TREES Model Introduction

D. Scott Mackay, December 16, 2020

The Terrestrial Regional Ecosystem Exchange Simulator (TREES) is a dynamic biophysical processbased simulation model. It is designed for simulating land-based systems, it uses leaf area and ground area as scalars, and so the model can be used at plant, stand, or landscape (regional) scales without any modification to the model code. TREES solves vertical, one-dimensional processes from a lower boundary, e.g. impermeable bedrock layer, to the atmosphere within the turbulent boundary layer of vegetation (see **Box 1**). This type of model is commonly called a soil-vegetation-atmosphere transfer (SVAT) model, but TREES has a few tricks that distinguish it from many other 1-D vegetation models. First, it couples canopy processes (e.g., stomatal conductance, photosynthesis, and transpiration) to a soilplant hydraulic system that supports cavitation in the plant xylem. This gives the model the ability to retain a memory of successive drought exposure on plants, and enables it to predict a wide range of emergent physiological responses to stressors using observational data (Mackay et al., 2015; Tai et al., 2017; Johnson et al., 2018; McDowell et al., 2019; Wang et al., 2020). Second, a newer version of the model grows the canopy and roots as functions of resource (e.g., carbon and nitrogen) limitations, hydraulic limitations on water accessibility and transport of water and nutrients from roots to leaves, and non-structural carbon and amino acids from the canopy down to roots (Mackay et al., 2020). Third, a novel canopy growth model allows for linking genetic complexity and dynamic physiological responses to environmental conditions (Wang et al., 2019), which also provides an alternative growth model for annuals to use instead of the climate-driven canopy phenology (Savoy and Mackay, 2015) used for simulating perennials. Fourth, TREES is equipped with both C3 and C4 photosynthesis models. Fifth, nitrogen cycling components connect microbial processes (e.g., immobilization, ammonification, nitrification) to plant-mediated substrates (e.g., organic material turnover and root exudates), affected by soil temperature and hydraulic properties, within rhizospheres tied to root growth dynamics.

TREES is a dynamic model, which means it updates its states (or pools) at each time step based on fluxes of water, carbon, nitrogen, and a memory of the lowest predawn water potential to which the simulated xylem has been exposed. The model keeps track of carbon pools (e.g., leaf, stem, fine and course roots, non-structural carbon, amino acids, soil organic material, microbial biomass), nitrogen (e.g., organic, ammonium, nitrate, amino acids), and water in the soil in multiple layers. The model is forced with micrometeorological data (**Table 1**) at 30-minute time steps, and it is parameterized with two additional files (**Tables 2** and **3**). One file contains the parameters shown in **Table 2**, which allow for specification of site properties, physical traits of the plant canopy that influence energy transfers, biological traits for photosynthesis and hydraulics, soil physical properties, root growth traits, microbial traits, and traits associated with leaf growth. The second parameter file shown in **Table 3** provides a way of specifying the hydraulic architecture of the soil-plant system, including axial and lateral lengths, and initial proportional root areas in each layer. This "param mod" file has a

There are three output files (**Table 4-6**). The primary flux and pool outputs are shown in **Table 4**. Note that the number of columns in this output file depends on how many soil-root layers are defined (see **Table 3**). **Table 5** provides information that can be used to reconstruct the cavitation status of each element of the plant at each time step. Specifically, all the information needed to reconstruct maximum (cavitated) hydraulic conductance and how the vulnerability curves have been modified from their native forms as a result of water stress. **Table 6** reports on the growth of individual leaves when the individual leaf growth model is used.

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Box 1. High-level view of processes in TREES. Functions in blue involve soil or xylem hydraulics, and
those in red involve nitrogen cycling.
trees main.cpp
        Read in parameter files
        Open output files and write out headers
        Call simulator()
simulator.cpp
        Compute soil hydraulic properties
        Initialize state variables
        Initialize bqc()
        Initialize hvdraulicModel()
        Call hydraulic model setup()
        Time loop {
                 Read in one line from the driver file
                 Recall hydraulic model setup() to account for plant growth
                 Call simulation functions()
                 Write results to output files }
simulation functions.cpp
        Compute canopy phenology or leaf area growth, one of:
                compute GSI LAI() in process functions.cpp. or
                bgc.updateLeafCarbonNitrogenPools(), or
                bgc.updateLeaf()
        Call infiltration() sub-model in process functions.cpp
        Call aerodynamic conductance with stability corrections in process functions.cpp
        Compute canopy absorb rad() in process functions.cpp
        Compute root weighted soil water potential
        Compute water stress function used to scale initial Gs
        Call compute_canopy_evaporation() in process functions.cpp
        Loop until hydraulics converges {
                 First iteration, calc_gvc(4 parameters) initial guess in process_functions.cpp
                 Subsequently, call DoHydraulicModel() and calc_gvc(10 parameters)
                 Compute sun and shade leaf temperatures
                 Compute sun and shade photosynthesis, calling one of:
                          bgc.photosynthesis() or bgc.coupledA3 gc() or bgc.coupledA4 gc()
                 Compute revised sun and shade stomatal conductances
                 Call do pm() in process functions.cpp to compute transpiration for sun and shade
                 Compute sun and shade leaf surface vapor pressure deficits
                 Re-call aerodynamic conductance in process_functions.cpp }
        Compute rhizosphere fluxes
        Compute ground surface evaporation
        Compute transpiration removal from each rhizosphere
        Call capillary rise() in process functions.cpp
        Call bgc.storeGlycineAndSerine()
        Compute maintenance respiration and update NSC
        Compute cost of loading NSC into the phloem
        Compute growth potential
        Call bgc.computeLeafAllocation()
        Call bgc.updateStemCarbonNitrogenPools()
        Call bgc.updateRootCarbonNitrogenPools()
        Compute NSC needed for defense
        Compute the circadian control of chloroplast starch and sugar
        Call bgc.computeRootExudates()
        Call bgc.computeRootNitrogenUptake()
        Call bgc.computeLeaching()
        Call bgc.updateRhizospherePools()
        Compute total respiration, NPP, and NEE
        Compute snowmelt
        Call infiltration() in process functions.cpp
```

Table 1. Information on the TREES driver (time-series of micrometeorological data) used as forcing for the model. Note that TREES must have data in 30-minute time steps (= 48 time steps per day).

Input Column	Units	Description	Notes			
Date	YEARDAY	Using year as well as day the code will expect leap-years to have 366 days	For example, 2020300 is YEAR 2020 DAY 300			
Time	Half-hours	Starting at 0 (midnight), incrementing by 0.5, ending with 23.5 (11:30 pm) for each day The model expects 48 time steps per				
u_ref	m s-1	Wind velocity at the reference height (assumed to be above the canopy)	This cannot have zeroes; model will force value > 0.0			
t_ref	deg C	Temperature at the reference height	This is a critical value to have			
d_ref	kPa	Vapor pressure deficit of the atmosphere at the reference height	This is a critical value to have			
precip	mm	Precipitation above the canopy or irrigation made directly to the soil surface	This is a critical value to have			
q_par	umol m-2 s-1	Incoming photosynthetically active radiation	This is a critical value to have			
t_canopy	deg C	Temperature within the canopy; use the same value as t_ref if you don't have this observation	n			
d_canopy	kPa	Vapor pressure deficit within the canopy; use d_ref if you don't have this observation				
p_atm	kPa	Atmospheric pressure observed at your location; can be computed from elevation	This is a critical value to have			
CO2_atm	ppm	Concentration of carbon dioxide in the atmosphere	This is a critical value to have			
T0	deg C	Temperature at the ground surface				
Tsurf	deg C	Temperature of the top soil layer				
Troot	deg C	Average temperature of the root zone				
Zw	m	Depth of the water table; can be used to provide a water source from below	This can be enabled or disabled in simulation_functions.c			
xylem scalar	unitless	Has been used for multiple purposes; currently, a 1.0 does nothing, 0.99 forces xylem refilling				
Carbon flux	umol m-2 s-1	Legacy column for use with the Bayesian MCMC algorithm	Use -999 if you have no data			
Water flux	mm 30min-1	Legacy column for use with the Bayesian MCMC algorithm	Use -999 if you have no data			
		Note: There can be no missing entries on a line				
		Also: Missing time steps will yield unexpected results, as the model uses location (.p file), da	te, and time to compute clear-sky radiation and day length			

Table 2. TREES parameters. Colors are used to distinguish parameters associated with each photosynthesis model, an older C3 Farquhar model, an experimental C3 model that includes novel nitrogen assimilation, and a C4 model.

Type Site	Value	Description Site Elevation	Units Meters	Parameter name in TREES code altitude	Typical Range	Representative Reference
Site	47.438	Site Elevation Latitude	Meters Degrees		0 - 30000 -90 - 90	
Site Site		Longitude Meteorological station reference height	Degrees Meters	longitude v and	-180 - 180	
Canopy	4.8	Leaf area index	m2 m-2	lai	0.05 - 10	
Canopy	20	Canopy height	Meters m2 m-2	canopy_height lai_at_full_canopy_height	0.05 - 10 0 - 100 0.05 - 10	
Canopy Canopy	1	Leaf area index at plant ful five nt Leaf angle distribution, verificative , spherical=1, horizontal>>1 Canceyo missivity Fraction of lifetice theam solar radiation that is photosynthetically active radiation Fraction of lifetice beam solar radiation that is photosynthetically active radiation Fraction of lifetiate polar radiation that is photosynthetically active radiation Fraction of lifetiate PRA Bubstrated	unitiess	Langle	0 - infinity 0.8 - 1.0	Campbell & Norman 1998
Canopy	0.97	Canopy emissivity Fraction of direct beam solar radiation that is photosynthetically active radiation	unitiess unitiess	Langle canopy_emissivity IPAR_beam		Campbell & Norman 1998 Campbell & Norman 1998
Canopy	0.5	Fraction of diffuse solar radiation that is photosynthetically active radiation	unitiess unitiess	PAR diff	0.5 - 0.5	Campbell & Norman 1998 Campbell & Norman 1998
Canopy			unitiess	PAR diff alpha_PAR alpha_NR	0.5 - 0.5 0.85 - 0.92 0.2 - 0.2	Campbell & Norman 1998
Canopy	0.5	Leaf clumping factor when viewed at nadir (<1 clumped; >1 uniform; 1 random)	unitiess unitiess		1 - 3.34	Campbell & Norman 1998 Campbell & Norman 1998
Canopy	0.67	Leaf culturing sum alique appointer (123 - 1049 * CroentLeptin Curowntainment) Halpforf this ame price adjustaments is a fraction of casepystery Halpforf this ame price adjustaments are largetion of promotion of the state of t	unitiess	d_factor	0.65 - 0.72	Campbell & Norman 1998 Campbell & Norman 1998
Canopy	0.1	Heat and vapor roughless length as a fraction of momentum roughness	unitiess	zh_factor	02-02	Campbell & Norman 1998
Photosynthesis Photosynthesis	0.01	Select photosynthesis model to use (1 = original C3; 2 = Experimental C3; C4) Dark respiration as a fraction of Vornax	integer unitess	ps_model, Rd_mult,	0.2 - 0.2 1, 2, or 3 0.001 - 0.05	von Caemmerer 2013 PC&E
Photosynthesis	1.85	Ratio of Jmax to Vcmax, for use with PS model 1	unitiess	Jmax_mult,	1.5 - 3.0	von Caemmerer 2013 PC&E
Photosynthesis Photosynthesis	0.3	Fixaci or i amate s votratik, fir tubu a wer'r or insteal. Curreluse parameter or votratik, or tubu a ver'r or insteal. Curreluse parameter yeld of photosynthistics for surtil kurses (wild wabkend) (Quantum yeld of photosynthistics for surtil kurses (wild subkend) (Quantum yeld of photosynthistics for surtil kurses (wild subkend) Leaf hologon concentration, for soft subkend per for folded to Leaf hologon for subkend for half is not alleved the form did if	unitiess mol e-/ mol photons	thetaJ, phiJ_sun,	0.7 - 0.9 0 - 0.5	von Caemmerer 2013 PC&E von Caemmerer 2013 PC&E
Photosynthesis Photosynthesis	0.3	Quantum yield of photosynthesis for shade leaves (well watered) Leaf nitropen concentration, for use with PS model 1	mol e-/mol photons kgN m-2 leaf	phiJ shd, Neaf	0 - 0.5 0.0001 - 0.003	von Caemmerer 2013 PC&E
		Fraction of Rubisco N that is not affected by N cycle, for use with PS model 1	unitiess	N_fixed_proportion	0 - 1	
Photosynthesis Photosynthesis	38.67764	Michaelis-Menten constant for carboxylase at 25 degree C	unitiess Pa	Kc25,	0.1 - 0.2	von Caemmerer 2013 PC&E
Photosynthesis	2.1	Q10 for ke	unitiess	Q_10		von Caemmerer 2013 PC&E
Photosynthesis Photosynthesis	1.2	Unit to the Menhalm constant for oxygeniase at 25 degree C (1010 for No. Michaelis-Menhalm constant for Rubisco activity at 25 degree C (1010 for Rubisco activity) (1010	unitiess	Ko25, Q_10		von Caemmerer 2013 PC&E
Photosynthesis Photosynthesis	3.6	Michaelis-Menten constant for Rubisco activity at 25 degree C Q10 for Rubisco activity	umol/mgRubisco/min unitiess	Rubisco q10act,		von Caemmerer 2013 PC&E von Caemmerer 2013 PC&E
Photosynthesis	30	Maximum Rubisco activity at 25 C, for use with PS models 2 and 3	umol m-2 s-1 umol m-2 s-1	Vcmax25,	10 - 200	
Photosynthesis Photosynthesis	50	Maximum PEP on mobile 2 airs 7 mobile 2 airs 7 mobile 3 airs 8 mobile 3 mob	umol m-2 s-1	Vpmax25, Jmax25,	10 - 500 15 - 600	von Caemmerer 2013 PC&E von Caemmerer 2013 PC&E
Photosynthesis Photosynthesis	38.6	CO2 compensation point at 25 C Michaelis-Menten constant of PEP carboxylase for CO2 at 25 C. PS model 3	umol Kρ25,	gammaStar25, Kp25		von Caemmerer 2013 PC&E von Caemmerer 2013 PC&E von Caemmerer 2013 PC&E
Photosynthesis Photosynthesis Photosynthesis	38	PEP regeneration rate, PS model 3 Correction for spectral quality of light, PS models 2 and 3	umol m-2 s-1 unitess	Vpr,		von Caemmerer 2013 PC&E von Caemmerer 2013 PC&E
Photosynthesis Photosynthesis	0.4	Partitioning factor of electron transport rate, for use with PS models 2 and 3	unitiess	×.	0 - 0.15	von Caemmerer 2013 PC&E
Photosynthesis Dhotosynthesis	0.92	Fraction of irradiance absorbed by mesophyll cells, PS models 2 and 3 Activation energy for the maximum carbonylation rate	unitiess k.i.mnl-1	absorptance, F. Vomay	0.85 - 0.92	von Caemmerer 2013 PC&E von Caemmerer 2013 PC&E
Photosynthesis Photosynthesis	70.373	Activation energy for the maximum PEP carboxylation rate	kJ mol-1 kJ mol-1 kJ mol-1	E_Vcmax, E_Vpmax, E_Jmax,		von Caemmerer 2013 PC&E von Caemmerer 2013 PC&E von Caemmerer 2013 PC&E
Photosynthesis Photosynthesis Photosynthesis	36.3	Activation energy for the Michaelis reaction of PEP		E_Kp, E_kc,		von Caemmerer 2013 PC&E von Caemmerer 2013 PC&E
Photosynthesis	59.36 35.94	Connection for special quality offsity, FP models 2 and 3 Perfections place of desire transportants, for our with PP models 2 and 3 Perfections place of desire transportants for our with PP models 2 and 3 Adultation energy for the maximum cateropistion rate. Adultation energy for the season of PP adultation energy for the season PP adultation energy for the season PP adultation energy for the Michaelian season of PPP adultation PPP Adultation energy for the Michaelian season of PPP adultation energy for the Michaelian energy for the Michaelian energy for the Michaelian energy for the Michaelian energy for the M	kJ mol-1	F kn		
Photosynthesis Photosynthesis	66.3	Activation energy for the Michaelis reaction of mitochondrial respiration	kJ mol-1 kJ mol-1	E_Rd, E_gammeStar,		von Caernmerer 2013 PC&E von Caernmerer 2013 PC&E von Caernmerer 2013 PC&E von Caernmerer 2013 PC&E
Photosynthesis Photosynthesis	1.78	Accession energy for the Michaelis reaction of the CO2 compensation point. Mesophyll conductance to CO2	noi m-2 s-1	gm,	0.5 - 3.0 0.003 - 0.003	von Caemmerer 2013 PC&E von Caemmerer 2013 PC&E
Photosynthesis Photosynthesis	0.003	Bundle sheath conductance to CO2 Fraction of physiciate partner (fuelted to physics shripe physics physics DC are \$1.2)	mol m-2 s-1 mol m-2 s-1 unitless	gbs, alphaGmax,	0.003 - 0.003	von Caemmerer 2013 PC&E Busch et al., 2017 Nature Plants
Photosynthesis Photosynthesis Photosynthesis	0.01	Buildia si selaiti controlatatios to CUD2 Sprinta mirrogi proteoragorianta, PS model 3 Faction of glopotatia curriero deveriante si sprinta atring photoragorianta, PS model 3 Faction of glopotatia curriero deveriante si selaiti si successivato, PS model 3 Maximum rate of de novo ristogra supply to the dislosopiast, PS model 3 Initial reference candro provingo supply to the dislosopiast, PS model 3 Initial reference candro conductance Sprintal reference candro conductance Sprintal reference candro conductance Sprintal reference candro provingo severage stomated conductance Sprintal reference candro conductance Sprintal reference candro conductance Sprintal reference candro conductance Sprintal reference conductance Sprintal reference conductance Sprintal reference Sprintal referen	unitiess	alphaSmax.		Busch et al., 2017 Nature Plants Busch et al., 2017 Nature Plants Busch et al., 2017 Nature Plants
Photosynthesis Diffusive Conductance	0.065	Maximum rate of de novo nitrogen supply to the chloroplast, PS model 3 Initial reference canopy average stomatal conductance	umol N m-2 s-1 mol m-2 s-1	Nmax, GSref0	0.01 - 1.0	Oren et al., 1999 PC&E
Diffusive Conductance Diffusive Conductance	0.59	Sensitivity of canopy average stomatal conductance to vapor pressure deficit	unitiess boolean	m isAmphistomatous,	0.01 - 1.0 0.45 - 0.59 0 or 1	Oren et al., 1999 PC&E Oren et al., 1999 PC&E
Soil-Plant Hydraulics Soil-Plant Hydraulics	-0.09	Booleain to define either typocolomitude (ef) or amphitimentate (e1) tauses Diagnetists to these faurel water person that mere positive than this value Diagnetists to these faurel water person that is mere positive than this value Tennepriment of the section of	MPa			Sperry et al., 1998 PC&E Sperry et al., 1998 PC&E
Soil-Plant Hydraulics Soil-Plant Hydraulics	-1.37 1.50	Midday leaf water potential at saturated hydraulic conductance Transpiration at saturated hydraulic conductance	MPa mmol m-2 s-1		-1.03.0 0.1 - 10.0	Sperry et al., 1998 PC&E Sperry et al., 1998 PC&E
Soil-Plant Hydraulics Soil-Plant Hydraulics Soil-Plant Hydraulics	3	Rhizosphere width (recommend using values between 3 and 5)	mm istoppe	e at saturated kl rhizosphere width (mm) solishells	0.1 - 10.0 3 - 5 2-6	Sperry et al., 1998 PC&E Sperry et al., 1998 PC&E Sperry et al., 1998 PC&E Sperry et al., 1998 PC&E
Soil-Plant Hydraulics	0.025	Number of soil shells in the rhizospheres (1 to 8) Geometric mean soil particle diameter	integer mm	GMP	0.001 - 1.0	Sperry et al., 1998 PC&E
Soil-Plant Hydraulics Soil-Plant Hydraulics	18	Geometric standard deviation of soil particle size Soil bulk density	mm MG m-3	GSD BD	2 - 32 0.7 - 1.7	Campbell 1985 Campbell 1985
Soil-Plant Hydraulics Soil-Plant Hydraulics Soil-Plant Hydraulics	0.76	Soil porosity Still fraction	unitiess unitiess	porosity silt fraction	0.7 - 1.7 0.35 - 0.75 0.01 - 0.7999	Rawls et al 1994 Rawls et al 1994
Soil-Plant Hydraulics Soil-Plant Hydraulics			unitiess unitiess	sit_fraction day_fraction	0.01 - 0.7999 0.01 - 0.7999	Rawis et al 1994 Rawis et al 1994
Soil-Plant Hydraulics Soil-Plant Hydraulics	0.04	Casy interests Residual water content Fraction of absorbing length of lateral roots (usually keep at 1)	unitiess	residual	0.02 - 0.12	Rawls et al 1994 van Genuchten et al., 1981 Sperry et al., 1998 PC&E
Soil-Plant Hydraulics	0.01	Praction of absorbing length of lateral roots (usually keep at 1) Capacitance	molMpa*m2	trac_absorbing_length, Capacitance (mol/Mpa*m2) on le	0.01 - 0.1	
Soil-Plant Hydraulics Soil-Plant Hydraulics	1	Capacitance (usually keep at 1) Ratio of note axial to lateral hydrautic conductances (usually keep at 1) Ratio of not axial to lateral hydrautic conductances (usually keep at 1) Perioded for lateral stateman (in the note of lateral hydrautic conductance (usually keep at 1) Protected for lateral stateman (in the note of lateral hydrautic conductance (lateral hydrautic c	unitiess unitiess	frac, absorbing, langth, Capacitance (moltMpa*m2) on le- ack/latfor shoot modules, ackristfor not, modules, Stotal R. in, root system, pd. at sat kl. ax Shoot-b value (weibuili) ax Shoot-b value (weibuili)	1	Sperry et al., 1998 PC&E Sperry et al., 1998 PC&E Sperry et al., 1998 PC&E
Soil-Plant Hydraulics Soil-Plant Hydraulics	50	Percent of total resistance in the root system (typically use 50)	percent MPa	%total_R_in_root_system,	25 - 75	Sperry et al., 1998 PC&E
Soil-Plant Hydraulics Soil-Plant Hydraulics	3.84247	Predawn leaf water potential at saturated hydraulic conductance Axial shoot vulnerability curve Weibull b parameter	-MPa	pd_at_sat_kl ax_Shoot-b_value_(weibull)	1.2 - 6.0	Sperry et al., 1998 PC&E Sperry et al., 1998 PC&E Sperry et al., 1998 PC&E
Soil-Plant Hydraulics Soil-Plant Hydraulics	0.43333	Axial shoot vurnerability curve wellout c parameter			1.0 - 12.0	Sperry et al., 1998 PC&E Sperry et al., 1998 PC&E
Soil-Plant Hydraulics	6.43333	Labarial stood vulnerability curve Webuld b parameter Labarial stood vulnerability curve Webuld parameter Asial not vulnerability curve Webuld parameter Asial not vulnerability curve Webuld parameter Labarial not vulnerability curve Webuld parameter	unitiess	at Shoot-c value (weibull) ax Root-c value (weibull) ax Root-c value (weibull) at Root-c value (weibull) lat Root-c value (weibull)	1.0 - 12.0	Sperry et al., 1998 PC&E
Soil-Plant Hydraulics Soil-Plant Hydraulics Soil-Plant Hydraulics	3.84247	Axial root vulnerability curve Weibull b parameter	-MPa unitiess	ax Rooth value (weibull) ay Roote value (weibull)	1.2 - 6.0	Sperry et al., 1998 PC&E Sperry et al., 1998 PC&E Sperry et al., 1998 PC&E
Soil-Plant Hydraulics Soil-Plant Hydraulics	3.84247	Lateral root vulnerability curve Weibull b parameter	-MPa	lat Root-b value (weibull)	1.2 - 6.0	Sperry et al., 1998 PC&E Sperry et al., 1998 PC&E
Soil-Plant Hydraulics Soil-Plant Hydraulics			unitiess used	lat_Root-c_value_(weibull) initial_conductivity(root),	10-120	Sperry et al., 1998 PC&E Sperry et al., 1998 PC&E
Soil-Plant Hydraulics Soil-Plant Hydraulics	0.02	Decrement rate for computing saturated Ks of roots	default used	decrement(root)- initial conductivity(shoot),	20 - 80	Sperry et al., 1998 PC&E Sperry et al., 1998 PC&E
Soil-Plant Hydraulics	0.03	Interac constructions for computing substruction Science Computing substruction No criticols. Decrement rate for computing substruction K of rocks Initial conductive success and substruction Science Scienc	Used	decrement(shoot)		Sperry et al., 1998 PC&E
Respiration Respiration	0.22	Optimal soil water content (% of saturation) for soil respiration	unitiess degrees C	theta_opt optimal_soil_T	0.2 - 0.3 25 - 35	
Respiration Respiration	1	Growth respiration fraction of maximum (experimental, keep at 1) Root respiration coefficient	unitiess kg kg-1 day-1 deg	growth_resp_proportion resp_coef_root,	1	Waring and Running 1995
Respiration	0.0001	Stem respiration coefficient	kg kg-1 day-1 dag kg kg-1 day-1 dag	resp_coef_root, resp_coefficient_stem,		Waring and Running 1995 Waring and Running 1995 Waring and Running 1995 Waring and Running 1995
Respiration	0.0004	Stem respiration coefficient Leaf respiration coefficient Respiration coefficient Perspiration coefficient Perspiration coefficient 010 Persmetter for the DAMM model	kg kg-1 day-1 deg kg kg-1 day-1 deg degC-1 kgmol-1	resp coefficient stem, resp coefficient leat, resp coefficient EaSx,		Waring and Running 1995
Respiration	72.26	Parameter for the DAMM model	kimal-1	EaSx,		
Respiration Respiration	9.95E-07 5.38E-10	Parameter for the DAMM model Parameter for the DAMM model	mnCom-3soilh-1	MMsx,		Davidson et al., 2011 GCB Davidson et al. 2011 GCB
Microbiome Microbiome	0.00425	Microbial biomass mortality rate constant	days-1 m3 days-1 gC-1 m3 days-1 gC-1 m3 days-1 gC-1	kd,	0.001 - 0.01 0.4 - 0.8	Porporato et al., 2003 AWR Porporato et al., 2003 AWR
Microbiome Microbiome	0.16	Amino acid exudate microbial consumption rate constant	m3 days-1 gC-1	kes,	0.4 - 0.0	P GEPORAL BEAR , 2003 AVIII
Microbiome Microbiome	0.000065	reterrecessor rate consum: Amino acid excelstate microbial consumption rate constant Sugar axudate microbial consumption rate constant Labilic carbon (Hater) microbial consumption rate constant Recololirant carbon (humas) microbial consumption rate constant	m3 days-1 gC-1 m3 days-1 gC-1 m3 days-1 gC-1	Nes, M,		Porporato et al., 2003 AWR Porporato et al., 2003 AWR
Microbiome Microbiome Carbon and Nitrogen			m3 days-1 gC-1 kgC kgN-1	kh, fr.minCN,	10 - 200	Porporato et al., 2003 AWR
Carbon and Nitrogen Carbon and Nitrogen	55	Frie root mentrum carbon introgen ratio Frie root mealiment carbon introgen ratio Leaf minimum carbon nitrogen ratio Leaf minimum carbon nitrogen ratio Carl mealimum carbon ratiogen ratio Total belowground carbon Total belowground carbon in littler - This is no tonger used	kgC kgN-1 kgC kgN-1	fr maxCN, leaf minCN,	10 - 200 10 - 200	
Carbon and Nitrogen Carbon and Nitrogen	14	Leaf minimum carbon nitrogen ratio	kgC kgN-1 kgC kgN-1	leaf_minCN, leaf_maxCN,	10 - 200	
Carbon and Nitrogen Carbon and Nitrogen	79200	Total belowground carbon	kgC ha-1	Chelowground, Clitter_frac,		
Carbon and Nitrogen	0.00	Fraction of belowground carbon in littler - This is no longer used Fraction of belowground carbon in fine roots (orders 1-5) Total carbon in stems	unitess	Croot frac, Cstem,		
Carbon and Nitrogen Carbon and Nitrogen	10000 4000	Total carbon in stems Total carbon in sapwood	kgC ha-1 kgC ha-1			
Carbon and Nitrogen Carbon and Nitrogen Hydrology	0.05	Fraction of belowground carbon in coarse roots (orders 6-10)	unitess m m-2 m2	Croot_coarse_frac, interception_per_leafArea	0.00025 typical	for considere
Hydrology	0.000001	Total carbon in sepwood	m	litter_capacity,	- Jours typical	
Hydrology Hydrology	0.32	Initial soil water content in soil layers 3 or deeper Initial soil water content in soil layer 2	m3 m-3 m3 m-3	theta_deep0, theta_mid0,		
Hydrology Hydrology	0.28	Initial soil water content in soil layer 1	m3 m-3	theta_shallow0,		
Carbon and Nitrogen	- 5	Initial specific leaf area	m m2 kgC-1	SLA, SRL1,	3 - 400	
Root Growth Root Growth	155.7	Initial specific teaf area Specific root length at a root diameter of 0.25 mm Finest order root diameter		minRootDiam,	15 - 1500 0.0001 - 0.001	Mackay et al., 2020 New Phytol Mackay et al., 2020 New Phytol
Boot Growth	0.2	Root collar (or highest order) diameter You can of the first order and at the lowest carbon nitropen ratio	m veers	mayRontDiam	0.01.20	Mackay et al., 2020 New Phytol Mackay et al., 2020 New Phytol
Root Growth Legacy	0.5	Spring minimum leaf water potential, can be used if the hydraulic model is turned off	-Mpa	minRootLifespan, LWP_spring_minimum, LWP_stomatal_closure, is_bryophyte		
Hydrology	2.35	Lear warer poeintial at stomater crosure, can be used if the hydraulic model is turned off A boolean variable to turn on if the system has bryophytes, e.g. sphagnum moss	-nspik boolean	LWP stomatal closure, is_bryophyte		
Hydrology Hydrology		A scalar to linearly adjust capillary rise, which uses a steady state form of the Richards equation A coular to linearly adjust excellent of a coular to linearly adjust excellent of a coular to linearly adjust excellent	unitiess	capRiseScalar, precipReduction		
Hydrology Hydrology Carbon and Nitrosen						
	1	A scalar to adjust the leakiness of the lower boundary of the system (lowest soil layer)	unitiess	drainScalar,		
Carbon and Nitrogen Canopy	0.1	A scalar to adjust the leakiness of the lower boundary of the system (lowest soil layer) A scalar to establish the target non-structural carbon in the leaf as a fraction of leaf structural of A boolean to but non the phenology model, which is used for perennial plant.	unitiess kgC kgC-1 boolean	In a BUSC constant		
Carbon and Nitrogen Canopy Canopy Soil Diage Hodowdiss	0.1 1 5	A scalar to adjust the leakiness of the lower boundary of the system (lowest soil layer). A scalar to establish the leakiness of the lower boundary of the system (lowest soil layer). A scalar to establish the leakiness of the lower boundary of the system (lowest soil layer). A scalar to establish the leakiness of the lower lower layer to establish the leaking t	unifess kgC kgC-1 boolean years	leafNSCscalar usePhenology		
Canopy Canopy Soil-Plant Hydraulics Microbiome	1 0.1 1 5 10 20	Ascalar to adjust the skalkness of the lower boundary of the system (lowest soll layer). Ascalar to establish the barget non-instructan celebra in this law as a feeding of lead arthrectural of Abodesan to turn on the phenology model, which is used for personnal plants. The length of time for leavest-lended as terminal layer (1 declines) = 2 der confidences). This sets an upper bound on the number of fines the hybrautic model is called at each time still. A casiar that adjust the initial ericoclorum action (and microgor) from what is set in log-copy.	unitiess kgC kpC-1 boolean years integer unitiess	leafNSCscalar usePhenology leafLifeSpan max iteration(the max number of microbiomeScalar,		
Carbon and Nitrogen Canopy Canopy Soil-Plant Hydraulics Microbiome Microbiome Microbiome		This sets a rate of rain in of NH4+	koN ha-1 30min-1	leatNSCscalar usePhenology leat.iteSpan max iteration(the max number of microbiomeScalar, microbia/vainrate rainin.Ammonium		
Canopy Canopy Soil-Plant Hydraulics Microbiome Microbiome Microbiome Microbiome Microbiome		This sets a rate of rain-in of NH4+ This sets a rate of rain-in of NC3-	kgN ha-1 30min-1 koN ha-1 30min-1	le aft/SC scalar usePhenology leaft.ideSpan max iteration(the max number of microbiomeScalar, microbia/siarrate rainin.Ammonium		
Canopy Canopy Soil-Parit Hydraulics Microbiome		This sets a rate of rain-in of NH4+ This sets a rate of rain-in of NG3- This sets a rate of rain-in of mineral nitrogen	koN ha-1 30min-1	a aftNSC scalar usePhanology is aft list pain max iteration(the max number of microbiomeScalar, microbiatrainnate sain inAmmonium sain inMineralin sain inMineralin sain inMineralin sain inMineralin		
Canopy Canopy Canopy Soil-Plant Hydraulics Microbiome Microbiome Microbiome Microbiome Microbiome Microbiome Microbiome Hydrology Hydrology Hydrology	0	This sets a rate of rais-in of NH4+ This sets a rate of rais-in of NH4- This sets a rate of rais-in of finder This sets a rate of rais-in of mineral nitrogen This sets a rate of rais-in of nibible carbon This variables is used to set the initial annewpack water equivalent	kgN ha-1 30min-1 kgN ha-1 30min-1 kgN ha-1 30min-1 kgC ha-1 30min-1 m	load/80C.cealar weePhanology loads.fis.Gpan max. Berasion/the, max, number_of microbiona@calar, microbian/mate rain is Ammonian rain is Ammonian rain is Alfanerally rain is Alfanerally deficit max,		
Canopy Canopy Canopy Soil-Plant Hydraudics Microbiome Microbiome Microbiome Microbiome Microbiome Microbiome Microbiome Hydrology Hydrology Hydrology Hydrology	0 0 0 0 0 0.0015	This sets are also frain-in-offNet4- This sets are set of real-in-offNet4- This sets are set of real-in-offNet4- This sets are set of real-in-offNet4- This variable is set to set the initial stronged water equivalent. This variable is set to set the initial stronged water equivalent. This variable sets the lower boundary on the smooped degree-day accumulation Materiate confidence used with the real-set mergy balance of their of snowmall	kgN ha-1 30min-1 kgN ha-1 30min-1 kgN ha-1 30min-1 kgC ha-1 30min-1 m deg m decC-1 30min-1	lead/BCS-cealar usePhanology asut.Melpain max. Baradon(Phanology max. Baradon(Phanology microbia/Bostair microbia/Baradon mic		
Canopy Canopy Canopy Canopy Soli-Flant Hydraulics Microbiome Micro	0 0 0 0 0 0.0015	This sets are also frain-in-offNet4- This sets are set of real-in-offNet4- This sets are set of real-in-offNet4- This sets are set of real-in-offNet4- This variable is set to set the initial stronged water equivalent. This variable is set to set the initial stronged water equivalent. This variable sets the lower boundary on the smooped degree-day accumulation Materiate confidence used with the real-set mergy balance of their of snowmall	kgN ha-1 30min-1 kgN ha-1 30min-1 kgN ha-1 30min-1 kgC ha-1 30min-1 m deg m decC-1 30min-1	lea/BVSCosalar use/Phenology leaft.fs/Span max. Ibarsfor/the_max_number_of microbioms/Scalar microbiars/aimate sain-harmonium		
Cancey Soil-Plane Hydraulics Microbiome Microbiome Microbiome Microbiome Microbiome Microbiome Microbiome Microbiome Hydrology Hydrology Hydrology Soil-Plane Hydraulics Soil-Plane Hydraulics Soil-Plane Hydraulics	0 0 0 0 0 0.0015	This sets are also frain-in-offNet4- This sets are set of real-in-offNet4- This sets are set of real-in-offNet4- This sets are set of real-in-offNet4- This variable is set to set the initial stronged water equivalent. This variable is set to set the initial stronged water equivalent. This variable sets the lower boundary on the smooped degree-day accumulation Materiate confidence used with the real-set mergy balance of their of snowmall	kgN ha-1 30min-1 kgN ha-1 30min-1 kgN ha-1 30min-1 kgC ha-1 30min-1 m deg m decC-1 30min-1 0 or 1	lead/BCS-cealar usePhanology asut.Melpain max. Baradon(Phanology max. Baradon(Phanology microbia/Bostair microbia/Baradon mic		
Cancey Soil-Flane hydraulics Microbiome Microbiome Microbiome Microbiome Microbiome Microbiome Microbiome Microbiome Microbiome Hydrology Hydrology Hydrology Soil-Flane Hydraulics	0 0 0 0 0 0.0015 1 0 0 0 0	This seal are set of main in of MOH4- This seal are set of main in of facilities cannot in the seal are set of main in of facilities cannot in the seal are set of main in of facilities cannot be a seal and a seal are set of main in ordinary and a commission. Mortrate conditions taked with the sign and maintain seal are of presented. A contain seal or facilities that the sign and maintain seal are set of presented and a contain seal are set of the seal are defended and a contain seal are set of the seal are defended as the seal are set of the seal are defended and a contain seal are set of the seal are defended as the seal and the seal and the seal are defended as the seal and the seal and the seal are defended as the seal and the se	kgN ha-1 30min-1 kgN ha-1 30min-1 kgC ha-1 30min-1 kgC ha-1 30min-1 m deg m decC-1 30min-1 0 or 1 0 or 1 0 or 1	learth/Cocaleir usath-Rendogy leart. Mogray		Wang et al., 2019 JVB
Canopy Canopy Soli-Plant Hydraulics Microbiume Microbiu	0.0015 0.0015 10.0015 11.213	This sake an old raish of 1944 This sake are fair after information (special policy) This sake are fair policy (special policy) This sake are fair policy (special policy) This sake are fair policy (special policy) This sake are fair policy) This is a policy (special policy) This	kgN ha-1 30min-1 kgN ha-1 30min-1 kgC ha-1 30min-1 kgC ha-1 30min-1 m deg m decC-1 30min-1 0 or 1 0 or 1 0 or 1	NambleContair usePhendogo, Nat Audige use The Mogor use The Mo		Wang et al., 2019 JMB Wang et al., 2019 JMB Wang et al., 2019 JMB
Cancey College Soll-Plant Hydraulics Microbiome Microbi	0.0015 0.0015 10.0015 11.213	This sake an old raish of 1944 This sake are fair after information (special policy) This sake are fair policy (special policy) This sake are fair policy (special policy) This sake are fair policy (special policy) This sake are fair policy) This is a policy (special policy) This	kgN ha-1 30min-1 kgN ha-1 30min-1 kgN ha-1 30min-1 kgC ha-1 30min-1 kgC ha-1 30min-1 deg m decC-1 30min-1 0 or 1 0 or 1 dey of the year 0 or 1 dey of the year	la artificio Caraliar unarbifinario (con una		Wang et al., 2019 JXB Wang et al., 2019 JXB Wang et al., 2019 JXB
Cantopy Ganty Soal-Park Hydradics Microbiome Micro	0.0015 0.0015 0.0015 10.0015 11.211 0.939134 0.0004958 11024.02	The sale as not drawn of DN4+ The sale as not drawn of Index of I	kgN ha-1 30min-1 kgN ha-1 30min-1 kgN ha-1 30min-1 kgC ha-1 30min-1 kgC ha-1 30min-1 deg m decC-1 30min-1 0 or 1 0 or 1 dey of the year 0 or 1 dey of the year	lashfelt-coalar usePhendogy lash fixing a number of miscotal animal metalonithe max number of miscotal animal miscotal mi		Wang et al., 2019 JXB Wang et al., 2019 JXB Wang et al., 2019 JXB Wang et al., 2019 JXB
Cantopy Soal-Piet hydradisc Soal-Piet hydradisc Soal-Piet hydradisc Microbiums Soal-Piet hydradisc Soal-Piet hydradisc Soal-Piet hydradisc Leaf Growth	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	The sale as not desired in ON44* The sale are not desired in offered in other of the other o	i kgN ha-1 30min-1 ikgN ha-1 30min-1 ikgN ha-1 30min-1 ikgC ha-1 30min-1 im decC-1 30min-1 (0 or 1 (0	la adhibit contail vasabili and an annotain de annotai		Wang et at., 2019 JXB
Cantopy Cantopy Soal-Piet hydradisis Microbiums Microbi	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	The sale as not desired in ON44* The sale are not desired in offered in other of the other o	kgN ha-1 30min-1 kgN ha-1 30min-1 kgN ha-1 30min-1 kgC ha-1 30min-1 kgC ha-1 30min-1 deg m decC-1 30min-1 0 or 1 0 or 1 dey of the year 0 or 1 dey of the year	la artheticaniar userPanning max number of m		Wang et al., 2019 JNB
Cantopy Cantopy Soal-Piet hydradisis Microbiums Microbi	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	The sales are of each of each of 1944. The sales are of each of the things of the thi	isgN ha-1 30min-1 isgN ha-1 30min-1 isgN ha-1 30min-1 isgN ha-1 30min-1 im decC-1 30min-1 m decC-1 30min-1 0 or 1 0 or 1	harbfilt-canial waterParents of the control of the		Wang et al., 2019 JNB
Canopy Control Microbiome Micr	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	The sales are of each of each of 1944. The sales are of each of the things of the thi	isgN ha-1 30min-1 isgN ha-1 30min-1 isgN ha-1 30min-1 isgN ha-1 30min-1 im decC-1 30min-1 m decC-1 30min-1 0 or 1 0 or 1	In artificionale vasificación y man interior de interi		Wang et al., 2019 JUB Wang et al., 2019 JUB
Canago, Canago, Saol-Tirate Hydradias Saol-Tirate Hydradias Saol-Tirate Hydradias Microbiome Microb	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	The sale are of each of each of 1944. The sale are of each of the order of 1949. The sale are of each of the order of 1949. The sale are of each of the order of 1949. The sale are of each of each of 1949. The sale are of the sale of 1949. The sale are of the sale of 1949. The sale are of 19	lagN has 1 30mins-1 lagN h	In an October 19 and American State of the Control		Wang et al., 2019 JXB Wang et al., 2019 JXB
Canopy Control Transcriptorials Soil - Transcriptorials Soil - Transcriptorials Microbiome Leaf Growth Le	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	The sale as and drawn of DMA* The sale as an of article and indirect indirection. The sale as an of article and indirection indirection. The sale as an of article and indirection indirection. The sale as an of article and indirection indirection. The sale as a few form of indirection indirection indirection. The sale as a few boards have been depressed degree day accomplished. A board and a sale board in the few few plant proposales in bits used article granulation. A board and a sale board in the few few plant proposales in bits in used an effective in the control of the sale in the sale and indirection. The sale personners resolvable that the sale repensable in the few feet few bits and are offered in the control of the sale in t	isgN ha-1 30min-1 isgN ha-1 30min-1 isgN ha-1 30min-1 isgN ha-1 30min-1 im decC-1 30min-1 m decC-1 30min-1 0 or 1 0 or 1	handlocasiar surfanology max. Instruction and management max. Instruction management max. Instruction m		Wang et al., 2019 JXB
Canopy Control Transcriptorials Soil - Transcriptorials Soil - Transcriptorials Microbiome Leaf Growth Le	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	The sale as and drawn of DMA* The sale as an of article and indirect indirection. The sale as an of article and indirection indirection. The sale as an of article and indirection indirection. The sale as an of article and indirection indirection. The sale as a few form of indirection indirection indirection. The sale as a few boards have been depressed degree day accomplished. A board and a sale board in the few few plant proposales in bits used article granulation. A board and a sale board in the few few plant proposales in bits in used an effective in the control of the sale in the sale and indirection. The sale personners resolvable that the sale repensable in the few feet few bits and are offered in the control of the sale in t	lagN has 1 30mins-1 dag has 1 30mins-1 dag m decC-1	la selficionale surfinenting su		Wang et al., 2019 JXB
Canopy. Canopy	0.0015 0.0015 11 0.0015 11 0.039134 0.039134 11024 0.25 11024 0.25	This sake a new of each of each of 1944 This sake a new of each of them of 1944 This sake a new of each of miner of 1944 This sake a new of each of miner of 1944 This sake a new of each of miner of 1944 This sake a new of each of miner of 1944 This sake a new of each of 1944 This sake a new of 1944 A boolean and the choice of 1944 A boolean and the third in 1944 Thi	lagN has 1 30mins-1 dag has 1 30mins-1 dag m decC-1	la selficionale surfinenting su		Wang et al., 2019 JMB Wang
Conspire Control Conspire Control Conspire Control Con	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	The sale are of each of each of DNHs. The sale are of each of each of DNHs. The sale are of each of each of the origination. The sale are of each of each of the origination. The sale are of each of each of the origination of the origination. The sale are of each origination of the origination origination of the origination origination or the origination originatio	lagN has 1 30mins-1 dag has 1 30mins-1 dag m decC-1	In an October 1 and Control of the C		Wang et al., 2019 JMB Wang
Consept Control Contro	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	The sale are of each of each of DNHs. The sale are of each of each of DNHs. The sale are of each of each of the origination. The sale are of each of each of the origination. The sale are of each of each of the origination of the origination. The sale are of each origination of the origination origination of the origination origination or the origination originatio	lagN has 1 30mins-1 dag has 1 30mins-1 dag m decC-1	la selficicaria variente de la constitución de la c		Wang et al., 2019 JKB
Conspire Control Conspire Control Conspire Control Con	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	The sale as and drawn of bible. The sale as an of an art on information proper. The sale as an of an art on of bible carbon. The sale as an of an art on of bible carbon. The sale as an of an art of man of bible carbon. The sale as a set of an art of bible carbon. The sale as a position of a sale of	lagN has 1 30mins-1 dag has 1 30mins-1 dag m decC-1	In an October 1 and Control of the C		Wang et al., 2019 JAB
Compy Grant Methods Monitorine Monitori	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	The sale as and drawn of bible. The sale as an of an art on information proper. The sale as an of an art on of bible carbon. The sale as an of an art on of bible carbon. The sale as an of an art of man of bible carbon. The sale as a set of an art of bible carbon. The sale as a position of a sale of	lagN Nat - 30min-1 (agN har - 30min-1 (agN har - 30min-1 (agN har - 30min-1 (agN har - 30min-1 (aga - 30min-1 (la selficicaria variente del mente d		Wang et al., 2019 JMB Wang
Company Control Information Control Information Monolation Monolat	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	The seaks and of each of bether 10044. The seaks are failed and freeder of inference of the control of the con	July Res 2 Solomen 1 July Res 2 Solomen 2	In an October 19 and American State of the Control		Wang et al., 2019 JMB Wang

Table 3. This 'param_mod' file describes the plant hydraulic segments, including lateral and axial shoot module (one) and six lateral and axial root modules with soil-root layer thicknesses of 5, 10, 15, 10, 5, and 55 cm. The sixth layer contains no roots.

Name in param mod file	Value	Description
#_of_shoot_modules	1	TREES is currently set up to use one lateral shoot in the hydraulic model
leaf_area_fraction	1	By default with one shoot module this should be set to 1
length_lateral	0.1	This is a scalar that is multiplied by length_axial to get lateral stem length
length_axial	20	Length of the axial stem in meters
#_of_root_modules	6	This can be from 1 to 21; typical numbers are 4 to 7
leaf_area_fraction	0.213	This sets the initial fraction of leaf (and root) area supported by this layer
length_lateral	2	This is a scalar that is multiplied by the sum of axial lengths to get lateral root length in this layer
length_axial	0.05	This layer has a thickness of 5 cm
leaf_area_fraction	0.213	
length_lateral	2	
length_axial	0.1	This layer has a thickness of 10 cm
leaf_area_fraction	0.32	
length_lateral	1.5	This layer has a lateral root extent that is 75% of that of the surface layer
length_axial	0.15	
leaf_area_fraction	0.213	
length_lateral	1	
length_axial	0.1	
leaf_area_fraction	0.041	
length_lateral	0.1	
length_axial	0.05	
leaf_area_fraction	0.000001	Setting this to a very small number sets the fine root area for this layer to near zero
length_lateral	0.000001	Setting this to a very small number (<0.00001) means this layer will never grow fine roots
length_axial	0.55	

Table 4. TREES main outputs (.sim). Each column is output at each 30-minute time step. This can produce a big file of about 20 MB per year of simulation.

		out 20 Mid per year of simulation.	
Output Column	Units	Description	Notes
ti		year-date-hour	
simET	mm s-1	evapotranspiration	This can be compared to eddy covariance tower ET data
WPlant_K	mmol m-2 s-1 MPa-1	whole plant hydraulic conductance	This is the full rhizosphere-plant hydraulic conductance
Soil_Psi	MPa	soil water potential	This is a root profile weighted average
Leaf_Psi	MPa	leaf water potential	
Psi_Crit	MPa	critical leaf water potential	
Ecrit	mmol m-2 s-1	critical transpiration	Maximum transpiration without causing hydraulic failure
Ec	mmol m-2 s-1	transpiration	
RhizFluxX	mmol m-2 s-1	rhizosphere flux - one column per soil-root layer	X = 0, 1, 2N soil-root layers
Gs	mol m-2 s-1	stomatal conductance	This is a canopy average stomatal conductance
LAI	m2 -m-2	actual leaf area index	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,
SLA	m2 kgC-1	Specific leaf area	
liveLAI	m2 -m-2	forecast live leaf area index	This variable is used internally to compute LAI potential for next year in perennials
Rmaint	kgC ha-1	maintenance respiration	Whole plant
Rgrowth	kgC ha-1	growth respiration	Whole plant
leafNSC	kgC ha-1	non-structural carbon	whole plant
stemNSC		non-structural carbon	
	kgC ha-1		
rootNSC	kgC ha-1	non-structural carbon	
chloroStarch	kgC ha-1	non-structural carbon	Follows a diel cycle; drives allocation of carbon for growth
chloroSugar	kgC ha-1	non-structural carbon	Follows a diel cycle; drives allocation of carbon for growth
waterStress	unitless	stress = Ecrit / Esat, plant is water stressed when this value is less than 1.0	Used for initial guess at stomatal conductance; used to reduce quantum yield
litterH2O	m3 m-3	litter layer water content	
thetaX	m3 m-3	layer soil water content - one column per soil-root layer	X = 0, 1, 2N soil-root layers
thetaRoot	m3 m-3	root average soil water content	
Can_Evap	mm s-1	free evaporation from wet canopy	
Snowpack	m	snow water equivalent	
SnowEdef	deg C-1	snow energy deficit	
Vcmax25	umol m-2 s-1	maximum carboxylation at 25 C	Currently writes out zeros for photosynthesis models 2 and 3
Vcmax_sun	umol m-2 s-1	leaf level Vcmax	Currently writes out zeros for photosynthesis models 2 and 4
Vcmax_shd	umol m-2 s-1		Currently writes out zeros for photosynthesis models 2 and 5
Jmax25	umol m-2 s-1	maximum J at 25 C	Currently writes out zeros for photosynthesis models 2 and 6
J_sun	umol m-2 s-1	leaf level J	Currently writes out zeros for photosynthesis models 2 and 7
J_shd	umol m-2 s-1		Currently writes out zeros for photosynthesis models 2 and 8
Asun	umol m-2 s-1	leaf level photosynthesis	
Ashd	umol m-2 s-1		
Lsun	m2 m-2	leaf level area	
Lshd	m2 -m-2	ical level alea	
Tsun	deg C	leaf level temperature	
Tshd		lear lever temperature	
Dsun	deg C kPa	leaf level vapor pressure defiit	
		lear lever vapor pressure deliit	
Dshd	kPa	1 (1 11 11 11 11 11 11 11 11 11 11 11 11	
Ci_sun	ppm	leaf level intercellular CO2	
Ci_shd	ppm		
PARsun	umol m-2 s-1	leaf level absorbed PAR	
PARshd	umol m-2 s-1		
gs_sun	mol m-2 s-1	leaf level stomatal conductance	
gs_shd	mol m-2 s-1		
NEE	umol m-2 s-1	net ecosystem exchange	This can be compared to eddy covariance tower ET data
NPP	umol m-2 s-1	net primary production	
R_total	umol m-2 s-1	total respiration	
R_ag	umol m-2 s-1	aboveground respiration	
R_bg	umol m-2 s-1	belowground respiration	
Rd_sun	umol m-2 s-1	dark respiration	
Rd_shd	umol m-2 s-1		
Csapwood	kgC ha-1	stem carbon	
FibRootCX	kgC ha-1	root order 1 carbon content, one column per soil-root layer	X = 0, 1, 2N soil-root layers
FineRootCX	kgC ha-1	root order 2 carbon content, one column per soil-root layer	X = 0, 1, 2N soil-root layers
TotRootCX	kgC ha-1	total root carbon content, one column per soil-root layer	X = 0, 1, 2N soil-root layers
FineRootCNX	kgC kgN-1	root orders 1&2 carbon to nitrogen ratio, one column per soil-root layer	X = 0, 1, 2N soil-root layers X = 0, 1, 2N soil-root layers
LeafCN	kgC kgN-1	leaf C:N	A - 0, 1, 2 Soil-100t layers
			V. A.4.2 Marilland laws
humusCX	kgC ha-1	humus carbon content, one column per soil-root layer	X = 0, 1, 2N soil-root layers
RhizCIX	kgC ha-1	labile organic carbon, one column per soil-root layer	X = 0, 1, 2N soil-root layers
RhizNIX	kgN ha-1	labile organic nitrogen, one column per soil-root layer	X = 0, 1, 2N soil-root layers
AAexudateCX	kgC ha-1	amino acid content, one column per soil-root layer	X = 0, 1, 2N soil-root layers
SugarExudateCX	kgC ha-1	sugar exudate content, one column per soil-root layer	X = 0, 1, 2N soil-root layers
MicrobCX	kgC ha-1	live microbial carbon, one column per soil-root layer	X = 0, 1, 2N soil-root layers
MicrobNX	kgN ha-1	live microbial nitrogen, one column per soil-root layer	X = 0, 1, 2N soil-root layers
RhizN-	kgN ha-1	rhizosphere nitrate content	
DI-1-NI	kgN ha-1	rhizosphere ammonium content	
KNIZN+			
RhizN+ PlantN	kgN ha-1	total plant nitrogen	
	kgN ha-1 unitless		
PlantN		total plant nitrogen Combined index of N available to the plant relative to N needed for incremental growth root-to-leaf area ratio	

Table 5. Hydraulic outputs used to reconstruct vulnerability to cavitation curves and identify hydraulic conductance changes in different xylem elements.

Output Column	Units	Description	Notes
ti		year-date-hour	
latStemK	mmol m-2 s-1 MPa-1	Lateral stem hydraulic conductance	Ignore this variable
latRootKX	mmol m-2 s-1 MPa-1	Lateral root hydraulic conductance, one column for each soil-root layer	X = 0, 1, 2,, N; ignore this variable
StemAxialYm	MPa	Axial stem minimum water potential reached	
StemLatYm	MPa	Lateral stem minimum water potential reached	
RootAxialYmX	MPa	Axial root minimum water potential reached, one column for each soil-root layer	X = 0, 1, 2,, N
RootLatYmX	MPa	Lateral stem minimum water potential reached, one column for each soil-root layer	X = 0, 1, 2,, N
StemAxialKm	mmol m-2 s-1 MPa-1	Axial stem maximum hydraulic conductance	
StemLatKm	mmol m-2 s-1 MPa-1	Lateral stem maximum hydraulic conductance	
RootAxialKmX	mmol m-2 s-1 MPa-1	Axial root maximum hydraulic conductance, one column for each soil-root layer	X = 0, 1, 2,, N
RootLatKmX	mmol m-2 s-1 MPa-1	Lateral root maximum hydraulic conductance, one column for each soil-root layer	X = 0, 1, 2,, N
StemAxial_b	-Мра	Axial stem Weibull b parameter	
StemLat_b	-Mpa	Lateral stem Weibull b parameter	
RootAxial_bN	-Мра	Axial root Weibull b parameter, one column for each soil-root layer	X = 0, 1, 2,, N
RootLat_bN	-Mpa	Lateral root Weibull b parameter, one column for each soil-root layer	X = 0, 1, 2,, N
StemAxial_c	unitless	Axial stem Weibull c parameter	
StemLat_c	unitless	Lateral stem Weibull c parameter	
RootAxial_cN	unitless	Axial root Weibull c parameter, one column for each soil-root layer	X = 0, 1, 2,, N
RootLat_cN	unitless	Lateral root Weibull c parameter, one column for each soil-root layer	X = 0, 1, 2,, N
Notes: These outp	uts are used to reconstru	ct vulnerability curves and hydraulic conductance of each plant segment at any point i	n time
Reference: Mackay	et al 2015 Water Resou	rces Research	

Table 6. Individual leaf model output of time series of each leaf area.

Output Column	Units	Description	Notes
ti		year-date-hour	
Area_Leaf_X	cm2	Area of individual leaf, one column per leaf	X = 0, 1, 2,, N
Reference: Wang et	al 2019 Journ		