp} + FC_{Veg,SOMc}$	
			$+CUE_{EcM} \cdot FC_{Veg,EcM} + CUE_{AM} \cdot FC_{Veg,AM}$	$-(1 - CUE_b)(FC_{LITm,SAPb} + FC_{LITs,SAPb} + FC_{SOMa,SAPb})$
				$-(1 - CUE_f)(FC_{LITm,SAPf} + FC_{LITs,SAPf} + FC_{SOMa,SAPf})$

0.1 Model Description

MIMICS+ is based on the MIMICS framework where microbial groups, litter and soil organic matter is represented as separate pools. In its current state, MIMICS+ is not coupled to a comprehensive land model, and therefore needs prescribed litter input, soil temperature, moisture and N deposition. The model is set up to use input from CLM history files. Fig. 1 shows the model structure, Table 1 and Table 2 give the mass balance equations for each pool in the system. Rate equations for C and N, and a list of parameters are given in the Appendix, Table A1, A2. Fluxes referred to as "C*" or "N*", where * is a number, can be found in those tables, and are illustrated as arrows in Fig. 1, A1a and A1b. A list of parameters is given in Table A3. By representing the same hydrologically and biogeochemically active layers as in CLM, MIMICS+ are able to represent the depth discretization of temperature and moisture dependent processes. For each layer the fluxes between the pools within the layer is calculated first, then we calculate the vertical transport. Unless otherwise stated, the equations below is pr. layer. The vertical transport is described in Section 0.2.3.

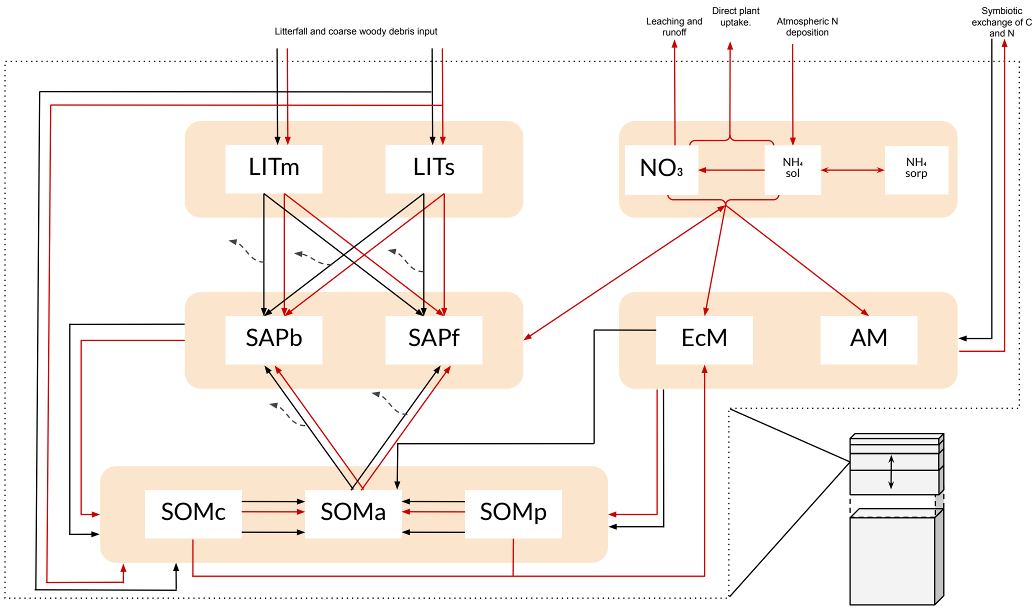


Figure 1: Schematic showing C and N flows within each layer of the model. Black arrows indicate carbon fluxes ($gCm^{-3}h^{-1}$ while red arrows indicate nitrogen fluxes ($gNm^{-3}h^{-1}$)). LITm, LITs: Metabolic and structural litter. SAPb, SAPf: saprotrophic Bacteria and Fungi. EcM, AM: Ecto- and Arbuscular mycorrhizal fungi. SOMc,SOMa,SOMp: Chemically protected, Available and physicochemically protected soil organic matter.

Table 2: Mass balance equations for the nitrogen pools in the model, calculated for each vertical layer (subscript dropped from equations for readability). Units; $FN_{donor,reciver}$: $gNm^{-3}h^{-1}$. Details about the fluxes are found in Table A2.

Eqn	Stores	Growth rates	Sources	Sinks	Exchange
(j)	Metabolic litter	$dN_{LITm}/dt =$	$FN_{Veg,LITm}$	$-FN_{LITm,SAPb} - FN_{LITm,SAPf}$	
(k)	Structural litter	$dN_{LITs}/dt =$	$FN_{Veg,LITs}$	$-FN_{LITs,SAPb} - FN_{LITs,SAPf}$	
(l)	Saprotrophic bacteria	$dN_{SAPb}/dt =$	$NUE(FN_{LITm,SAPb} + FN_{LITs,SAPb} + FN_{SOMa,SAPb})$	$-FN_{SAPb,SOMp} - FN_{SAPb,SOMa} - FN_{SAPb,SOMc}$	$+FN_{IN,SAPb}$
(m)	Saprotrophic fungi	$dN_{SAPf}/dt =$	$NUE(FN_{LITm,SAPf} + FN_{LITs,SAPf} + FN_{SOMa,SAPf})$	$-FN_{SAPf,SOMp} - FN_{SAPf,SOMa} - FN_{SAPf,SOMc}$	$+FN_{IN,SAPf}$
(n)	Ectomycorrhiza	$dN_{EcM}/dt =$	$FN_{IN,EcM} + FN_{SOMp,EcM} + FN_{SOMc,EcM}$	$-FN_{EcM,SOMp} - FN_{EcM,SOMa} - FN_{EcM,SOMc}$	
				$-FN_{EcM,Veg}$	
(o)	Arbuscular mycorrhiza	$dN_{AM}/dt =$	$FN_{IN,AM}$	$-FN_{AM,SOMp} - FN_{AM,SOMa} - FN_{AM,SOMc}$	
				$-FN_{AM,Veg}$	
(p)	Physically protected SOM	$dN_{SOMp}/dt =$	$FN_{SAPb,SOMp} + FN_{SAPf,SOMp}$		
			$+FN_{EcM,SOMp} + FN_{AM,SOMp} + FN_{Veg,SOMp}$	$-FN_{SOMp,SOMa} - FN_{SOMp,EcM}$	
(q)	Chemically protected SOM	$dN_{SOMc}/dt =$	$FN_{SAPb,SOMc} + FN_{SAPf,SOMc}$		
			$+FN_{EcM,SOMc} + FN_{AM,SOMc} + FN_{Veg,SOMp}$	$-FN_{SOMc,SOMa} - FN_{SOMc,EcM}$	
(r)	SOM available	$dN_{SOMa}/dt =$	$FN_{SAPb,SOMa} + FN_{SAPf,SOMa}$		
			$+FN_{SOMp,SOMa} + FN_{SOMc,SOMa}$		
			$+FN_{EcM,SOMa} + FN_{AM,SOMa}$	$-FN_{SOMa,SAPb} - FN_{SOMa,SAPf}$	
(s)	Ammonium, solved	$dN_{NH4_{sol}}/dt =$	$FN_{DEP} + (1 - NUE)(FN_{uptake,sap})$[a]	$-f_{NH4}(FN_{IN,EcM} + FN_{IN,AM} + FN_{IN,Veg})$	$-f_{NH4}(FN_{IN,SAPb} + FN_{IN,SAPf})$
				$-FN_{NH4,NO3}$	$+FN_{sol,sorp}$
(t)	Ammonium, sorbed	$dN_{NH4_{sorp}}/dt =$			$-FN_{sol,sorp}$
(u)	Nitrate	$dN_{NO3}/dt =$	$FN_{NH4,NO3}$	$-FN_{run+leach}-$	
				$(1 - f_{NH4})(FN_{IN,EcM} + FN_{IN,AM} + FN_{IN,Veg})$	$-(1 - f_{NH4})(FN_{IN,SAPb} + FN_{IN,SAPf})$
	Net Nitrogen change:	$dN/dt =$	$FN_{DEP} + FN_{Veg,LITm} + FN_{Veg,LITs}$	$-FN_{run+leach} - FN_{IN,Veg} - FN_{EcM,Veg} - FN_{AM,Veg}$	
			$FN_{Veg,SOMc} + FN_{Veg,SOMp}$		

[a] $FN_{uptake,sap} = N_{LITm,SAPb} + FN_{LITs,SAPb} + FN_{SOMa,SAPb} + FN_{LITm,SAPf} + FN_{LITs,SAPf} + FN_{SOMa,SAPf}$

0.2 Litter and SOM pools

Fig. 1 illustrates how organic C and N enters the litter and SOM pools as dead plant material. The mycorrhizal pools receive a C supply from plants, and in return provides N to its associated plants. Atmospheric N deposition is a source of inorganic N (N32). As in MIMICS (?, ?) and ORCHIDEE-SOM (?, ?), we separate between metabolic (labile) litter mainly originated from leafs and fine roots, and structural litter, which also include Coarse Woody Debris (CWD). For SOM we again follow the MIMICS approach with two SOM pools that are protected, either physicochemically or chemically, from saprotrophic decomposition, and one pool that is available for decomposition. Desorption and oxidation moves organic matter from physiochemically and chemically protected pools,respectively, to the available pool (C11,C12,N11,N12). 50% of the incoming metabolic and structural litter fluxes goes directly to SOMp and SOMc, respectively (C3,C4,N3,N4). This is a higher fraction than what is used in comparable models (?, ?, ?). The decision to increase the fraction was made to better represent the high C:N ratio observed in Norwegian forests (?, ?). The direct litter fluxes, together with microbial necromass (C13-C24,N13-N24) and a flux representing EcM enzyme production (C27) are the sources of input to the

SOM pools. The microbial pools determines the rates of decomposition, and thereby the transfer rates between the main storage pools, SOM and litter.

0.2.1 Microbial processes

We separate between saprotrophic fungi (SAPf; analog to MIMICS k-strategists) and bacteria (SAPb; analog to MIMICS r-strategists). Temperature sensitive reverse Michaelis-Menten kinetics, together with a moisture modifier (?, ?), determines the rates at which saprotrophs decompose substrate from the two litter pools, and the available SOM (C5-C10,N5-N10). The N fluxes are determined from the C flux and the C:N ratio of the substrate pools. During decomposition, a fraction of the incoming C is lost from the soil as heterotrophic respiration (HR), while the rest is contributing to saprotrophic biomass. The respired fraction is determined by the Carbon Use Efficiencies CUE_b and CUE_f which have maximum values of 0.4 and 0.7 for bacteria and fungi respectively, but is reduced under low nutrient conditions. This is based on the theory that microbes adjust their efficiencies to maintain a relatively constant, low C:N ratio despite the higher C:N ratio of substrates (?, ?). The C:N ratio of the model saprotrophs is assumed to be constant ($CN_b = 5$ and $CN_f = 8$, Table A3). To ensure that this ratio is fulfilled in each layer and time step (in addition to potentially reduce CUE,) N is exchanged between the saprotrophs and the inorganic pools (N36 and N37). The exchange rates can be positive or negative, leading to either immobilization or mineralization of inorganic N. We first calculate the uptake and demand of N to determine if there is enough to meet the requirement for optimal saprotrophic decomposition.

$$N_{demand,x} = \frac{CUE_x \cdot (FC_{LITm,SAPx} + FC_{LITs,SAPx} + FC_{SOMa,SAPx})}{CN_x} \tag{1}$$

$$N_{uptake,x} = NUE \cdot (FN_{LITm,SAPx} + FN_{LITs,SAPx} + FN_{SOMa,SAPx}) \tag{2}$$

Here, x represents either b (bacteria) or f (fungi) and NUE is Nitrogen Use Efficiency, further described below. This calculation results in one of four possibilities:

1. The N demand is greater than the uptake for both bacteria and fungi, meaning both groups will immobilize inorganic N. In this case we check if there is enough available inorganic N to fulfill the demand from both groups. If not, CUE is reduced (according to Eq. 3 and 4) so that the saprotrophs utilize all N that is avail-

able to them, before the demand is recalculated. Here, N_{for_sap} is referring to the sum of the available N pools, $N_{NH4,sol}$ and N_{NO3}:

$$CUE_b = \frac{(f_b \cdot N_{for\_sap} + N_{uptake,b} \cdot dt) \cdot CN_b}{(FC_{LITm,SAPb} + FC_{LITs,SAPb} + FC_{SOMa,SAPb}) \cdot dt} \tag{3}$$

$$CUE_f = \frac{((1 - f_b) \cdot N_{for\_sap} + N_{uptake,f} \cdot dt) \cdot CN_f}{(FC_{LITm,SAPf} + FC_{LITs,SAPf} + FC_{SOMa,SAPf}) \cdot dt} \tag{4}$$

where f_b determines the division of the available inorganic N between bacteria and fungi, and is calculated as:

$$f_b = FN_{IN,SAPb}/(FN_{IN,SAPb} + FN_{IN,SAPf}) \tag{5}$$

This reduces the CUE (and increase the respired fraction) enough to maintain the C:N ratios under the prevailing conditions, and the resulting exchange rates is:

$$FN_{IN,SAPb} = f_b \cdot N_{for\_sap} \tag{6}$$

$$FN_{IN,SAPf} = (1 - f_b) \cdot N_{for\_sap} \tag{7}$$

2. N uptake is larger than demand for both saprotrophic groups, meaning both will mineralize inorganic N. The mineralized N will enter the $N_{NH4_{sol}}$ pool.
3. Fungi will mineralize N (uptake>demand), while bacteria immobilizes N (uptake<demand). In this case bacteria can access the N mineralized by fungi in addition to the inorganic N if needed.
4. Bacteria will mineralize N (uptake>demand), while fungi immobilizes N (uptake<demand). In this case fungi can access the N mineralized by bacteria in addition to the inorganic N if needed.

Saprotrophic necromass is transferred to the SOM pools, and is partitioned between the three pools based on clay content of the soil and the metabolic fraction of incoming litter (C13-C18 and N13-N18). Only a fraction of the N released during decomposition is available to saprotrophs, determined the Nitrogen Use Efficiency (constant NUE = 0.8, ? (?)). The remaining fraction is directly converted to inorganic $N_{NH4,sol}$.

The model represent two different types of mycorrhizal fungi: Ectomycorrhiza (EcM) and Arbuscular Mycorrhiza (AM). How the incoming carbon ($I_{veg,Myc}$, cf. C28 and C29 in Table A1) is partitioned between EcM and AM is determined dynamically through a Return Of Investment (ROI) function based on the method from ? (?). The partition between EcM and AM is determined by

$$f_{alloc,i} = \frac{ROI_i}{\Sigma_i ROI_i} \tag{8}$$

where ROI_i is the return of investment from mycorrhizal association i (EcM or AM);

$$ROI_i = \frac{N_{aquired,i} \cdot \tau_{myc,som} \cdot CUE_i}{C_i} \tag{9}$$

EcM acquires N from the protected SOM and inorganic N pools ($N_{aquired,EcM} = N25 + N26 + N27$) while AM only aquires inorganic N ($N_{aquired,AM} = N28$). See Fig. A1b and Table A2 for details. $\tau_{myc,som}$ is the mycorrhizal turnover time, while ϵ_i is the growth efficiency for mycorrhizal association i. N25 and N26 represent ectomycorrhizal mining (?, ?). By releasing enzymes (C27), EcM access N from SOM, and at the same time release C and make it available for the saprotrophs (C25 and C26). The mining algorithm is based on ? (?)

To ensure that the most efficient mining happens when the influx of C to mycorrhizal associations is largest, and to avoid that ectomycorrhiza provides "free" N to the plant during winter when C flux is assumed to be close to zero, we scale the mining rates (C25 and C26) according to the carbon input from the plants with a scaling factor;

$$r_{myc} = \frac{I_{veg,myc}(t)}{max(I_{veg,myc})} \tag{10}$$

Here, $I_{veg,myc}(t)$ $(gCm^{-2}hr^{-1})$ is the flux of C the vegetation will use on mycorrhizal N uptake (prescribed from CLM), and $max(I_{veg,myc})$ is the maximum value of $I_{veg,myc}$ in the current year. In the current off-line model version, $I_{veg,myc}(t)$ is taken from the CLM input, meaning it will not respond to changes is soil N availability. [Add something about how this can change when we couple?]

Constant mortality rates determine the transfer from mycorrhizal fungi to the SOM pools (C19-C24 and N19-N24).

0.2.2 Inorganic N processes

Inorganic N is divided between nitrate and ammonium dissolved in soil water (N_{NO3} and $N_{NH4,sol}$), and ammonium sorbed to soil particles ($N_{NH4,sorb}$). Reactive nitrogen from atmospheric deposition enters $N_{NH4,sol}$ (N32) where it can undergo nitrification to N_{NO3} (N34) or become sorbed (N35). N_{NO3} is exposed to leaching and runoff based on CLM algorithms (N31). Both dissolved pools, $N_{NH4,sol}$ and N_{NO3}, can be taken up by mycorrhizal fungi (N26,N27) or directly by plants (N33). Since the model is not coupled to above-ground vegetation, direct plant uptake is a constant loss rate in this model iteration. Within a time step, the different processes affecting inorganic N is calculated in a sequence: 1) Deposition, leaching and runoff 2) nitrification 3) N from decomposition 4) direct uptake by vegetation 5) uptake by mycorrhiza 6) exchange with saprotrophs 7) Sorption-desorption algorithm. The Sorption-desorption algorithm is based on ? (?) and described below.

Before pt. 7) the total concentration of ammonium is

$$N_{NH4,tot} = N_{NH4,sorp} + N_{NH4,sol} \tag{11}$$

Using Eq. 11 together with the Langmuir isotherm equation, we find the equilibrium partition between $N_{NH4,sol}$ and $N_{NH4,sorp}$ given the total amount $N_{NH4,tot}$. The Langmuir isotherm equation is given by

$$N_{NH4,sorp,eq} = \frac{NH4_{sorp,max} \cdot K_L' \cdot N_{NH4,sol,eq}}{1 + K_L' \cdot N_{NH4,sol,eq}} \tag{12}$$

where K_L' is a Langmuir constant related to adsorption energy, and a function of soil water content. $NH4_{sorp,max}$ is the maximum adsorption capacity. We assume that the system moves towards the equilibrium value during the timestep, via the following mechanism: [format equation better]

$$N_{NH4,sorp} =$$

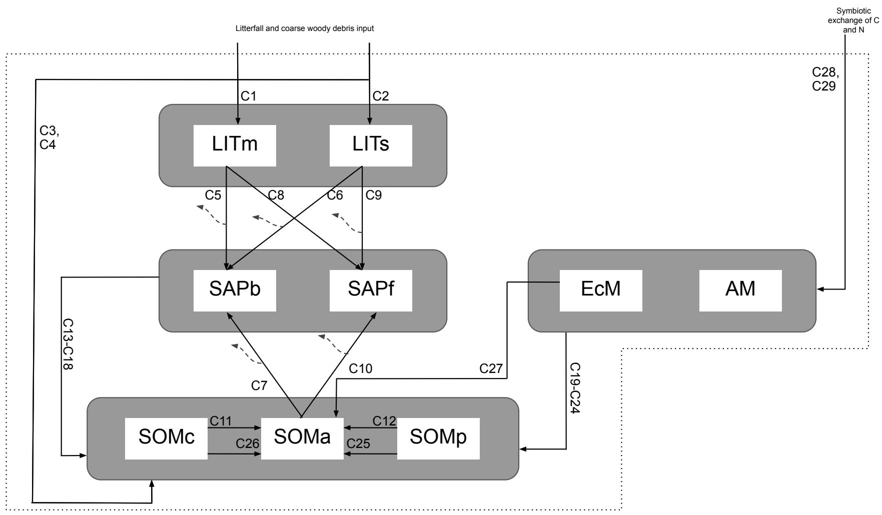
$$\begin{cases} N_{NH4,sorp,eq} - \frac{1}{\frac{1}{N_{NH4,sorp,eq} - NH4_{sorp,prev.}} + k \cdot \Delta t} & N_{NH4,sorp,eq} > N_{NH4,sorp,prev}, \\ N_{NH4,sorp,eq} + \frac{1}{\frac{1}{N_{NH4,sorp,prev} - N_{NH4,sorp,eq}} + k \cdot \Delta t} & N_{NH4,sorp,eq} < N_{NH4,sorp,prev}, \\ N_{NH4,sorp,prev} & N_{NH4,sorp,eq} = N_{NH4,sorp,prev} \end{cases} \tag{13}$$

Here k is a rate constant and Δt is the timestep. The top option corresponds to absorption, the middle option to desorption and the third if equilibrium is already reached. All parameter values are from ? (?), converted to appropriate model units.

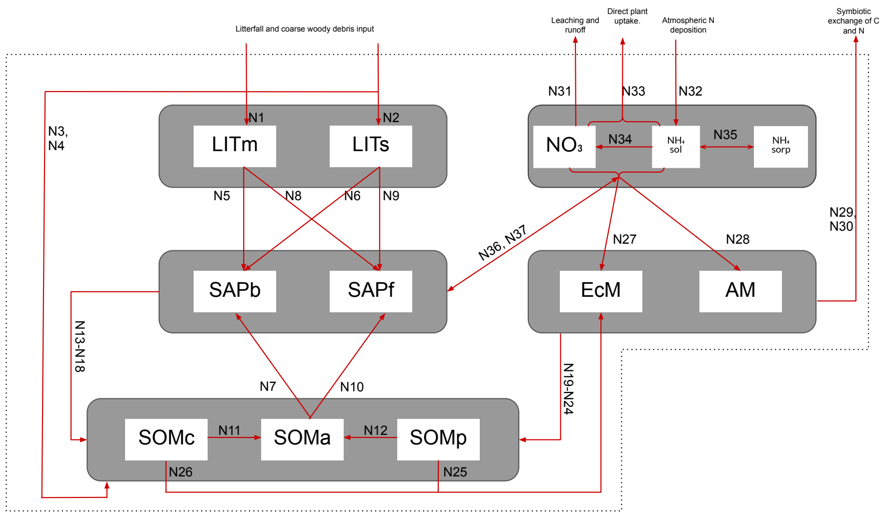
0.2.3 Vertical structure

The discrete vertical layers of the model follows the same structure as CLM (?, ?) with increasing layer thickness with depth. This allows incoming litter and and N deposition to be distributed following the same vertical profile as in CLM. We use vertically resolved soil temperature and soil moisture from CLM to force MIMICS+. We also use runoff and leaching rates from CLM to determine N leaching. Each layer includes a set of the pools described above (Fig. 1) . Within each time step the fluxes between the pools are calculated and applied first, then vertical transport is calculated and applied. This transport is calculated as a simple diffusion equation between adjacent layers (?, ?), using a diffusion coefficient from ? (?).

Appendix A Tables



(a) Schematic of carbon pools and flows for each layer in the model. The numbers indicated correspond to the expressions in Table A1.



(b) Schematic of nitrogen pools and flows for each layer in the model. The numbers indicated correspond to the expressions in Table A2 in the Appendix.

Figure A1: Illustration of the total system of pools and fluxes in the system, A1a shows the C flows while A1b show the N flows.

Table A1: Details about C fluxes in the model. The flux numbers corresponds to the arrows in Fig. A1a. The equation letters in the last column matches with those given in Table 1. All $FC_{donor,reciver}$ has units $gCm^{-3}h^{-1}$. Parameters are described in Table A3.

Eq.	Description	Flux Name	Rate functions	Used in eqn	Notes
C1	Metabolic litter from vegetation	$FC_{Veg,LITm} =$	$f_{met} \cdot I_C \cdot (1 - f_{met,SOM})$	(a)	
C2	Structural litter from vegetation	$FC_{Veg,LITs} =$	$((1 - f_{met}) \cdot I_C + CWD_C) \cdot (1 - f_{struct,SOM})$	(b)	
C3	Met. Lit to SOMp	$FC_{Veg,SOMp} =$	$f_{met} \cdot I_C \cdot f_{met,SOM}$	(g)	
C4	Struct. Lit to SOMc	$FC_{Veg,SOMc} =$	$((1 - f_{met}) \cdot I_C + CWD_C) \cdot f_{struct,SOM}$	(h)	
	<u>SAPb decomposition of:</u>				
C5	LITm to SAPb	$FC_{LITm,SAPb} =$	$C_{SAPb} \cdot V_{max1} \frac{C_{LITm}}{K_{m1}+C_{SAPb}}$	(a)(c)	Reverse MMK
C6	LITs to SAPb	$FC_{LITs,SAPb} =$	$C_{SAPb} \cdot V_{max2} \frac{C_{LITs}}{K_{m2}+C_{SAPb}}$	(b)(c)	Reverse MMK
C7	SOMa to SAPb	$FC_{SOMa,SAPb} =$	$C_{SAPb} \cdot V_{max3} \frac{C_{SOMa}}{K_{m3}+C_{SAPb}}$	(i)(c)	Reverse MMK
	<u>SAPf decomposition of:</u>				
C8	LITm to SAPf	$FC_{LITm,SAPf} =$	$C_{SAPf} \cdot V_{max4} \frac{C_{LITm}}{K_{m4}+C_{SAPf}}$	(a)(d)	Reverse MMK
C9	LITs to SAPf	$FC_{LITs,SAPf} =$	$C_{SAPf} \cdot V_{max5} \frac{C_{LITs}}{K_{m5}+C_{SAPf}}$	(b)(d)	Reverse MMK
C10	SOMa to SAPf	$FC_{SOMa,SAPf} =$	$C_{SAPf} \cdot V_{max6} \frac{C_{SOMa}}{K_{m6}+C_{SAPf}}$	(i)(d)	Reverse MMK
	<u>Desorption and oxidation:</u>				
C11	Oxidation from SOMc to SOMa	$FC_{SOMc,SOMa} =$	$\frac{C_{SAPf} \cdot V_{max2} \cdot C_{SOMc}}{KO \cdot K_{m2}+C_{SAPb}} + \frac{C_{SAPb} \cdot V_{max5} \cdot C_{SOMc}}{KO \cdot K_{m5}+C_{SAPf}}$	(h)(i)	As in MIMICS
C12	Desorption from SOMp to SOMa	$FC_{SOMp,SOMa} =$	$C_{SOMp} \cdot k_{desorp}$	(g)(i)	As in MIMICS

Continued on next page

Table A1 – Continued from previous page

Eq.	Description	Flux Name	Rate functions	Used in eqn	Notes
	Saprotrophic bacteria necromass to:				
C13	SOMp	$FC_{SAPb,SOMp} =$	$C_{SAPb} \cdot k_{SAPb,som} \cdot f_{SAPb,SOMp}$	(c)(g)	
C14	SOMc	$FC_{SAPb,SOMc} =$	$C_{SAPb} \cdot k_{SAPb,som} \cdot f_{SAPb,SOMc}$	(c)(h)	
C15	SOMa	$FC_{SAPb,SOMa} =$	$C_{SAPb} \cdot k_{SAPb,som} \cdot f_{SAPb,SOMa}$	(c)(i)	
	Saprotrophic fungi necromass to:				
C16	SOMp	$FC_{SAPf,SOMp} =$	$C_{SAPf} \cdot k_{SAPf,som} \cdot f_{SAPf,SOMp}$	(d)(g)	
C17	SOMc	$FC_{SAPf,SOMc} =$	$C_{SAPf} \cdot k_{SAPf,som} \cdot f_{SAPf,SOMc}$	(d)(h)	
C18	SOMa	$FC_{SAPf,SOMa} =$	$C_{SAPf} \cdot k_{SAPf,som} \cdot f_{SAPf,SOMa}$	(d)(i)	
	Ectomycorrizal necromass to:				
C19	SOMp	$FC_{EcM,SOMp} =$	$C_{EcM} \cdot k_{myc,som} \cdot f_{EcM,SOMp}$	(e)(g)	
C20	SOMc	$FC_{EcM,SOMc} =$	$C_{EcM} \cdot k_{myc,som} \cdot f_{EcM,SOMc}$	(e)(h)	
C21	SOMa	$FC_{EcM,SOMa} =$	$C_{EcM} \cdot k_{myc,som} \cdot f_{EcM,SOMa}$	(e)(i)	
	Arbuscular mycorrizal necromass to:				
C22	SOMp	$FC_{AM,SOMp} =$	$C_{AM} \cdot k_{myc,som} \cdot f_{AM,SOMp}$	(f)(g)	
C23	SOMc	$FC_{AM,SOMc} =$	$C_{AM} \cdot k_{myc,som} \cdot f_{AM,SOMc}$	(f)(h)	
C24	SOMa	$FC_{AM,SOMa} =$	$C_{AM} \cdot k_{myc,som} \cdot f_{AM,SOMa}$	(f)(i)	
	Mycorrhiza related fluxes:				

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Table A1 – Continued from previous page

Eq.	Description	Flux Name	Rate functions	Used in eqn	Notes
C25	C made available by mining	$FC_{EcMdecompSOMp} =$	$K_{MO} \cdot H \cdot C_{EcM} \cdot C_{SOMp} \cdot r_{myc}$	(g)(i)	Baskaran + mining term
C26	C made available by mining	$FC_{EcMdecompSOMc} =$	$K_{MO} \cdot H \cdot C_{EcM} \cdot C_{SOMc} \cdot r_{myc}$	(h)(i)	Baskaran + mining term
C27	EcM enzyme production	$FC_{enzEcM,SOMa} =$	$f_{enz} \cdot CUE_m \cdot FC_{Veg,EcM}$	(e)(i)	Fraction of input goes directly to enzyme prod.
C28	EcM	$FC_{Veg,EcM} =$	$f_{alloc,EcM} \cdot I_{veg,Myc}$	(e)	
C29	AM	$FC_{Veg,AM} =$	$f_{alloc,AM} \cdot I_{veg,Myc}$	(f)	

Table A2: Details about N fluxes in the model. The flux numbers corresponds to the arrows in Fig. A1b. The equations in the last column matches with those given in Table 2. Parameters are described in Table A3.

Eq.	Description	Flux Name	Rate functions	Used in eqn	Notes
	Litter input				
N1	Metabolic litter from vegetation	$FN_{Veg,LITm} =$	$f_{met} \cdot I_N \cdot (1 - f_{met,SOM})$	(a)	
N2	Structural litter from vegetation	$FN_{Veg,LITs} =$	$((1 - f_{met}) \cdot I_N + CWD_N) \cdot (1 - f_{struct,SOM})$	(b)	
N3	Met. Lit to SOMp	$FN_{Veg,SOMp} =$	$f_{met} \cdot I_C \cdot f_{met,SOM}$	(g)	
N4	Struct. Lit to SOMc	$FN_{Veg,SOMc} =$	$((1 - f_{met}) \cdot I_N + CWD_N) \cdot f_{struct,SOM}$	(h)	
	SAPb decomposition of:				
N5	LITm	$FN_{LITm,SAPb} =$	$FC_{LITm,SAPb} \cdot \left(\frac{N_{LITm}}{C_{LITm}}\right)$	(j)(l)	as in MIMICS
N6	LITs	$FN_{LITs,SAPb} =$	$FC_{LITs,SAPb} \cdot \left(\frac{N_{LITs}}{C_{LITs}}\right)$	(k)(l)	as in MIMICS
N7	SOMa	$FN_{SOMa,SAPb} =$	$FC_{SOMa,SAPb} \cdot \left(\frac{N_{SOMa}}{C_{SOMa}}\right)$	(r)(l)	as in MIMICS
	SAPf decomposition of:				
N8	LITm	$FN_{LITm,SAPf} =$	$FC_{LITm,SAPf} \cdot \left(\frac{N_{LITm}}{C_{LITm}}\right)$	(j)(m)	as in MIMICS
N9	LITs	$FN_{LITs,SAPf} =$	$FC_{LITs,SAPf} \cdot \left(\frac{N_{LITs}}{C_{LITs}}\right)$	(k)(m)	as in MIMICS
N10	SOMa	$FN_{SOMa,SAPf} =$	$FC_{SOMa,SAPf} \cdot \left(\frac{N_{SOMa}}{C_{SOMa}}\right)$	(r)(m)	as in MIMICS
	Desorption and oxidation:				

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Table A2 – Continued from previous page

Eq.	Description	Flux Name	Rate functions	Used in eqn	Notes
N11	Oxidation	$FN_{SOMc,SOMa} =$	$FC_{SOMc,SOMa} \cdot \left(\frac{N_{SOMc}}{C_{SOMc}}\right)$	(q)(r)	
N12	Desorption	$FN_{SOMp,SOMa} =$	$FC_{SOMp,SOMa} \cdot \left(\frac{N_{SOMp}}{C_{SOMp}}\right)$	(p)(r)	
	<u>Saprotrophic bacteria necromass to:</u>				
N13	SOMp	$FN_{SAPb,SOMp} =$	$FC_{SAPb,SOMp} \cdot \left(\frac{N_{SAPb}}{C_{SAPb}}\right)$	(l)(p)	
N14	SOMc	$FN_{SAPb,SOMc} =$	$FC_{SAPb,SOMc} \cdot \left(\frac{N_{SAPb}}{C_{SAPb}}\right)$	(l)(q)	
N15	SOMa	$FN_{SAPb,SOMa} =$	$FC_{SAPb,SOMa} \cdot \left(\frac{N_{SAPb}}{C_{SAPb}}\right)$	(l)(r)	
	<u>Saprotrophic fungi necromass to:</u>				
N16	SOMp	$FN_{SAPf,SOMp} =$	$FC_{SAPf,SOMp} \cdot \left(\frac{N_{SAPf}}{C_{SAPf}}\right)$	(m)(p)	
N17	SOMc	$FN_{SAPf,SOMc} =$	$FC_{SAPf,SOMc} \cdot \left(\frac{N_{SAPf}}{C_{SAPf}}\right)$	(m)(q)	
N18	SOMa	$FN_{SAPf,SOMa} =$	$FC_{SAPf,SOMa} \cdot \left(\frac{N_{SAPf}}{C_{SAPf}}\right)$	(m)(r)	
	<u>Ectomycorrhizal necromass to:</u>				
N19	SOMp	$FN_{EcM,SOMp} =$	$FC_{EcM,SOMp} \cdot \left(\frac{N_{EcM}}{C_{EcM}}\right)$	(n)(p)	
N20	SOMc	$FN_{EcM,SOMc} =$	$FC_{EcM,SOMc} \cdot \left(\frac{N_{EcM}}{C_{EcM}}\right)$	(n)(q)	
N21	SOMa	$FN_{EcM,SOMa} =$	$FC_{EcM,SOMa} \cdot \left(\frac{N_{EcM}}{C_{EcM}}\right)$	(n)(r)	
	<u>Arbuscular mycorrhizal necromass to:</u>				
N22	SOMp	$FN_{AM,SOMp} =$	$FC_{AM,SOMp} \cdot \left(\frac{N_{AM}}{C_{AM}}\right)$	(o)(p)	
N23	SOMc	$FN_{AM,SOMc} =$	$FC_{AM,SOMc} \cdot \left(\frac{N_{AM}}{C_{AM}}\right)$	(o)(q)	

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Table A2 – Continued from previous page

Eq.	Description	Flux Name	Rate functions	Used in eqn	Notes
N24	SOMa	$FN_{AM,SOMa} =$	$FC_{AM,SOMa} \cdot \left(\frac{N_{AM}}{C_{AM}}\right)$	(o)(r)	
	<u>Mycorrhiza related fluxes:</u>				
N25	N aquired from SOMp	$FN_{SOMp,EcM} =$	$FC_{EcMdecompSOMp} \cdot \left(\frac{N_{SOMp}}{C_{SOMp}}\right)$	(g)(e)	
N26	N aquired from SOMc	$FN_{SOMc,EcM} =$	$FC_{EcMdecompSOMc} \cdot \left(\frac{N_{SOMc}}{C_{SOMc}}\right)$	(h)(e)	
N27	N from inorganic to EcM	$FN_{IN,EcM} =$	$V_{max,myc} \cdot N_{IN} \cdot \left(\frac{C_{EcM}}{(C_{EcM}+K_{m,myc}/H)}\right) \cdot r_{myc}$	(s)(u)(n)	? (?)
N28	N from inorganic to AM	$FN_{IN,AM} =$	$V_{max,myc} \cdot N_{IN} \cdot \left(\frac{C_{AM}}{(C_{AM}+K_{m,myc}/H)}\right) \cdot r_{myc}$	(s)(u)(o)	
	<u>N from myc. fungi to plant:</u>				See main text for details
N29	EcM	$FN_{EcM,Veg} =$	$(FN_{IN,EcM} + FN_{SOMc,EcM} + FN_{SOMp,EcM})$	(n)	
			$-CUE_{EcM} \cdot FC_{Veg,EcM} \cdot (1 - f_{enz})/CN_{EcM}$		
			or lower, if N limited (reduced CUE)		
N30	AM	$FN_{AM,Veg} =$	$FN_{IN,AM} - CUE_{AM} \cdot FC_{Veg,AM}/CN_{EcM}$	(o)	
			or lower, if N limited (reduced CUE)		
	<u>Inorganic N related:</u>				
N31	Leaching	$FN_{run+leach} =$	$N_{NO3} \cdot \left(\frac{QDRAI}{H_2O_{tot}} + \frac{QRUNOFF}{H2O_{top5cm}}\right)$	(u)	See CTSM doc. 2.22.6
N32	Deposition	$FN_{DEP} =$	$NDEP\_TO\_SMINN \cdot NDEP\_PROF_j$	(s)	
N33	Direct plant uptake	$FN_{Inorg,Veg} =$	$(N_{NH4} + N_{NO3}) \cdot k_{uptake}$	(s)(u)	

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Table A2 – Continued from previous page

Eq.	Description	Flux Name	Rate functions	Used in eqn	Notes
N34	Nitrification	$FN_{NH4,NO3} =$	$NH4 \cdot k_{nitr}$ or	(s)(u)	based on CTSM doc.
			zero if temp. is below freezing		chapter 2.22.5
N35	Equil. kinetics NH4	$FN_{sol,sorp} =$			
Exchange of N between saprotrophic pools and inorg. N:					See main text for details
	Here $U_{S*} = FC_{LITm,SAP*} + FC_{LITs,SAP*} + FC_{SOMa,SAP*}$, * is B or F.				
N36	SAPb	$FN_{IN,SAPb} =$	$(1 - NUE) \cdot (FN_{LITm,SAPb} + FN_{LITs,SAPb} +$		
			$FN_{SOMa,SAPb}) - CUE_b \cdot U_{SB} / CN_b$	(l)(u)(s)	
		or =	$f_b \cdot N_{for\_sap}$ if limited N		
N37	SAPf	$FN_{IN,SAPf} =$	$(1 - NUE) \cdot (FN_{LITm,SAPf} + FN_{LITs,SAPf} +$		
			$FN_{SOMa,SAPf}) - CUE_f \cdot U_{SF} / CN_f$	(m)(u)(s)	
		or =	$(1 - f_b) \cdot N_{for\_sap}$ if limited N		

[for mycorrizal turnover rates, Baskaran refers to Edblad 2013, which gives 0.1/year?]

Table A3: Description of parameters and other relevant sizes used in the model.

Parameter	Description	Value	Units	Notes
f_{met}	Met. frac. of plant litter	0.0-1.0	-	(?, ?)
f_{clay}	Clay fraction in soil	0.0-1.0	-	
T	Soil temperature	-	$^{\circ}C$	Vary with season and depth
Michaelis Menten kinetics param. for SAP: ? (?), ? (?)				
V_{max}	Max reaction velocity	$exp(V_{slope} \cdot T + V_{int}) \cdot a_V \cdot V_{mod} \cdot r_{moist}$	$mg(mg)^{-1}h^{-1}$	
K_m	Half saturation constant	$exp(K_{slope} \cdot T + K_{int}) \cdot a_K \cdot K_{mod}$	$mgCcm^{-3}$	
K_{slope}	Regression coefficient	lit: 0.017, SOMa: 0.027	$ln(mgCcm^{-3})^{\circ}C^{-1}$	For all 6 fluxes
V_{slope}	Regression coefficient	0.063	$ln(mg(mg)^{-1}h^{-1})^{\circ}C^{-1}$	For all 6 fluxes
K_{int}	Regression intercept	3.19	$ln(mgCcm^{-3})$	Directly (?, ?)
V_{int}	Regression intercept	5.47	$ln(mg(mg)^{-1}h^{-1})$	Directly (?, ?)
a_V	Tuning coefficient	$1.25 \cdot 10^{-8}$	-	
P	Physical protection scalar used in K_{mod}	$1/(2.0 \cdot exp(-2\sqrt{f_{CLAY}}))$	-	range: 0.5-3.7

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Parameter	Description	Value	Units	Notes
$a_K \cdot K_{mod}$	Tuning coefficients	$1.953125, 7.81250, 3.90625 \cdot P,$ $7.8125, 3.90625, 2.604167 \cdot P$		As in MIMICS CLM version for LITm, LITs, SOMa
V_{mod}	Modifies V_{max}	$10.0, 3.0, 10.0, 3.0, 5.0, 2.0$	-	for LITm, LITs, SOMa entering SAPb, SAPf
KO	Increase Km in eq. C11	6	-	(?, ?)
$k_{myc,som}$	Turnover rate	$1.14 \cdot 10^{-4}$	h^{-1}	1/year as ? (?) and ? (?)
$k_{SAPb,som}$	Turnover rate of SAPb	$5.2 \cdot 10^{-4} \cdot exp(0.3 \cdot f_{met}) \cdot$ $max(p_{mod}, m_{mod})$	h^{-1}	
$k_{SAPf,som}$	Turnover rate of SAPf	$2.4 \cdot 10^{-4} \cdot exp(0.1 \cdot f_{met}) \cdot$ $max(p_{mod}, m_{mod})$	h^{-1}	
	p_{mod} scales with root profile, $m_{mod} = 0.1$ is the minimum value of the modifier. m_{mod} is used when $T < 0$			
k_{desorp}	desorption rate	$1.5 \cdot 10^{-5} \cdot exp(-1.5 \cdot f_{clay})$	h^{-1}	? (?)
K_{MO}	Mycorrhizal decay rate constant for oxidizable store	$3.42 \cdot 10^{-7}$	$m^2/(gC \cdot hr)$	? (?)

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Table A3 – Continued from previous page

Parameter	Description	Value	Units	Notes
$V_{max,myc}$	Max. mycorrhizal uptake of inorg N	$2.05 \cdot 10^{-4}$	$g/(g \cdot hr)$	? (?) for EcM, we also use it for AM
$K_{m,myc}$	Half saturation constant of ectomycorrhizal uptake of inorg N	0.08	gN/m^2	(?, ?) for EcM, we also use it for AM
CUE_{EcM}	Growth efficiency of mycorrhiza	0 - 0.5	-	? (?)
CUE_{AM}	Growth efficiency of mycorrhiza	0 - 0.5	-	? (?)
CUE_b	Growth efficiency of sap. bacteria	0 -0.4	-	Determined by N availability
CUE_f	Growth efficiency of sap. fungi	0 -0.7	-	Determined by N availability
NUE	Nitrogen use efficiency of saprotrophs	0.7	-	Assumed
r_{moist}	Moisture function	0.05-1	-	
r_{myc}	Mycorrhizal modifier	0-1	-	
$f_{SAPb,SOMp}$	Frac. necromass into SOMp	$0.3 \cdot exp(1.3 \cdot f_{clay})$	-	
$f_{SAPb,SOMc}$	Frac. necromass into SOMc	$0.1 \cdot exp(-3 \cdot f_{met})$	-	
$f_{SAPb,SOMa}$	Frac. necromass into SOMa	$1 - (f_{SAPb,SOMp} + f_{SAPb,SOMc})$	-	
$f_{SAPf,SOMp}$	Frac. necromass into SOMp	$0.2 \cdot exp(0.8 \cdot f_{clay})$	-	
$f_{SAPf,SOMc}$	Frac. necromass into SOMc	$0.3 \cdot exp(-3 \cdot f_{met})$	-	
$f_{SAPf,SOMa}$	Frac. necromass into SOMa	$1 - (f_{SAPf,SOMp} + f_{SAPf,SOMc})$	-	

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Parameter	Description	Value	Units	Notes
$f_{EcM,SOMp}$	Frac. necromass into SOMp	0.4	-	Assumed
$f_{EcM,SOMc}$	Frac. necromass into SOMc	0.2	-	Assumed
$f_{EcM,SOMa}$	Frac. necromass into SOMa	0.4	-	Assumed
$f_{AM,SOMp}$	Frac. necromass into SOMp	0.3	-	Assumed
$f_{AM,SOMc}$	Frac. necromass into SOMc	0.4	-	Assumed
$f_{AM,SOMa}$	Frac. necromass into SOMa	0.3	-	Assumed
f_{enz}	Frac. of EcM C uptake used for enzyme prod.	0.10	-	Assumed
f_{use}	Frac. C released by mining taken up by EcM.	0.10	-	Assumed
$f_{alloc,i}$	Frac. of C from plant alloc. to myc. i	0-1	-	See Sec. 0.2.1
$f_{met,SOM}$	Frac. of metabolic litter prod.	0.1	-	
	going directly to SOMp			
$f_{struct,SOM}$	Frac. of structural litter prod.	0.3	-	
	going directly to SOMc			
H	Soil depth (column height)		m	Depth of active layers in CLM
I_C, I_N	Litter and fine root C and N input	$FROOT*\_TO\_LIT \cdot FROOT\_PROF$		
		$+LEAF*\_TO\_LIT \cdot LEAF\_PROF$	$g*/m3h$	*: C or N
CWD_C,	Coarse woody debris C and N input	CWD*_TO_LITR2,	$g*/m3h$	*: C or N

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Table A3 – Continued from previous page

Parameter	Description	Value	Units	Notes
		CWD*_TO_LITR3		
CWD_N				
D	Diffusion coefficient	$1.14 \cdot 10^{-8}$[c1]	m^2/hr	$1cm^2/yr$, ? (?)
CN_b	Optimal CN ratio for bacteria	5	-	? (?)
CN_f	Optimal CN ratio for sap. fungi	8	-	? (?)
CN_m	Optimal CN ratio for myc. fungi	20	-	? (?)
BD_{soil}	Soil Bulk density	$1.6 \cdot 10^6$	g/m^3	? (?)
$NH4_{sorp,max}$	Max. adsorption capacity	$0.09 \cdot BD_{soil}/(10^3 mg/g)$=144	$mgNH4/gsoil$	? (?)
$K_L^{'}$	Modified Lagmuir constant	$0.4/soil\_water\_frac$	$m3/g$	
k_{pseudo}	Rate constant		$m^3/(g \cdot hr)$	

[c0] 1/3 of this value for $N_{NH4,sorp}$

Table A4

CLM-BGC variable	Units	Long name	Notes
LEAFC_TO_LITTER	$gCm^{-2}s^{-1}$	leaf C litterfall	Partitioned between the two litter pools based on f_{MET}.
FROOTC_TO_LITTER	$gCm^{-2}s^{-1}$	fine root C litterfall	Partitioned between the two litter pools based on f_{MET}
CWDC_TO_LITR2C_vr	$gCm^{-3}s^{-1}$	decomp. of coarse woody debris C to litter 2 C	Input to structural litter (LITs)
CWDC_TO_LITR3C_vr	$gCm^{-3}s^{-1}$	decomp. of coarse woody debris C to litter 3 C	Input to structural litter (LITs)
LEAFN_TO_LITTER	$gNm^{-2}s^{-1}$	leaf N litterfall	Partitioned between the two litter pools based on f_{MET}
FROOTN_TO_LITTER	$gNm^{-2}s^{-1}$	fine root N litterfall	Partitioned between the two litter pools based on f_{MET}
CWDN_TO_LITR2N_vr	$gNm^{-3}s^{-1}$	decomp. of coarse woody debris N to litter 2 N	Input to structural litter (LITs)
CWDN_TO_LITR3N_vr	$gNm^{-3}s^{-1}$	decomp. of coarse woody debris N to litter 3 N	Input to structural litter (LITs)
NPP_NACTIVE	$gCm^{-2}s^{-1}$	Mycorrhizal N uptake used C (WRONG??)	First subtract NPP_NNONMYC, then partition between EcM and AM based on $f_{alloc,i}$
NPP_NNONMYC	$gCm^{-2}s^{-1}$	Non-mycorrhizal N uptake used C	Subtracted from NPP_NACTIVE
NDEP_TO_SMINN	$gNm^{-2}s^{-1}$	atmospheric N deposition to soil mineral N	N deposition to NH4 pool
LEAF_PROF	m^{-1}	profile for litter C and N inputs from leaves	Multiplied with LEAF_TO_LITTER to get rates for each depth layer, $gm^{-3}s^{-1}$
FROOT_PROF	m^{-1}	profile for litter C and N inputs from fine roots	Multiplied with FROOT_TO_LITTER to get rates for each depth layer, $gm^{-3}s^{-1}$
NDEP_PROF	m^{-1}	profile for atmospheric N deposition	Multiplied with NDEP_TO_SMINN to get

			deposition for each depth layer, $gNm^{-3}s^{-1}$
Environmental variables:			
TSOI	K	soil temperature	Converted to $°C$
WATSAT	mm^3mm^{-3}	saturated soil water content (porosity)	Used for calculating r_{moist}
SOILLIQ	kgm^{-2}	soil liquid water	Used for calculating r_{moist}
SOILICE	kgm^{-2}	soil ice water	Used for calculating r_{moist}
W_SCALAR	-	Moisture (dryness) inhibition of decomposition	Used in nitrification algorithm
T_SCALAR	-	temperature inhibition of decomposition	Used in nitrification algorithm
QDRAI	mms^{-1}	sub-surface drainage	Used for calculating leaching
QOVER	mms^{-1}	surface runoff	Used for calculating Runoff
nbedrock	mm^3mm^{-3}	index of shallowest bedrock layer	for determining how many layers to use in the simulations
Read from surface data file:			
PCT_CLAY	-	percent CLAY	
PCT_NAT_PFT	-	percent plant functional type on the natural veg landunit	