DayCent Ecosystem Model

The Daily Century Ecosystem, Soil Organic Matter, Nutrient Cycling, Nitrogen Trace Gas, and Methane Model

User Manual, Scientific Basis, and Technical Documentation

Natural Resource Ecology Laboratory
Colorado State University
Fort Collins
Colorado

Melannie D. Hartman
William J. Parton
Stephen J. Del Grosso
Mark Easter
Judy Hendryx
Thomas Hilinski
Robin Kelly
Cindy A. Keough
Kendrick Killian
Susan Lutz
Ernest Marx
Rebecca McKeown
Stephen Ogle
Dennis S. Ojima
Keith Paustian
Amy Swan
Stephen Williams

Acknowledgements

This manual was partially funded by US Environmental Protection Agency under Contracting Agreement No. EP-W-13-005 and US Department of Agriculture Cooperative Agreement No. 58-5402-4-011.

APPLICATION OF THE DAYCENT MODEL

The DayCent Model embodies our best understanding to date of the biogeochemistry of Carbon, Nitrogen, Phosphorus, and Sulfur and the emissions of nitrous oxide and methane. The primary purposes of the model are to provide a tool for ecosystem analysis, to test the consistency of data and to evaluate the effects of changes in management and climate on ecosystems. Evolution of the model will continue as our understanding of biogeochemical processes improves. The identification of problem areas where processes are not adequately quantified is key to further developments. Ideally, model application will lead to the identification of needed research and new experimentation to improve understanding.

We value the responses and experiences of our collaborators in using DayCent and encourage their feedback on problems in the current model formulation, as well as insight and suggestions for future model refinement and enhancement. It would be particularly helpful if users would communicate such feedback informally and where possible share with us documented model applications including manuscripts, papers, procedures, or individual model development.

DISCLAIMER

Neither Colorado State University (CSU) nor any of their employees make any warranty or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference to any special commercial products, process, or service by tradename, trademark, manufacturer, or otherwise, does not necessarily constitute or imply endorsement, recommendation, or favoring by CSU. The views and opinions of the authors do not necessarily state or reflect those of CSU and shall not be used for advertising or product endorsement.

Table of Contents

PART 1. DayCent User's Manual

Table of Figures

List of Tables

Preface

Daily Century, or DayCent, (Parton et al. 1998, Kelly et al. 2000, Del Grosso et al. 2001) is the daily time step version of the CENTURY model. CENTURY (Parton et al. 1994) operates on a monthly time step and was originally developed in the 1970s to simulate changes in soil organic matter (SOM), plant productivity, nutrient availability, and other ecosystem parameters in response to changes in land management and climate. CENTURY has been widely applied and has been shown to reliably simulate plant growth and changes in soil organic matter for most terrestrial ecosystems world-wide (Parton et al. 1988, Parton et al. 1993, Parton et al. 1995, Kelly et al. 1997, Pepper et al. 2005, Yarie and Parton 2005, Parton et al. 2007b, Parton et al. 2011). However, finer time-scale resolution is required to accurately simulate N gas emissions from soils because the processes that result in N gas fluxes respond nonlinearly to important controls, such as soil water content. Increased interest in performing complete greenhouse gas analyses, including soil nitrous oxide (N_2O) emissions, led to the development of DayCent in 1994 by William Parton, Dennis Ojima, and Melannie Hartman (Parton et al. 1998). Since then there have been many contributors to DayCent model including Mark Easter, Stephen Del Grosso, Thomas Hilinski, Cindy Keough, Kendrick Killian, Stephen Ogle, Keith Paustian, Steve Williams, and many unnamed researchers, post docs, and graduate students.

In terms of processes, the major difference between DayCent and CENTURY is that DayCent explicitly represents the processes (nitrification and denitrification) that lead to N_2O, NO_x, and N_2 emissions, whereas CENTURY assumes that a constant proportion of available N in a time step is lost as N gas, but the different N gas species are not distinguished. The SOM decomposition and plant growth submodels are similar, but the different time steps dictate that the equations representing the controls are different. The soil water and temperature submodels are also more finely resolved both spatially and temporally in DayCent.

DayCent simulates exchanges of carbon, nutrients, and trace gases among the atmosphere, soil, and plants as well as events and management practices such as fire, plant harvest, grazing, cultivation, irrigation, and organic matter or fertilizer additions. Required model inputs are soil texture, current and historical land use, and daily maximum and minimum temperature and precipitation data.

Part 1 of this manual provides an overview of the DayCent environment including how to install and execute DayCent. Part 2 provides a detailed description of the scientific basis and includes model algorithms and equations. Many DayCent model parameter names and output state variables and flows are shown in the figures and referred to in the text. The exact definitions of the parameter values are found in Appendix 1 and output variables are described in Appendix 2. When running the DayCent model it is quite useful to have copies of flow diagram figures since they indicate the names of the output variables for the different submodels.

This manual is a work in progress. There may be empty sections where text will be inserted later. We have inserted some temporary figures until the final figures are created. This manual also contains figures from the original Century Manual (Metherell et al. 1993b) which are prefaced with the number “3-“.

The model attempts to document multiple versions of the DayCent model that differ in the set processes they include, the way these processes are calculated, and the format of input and output files. Different versions emerge as separate research groups modify the model to meet the requirements of their research and applications. We have done our best to document the different features of each model version, but it is likely we did not describe all the discrepancies and exceptions.

We welcome feedback about the content and organization of this manual. Please send any comments or suggestions to Dr. Melannie Hartman (melannie.hartman@colostate.edu).

Part 1. DayCent User's Manual

1. Overview of DayCent

The program DayCent model is written in the FORTRAN and C programming languages and can be operated from a DOS window on a PC or on a UNIX/Linux platform. The model simulates daily C, N, P, and S dynamics through an annual cycle to centuries and millennia. A grassland/crop, forest or savanna system may be selected as a producer submodel with the flexibility of specifying potential primary production curves which represent the site-specific plant community. While running, the simulation writes monthly output variables to a binary file and daily output variables to text files. Once the simulation is complete, the LIST100 utility is used to read the binary file and create an ASCII list of selected variables.

The DayCent environment **(Figure 1)** consists of the DayCent model, a number of parameter files, a schedule file, a weather file, and many output files. It is in many ways similar to the monthly CENTURY environment. Input parameter files with a ".100" extension are also used in monthly CENTURY. Input parameter files unique to DayCent have a ".in" extension. Daily weather files have a ".wth" extension. The timing variables and the schedule of events to occur during the simulation are maintained in the schedule file, named with a ".sch" or ".evt" extension. All input parameter files (*.100, *.in, *.dat), weather files (*.wth), and schedule files (*.sch) are text files that can be updated with any text editor. Output binary files with a ".bin" are common with monthly CENTURY, while unique DayCent output files have a ".out" and ".csv" extensions. The output binary files are not human readable, and the List100 program is used to extract values from the binary file and write them to a text file with a ".lis" extension.

The DayCent environment must be installed on the computer to be used (Section 2 below). Then, follow these steps:

1. Establish the simulation time and schedule events to occur during the simulation by creating a schedule file.

2. Create a weather file.

3. Update values or create new options in any of the .100 data files.

4. Run the DayCent model.

5. Run the list100 utility to extract monthly output variables.

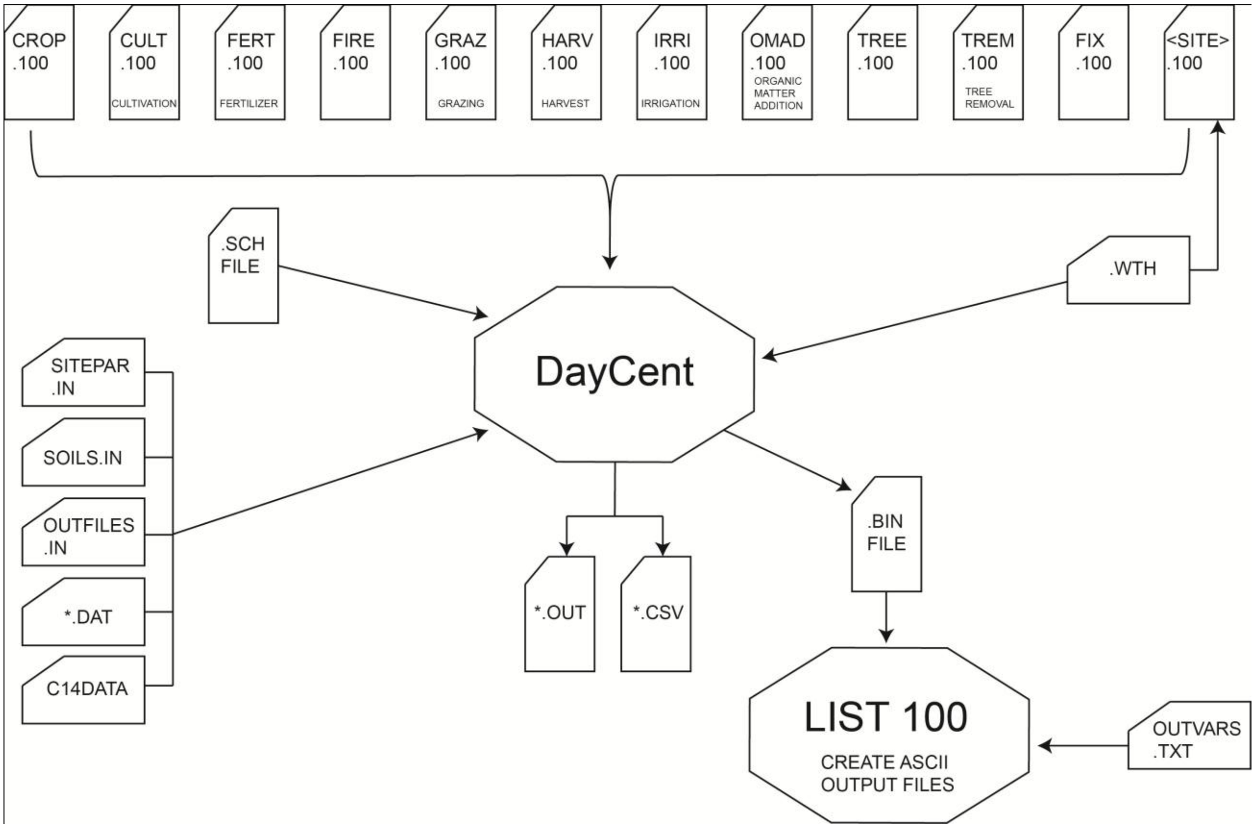


Figure 1 DayCent Environment

Files in the DayCent Environment

Table 1 Files in the Daycent Environment

File Name	Description
DailyDayCent.exe DDcentEVI.exe	DayCent executable model. There are multiple names for this file, depending on the version.
DailyDayCent_list100.exe DDlist100.exe	The List100 program reads the binary (.bin) output file, extracts a subset of variables values from the .bin file, and writes these variables to a text file (.lis) file. There are multiple names for this file, but it usually contains “list100” in the name.
fix.100	Fixed parameters primarily relating to organic matter decomposition and not normally adjusted between runs.
<site>.100	Site-specific parameters such as precipitation, soil texture, and the initial conditions for soil organic matter; the name of this file is provided by the user. The value <site> is replaced with the name of the site, and the name of the site file to read is specified in the schedule file.
sitepar.in	Additional site-specific parameters that are strictly DayCent parameters. (In the DayCentEVI versions, sitepar.in parameters have been moved to the <site>.100 and fix.100 files, and sitepar.in is no longer used).
soils.in	Information about the soil layer structure and soil properties of each soil layer. (In the DayCentEVI versions, there is an option to define soil in the fix.100 file instead of in soils.in).
outfiles.in	A list of .out and .csv output files to generate. Writing to any output file slows down DayCent execution and consumes disk space; therefore it is advantageous to select a subset of all possible output files.
crop.100	Crop/Grass options. Any CROP event in the schedule file must have a corresponding set of parameters in this file.
cult.100	Cultivation options. Any CULT event in the schedule file must have a corresponding set of parameters in this file.
fert.100	Fertilizer options. These are parameters for FERT events in the schedule file. In some versions of DayCent, fertilizer options can be specified within the schedule file without need for a fert.100 entry (section 4.8.2.1 below).
fire.100	Fire options. Applies to the burning of crops/grasses, surface litter, and dead wood. For burning of live trees see trem.100. Any FIRE event in the schedule file must have a corresponding set of parameters in this file.

graz.100	Grazing options. Any GRAZ event in the schedule file must have a corresponding set of parameters in this file.
harv.100	Harvest options. Applies to crops and grasses only. For trees see trem.100. Any HARV event in the schedule file must have a corresponding set of parameters in this file.
irri.100	Irrigation options. Any IRRI event in the schedule file must have a corresponding set of parameters in this file. In some versions of DayCent, irrigation options can be specified within the schedule file without need for a irri.100 entry (section 4.8.2.2 below).
omad.100	Organic matter addition options. Any OMAD event in the schedule file must have a corresponding set of parameters in this file.
tree.100	Tree options. Any TREE event in the schedule file must have a corresponding set of parameters in this file.
trem.100	Tree removal options. Includes burning, harvest, and storm events. Any TREM event in the schedule file must have a corresponding set of parameters in this file.
<site>.wth	Daily weather file. One or more weather files are specified in the blocks of the schedule file. See section 3.63.6 below for more details.
c14data	<Insert information here>. Optional input file. See section 4.4.2 below for more details.
<site>.sch or <site>.evt	Schedule/Event file. See section 4 below for more details.
nscale.dat	Nitrogen scalars. Optional input file. See section 4.4.7 below for more details.
omadscale.dat	Organic matter addition scalars. Optional input file. See section 4.4.8 below for more details.
precscale.dat	Precipitation scalars. Optional input file. See section 4.4.9 below for more details.
tminscale.dat	Scalars (actually deltas) for minimum air temperatures. See section 4.4.9 below for more details. Optional input file.
tmaxscale.dat	Scalars (actually deltas) for maximum air temperatures. Optional input file. See section 4.4.9 below for more details.

phscale.dat	Soil pH scalars. Optional input file. See section 4.4.5 below for more details.
.bin file	The binary output file contains all of the 500+ monthly output variables that DayCent produces. This binary file is a compact way to store many variable values, but it is not human readable. The List100 program is needed to extract variables values from this file and to save them to a text (.lis) file. The binary file also saves the state of the model and can be used to initialize subsequent DayCent runs, allowing DayCent to be run in stages; this is called “extending” from the existing binary file (Section 2.1.2.2 below).
*.out *.csv	DayCent output files in text format. Most of these files contain daily output, but a few contain annual or monthly output (Appendix 2). The *outfiles.in* file mentioned above contains a list of all possible output text files that DayCent generates.

1. Units of Major Parameters

Model time step:	one day (365 or 366 days per year)
List100 output:	one month (1/12 year or .083333 year)
Minimum time:	year
Soil Organic Matter:	grams C, N, P, or S per meter square (g C m^{-2}, g N m^{-2}, g P m^{-2}, or g S m^{-2})
Plant Material:	grams C, N, P, or S per meter square (g C m^{-2}, g N m^{-2}, g P m^{-2}, or g S m^{-2})
Mineral pools:	grams N, P, or S per meter square (g N m^{-2}, g P m^{-2}, or g S m^{-2})
Temperature:	degrees Centigrade (°C)
Precipitation:	centimeters per day (cm d^{-1})

2. Installing and Executing DayCent

2.1.PC Version

2.1.1. Hardware/Operating System Requirements and Installation

Since January 2015, all PC versions of DayCent, List100, and supporting programs have been compiled for a 64-bit version of Microsoft Windows. These recent versions will not run under 32-bit versions of Windows. Some older DayCent executables will run under both 32-bit and 64-bit Windows versions. To run DayCent on an Apple MacIntosh will require installing a Windows Emulator first. Please note that there is no standard DayCent distribution. DayCent is under constant development by several different research groups, and therefore there are many variations of the model. More specific information about various versions of DayCent may be included in the files distributed with the model.

The PC version of the model and supporting example files are usually distributed in a .zip file. Once this .zip file is unzipped, no further installation is required.

2.1.2. Executing the PC version of DayCent and List100

The PC versions of DayCent are usually run in the DOS Command Prompt, with command line arguments as shown in the examples below. Double-clicking on the executables in Windows Explorer will also start the model but the user will be required to provide information by responding to questions from the model.

The DOS Command Prompt is accessed from the Start menu by Selecting "All Programs" then "Accessories", although this may vary among computers. The instructions below assume that the name of the DayCent model is DDcent.exe and the name of the List100 program is DDlist100.exe. Note that it is not necessary to type the ".exe" portion of the executable name, but the complete name of the file is shown below for clarity. Additionally, the DOS environment is not case-sensitive.

2.1.2.1. Running DayCent by specifying a schedule file and binary output file name

To run the DDcent.exe model with command line arguments:

```
DDcent.exe -s <sch_file> -n <bin_file>
```

where

<sch_file> = schedule file name (do not include the .sch extension on the command line)

<bin_file> = binary file containing all DayCent's monthly output variables (do not include the .bin extension on the command line). Note: This file is not readable; it requires the List100 program **DDlist100.exe** to extract output.

For instance, run DDcent.exe with schedule file spinup.sch, producing binary file spinup.bin:

```
DDcent.exe -s spinup -n spinup
```

2.1.2.2. Running DayCent using an existing binary file to initialize the model

To run the DDcent.exe model extending from a previous simulation:

```
DDcent.exe -s <sch_file> -n <bin_file> -e <extend_file>
```

where

<extend_file> = binary file from a previous simulation used to initialize the model for the next simulation (do not include the .bin extension on the command line)

For instance, run DDcent.exe with schedule file example1.sch by extending the simulation from spinup.bin, producing binary file example1.bin

```
DDcent.exe -s example1 -n example1 –e spinup
```

2.1.2.3. Using the List100 program to extract output from the binary file

To run the List100 without command line arguments simply type the name of the program on the command line. When List100 is run this way, the user will be required to respond to questions from the program.

```
DDlist100.exe
```

To run the DDlist100.exe program using a list of output variables:

```
DDlist100.exe <bin_file> <lis_file> <txt_file>
```

where

<bin_file> = binary file containing all DayCent's monthly output variables (do not include the .bin extension on the command line).

<lis_file> = ASCII output file containing output extracted from binary file (do not include the .lis extension on the command line)

<txt_file> = text file that contains a list of variables to extract from the binary file output (for example, outvars.txt)

For instance, run DDlist100.exe, reading binary file example1.bin, producing the ASCII file example1.lis that contains the variables listed in outvars.txt.

```
DDlist100.exe example1 example1 outvars.txt
```

2.2. Unix/Linux Version

2.2.1. Hardware/Operating System Requirements and Installation

The source code (FORTRAN and C) and Makefiles are distributed instead of the executables. The Linux versions of DayCent and List100 must be compiled by the user. Instructions for building DayCent for a Linux system are included with the distributed files. One may need to update the Makefiles to use the specific compilers residing on their own system.

2.2.2. Executing the Linux version of DayCent and List100

The Linux versions of DayCent are usually run with command line arguments, almost identical to the way these models are run in the DOS Command Prompt. Please see the previous section for more information. The only difference is the way one types the name of the executable. The Linux environment is case-sensitive, so the complete name of the model, preceded by './' (indicating that the executable is in the current directory and is not a system file), must appear on the command line.

2.2.2.1. Running the Linux version DayCent using an existing binary file to initialize the model

To run the DDcent model extending from a previous simulation:

```
./DDcent <sch_file> -n <bin_file> -e <extend_file>
```

where

<sch_file> = schedule file name (do not include the .sch extension on the command line)

<bin_file> = binary file containing all DayCent's monthly output variables (do not include the .bin extension on the command line). Note: This file is not readable; it requires the List100 program **DDlist100.exe** to extract output.

<extend_file> = binary file from a previous simulation used to initialize the model for the next simulation (do not include the .bin extension on the command line)

For instance, run DDcent.exe with schedule file example1.sch by extending the simulation from spinup.bin, producing binary file example1.bin

```
./DDcent -s example1 -n example1 –e spinup
```

2.2.2.2. Using the Linux version of List100 program to extract output from the binary file

To run the DDlist100 program using a list of output variables:

```
./DDlist100  <bin_file> <lis_file> <txt_file>
```

where

<bin_file> = binary file containing all DayCent's monthly output variables (do not include the .bin extension on the command line).

<lis_file> = ASCII output file containing output extracted from binary file (do not include the .lis extension on the command line)

<txt_file> = text file that contains a list of variables to extract from the binary file output (for example, outvars.txt)

For instance, run DDlist100, reading binary file example1.bin, producing the ASCII file example1.lis that contains the variables listed in outvars.txt.

```
./DDlist100 example1 example1 outvars.txt
```

2.3.DayCent Graphical User Interface

The DayCent Graphical User Interface (GUI) is under development therefore instructions are not included here at this time.

2.3.1. System Requirements

2.3.2. GUI Layout

2.3.3. How to use the GUI

2.3.4. How to add a new Model Version to the GUI

2.3.5. Evaluating model performance with the DayCent GUI

3. Characterizing the “System”: Input Data Requirements

3.1.Introduction

DayCent model inputs can be divided into four categories: (i) weather information, (ii) soil information, (iii) plant information, and (iv) management information.

The model runs using a daily time step and the major input variables for the model include:

(1) daily average maximum and minimum air temperature,
(2) daily precipitation,
(3) lignin content of plant material,
(4) plant N, P, and S content,
(5) soil texture,
(6) atmospheric and soil N inputs, and
(7) initial soil C, N, P, and S levels.

The input variables are available for most natural and agricultural ecosystems and can generally be estimated from existing literature. Most of the parameters that control the flow of C in the system are in the fix.100 file.

Site specific parameters and initial pool amounts are found in the sitepar.in and <*site.100*> files. The number of elements to simulate is determined by the value of NELEM in *site.100*. The user can choose to run the model considering only C and N dynamics (NELEM=1) or C, N, and P (NELEM=2) or C, N, P, and S (NELEM=3).

Many of the internal parameters in DayCent were determined by fitting the model to long-term soil decomposition experiments (1 to 10 years) where different types of plant material were added to soils with a number of soil textures (Parton et al. 1987, Parton et al. 2007a, Bonan et al. 2013). Other more general databases (Parton et al. 1988, Parton et al. 1989) were used to parameterize the P and S submodels and flows for the formation of passive SOM. Many of the parameters such as the plant nutrient content and lignin content were determined using a linear equation where the slope and intercept were the input parameters. Work in the Great Plains suggested that lignin and N content changed as a linear function of annual precipitation. To specify constant values for these parameters, set the slope parameter (FLIGNI(2,*), crop.100) equal to zero and set the intercept (FLIGNI(1,*), crop.100) equal to the desired value for the parameter.

The model includes a method for estimating steady state soil C and N levels in grassland systems which was developed for the U.S. Great Plains. If IVAUTO (<site>.100) is set to 1, the model will estimate initial soil C and N levels for the different soil fractions based on the mean annual temperature, annual precipitation and soil texture of grassland (Burke et al. 1989). IVAUTO = 2 uses the cultivated fields equations to estimate these levels. IVAUTO = 3 initializes soil C and N levels for forest soils (but currently this option has the same results as IVAUTO = 1). If IVAUTO = 0, initial soil C and N levels are specified in the <site>.100 file. The soil P and S levels are quite different depending on soil parent material and need to be estimated with site-specific data.

One of the most difficult parts of initializing the model is estimating the C, N, P, and S levels for the different soil fractions. Often these quantities are not known and are initialized by running the model for several thousand years under native vegetation and site-specific climate drivers. However, there are methods for approximating the size of the soil fractions from measurements. The active soil fraction includes the live soil microbes and microbial products. This fraction can be estimated by using the microbial fumigation technique (Jenkinson and Powlson 1976, Jenkinson et al. 1976, Jenkinson and Rayner 1977) to estimate the live microbial biomass and then doubling the live microbial biomass to account for the microbial products (active SOM = 2 to 3 times the live microbial biomass). In most soils the active soil fraction is approximately 2 to 4% of the total soil C. The slow SOM fraction is made up of lignin derived plant material and stabilized microbial products. This fraction makes up approximately 55% of the total SOM. SOM fractionation methods (Elliott and Cambardella 1991) suggest that 40% of the total SOM in grasslands is lignin-derived plant material (referred to as POM (partial organic matter) in the paper). Comparison of the size of the slow pool from C simulations with measurements of SOM indicate that the slow pool is approximately 1.6 times the amount of POM (Metherell et al. 1993b).

Unfortunately, there is not a good technique for estimating the size of the stabilized microbial products pool; however, it is estimated that it is approximately 10 to 20% of the soil. The passive SOM generally makes up 30 to 40% of the total SOM and will have a higher value for high clay content soils. The best estimate of the N content of these fractions are that the slow fraction has a C:N ratio of 15 to 20, the active SOM has a C:N ratio of 8 to 12, while the passive SOM has a C:N ratio of 7 to 10. Clay soils have lower C:N ratios while silty soils have higher C:N ratios for the passive SOM. These approximations seem to work well for a large number of different soils.

The C:P and C:S ratios are not as predictable and are functions of the initial soil parent material and degree of soil weathering. The same general rules apply for C:P and C:S ratios with the active SOM having relatively low ratios (50-100), the slow SOM the highest C:P and C:S ratios (100-300), while the passive C:P and C:S ratios are fairly low (40-120). These values are appropriate for the relatively unweathered soils in the U.S. Great Plains. More weathered tropical soils have much higher C:P and C:S ratios that can be as high as 800. To use the P and S submodels, determine the organic P and S levels and it would be preferable to run full P fractionation of the soil (see citations in Hedley et al. 1982). The C:N ratio and relative size approximations are incorporated into the model when the Burke equations are used (IVAUTO=1, <site>.100) to estimate initial SOM pools. For cultivated soils it is generally assumed that the size of the slow pool is lower because of cultivation (40 to 50% of the total SOM) while the size of the passive pool is increased (45 to 50%).

3.2.Soil Properties and Soil Layer Structure

Soil properties for a site are defined in three different files: *soils.in*, *<site.100>*, and *fix.100*. Soil properties **(Table 2)** are probably the most important site level data needed because they influence plant growth, water and nutrient flows, and decomposition processes. Users specify soil horizonation (i.e., layer thickness and number of layers to bedrock or water table). Required soil properties for each layer include texture, bulk density, wilting point, field capacity, the extent to which water content can drop below the wilting point, root fraction, organic matter fraction, saturated hydraulic conductivity (Ksat), and pH. Soil texture, depth to bedrock, and pH are typically available for experimental plots and can also be derived from soil map units. If time series data for soil water content are available, then field capacity and wilting point can be estimated by observing maximum soil water contents a day or two after rainfall events and minimum soil water contents during dry down periods. Field capacity and wilting point, as well as Ksat, can be derived based on soil texture. We recommend using the algorithm developed by Saxton and Rawls (2006) (available at http://hydrolab.arsusda.gov/soilwater/Index.htm [verified 18 Mar. 2016]). Default values for organic matter fraction are usually used, but root fraction will depend on the suite of vegetation represented during the simulation period. A water table can be simulated by specifying water table depth on a monthly basis. The water table can be a source of water flowing up the profile via unsaturated flow. When a water table is implemented, drainage out the bottom of the soil profile does not occur, so rainfall events can saturate soil layers above the water table. When running the model at the plot level, site-specific soil characteristics should be used. However, when running at regional or larger scales, datasets such STATSGO (http://www.soilinfo.psu.edu/index.cgi?soil_data&statsgo [verified 18 Mar. 2016]) can be used.

The soil structure for the monthly CENTURY model includes 1 – 10 soil layers where the minimum thickness of any soil layer is usually no less than 15 cm. Soil layer thickness was defined by the ADEP(*) values in the fix.100 parameter file. The number of actual layers used was defined by the NLAYER parameter in the <site>.100 parameter file. The soil sand, silt, and clay fractions, along with bulk density and soil pH and were defined by the SAND, SILT, CLAY, BULKD, and PH values, respectively, in the <site>.100 file. Field capacity and wilting point values were defined for each layer using the AFIEL(*) and AWILT(*) parameters in the <site>.100 file.

In order to simulate daily soil water fluxes, soil temperature distribution with depth, and nitrogen trace gas fluxes, the DayCent model requires a finer soil layer structure than the CENTURY model. DayCent defines multiple layers within a coarser CENTURY layer to allow for a finer soil layer structure in the soil water submodel, soil temperature submodel, and trace gas submodels without impacting other code that still required the coarser CENTURY soil layer structure. It is important that boundaries of the layers coincide as shown in **Figure 2**. The soil layer structure and properties of the

DayCent model are defined in the soils.in parameter file **(Table 2)**. For both models, soil layer thicknesses (cm) are defined as integer values. In DayCent, the sand, silt, and clay fractions used by the decomposition model are computed as the weighted average sand content from all soil layers in soils.in – the SAND, SILT, CLAY, values entered in the <site>.100 file are ignored. Likewise, the values BULKD, PH, AFIEL(*), and AWILT(*) in the <site>.100 file are recalculated from values in the soils.in file.

Inorganic soil N is also defined differently between the CENTURY and DayCent models. The monthly CENTURY model defines 1 – 10 inorganic N layers as MINERL(*,N). In DayCent, the nitrogen trace gas submodel requires that inorganic soil N be partitioned into nitrate and ammonium in order to calculate nitrification and denitrification; inorganic N exists as a number of nitrate layers (nitrate(*), g N m^{-2}) that have the same thicknesses as the DayCent soil layers, plus a single ammonium layer that is assumed to be approximately in the top 10 – 15 cm of the soil profile. The CENTURY MINERL(*,*) values are still used in portions of the DayCent code. For example, the decomposition submodel uses MINERL(1,N) as the labile N pool that is the source/sink for N produced from mineralization and N consumed by immobilization. MINERL(1,N) is equal to ammonium plus nitrate from any DayCent layer that is mapped to the top CENTURY layer.

Table 2 An Example Soils.in Parameter File for Defining DayCent Soil Layers

thickness (cm)	upper depth (cm)	lower depth (cm)	bulk density (g cm^{-3})	field capacity (volu-metric)	wilting point (volu-metric)	evap. coeff	frac. roots	sand frac.	clay frac.	Org. Frac.	Δmin (volu-metric)	ksat (cm sec^{-1})	pH
2	0	2	0.83	0.121	0.035	0.8	0.01	0.9	0.02	0.02	0.008	0.042	4.5
3	2	5	0.83	0.121	0.035	0.2	0.04	0.9	0.02	0.02	0.008	0.042	4.5
5	5	10	0.83	0.121	0.035	0	0.25	0.9	0.01	0.02	0.006	0.042	4.5
10	10	20	0.83	0.121	0.035	0	0.3	0.9	0.01	0.02	0.004	0.042	4.5
10	20	30	1.01	0.121	0.035	0	0.1	0.9	0.02	0.02	0.002	0.042	4.5
15	30	45	1.01	0.125	0.035	0	0.05	0.9	0.02	0.02	0.000	0.042	4.5
15	45	60	1.01	0.065	0.035	0	0.04	0.9	0.03	0.01	0.000	0.042	4.5
15	60	75	1.01	0.065	0.035	0	0.03	0.96	0.03	0.01	0.000	0.042	4.5
15	75	90	1.01	0.065	0.035	0	0.02	0.96	0.03	0.01	0.000	0.042	4.5
15	90	105	1.23	0.065	0.035	0	0.01	0.96	0.03	0.01	0.000	0.042	4.5
15	105	120	1.23	0.065	0.035	0	0	0.96	0.03	0.01	0.000	0.042	4.5
30	120	150	1.23	0.065	0.035	0	0	0.96	0.03	0.01	0.000	0.042	4.5
30	150	180	1.23	0.065	0.035	0	0	0.96	0.03	0.01	0.000	0.042	4.5
30	180	210	1.54	0.065	0.035	0	0	0.89	0.1	0.01	0.000	0.042	4.5

An example *soils.in* parameter file for defining DayCent soil layers. (Note: the actual soils.in file does not have a row with column names). (In the DayCentEVI versions, the user has the option to specify these properties in the fix.100 file instead of soils.in). The minimum volumetric soil water content of a layer (*swclimit*) is calculated from two columns, *swclimit = wilting point – Δmin*. The value *ksat* is the saturated hydraulic conductivity (cm sec^{-1}). The *sand* and *clay* weight fractions used by the decomposition model are computed as the weighted average their corresponding values in top 3 soil layers of this file. The organic matter weight fraction (*org*) in *soils.in* is only used in the soil temperature model. The value of *silt = 1.0 – sand – clay*, except in the soil temperature model *silt = 1.0 – sand – clay – org*. The SAND, SILT, CLAY, values in the *<site>.100* file are ignored. Likewise, the values BULKD, PH, AFIEL(*), and AWILT(*) in the *<site>.100* file are recalculated from values in the *soils.in* file. The bands of colors are to illustrate that multiple DayCent soil layers may comprise a single CENTURY soil layers.

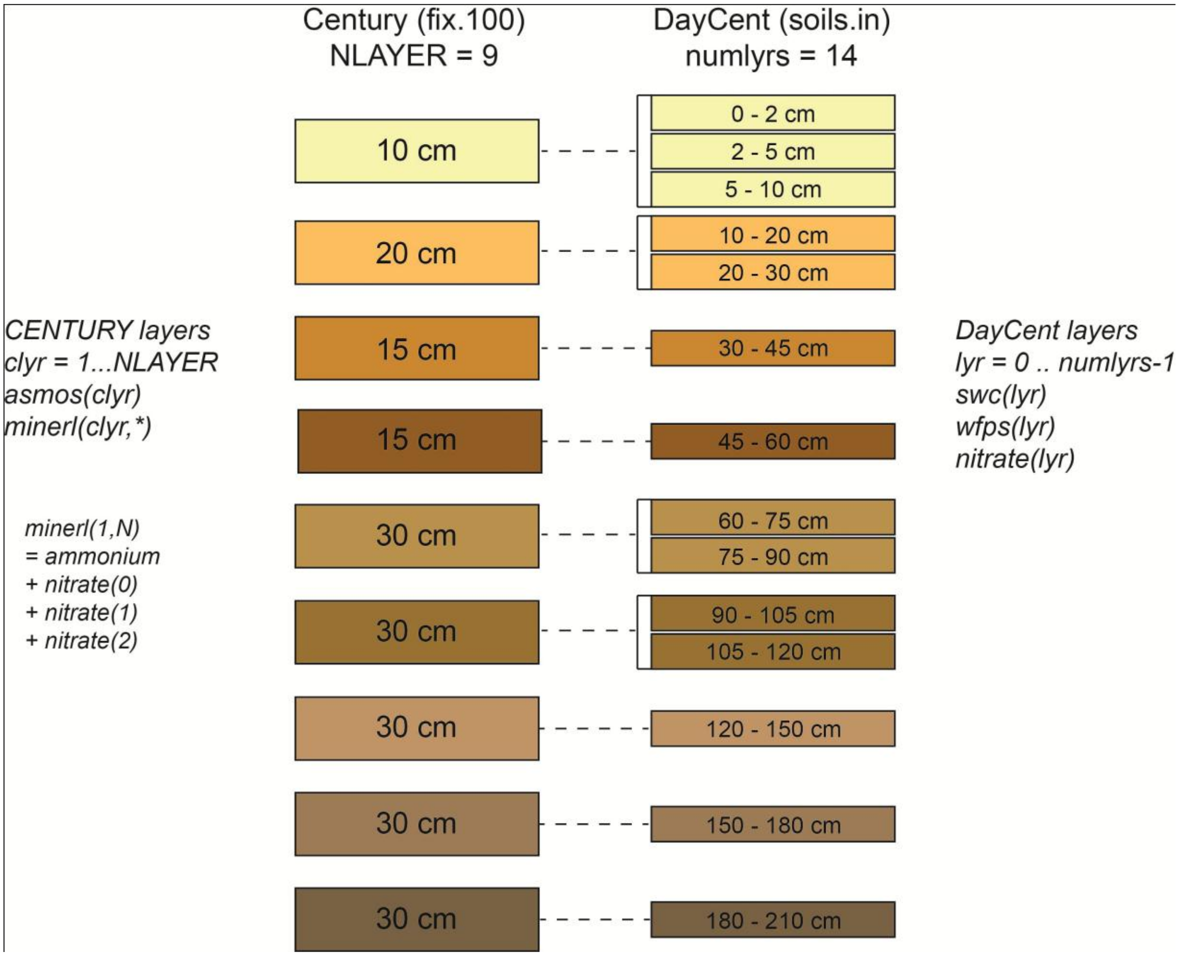


Figure 2 Soil Layer Structure

Figure 2. Soil Layer Structure. The relationship between “CENTURY” soil layers and finer “DayCent” soil layers. The CENTURY soil layer thicknesses are defined by *ADEP(*)* in the *fix.100* parameter file, and the number of layers to simulate is defined as *NLAYER* in the <site>.100 parameter file. The DayCent soil layers are defined in the *soils.in* parameter file **(Table 2)**. There can be multiple DayCent soil layers within a CENTURY soil layer, but layer boundaries must coincide as illustrated. The soil thicknesses shown above are for example; actual values are defined by the user.

3.3.Parameterizing new crops in the crop.100 file

DayCent has been parameterized to grow all the major U.S. commodity crops—corn (Zea mays L.), soybean [Glycine max (L.) Merr.], wheat (Triticum aestivum), hay, sorghum [Sorghum bicolor (L.) Moench, and cotton (Gossypium hirsutum L.)—as well as some other crops—barley (Hordeum vulgare L.), potato (Solanum tuberosum L.), millet [Pennisetum glaucum (L.) R. Br.???], tomato (Solanum lycopersicum L.), and sweet corn). The model also includes parameterizations to represent various grassland, forest, and savanna biomes (e.g., tallgrass prairie, shortgrass steppe, boreal forest, arid shrubland, tropical savanna). If users are growing a crop or vegetation mix that is not represented in our crop library, then we recommend modifying an existing parameterization that most closely resembles the new crop of interest. Data or estimates for the following are typically needed for each plant component (e.g., roots, shoots) to parameterize a new crop: C/nutrient ratio, C allocation fraction, death rate, and lignin concentration. In addition, maximum growth rate, growth response to temperature, harvest index, soil temperature for germination, and accumulated growing degree day impacts on phenology are required. When growing vegetation, users need to specify phenology options. In addition to designating whether the vegetation is a perennial or an annual, users choose if the beginning and end of the growing season are specified or generated by the model. Specifically, users can designate the calendar day when growth for perennials or germination for annuals begins, and the day when harvest or senescence occurs at the end of the growing season. Alternatively, the beginning of the growing season can be made a function of soil temperature and the end of the growing season a function of accumulated growing degree days. For grain-filling annuals, users have the further option of using accumulated growing degree days to initiate anthesis (flowering), as well as harvest.

3.4.Parameterizing new trees in the tree.100 file

Insert text here…

3.5.Creating a new site.100 File

Insert text here…
(Refer also to section 3.6.1 below about generating weather statistics).

3.6.Weather Data

DayCent requires daily meteorological inputs from a weather file. There are multiple weather file formats, but in all formats the first 7 columns are required and are defined in the same order (day of month, month, calendar year, day of year, maximum air temperature (°C), minimum air temperature (°C), and precipitation (cm). For calendar years which are leap years, 366 days of data are required. The additional optional meteorological inputs available depend on the model version and are summarized in **Table 3**. For several model versions the weather option to use is specified by the *usexdrivers* parameter in the first line of the sitepar.in file. The DayCentEVI version no longer uses a sitepar.in file, and the definitions for the extra columns in the weather file are inferred from the number of columns in the weather file.

Table 3 Weather Options: Summary of Alternative Weather File Formats for the DayCent model

Model Version	**Columns**	**usexdrivers (sitepar.in)**	**Description**
These 7 columns are required in all weather files regardless of the DayCent version.	1: day of month 2: month 3: calendar year (4 digits) 4: day of year 5: maximum air temperature (°C) 6: minimum air temperature (°C) 7: precipitation (cm)	usexdrivers = 0 means use only the first 7 columns even if there are additional columns.	When there are exactly 7 columns, potential evapotranspiration (PET) is calculated from air temperature.
The 10-column format is available to all DayCent versions.	8: solar radiation (langley d^{-1}) 9: wind speed (mph) 10: relative humidity (%)	usexdrivers = 1 In all but DayCentEVI, if these columns exist but usexdrivers=0, they will be ignored.	If there are 10 columns in the weather file, columns 8 – 10 have these definitions. If columns 8 – 10 exist, they are used in an alternative method for calculating PET.
DayCent_Photosyn versions only	8: mean daytime solar radiation (W m^{-2}) 9: vapor pressure deficit (kPa)	usexdrivers = 2 If these columns exist but usexdrivers=0, they will be ignored.	Photosynthesis drivers
DayCent_Photosyn versions only	8: solar radiation (langley d^{-1}) 9: wind speed (mph) 10: relative humidity (%) 11: mean daytime solar radiation (W m^{-2}) 12: vapor pressure deficit (kPa)	usexdrivers = 3 If these columns exist but usexdrivers=0, they will be ignored.	Both PET and Photosynthesis drivers

DayCentEVI versions only	8: mean daytime solar radiation (W m^{-2}) 9: EVI	usexdrivers = 4	

When running the model at the plot level, local weather station data should be used. But when running at regional or larger scales, datasets such as DAYMET (available at http://daymet.ornl.gov/ [verified 08 Jan. 2015]; (Thornton et al. 1997, Thornton and Running 1999b, Thornton et al. 2000) can be used.

If a daily value from columns 5, 6, or 7 is missing from an actual weather file, it should be set equal to the value "-99.99" within the file. If a minimum or maximum temperature is missing, the mean monthly value (TMN2M(*) or TMX2M(*)) from the <site>.100 file will be used. If a precipitation amount is missing, precipitation will be set to 0.0 for the day. A weather file template (.xlsx file) for the first four columns may be included with the DayCent distribution. Missing values are not permitted in columns 8 – 11.

3.6.1. Generating Weather Statistics

In addition to creating a daily weather file, users must also specify mean monthly weather statistics in the <site>.100 file. These weather statistics are the first 36 parameters in the <site>.100 file and include mean monthly minimum and maximum air temperatures (at 2 meters), TMN2M(1-12) and TMX2M(1-12) (°C), and mean monthly precipitation totals, PRECIP(1-12) (cm). If the user has actual daily weather data for a minimum ten-year period, supplemental software, including the old FILE100 program (option 13) and the newer *mksitesoil* program, can be used to compute the weather statistics and update the <site>.100 file. If you did not receive a supplemental program that computes weather statistics, please contact the person who sent you the DayCent model or this manual. The precipitation standard deviations and skewness values, PRCSTD (1-12), and PRCSKW(1-12) in the <site>.100 file, are computed by the weather statistics programs and written to <site>.100 as placeholders, but these parameters are not used by DayCent (they are used by the monthly CENTURY model only). There are no weather statistics for solar radiation, wind speed, relative humidity, or EVI.

DayCentEVI will compute weather statistics from a weather file and write them to <site>.100 automatically if the second line in <site>.100 is changed from "Climate parameters" to “Climate statistics” followed by a weather file name on the same line. For example, to create weather statistics from a weather file named *mysite.wth*, the second line in <site>.100 looks like this:

```
*** Climate statistics    mysite.wth
```

DayCent sums mean monthly precipitation (PRECIP(*), *<site>.100*) to get mean annual precipitation (PRCANN) which is then used to calculate annual N and S inputs from atmospheric deposition. PRCANN is also used to calculate the base-level site potential (SITPOT) used for grass/tree competition in savannas (this SITPOT value is multiplied by the SITPOT parameter in tree.100). DayCent uses mean monthly minimum and maximum temperatures (TMN2M(*), TMX2M(*), *<site>.100*) to fill in missing daily temperature values.

4. Scheduling Events

4.1. Introduction

With DayCent it is easy to represent a timeline of common cropland and grassland management options (e.g., planting, harvesting, tillage, irrigation, fertilization, organic matter additions, burning, grazing) and common forest events (e.g. fire and other forest disturbance, and wood harvest). In general, a schedule file is a series of one or more management blocks. In each block the user specifies a list of the types of management or disturbance events that occur and the year and day of the year on which each event occurs. The type of event designated by the user supplies the model with parameters controlling impacts on soil, vegetation, and litter pools.

4.1.1. Herbaceous systems: Croplands and Grasslands

The list of common events used for timelines for crops and grasses (herbaceous plants) are given in

Table 4. A complete set of schedule file event options can be found in Section 4.6 below.

Table 4 Common Events Used in Constructing Timelines for Croplands and Grasslands

Common events used in constructing management timelines for croplands and grasslands. The value of <argument> is an abbreviation ≤ 5 characters.

Schedule Event Type – Crops/Grasses	DayCent Definition
CROP <argument>	Type of crop or grass to grow. The argument is a crop type, the name of the set of parameters found in the CROP.100 file that will be used.
AFERT <argument>	Persistent automatic fertilization event. The argument is equivalent to the AUFERT parameter in FERT.100, although this event does not use FERT.100. Automatic fertilization is turned off with a later FERT event. The AFRT event is not available in all versions of DayCent.
CULT <argument>	Cultivation or tillage event. The argument is a cultivation type, the name of a set of parameters found in the CULT.100 file that will be used.
PLTM	Planting event (no arguments) – applies to annual plants and perennials at the time of planting.
FRST	First day of potential growth (no arguments) – applies to perennial crops/grasses in non-plant years.
FERT <argument>	N, P, or S fertilizer addition. The argument refers to name of set of parameters found in FERT.100 file. Available for all versions of DayCent.
FERT (argument list)	Alternative method of scheduling FERT events that does not require FERT.100. The argument list is explained later in the document. This “immediate mode” scheduling format for FERT events is not available in all versions of DayCent (Section 4.8.2.1 below).
OMAD <argument>	Organic matter addition. The argument is a type of organic matter addition, the name of the set of parameters found in the OMAD.100 file that will be used.
IRRI <argument>	Begin month-long irrigation with 4 events per month. The argument is a type of irrigation, the name of the set of parameters found in the IRRI.100 that will be used. This option is available in all versions of DayCent.
IRRI (argument list)	Alternative format for month-long irrigation. This is “immediate mode” scheduling format which does not use IRRI.100. Irrigation amount and frequency are specified in an argument list (Section 4.8.2.2 below). The immediate mode format for IRRI events is not available in all versions of DayCent.
IRIG (argument list)	Begin daily irrigation. This event uses “immediate mode” scheduling format and does not use IRRI.100. Irrigation amount and frequency are specified in an argument list (Section 4.8.2.2 below). The IRIG event is not available in all versions of DayCent.
GRAZ <argument>	Begin grazing. The argument is a type of grazing, the name of the set of parameters found in the GRAZ.100 file that will be used.
HARV <argument>	Harvest event. The argument is a harvest type, the name of the set of parameters found in the HARV.100 file that will be used.
LAST	Last day of potential growth (no arguments)
SENM	Senescence of crop/grass (no arguments)

FIRE <argument>	Fire event. The argument is a type of fire, the name of the set of parameters found in the FIRE.100 file that will be used. A “FIRE” event burns aboveground live and dead herbaceous biomass, dead wood, and litter (but not live wood).

The user should gather management pertinent data in as much detail as possible in an organized timeline. For example:

Year 1
March 27 - Tillage with moldboard plow
April 28 – Soil finishing – harrows
April 30 – corn planted, starter fertilizer (50 kg N ha^{-1} = 5 g N m^{-2})
June 5 – row cultivator
June 10 – post-plant fertilizer (100 kg N ha^{-1} = 10 g N m^{-2})
Sept 27 – harvest corn (grain only)

A list of events in a schedule file this could be represented as:

```
1   86  CULT  P
1  118 CULT H
1  120 CROP C6
1  120 PLTM
1  120 FERT 5N
1  155 CULT C
1 160 FERT 10N
1 270 HARV G
1 270 LAST
```

The columns in this timeline are: year in cropping sequence, day of year, event, and event argument (if any). Years and days of year must be in correct order. Events that occur on the same day can be in any order. Schedule building can be done in any text editing software but the files must bear a .sch or an .evt extension. The .evt extension was adopted after Microsoft began using .sch extension for its Scheduler.

There are several limitations regarding event scheduling. Some events have effects that last for an entire month (grazing, irrigation, and cultivation). If more than one event of the same type is scheduled during a month, the second event will cease the first event. For example, if a GRAZ event, which normally affects vegetation offtake for 30 days, is scheduled for 7 June and an another is scheduled for 20 June, the first type of GRAZ event will be in effect June 7 – 19, and the second type of GRAZ event will replace it and commence June 20 and continue for another 29 days. In some model versions if a CULT event, which normally affects decomposition rates for 30 days, is scheduled for 7 June and an another is scheduled for 20 June, the first type of CULT event will be in effect June 7 – 19, and the second type of CULT event will replace it and commence June 20 and continue for another 29 days. However, in another model version the residual effect of the first scheduled CULT event in a month is combined with the effect of the second CULT event and this combined effect on decomposition rates is modeled for a full month (see version write-up).

Scheduling a new CROP while the previous crop still has living biomass will assign that living biomass to the new crop. For example, if a HARV event is accidentally omitted before a new crop is planted, the existing live biomass from the first crop will be assigned to the second crop on the day the second crop is scheduled. The results include large discrepancies in yields and carbon and nutrient dynamics for those years.

Another scheduling limitation is that events scheduled for the last day of the month during leap years (except for January) will not be implemented. There are also caveats when using soil temperature and accumulated growing degree days (GDD) to control plant phenology. For example, if the soil temperature is cool in spring, then a fertilizer event scheduled on the typical planting day could occur before crop emergence. See Part 2, section 3.7.1.2 below about the GDD crop model.

Automatic fertilization and irrigation options are also available. Regarding automatic fertilization, the user specifies the degree to which fertilizer application will meet or exceed nutrient demand. When using the automatic irrigation option, the user specifies either to irrigate to field capacity, field capacity plus potential evapotranspiration, or to apply a specified amount of water.

4.1.2. Woody Systems: Forests, Shrublands, and Plantations

A schedule file can represent both natural woody systems (such as forests) and managed woody systems (such as tree plantations). The list of common events used for timelines for trees and shrubs (woody plants) are given in **Table 5**. Some events may be common to the management of crops, grasses, and trees, such as fertilization, organic matter additions, and irrigation.

Table 5 Common Events Used in Constructing Management Timelines for Trees and Shrubs

Common events used in constructing management timelines for trees and shrubs. The value of <argument> is an abbreviation ≤ 5 characters.	
Schedule Event Type – Trees/Shrubs	DayCent Definition
TREE <argument>	Type of tree to grow. The argument is a tree type, the name of the set of parameters found in the TREE.100 file that will be used.
TFST	First day of potential growth (no arguments) of trees
AFERT <argument>	Persistent automatic fertilization event. The argument is equivalent to the AUFERT parameter in FERT.100, although this event does not use FERT.100. Automatic fertilization is turned off with a later FERT event. The AFRT event is not available in all versions of DayCent.
FERT <argument>	N, P, or S fertilizer addition. The argument refers to a name of set of parameters found in FERT.100 file. Available for all versions of DayCent.
FERT (argument list)	Alternative method of scheduling FERT events that does not require FERT.100. The argument list is explained later in the document. This “immediate mode” scheduling format for FERT events is not available in all versions of DayCent (Section 4.8.2.1 below).

FIRE <argument>	Fire event. The argument is a type of fire, the name of the set of parameters found in the FIRE.100 file that will be used. A “FIRE” event burns aboveground live and dead herbaceous biomass, dead wood, and litter (but not live wood).
OMAD <argument>	Organic matter addition. The argument is a type of organic matter addition, the name of the set of parameters found in the OMAD.100 file that will be used.
IRRI <argument>	Begin month-long irrigation with 4 events per month. The argument is a type of irrigation, the name of the set of parameters found in the IRRI.100 that will be used. This option is available in all versions of DayCent.
IRRI (argument list)	Alternative format for month-long irrigation. This is “immediate mode” scheduling format which does not use IRRI.100. Irrigation amount and frequency are specified in an argument list (Section 4.9 below). The immediate mode format for IRRI events is not available in all versions of DayCent.
IRIG (argument list)	Begin daily irrigation. This event uses “immediate mode” scheduling format and does not use IRRI.100. Irrigation amount and frequency are specified in an argument list (Section 4.8.2.2 below). The IRIG event is not available in all versions of DayCent.
TREM <argument>	Tree removal event. The argument is a tree removal event type, the name of the set of parameters found in the TREM.100 file that will be used. Tree removals events are used to represent live tree burning, wood harvest, and other tree disturbance events such as death due to pests, disease, and wind damage. (Note: to burn dead wood, litter, and herbaceous biomass, use a “FIRE” event.)
TLST	Last day of potential growth for trees (no arguments)

Below is an example using two blocks to grow a boreal forest for 2000 years with a tree harvest event (CUT) in 2001.

```
1          Block #   Boreal Forest
2000       Last year
1          Repeats # years
1          Output starting year
12         Output month
1.0        Output interval
C          Weather choice
  1    1 TREE TMCF
  1    98 TFST
  1   310 TLST
-999 -999 X

2          Block #   Boreal Forest
```

```
2001      Last year
1          Repeats # years
2001      Output starting year
12         Output month
1.0        Output interval
C          Weather choice
   1    1 TREE TMCF
   1    98 TFST
   1  190 TREM CUT
   1  310 TLST
-999 -999 X
```

4.1.3. Savannas

A savanna in DayCent is a system with both a crop/grass type and a tree/shrub type. In any block there is a maximum of one type of herbaceous vegetation and one type of woody vegetation. Events for grasses and trees are combined in the same block, with the years and days in order.

In the following example a “Xeromorphic” Forest is grown with a burn every other year. Note that this example is for illustration purposes only, natural burns in this type of system may occur much less frequently (such as every 30 years). An annual grass (ANGR) is grown with a Mediterranean shrub (MDSH) in the northern hemisphere. The TFST and TLST events indicate that the tree can grows all year long (days 1 – 365). In such a system annual grasses grow during the wet season; the FRST and LAST events indicate that the grass begins its annual growth on day 289 (mid-October) and ends its annual growth on day 167 (mid-June). There are 4 grazing events each year. In the second year both a FIRE and a TREM event are scheduled to burn grasses and live trees.

```
Year Month Option
1            Block #   Xeromorphic Forest
2000        Last year
3            Repeats # years
1500        Output starting year
12           Output month
1.000       Output interval
F            Weather choice
pnh_lu35.wth
   1     1 CROP ANGR
   1     1 TREE MDSH
   1     1 TFST
   1  106 GRAZ GM
   1  136 GRAZ GM
   1  167 LAST
   1  167 GRAZ GM
   1  289 PLTM
   1  289 FRST
   1  350 TLST
   2    1 CROP ANGR
   2    1 TREE MDSH
```

```
  2    1 TFST
  2  106 GRAZ GM
  2  106 TREM BURN
  2  106 FIRE H
  2  136 GRAZ GM
  2  167 LAST
  2  167 GRAZ GM
  2  289 PLTM
  2  289 FRST
  2  365 TLST
-999 -999 X
```

4.2.The Concept of Blocks

Each schedule file has a header (Section 4.4 below) and one or more blocks of events. Each schedule block also has its own header indicating how many years are depicted in the block, start and end years for the block, weather file options, and output options. A block is a series of events which will execute once and may be repeated, in sequence, until the ending time of the block is reached. An example of a schedule block that repeats the same two-year sequence over a 20-year period (1900 to 1919) is given here:

```
Year Day Event
1                  Block #   Perennial Grass with grazing and burning
1919               Last year
2                  Repeats # years
1900               Output starting year
1                  Output month
0.0833             Output interval (1=annual; 0.0833=monthly)
F                  Weather choice
example.wth
  1   15 CROP G3
  1   74 GRAZ W
  1  105 FRST
  1  203 GRAZ GM
  1   320 LAST
  1   350 SENM
  2    15 CROP G3
  2   105 FRST
  2   289 FIRE MED
  2   320 LAST
  2   350 SENM
-999 -999 X
```

Above the first block in any schedule file is an explanation line “Year Day Event” which is required – this line occurs only once in the schedule file. Each block begins with a line that contains “Block #” and ends with “-999 -999 X”. The above example will repeat the 2-year sequence of events 10 times using the daily weather file named (example.wth) and provide monthly output to the binary file (0.0833 output interval) starting in January of 1900.

In another example, a series of historical farm practices might be: a wheat-fallow rotation with plow cultivation and straw removal from 1918 until 1957, wheat-fallow with stubble-mulch management and low nitrogen fertilization rates until 1975, followed by fallow-wheat with higher nitrogen fertilizer rates until 1994. A schedule file, with a header and a series of blocks, could be represented as:

```
1918        Starting year
1994       Last year
walsh.100    Site file name
0          Labeling type
-1         Labeling year
-1         Microcosm
-1         CO2 Systems
-1         pH Effect
-1         Soil Warming
0          N input scalar option
0          OMAD scalar option
0          Climate scalar option
1          Initial system
W1         Initial crop
           Initial tree

Year Day Event
1          Block #   W-F_Sterling_Base_144
1957       Last year
2          Repeats # years
1918       Output starting year
1          Output month
1.0        Output interval
F          Weather choice
walsh.wth
  1  105 CULT K
  1  136 CULT A
  1  167 CULT A
  1  197 CULT A
  1  228 CULT A
  1  259 CROP W1
  1  259 PLTM
  2  197 LAST
  2  197 HARV G75S
-999 -999 X
2          Block #   W-F_Sterling_Base_145
1975       Last year
2          Repeats # years
1958       Output starting year
```

```
1         Output month
1.0       Output interval
F         Weather choice
walsh.wth
  1  105 CULT F
  1  136 CULT A
  1  167 CULT A
  1  197 CULT A
  1  228 CULT A
  1  259 CROP W2
  1  259 PLTM
  1  259 FERT N1
  2  197 LAST
  2  197 HARV G
-999 -999 X
3         Block #   W-F_Sterling_Base_146
1994      Last year
2         Repeats # years
1976      Output starting year
1         Output month
0.0833    Output interval
C         Weather choice
  1  105 CULT F
  1  136 CULT A
  1  167 CULT A
  1  197 CULT A
  1  228 CULT A
  1  259 CROP W3
  1  259 PLTM
  1  259 FERT N3.5
  2  197 LAST
  2  197 HARV G
-999 -999 X
```

The wheat crops used (W1, W2, W3) are to illustrate the varietal improvement through time (reflected in the parameters found in the CROP.100). The above example also illustrates the two possible choices for calling upon the weather file. The option used in the first two blocks of the example (F) reads the daily values for precipitation, minimum and maximum air temperature plus extra optional weather drivers from the start of a weather data file (see sitepar.in parameter “use extra weather drivers” to set this option). Each block starts at the beginning of the weather file. The option in the third block of the example (C) will continue to read the same file where it left off in the previous block; there is no need to specify the weather file name again in this block, and the weather file will be rewound if the end of the weather file is reached before the end of the block. Since these are currently the only options the user will often find it advantageous to produce a version of his weather file that is synchronized as much as possible with the dates in his schedule file blocks.

4.3.Creating a schedule (event) file

Schedule files are composed and modified using a text editor. This process can usually be simplified by making a copy of a previously constructed schedule and making the appropriate revisions. Much of the schedule file header and the block header format and end formats are the same in every schedule. The headers often only require changes in start and end dates and weather file calls. Where the same or similar rotations are used in different blocks much of one block can be copied into another and only minor changes made. The user must be careful not to leave behind unintended snippets of the original schedule file as these may not generate error messages but can alter results.

4.4.Schedule File Header

Each schedule file has one header section that consists of start year and end year, the name of the <site>.100 file to be used for the simulation, and a series of options that can be implemented if the user desires. The most commonly used header format has all the options turned off **(Table 6)**.

4.4.1. Example schedule file header

Table 6 Two Example Schedule File Headers

Two example schedule file headers. On the left side all optional features in the schedule file header are turned off while on the right side all these options are turned on.

A. Example schedule file header - all options turned off	**B. Example of schedule file header – all options turned on**
1 Starting year 2010 Last year mysite.100 Site file name 0 Labeling type -1 Labeling year -1 Microcosm -1 CO2 Systems -1 pH Effect -1 Soil Warming 0 N input scalar option 0 OMAD scalar option 0 Climate scalar option 1 Initial system C2 Initial crop Initial tree Year Month Option 1 Block # initialize *Etc…*	1 Starting year 2010 Last year mysite.100 Site file name 2 Labeling type 1990 Labeling year -1 Microcosm 1 CO2 Systems 1850 2010 1 pH Effect 1980 1 Soil Warming 1990 0.5 2 N input scalar option 1950 1 OMAD scalar option 1900 3 Climate scalar option 1975 1 Initial system C2 Initial crop Initial tree Year Month Option 1 Block # initialize *Etc…*

4.4.2. ^{13}C or ^{14}C labeling option

Labeling type: 0= none; 1 = 14C; 2= 13C-stable isotope

The DayCent model can simulate labeling by either 14C or 13C. C labeling is specified in the schedule file header. The 14C simulations act as a labeled tracer from atmospheric sources or added organic matter (ASTLBL, omad.100). The c14data file contains a record of atmospheric 14C concentrations which are used by the model to label new plant material, which then flows through the other organic matter pools. Simulations using the option for 13C give a constant label to plant material based on the value of DEL13C in the crop.100 and tree.100 files. This option will primarily be of use to follow the change in stable isotope signal when there has been a switch from C3 to C4 vegetation or vice-versa.

4.4.3. Microcosm option (deprecated)

-1 Microcosm

The microcosm option was available in the monthly CENTURY model to simulate litter bag decomposition or soil incubations at constant temperature and soil moisture. The microcosm option is currently not available for DayCent; any number other than -1 for this option will cause the DayCent to halt execution.

4.4.4. CO_2 systems option

DayCent can simulate effects of atmospheric CO_2 concentration on transpiration, plant production, plant C to element ratios, and plant root to shoot ratios. With the "CO2 Systems" option in the schedule file header, the user can choose between several types of fertilization effects: no CO_2 fertilization, and a step increase/decrease in CO_2 concentration, or a linear increase/decrease of atmospheric CO_2 concentration. The equations governing the CO_2 effects on transpiration and production are relative to 350 ppm, the atmospheric CO_2 concentrations that existed around the time CENTURY was developed. Therefore, specifying an atmospheric CO_2 concentration of 700 ppm would be a "doubling" of CO_2.

The CO2 Systems option in the schedule file header, in combination with three fix.100 parameters, define how atmospheric CO_2 changes during the simulation. When CO2 Systems ≤ 0 there is no CO_2 effect. When CO2 Systems = 1, the change in atmospheric CO_2 concentrations over time will depend on the values CO2RMP, CO2PPM(1), and CO2PPM (2) from fix.100.

CO2PPM(1) – Base concentration in CO_2 (ppm)
CO2PPM(2) – Final concentration in CO_2 (ppm)
CO2RMP – Flag indicating the type of change in CO_2 concentration:
  = 0 step increase or decrease
  = 1 linear increase or decrease

If CO2 Systems = 1, the CO2 Systems line in the schedule file header is followed by a line with the first year and last year of the CO_2 change (co2tm(1) and co2tm(2), respectively), and the following rules apply. The value *time* refers to the simulation time and the value *co2conc* refers to the corresponding atmospheric CO_2 concentration (ppm). The value of *co2conc* is updated once a year.

if (*time* ≤ co2tm(1)) then use base concentration from fix.100 file
    co2conc = CO2PPM(1)

if (CO2RMP = 0) and (*time* > co2tm(1)) then use raised constant concentration for the remainder of the simulation
    co2conc = CO2PPM(2)

if (CO2RMP = 1) and (*time* > co2tm(1)) and (time ≤ co2tm(2)) then use a linearly ramped concentration between CO2PPM(1) and CO2PPM(2)

if (CO2RMP = 1) and (*time* > co2tm(2)) then use the final concentration from fix.100 file
    co2conc = CO2PPM(2)

For more information about the CO_2 effect on production, transpiration, C to element ratios, and the root to shoot ratio, see Part 2, Section 3.8.9 below (Enriched CO_2 Effects).

4.4.5. Soil pH shift option (using the phscale.dat file)

The pH scalar option in the schedule file header allows the user shift the pH value of the soil over time, for example to simulate liming experiments. Valid values for the pH scalar option are:

0 – No scalar used, pH is constant throughout the simulation based on values in the soils.in file.
1 – use the pH scalars in the phscale.dat file to change soil pH, beginning in the year specified on the next line

The phscale.dat file is organized in 13 columns. Column 1 is the year. Columns 2 – 13 contain the pH scalars for each month of the year with column 2 = scalar value for January, column 3 = scalar value for February, ..., column 13 = scalar value for December. A value of 1.0 used for a scalar will have no effect on the soil pH. A value of less than 1.0 used for a scalar will reduce the soil pH. A value of greater than 1.0 used for the scalar will increase the soil pH. All of the scalars are applied against the pH value as read from the soils.in file. A value of less than 0.0 in the phscale.dat file is invalid and the model will use the value of 1.0 for the scalar in this case, in effect eliminating any shift in pH.

Since pH is a negative logarithm (pH = $-\log10[H^+]$), using a pH scalar of 1.5 will decrease the hydrogen ion concentration (mol/L) by multiple powers of 10. Similarly, using a pH scalar of 0.5 will increase the hydrogen ion concentration by multiple powers of 10, depending on the baseline pH value. For example, if the baseline pH of the soil is 6.0, and the pH scalar is 1.5, the hydrogen ion concentration will decrease by a factor of 10^{-3} ($10^{-9}/10^{-6}$). If the pH of the soil is 6.0 and the pH scalar is 0.5, the hydrogen ion concentration will increase by a factor of 1000 ($10^{-3}/10^{-6}$).

Shifting pH may change soil organic matter decomposition rates (Part 2, Section 3.1.5 below) and affect the solubility of secondary phosphorus (Part 2, Section 3.3 below).

4.4.6. Soil warming option

The soil warming option in the schedule file header allows the user to increase or decrease soil surface temperatures without increasing air temperature, for example to simulate soil warming experiments. There is no additional file associated with this option. Valid values for the soil warming option are:

0 – No soil warming
1 – Implement soil warming. Start soil warming in the year specified on the next line by adding the temperature amount (°C) specified on the following line.

In the example below, soil warming of 0.5 °C will commence in 1990 and continue for the remainder of the simulation:

```
1           Soil warming
1990
0.5
```

The soil warming option can also be used to decrease soil temperatures when the amount of “warming” is negative. An increase/decrease in the soil surface temperature may affect the rate of soil organic matter decomposition, the rate that juvenile roots age into mature fine roots, and the root death rate.

4.4.7. Nitrogen input scalar option (using the nscale.dat file)

The N input scalar option in the schedule file header can be used to continuously adjust N input rates without making changes to the schedule file or <site>.100 parameters. When this option is turned on, the multipliers in nscale.dat are used to scale the amount of fertilizer added through FERT events, the amount of atmospheric N deposition, or both. Valid values for the N input scalar option are:

0 – No N scalar used
1 – Use N scalar on FERT options only, beginning in the year on the next line
2 – Use N scalar on atmospheric N deposition only, beginning in the year on the next line
3 – Use N scalar on both FERT options and atmospheric N deposition, beginning in the year on the next line

The nscale.dat file is organized in 13 columns. Column 1 is the year. Columns 2 – 13 contain the N input scalars for each month of the year with column 2 = scalar value for January, column 3 = scalar value for February, ..., column 13 = scalar value for December. A value of 1.0 used for a scalar will have no effect on the amount of N input. A value of less than 1.0 used for a scalar will reduce the N input amount. A value of greater than 1.0 used for the scalar will increase the N input amount. A value of less than 0.0 in the nscale.dat file is invalid and the model will use the value of 0.0 for the scalar in this case, in effect eliminating the N inputs. The nscale.dat file must have one line for every year from the first year of N-scaling to the final year of the simulation.

4.4.8. Organic Matter Addition scalar option (using the omadscale.dat file)

The OMAD input scalar option in the schedule file header can be used to continuously adjust the amount organic matter added through OMAD events without making changes to the schedule file. Valid values for the OMAD input scalar option are:

0 – Do not scale organic matter additions
1 – Use OMAD scalars, beginning in the year on the next line

This omadscale.dat is organized in 13 columns. Column 1 is the year. Columns 2 – 13 contain the OMAD scalars for each month of the year with column 2 = scalar value for January, column 3 = scalar value for February, ..., column 13 = scalar value for December. A scalar of 1.0 will have no effect on the amount of organic matter input. A value of 0.0 can be used to essentially turn off OMAD events. A scalar between 0.0 and 1.0 will reduce the organic matter input amount. A scalar greater than 1.0 will increase the organic matter input amount. A value of less than 0.0 in the omadscale.dat file is invalid and the model will use a value of 0.0 for the scalar in this case, in effect eliminating the OMAD inputs. The omad.dat file must have one line for every year from the first year of OMAD-scaling to the final year of the simulation.

4.4.9. Climate scalar option (using the tminscale.dat, tmaxscale.dat, precscale.dat files)

The climate scalar option in the schedule file header can be used to modify temperature and/or precipitation values read from the weather file to simulate climate change scenarios. The scalars are stored in the tmaxscale.dat, tminscale.dat, and precscale.dat for modifying maximum temperature, minimum temperature, and/or precipitation respectively. Values for the climate scalar options are:

0 – do not use any climate scalars
1 – use climate scalars in tminscale.dat to adjust minimum air temperature only
2 – use climate scalars in tmaxscale.dat to adjust maximum air temperature only
3 – use climate scalars in tminscale.dat to adjust minimum air temperature and in tmaxscale.dat to adjust maximum air temperature
4 – use climate scalars in precscale.dat to adjust precipitation only
5 – use climate scalars in tminscale.dat to adjust minimum air temperature, in tmaxscale.dat to adjust maximum air temperature, and in precscale.dat to adjust precipitation

When the climate scalar option > 0, climate scaling will begin in the year specified on the next line. The *.dat files used must have one line for every year from the first year of climate-scaling to the final year of the simulation. The temperature scalars are addends and the precipitation scalars are multipliers. These files are organized in 13 columns. Column 1 is the year. Columns 2 – 13 contain the scalars for each month of the year with column 2 = scalar value for Jan, column 3 = scalar value for February, ..., column 13 = scalar value for December.

Temperature scalars of 0.0 will have no effect on the simulated temperature. A value of greater than 1.0 used for the temperature scalar will increase the temperature. A value of less than 0.0 used for the temperature scalar will decrease the temperature.

Precipitation scalars of 1.0 will have no effect on the simulated precipitation amount. A value of less than 1.0 used for a precipitation scalar will reduce the precipitation amount. A value of greater than 1.0 used for the precipitation scalar will increase the precipitation amount. A value of less than 0.0 in the precscale.dat file is invalid and the model will use a value of 1.0 for the scalar in this case, which will have no effect on the precipitation inputs.

4.4.10. Initial System

The initial system is 1) for croplands or grasslands, 2) for forests, and 3) for savannas. If the system changes later in the schedule file, DayCent will be able to determine that based on how the CROP and TREE events are used in each schedule file block.

4.4.11. Block ‘0’ (Block zero) events.

Some versions of DayCent allow what are called “Block 0” events which occur before the first schedule file block. This is a condensed way of specifying repeated regular events that occur in subsequent blocks. Insert more information and examples here….

4.5. Schedule File Block Headers

While there is only one schedule file header in a schedule file, each block in the schedule file must also have a header. A block header has 7 or 8 lines, depending on which “Weather choice” is specified.

An example of a block header looks like this:

```
3         Block #   Insert your own comment here
1975      Last year
2         Repeats # years
1958      Output starting year
12        Output month
1.0       Output interval
F         Weather choice
example.wth
```

In the above example, this is the third block of the schedule file. It ends in 1975 (and it begins the year after the end of Block #2). Output starts in year 1958. It specifies annual output at the end of December. It also specifies to read weather file “example.wth” from the beginning.

line 1: Block # and optional comment. Note: for readability it is best to number blocks sequentially in the schedule file and to insert meaningful comments, but if these block numbers are not in sequence it won’t cause an error.

line 2: Last year. The last year of the block. The first year of a block is the last year of the previous block plus one year. In the very first block of the schedule file, the first year of the block is the “Starting year” in the schedule file header.

line 3: Repeats # years. The number of years of events listed in the block. This is ≤ the duration of the block, where the duration is Last year – first year + 1.

line 4: Output starting year. The year output begins for the block (not necessarily the first year of the block). The “Output starting year” applies to both binary file output and to DayCent text output files (*.out, *.csv). This is often set to the first year in the block, but during a spinup the user may want to set it to a later year to avoid creating large output files.

line 5: Output month.

If the “Output interval” is ≥ 1.0, this is the month output will be written to the binary file.
If the “Output interval” = 0.0833, the “Output month” is ignored.

line 6: Output interval (this applies to the binary file only)

1.0 = write to the binary file once a year
0.0833 = write to the binary file monthly
This number could also be an integer > 1 for less frequent output (such as during a spinup that lasts thousands of years)

line 7: Weather choice

F = read a new weather file from the beginning
C = continue reading the weather file specified in a previous block)

line 8: The name of the weather file to read from the beginning (applies only for Weather choice F). This line is omitted for Weather choice C.

4.6.Complete List of Event Commands

Below is a complete list of all schedule file event options available. The value of <argument> is an abbreviation ≤ 5 characters.

AFRT <argument> – A persistent automatic fertilization event where <argument> is equivalent to the AUFERT parameter in FERT.100 (Appendix 1). An AFRT event does not use FERT.100. Automatic fertilization will continue each day until it is turned off with a FERT event (FERT(0.0N) for example). This event is not available in all versions of DayCent.

<argument>: An AUFERT value greater than 0 and less than or equal to 2.0.

Format: The year within the block, day of year, and the word "AFERT", followed by the AUFERT value.

Example:

1 131 AFRT 1.25
1 131 CROP C6
1 131 CULT D
1 131 PLTM
1 161 CULT HW-7
1 262 FERT (0.0N)

CROP <argument> – Designates which crop/grass is growing. Only one crop/grass can be grown at a time. One crop/grass can also be growth with one tree type in a savanna.

<argument>: Acceptable abbreviations are from the *crop.100* file.

Format: The year within the block, day of year, and the word "CROP", followed by the crop selected.

Example:

1 136 CROP ALF
1 136 PLTM
1 259 HARV
1 289 LAST
1 300 SENM

PLTM – Marks the day in which the current annual crop/grass is planted. Use FRST for a perennial crop/grass.

Format: The year within the block, day of year, and the word "PLTM".

Example:

1 136 CROP ALF
1 136 PLTM
1 259 HARV
1 289 LAST
1 300 SENM

HARV <argument> – Schedules a harvest of the current crop/grass and designates which type of harvest to use.

<argument>: An acceptable abbreviation from the *harv.100* file.

Format: The year within the block, day of year, and the word "HARV", followed by the harvest method selected.

Example:

1 228 HARV G

FRST – Marks the day as the first day of growing for a perennial crop/grass. Use PLTM for an annual crop/grass.

Format: The year within the block, day of year, and the word "FRST".

Example:

```
1   16 CROP TMC4
1   32 FRST
1  300 LAST
1  335 SENM
```

LAST – Marks the day as the last day of growing for crops. Applies to both annual and perennial crops/grasses.

Format: The year within the block, day of year, and the word "LAST".

Example:

```
1   16 CROP TMC4
1   32 FRST
1  289 LAST
1  300 SENM
```

SENM – Marks the current day as the day of senescence for crops. No growth will occur in the one month period that follows the scheduled senescence event.

Format: The year within the block, day of year, and the word "SENM".

Example:

```
1   16 CROP TMC4
1   32 FRST
1  289 LAST
1  300 SENM
```

FERT <argument> – Schedules a fertilization event for the current day.

<argument>: An acceptable abbreviation from the *fert.100* file.

Format: The year within the block, day of year, and the word "FERT", followed by the fertilization method selected.

Example:

```
1        133 FERT N5    #N5 must be found in FERT.100
```

FERT (argument list) – Alternative method of scheduling a fertilization event that does not require FERT.100. See Section 4.8.2.1 below (Fertilizer Events with Immediate Input Mode) for more information.

Example:

```
1        133 FERT (5N,8.50I,1.0F)
```

CULT <argument> – Schedules a cultivation event for the current day. The effects of cultivation on decomposition will last for 30 days, or until another CULT event is scheduled.

<argument>: An acceptable abbreviation from the *cult.100* file.

Format: The year within the block, day of year, and the word "CULT", followed by the cultivation method selected.

Example:

1 106 CULT K

OMAD <argument> – Schedules an organic matter addition event on the current day.

<argument>: An acceptable abbreviation from the *omad.100* file.

Format: The year within the block, day of year, and the word "OMAD", followed by the type of organic matter addition selected.

Example:

1 100 OMAD M14

IRIG (argument list) – Schedules a <u>daily</u> irrigation event for one or more consecutive days. Does not require IRRI.100. The amount, type, and duration of the irrigation events are specified in the argument list. See Section 4.8.2.2 (Irrigation Events with Immediate Mode) for more information.

Example:

1 300 IRIG (1A,0.925F,100L)

IRRI <argument> – Schedules a <u>month-long</u> irrigation event beginning on the current day. The amount of irrigation specified will be distributed in 4 separate weekly events.

<argument>: An acceptable abbreviation from the *irri.100* file.

Format: The year within the block, day of year, and the word "IRRI", followed by the irrigation method selected.

Example:

1 136 IRRI A100

IRRI (argument list) – Schedules a <u>month-long</u> irrigation event consisting of 4 weekly events. Does not require IRRI.100. The amount and type of the irrigation events are specified in the argument list. See Section 4.8.2.2 (Irrigation Events with Immediate Mode) for more information.

Example:

1 300 IRRI (0A,5C)

GRAZ <argument> – Schedules a grazing event on the current day. Grazing will occur for the next 30 days.

<argument>: An acceptable abbreviation from the *graz.100* file.

Format: The year within the block, day of year, and the word "GRAZ", followed by the grazing type selected.

Example:

1 258 GRAZ GM

EROD <argument> – Schedules an erosion event on the current day.

<argument>: The amount of soil loss (kg m^{-2} $month^{-1}$). The erosion amount will be distributed over the next 30 days.

Format: The year within the block, day of year, and the word "EROD", followed by the amount of erosion.

Example:

1 221 EROD 10.0

FIRE <argument> – Schedules a fire on the current day. This event burns herbaceous crops/grasses, litter, and dead wood on the ground. Use a TREM event to burn live tree biomass.

<argument>: An acceptable abbreviation from the *fire.100* file.

Format: The year within the block, day of year, and the word "FIRE", followed by the type of fire selected.

Example:

1 289 FIRE HOT

FLOD <argument> – Schedules flooded soil conditions and sets water table

<argument>: 0 = not flooded; 1 = soil saturation controlled by precipitation and irrigation; 2 = soil saturation maintained by automatic water additions

Format: The year within the block, day of year, and the word "FLOD", followed by the appropriate argument.

Example:

1 179 CROP RICL
1 179 PLTM
1 189 FLOD 2
1 248 FLOD 0

1 262 HARV G

DRAN <argument> – Schedules change in soil drainage (DRAIN parameter in <site>.100)

<argument>: value ≤ 1 = new value for DRAIN parameter; -2 = return to original value for DRAIN found in <site>.100 file
Format: The year within the block, day of year, and the word "DRAN", followed by the appropriate argument.
Example:

1 179 CROP RICL
1 179 PLTM
1 179 DRAN 0.1
1 248 DRAN -2
1 262 HARV G

TREE <argument> – Selects a tree type to grow. Only one tree can be grown at a time. One tree can also be growth with one crop/grass type in a savanna.

<argument>: An acceptable abbreviation from the *tree.100* file.

Format: The year within the block, day of year, and the word "TREE" followed by the type of tree selected.

Example:

1 16 TREE TMSH
1 16 TFST
1 350 TLST

TREM <argument> – Schedules a tree removal event (fire, cutting, or wind damage) on the current day.

<argument>: An acceptable abbreviation from the *trem.100* file.

Format: The year within the block, day of year, and the word "TREM" followed by the type of tree removal selected.

Example:

28 106 TREM BURN

TFST – Marks the day of year that growth commences for a forest.

Format: The year within the block, day of year, and the word "TFST".

Example:

1 16 TREE TMSH
1 16 TFST

1 350 TLST

TLST – Marks the current day as the last day of growth for a forest.

Format: The year within the block, day of year, and the word "TLST".

Example:

1 16 TREE TMSH
1 16 TFST
1 350 TLST

4.7. Event Priority and Duration

Because DayCent uses a daily timestep and incorporates both continuous events such as crop growth and decomposition, and discrete events such as fertilizer addition, cultivation and harvest, it is necessary to set a priority order for calls to the model's subroutines **(Figure 3)**.

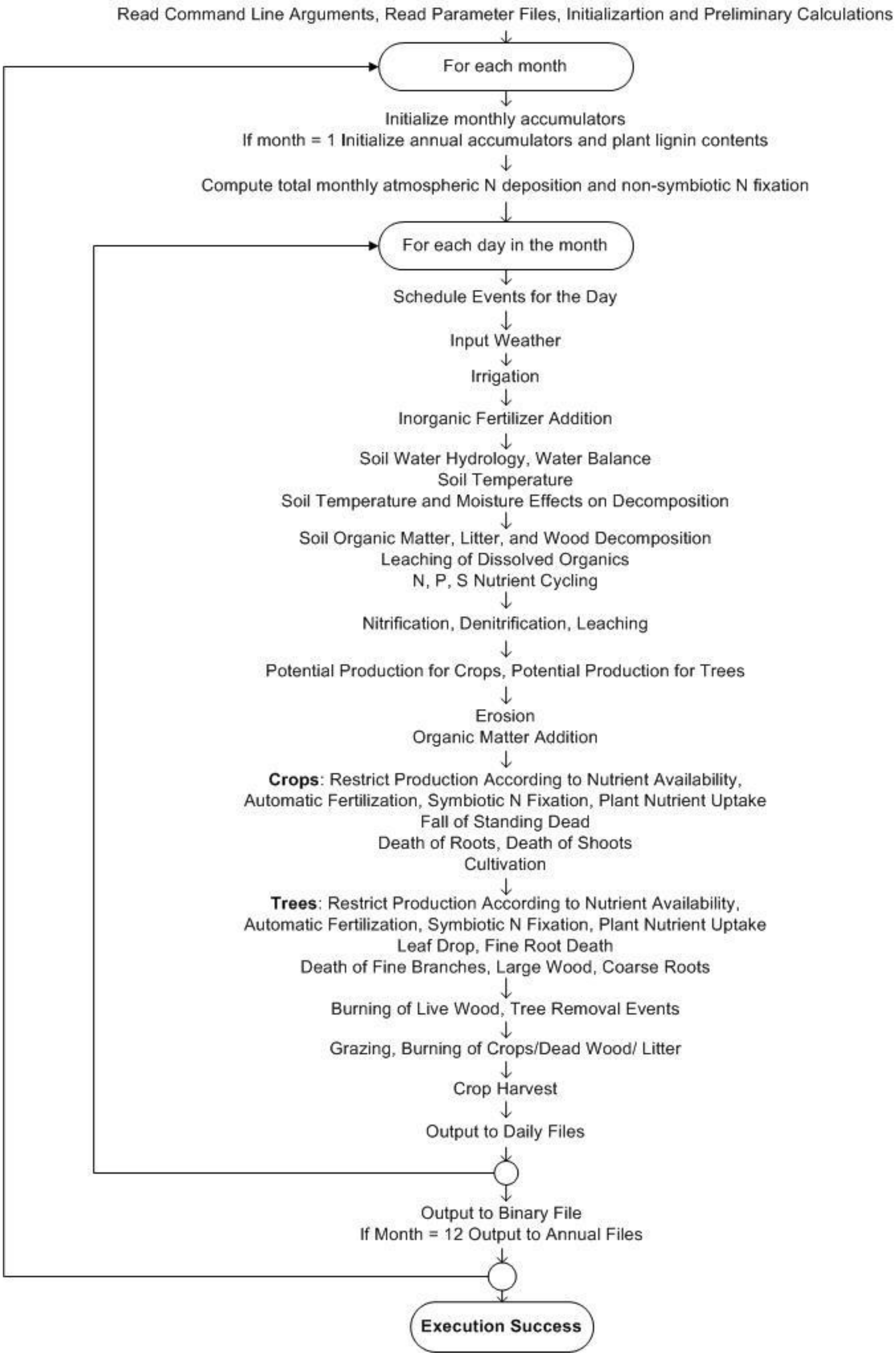


Figure 3 Sequencing of Events and Processes in the Daycent Model

In the daily scheduling scheme the following events will have effects that will continue over a 1 month period (30 day):

CULT – the multipliers for increased decomposition will be used for one month
EROD – enter the per week amount of erosion, this erosion loss will continue over a one-month period
GRAZ – grazing events will continue for a month and restrictions on production due to grazing will be effect for one month
IRRI – the amount of specified irrigation will be applied weekly over a 1-month period, the amount of irrigation that will be applied during a given week will depend on the fraction of the month that the simulation week represents
SENM – no growth will occur in the one-month period that follows the scheduled senescence event

NOTE: If more than one of these events is scheduled within a one-month period the original unexpired event will be replaced by the new event and the new event's effects will linger as described above. Similarly, a month-long event can be “turned off” before the month is complete by scheduling a similar even with “no effect”. This is discussed in more detail in Section 4.9 below (Schedule File Tips and Tricks).

4.8.Schedule File Alternative Formats

4.8.1. Free Form Input

Most DayCent versions accept free form input for schedule files. The user has a lot of flexibility in building schedule files and can switch from one format to another. Older formats are still usable. There is a line limit of 80 characters. An event can span multiple lines and can be broken between any fields.

Format 1. The original schedule file format with the event arguments on a separate line. This format is still usable but less readable than other formats.

```
          1   15 CROP
 G3
           1   74 GRAZ
W
            1  105 FRST
            1  203 GRAZ
GM
            1   320 LAST
            1   350 SENM
            2    15 CROP
 G3
            2   105 FRST
            2   289 FIRE
MED
            2   320 LAST
            2   350 SENM
          -999 -999 X
```

Format 2. Type commonly used when employing text editor and the easiest to read and edit.

```
  1   15 CROP G3
  1   74 GRAZ W
  1  105 FRST
  1  203 GRAZ GM
  1   320 LAST
  1   350 SENM
  2    15 CROP G3
  2   105 FRST
  2   289 FIRE MED
  2   320 LAST
  2   350 SENM
-999 -999 X
```

Format 3. Other free form versions of DAYCENT are more compact.

```
  1   15 CROP G3,  74 GRAZ W,  105 FRST,   203 GRAZ GM,
  1   320 LAST,    350 SENM,
  2    15 CROP G3,   105 FRST,   289 FIRE MED,   320 LAST,
  2   350 SENM,
-999 -999 X
```

Format 4. Commas are not required but may provide a more easily read file. The previous block can also be written as:

```
  1   15 CROP G3  74 GRAZ W  105 FRST   203 GRAZ GM   320 LAST   350 SENM
  2    15 CROP G3   105 FRST   289 FIRE MED   320 LAST   350 SENM
-999 -999 X
```

4.8.2. Immediate Schedule File Input Mode

Immediate schedule file input mode is available in some versions for fertilizer both daily and monthly irrigation events.events and for Immediate input mode allows the user to specify all the information about the event on the schedule file line, eliminating the need for FERT.100 or IRRI.100 files.

4.8.2.1. Fertilizer Events with Immediate Input Mode

The immediate mode input for fertilizer events is a 28-character string of delimited values enclosed in parenthesis. Without the parenthesis the fertilizer events will read the FERT.100 file for a named option. The values enclosed in parenthesis correspond to FERT.100 parameters.

xN – fertilize with x g N m^{-2}
xP – fertilize with x g P m^{-2}
xS – fertilize with x g S m^{-2}

xF – for N fertilizers, this is the fraction of that is NH_4-N. The remaining fraction is assumed to be NO_3-N. If this option is not specified, the default is 80% NH_4-N and 20% NO_3-N.

ninhtm.ninib I – 'I' stands for Inhibitor. Apply nitrification inhibitors for *ninhtm* weeks using a reduction factor of *ninib*

Immediate mode examples:

1 100 FERT (3.7N,1.0F)	apply 3.7 g N m^{-2} as 100% NH_4-N
1 226 FERT (6.5N,8.60I)	apply 6.5 g N m^{-2} and use nitrification inhibitors to reduce nitrification to 60% of the original rate for 8 weeks

4.8.2.2. *Irrigation Events with Immediate Input Mode*

Using a syntax similar to the FERT event, the immediate mode input for irrigation events is a 28-character string of delimited values enclosed in parenthesis. Without the parenthesis the irrigation events will read the IRRI.100 file for a named option.

Immediate mode input values can be delimited by the variable key, spaces or commas. If the key letter is present then the values can be input in any order. If keys are missing then values will be read in the irri.100 order. *It is best to use key letters to insure that correct irrigation options are scheduled*!

All argument keys correspond to IRRI.100 parameters (with the exception of AINTVL) with the following default order:

A = AUIRRI, irrigation type
  0 - automatic irrigation is off
  1 - irrigate top 30 cm to field capacity
  2 - irrigate with a specified amount of water applied
  3 - irrigate top 30 cm to field capacity plus PET
  4 – irrigate rooting zone to field capacity
F = FAWHC, fraction available soil water below which irrigation will occur (AUIRRI = 1,2,3,4). Available soil water is the amount above wilting point and below field capacity.
C = IRRAMT or IRRAUT, irrigation amount (cm) (IRRAMT if AUIRRI = 0, IRRAUT if AUIRRI = 2)
L = AINTVL, auto irrigation interval
  1L irrigate on the scheduled day only (applies to IRIG events only)
  xL means for x days where x > 0 (applies to IRIG events only)
  0L means manually stop automatic irrigation (IRRI or IRIG events)
  -1L means until the end of the growing season (applies to IRIG events only)

Immediate mode examples (all examples use year 1, day 80):

1 80 IRIG (1,0.925F,100L)	irrigate to field capacity for 100 days whenever available water content falls below 0.925
1 80 IRIG (0,5) or 1 80 IRIG (5C)	single irrigation of 5 cm

1 80 IRIG (1, 0.925F, -1L)	irrigate to field capacity until end of growing season whenever available water content falls below 0.925
1 80 IRIG (3A 0.99F -1L)	growing season irrigation of top 30 cm to field capacity whenever available water content falls below 0.99
1 80 IRIG (4A 0.96F -1L)	growing season irrigation of rooting zone to field capacity whenever available water content falls below 0.96
1 80 IRRI (0 5) or 1 80 IRRI (5C)	month-long irrigation of 5 cm (1.25 cm each week)
1 80 IRRI (4A, 0.96F)	month-long irrigation of rooting zone to field capacity whenever available water content falls below 0.96
1 80 IRRI (0L) or 80 IRIG	stop month-long irrigation by specifying a single event if 0 cm

4.9. Schedule File Tips and Tricks

4.9.1. Turning off month-long events with null events

Some events are meant to a continuous effect for up to a month. For example, a grazing event will continue for 31 days. If another grazing event is scheduled before the 31 days are up, the parameters for the later event supersede the parameters for the earlier event, and the grazing parameters from the later event will continue for 31 more days. In this way, the grazing intensity can be changed more frequently than once a month. To "turn off" grazing before the month is up, schedule a grazing event that does not remove any biomass and does not affect production.

Irrigation events are implemented weekly for four weeks. When an amount of water to be added is specified (‘fixed amount” event) the amount of specified irrigation will be applied weekly over a 1-month period with the amount of irrigation that will be applied during a given week will dependent on the fraction of the month that the simulation week represents. “Automatic” irrigation events check weekly to see if soil water conditions specified are met before irrigated to saturation. Both of these types of irrigation events can be turned off early by scheduling a null irrigation event that adds a fixed amount of water equal to 0cm as in the example below.

Example: Null irrigation event – used to terminate previous irrigation event

```
F0     NULL _irr_amount__0cm
0.0           'AUIRRI'
0.0           'FAWHC'
0.0           'IRRAUT'
0.0          'IRRAMT'
```

4.9.2. Crop/grass FIRE vs. tree/shrub BURN

Burning events are handled differently for crops/grasses and trees/shrubs even though both may be simulated together in DAYCENT. For crops and grasses the parameters for a burning event a found in the FIRE.100 and for trees/shrubs the parameters are found in the TREM.100. When crops/grasses alone are simulated only the FIRE.100 is used. However, when trees/shrubs are simulated alone it is sometimes necessary to use both the TREM.100, to define effects on live and standing dead biomass, and the FIRE.100 to define the effects on litter.

4.9.3. CULT event during growing season

Scheduling a CULT event before or even on the day of planting of a crop is not a problem for the crop growth. However, the user needs to be careful in choosing or defining CULT event intended for use after the plant has started growing and prior to harvest or senescence. Many of the pre-defined CULT events have major impacts on aboveground and belowground live biomass. A few pre-defined CULT events have been parameterized to have no impact on live biomass and are meant to mimic the soil mixing and disturbance of implements such as row cultivators. The user is also able to define other growing season CULT events.

4.9.4. Northern hemisphere and southern hemisphere scheduling

In the northern hemisphere most crops are planted and harvested and most grasses green up and senesce within a single calendar year. Winter wheat is one dominant exception. Scheduling such overwintering crops takes a little more care to avoid discontinuities (missed plantings or missed harvests, etc.) between schedule blocks. Avoiding such discontinuities is critical in that part of the simulation of most interest to the user.

In the southern hemisphere many crops are planted in one year and harvested the next. The user will encounter the problem of discontinuities more often in the southern hemisphere. Telltale signs found in the model output are missing yields and low carbon inputs one year followed by very high yields and very high carbon inputs the next year. Usually it is possible to arrange the simulation schedules to allow for a smooth transition between schedule blocks.

In the block below soybeans are planted in December and harvested in mid-May; notice that the LAST event comes before the PLTM event since a schedule file block must be ordered by day of year.

```
Year Day Option
3          Block   #  Soybean crop in southern hemisphere
2010       Last year
1          Repeat # years
2000       Output starting year
1          Output month
0.083      Output interval
F          Weather choice
example.wth
  1 135 HARV G
  1 135 LAST
  1 287 CULT I
```

```
  1 317 FERT (0.45N)
  1 318 CROP SYBN
  1 318 CULT D
  1 318 PLTM
  1 348 CULT ROW
-999 -999 X
```

4.9.5. Designing schedule blocks around available weather data

Simulation spinups that cover native conditions and/or early cropping history can be satisfactorily modeled by repeating the best available weather data many times over. However, for the period of time of most interest to the user it is best to synchronize the weather data to the schedule block(s) of that time period. This must take the form of starting a block at the year the weather file starts. For later blocks the C (continue reading the weather file) option in the block header can be used. Another option is to break up the weather file into two or more files and call them for the appropriate schedule blocks.

4.9.6. Spinup schedule files

Since users will seldom have all the data needed to initialize the soil carbon pools, soil nutrient pools and litter pools some sort of model “spinup” is needed. For many this will involve one or more schedule files meant to mimic the site history from native conditions to modern times. Native conditions can often be adequately modeled by simple grass or forest systems blocks that are repeated over a few thousand years of simulation with site specific weather and soils data. These are often referred to as equilibrium schedules as they are run for the period of time necessary for the soil pools to reach a steady state. An example of a grassland equilibrium block is given below. A second schedule file, often called the base history, is then used to simulate the past cropping, grazing, and/or woodland history prior to time frame of most interest to the user.

While common cropping practices for the region are sufficient for the early part of the base schedule the user should strive to employ as much site specific detail in the later part of this schedule as this will allow for a smoother transition into the schedule(s) for the period of interest. After testing and debugging of the spinup schedules (equilibrium and base) is complete the output binary files can be stored. Since the user can employ “extend” options to initialize other schedule file runs from these stored binary file it is not necessary to rerun the spinup again. The initial conditions from the spinup will more accurately reflect the soil conditions and distributions among the various pools as dictated by the site weather and soils and past history.

Example: Grassland equilibrium (native conditions) schedule.

Insert a header

```
Year Month Option
1         Block #   Equilibrium
4000     Last year
3         Repeats # years
1         Output starting year
1         Output month
100.0    Output interval
```

```
F           Weather choice
example.wth
  1 62 CROP GI3
  1 62 FRST
  1 136 GRAZ GM
  1 167 GRAZ GM
  1 197 GRAZ GM
  1 256 GRAZ GM
  1 286 GRAZ GM
  1 302 LAST
  1 302 SENM
  2 62 FRST
  2 136 GRAZ GM
  2 167 GRAZ GM
  2 197 GRAZ GM
  2 256 GRAZ GM
  2 286 GRAZ GM
  2 302 LAST
  2 302 SENM
  3 62 FRST
  3 136 GRAZ GM
  3 167 GRAZ GM
  3 197 GRAZ GM
  3 225 FIRE M
  3 302 LAST
 3 302 SENM
-999 -999 X
```

Example: Base history schedule file.

Insert a header

```
Year Month Option
1           Block #   pasture
1906      Last year
1           Repeats # years
1900      Output starting year
12          Output month
1.0        Output interval
F           Weather choice
example.wth
   1   75 CROP G5
   1   75 FRST
   1   136 GRAZ GM
   1   167 GRAZ GM
   1   197 GRAZ GM
   1   228 GRAZ GM
   1   259 GRAZ GM
```

```
  1   289 LAST
  1   289 SENM
-999 -999 X
2           Block #   F-W_
1948       Last year
2           Repeats # years
1907       Output starting year
12          Output month
1.0         Output interval
C           Weather choice
  1   106 CULT K
  1   136 CULT A
  1   167 CULT D
  1   197 CULT A
  1   228 CULT D
  1   289 CROP W1
  1   289 PLTM
  1   289 CULT D
  2   228 LAST
  2   228 HARV GS
  2   259 CULT K
-999 -999 X
3           Block #   F-W-C_
1966         Last year
3           Repeats # years
1949         Output starting year
12           Output month
1.0        Output interval
C           Weather choice
  1   106 CULT K
  1   136 CULT A
  1   167 CULT D
  1   197 CULT A
  1   228 CULT D
  1   289 CROP W2
  1   289 PLTM
  1   289 FERT N0.3
  1   289 CULT D
  2   228 LAST
  2   228 HARV G
  2   259 CULT K
  3   106 CULT K
  3   136 CROP C4
  3   136 PLTM
  3   136 FERT N3
  3   136 CULT D
  3   289 LAST
  3   289 HARV G
```

```
  3   295 CULT K
-999 -999 X
```

5. Initialization Options

Users can choose to enter initial values for C and nutrient quantities in the different soil organic matter and vegetation component pools or initial values can be generated using long-term simulations. We advocate using the latter because C and nutrient values are rarely known for all of the pools and using long-term simulations ensures that the model is close to equilibrium. Specifically, we recommend that users simulate at least 1000 years of native vegetation (spin up simulation) followed by plow out and historical land use (base simulation). (As mentioned above, the IVAUTO options (<site>.100) can be used to initialize soil C and N pools for spinup simulations, but IVAUTO options 1-3 are ignored when extending from a spin up run). Before implementing the base simulation, users should verify that the spin up simulation was of sufficient duration to result in relatively stable intermediate and slow SOM pools. If local information regarding pre-settlement vegetation is not available, then the potential native vegetation map developed by (Kuchler 1993) can be used to derive an appropriate vegetation mix to simulate during the spin up. For the base simulation, users should use their best guesses regarding when plow out occurred and what the land use history was likely to have been. Fortunately, model results are more sensitive to recent land management, which is likely to be known with greater confidence than earlier land management.

5.1.Extending from a binary file

Binary output from previous simulations can be to initialize the state of the model for subsequent simulations. It is common practice to create a schedule file for the spinup run and one or more other schedule files that define more recent land use and management. To run the DDcent.exe model extending from a previous simulation:

```
DDcent.exe -s <sch_file> -n <bin_file> -e <extend_file>
```

Where

<sch_file> = schedule file name (do not include the .sch extension on the command line)

<bin_file> = binary file containing all DayCent's monthly output variables (do not include the .bin extension on the command line). Note: This file is not human readable, it requires the List100 program **DDlist100.exe** to extract output.

<extend_file> = binary file from a previous simulation used to initialize the model for the next simulation (do not include the .bin extension on the command line)

See section 2.1.2.2 above for more information.

5.2.Using the extended <site>.100

<insert text>

6. Model Calibration and Validation

DayCent is a general model that can be applied across different ecosystems without changing parameters other than site-specific ones relating to weather, soils, vegetation, and land management. However, use of generalized parameters will likely lead to poor model performance for at least some site–treatment combinations, and model results can always be improved by tuning the model to better represent particular conditions. We do not recommend arbitrarily changing parameters to improve model fit but instead following the guidelines in the book chapter by Del Grosso et al. (2011), “Features of the DayCent Modeling Package and Additional Procedures for Parameterization, Calibration, Validation, and Applications”. Del Grosso et al. explain DayCent calibration steps in great detail. We summarize them here. The chapter is included in the documents distributed with this manual and we highly recommend that users read through it.

There are more than 1000 parameters in the DayCent model. Fortunately, users typically only need to calibrate a small subset of these. After input files have been formatted and checked for accuracy, the next step is to run the model and evaluate if the results are reasonable. We advocate verifying model outputs in the following order: soil water content, crop yields and plant growth rates, soil organic C levels, and N loss vectors **(Figure** 4**).** Soil water content should be looked at first because this is a primary control on most of the key processes represented in the model. Plant growth rates and crop yields should be verified next because yield data are almost always available, and if growth and harvest are not simulated correctly then other variables of interest are also likely to be simulated incorrectly. It is important to verify that SOC levels appear reasonable because SOC integrates many processes in the model (e.g., NPP, decomposition) that are sensitive to both environmental conditions and management decisions. Lastly, N flows should be verified. These steps may need to be reiterated until desired results are achieved.

It is very important to use only a subset of measurement data in the calibration process. If you use all measurement data to calibrate DayCent you risk over-fitting the parameters to the data. Model validation requires that independent data sets are compared against model results to demonstrate the model’s credibility and predictive ability. Model validation is a requirement in peer-reviewed publications.

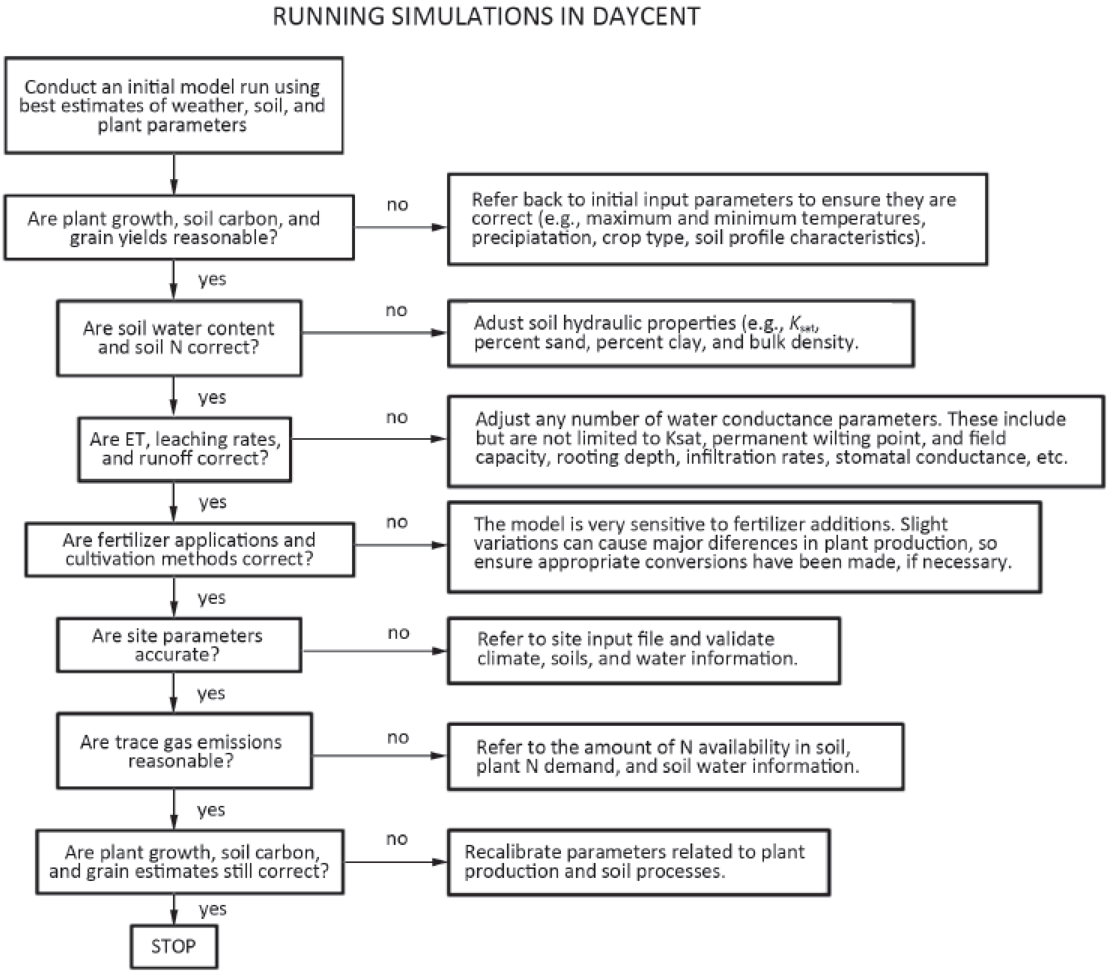


Figure 4: Steps for Calibrating the Daycent Model

Steps for calibrating the DayCent model. (From Del Grosso et al. (2011): Special Features of the DayCent Modeling Package and Additional Procedures for Parameterization, Calibration, Validation, and Applications)

Part 2. DayCent Model Description

1. Introduction

The DayCent model simulates the long-term dynamics of Carbon (C), Nitrogen (N), Phosphorus (P), and Sulfur (S) for different Plant-Soil Systems. DayCent includes submodels for plant productivity, decomposition of dead plant material and SOM, soil water and temperature dynamics, and N gas fluxes **(Figure 5)**.The model can simulate the dynamics of grassland systems, agricultural crop systems, forest systems, and savanna systems. The grassland/crop and forest systems have different plant production submodels which are linked to a common soil organic matter submodel. The savanna model uses the grassland/crop and forest subsystems and allows for the two subsystems to interact through shading effects and nitrogen competition. The soil organic matter submodel simulates the flow of C, N, P, and S through plant litter and the different inorganic and organic pools in the soil.

Flows of C and nutrients are controlled by the amount of C in the various pools, the nutrient concentrations of the pools, abiotic temperature and soil water factors, and soil physical properties related to texture. Net primary productivity (NPP) is a function of nutrient availability, soil water and temperature, shading, vegetation type, and plant phenology (Metherell et al. 1993b). Net primary productivity is divided among leafy, woody, and root compartments on the basis of plant type and phenology. The root/shoot ratio of NPP allocation is a function of soil water content and nutrient availability. The death rate of plant compartments is controlled by soil water, temperature, season, and plant-specific senescence parameters. Germination for annuals and beginning of the growing season for perennials can be defined by the user or made a function of soil temperature. Harvest dates and the end of the growing season can similarly be defined by the user or made a function of accumulated growing degree days. Management and disturbance events (e.g., grazing, fire, cultivation, irrigation, fertilization, and clear cuts) can easily be implemented.

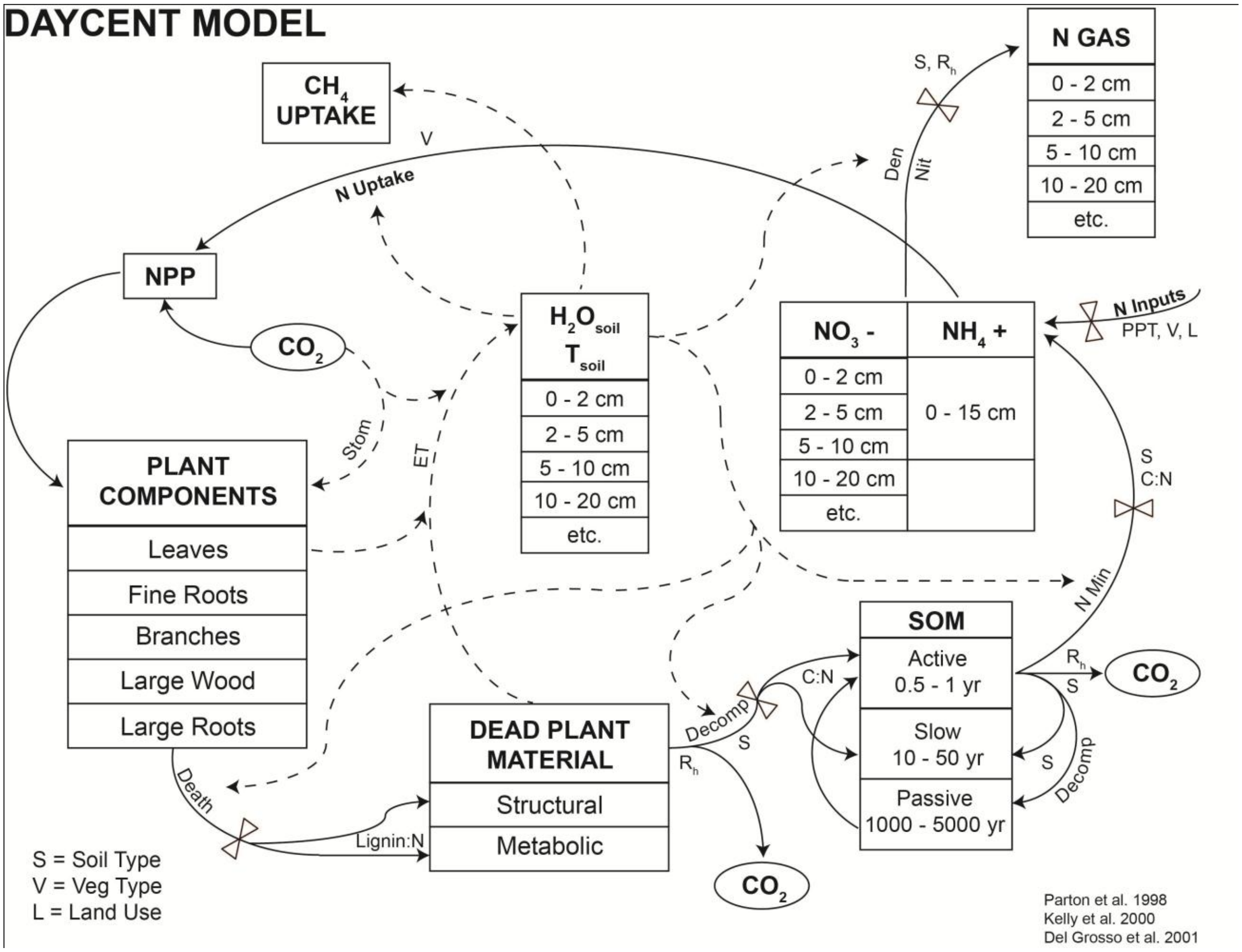


Figure 5 Conceptual Model Diagram

Conceptual diagram of the DayCent ecosystem model.

2. Soil Physical Submodels

2.1.Water flow submodel

The water flow submodel simulates the daily flow of water through the plant canopy, litter, and soil layers (Parton et al. 1998) **(Figure 6)**. When the air temperature is cold enough, precipitation becomes snow and is accumulated in a snowpack. The snowpack could be reduced by sublimation and melting. Water loss occurs first as sublimation followed by the interception of rainfall by surface litter and the plant canopy. Water is evaporated from these surfaces before any remaining rainfall, snowmelt, or irrigation is added to the soil surface. Evaporation of water from the soil occurs from upward movement of water during soil water distribution (as discussed below), runoff occurs from infiltration excess, and baseflow occurs from water exiting the bottom of the soil profile or deep storage. Transpiration is calculated after water has been redistributed in the soil. The sum of sublimation, interception, soil evaporation, and transpiration does not exceed the daily potential evapotranspiration (PET) rate.

The potential daily evapotranspiration rate (PET, cm day^{-1}) is calculated either as a function of the average daily air temperature or as a function of incoming solar radiation. PET based on average daily air temperature, used when extra drivers are not included in the weather file, is based on the equations developed by Linacre (1977) and may be modified by a user specified multiplier (FWLOSS(4), fix.100). PET based on incoming solar radiation, wind speed, and relative humidity is based on equations by Penman (1948) and using cloud cover (*cldcov[month]*, sitepar.in), *latitude* (sitepar.in), fraction of light reflected by vegetation (*reflect,* sitepar.in), and snow albedo (sitepar.in).

Precipitation accumulates as snow when the minimum daily temperature is ≤ 1°C. Snow melt and sublimation may occur whenever there is snow, even on the same day it accumulates. Sublimation is a function of the PET rate and the latent heat of vaporization. Snowmelt can occur whenever the maximum daily air temperature is greater than 0°C. The maximum amount of snow that can melt in a given day (*melt*, cm SWE) is a function on the maximum daily air temperature (*tmax*, °C) and total daily incoming solar radiation ($srad_{langleys}$, langleys d^{-1}):

Equation 1

$$melt = tmelt(2) * (tmax - tmelt(1)) * srad_{langleys}$$

where *tmelt(1)* (°C) and tmelt(2) (cm SWE (°C * $langleys)^{-1}$) are fix.100 parameters. If $tmax - tmelt(1) < 0$ then melt=0. The definitions of the two TMELT parameters have changed from the original CENTURY parameter definitions. The value $srad_{langleys}$ calculated from the *srad* input (W m^{-2}) from the weather file and converted to units of langleys (calories cm^{-2}) when usexdrivers = 2, 3, or 4 (see the section “Weather Data”); otherwise *srad* is calculated from air temperature (Thornton and Running 1999a).

Interception water loss is a function of aboveground plant and litter biomass (increases with biomass level), rainfall and PET (Parton 1978). Maximum potential evaporation from the soil (bare soil water loss) is a function of aboveground plant and litter biomass (lower for high biomass levels), soil moisture, and PET. Potential transpiration water loss (PTTR) is a function of the live leaf biomass, dead biomass (shading effects), soil water content in the wettest layer in the rooting zone, and PET. Actual soil transpiration is restricted by available soil moisture and reduces soil water content. The optional daily output file, watrbal.out, shows all water inputs and losses each day.

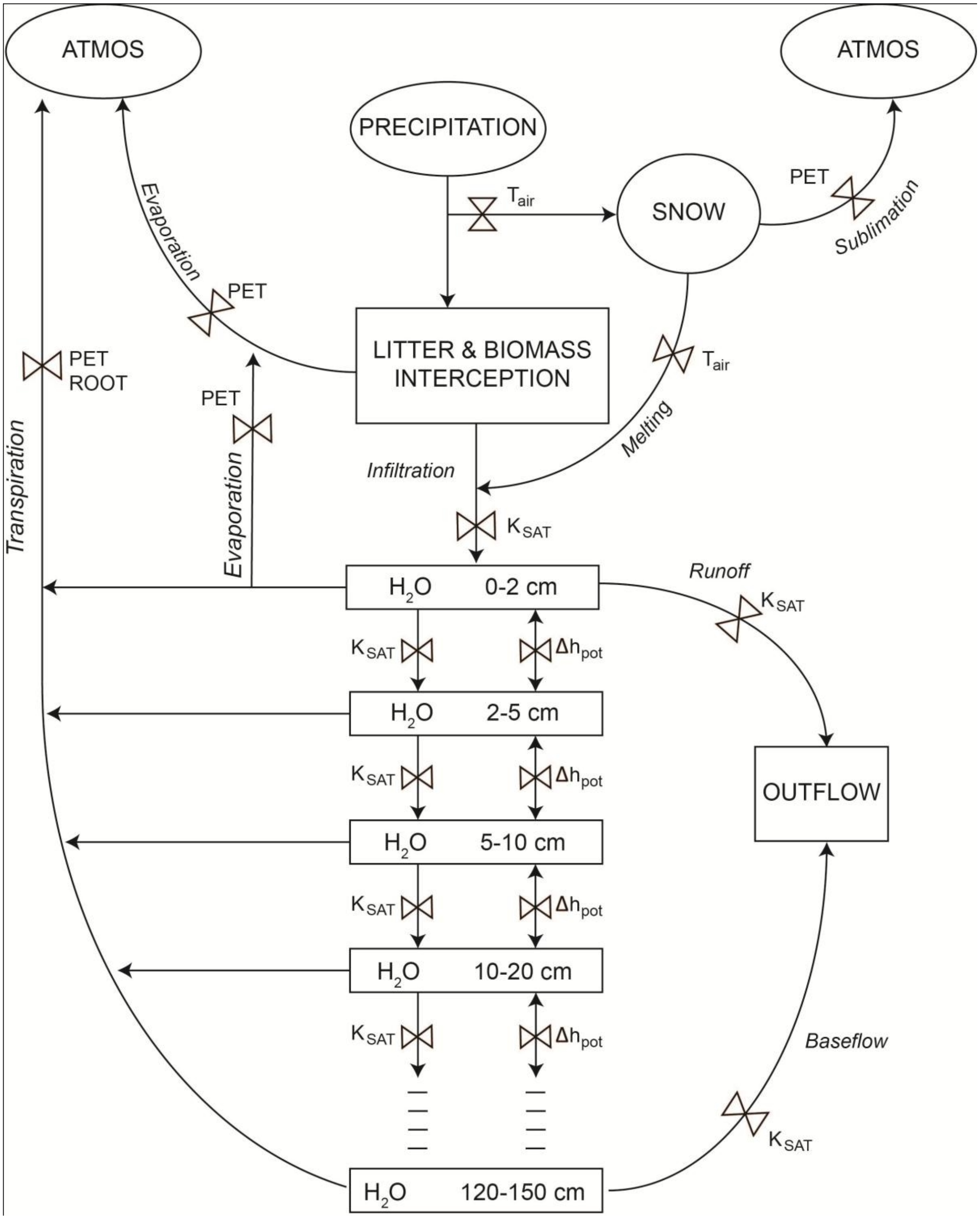


Figure 6 Water Flow Submodel

2.2. Soil Water Movement

The soil water model simulates above field capacity water content, unsaturated water flow using Darcy's equation, runoff, snow dynamics, and the effect of soil freezing on saturated water flow (Parton et al. 1998). Each soil layer **(Table 2)** is assigned unique properties including thickness, field capacity, wilting point, proportion of roots, bulk density, soil texture, percent sand and clay, saturated hydraulic conductivity, minimum water content, and pH. These values are based on observed data from each site or estimates based on soil texture at the site.

Water inputs to the soil (rainfall not intercepted, melted snow, and irrigation) either enter the soil or goes to surface runoff. Infiltration (saturated flow), runoff, evaporation, and the redistribution of water in the soil (unsaturated flow) are based on a two-process algorithm. When there is water input, infiltration, runoff, and saturated flow are simulated first. Water is then evaporated and redistributed throughout the soil profile by an unsaturated flow algorithm modified from the work of Hillel (1977) (Section 2.2 above).

Unsaturated flow calculations are followed by transpiration water loss calculated using equations developed by Parton (1978). The potential evapotranspiration water loss rate (PET, cm day^{-1}) is calculated using the equation of Penman (1948). The maximum fraction of PET allocated to transpiration (*fbst*) and to bare soil evaporation (*fbse*) are calculated as a function of live leaf biomass **(Figure 7)**. Soil evaporation decreases and transpiration increases as live leaf biomass increases (Parton 1978). During evaporation, if the top soil layer is too dry to allow evaporation the water evaporation will come from the second soil layer. The potential daily transpiration rate (*bstrate*, cm day^{-1}) is reduced under low soil water conditions as a function of the relative water content fraction (equal to 1.0 at field capacity) of the wettest soil layer within the plant rooting zone (*h2ogef*, 0.0 – 1.0) **(Figure 8)**, and a shading effect from dead biomass (*shadeaf*, 0.0 – 1.0). If simulating a CO_2 effect on transpiration, the *co2eff* value will differ from 1.0 (Section 3.8.9 below, Enriched CO_2 Effects).

Equation 2

$$fbse = max\left(0.995,\ exp\left(-0.6 * LAI\right)\right)$$
$$fbst = 1.0\ -\ fbse$$

$$bstrate = h2ogef * shadeaf * PET * fbst * co2eff$$

$h2ogef\ = 1.0 - exp(-3.0 \cdot rwcf\,)$ for the wettest soil layer in the rooting zone.

The shading effect (*shadeaf*, 0.0 – 1.0) is a function of live above-ground biomass (biolive, g/m2) and dead above-ground biomass (biodead, g/m2)

$$shadeaf\ = \frac{12+\left(34/\pi\right)\cdot arctan\left(0.002\pi\left(biolive-300\right)\right)}{12+\left(34/\pi\right)\cdot arctan\left(0.002\pi\left(biodead-300\right)\right)}\left(1.0-0.3\right)+0.3$$

The actual transpiration rate from each soil layer in the rooting zone is weighted by the soil water potential of the layer and by the relative root biomass fraction for the layer (soils.in) (Parton et al.

1998). For annual crops/grasses, the number of layers in the rooting zone increases linearly from 1 to CLAYPG (crop.100) through the growing season as determined by the FRTC(3) parameter (crop.100). For perennial crops/grasses the number of layers in the rooting zone is constant and set to CLAYPG (crop.100). For trees the number of layers in the rooting zone is constant and set to TLAYPG (tree.100). Actual total transpiration from all soil layers will be less than potential transpiration rate (*bstrate*) if the amount of water in the soil profile is not sufficient to meet the potential demand.

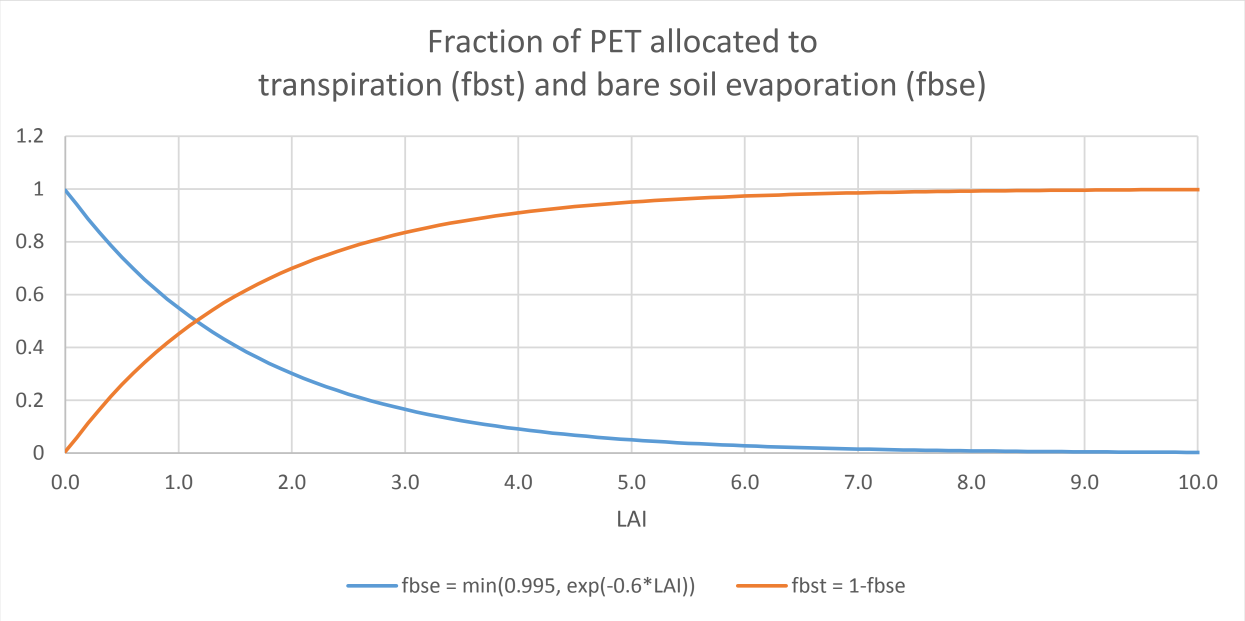


Figure 7 Allocation of Potential Evapotranspiration

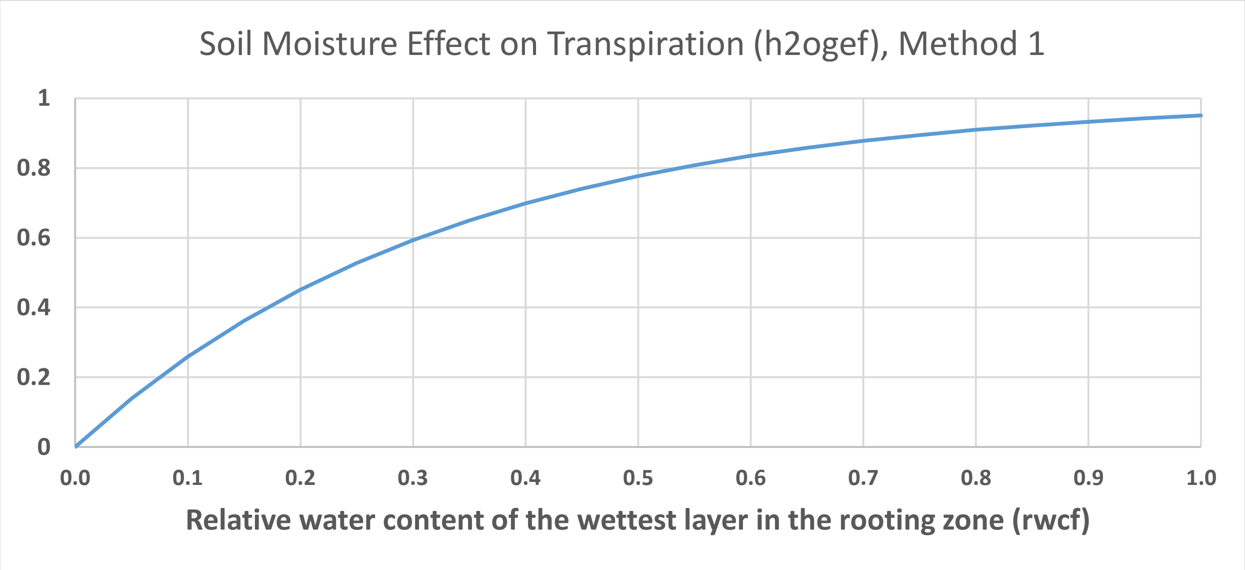


Figure 8 Soil Moisture Effect on Transpiration

On days when there is water input, a multi-hour (*hours_rain* ≤ 24) infiltration saturated flow period is followed by one or more 2-hour ((24 - *hours_rain*) / 2) cycles of unsaturated flow. The water input intensity (cm s^{-1}) is equal to the sum of rainfall and snowmelt (cm) divided by *hours_rain* *3600 sec. When there is no water input, there are twelve 2-hour cycles of unsaturated flow. The length of the infiltration/saturated flow period is a model input that can be altered, unfortunately observed data is rarely available for this driving variable.

Infiltration and saturated flow of water through the soil profile are represented by a unidirectional downward flow **(Figure 6)**. During infiltration the hydraulic conductivity of layer *i* equals its saturated hydraulic conductivity ($k_{sat,i}$, cm s^{-1}) unless the layer is sufficiently cold and moist to freeze and impede water flow. A sat *i* layer is considered frozen if its average soil temperature is below the freezing temperature (-1 °C), and $\Theta_{sat} - \Theta_{cur} < 0.13$, where Θ_{sat} is the saturated volumetric wetness of the layer and Θ_{cur} is the simulated volumetric wetness (Flerchinger and Saxton 1989). The hydraulic conductivity of a frozen layer is reduced to 0.00001 cm s^{-1}.

Initially, the rate at which water enters the soil equals the saturated hydraulic conductivity of the top soil layer ($k_{sat,0}$). As water input continues, the rate at which the water enters the soil and percolates downward becomes the minimum of the hydraulic conductivities of the soil layers that have been encountered by the wetting front. Water fills a soil layer to saturation before percolating to the next layer. If water input intensity is greater than the rate at which water can enter the soil, the difference goes to runoff and is added to outflow. Water is added to the profile until the *hours_rain* input window is over. Then if there is no impedance (frozen layer in the profile), any layer that exceeds its field capacity is drained. Starting at the top of the soil profile and progressing downward, water in excess of field capacity is drained to the layer below it. Any water that exits the bottom layer is added to outflow.

Unsaturated flow is represented by a bidirectional vertical flow **(Figure 6).** At each 2-hour time step, the hydraulic potential and hydraulic conductivity of each soil layer were recalculated; from these, bidirectional water fluxes and net water flux to each soil layer were computed. Based on Darcy's law, the bidirectional water flux (cm s^{-1}) between two adjacent layers, *i-1* and *i*, is calculated as:

Equation 3

$$flux_i = \frac{dmp_{flux} * (hpot_{i-1} - hpot_i) * av_{cond_i}}{dist_i}, \qquad i = 1 \ldots nlyr - 1$$

where, dmp_{flux} is the damping multiplier (*dmpflux*, sitepar.in); h_{poti} is the hydraulic potential of layer *i* (cm), the sum of the matric potential and gravitational head, where $hpot_i = mpot_i - depth_i$; $mpot_i$ is the matric potential of layer i (cm); $depth_i$ is the distance from the soil surface to the middle of layer *i* (cm); av_{condi} is the average hydraulic conductivity of layer *i* (cm s^{-1}), a weighted average of $cond_{i-1}$, $cond_i$, and $cond_{i+1}$; $cond_i$ is the hydraulic conductivity of layer *i* (cm s^{-1}); $dist_i$ is the distance between the midpoints of two adjacent soil layers, *i-1* and *i* (cm); *nlyr =* the number of layers in the soil profile (0..*nlyr-1*).

The flux at the top of the soil profile ($flux_0$, cm s^{-1}) is dependent on the potential soil evaporation rate ($soilpet_{max}$, cm s^{-1}), the current soilwater content of the top layer (swc_0, cm), and the minimum allowable water max content in the top soil layer (swc_{min}, cm). The flux at the bottom of the soil profile ($flux_{nlyr}$, cm s^{-1}) is dependent on the hydraulic conductivity of the bottom soil layer:

Equation 4

$$flux_0 = \begin{cases} -soilpet_{\max}, & swc_0 > swc_{\min_0} \\ 0.0, & swc_0 \le swc_{\min_0} \end{cases}$$

$$flux_{nlyr} = dmp_{flux} * cond_{nlyr-1}$$

If flux is positive, water moves downward from layer *i*-1 to layer *i*; if flux is negative, water moves upward from layer *i* to layer *i*-1. The net flux of water into or out of a layer *i*, $netflux_i$, is positive when soil layer *i* has a net water gain and is negative when layer *i* has a net water loss:

Equation 5

$$netflux_i = flux_i - flux_{i+1}$$

Adjustments to the bidirectional fluxes ($flux_i$) and net fluxes ($netflux_i$) are computed if the addition of the $netflux_i$ has dried out a layer below its minimum allowable water content. If the addition of a net flux brings a soil layer above saturation, water in excess of saturation is considered runoff and is added to outflow.

Any of water exiting the bottom layer of the soil profile (layer *nlyr*-1) is added to deep water storage (layer *nlyr*). The fraction of water that exits deep water storage each day (BASEF, fix.100) is added to baseflow. Baseflow and runoff are the two components of streamflow (STREAM(1)).

The runoff calculation in DayCent replaces the storm flow calculation that was in the monthly CENTURY model; therefore, the STORMF variable in the <site>.100 file in no longer being used and should be set to a value of 0.0.

2.2.1. Leaching

Inorganic N, P, S leaching

Leaching of labile mineral N (nitrate), P, and S pools occurs when there is water flow between soil layers. The fraction of the mineral pool that flows from the upper layer (*lyr*) to the lower layer (*lyr+1*) increases with increasing sand content and water flow. The texture effect ($texeff_{inorg}$) increases linearly with sand content – FLEACH(1) and FLEACH(2), fix.100). The leaching intensity ($0.0 \le linten_{inorg} \le 1.0$) increases with water flow between the layers (*wfluxout(lyr)*) up to a maximum value – MINLCH, fix.100 cm day^{-1}). FLEACH(3), FLEACH(4) and FLEACH(5) (fix.100) control inorganic N, P, and S leaching respectively. Sand content is calculated as the weighted average of sand from all layers in the soil profile (soils.in). (Note: It does not appear that DayCent computes inorganic P and S leaching losses.)

The amount of N leached from soil layer *lyr* into soil layer *lyr+1* (*amtlea(lyr)*, g N m^{-2} day^{-1}) is calculated as

Equation 6

$$amtlea(lyr) = frlechd(N) * \ nitrate(lyr) * \ linten_{inorg}$$

Equation 7

$$texeff_{inorg} = FLEACH(1) + FLEACH(2) * sand$$

Equation 8

$$frlechd(N) = texeff_{inorg} * FLEACH(3)$$

Equation 9

$$\begin{aligned} linten_{inorg} &= min\left(1.0 - \frac{MINLCH - wfluxout(lyr)}{MINLCH}, 1.0\right) \\ linten_{inorg} &= max\left(linten_{inorg},\ 0.0\right) \end{aligned}$$

Leaching of Organic Carbon, Nitrogen, Phosphorus, and Sulfur

Organic leaching is a function the amount of the active soil pool that decomposes ($tcflow_{som1c(SOIL)}$), sand content, and the amount of water leached from the organic layer. The texture effect ($texeff_{org}$) increases linearly with sand content – OMLECH(1) and OMLECH (2), fix.100). The leaching intensity ($0.0 \le linten_{org} \le 1.0$) increases with water flow below 20 cm (*wfluxout(20 cm)*) up to a maximum value – OMLECH(3), fix.100 cm day^{-1}). Total daily C leaching (*Cleach*, g C m^{-2} day^{-1}) is computed below. Organic N, P, and S leaching is proportional to *Cleach* based on the C:element ratios of the active soil pool. Sand content is calculated as the weighted average of sand in all layers of the soil profile.

Equation 10

$$texeff_{org} = OMLECH(1) + OMLECH(2) * sand$$

Equation 11

$$Cleach = texeff_{org} * tcflow_{som1c(SOIL)} * linten$$

Equation 12

$$\begin{aligned} linten_{org} &= min\left(1.0 - \frac{OMLECH(3) - wfluxout(20\ cm)}{OMLECH(3)}, 1.0\right) \\ linten &= max\left(linten,\ 0.0\right) \end{aligned}$$

Nitrate leaching is calculated near the end of the daily timestep, after water budget, decomposition, and nitrification calculations, but just before the denitrification calculations.

Monthly watershed losses of H_2O (STREAM(1)), inorganic N, P, and S (STREAM(2), STREAM(3) and STREAM(4)), and organic C, N, P, and S (STREAM(5), STREAM(6), STREAM(7), and STREAM(8)) in list100 output are the sum of daily leaching losses that occurred during the month.

2.3.Water Table and Flooding

DayCent can simulate saturated soil conditions that occur from flooding and poor soil drainage. Saturated soils lead to methanogenesis (Section 3.6.1 below) and anaerobiosis (Section 3.1.6 below). DayCentEVI implements flooding with FLOD events in the schedule file (Section ??). These FLOD events replace the "watertable[1..12]" parameters that currently exist in the sitepar.in file for other versions of DayCent. DayCentEVI also implements controls on the rate of soil drainage with "DRAN" events. **Table 7** summaries the effects of the FLOD and DRAN events.

FLOD events specify when flooding begins and ends, the source of water for flooding, and whether or not flooding includes the ponding of water on the surface **(Table 7)**. FLOD events set internal flags: when watertable= 1 water inputs collect in the soil layers without drainage; when watrflag = 1 the model will automatically add the amount of water needed to keep the soil layers saturated; when watrflag = 0 any water added from rain and irrigation won't drain, but no additional water is added if rain and irrigation aren't enough to bring to saturation. The only effect of ponding is on the soil surface temperature. When there is ponding, then the soil surface temperature equals the air temperature, but the soil surface temperature will never fall below 0.0 °C. There is no mechanism to keep track of the depth of ponding.

The rate of soil drainage when soil water content is above field capacity is usually controlled by the DRAIN (<site>.100, $0.0 \le DRAIN \le 1.0$), but DRAN events can temporarily modify this drainage rate. Specifically, DRAIN is the fraction of excess water (water above field capacity) lost by a soil layer by drainage. DRAIN=1.0 indicates water in all layers above field capacity will drain to field capacity. DRAIN=0 specifies that no soil water drainage occurs from any soil layer that is above field capacity. Anaerobic conditions (high soil water content) may reduce organic matter decomposition rates (See section 3.1.6 below).

Table 7 Schedule File and Parameter Controls on Flooding and Drainage of Soil Layers

Schedule File Event	Internal flags/parameters	Description	Other Notes
FLOD 1	watertable=1 watrflag=0 ponding=0	Rain and irrigation accumulates without drainage	For methanogenesis, Eh = -20
FLOD 2	watertable=1 watrflag=1	Automatically saturate and indicate standing water. The amount of water	For methanogenesis, flooded Eh is used (Equation 25)

	ponding=1	added to bring to saturation is accumulated in the ANNPPT output variable (yearsum.out)	
FLOD 3	watertable=1 watrflag=1 ponding=0	Automatically saturate but without standing water	
FLOD 0	watertable=0 watrflag=0 ponding=0	Reset to non-flooded conditions (drain water from the soil layers)	For methanogenesis, drainage course Eh is used (Equation 26)
DRAN ≤ 1	Reset the DRAIN parameter (<site>.100) to the value indicated. Maintain this value until drain is reset.	Allows temporary change in the rate of soil water drainage.	DRAIN = the fraction of excess water (water above field capacity) lost by a soil layer during drainage (<site>.100)
DRAN -2	Reset the DRAIN parameter to the value in <site>.100.		
DRAN -1	Revert back to previous value of DRAIN (not necessarily the <site>.100 value)?		

2.4. Soil Temperature

2.4.1. Surface Soil Temperature

The average daily soil temperature at the soil surface is used to initialize the boundary temperature at the top of the soil profile (see the next section), but otherwise it is not used directly in any model calculation. It is a weighted average of the maximum and minimum soil surface temperatures. The maximum soil surface temperature as a function of the maximum air temperature and the canopy biomass (lower for high biomass) while the minimum soil temperature is a function of the minimum air temperature and canopy biomass (higher for higher biomass). Any snow will insulate the soil surface temperature from changes in air temperature and reduce the diurnal surface temperature range. The effect of snow on the diurnal range decreases as the snow water equivalent (SWE) on soil surface decreases. Relative weighting of minimum and maximum temperature on the average is a function of daylength. Minimum soil surface temperate has greater weight on the average in the winter between the autumnal and vernal equinox when nights are longer than days whereas maximum soil surface temperature has greater weight on the average during the summer.

2.4.2. Soil Temperature Profile

Several calculations in DayCent require soil temperature at different depths. The soil temperature used for decomposition and nitrification rate functions is the mean daily soil temperatures in the second and third DayCent soil layers (approximately 2 – 10 cm depth). The methane oxidation submodel requires the mean daily soil temperature in the top 15 cm of soil. The soil temperature profile calculations, along with soil water content, are also used to determine if a soil layer is cold and wet enough to form ice that impedes infiltration of water into the soil profile.

The soil temperature model (Parton et al. 1998, Eitzinger et al. 2000), which calculates thermal diffusivity and predicts daily minimum and maximum soil temperatures at depth, is a modification of the model described in the work of Parton (1984). Required inputs to the model are daily minimum and maximum air temperatures, plant biomass, snow cover, soil moisture, soil texture, and average soil temperature at the bottom of the soil profile.

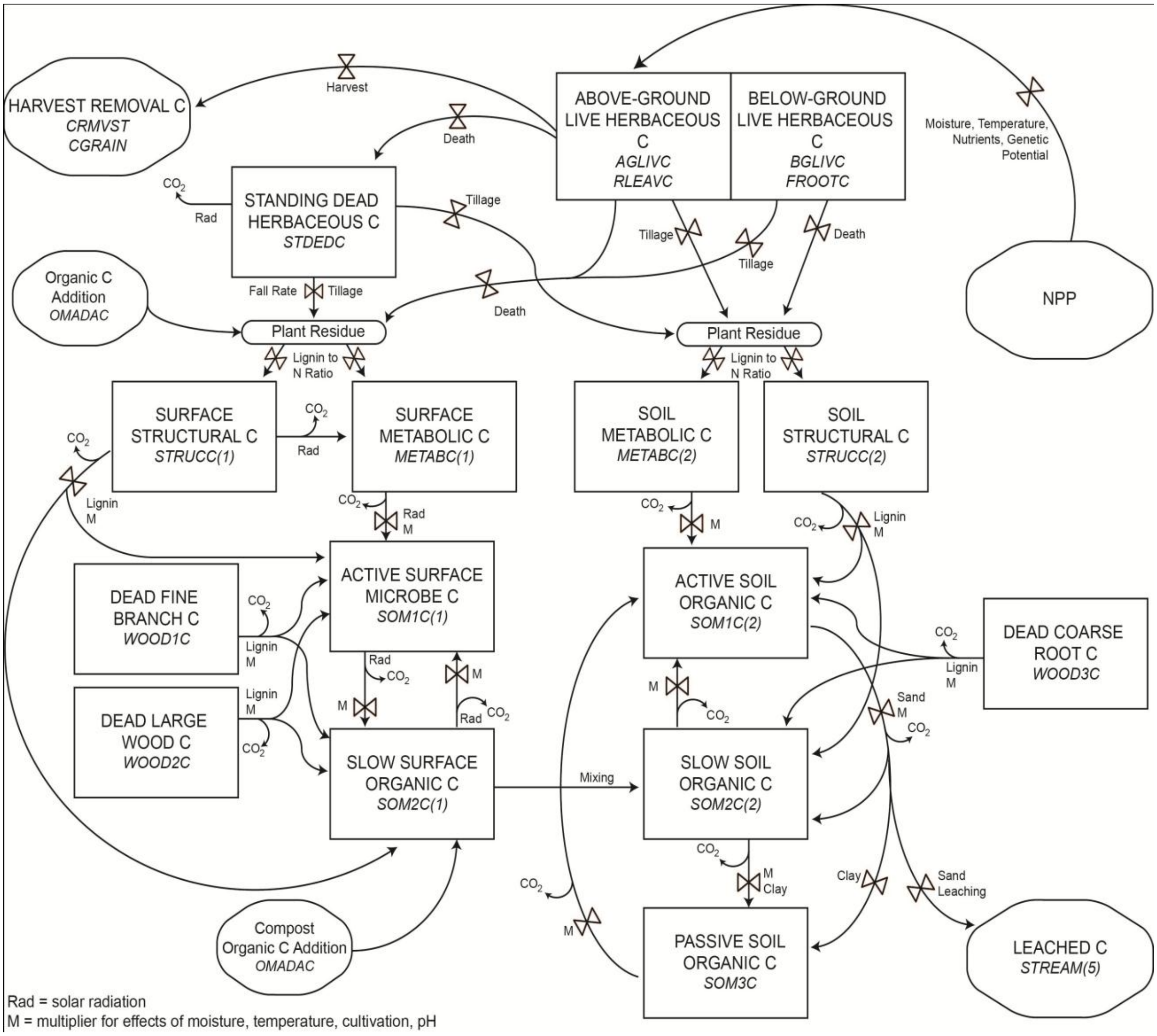
The average daily soil surface temperature is the upper boundary for the one-dimensional Fourier heat flow equation described in the work of Parton (1984). The lower boundary temperature is site dependent and is a sine function of the annual average soil temperature at the bottom of the soil profile and Julian Date.

3. Soil Biogeochemical Submodels

3.1.Soil Organic Matter Submodel

3.1.1. Soil Organic Matter Pools

The soil organic matter submodel of the DayCent model is based on multiple compartments for soil organic matter (Parton et al. 1987). Soil organic matter is simulated for the top 20-cm soil layer and is divided into three pools (active, slow, and passive) with different potential decomposition rates. Both the active and the slow organic matter pools have a surface and soil component while the passive pool has only a soil component. Plant material is transferred into these soil organic matter pools from above and belowground litter pools and three dead wood pools **(Figure 9)**.



Rad = solar radiation
M = multiplier for effects of moisture, temperature, cultivation, pH

Figure 9 Carbon Cycle

The model has been parameterized to simulate soil organic matter dynamics in the top 20 cm of the soil. The model does not simulate organic matter in the deeper soil layers and increasing the soil depth parameter (EDEPTH, fix.100) does not have much impact on the model. EDEPTH is only used to calculate C, N and P loss when erosion occurs. To simulate a deeper soil depth (i.e., 0-30 or 0-40 cm depth) the soil organic matter pools must be initialized appropriately. As a general rule deeper soil depths have older soil carbon dates (Jenkinson et al. 1992) and lower decomposition rates (lower temperature at deeper depths). Thus, it would be assumed that the fraction of total SOM in the passive SOM would be greater. The major change for initializing the model for deep soil depths is adjusting the fraction of SOM in the different pools (more C in passive SOM). The initial soil C levels should reflect the observed soil C levels over that depth and the decomposition rates should be decreased for all of the SOM pools (DEC3(2), DEC4, and DEC5(2)). To increase the soil depth from 20 cm to 30 cm, the decomposition rates should be decreased by 15%. The other adjustment would be to increase the rate of formation of passive SOM; the recommended way is to increase the flow of C from active and slow SOM to passive SOM (PS1S3(*) and PS2S3(*), fix.100). For example, increasing the coefficients in PS2S3(*) and PS1S3(*) will increase the amount of passive SOM formed from slow SOM and active SOM.

3.1.2. Structural and Metabolic Litter

Above and belowground non-woody plant residues and organic animal excreta are partitioned into structural (STRUCC(*)) and metabolic (METABC(*)) pools as a function of the lignin to N ratio in the residue. Structural material is assumed to contain cellulose and all of the lignin whereas metabolic material is readily decomposable. With increases in the ratio, more of the residue is partitioned to the structural pools which have much slower decay rates than the metabolic pools **(Figure 11).** The lignin fraction of the plant material does not go through the surface microbe (SOM1C(1)) or active pools (SOM1C(2)) but is assumed to go directly to the slow C pool (SOM2C) as the structural plant material decomposes. Metabolic pools are decomposed primarily by bacteria while structural pools are decomposed primarily by fungi. Dead wood pools (WOOD1C, WOOD2C, and WOOD3C) decompose directly into the active pools (SOM1C(*)), and the slow pools (SOM2C(*)). The decomposition rate of the structural material is a function of the fraction of the structural material that is lignin, and the decomposition of dead wood is a function of the fraction of wood that is lignin **(Figure 10)**

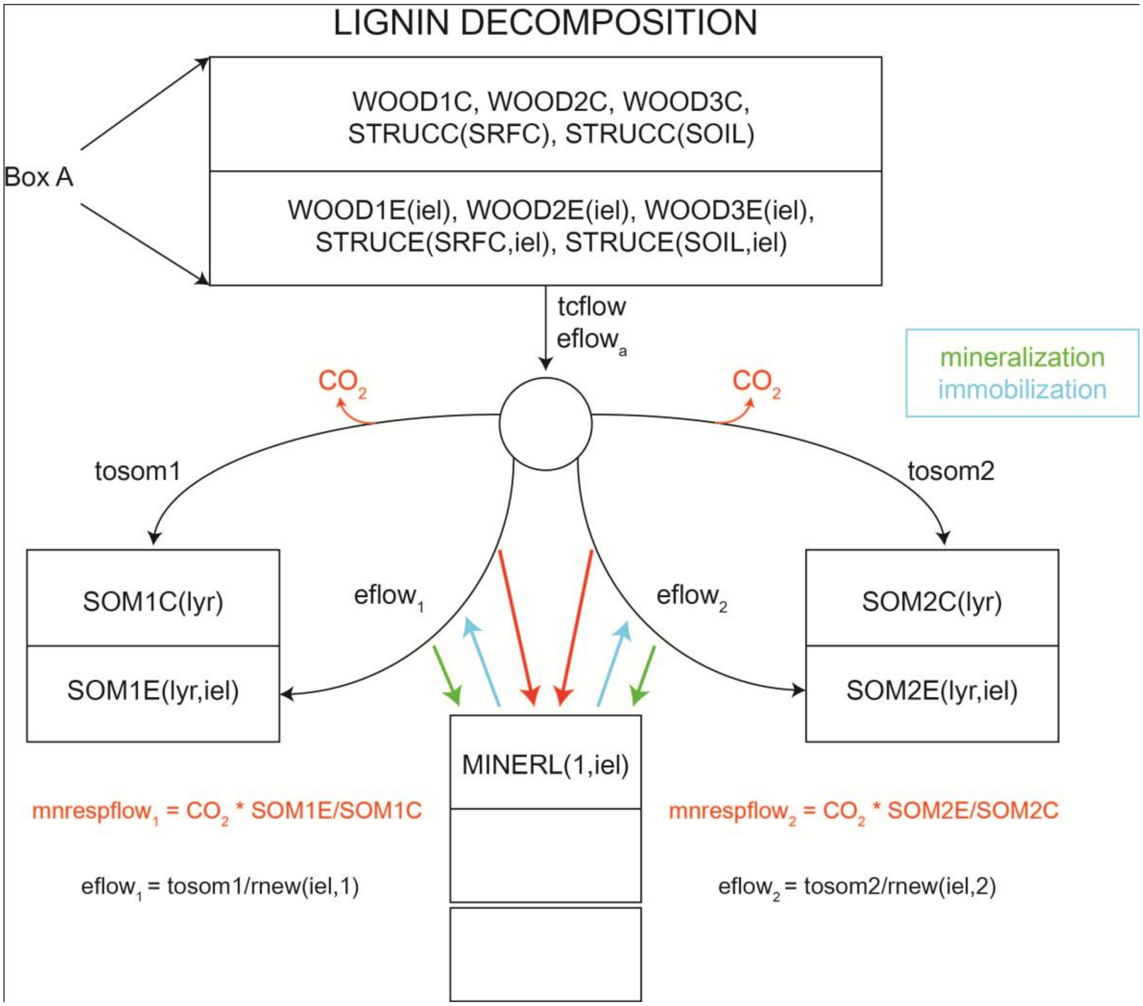


Figure 10 Lignin Decomposition

.

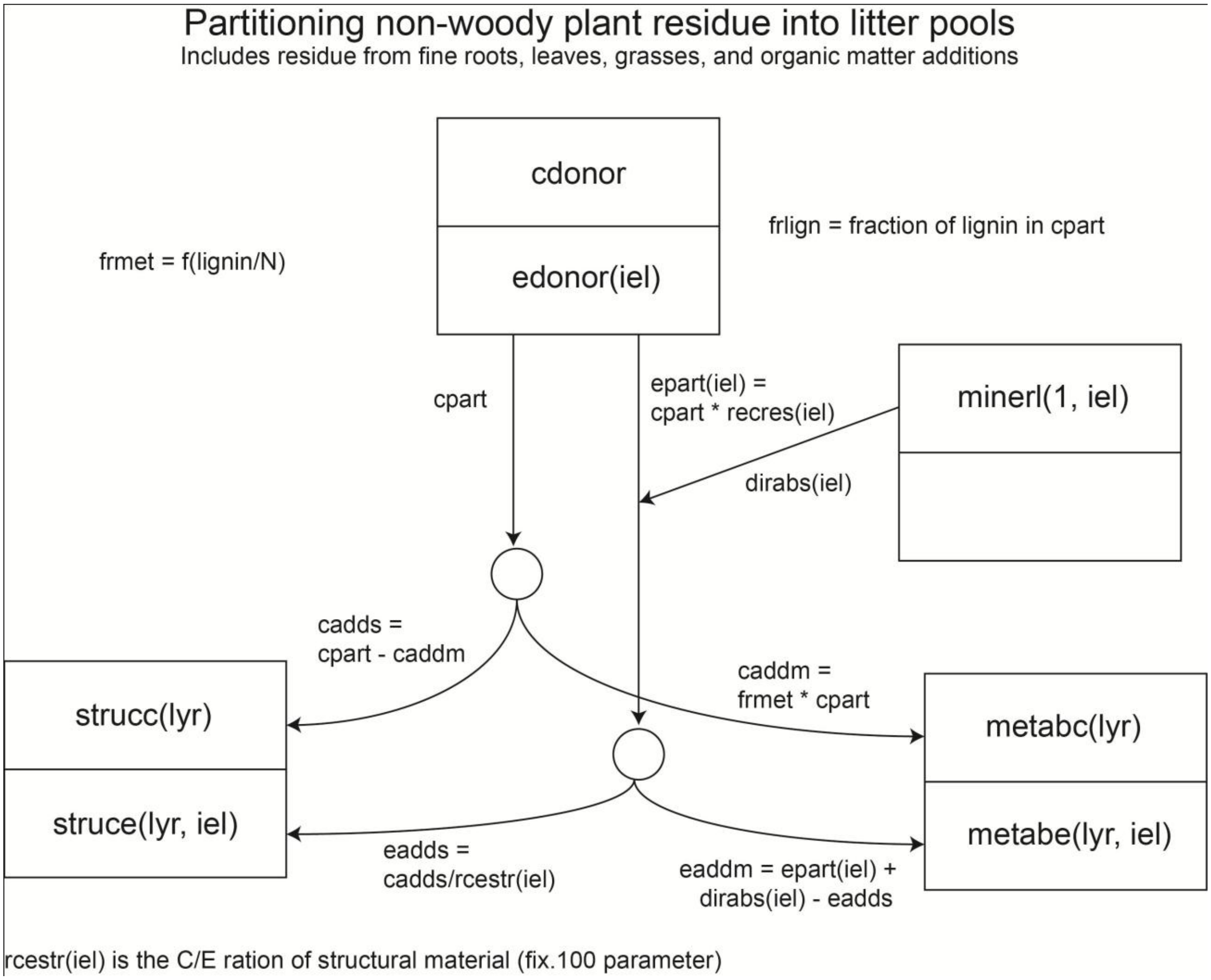


Figure 11 Partitioning Plant Residue into Structural and Metabolic Litter

The partitioning of non-woody plant residue into structural and metabolic litter pools. The carbon that flows (*cpart*) from the C component of plant residue (*cdonor*) is partitioned into the structural C (*strucc(lyr)*) and metabolic C (*metabc(lyr)*) litter pools. The N, P, and S that flows (*epart(iel)*) with possible direct absorption (*dirabs(iel)*) from the N, P, or S component of plant residue (*edonor(iel)*) is partitioned into structural E (*struce(lyr,iel)*) and metabolic E (*metabe(lyr,iel)*) litter pools. The value of *epart(iel)* is determined from the amount of *cpart* and the E to C ratio of the residue (*recres(iel)*). The fraction of *cpart* that flows into metabolic litter (*frmet*) is dependent on the lignin:N ratio of the residue **(see also Figure 12).** The value *caddm* is the portion of *cpart* that flows into *metabc(lyr)* while *cadds* is the portion that flows into *strucc(lyr)*. The value *eaddm* is the portion of *epart(iel)* that flows into *metabe(iel)* while *eadds* is the portion that flows into *struce(iel)*. The value *rcestr(iel)* is the C/E ratio of structural material (*fix.100*).

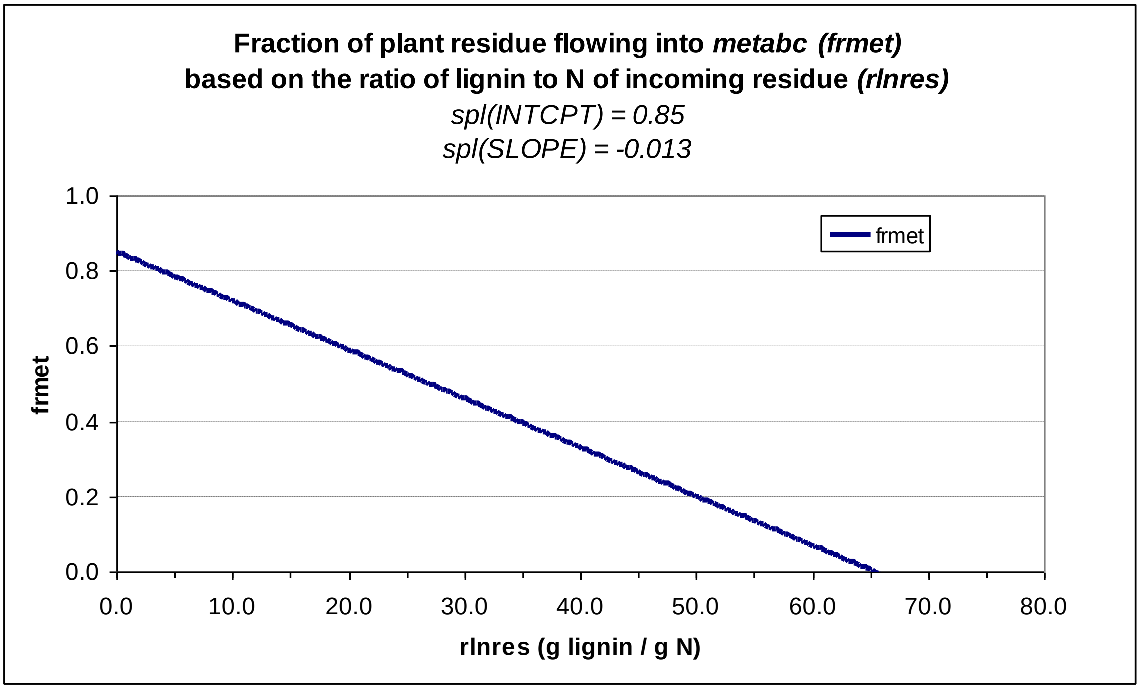


Figure 12 Fraction of Metabolic Litter

The fraction of organic residue that is partitioned to the metabolic litter pool (*frmet*) decreases linearly as the ratio of lignin to N in the incoming residue (*rlnres,* g lignin biomass / g N) increases. The remaining fraction of the residue (1 – *frmet*) is partitioned to the structural litter pool. For this example, *spl(INTCPT)* = 0.85 and *spl(SLOPE) = -0.013.* The values *spl(INTCPT)* and *spl(SLOPE)* are *fix.100* parameters. Note: a positive value of SPL(2) in *fix.100* is negated in the code to create a negative slope; do not assign SPL(2) a negative number.

The decomposition of both plant residues and soil organic matter are assumed to be microbially mediated with an associated loss of CO_2 as a result of microbial respiration, with the exception of photodecomposition. The abiotic process of photodecomposition, where incoming solar radiation accelerates the decomposition of dead plant material, may be and important process in arid grasslands (Parton et al. 2007a, Adair et al. 2008). The loss of C from the standing dead pool (STDEDC) or from the surface structural (STRUCC(1)) is proportional to the amount of solar radiation each absorbs. Photodegradation of STDEDC results in a CO_2 loss without nutrient loss. Photodegradation of STRUCC(1) results in a CO_2 loss as well as a flow of C to surface metabolic METABC(1), with some nutrient flow from STRUCE(*) to METABE(*).

Decomposed detrital material that has a low C/N ratio flows to the active SOM pool, which includes microbial biomass and the highly labile byproducts of decomposition. The active surface pool (SOM1C(1) and active soil pool (SOM1C(2)) (total active pool is ~2 to 3 times the live microbial biomass level) and have a turnover time of months to a few years depending on the environment. The soil texture influences the turnover rate of the active SOIL organic matter (higher rates for sandy soils) and the efficiency of stabilizing active SOIL organic matter into slow SOIL organic matter (higher stabilization rates for clay soils). The surface microbial pool (SOM1C(1)) turnover rate is independent of soil texture, and it transfers material directly into the surface slow soil organic matter pool (SOM2C(1)).

The products of detrital decomposition that have a higher C/N ratio flow to the slow SOM pool, which includes the relatively resistant byproducts of decomposition derived from the structural pool and dead wood biomass. The slow surface pool (SOM2C(1)) and slow soil pool (SOM2C(2) include this resistant plant material. The soil slow pool (SOM2C(2)) also includes soil-stabilized microbial products derived from the active soil pool. These pools have a turnover time of a couple years to a decade or more. There is a transfer of SOM2C(1) to SOM2C(2) due to physical mixing. The transfer of SOM2C(2) to SOM1C(2) is probably not very important (5%), and most of this flow results in a CO_2 loss.

The passive soil pool (SOM3C) consists of humus that is extremely resistant to decomposition and includes physically and chemically stabilized soil organic matter and has a turnover time of 300 to 1000 years. The proportions of the decomposition products which enter the passive pool from the slow and active pools increase with increasing soil clay content. As soils become finer textured a lower portion of SOM is respired as CO_2 and more SOM is retained in stable form due to physical and chemical protection. The stabilization of the active soil pool is the primary source for the passive pool. Some passive SOM is also created by the decomposition of slow organic matter. There is no transfer of surface litter or SOM1C(1) to SOM3C. Flows to SOM3C occur in only in the soil.

3.1.3. Soil Temperature and Moisture Effects on Decomposition

The potential decomposition rates of surface and soil pools are reduced by multiplicative functions of soil moisture and soil temperature. In the CENTURY/DayCent context, this temperature/moisture multiplier has often been referred to as the decomposition factor (DEFAC), and may be known as the climate decomposition index (CDI). The temperature/moisture effects on aboveground and belowground decomposition are known as *agdefac* and *bgdefac,* respectively. The soil temperature effect on decomposition is computed as variable Q_{10} function, with low Q_{10} values at high temperatures and high Q_{10} values at low temperatures (Del Grosso et al. 2005) **(Figure 13)**. The IDEF parameter (*fix.100*) determines the if the moisture function uses relative water content **(IDEF=1, Figure 14)**, the ratio of stored soil water (0-30 cm depth, AVH2O(3)) plus current day's precipitation to potential evapotranspiration **(rprpet) (IDEF=2, Figure 14),** or water-filled pore space and soil texture **(IDEF=3, Figure 14)**. The relative water content and rprpet methods are independent of soil texture.

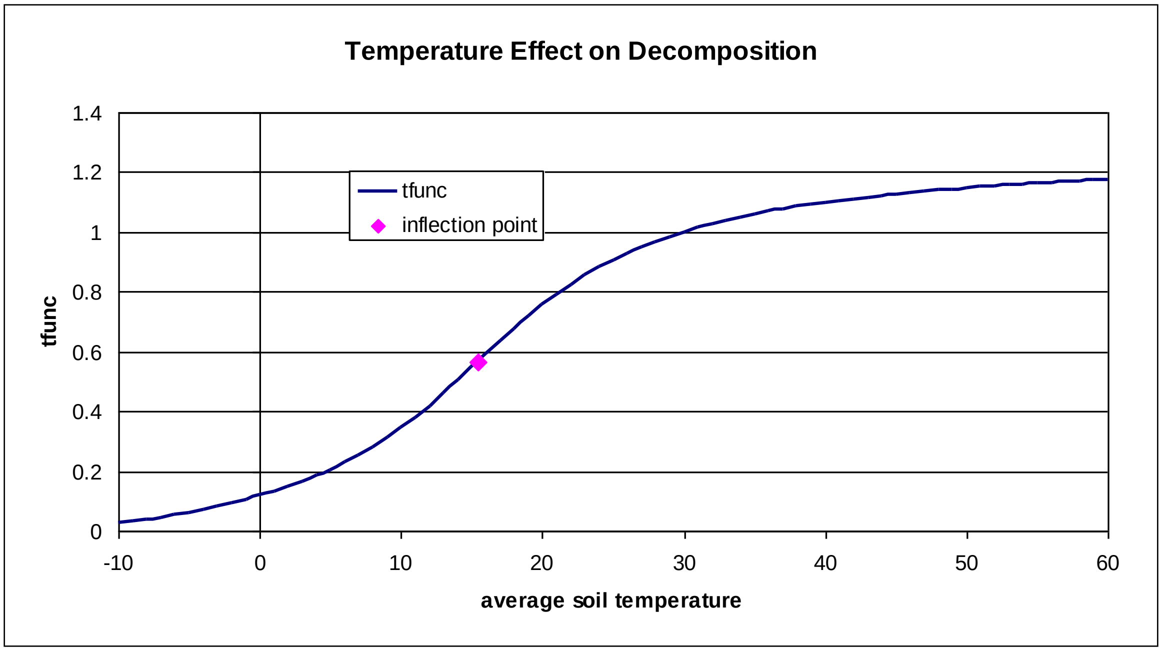
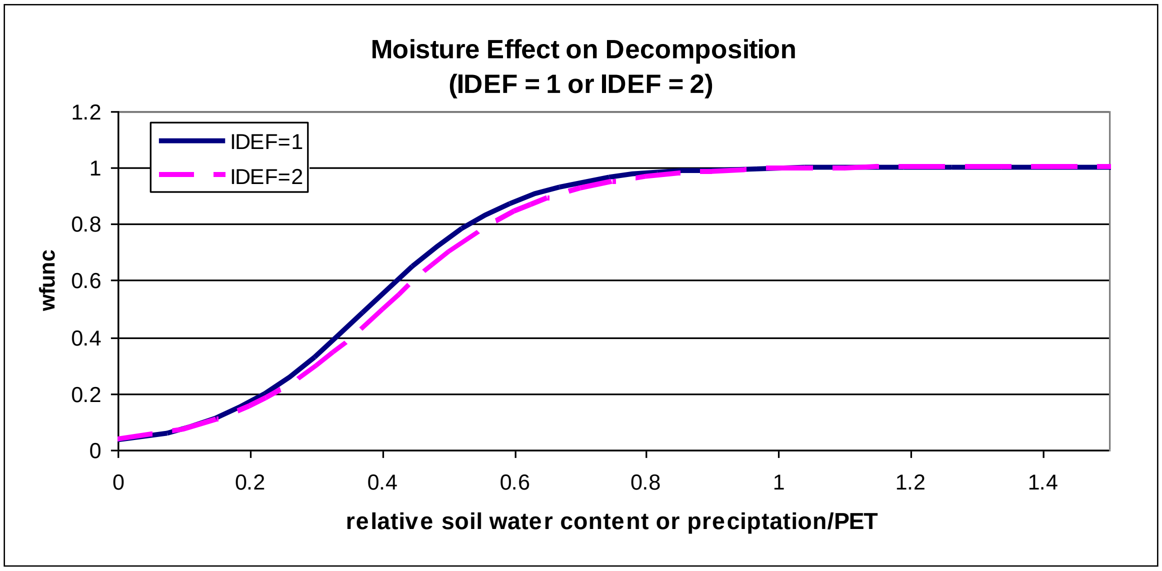


Figure 13 Soil Temperature Effect on Decomposition

Figure 13. Soil Temperature Effect on Decomposition. The variable Q_{10} temperature effect on decomposition (*tfunc*) with $teff_1$ = 15.4, $teff_2$ = 11.75, $teff_3$ = 29.7, and $teff_4$ = 0.031. The value of *tfunc* strictly increases with average soil temperature, but has a low Q_{10} values at high temperatures and high Q_{10} values at low temperatures. The $teff_1$ parameter determines the x-location of the inflection point. See also Del Grosso, Parton et al. (2005) that expresses this function without the *normalizer* in the denominator.



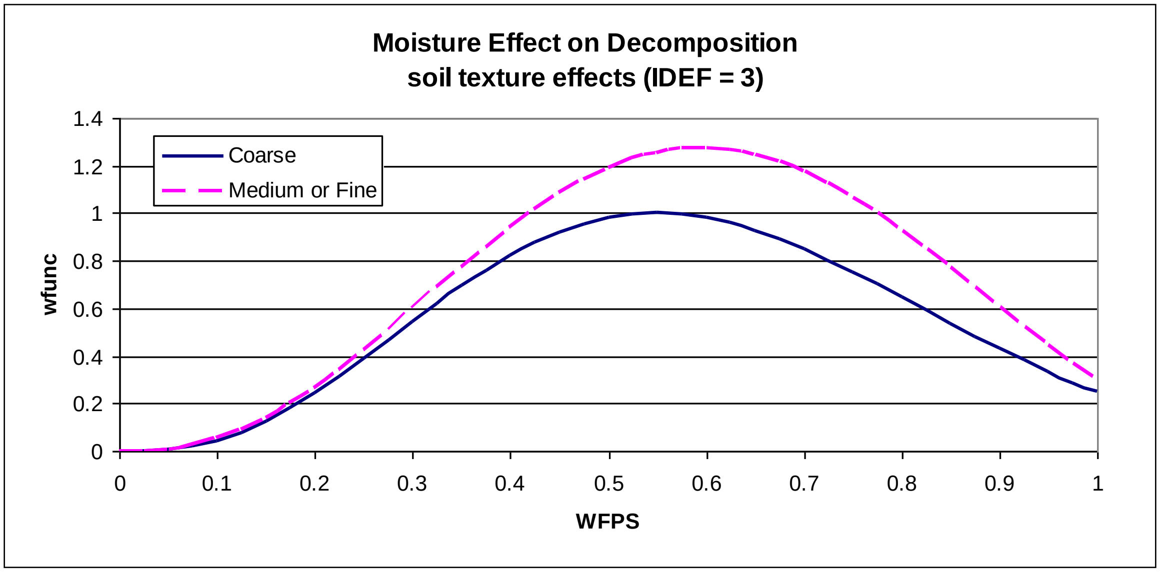


Figure 14 Soil Moisture Effect on Decomposition

The moisture effect on decomposition (*wfunc*): (a) When IDEF = 1 or 2. For these cases, *wfunc* strictly increases with available moisture. (b) When IDEF = 3. For this case, *wfunc* is a maximum when soil moisture is close to 50% saturated, and decreases as the soil dries or as it becomes saturated. For a given moisture content, *wfunc* is less in coarse soils compared to finer soils.

When using the relative water content option, IDEF = 1 in the fix.100 file, the model computes separate *agdefac* and *bgdefac* values for surface and soil decomposition rates; otherwise, these rates are equal. The *agdefac* multiplier modifies the decomposition rates for the surface pools: METABC(1), STRUCC(1), SOM1C(1), SOM2C(1), WOODC1, and WOODC2. The *bgdefac* multiplier modifies the decomposition rate of for the soil pools: METABC(2), STRUCC(2), SOM1C(2), SOM2C(2), SOM3C, and WOOD3C. In addition *bgdefac* will be used in the growth and phosphorous weathering calculations.

3.1.4. Tillage and Rainfall Effects on Decomposition

Decomposition rates may be increased as an effect of tillage (CLTEFF(*), cult.100) when these parameters are greater than 1.0. Additionally, decomposition rates are enhanced with a pulse multiplier when a drying down period is followed re-wetting of the soil. This multiplier is calculated in the same manner as the pulse multiplier that is used to increase of NOx emissions (See Section 3.5.3 below).

3.1.5. Soil pH Effects on Decomposition

The potential decomposition rate of surface and soil pools is reduced by the effect soil pH on the dominant type of decomposer **(Figure 15)**. Fungi are the dominant composer for SOM3C, and bacteria are the primary composer for METABC(1) , METABC(2), and SOM1C(2). For all other pools, SOM1C(1), SOM2C(*), STRUCC(*), WOOD1C, WOOD2C, and WOOD3C, a combination of fungi and bacteria is used. Soil pH is determined as the weighted average of the pH of the top three DayCent soil layers (soils.in). Soil pH can be shifted using the pH scalars (Section 4.4.5 above).

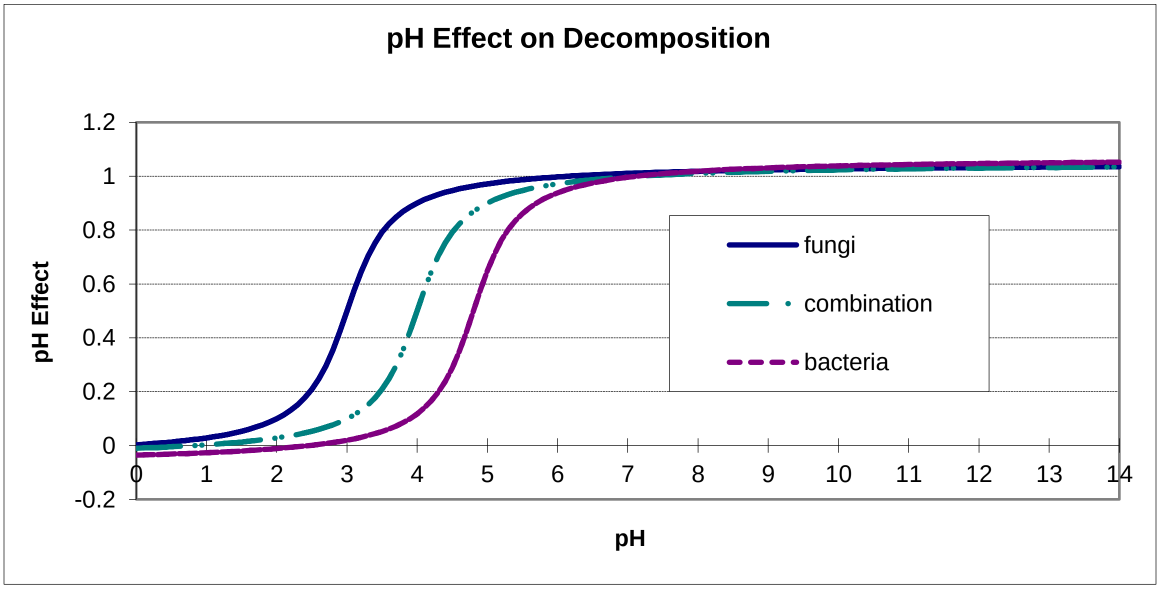


Figure 15 Soil pH Effect on Decomposition

Figure 15. Soil pH Effect on Decomposition. The three functions to determine the pH effect on decomposition vary with the type of decomposer. Minimum decomposition rates occur when the value of *pHEffect* is near zero, while the maximum rate of decomposition occurs when the value of *pHEffect* is 1.0. Decomposition at low pH is promoted by fungi, while decomposition at higher pH is it is regulated by bacteria. When pH ≥ 7.0, *pHEffect* is always 1.0.

The potential decomposition of soil pools can be further reduced by the effect of anaerobic conditions (high soil water content) (ANERB) **(Figure 16)**, or increased as an effect of cultivation (CLTEFF(*), cult.100). The soil drainage factor (DRAIN, <site>.100) allows a soil to have differing degrees of wetness (e.g., DRAIN=1 for well drained sandy soils and DRAIN=0 for a poorly drained clay soil).

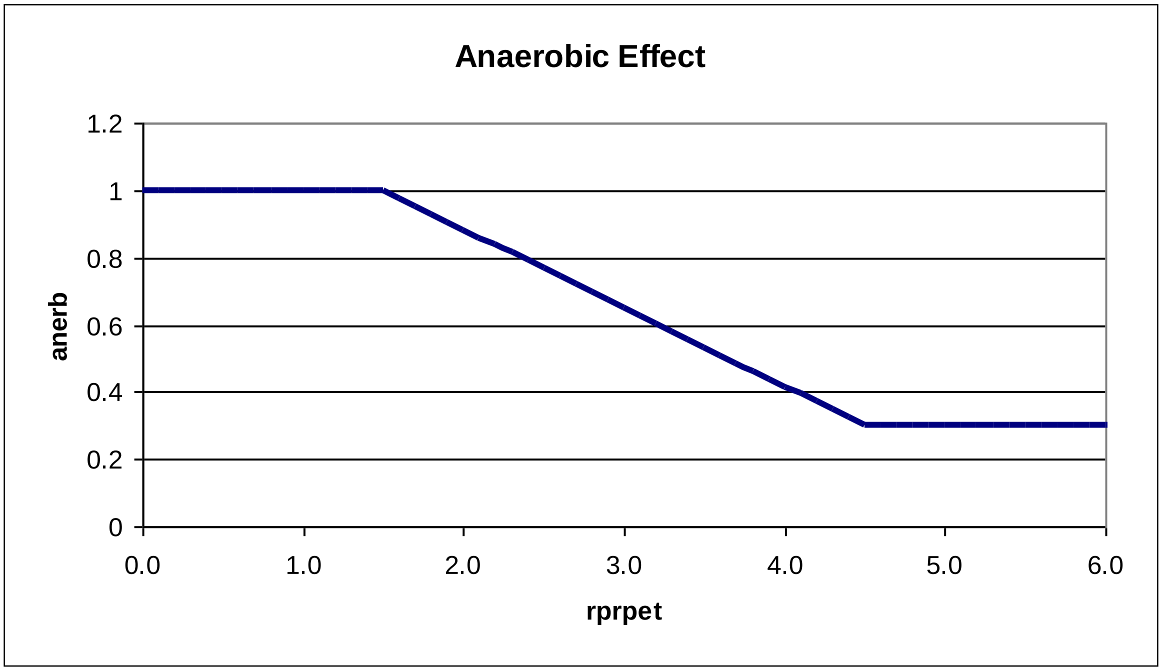


Figure 16 Anaerobic Effect on Decomposition

In the example graph above, *aneref(1)* = 1.5, *aneref(2)* = 3.0; *aneref(3)* = 0.3; *drain* = 0.5. When *anerb* is 1.0, there is no reduction in the decomposition rate.

3.1.6. Effects of Saturated Soil Conditions on Decomposition rates

(This section applies to only versions of DayCent that implement methanogenesis, currently this includes only DDcentEVI)

Anaerobic decomposition factors reduce decomposition rates as water content increases from field capacity to saturation. Anaerobic decomposition factors are specific to the type of organic matter being decomposed. In general, under anaerobic conditions, the decomposition rates of metabolic litter and the active soil pool are reduced least, decomposition rates of structural litter dead wood pools is reduced the most, and the decomposition rates of the slow and passive pools are reduced at intermediate rates.

Four parameters in fix.100, SATDEC(1)…SATDEC(4), specify the reduction in decomposition rates under saturated conditions for different types of organic matter pools. The range of these parameters is 0.0 – 1.0, where 0.0 indicates that decomposition will cease under saturated conditions and 1.0 means that saturated conditions have no effect on decomposition **(Table 8)**.

Table 8 Definition of Parameters that Slow Organic Matter Decomposition Rates when Soil Water Content is Greater Than Field Capacity

Fix.100 parameters	**Description**	**Suggested Value**
SATDEC(1)	Effect of saturation on the rates of metabolic litter and som1c (active pool) decomposition	1.0
SATDEC(2)	Effect of saturation on the rates of structural litter decomposition	0.45
SATDEC(3)	Effect of saturation on the rates of som2c (slow pool) and som3c (passive pool) decomposition	0.25
SATDEC(4)	Effect of saturation on the rates of wood decomposition	0.45

When IDEF=1 or 4 (fix.100), the effect of anaerobic conditions on decomposition rates (*anerdcmp*, 0.0 – 1.0) for any pool is a function of relative water content with respect to saturation. Each pool has a separate value of *anerdcmp* for surface (*srfc*) and belowground (*soil*) decomposition. Relative water content is the weighted mean of the relative water content of one or more layers (**Table 9).** When soil water content is greater than field capacity, the *anerdcmp* value for a pool is just another multiplier on the maximum turnover rate during decomposition and replaces agwfunc or bgwfunc (EQN ??).

Equation 13

$$anerdcmp(pool, SRFC) = 1.0 - relWaterContent_{srfc} \times \left(1.0 - SATDEC(pool)\right)$$
$$anerdcmp(pool, SOIL) = 1.0 - relWaterContent_{soil} \times \left(1.0 - SATDEC(pool)\right)$$

The relative water content with respect to saturation for soil layer *i* is calculated as:

Equation 14

$$relWaterContent_i = \frac{swc_i - swcfc_i}{swcsat_i - swcfc_i} \times \left(1.0 - SATDEC(pool)\right)$$

where swc_i is the soil water content of the soil layer *i* (cm H_2O), $swcfc_i$ is the soil water content at field capacity for soil layer *i* (cm H_2O), and *swcsati* is the soil water content at saturation for soil layer *i* (cm H_2O)

Table 9 Effects of the IDEF Parameter on the Anaerobic Decomposition Factor (*anerdcmp*) Calculation

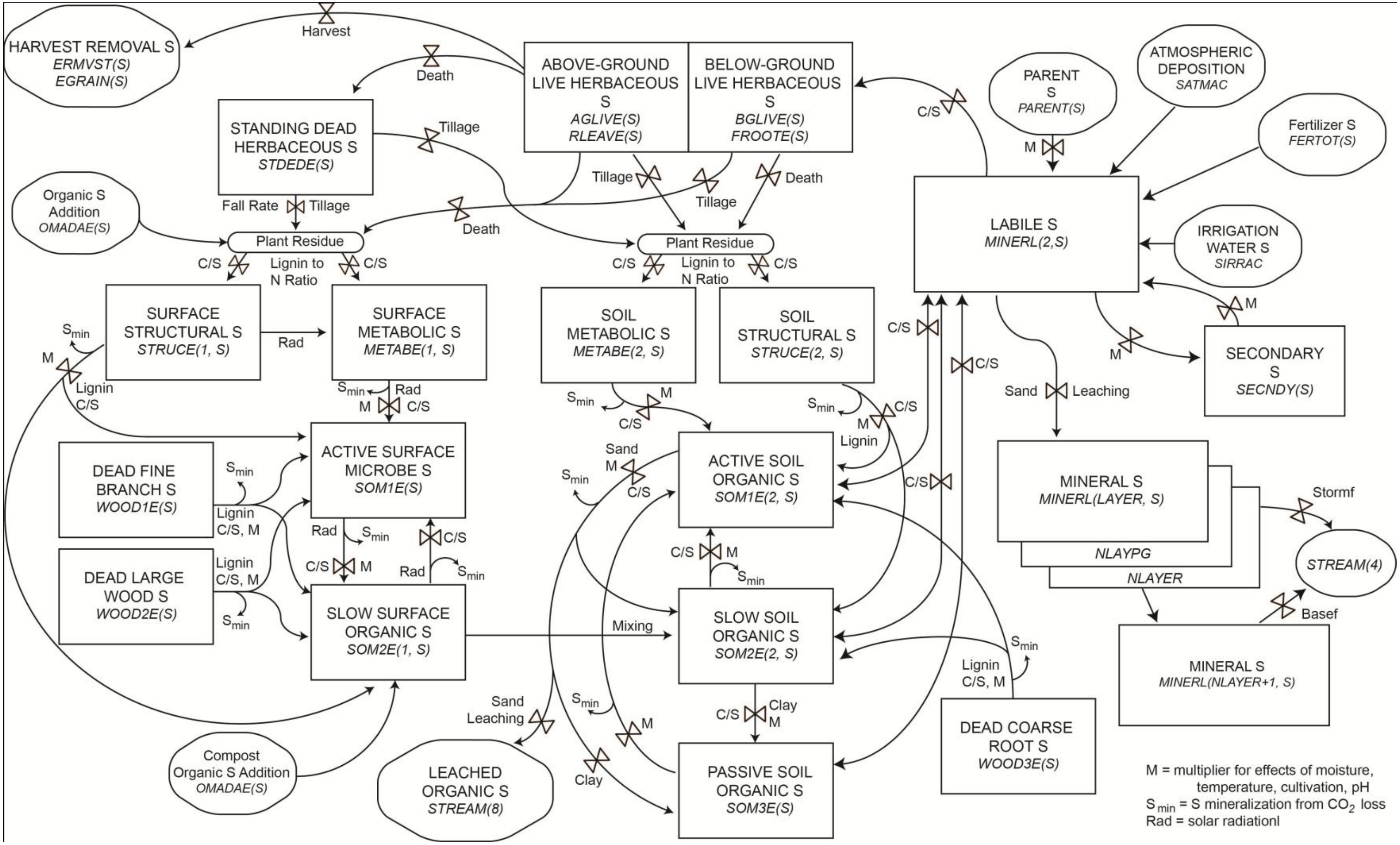
IDEF (fix.100)	**Surface layers**	**Soil layers**
1	1	2 and 3
2	No definition for saturated decomposition since the ratio of precipitation to PET is used for the water function calculation.	
3	Not documented yet	Not documented yet
4	2	2, 3, and 4

3.1.7. Leaching of Organics

A fraction of the products from the decomposition of the active pool is lost as leached organic C (STREAM(5)). Leaching of organic matter is a function of the decay rate for active soil organic matter, and the sand content of the soil (more for sandy soils based on OMLECH(1) and OMLECH(2) parameters, fix.100) and only occurs if there is drainage of water below the 20 cm soil depth. Leaching loss increases with increasing water flow up to a critical level – OMLECH(3), *fix.100*). Organic leaching is compared to inorganic leaching in Section 2.2.1 above.

3.1.8. Organic Nitrogen, Phosphorus, and Sulfur Pools

The model has N, P, and S pools analogous to the C pools **(Figure 19, Figure 20, Figure** 22**).** Each soil organic matter pool has an allowable range of C to element (C/E) ratios based on the conceptual model of McGill and Cole (1981). Reflecting the concept that N is stabilized in direct association with C, C/N ratios are constrained within narrow ranges, while the ester bonds of P and S allow C/P and C/S ratios to vary widely. The ratios in the structural pool are fixed at high values (RCESTR(*), <site>.100), while



the ratio in the metabolic pool is allowed to float in concert with the nutrient content of the plant residues. The N, P, and S flows between soil organic matter pools are related to the C flows. The quantity of each element flowing out of a particular pool equals the product of the C flow and the element to C ratio of the pool. The C/E ratios for material entering each destination soil organic matter pool are linear functions of the labile inorganic mineral pools in the surface soil layer (AMINRL(*)) **(Figure 17).** Low nutrient levels in the labile pools result in high C/E ratios in the various soil organic matter pools. Mineralization or immobilization of N, P, and S occurs as is necessary to maintain the C/E ratios required for the destination pool. Thus, mineralization of N, P, and S occurs as C is lost in the form of CO_2 and as C flows from pools with low C/E ratios, such as the active pool, to those with higher C/E ratios, such as the slow pool. Immobilization occurs when C flows from pools with high C/E ratios, such as the structural pool, to those with lower C/E ratios, such as the active pool; the maximum amount of immobilization occurs when aminrl(iel) is greater than VARAT(3) and the C/E ratio of the destination pool is at a minimum **(Figure 18)**. The decomposition will not occur if the quantity of any element is insufficient to meet the immobilization demand. The initial content of N in plant litter is very important. Low litter N leads to immobilization while high litter N leads to mineralization (Parton et al. 2007a).

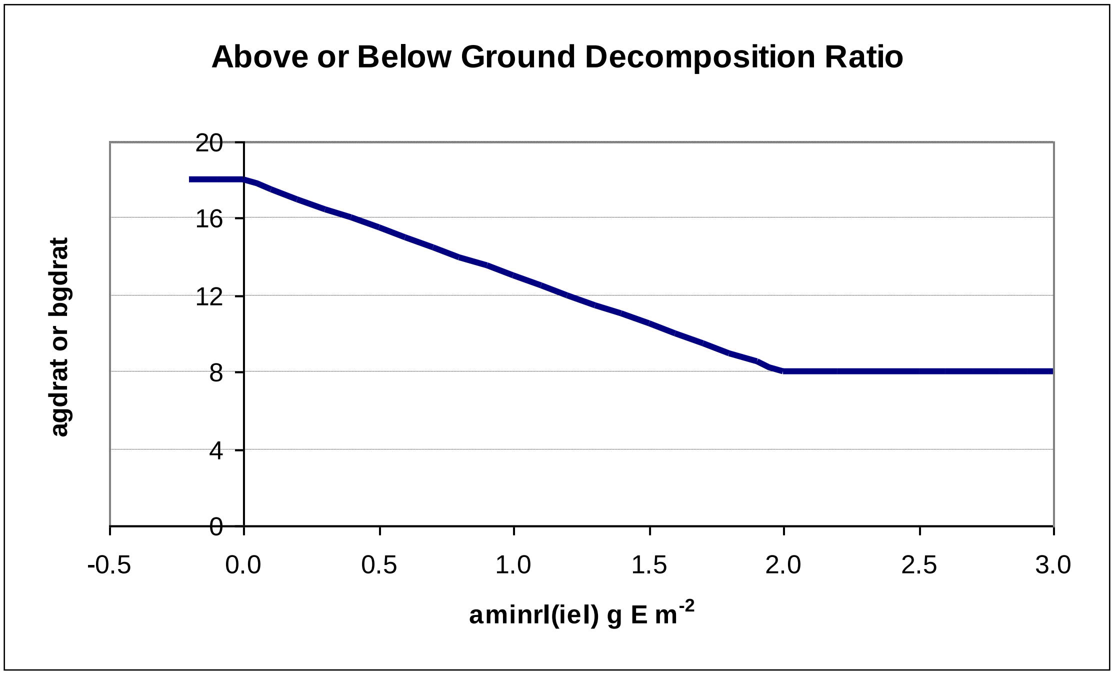


Figure 17 Variable Carbon: Element Ratios of Soil Organic Pools

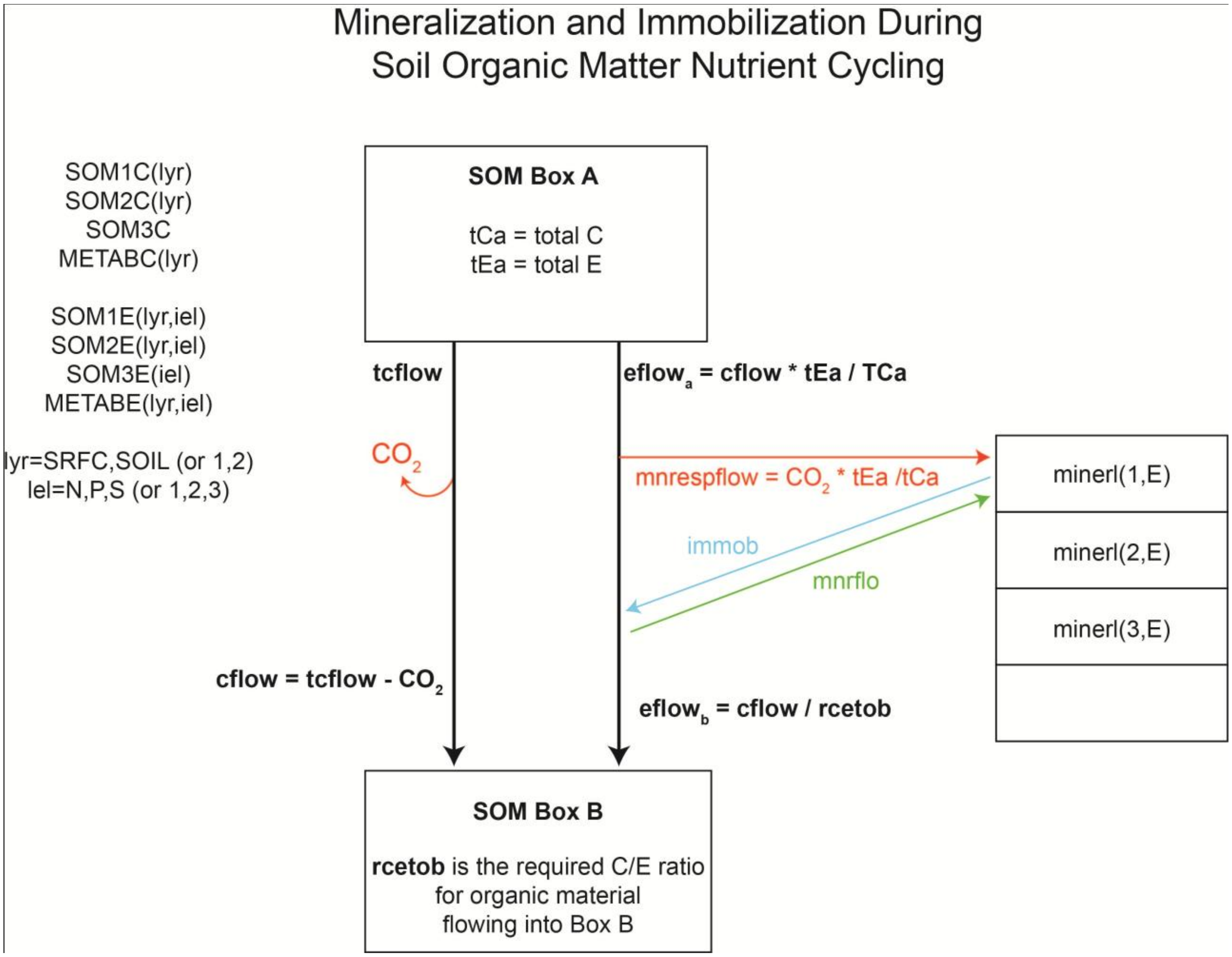


Figure 18 Mineralization and Immobilization

The flow of C and E (N, P, or S) when organic matter in Box A decomposes to Box B. The C state variables represented by Box A (with **tCa** g C m^{-2}) or Box B include *som1c*, *som2c*, *som3c*, and *metabc*. The E state variables represented by Box A (with **tEa** g E m^{-2}) or Box B include *som1e*, *som2e*, *som3e*, or *metabe*. Decomposition can occur if the C/E ratio of material flowing from Box A to Box B (**tCa / tEa**) is less than **rcetob,** or the amount of available E in **minerl(1, E)** is > 10^{-7} g E m^{-2}. If decomposition can occur, the amount of C flowing out of Box A (**tcflow**) minus the amount of C lost to respiration (**CO_2**, g C m^{-2}) is **cflow** (g C m^{-2}). The mineralization associated with respiration (**mnrespflow**, g E m^{-2}) (red arrow) is equal to the amount of C lost by respiration multiplied by the E/C ratio of material in Box A. The amount of E flowing out of Box A is **eflow$_a$** (g E m^{-2}), and the amount of E flowing into Box B is **eflow$_b$** (g E m^{-2}). If **eflow$_a$** – **mnrespflow** > **eflow$_b$** then mineralization (**mnrflo**) occurs (green arrow), otherwise if **eflow$_b$** > **eflow$_a$** – **mnrespflow** then immobilization (**immob**) occurs (blue arrow). The amount of **mnrflo** or **immob** is |**eflow$_a$** – **mnrespflow** – **eflow$_b$|.**

3.2.Nitrogen Submodel

The N submodel **(Figure 19)** has the same structure as the soil C model **(Figure 9).** Nitrogen flows follow C flows and are equal to the product of the carbon flow and the N:C ratio of the state variable that receives the carbon. The C:N ratio of the structural pools (RCESTR(1), fix.100) remains fixed while the N contents of the metabolic pools vary as a function of the N content of the incoming plant residue. The C:N ratio of newly formed surface microbial biomass is a function of the N content of the material being decomposed (C:N increases for low N content). The C:N ratios of organic matter entering each of the three soil pools vary as linear functions of the size of the mineral N pool with endpoints defined by the VARAT* parameters (fix.100). As mineral N in the surface soil layer increases from 0.0 to VARAT*(3,N) (usually 2 g N m^{-2}), the C:N ratios decrease from VARAT*(1,N) to VARAT*(2,N) **(Figure 17)**. The range of C:N ratios is approximately 15 to 3 for the active pool, from 20 to 12 for the slow pool and from 10 to 7 for the passive pool.

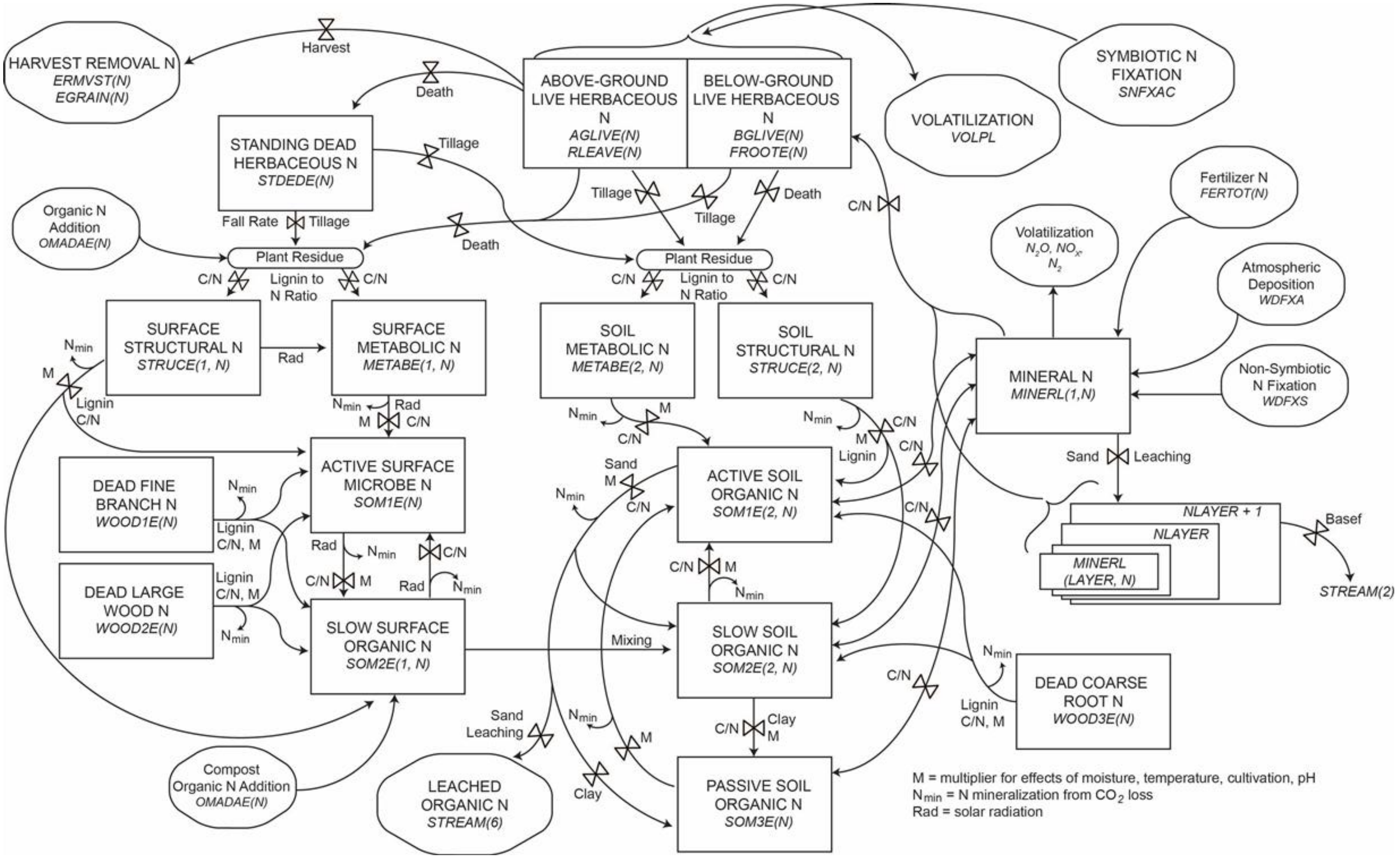


Figure 19 Nitrogen Cycle

The N associated with carbon lost in respiration (30% to 80% of the carbon flow is respired) is assumed to be mineralized. Given the C:N ratio of the state variables and the microbial respiration loss for each flow, decomposition of metabolic residue, active, slow, and passive pools generally result in net mineralization of N, while decomposition of structural residue immobilizes N.

The model uses simple equations to represent N inputs due to atmospheric deposition (WDFXA), non-symbiotic soil N fixation (WDFXS), and symbiotic plant N fixation (SNFXAC). Atmospheric N inputs (EPNFA(*), <site>.100) are a linear function of annual precipitation from the previous year (PRCANN, cm yr^{-1}). The model has the option (NSNFIX) of calculating soil N fixation rates as a function of the mineral N to labile P ratio (high fixation with lower ratios) or as a linear function (EPNFS(*), <site>.100) of annual evapotranspiration from the previous year (ANNET, cm yr^{-1}) (WDFXS = EPNFS(2) * (ANNET - EPNFS(1))). Symbiotic plant N fixation (SNFXAC, crop.100) is assumed to occur only when there is insufficient mineral N to satisfy the plant N requirement, having taken into account all possible growth reductions including P or S deficiency. Symbiotic N fixation can occur up to a maximum level of g N fixed per g C fixed (SNFXMX, crop.100) specified for each crop type and is hence related to the plant growth rate. The model also includes fertilizer N inputs and N inputs through organic matter additions (see parameters in the fert.100 and omad.100 files, Appendix 1).

The losses of N due to leaching of NO_3^- are related to soil texture and the amount of water moving through the soil profile (see water flow submodel description, Section 3.3). Inorganic N losses accumulate in the layer below the last soil layer (MINERL (NLAYER+1,1)) or are lost in the stream flow (STREAM(2)). Loss of organic N (STREAM(6)) occurs with the leaching of organic matter. Gaseous losses of N compounds associated with nitrification and denitrification (N_2O, NO_x, N_2) are computed by the trace gas submodel (Section 3.5 below). CENTURY output variables VOLGMA and VOLEXA are no longer used. Volatilization from maturing crops or senescing grassland (VOLPL) and losses due to crop removal, burning, transfer of N in animal excreta, and soil erosion are also accounted for.

3.3.Phosphorus Submodel

The Phosphorus submodel **(Figure 20)** has the same general structure as the Nitrogen submodel. The major difference is that there are five mineral P pools (labile P (PLABIL), sorbed P, strongly sorbed P (SECNDY(2)), parent P (PARENT(2), and occluded P (OCCLUD)). The phosphorus submodel **(Figure 20)** has been revised to give a better representation of phosphorus sorption. Because CENTURY and DAYCENT uses a relatively long timesteps (¼ month for the soil nutrient submodel in CENTURY and 1 day for DAYCENT) and soil solution very rapidly equilibriates with the labile fraction of adsorbed P (Cole et al. 1977) it is not appropriate to use soil solution P for the available nutrient pool. Instead, a labile P pool (PLABIL) has been defined, equivalent to resin extractable P, which is in equilibrium with a sorbed P pool **(Figure 21).** The equilibrium between the labile and sorbed P pools is recalculated after any P additions or removals from the soil. The sum of labile P and sorbed P are represented by the state variable MINERL(1,2). Plant uptake, immobilization and leaching of P (if allowed) are controlled by the size of the labile P pool. The fraction of labile P that is available for plant uptake varies from 0.4 to 0.8 as a function (FAVAIL(*), fix.100) of the mineral N pool size (higher fractions for high mineral N levels). As more P is removed through plant and soil microbial uptake, larger amounts become immobilized in organic matter.

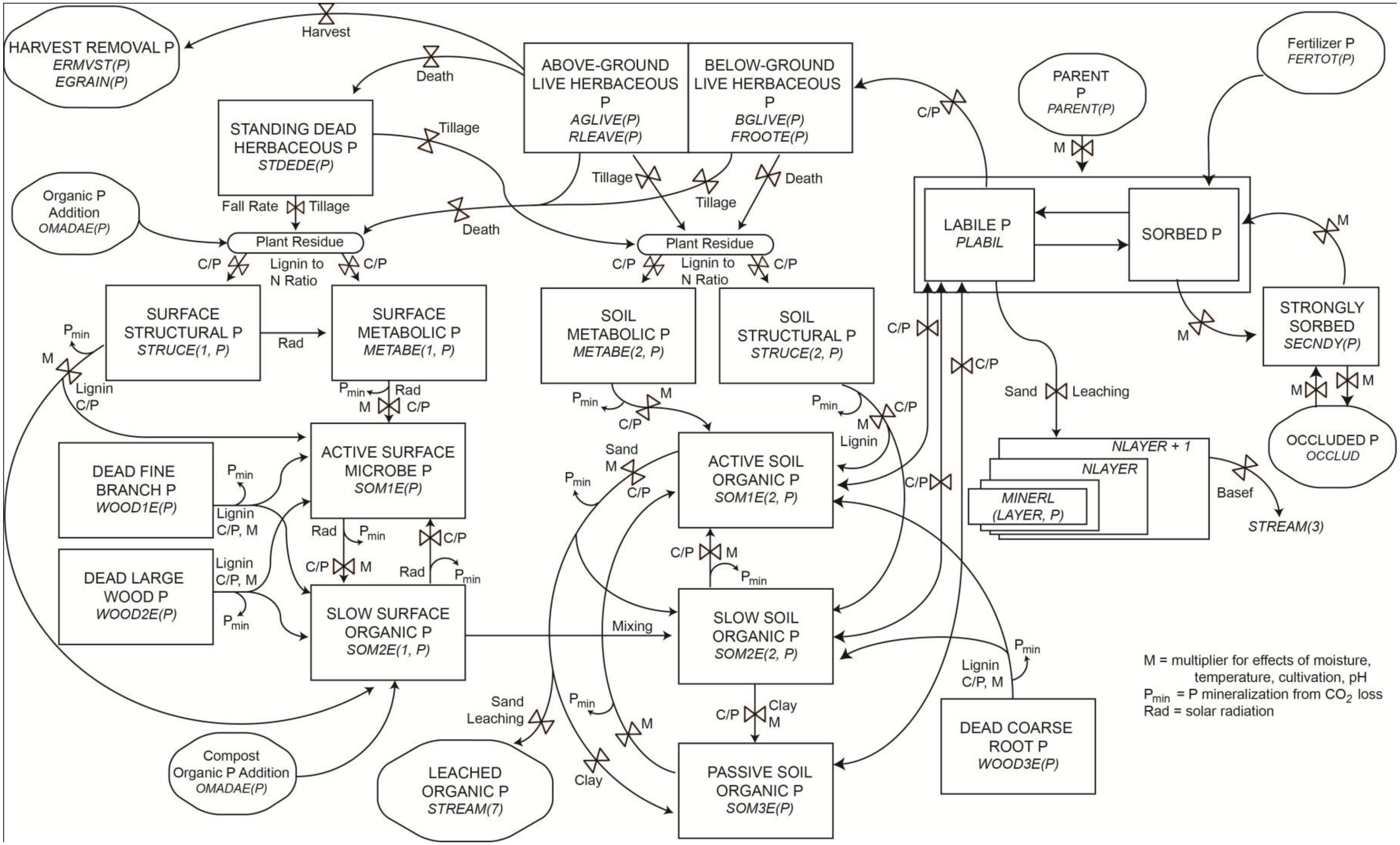


Figure 20 Phosphorus Cycle

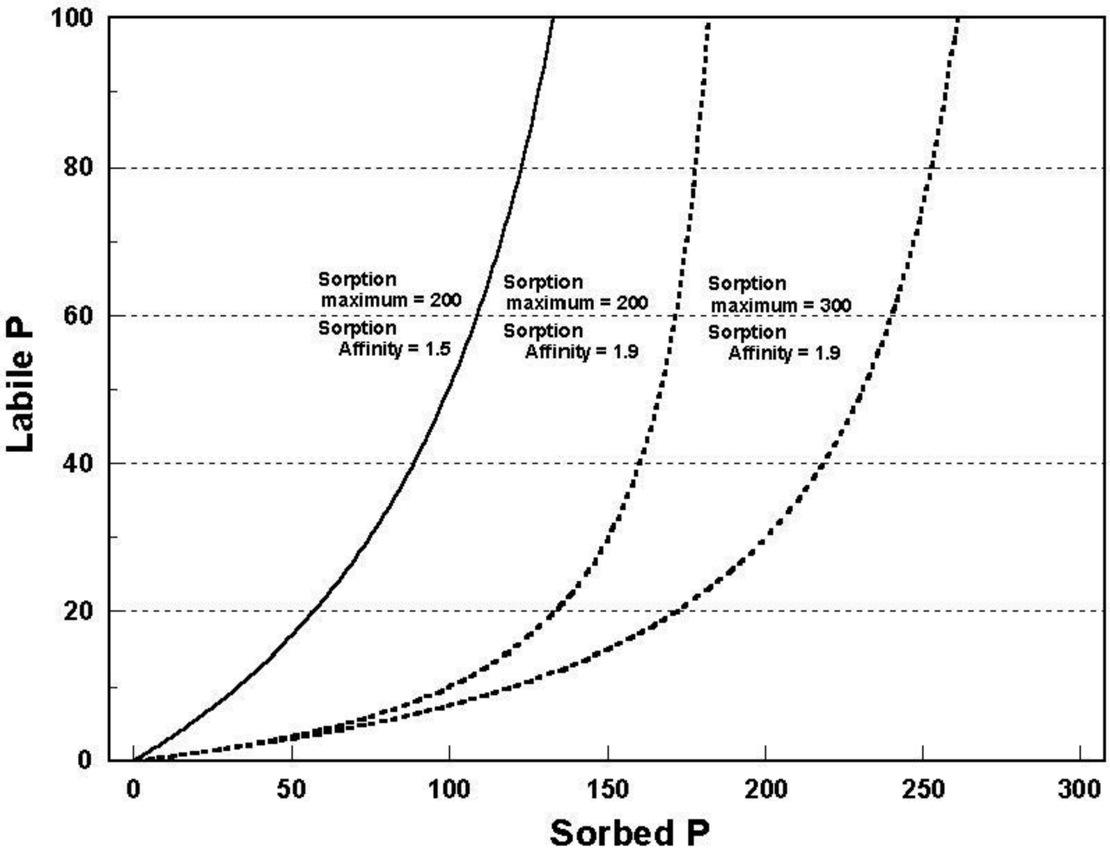


Figure 3-5: The equilibrium between labile and sorbed P pools, showing the effect of changing the sorption affinity or the sorption maximum.

Figure 21 Equilibrium between Labile and Sorbed P Pools

Note: The fraction of labile (non-sorbed) P in the surface layer available to plants, FAVAIL(2), may not be in the fix.100 parameter file in some older versions of DayCent. Instead, this value is calculated in the model. Explain why MINERL(SRFC,N) is used instead of MINERL(SRFC,P).

Equation 15

$$favail(2) = \max\left(favail(4), \min\left(favail(4) + minerl(SRFC,N) * \frac{favail(5) - favail(4)}{favail(6)},\ favail(5) \right)\right)$$

Phosphorus can enter the cycling P pools by weathering of parent material P (PARENT(2)), which is typically apatite. The rate of weathering (PPARMN(2), fix.100) can be a function of soil texture (TEXEPP(*), fix.100) (higher for fine textured soils).

The equilibrium relationship between labile P and sorbed P is defined in terms of two parameters, sorption affinity (PSLSRB, <site>.100) and sorption maximum (SORPMX, <site>.100). The sorption affinity parameter controls the fraction of the labile plus sorbed pools which is in the labile pool at low levels of P in these pools. The sorption maximum is the maximum amount of P which can be in the sorbed P pool. The sorption maximum controls the curvature of the relationship between labile P and the sum of the labile and sorbed P pools.

The sorbed P is in dynamic equilibrium with a more strongly sorbed P pool (SECNDY(2)). The maximum rate of flow from SECNDY(2) to the sorbed P pool (PSECMN(2), yr^{-1}) is a fix.100 parameter that may be reset based on pH and texture effects (PHESP(*) and TEXESP(*), fix.100). The rate of flow from the sorbed P pool to SECNDY(2) is also a controlled by PSECMN(2) as well as fraction of MINERL(1,P) that is labile. The rate of these P flows are all multiplied by the same belowground moisture and temperature functions (bgdefac) that are used for organic matter decomposition.

Strongly sorbed P (secndy(2)), in turn, may lose or gain P to/from an occluded P pool (OCCLUD) according to rates specified in fix.100 (PSECOC1, PSECOC2, yr^{-1}). The rate of these P flows are all multiplied by the same belowground moisture and temperature functions (bgdefac) that are used for organic matter decomposition.

The organic part of the P submodel operates in the same way that the N submodel works; C:P ratios of organic fractions are fixed for the structural P pool (500) and vary as a function of the labile P pool (PLABIL) for the active (30-80), slow (90-200), and passive (20-200) SOM pools. The C:P ratios of newly formed surface microbes are functions of the P content of the material decomposing, and the C:P ratio of slow material formed from the surface microbes is a function of the C:P ratio of surface microbes. The flows for the organic P pools are calculated in exactly the same way as organic N flow.

Inorganic P losses from the system occur as result of leaching of labile P (stream(4)) which accumulate in the mineral soil layer below the last layer, MINERL(NLAYER+1,2). Organic P losses occur from organic leaching (stream(7)), soil erosion, crop removal, grazing, and biomass burning. Phosphorus additions come from inorganic P fertilizer and organic matter additions (see parameters in the fert.100 and omad.100 files).

3.3.1. Equilibrium relationship between labile P and sorbed P

The function *fsfunc* calculates equilibrium relationship between labile P (*labile*, g P m^{-2}) and sorbed P as a function of the maximum sorption potential (*SORPMX*) of the soil and sorption affinity (*PSLSRB*). Both *SORPMX* and *PSLSRB* are *<site>.100* variables dependent on the soil mineralogy. The function returns the fraction of *MINERL(1,P)* that is labile.

MINERL(1,P) – Total mineral phosphorous (labile P+ sorbed P) in the first soil layer (g P m^{-2}).

SORPMX – Maximum P sorption potential for a soil (g P m^{-2}), *<site>.100*.

PSLSRB – Sorption affinity which controls the slope of the sorption curve when mineral P = 0 (range 1.0 – 2.0), *<site>.100*. It is mathematically defined as the ratio of mineral P / sorption max when labile P equals sorbed P.

fsfunc – fraction of *MINERL(1,P)* that is labile (0–1)

Equation 16

$$c = SORPMX * \frac{2.0 - PLSLSRB}{2}$$

Equation 17

$$b = SORPMX - minerl(1,P) + c$$

Equation 18

$$labile = \frac{-b + \sqrt{b^2 + 4 * c * minerl(1,P)}}{2}$$

Equation 19

$$fsfunc = \frac{labile}{minerl(1,P)}$$

3.3.2. Organic P cycling

The organic part of the P submodel operates in the same way that the N submodel works; C:P ratios of organic fractions are fixed for the structural P pool at approximately 500 (RCESTR(2), <site>.100) and vary as a function of the labile P pool (PLABIL) for the active (30-80), slow (90-200), and passive (20-200) SOM pools. The C:P ratios of newly formed surface microbes are functions of the P content of the material decomposing, and the C:P ratio of slow material formed from the surface microbes is a function of the C:P ratio of surface microbes. The flows for the organic P pools are calculated in exactly the same way as organic N flow.

Phosphorus losses from the system occur as result of leaching of labile P (MINERL(NLAYER+1,2) – P losses accumulate in the soil layer below the last layer) and organic P compounds (STREAM(7)), soil erosion, crop removal, grazing, and burning P losses. P additions come from P fertilizer and organic matter additions (see parameters in the fert.100 and omad.100 file).

3.4.Sulfur Submodel

The structure of the sulfur submodel (is similar to the P submodel. The only major difference is that the S model does not include occluded or sorbed pools. The main source of S in most soils is the weathering of primary minerals. Secondary S is formed as a result of adsorption of S on clay minerals. Organisms in the soil and plant roots take up S from soil solution and start the formation of organic S compounds. The organic component of the S model operates in the same way as the organic N and P submodels with the C:S ratio of the structural pool being fixed at approximately 500 (RCESTR(3), <site>.100) while the C:S ratios for the active (20-80), slow (90-200) and passive (20-200) pools vary as a function of the labile S pool (MINERL(1,3)). C:S ratios for surface microbes are calculated in the same way as the C:N and C:P ratios. The C:S ratios for the organic components are specified in the file fix.100 (see Appendix 1). The organic S flows are calculated in the same manner as the organic N and P flows while the inorganic S flows are functions of specified rate parameters (PPARMN(3), PSECMN(3), PMNSEC(3), fix.100) and the moisture and temperature functions that are used for organic matter decomposition (agdefac, bgdefac). The model allows for S fertilization, addition of organic S material (see parameters in the fert.100 and omad.100 files, Appendix 1), atmospheric deposition (SATMOS(*), <site>.100), S in irrigation water (SIRRI, <site>.100), and accounts for S losses due to crop removal, grazing, leaching of organic S compounds (STREAM(8)), erosion of SOM, and fire. The S submodel has not been as well tested as the N and P submodels. Parton et al. (1988), Metherell (1992), and Metherell et al. (1993a) describe interactions of S with C, N, and P. The S model could be set up to simulate K dynamics instead of S dynamics if K is a limiting factor in particular soils.

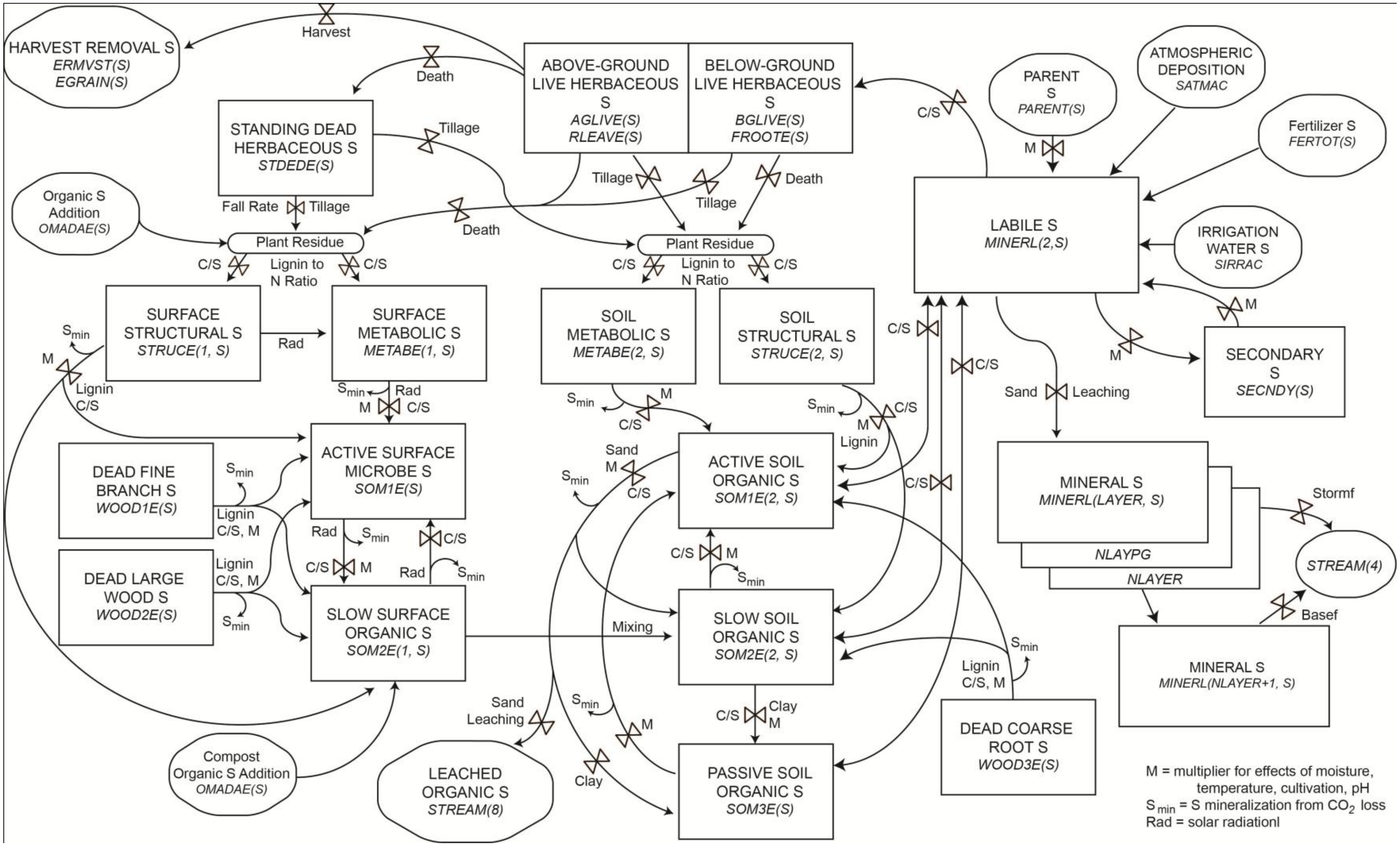


Figure 22 Sulfur Cycle

3.5.Nitrogen Trace Gas Submodel (N_2O, NO_x)

Decomposition of SOM and external nutrient additions supply the nutrient pool, which is available for plant growth and microbial processes that result in trace gas fluxes. Ammonium (NH_4^+) is modeled for the top 15 cm, while nitrate (NO_3^-), P, and S are distributed throughout the soil profile. The bacterial processes of nitrification and denitrification are dominant sources of nitrous oxide (N_2O) and nitric oxide (NO). N_2O is a greenhouse gas with a 100-year time horizon global warming potential ~298 times that of CO_2 (Forster et al. 2007). NO is rapidly oxidized in air to nitrogen dioxide (NO_2), a major air pollutant. NO in the air may convert to nitric acid, which has been implicated in acid rain, and both NO and NO_2 participate in tropospheric ozone production. Furthermore, N_2O gives rise to NO.

The trace gas submodel of DayCent simulates soil N_2O and NO_x gas emissions from nitrification and denitrification as well as N_2 emissions from denitrification **(Figure 23)**. The model simulates the pulse of NO due to the wetting of dry soils. It also incorporates a soil NO_3^- leaching. Additionally, it calculates methane (CH_4) oxidation in the soil. CH_4 is a greenhouse gas with a 100-year time horizon global warming potential ~21 times that of CO_2 (Forster et al. 2007). The trace gas model is called daily after decomposition calculations have been completed since the amount of N supplied by mineralization drives the nitrification and denitrification calculations.

The trace gas model has been has used extensively in DayCent simulations cross the globe (Del Grosso et al. 2000a, Del Grosso et al. 2000b, Parton et al. 2001, Del Grosso et al. 2008, Del Grosso et al. 2009, Del Grosso et al. 2010).

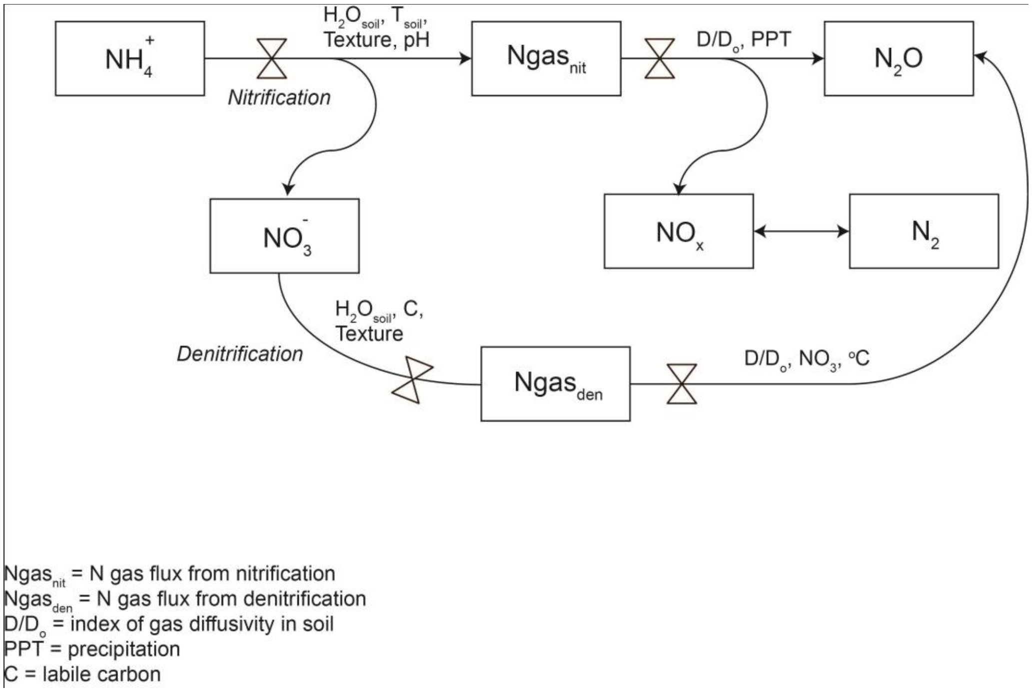


Figure 23 Nitrogen Trace Gas Submodel

3.5.1. Nitrification

Nitrification is the biological oxidation of ammonium (NH_4^+) to nitrite (NO_2^-) or nitrate (NO_3^-) under aerobic conditions. Under oxygen limited conditions nitrifying bacteria can use NO_2^- as a terminal e^- acceptor to avoid accumulation of the toxic NO_2^-, whereby N_2O and NO are produced. Inputs to the nitrification calculations include soil ammonium concentration (µg N $gsoil^{-1}$ or ppm N), volumetric soil water content (cm^3 H_2O cm^{-3} soil), soil water-filled pore space (WFPS = % relative saturation), minimum allowable volumetric soil water content (cm^3 H_2O cm^{-3} soil), volumetric field capacity (cm^3 H_2O cm^{-3} soil), soil temperature, soil pH, and soil bulk density (g cm^{-3}). Nitrogen gas flux from nitrification is assumed to be a function of soil NH_4^+ concentration, water content, temperature, and pH (Parton et al. 1996, Parton et al. 2001). Nitrification rates increase linearly with soil NH_4^+ concentration when soil NH_4^+ concentrations are low (< 100 ppm), and increase asymptotically as ammonium concentrations increase. Nitrification is limited by moisture stress on biological activity when WFPS is too low and by O_2 availability when WFPS is too high. Nitrification increases exponentially with temperature, stabilizes when soil temperature reaches the site-specific average high temperature for the warmest month of the year, and decreases exponentially when soil temperature is hotter. Nitrification is not limited when pH is greater than neutral, but decreases exponentially as soils become acidic. A maximum of 15% of soil NH_4^+ can be nitrified in a day, however the user can specify a lower maximum amount in the sitepar.in file (*maxNitAmt*, g N m^{-2} day^{-1})

3.5.2. Denitrification

Denitrification is the reduction of NO_3^- or NO_2^- to gaseous N oxides and molecular N_2 by facultative heterotrophic bacteria. An important aspect of denitrification is the requirement for sufficient organic matter to drive the denitrification reaction. Since denitrifying bacteria are facultative organisms, they can use either dissolved O_2 or N oxides to serve as e^- acceptors during oxidation of labile C (e^- donor). The preferred nitrogen e^- acceptors in order of most to least thermodynamically favorable include NO_3^-, NO_2^-, NO, and N_2O. If dissolved O_2 and NO_3^- are present, bacteria will use the dissolved O_2 first. Therefore, denitrification occurs only under anaerobic or anoxic conditions. The nitrate reduction sequence under anaerobic conditions is described by Paul and Clark(1989):

$$NO_3^- \rightarrow NO_2^- \rightarrow NO^{\uparrow} \rightarrow N_2O^{\uparrow} \rightarrow N_2^{\uparrow}$$

Denitrification is a function of soil NO_3^- (e^- acceptor) concentration, labile C (e− donor) availability, O_2 (competing e^- acceptor), and soil physical properties related to texture that influence gas diffusivity (Parton et al. 1996, Del Grosso et al. 2000a). Inputs to the denitrification calculations include soil nitrate concentration (µg N $gsoil^{-1}$ or ppm N), heterotrophic CO_2 respiration rate (µg C $gsoil^{-1}$ day^{-1}), WFPS, soil bulk density (g cm^{-3}), soil texture, and volumetric field capacity (cm^3 H_2O cm^{-3} soil). Soil heterotrophic respiration is used as a proxy for labile C availability. No denitrification is assumed to occur until WFPS values exceeds approximately 60%, then denitrification increases exponentially until WFPS reaches about 90%, and it stabilizes as soil water content approaches saturation. Note that the water content required to support denitrification varies because the inflection point of the equation shifts based on an index of O_2 availability. O_2 availability is a function of soil physical properties that influence gas diffusivity, soil WFPS, and O_2 demand. The potential O_2 demand, as indicated by respiration rates, is assumed to contribute to soil anoxia and varies inversely with a soil gas diffusivity coefficient which is regulated by soil water content, porosity and pore size distribution. The model calculates N_2 + N_2O emissions from denitrification by assuming that the process is controlled by the input (NO_3^- , respiration, WFPS) that is most limiting. Maximum daily denitrification rates range from close to 100% of soil NO_3^- at low soil NO_3^- concentration to 15% or less of soil NO_3^- at high soil NO_3^- concentration. Nitrous oxide emissions are calculated from N_2 + N_2O gas emissions and an N_2/N_2O ratio function. The default ratio of N_2/N_2O gases emitted due to denitrification ranges from 1 to 23 and is assumed to increase as the ratio of e^- acceptor (NO_3^-) to e^- donor (labile C) decreases and as soil gas diffusivity and O_2 availability decrease (Del Grosso et al. 2000a). The output of the ratio function is combined with the estimate of the total N gas flux rate to infer N_2O emissions (Del Grosso et al. 2000a). Limited model sensitivity analyses showed that more than 2% and approximately 0.75% of N inputs were lost as N_2O from clay and sandy soils, respectively, on an annual basis (Del Grosso et al. 2006).

3.5.3. NO_x production

Nitrogen oxide gas emissions (NO_x) from soil are a function of total N_2O emissions, a NO_x/N_2O ratio equation, and a precipitation initiated pulse multiplier (Parton et al. 2001). Simulated N_2O gas emissions from nitrification and denitrification are summed to obtain total N_2O flux. The NO_x/N_2O ratio is high (maximum of 17) when soil gas diffusivity is high and decreases to a minimum of 0.28 as diffusivity decreases. The base NO_x emission rate may be modified by a pulse multiplier. Large pulses of NO_x are often initiated when precipitation falls on soils that were previously dry (Hutchinson et al. 1993, Martin et al. 1998, Smart et al. 1999). To account for these pulses the model incorporates the pulse multiplier submodel described by Yienger and Levy (1995). The magnitude of the multiplier is proportional to the amount of precipitation and the number of days since the latest precipitation event, with a maximum multiplier of approximately 4.6.

A small amount of the NO flux that absorbed by leaves of plants, and this amount increases as the sum of LAI from grasses and trees increases.

3.5.4. Ammonia volatilization

Ammonia volatilization is not associated with nitrification or denitrification and is simulated less mechanistically than the other N gas species. A soil texture specific portion of N excreted from animals is assumed to be volatilized (with more volatilization as soils become coarser), and a plant specific portion of harvested or senesced biomass N is assumed to be volatilized. Ammonia N volatilization is added to the VOLPL, VOLPLA, and VOLPAC output variables.

3.6. Methane Submodel (CH_4)

3.6.1. Methanogenisis

The methanogenesis submodel was developed by Cheng et al. (2013), building upon the earlier work of Huang et al. (1998) and Huang et al. (2004).

Within plant–soil systems, CH_4 is produced under anaerobic conditions by methanogens, while CH_4 oxidation occurs under aerobic conditions through the activity of methanotrophs. This latter process will even occur in rice paddies when CH_4 passes through the oxic–anoxic boundary in the soil before entering the atmosphere during drainage events. Rates of CH_4 production are primarily determined by the availability of carbon substrate for methanogens and the impact of environmental variables. Carbon substrate is derived from soil organic matter decomposition and root rhizodeposition. The environmental variables influencing CH_4 production include soil texture (redox potential, pH, soil temperature), climate and agricultural practices (water management, mineral fertilizer application).

The two main pathways for CH_4 emissions from soil to the atmosphere are transfer through rice plants (Bont et al. 1978, Schutz et al. 1989, Sass et al. 1992, Kludze and Delanne 1995) and ebullition in the water (Nouchi 1994, Wassmann et al. 1996). As reported by Wassmann et al. (1996), the contribution of plant-mediated transport ranged from 38 to 85% over the rice growing season, which implied that plant-mediated transport could be significant to overall CH_4 emissions. A small proportion of the CH_4 is emitted via ebullition (Schutz et al. 1989). When the flooded soil reaches the max solubility of CH_4, methane produced in the soil will aggregate to form bubbles, travel upward to the water surface, and release into the atmosphere with very little oxidization. The methane ebullition occurs predominantly in the early phase of plant growth season, trailing off as the plant matures (Shangguan and Wang 1993).

Only part of the CH_4 produced in the process of methanogenesis is emitted to atmosphere because about 40–90% of CH_4 is oxidized to CO_2 by methanotrophs at aerobic/anaerobic interfaces. This interface occurs in the surface layer of submerged soils (for example, during drainage events) and in the rhizosphere where CH_4 and O_2 gradients overlap due to diffusion of O_2 by plant-mediated transport. (Holzapfel-Pschorn et al. 1985, Gilbert and Frenzel 1995). Vascular plants rooted in anoxic soils, such as rice, mediate the transport of oxygen down to the rhizosphere through their aerenchymal system (spaces or air channels in the leaves, stems and roots). As plant growth proceeds the aerenchymal system becomes more developed and oxidation is enhanced. As oxidation is enhanced the fraction of CH_4 produced that is emitted declines.

The diffusion of CH_4 across the air–water interface is a relatively minor pathway for transporting CH_4 to the atmosphere (Shearer and Khalil 1993, van Bodegon et al. 2001) and is not addressed in the DayCent model.

Output from the methanogenesis model is found in the daily output file methane.out. Methanotrophy during flooded conditions is the difference between CH_4 production and CH_4 emissions from plant-mediated transport and from ebullition (CH4_prod – CH4_Ep – CH4_Ebl). Also see the section titled “Methane Oxidation” below.

3.6.1.1. CH4 production

On the basis of this scientific understanding, a methanogenesis sub-model was developed in the DAYCENT model **(Figure 24)**. CH_4 production was simulated based on carbon substrate supply and associated influence of Eh and temperature using the following equation (Huang et al. 1998):

Equation 20

$$CH_4Prod = C_6H_{12}O_6\_to\_CH_4 \times FEh \times \left(Csoil + F_T \times Croot\right)$$

where CH_4Prod is the CH_4 production rate (g CH_4-C $m^{-2}d^{-1}$); $C_6H_{12}O_6\_to\_CH_4$ is a conversion factor of carbohydrate decomposition to CH_4 (mole weight $C_6H_{12}O_6$ to CH_4); *Csoil* is the daily amount of carbon substrate from degradation of organic matter (gC $m^{-2}d^{-1}$) **(Equation 21)**; *Croot* is the daily amount of carbon substrate occurring through rhizodeposition (gC $m^{-2}d^{-1}$) **(Equation 23)**; *FEh* is a reduction factor for soil redox potential **(Equation 25)**; and F_T is the influence of soil temperature **(Equation 24).** Only the effect of temperature on *Croot* was considered because the temperature effects on *Csoil* have already been included in the algorithms for estimating soil organic matter decomposition in the DayCent model.

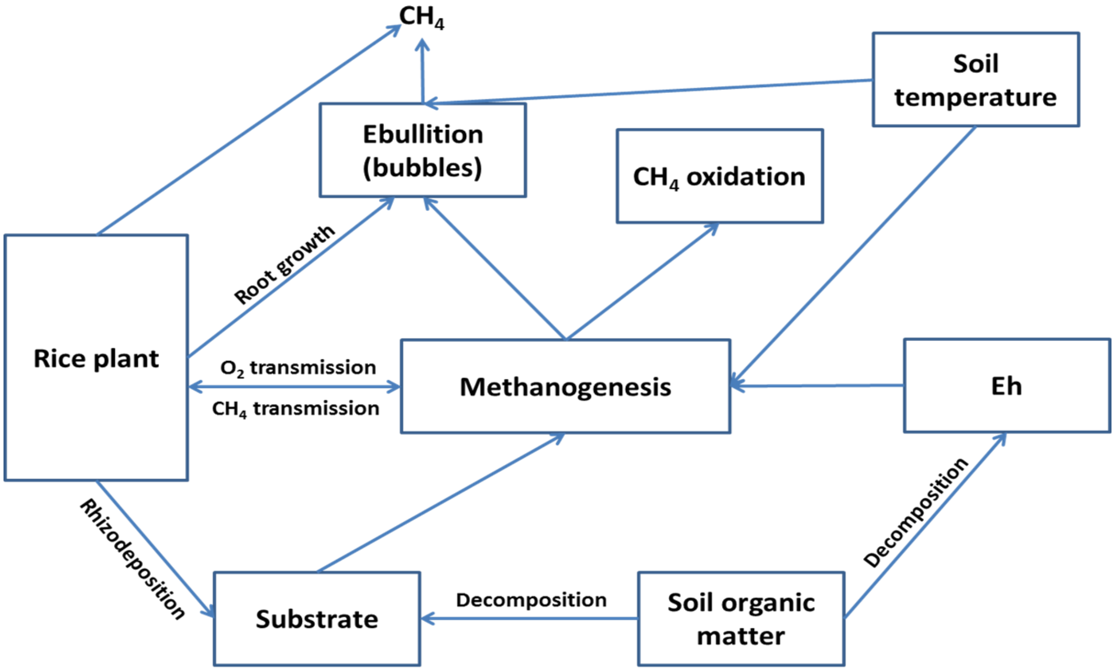


Figure 24 Conceptual Diagram of the Methanogenesis Submodel (Adopted from Cheng et al., 2013)

Anaerobic carbohydrate fermentation and methanogenesis occur through the following reactions, $2(CH_2O) \rightarrow CO_2 + CH_4$ (Conrad 1989, Matthews et al. 2000) or $C_6H_{12}O_6 \rightarrow 3CO_2 + 3CH_4$ (Huang et al. 1998). Both of these equations illustrate that the carbon substrate producing CH_4 also produces the same carbon equivalent of CO_2. Hence, a conversion factor $C_6H_{12}O_6\_to\_CH_4$ on a mole weight basis of carbohydrate to CH_4 is set at 0.5 based on the reactions.

3.6.1.2. Carbon substrate for CH_4 production

The first step in modeling methanogenesis is to estimate the amount of carbon substrate available for CH_4 production. DayCent's methanogenesis submodel includes soil organic matter degradation and rhizodeposition as the sources of carbon.

A fraction (β_1) is defined to quantify the amount of substrate available for methanogens based on the simulation of heterotrophic respiration by the DayCent model as described in **Equation 21**.

Equation 21

$$Csoil = C_6H_{12}O_6\_to\_CH_4 \times \beta_1 \times SI \times Rh$$

where *Rh* is heterotrophic respiration from decomposition of organic matter (above- and below-ground structural and metabolic litter and above- and below-ground SOC pools) (g CO_2-C m^{-2} d^{-1}); β_1 (CO2CH4, fix.100) is the fraction of *Rh* converted to CH_4 under anaerobic conditions; *SI* (0.0 – 1.0) is the soil texture index which is a function of the average sand content fraction (*sand*, 0.0 – 1.0) in the top 10 cm of soil (**Equation 22**).

Equation 22

$$SI = 0.325 + 2.25 * sand$$

Rice plants directly contribute carbon substrate for CH_4 production through root exudation and root decay, which are sometimes referred to as rhizodeposition (Seiler et al. 1984). The algorithm to estimate the amount of carbon added to the soil through rhizodeposition was adopted from Cao et al. (1995). Root exudates and decay are treated as one source of carbon in a single algorithm because it was assumed that there was a strong relationship between exudation and root turnover. The rate of rhizodeposition (*Croot*, gC m^{-2} d^{-1}) is calculated using **Equation 23**.

Equation 23

$$Croot = fracToExudates * SI * rootCprod$$

where *rootCprod* is the previous day's fine root production estimated by the plant production sub-model in DayCent (gC m^{-2} d^{-1}), *SI* is the soil texture index **(Equation 22)**, and *fracToExuduates* (FREXUD, fix.100) is the fraction of root carbon production contributing to rhizodeposition (range of 0.35–0.6 described in Cao et al. (1995)).

3.6.1.3. Redox and soil temperature effects on CH_4 production

With a supply of carbon, CH_4 production will occur in soils if environmental conditions are favorable. CH_4 is produced in flooded soils under anaerobic. Redox potential (*Eh*) has been adopted as a key variable impacting CH_4 production in several models because it is an indicator of oxidation–reduction conditions, which is critical for determining the amount of methanogenesis (Cao et al. 1995, Huang et al. 1998, Zhang et al. 2002). In addition, soil temperature impacts CH_4 production based on incubations and field experiments (Schutz et al. 1990, Parashar et al. 1993) by influencing methanogen population growth, SOM fermentation and root exudation. To simulate CH_4 production, we adopted the approach by (Huang et al. 1998) and (Huang et al. 2004). First, the influence of soil temperature was simulated using the following equation:

Equation 24

$$F_T = Q_{10}^{\frac{(Tsoil-30)}{10}} \quad (Tsoil = 30°C \ for \ Tsoil > 30°C)$$

where *Tsoil* is the average soil temperature in the top 10 cm of soil (◦C); Q_{10} is a temperature coefficient representing the change of a biological or chemical system as a consequence of increasing the temperature by 10°C, and was assumed to be a value of 3.0 (Huang et al. 1998). *FEh*, a reduction factor for soil redox potential (Eh) (mV), is estimated using the following equations from Huang et al. (1998) and Huang et al. (2004):

Equation 25

$$FEh_t = exp\left(-1.7 \times \frac{150 + Eh_t}{150}\right) \; \left(Eh_t = -150\ mV\ for\ Eh_t < -150\ mV\right)$$

Equation 26

Equation 27

$$Eh_{t+1} = \begin{cases} Eh_t - DEh \times \left(AEh + min\left(1, Csoil\right)\right) \times \left(Eh_t - Beh_{flood}\right),\ flooding\ course \\ Eh_t - DEh \times \left(AEh + 0.7\right) \times \left(Eh_t - Beh_{drain}\right),\ drainage\ course \\ -20\ mV,\ water\ added\ via\ rain\ and\ irrigation\ events \end{cases}$$

As detailed in Huang et al. (2004), *Eh* is simulated by **Equation 26** for a flooding course and **Equation 27** for drainage course in the water management cycle. Eh_t represents the *Eh* value at time *t*, and *t* is the number of days after flooding began or since drainage occurred in the cycle. *DEh* and *AEh* (DEH and AEH, fix.100) are differential coefficients that were estimated as 0.16 and 0.23, respectively. The BEh_{flood} (BEHFL, fix.100) is set at a low-limit value of −250 mV, and Beh_{drain} (BEHDR, fix.100) is set to an upper-limit value of 300 mV (Cao et al. 1995, Huang et al. 2004). Soil Eh is a constant value of −20 mV when intermittent irrigation is used in rice paddies as discussed in Huang et al. (2004).

3.6.1.4. CH_4 emissions

Only part of the CH_4 produced in the process of methanogenesis is emitted to atmosphere because about 40–90% of CH_4 is oxidized to CO_2 by methanotrophs at aerobic/anaerobic interfaces. This interface occurs in the surface layer of submerged soils and in the rice rhizosphere where CH_4 and O_2 gradients overlap due to diffusion of O_2 by plant-mediated transport (Holzapfel-Pschorn et al. 1985, Gilbert and Frenzel 1995). DayCent adopts the approach by Huang et al. (1998) and Huang et al. (2004) to simulate CH_4 emissions through the rice plant and ebullition. As rice plants grow, aeration tissue will develop that allows for greater transport of oxygen from the atmosphere to the rhizosphere, which increases the oxidation of CH_4. Consequently, it was hypothesized that the fraction of CH_4 emissions occurring through the rice plants decreases with growth. CH_4 emission rates through the rice plants (CH_4EP) (g CH_4-C $m^{-2}d^{-1}$) were simulated using **Equation 28**:

Equation 28

$$CH_4EP = FP \times CH_4Prod$$

where *FP* is the fraction of CH_4 emitted via rice plants; CH_4Prod is total methane production (g CH_4-C $m^{-2}d^{-1}$) **(Equation 20)**. *FP* was estimated using **Equation 29**:

Equation 29

$$FP = MXCH4F \times \left(1.0 - \frac{aglivc * 2.5}{tmxbio}\right)^{0.25}$$

where *aglivc* is the amount of above-ground live C for the crop as simulated by DayCent (g C m^{-2}) and the multiplier 2.5 (g biomass/g C) converts C to biomass (g biomass m^{-2}); *tmxbio* (crop.100) is the maximum aboveground biomass at the end of growing season (g biomass m^{-2}).

Ebullition occurs when the soil CH_4 concentration exceeds a critical state that leads to formation of bubbles (Li 1999). The algorithm for calculating transport of CH_4 via ebullition to the atmosphere (CH_4Ebl) was also adopted from Huang et al. (2004):

Equation 30

$$CH_4Ebl = METHZR \times \left(CH_4Prod - CH_4EP - Mo\right) \times \min\left(\ln(Tsoil), 1.0\right) \times \left(\frac{MRTBLM}{bglivc * 2.5}\right)$$

where *METHZR* (fix.100) is the fraction of CH_4 emitted via bubbles when there is zero fine root biomass; Mo was set to 0.0015 gC $m^{-2}d^{-1}$ (Huang et al. 2004) but is set to 0.002 in DayCent; MRTBLM (fix.100) is the root biomass that starts to reduce CH_4 bubble formation (g biomass m^{-2}); *bglivc* is the amount of fine root C for the crop as simulated by DayCent (g C m^{-2}) and the multiplier 2.5 (g biomass/g C) converts C to biomass; *Tsoil* is the average soil temperature in the top 10 cm of soil (◦C). CH_4 ebullition is reduced when *Tsoil* < 2.718282 °C.

A summary of input parameters and their currently suggested defaults are given in **Table 10**. These fix.100 and crop.100 parameters are optional, and if they don't appear in their respective files, the default values will be used by the model.

Anaerobic soil conditions will reduce decomposition rates. See section 3.1.6 above (Effects of saturated conditions on decomposition rates) for more information.

Table 10 Fix.100 Parameters Needed for the Methane Sub-model

FIX.100 parameters for methane sub-model	Definition	Default Value
FLDN2D	days to transition to flooded N2/N2O ratio	7
FLN2OR (a.k.a. flood_N2toN2O)	N_2/N_2O ratio for flooded state	100
CO2CH4 (a.k.a. CO2_to_CH4)	Fraction of CO_2 from soil respiration used to produce CH_4	0.50
MXCH4F (a.k.a. frCH4emit)	MaXimum Fraction of CH_4 production emitted by plants.	0.55

FREXUD (a.k.a. frac_to_exudates)	Fraction of root production that is root exudates (0.0 – 1.0)	0.45
AEH (a.k.a. Aeh)	Differential coefficient	0.23
Deh (a.k.a. Deh)	Differential coefficient	0.16
BEHFL (a.k.a. Beh_flood)	Lower limit value for Eh during flooding course (mv)	-250
BEHDR (a.k.a. Beh_drain)	Upper limit value of Eh during drainage course (mv)	300
METHZR (a.k.a. zero_root_frac)	Fraction CH_4 emitted via bubbles when zero root biomass (0.0-1.0)	0.7
MRTBLM (a.k.a. ch4rootlim)	Root biomass that when exceeded starts to reduce methane bubble formation (g biomass m^{-2})	1.0
CROP.100 parameter for methane sub-model	**Definition**	**Default value**
TMXBIO	Maximum above-ground plant biomass for the crop at the end of growing season. Also the theoretical maximum crop biomass where no more methane is emitted by the plant (g biomass m^{-2}).	1260 (rice)

Some CH_4 production, and therefore CH_4 emissions, can occur when modeling any type of system (forest, grassland, cropland) regardless of the type of vegetation or if the system was ever flooded. Under non-saturated conditions the drainage course Eh (Equation 26) is used in the CH_4 production calculation (Equation 25).

3.6.2. Methane Oxidation

Methane oxidation (consumption) is a function of soil temperature, soil water content, porosity, and field capacity. The methane oxidation model of DayCent (Del Grosso et al. 2000b) is based on soil characteristics in the top 15 cm of the soil profile including fixed soil properties such as field capacity and bulk density, and transient soil properties including daily mean soil temperature, water-filled pore space, and volumetric soil water content. The soil diffusivity function used by the model computes the estimated normalized diffusivity in soils as a function of soil porosity and field capacity and is based on the method of Potter et al. (1996). There two separate sets of calculations: one for deciduous forests and one for grasslands, tropical forests, coniferous forests, and agricultural lands. The CH_4 oxidation calculation assumes that the only source of CH_4 is that which diffuses down form the atmosphere.

The methane oxidation calculation has been part of DayCent long before the methanogenesis model was implemented, however this methane oxidation, reported in the CH4_oxid column in the methane.out daily output file, is a separate process than the methanotrophy that occurs when the soil is saturated. Methanotrophy during flooded conditions is the difference between CH_4 production and CH_4 from plant-mediated transport and from ebullition (CH4_prod – CH4_Ep – CH4_Ebl from methane.out), not CH4_oxid. Because both the CH_4 oxidation and CH_4 production calculations depend on soil moisture status, CH4_oxid described here diminishes as CH4_prod increases.

3.7.Plant Growth Submodels

The grassland/crop production model simulates plant production for different herbaceous crops and plant communities (e.g. warm or cool season grasslands, wheat and corn). Grassland/crop options are selected from the crop.100 file. Existing crop options may be altered to suit particular varieties or environments, or new options can be added to this file. Harvest, grazing, fire, and cultivation can all directly affect aboveground biomass, while grazing and fire may also impact root to shoot ratios and nutrient content. The forest model simulates the growth of deciduous or evergreen forests in juvenile and mature phases. Fire, large scale disturbances (e.g. hurricanes), and tree harvest practices may impact forest production.

DayCent can grow only one type of grass, crop, or tree at a time, but does simulate competition between trees and grasses (i.e., a savanna system). The savanna system is simulated using the existing tree and grassland–crop submodels, with the two subsystems interacting through shading effects and nutrient competition. The fraction of the nutrient pools that are available for plant growth is a function of root biomass. The savanna model modifies maximum grass production by a shade modifier that is a function of tree leaf biomass and canopy cover. Additional constraints on plant production due to nutrient allocation between trees and grasses decrease maximum production rates for the grasses.

Both grassland/crop and forest production models assume that the daily maximum plant production is controlled by moisture, temperature, and solar radiation, and that maximum plant production rates are decreased if there are insufficient nutrient supplies (the most limiting nutrient constrains production). The fraction of the mineralized pools that are available for plant growth is a function of the root biomass with the fraction of nutrients available for uptake increasing exponentially as live root biomass increases from 20 to 300 g m^{-2}. Most forest or grassland/crop systems are limited by nutrient availability and generally respond to the addition of N and P.

3.7.1. Grassland/Crop Submodel

The model can simulate a wide variety of crops and grasslands by altering a number of crop specific parameters (see Appendix 1 for the crop.100 parameters). Some parameters may have to be calibrated for specific environments. The grassland/crop production model **(**
Figure 25**)** has pools for live shoots and fine roots (juvenile and mature), and standing dead plant material.

3.7.1.1. Potential Crop and Grass Production

The maximum potential production of a crop or grass, unlimited by temperature, moisture or nutrient stresses, is primarily determined level of incoming radiation, the maximum net assimilation rate of photosynthesis, the efficiency of conversion of carbohydrate into plant constituents, and the maintenance respiration rate (van Heemst 1986).

Total potential production (g C m^{-2} day^{-1}) calculation in DayCent is a product of a genetic maximum defined for each crop (PRDX(1), crop.100), solar radiation input, and 0 – 1 scalars that are functions air temperature, soil moisture status, shading by dead vegetation (physical obstruction of litter and standing dead), plant phenological stage including stage of seedling growth or senescense, and atmospheric CO_2 concentrations. The parameter for maximum potential production (PRDX(1), crop.100) is a radiation use efficiency that has both genetic and environmental components. PRDX(1) will frequently be adjusted to calibrate the predicted total crop production for different environments, species, and varieties. In general, C4 species have higher potential growth rates than C3 species because of higher maximum net assimilation rates (van Heemst 1986).

There is some variation in the total potential production calculation between DayCent versions. The variations in this calculation stem mainly from the type of solar radiation input used, but there are other minor differences (Equation 31, Equation 32, Equation 33).

In DailyDayCent versions other than DDcentEVI, the potential production calculation (*potprod*, g biomass m^{-2} day) is:

Equation 31

$$potprod = \begin{cases} shwave(sitlat, curday) \times prdx(1) \\ \times fprod_{Tave} \times h2ogef(CRPSYS) \times biof \times shdmod \\ \times sdlng \times co2cpr(CRPSYS) \times tfrac \times scenfrac \end{cases}$$

where *shwave(sitlat,cuday)*, the incoming radiation at the top of the atmosphere, is function of the day of year and the latitude (langleys day^{-1}), *prdx(1)* is the genetic potential radiation use efficiency (crop.100), $fprod_{Tave}$ is the temperature effect (0.0 – 1.0) (**Figure 26**), *h2ogef(CRPSYS)* is the effect of soil moisture (0.0 – 1.0) (Equation 34), *biof* is the effect of shading by dead vegetation (0.0 – 1.0), *shmod* is the effect of shading by trees (1.0 except in savannas where it ranges from 0.0 – 1.0), *sdlng* is the seedling reduction when the crop is at an early growth stage (0.0 – 1.0), *co2cpr(CRPSYS)* is the effect of CO_2 fertilization (Section 3.8.9, **Figure 42**), *tfrac* is the daily timestep fraction (1 divided by the number of days in the month), and *scenfrac* is the fraction of senescense that has occurred (1.0 except when the GDD model is used as explained in section 3.7.1.2). The other scalars on potential production are described in more detail below.

DayCentEVI has two methods for calculating potential production of crops and grasses, one when the MODIS enhanced vegetation index (EVI) is included in the weather file, and the other when it is not. When EVI is used, the equation for total potential production is adapted from Potter et al. (2007):

Equation 32

$$potprod_{EVI} = srad_{MJ} \times h2ogef(CRPSYS) \times eviday \times eMax$$

where $srad_{MJ}$ is surface solar irradiance (MJ day^{-1}), *h2ogef(CRPSYS)* is the effect of soil moisture (0.0 – 1.0) (Equation 34), *eviday* is the daily EVI derived from MODIS data, *eMax* is the radiation utilization coefficient (g C MJ $^{-1}$, crop.100). When EVI is not available, total potential production is a function of incoming solar radiation (*srad*, langleys day^{-1}) and PRDX(1). The value *srad* (W m^{-2}) is read from the weather file and converted to units of langleys day^{-1}. The other factors in Equation 33 are defined the same as in Equation 31.

Equation 33

$$potprod = \begin{cases} srad_{langleys} \times prdx(CRPSYS) \\ \times fprod_{Tave} \times h2ogef(CRPSYS) \times biof \times shdmod \\ \times sdlng \times co2cpr(CRPSYS) \times tfrac \end{cases}$$

The allocation of potential production to above- and below-ground components (PTAGC and PTBGC) is determined by the dynamic root allocation fraction and grazing effects. Actual production is less than or equal to potential production and depends on nutrient availability.

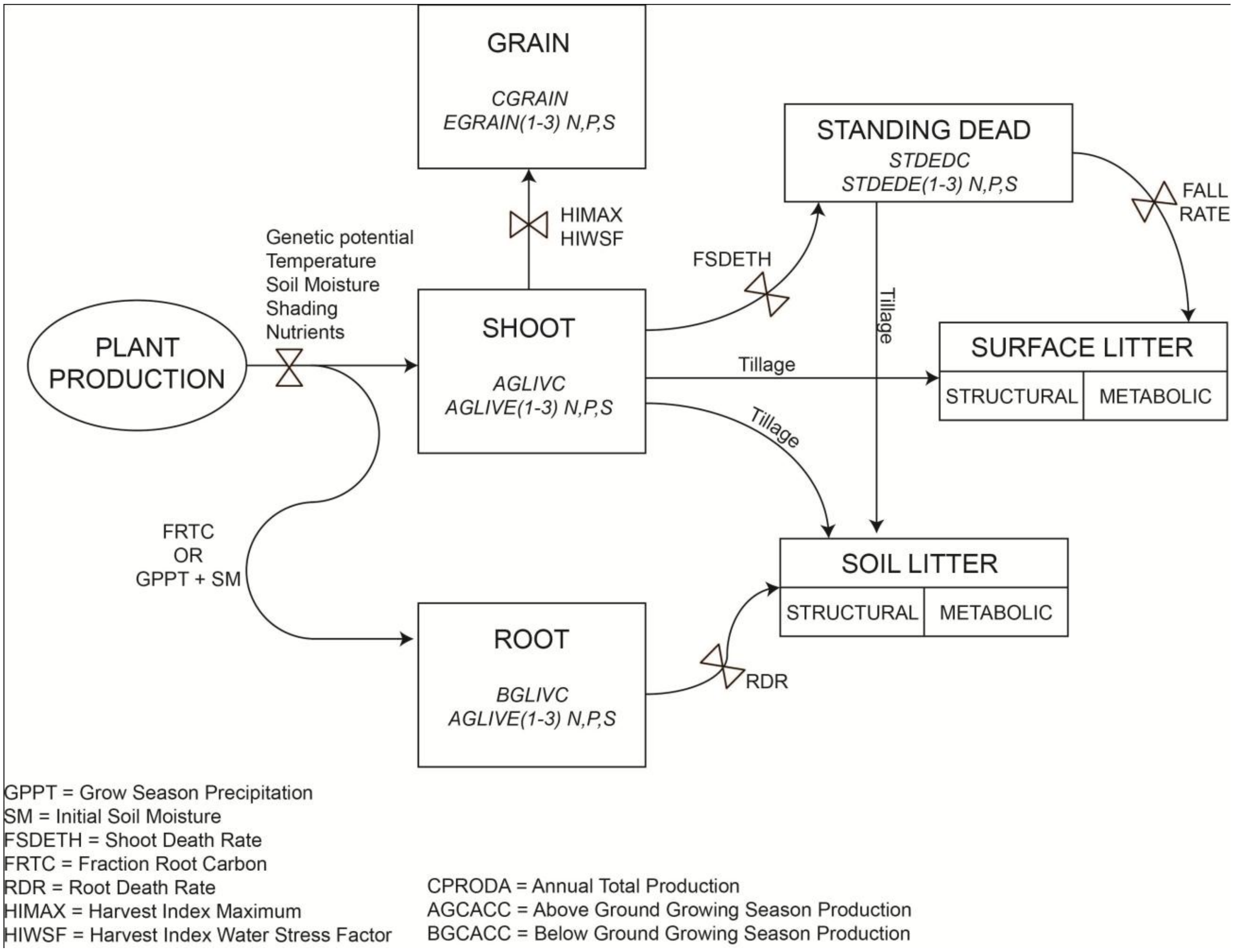


Figure 25 Grassland/Cropland Production Model

3.7.1.2. Temperature Effect on Potential Crop/Grass Production

The growth of most plant species exhibits a response curve to mean daily air temperature which is sigmoidal up to an optimum temperature, has a band of optimum temperatures over which there is relatively little effect on growth, and a rapid decline above the optimum (Cooper 1973). Plant growth rates will depend on the combined temperature response of photosynthesis and respiration. For most temperate species the lower limit at which the rate of development is perceptible is between zero and 5° C. Development increases in rate up to an optimum of 20° to 25° C and then declines to an upper limiting temperature between 30° and 35° C. For tropical species the base, optimum and maximum temperatures are approximately 10° higher (Monteith 1981). In the DayCent model the temperature response curve can be parameterized for each crop using a generalized Poisson density function (PPDF(1...4), crop.100) **(Figure 26).**

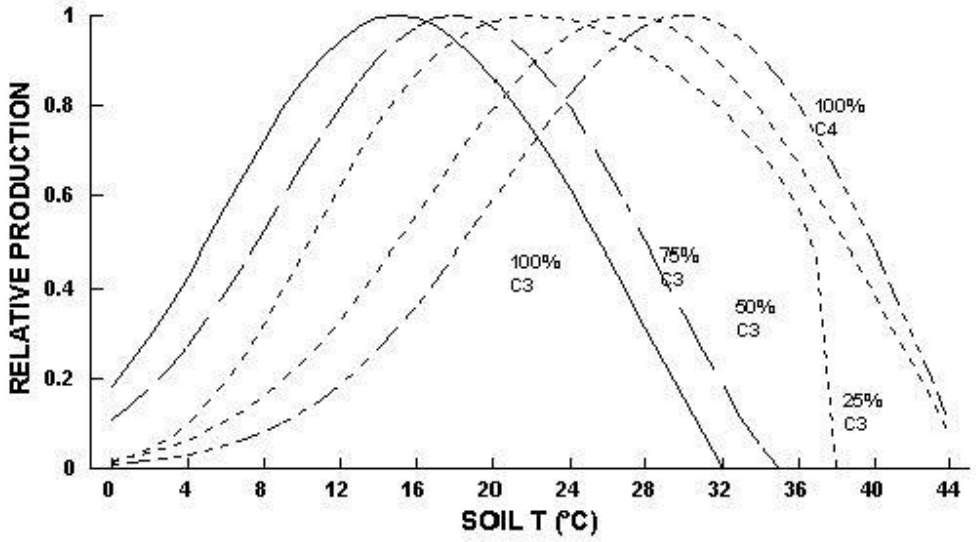


Figure 3-8A: The impact of soil temperature on potential plant growth of different communities of C3 and C4 plants.

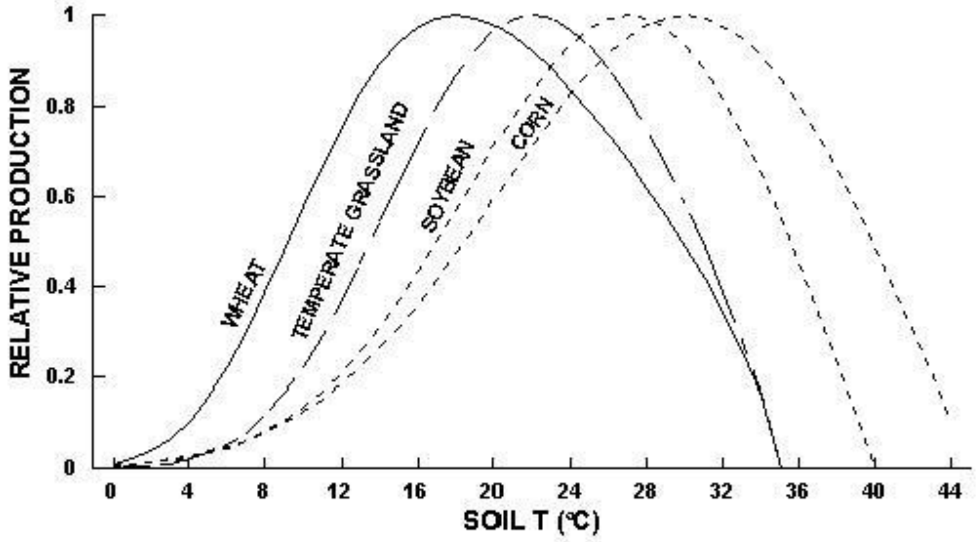


Figure 3-8B: The impact of soil temperature on potential plant growth of different crops.

Figure 26 The Impact of Air Temperature (not Soil Temperature) on Potential Crop/Grass Growth

3.7.1.3. Soil Moisture Effect on Potential Crops/Grass Production

The moisture stress effect on potential production (*h2ogef(1)*, 0.0 – 1.0) is a function of the maximum relative water content of any layer in the plant rooting zone (*maxrwcf*, 0.0 – 1.0) and crop.100 parameters WSCOEFF(1,1) and WSCOEFF(1,1) (**Figure 34**). Potential production is limited when *h2ogef(1)* < 1.0.

Equation 34

$$h2ogef(1) = \frac{1.0}{1.0 + \exp\left(wscoeff\left(1,2\right) * \left(wscoeff\left(1,1\right) - maxrwcf\right)\right)}$$

The value CLAYPG (crop.100) is the number of soil layers in the crop rooting zone and can be less than or equal to the total number of soil layers (NLAYERS, <site>.100). Both CLAYPG and NLAYER refer to the CENTURY soil layers whose depths are determined by the ADEP(*) parameters in the fix.100 file (not by the finer soil layers in the soils.in file).

3.7.1.4. Effect of Physical Obstruction of Litter and Standing Dead on Potential Crop/Grass Production

The effect of physical obstruction of litter and standing dead on potential growth rate is a response surface dependent on the amounts of live and dead vegetation. This function, which was originally developed for the tall grass prairie, was found to be too restrictive for no-till cropping systems. Therefore, the magnitude of the effect has been greatly reduced for crops by increasing the value of BIOK5 (crop.100).

3.7.1.5. Scaling factor for crops growing from seedlings

A scaling factor for crops growing from seedlings (PLTMRF, FULCAN, crop.100) reflects the partial interception of light with less than a full canopy present **(Figure 27)**. This factor takes effect after a PLTM (planting date) event in the schedule file, but not after a FRST (first day of growth) command.

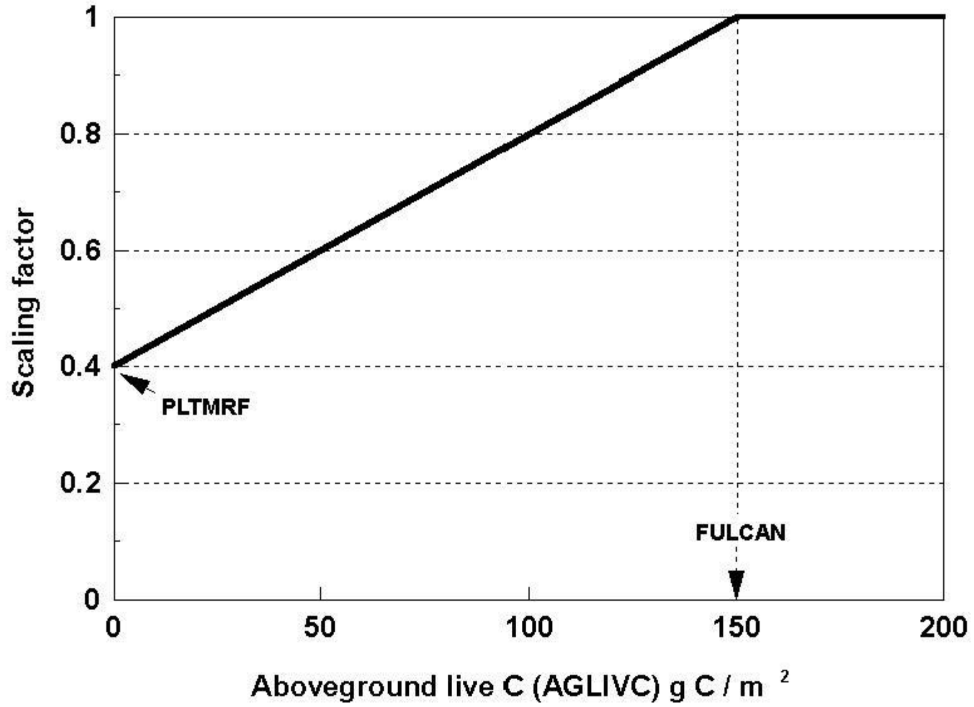


Figure 3-10: The effect of plant growth on the scaling factor for seedling growth.

Figure 27 The Effect of Plant Growth on the Scaling Factor for Seedling Growth

3.7.1.6. Dynamic Carbon Allocation

The fraction of total production allocated to roots is a dynamic function of soil moisture and nutrient availability according to crop.100 parameters FRTCINDX, CFRTCW(1..2), and CFRTCN(1..2). In an alternative formulation (FRTC(1) = 0.0) developed for Great Plains grasslands, the root-shoot ratio is controlled by annual precipitation (Parton et al. 1987) **(Figure 28)**.

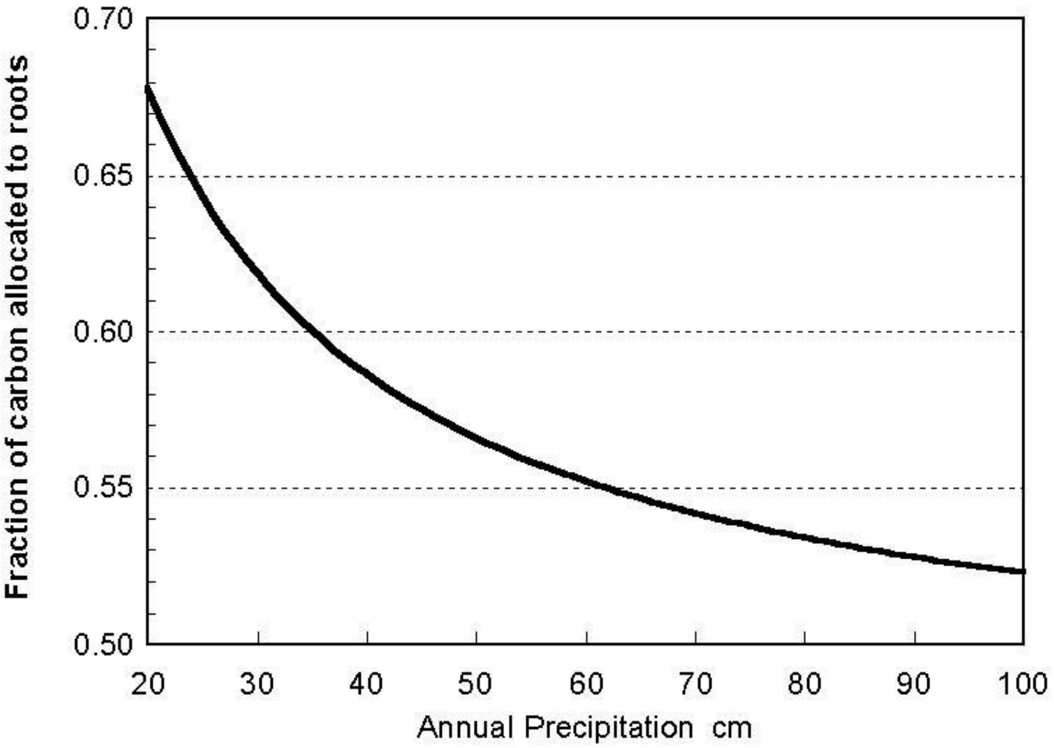


Figure 3-12: The effect of annual precipitation on the allocation of carbon to roots for Great Plains grasslands used when FRTC(1) = 0.

Figure 28 Effect of Annual Precipitation on the Allocation of Carbon to Roots for Great Plains Grasslands used when FRTC(1)=0

3.7.1.7. Nutrient Limited Production

The actual production is limited to that achievable with the currently available nutrient supply with plant nutrient concentrations constrained between upper and lower limits set separately for shoots and roots. Invoking Liebig's Law of the Minimum, the most limiting nutrient (ELIMIT) constrains production (RELYLD). The limits of nutrient content for shoot growth are a function of plant biomass in order to reflect the changing nutrient content with plant age **(Figure 29)**. The user specifies the effect of live shoot biomass on maximum and minimum nutrient content (BIOMAX, PRAMN(*,*), PRAMX(*,*), crop.100). This formulation does cause some anomalies when growth is limited by nutrients, as a nutrient limited crop can have a higher nutrient concentration than an unlimited crop of the same age with greater biomass. The limits on nutrient content of roots are a function of annual precipitation (PRBMN(*,*), PRBMX(*,*), crop.100). DayCent also incorporates a function to restrict nutrient availability in relation to root biomass (RTIMP); **(Figure 30)**. For legume crops the potential rate of symbiotic nitrogen fixation is specified in terms of grams N fixed per gram C fixed (SNFXMX, crop.100). It is assumed that plant available soil N will be preferentially used by the crop. All other potential limitations to growth, including P and S supply, are taken into account before calculating symbiotic N_2 fixation.

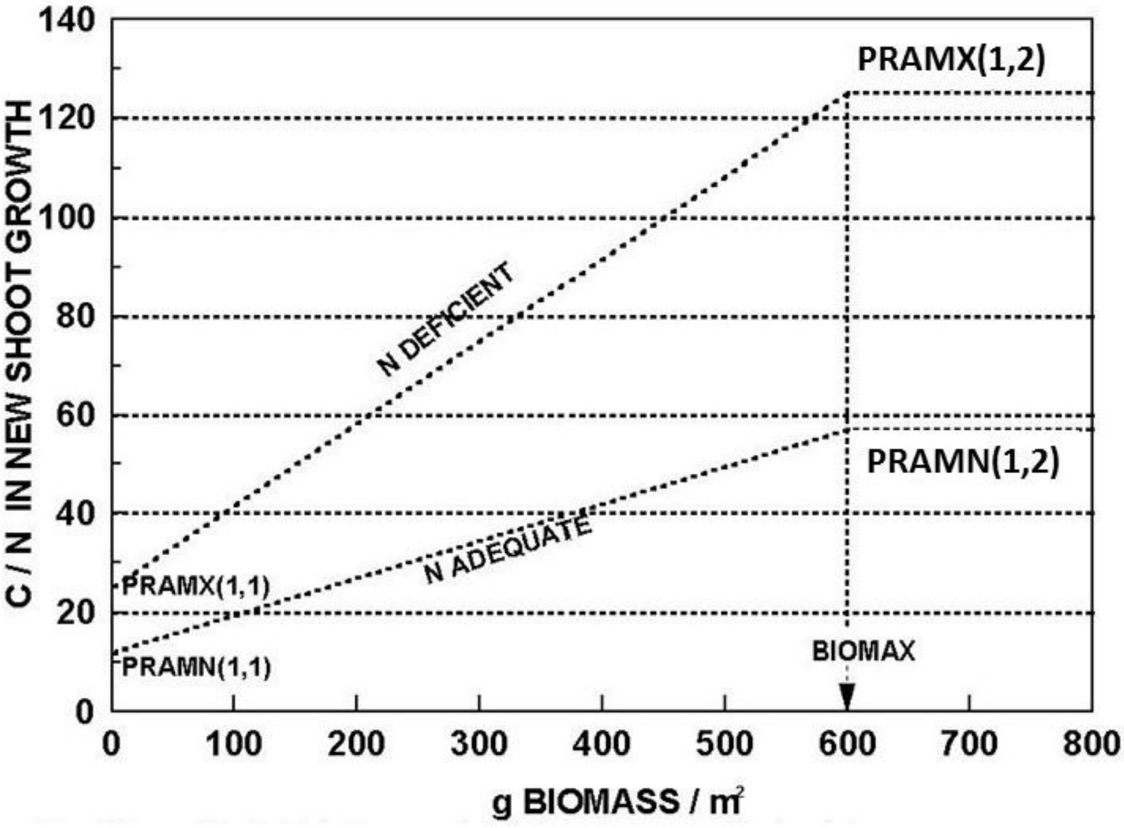


Figure 29 Effects of Plant Biomass on the C/N Ratio in new Increments of Plant Growth

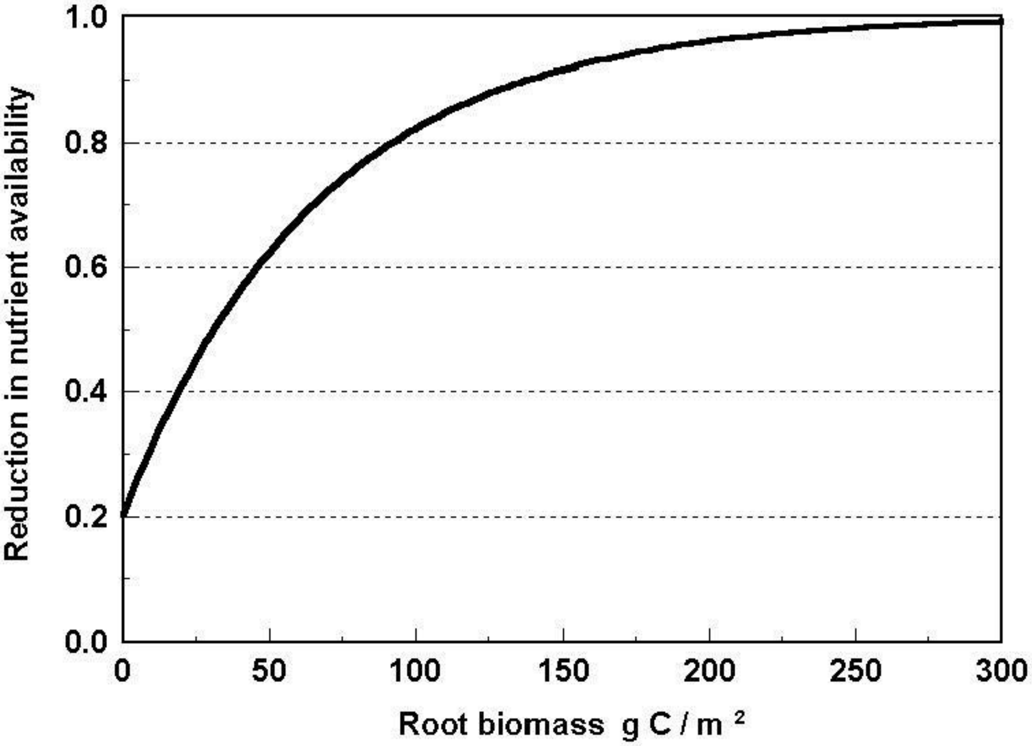


Figure 3-14: The effect of root biomass on nutrient availability.

Figure 30 Effects of Root Biomass on Nutrient Availability

Discuss plant respiration calculations here….

Fertilizer addition can be either fixed amounts (FERAMT, fert.100) or calculated automatically according to the crop requirements. The automatic option (AUFERT, fert.100) can be set to maintain crop growth at a particular fraction of potential production with the minimum nutrient concentration or to maintain maximum production with plant nutrient concentrations at a nominated level between the minimum and maximum for that growth stage.

3.7.1.8. Grain Harvest

At harvest, grain is removed from the system and live shoots can either be removed or transferred to standing dead and surface residue. For grain crops a harvest index is calculated based on a genetic maximum (HIMAX, crop.100) and moisture stress (HIWSF, crop.100) in the months corresponding to anthesis and grain fill (HIMON(1,2), crop.100) **(Figure 31)**. Moisture stress is calculated as the ratio of actual to potential transpiration in these months. The fractions of aboveground N, P, and S partitioned to the grain are crop-specific constants (EFRGRN(*), crop.100) modified by the square root of the moisture stress term, resulting in higher grain nutrient concentrations when moisture stress reduces the harvest index. At harvest a proportion of the aboveground nitrogen is lost to volatilization (VLOSSP, crop.100). The crop harvest routine also allows for the harvest of roots, hay crops or straw removal after a grain crop (see harv.100; Appendix 1). The crop may be killed at harvest, as for cereal grain crops, or a fraction of roots and shoots may be unaffected by harvest operations and growth may continue.

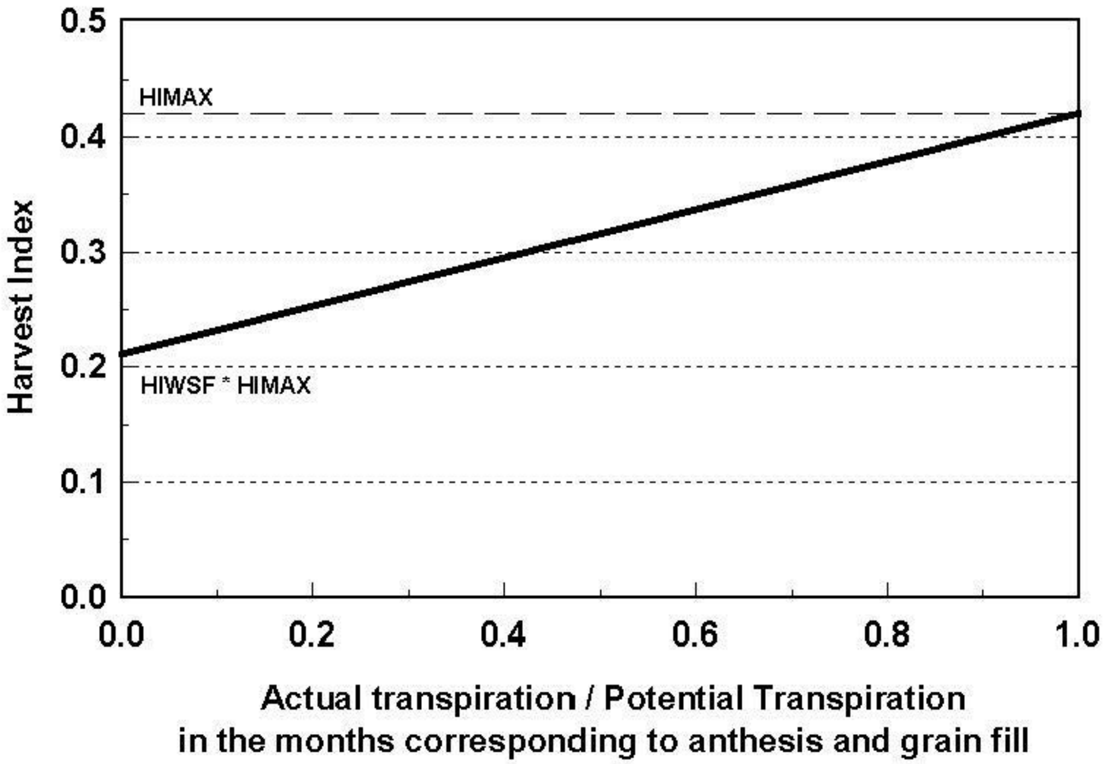


Figure 3-15: The effect of moisture stress on harvest index.

Figure 31 Effects of Moisture Stress on Harvest Index

3.7.1.9. Death of Shoots and Roots

The crop model allows for the death of shoots and roots during the growing season. Shoot death is a function of available soil water in the plant root zone **(Figure 32)**. Root death is a function of both available soil water and average soil temperature in the plant root zone. The water and/or temperature effects (0.0 – 1.0) are multiplied by crop specific maximum death rates (FSDETH(1) for shoots, RDRJ and RDRM for roots, crop.100). Shoot death rates may be further increased (FSDETH(3)) due to shading if the live biomass is greater than a critical level (FSDETH(4)). Root death is only allowed to occur when roots are physiologically active, defined by soil temperature being greater than -2°C and less than 28°C. When senescence occurs, the both the shoot and root death rates are set to a fixed fraction of live biomass (FSDETH(2)). However, for perennial plants, the death rate of juvenile roots during senescence will not exceed 0.30 regardless of the value of FSDETH(2), and the death rate of mature fine roots is 0.30. Standing dead material is transferred to surface litter at a crop specific relative fall rate (FALLRT, crop.100).

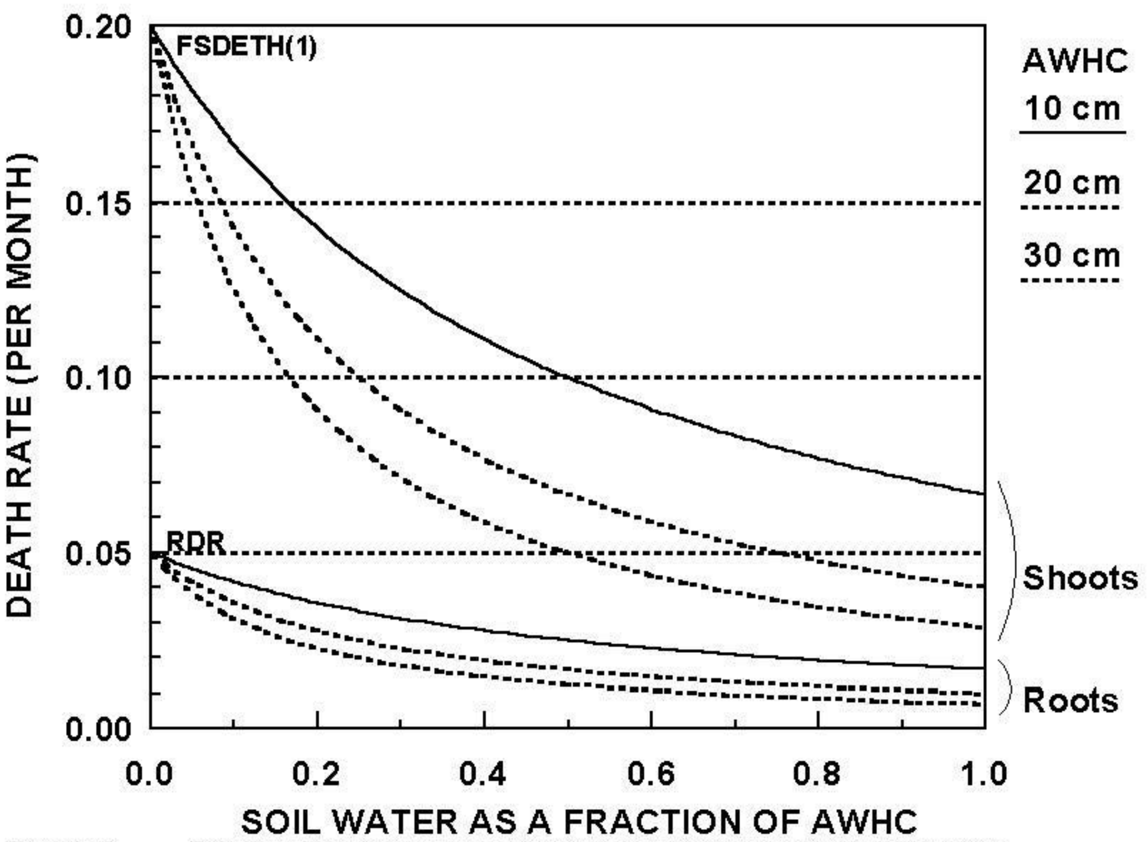


Figure 3-16: The effect of soil moisture status and available water holding capacity (AWHC) on shoot and root death.

Figure 32 Effect of Soil Moisture Status and Available Water Holding capacity (AWHC) on Shoot and Root Death.

3.7.1.10. Plant Lignin Contents

Plant lignin contents (FLIGNI(*,*), crop.100) are specified for shoots and roots, and may be constants or a linear function of annual precipitation (Parton et al. 1992). They should reflect the lignin content of senescent plant material.

3.7.1.1. Effects of Grazing and Fire

The effects of grazing and fire on plant production are represented in the model by using data from Holland et al. (1992) and Ojima et al. (1990). The major impacts of fires are to increase the root to shoot ratio (FRTSH, fire.100), to increase the C:N ratio of live shoots and roots (FNUE(1..2), fire.100), to remove vegetation, and to return nutrients during the years when fire occurs (Ojima et al. 1990). Grazing removes vegetation, returns nutrients to the soil, alters the root to shoot ratio, and increases the N content of live shoots and roots (Holland et al. 1992).

The model has seven options (GRZEFF = 0, 1, 2, 3, 4, 5, 6) for dealing with the impact of grazing on the system **(Table 11)**. For GRZEFF=0 there are no direct impacts of grazing on plant production except for the removal of vegetation and return of nutrients by the animals. GRZEFF=1 is referred to as the lightly grazed effect (Holland et al. 1992) and includes a constant root:shoot ratio (not changing with grazing) and a linear decrease in potential plant production with increasing grazing intensity. GRZEFF=2 is referred to as the heavy grazed (Holland et al. 1992) option and includes a complex grazing optimization curve where aboveground plant production is increased for moderate grazing and decreasing sharply for heavy grazing levels (>40% removed per month). The root:shoot ratio increases for light grazing and decreasing sharply for moderate to heavy grazing (>20% removed per month). For GRZEFF = 3, there is increased below-ground production for light to moderate grazing and decreasing sharply for heavy grazing levels (>30% removed per month), but no direct impacts on aboveground production. For GRZEFF = 4, 5, or 6, there is a linear decrease in the root:shoot ratio as FLGREM increases whenever GREMB (fix.100) > 0; otherwise the root:shoot ratio is constant. In all options the nutrient content of new shoot will increase in relation to the residual biomass (PRAMN(*,*), PRAMX(*,*), BIOMAX, crop.100).

Table 11 Grazing Effects

GRAZEFF	Effect of grazing on aboveground plant production	Effect of grazing on root production	Effect of grazing on root: shoot ratio
0	no direct impacts	no direct impacts	no direct impacts
1	linear decrease as FLGREM increases	linear decrease as FLGREM increases	constant
2	increased for moderate grazing and decreasing sharply for heavy grazing levels (>40% removed per month)	increased for light to moderate grazing and decreasing sharply for heavy grazing levels (>25% removed per month)	increased for light grazing and decreasing sharply for moderate to heavy grazing (>20% removed per month)

3	no direct impacts	increased for light to moderate grazing and decreasing sharply for heavy grazing levels (>30% removed per month)	increased for light to moderate grazing and decreasing sharply for heavy grazing levels (>30% removed per month)
4	no direct impacts		linear decrease if GREMB > 0, otherwise constant
5	increased for moderate grazing and decreasing sharply for heavy grazing levels (>40% removed per month)		linear decrease if GREMB > 0, otherwise constant
6	linear decrease as FLGREM increases	linear decrease as FLGREM increases	linear decrease if GREMB > 0, otherwise constant

3.7.1.2. Growing degree day model for plant production

The implementation of the growing degree day (GDD) model varies among DayCent versions. If the version of the model you are using has the crop.100 parameter “DDEMERG” instead of “TMPGERM”, it implements the most recent version for the GDD model.

Table 12 summarizes crop.100 parameters for growing degree day (GDD) model. Here, *thermUnits* is the number of growing degree days accumulated in the current growing season (°C).

Table 12 Growing Degree Days Crop Parameters

A summary or parameters in crop.100 that regulate the GDD model.

FRTCINDX	Non-growing degree day implementation: **1** - perennial plant **2** - annual plant Growing degree day implementation: **3** - perennial plant (GDD) **4** - non-grain filling annual plant (GDD) **5** - grain filling annual plant (GDD) **6** - grain filling annual plant that requires a vernalization period (i.e. winter wheat) (GDD)	index	1, 2, 3, 4, 5, 6
DDEMERG	Number of growing degree days that need to accumulate after the PLTM event in order for plant emergence to occur when FRTCINDX = 4, 5, or 6 (annuals only).	number of degree days (°C)	

DDBASE	Number of degree days required to • trigger a senescence (SENM) event for a perennial (FRTCINDX = 3) • reach maturity and trigger harvest (HARV) for a non-grain filling annual (FRTCINDX = 4) • reach anthesis (flowering) and begin gradual reduction photosynthetically active portion of the plant for a grain filling annual (FRTCINDX = 5 or 6).	number of degree days (°C)	
TMPKILL	The minimum daily temperature at which growth will stop when using the growing degree day submodel, FRTCINDX = 3, 4, 5, or 6. (However, growth will only stop if *thermUnits* ≥ DDBASE / 2.0).	°C	
BASETEMP(1)	Base temperature for crop growth, growing degree days will accumulate only on days when the average temperature is greater than BASETEMP(1) for the crop.	°C	
BASETEMP(2)	Ceiling on the maximum temperature used to accumulate growing degree days.	°C	
MNDDHRV	Minimum number of degree days from anthesis (flowering) to plant maturity for grain filling annuals (FRTCINDX = 5 or 6). This minimum number of GDD occurs under very dry soil moisture conditions.	number of degree days (°C)	
MXDDHRV	Maximum number of degree days from anthesis (flowering) to plant maturity for grain filling annuals (FRTCINDX = 5 or 6). This minimum number of GDD occurs under very wet soil moisture conditions.	number of degree days (°C)	
WSCOEFF (1,1)	Water Stress Coefficient used to calculate the water stress multiplier on potential growth based on the relative water content of the wettest soil layer in the rooting zone (*maxrwcf, 0-1*). $\frac{1.0}{1.0+\exp\left(wscoeff\left(1,2\right)*\left(wscoeff\left(1,1\right)-maxrwcf\right)\right)}$		0.2 – 0.5 0.35
WSCOEFF(1,2)	Water Stress Coefficient used to calculate the water stress multiplier on potential growth based on the relative water content of the wettest soil layer in the rooting zone.		6.0 – 30.0 9.0

FSDETH (1)	Maximum shoot death rate at very dry soil conditions; to get the monthly shoot death rate, this fraction is multiplied by a reduction factor depending on the soil water status.	fraction / month	0.0 – 1.0
FSDETH (2)	Fraction of shoots which die during senescence; must be ≥ 0.4.	fraction / month	0.4 – 1.0
FSDETH(3)	Additional fraction of shoots which die when aboveground live C is greater than fsdeth(4).	fraction / month	0.0 – 1.0
FSDETH(4)	Level of aboveground C above which shading occurs and shoot senescence increases.	g C m-2	0.0 – 500.0

The temperature used to calculate growing degree day accumulation (*thermTemp*, °C) is a function of *daylength* (hours) and air temperature. Minimum and maximum air temperature (*Tmin* and *Tmax*,°C) are weighted by *tmnsMlt* and *tmxsMlt (0.0 – 1.0)*, respectively **(Figure 33)**.

Equation 35

$$tmnsMlt = \frac{(12.0 - daylength)*3.0+12.0}{24.0}, \qquad daylength < 12.0$$
$$tmnsMlt = \frac{(12.0 - daylength)*1.2+12.0}{24.0}, \qquad daylenth \geq 12.0$$

$$tmnsMlt = \min(0.95,\ tmnsMlt)$$
$$tmnsMlt = \max(0.05,\ tmnsMlt)$$
$$tmxsMlt = 1.0 - tmnsMlt$$

Equation 36

$$thermTemp = tmnsMlt * \max(BASETEMP(1), Tmin) + tmxsMlt * \min(BASETEMP(2), Tmax)$$

Thermal units (growing degree days) accumulate daily according to the following equation:

Equation 37

$$thermUnits = thermUnits + \max(0.0,\ thermtemp - BASETEMP(1))$$

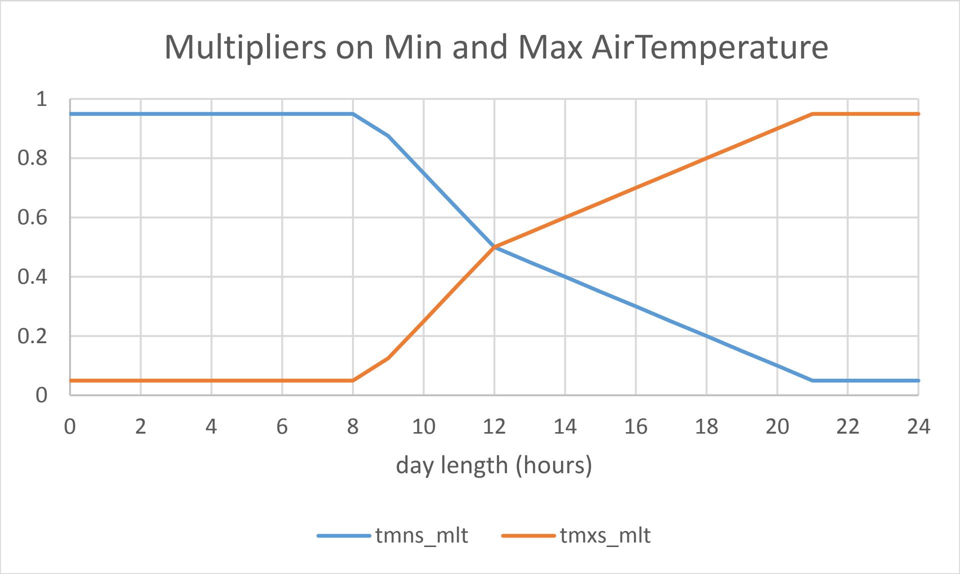


Figure 33 Relative Weighting of Minimum and Maximum Air Temperature

For an annual plant (FRTCINDX ≥ 4), the accumulation of *thermUnits* begins with a PLTM event, and emergence will occur when *thermunits* ≥ DDEMRGE.

For a grain-filling annual, anthesis occurs and grain filling begins when *thermunits* ≥ DDBASE

For grain filling annuals, an average daily water stress term (*gwstress/grnfldys*, 0.0 – 1.0) is computed during the grain filling period, where *grnfldys* in the number of days grain filling has been occurring.

Equation 38

$$gwstress = gwstress + \frac{1.0}{1.0 + \exp\left(wscoeff\,(1,2) * \left(wscoeff\,(1,1) - maxrwcf\,\right)\right)}$$

The second half of the equation is the daily water stress term **(Figure 34)**.

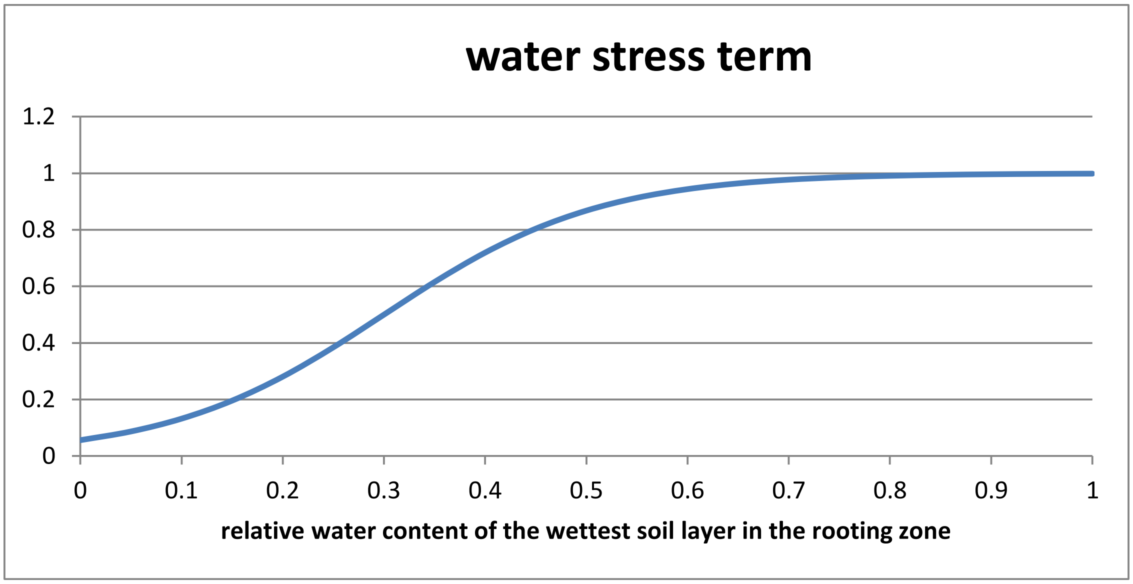


Figure 34 Effect of Water Stress on Potential Production

Figure 34. Effect of Water Stress on Potential Production. In this example, wscoeff(1,1) = 0.3, wscoeff(1,2) = 9.41 (crop.100 parameters).

A gradual senescence of annual plants begins after anthesis occurs (*thermUnits* > DDBASE). This gradual senescence reduces the amount of photosynthetic active carbon (*aggreenc*), based on water stress, reducing potential production and transpiration. The multiplier *liveGreenFraction* (0.0 - 1.0) indicates the fraction of the above live carbon that is photosynthetically active carbon.

liveGreenFraction:
1.0 = 100% photosynthetic active carbon
0.0 = 0% photosynthetic active carbon

The average grain water stress term (gwstress/grnfldys) determines if the plant has reached maturity, or is no longer photosynthetically active. Under dry soil moisture conditions, maturity is reached sooner (in MNDDHRV GDDs). Under wet conditions, maturity is reached later (in MXDDHRV GDDs).

Equation 39

$$hwstress = ramp\left(gwstress / grnfldys,\ 0.0,\ mnddhrv, 1.0,\ mxddhrv\right)$$

$$liveGreenFraction = ramp\left(thermunits - ddbase,\ 0.0,\ 1.0,\ hwstress,\ 0.0\right)$$

$$aggreenc = aglivc * liveGreenFraction$$

Note: aglivc (above ground live carbon, g C m^{-2}) is not reduced by this gradual senescence. Aglivc is reduced when there is partial senescence due to water stress, or when a SENM event occurs (See the FSDETH(*) parameters in crop.100). For a graph of *hwstress* **(Figure 35)**. For a graph of *liveGreenFraction* **(Figure 36).**

See daily.out file for daily output of thermunits, aglivc, aggreenc, hwstress, scenfrac (scenfrac = liveGreenFraction).

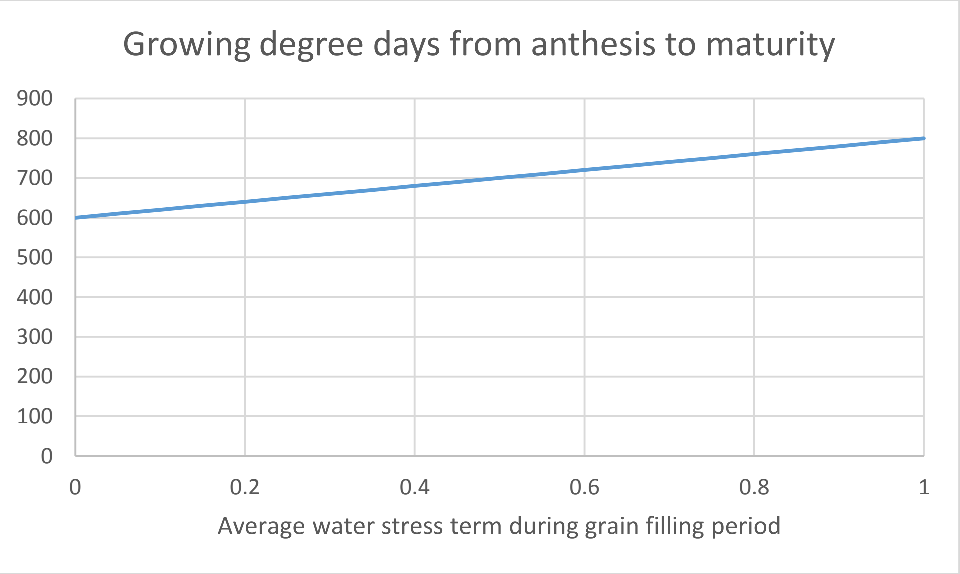


Figure 35 Growing Degree Days from Anthesis to Maturity.

Figure 35. The number of growing degree days from anthesis to maturity is a function of average soil moisture during the grain-filling period. In this example, the number of *thermUnits* after anthesis ranges from MNDDHRV=600 °C and MXDDHRV=800 °C. When soil moisture conditions are dry, the plant matures more quickly than under moist conditions.

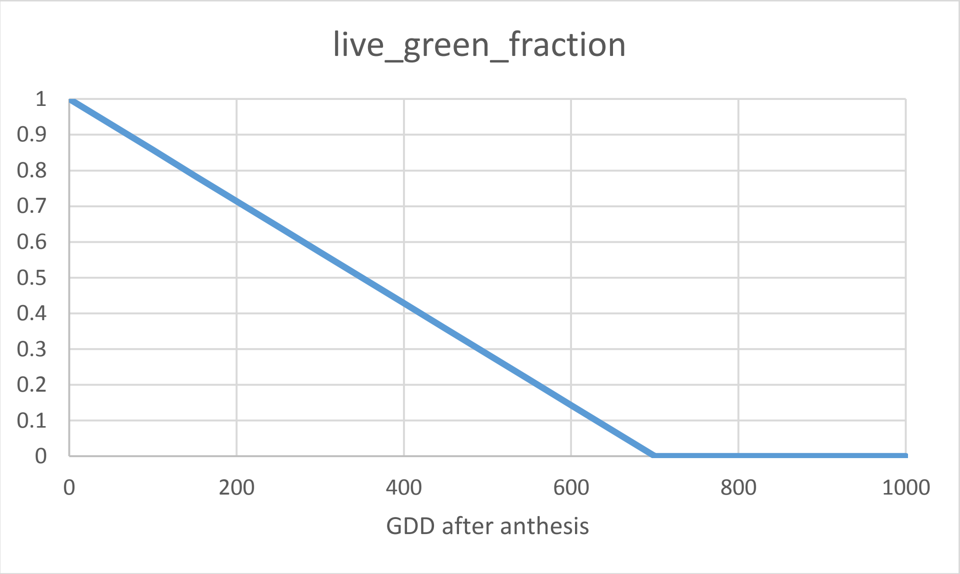


Figure 36 Fraction of Live Green Shoots after Anthesis

Figure 36. The fraction of photosynthetically active leaves (*live_green_fraction*, 0.0 – 1.0) after anthesis occurs. In this example, the number of *thermUnits* (GDD) from anthesis to maturity = 700 °C.

The GDD model and schedule file events for grain filling annuals

PLTM, HARV, SENM, and LAST events

1. **PLTM event** – begin accumulating *thermUnits*.
2. Emergence occurs when *thermUnits* ≥ DDEMRGE
3. Anthesis occurs, and the fraction of aglivc that is photosynthetically active begins to decrease when *thermUnits* ≥ DDBASE **(Figure 35 and Figure 36).**
4. Aglivc is no longer photosynthetically active when DDBASE+MNDDHRV ≤ *thermUnits* ≤ DDBASE+MXDDHRV, depending on soil moisture conditions.
5. If minimum daily temperature is < TMPKILL AND thermUnits > DDBASE/2.0 growth will cease for the remainder of the growing season.
6. **SENM event** – aglivc is reduced according to the FSDETH(*) parameters in crop.100. When aglivc dies it goes to standing dead (stdedc, g C m^{-2}).
7. **HARV event** – Harvest happens only when there is a **HARV event**, regardless of the stage of maturity of the plant. A HARV event can occur before or after a SENM event, depending on the crop.
8. **LAST event** – stops all plant growth if it was not stopped already. If there was any photosynthetically active carbon it is reduced to 0. Growing season accumulators are reset after output.

Note: the relative placement of PLTM, SENM, HARV, and LAST does not change between GDD and non-GDD plant models. However, in non-GDD version, emergence begins with the PLTM event. There is no “liveGreenFraction” calculation in the non-GDD model – it is always 1.0.

3.7.2. Forest Submodel

The forest plant production model **(Figure 37)** divides the tree into leaves, fine roots (juvenile and mature), fine branches, large wood, and coarse roots with carbon and nutrients allocated to the different plant parts using a dynamic allocation scheme.

3.7.2.1. Potential Production for Trees

As with crops/grasses, total potential tree production (g C m^{-2} day^{-1}) is a product of a genetic maximum defined for each crop (PRDX(2), tree.100), incoming solar radiation, and several 0 – 1 scalars. These scalars are functions soil temperature, soil moisture status, live leaf area index (LAI), and atmospheric CO_2 concentrations. Actual total production occurs at or below the potential amount depending on nutrient availability.

There is some variation in the total potential production calculation between DayCent versions. The variations in this calculation stem mainly from the type of solar radiation input used, but there are other minor differences (Equation 40, Equation 41).

In DailyDayCent versions other than DDcentEVI, the radiation input to the potential production calculation (*pforc*, g C m^{-2} day) is incoming radiation at the top of the atmosphere (*shwave(sitlat,curday)*:

Equation 40

$$pforc = \begin{cases} shwave(sitlat, curday) \times prdx(2) \times fprod_{Tave} \times h2ogef(FORSYS) \\ \times laprod \times co2cpr(FORSYS) \times tfrac \end{cases}$$

where *shwave(sitlat,cuday) is* function of the day of year and the latitude (langleys day^{-1}), *prdx(2)* is the genetic potential radiation use efficiency (tree.100), $fprod_{Tave}$ is the temperature effect on potential production (0.0 – 1.0) (**Figure 26**), *h2ogef(FORSYS)* is the effect of soil moisture (0.0 – 1.0) (Equation 34), *laprod* is the effect live leaf LAI on production (0.0 – 1.0), *co2cpr(FORSYS)* is the effect of CO_2 fertilization (Section 3.8.9, Figure 42), *tfrac* is the daily timestep fraction (1 divided by the number of days in the month).

DayCentEVI has just one method for calculating potential tree production; for trees it does not have a method that uses the MODIS Enhanced Vegetation Index (EVI) as it does from crops/grasses. Total potential production is a function of incoming solar radiation (*srad*, langleys day^{-1}). The value *srad* (W m^{-2}) is read from the weather file and converted to units of langleys day^{-1}. The other factors in Equation 40 are defined the same as in Equation 41.

Equation 41

$$pforc = \begin{cases} srad_{langleys} \times prdx(2) \times fprod_{Tave} \times h2ogef(FORSYS) \\ \times laprod \times co2cpr(FORSYS) \times tfrac \end{cases}$$

The effect of moisture and air temperature on potential productions are the same functions used for cropland/grassland production **(Figure 26 and Figure 34).** The effect of live leaf-area-index on production increases with LAI **(Figure 38)**.

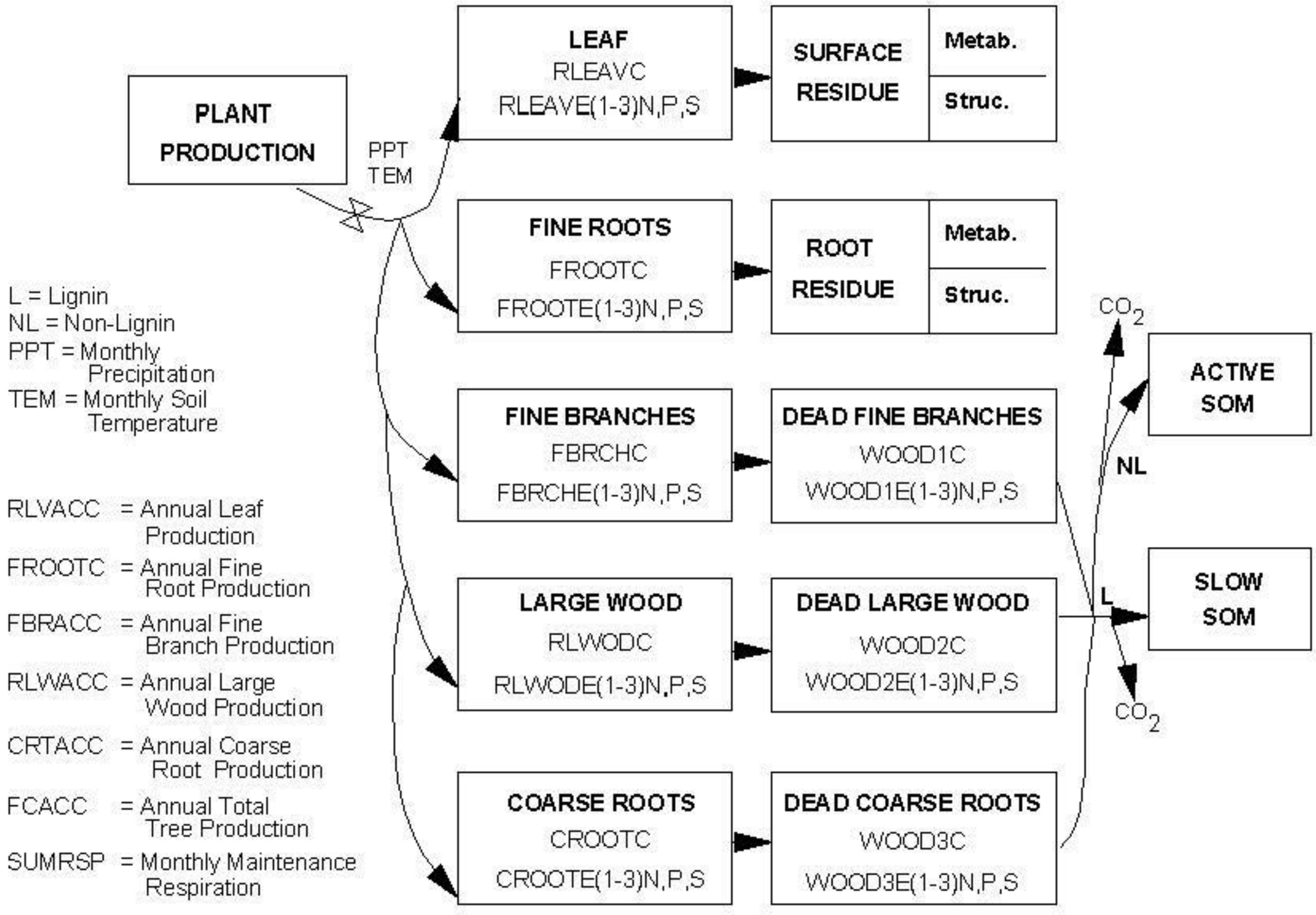


Figure 3-17: Flow diagram for the forest production submodel.

Figure 37 Forest Production Submodel

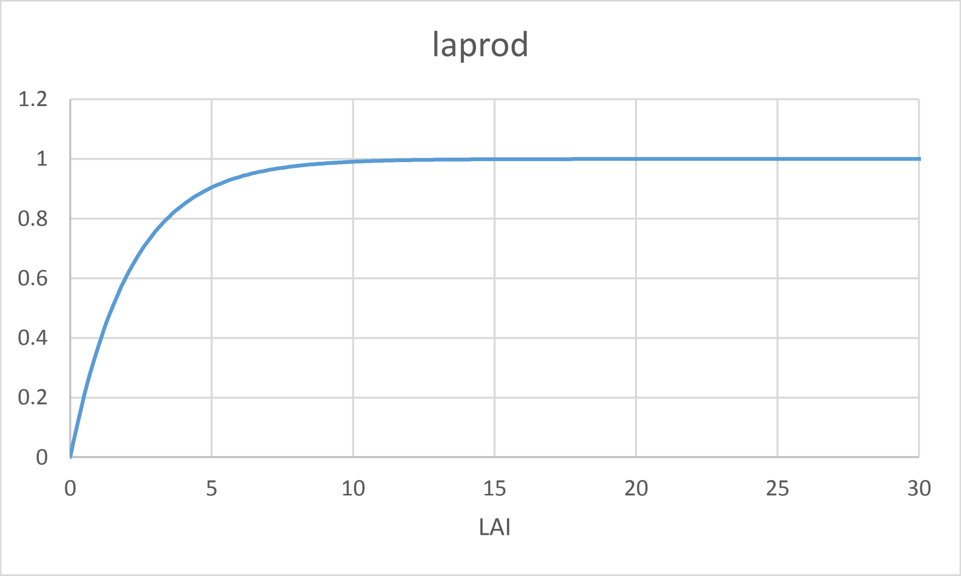


Figure 38 Effect of LAI on Relative Forest Production

Figure 38. The effect of LAI on relative forest production. In this example, LAITOP (tree.100) is -0.47.

3.7.2.2. Dynamic Carbon Allocation for Trees

The model has two carbon allocation patterns for young and mature forests and can represent either deciduous forests or forests that grow continuously. For deciduous forest the leaf growth rate is also much higher during the first month of leaf growth.

For deciduous trees, allocation during the month of greenup is 90% to leaves, 10% to fine roots, and 0% to woody parts. If between leaf out and leaf drop, C is allocated to fine roots first based on soil moisture and N availability, then to leaves, then to woody plant parts.

For drought deciduous trees, if it is springtime and soil moisture is adequate (*h2ogef(FORSYS)* > 0.5) then 90% of C is allocated to leaves and 10% is allocated to fine roots; otherwise, C is allocated to first to fine roots based on soil moisture and N availability, then to leaves, then to woody plant parts.

For evergreen trees, C is allocated first to fine roots based on soil moisture and N availability, then to leaves, then to woody plant parts.

When the leaf allocation fraction is being determined, the leaf biomass, expressed as LAI, is not allowed to exceed a maximum value that is a function of the live wood biomass **(Figure 39).** This function specifies the effect of tree allometry and structure on maximum leaf area and is potentially different for different species. The values of MAXLAI and KLAI (tree.100) are parameters to a Michalis-Mention function where MAXLAI is the upper LAI limit and KLAI is the aboveground wood biomass (g C m^{-2}) required to reach half the maximum LAI. In this way, the model can initially allocate most of the carbon to leaves until full canopy has been achieved, then C allocation can go to the fine branches, large wood, and coarse roots.

Allocation to fine roots is based on soil moisture and N availability. The assumption is that trees will invest more C into roots when resources are limited. The fraction of new growth allocated to fine roots has maximum and minimum values according to bounds set by the TFRTCN(1), TFRTCW(2), TFRTCW(1), and TFRTCW(2) parameters in tree.100. When the tree is severely limited by water or N availability, the maximum fine root allocation fractions (TFRTCN(1) and TFRTCW(1), respectively) are used; when there is no N or water limitation, the minimum fine root allocation fractions (TFRTCN(2) and TFRTCW(2), respectively) are used. For moderate limitation, the fine root allocation fraction linearly interpolated between the maximum and minimum. Maximum N limitation occurs when (mineral N available / plant N demand) = 0.0. There is no N limitation when (mineral N available / plant N demand) >= 1.0. Maximum water limitation occurs at wilting point. There is no water limitation when soil is at field capacity. These fraction of new C allocated to roots based on N and the fraction of new C allocated to roots based on water are computed separately, then the maximum of those two values is the final fraction.

For all types of trees, any remaining C not allocated to leaves or fine roots is allocated to fine branches, large wood, and coarse roots in fixed proportions determined (FCFRAC(3-5,1-2), tree.100). These fractions are normalized if necessary so that the sum of all allocation fractions does not exceed 1.0. Note that FCFRAC(1-2,*), allocation fractions for leaves and fine roots, are no longer used.

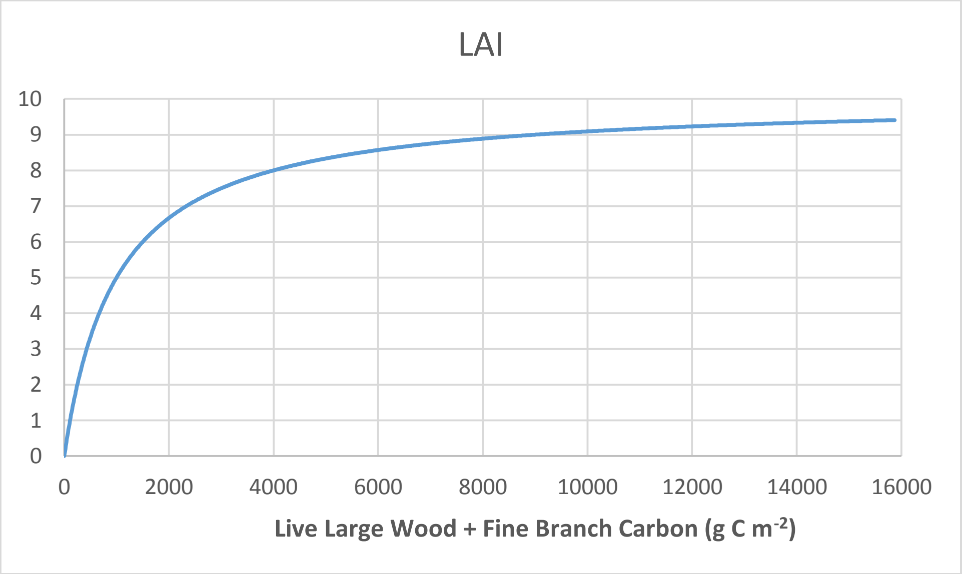


Figure 39 Relationship between Wood Carbon and Optimal LAI

Figure 39. The relationship between aboveground wood carbon and LAI. Here, KLAI = 1000 and MAXLAI = 10.

3.7.2.3. Phenology of Trees

There are two parameters in the tree.100 file to specify the temperature values for controlling leaf out, TMPLFS, and leaf drop, TMPLFF, for the specified tree. These temperature values are in °C.

With a continuous growth or evergreen forest the death of the live leaves is specified as a function of month (LEAFDR(1-12), tree.100), while with a deciduous forest the leaf death rate is very high at the senescence month. Dead leaves and fine roots are transferred to the surface and soil residue pools and are then allocated into structural and metabolic pools. Dead fine branch, large wood, and coarse root pools receive dead wood material from the live fine branch, large wood, and coarse root pools respectively. Each dead wood pool has a specific decay rate. The dead wood pools decay in the same way that the structural residue pool decomposes with lignin going to the slow SOM pool and the non-lignin fraction going to active surface and soil SOM pools. The decay rates of the dead wood pools are also reduced by the temperature and moisture decomposition functions, and include CO_2 losses.

3.7.2.4. Tree Removal Events

A tree removal event, which is defined in the trem.100 file, can simulate the impact of different forest harvest practices, fires, and the effect of large scale disturbances such as hurricanes. For each disturbance or harvest event, the fraction of each live plant part lost and the fraction of material that is returned to the soil system is specified (see Appendix 1). Death of fine and coarse roots are also considered in the removal event along with the removal of dead wood. Another feature is that the nutrient concentration of live leaves that go into surface residue can be elevated above the dead leaf nutrient concentration (e.g. simulating the effect of adding live leaves to surface residue as a result of hurricane disturbance) by specifying the return nutrient fraction of the leaves to be greater than one (RETF(1,*), trem.100).

3.7.2.5. Fruit Trees

<Insert text about how to grow and harvest fruit trees>

3.7.3. Savanna Submodel

The savanna model is a coupled tree-grass system and uses the forest and grassland/crop submodels already described. The fundamental difference in the savanna submodel is the manner in which total system production is obtained. Total system production is the sum of forest and grass production. Potential maximum production of forest is computed in the manner described above. Grassland/crop production is modified to include the effect of tree canopy cover on grassland/crop production. A shade modifier is calculated as a function of canopy cover and leaf biomass **(Figure 40)** and is multiplied by the normal grassland/crop production equation (see Grassland/Crop Submodel, Section 3.7.1 above). Increasing canopy cover and leaf biomass reduces the potential grass production. Removal of grass or forest is accomplished independently with the FIRE and TREM commands in the schedule file, so that user can specify fire intensity and frequency as desired. Fire removal parameters for grassland/crop vegetation are specified in fire.100, while forest fire parameters are specified in trem.100. In this manner, a grass fire can occur at a higher intensity and/or frequency than fires affecting forest combustion losses. In the present model, fire does not influence tree distribution and establishment.

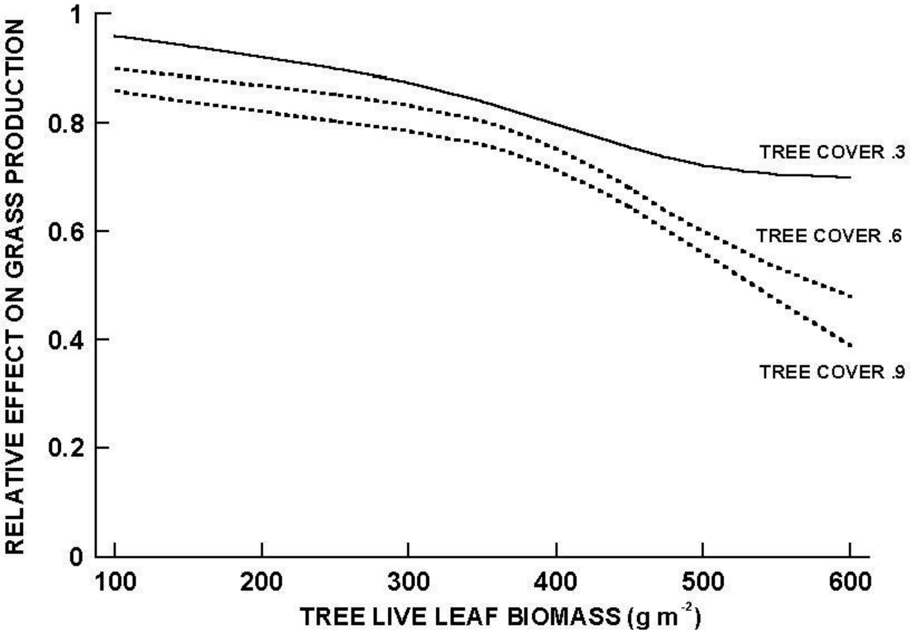


Figure 3-21: The effect of tree cover and live leaf biomass on the shade modifier for grassland/crop growth.

Figure 40 Effect of Tree Cover and Live Leaf Biomass on the Shade Modifier for Grassland/Cropland Growth.

Nitrogen competition is the other major interaction between the forest and grass systems. The interaction is controlled by the amount of tree basal area, total N available, and site potential for plant production. The fraction of N available for tree uptake is calculated as a function of tree basal area (m^2 ha^{-1}) and available mineral N using the function shown in **Figure 41**. The fraction of N uptake by grass is one minus the forest fraction and if grass N uptake did not consume all of the N allocated to it, this amount is added to the pool of N which is available to the trees. Two important site-specific parameters for the savanna model are the site potential parameter (SITPOT, tree.100) and the basal area conversion factor (BASFCT, tree.100) which calculates tree basal area as a function of large wood C level. SITPOT controls how fast trees can dominate grasslands with values < 1.0 leading to quicker dominance by trees and values > 1.0 allowing grass to be more competitive for available N **(Table 13)**.

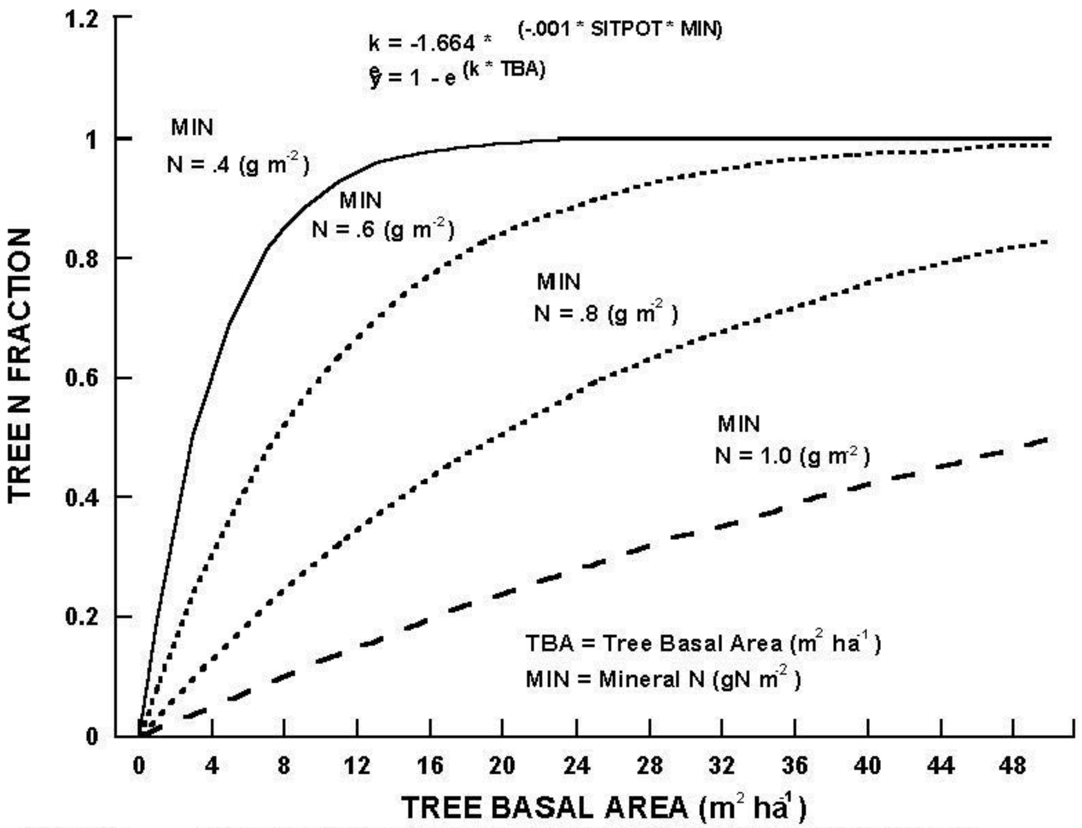


Figure 3-22: The fraction of N available for tree growth as a functin of available N and tree basal area.

Figure 41 Fraction of N Available for Tree Growth as a Function of Available N and Tree Basal Area.

Table 13 Savanna

Tree and Grass competition for available N in savannas.

tree.100 parameters	No savanna	To increase the fraction of N available to grasses	To increase the fraction of N available to trees
SITPOT	1.0 (ignored)	Increase to a value > 1.0	Decrease to a value < 1.0
BASFC2	1.0	Decrease to a value < 1.0	Increase to a value > 1.0

BASFCT – not important unless fbrchc + rlwodc < 125 g C m^{-2}	1.0	Increase to a value > 1.0 to decrease tree basal area and cause trees to be less competitive for N	Decrease to a value < 1.0 to increase tree basal area and allow trees to be more competitive for N

3.8.Management

3.8.1. Fertilizer Additions

Mineral N, P, and S fertilizer additions are scheduled with FERT events in the schedule file as defined by the corresponding fert.100 parameters. Fertilizer can be added in fixed amounts (FERAMT(*), fert.100) or calculated automatically (AUFERT > 0, fert.100) according to the crop nutrient requirements. The automatic option can be set to maintain crop growth at a particular fraction of potential production with the minimum nutrient concentration ($0.0 < \text{AUFERT} \leq 1.0$) or to maintain maximum production with plant nutrient concentrations at a nominated level between the minimum and maximum for that growth stage ($1.0 < \text{AUFERT} \leq 2.0$). If AUFERT > 0 and FERAMT > 0, the fixed amount of fertilizer will be added first before the automatic fertilizer calculation. Automatic fertilization continues until it is turned off by a FERT event that sets AUFERT = 0 regardless of FERAMT.

Mineral N additions occur as NH_4-N, NO_3-N, or a combination of the two. The relative fractions of each type of mineral N are specified by FRAC_NH4 and FRAC_NO3 parameters in fert.100 (sum to 1.0). Organic C, N, P, and S additions are scheduled by OMAD events as defined by the correspond parameters in omad.100 (Appendix 1).

The DayCentEVI versions have an “immediate mode” format for FERT events that allows the user to specify all fertilization options on the schedule file line instead of through FERT.100 (4.8.2.1 above).

3.8.1.1. *Nitrification inhibitors*

Nitrification, the conversion of ammonium to nitrate with N_2O loss, can be reduced by applying nitrification inhibitors, as defined by the parameters NINHIB and NINHTM in fert.100. Nitrification inhibitors are used to reduce N_2O emissions and nitrate leaching. If NINHIB = 1.0, there is no reduction of nitrification. When $0.0 \leq \text{NINHIB} < 1.0$ then the nitrification rate is multiplied by NINHIB. This reduction in nitrification occurs for NINHTM weeks.

3.8.2. Organic Matter Additions

DayCent allows two types of organic matter additions (OMAD). The first is tradition type of OMAD addition where material added is partitioned into metabolic and structural surface litter. The second, and relatively new option, is to add organic matter as partially decomposed compost to the surface slow pool (SOM2C(1)). Furthermore, organic matter additions can be labeled so the user can trace the fate of the addition. A new parameter, OMADTYP, was added to the omad.100 file.

OMAPTYP = 1.0: Add 100% organic matter to surface litter pools. The CONCENTRATION that is labeled is specified by the ASTLBL parameter.
OMAPTYP = 2.0: Add 100% organic matter to surface slow pool (SOM2C(1)) because it is partially decomposed, like compost. The CONCENTRATION that is labeled is specified by the ASTLBL parameter

1.0 ≤ OMAPTYP ≤ 2.0: The fraction to surface som2 is OMADTYP – 1.0. The remaining fraction goes to surface litter pools.

OMAPTYP = 3.0: Add 100% labeled organic matter to surface litter pools. The FRACTION that is labeled is specified by the ASTLBL parameter.
OMAPTYP = 4.0: Add 100% labeled organic matter to surface slow pool (SOM2C(1)) because it is partially decomposed, like compost. The FRACTION that is labeled is specified by the ASTLBL parameter

3.0 ≤ OMAPTYP ≤ 4.0: The fraction to surface som2 is OMADTYP – 3.0. The remaining fraction goes to surface litter pools.

3.8.3. Irrigation

Irrigation is scheduled with IRRI events in the schedule file. Irrigation amounts can be either fixed amounts (IRRAMT, irri.100) or automatically set (AUIRRI, irri.100) according to the soil moisture status. An IRRI event distributes the irrigation amount in 4 weekly applications over a 30-day period where each weekly application is 25% of the irrigation amount. Automatic irrigations also occur weekly for 30 days if the available water stored in the plant root zone falls below a nominated fraction of the available water holding capacity (FAWHC, irri.100). The amount of water applied by the automatic option allows for the addition of a nominated amount of water (IRRAUT, irri.100) or for irrigation up to field capacity or up to field capacity plus an allowance for potential evapotranspiration. Any irrigation event that occurs < 30 days after a previous irrigation event will cancel the previous event then continue for 30 days. To turn off irrigation before the 30-day period is up, schedule another irrigation event where no water is applied (AUIRRI = 0 and IRRAMT = 0).

The DayCentEVI versions have an “immediate mode” format for month-long (IRRI) and daily (IRIG) events that allow the user to specify all irrigation options on the schedule file line instead of through IRRI.100 (Section 4.8.2.2 above).

3.8.4. Cultivation and Tillage

Tillage is scheduled with CULT events in the schedule file. Cultivation options allow for the transfer of defined fractions (CULTRA(*), cult.100) of shoots, roots, standing dead and surface litter into standing dead, surface and soil litter pools as is appropriate. Thus the model can simulate a variety of conventional cultivation methods, such as plowing or sweep tillage, thinning operations or herbicide application. Each cultivation option also has parameters (CLTEFF(*) cult.100) for the multiplicative effect of soil disturbance by cultivation on organic matter decomposition rates for the structural, active, slow and passive pools. The values for these parameters range from 1.0 to about 4.0 with the actual value dependent on the degree of soil stirring and disruption caused by each implement. The effect of cultivation disturbance on decomposition will continue for 30 days after the cultivation event is scheduled. Any grazing event that occurs < 30 days after a previous grazing event will cancel the effect of the previous event, and the cultivation effect will continue for 30 days. To turn off the cultivation effect before the 30-day period is up, schedule another cultivation event with CULTRA(*) = 0.0 and CLTEFF(*) = 1.0.

3.8.5. Grazing

Grazing is scheduled with GRAZ events in the schedule file. The grazing options can be parameterized to remove defined fractions of aboveground live (FLGREM, graz.100) and standing dead (FDGREM, graz.100) plant material each month. The fractional returns of C (GFCRET, graz.100), N, P, and S (GRET(1..3), graz.100) are specified, having allowed for losses in animal carcasses and milk, transfer of dung and urine off the area being simulated, volatile losses of N from dung and urine patches, and leaching of N and S under urine patches. The proportion of N, P, and S returned in organic forms (FECF(1..3), graz.100) is also specified as is the lignin content of the feces (FECLIG, graz.100). As discussed above in Section ??, grazing can have variable effects on plant production (GRZEFF, graz.100).

Grazing events will continue for 30 days. Any grazing event that occurs < 30 days after a previous grazing event will cancel the previous event then continue for 30 days. The fraction of biomass removed daily is approximately (FLGREM + FDGREM) / 30. To turn off grazing before the 30 day period is up, schedule another grazing event where no grass is removed (FLGREM = 0, FDGREM = 0) and there are no grazing effects on production (GRZEFF = 0).

3.8.6. Fire

3.8.6.1. Burning of herbaceous plants, litter, and dead wood

A FIRE event can be scheduled to burn live aboveground live and standing dead herbaceous biomass, surface litter, and aboveground dead wood. The effect of different intensities of fire in herbaceous vegetation can be parameterized by specifying the fractions of live shoots (FLFREM, fire.100), standing dead (FDFREM(1), fire.100) and surface litter (FDFREM(2), fire.100) removed by a fire.

The effect of fire on surface litter (surface structural, metabolic, fast, and slow pools) can be parameterized by the fraction of surface litter removed (FDREM(2), fire.100). The effect of fire on dead wood can be parameterized by the fractions of dead fine branches (FDREM(3), fire.100) and dead large wood (FDREM(4) removed by fire.

FIRE events remove C as well as N, and S stored in live shoot, standing dead, surface litter, and dead wood. The fractions of N, P, and S that are removed from these pools but not volatilized (i.e. returned to the soil in inorganic form) are specified by the FRET(*,2-4) parameters in fire.100. Similarly, a fraction of the C burned from each pool can be returned to the system as charcoal which gets added to the passive soil pool; these fractions are specified by the FRET(*,1) parameters in fire.100.

3.8.6.2. Burning of live trees

The burning of live tree parts is accomplished by scheduling a TREM event. See Section 3.8.7 below for more information.

3.8.7. Tree Removal Events

A TREM event can be scheduled to remove live tree parts either through fire (EVNTYP=1, trem.100) or from cutting, wind, or other non-burning event (EVNTYP=0, trem.100). The fractions of live leaves, live fine branches, and live large wood removed are specified with the REMF(1), REMF(2), and REMF(3) parameters (trem.100), respectively. The fractions of live fine roots and live coarse roots that die are specified by FD(1) and FD(2). The fractions of C, N, P, and S in killed biomass that are returned are to the system are specified with the RETF(*,*) parameters. See Appendix 1 for more information about trem.100 parameters.

When the TREM event is a fire, any C returned is charcoal that gets added to the passive soil pool while any N, P, or S that is returned is added to the soil in inorganic form. When the TREM event is a non-burning removal, any C, N, P, or S that returned from killed leaves is added to surface litter in organic form; any C, N, P, or S returned from killed fine branches or large wood is added to dead wood pools, also in organic form.

3.8.8. Labeled C Simulation (^{14}C and ^{13}C)

Due to modifications to the way that labeled ^{14}C is being simulated the value read from the c14.dat file represents the concentration rather than the percentage.

Additional output variables added to the *.bin file for tracking $\delta\ ^{13}C/^{14}C$:

DAUTORESP(1) – $\delta\ ^{13}C/^{14}C$ value for autotrophic respiration for grass/crop system for stable isotope labeling
DAUTORESP(2) – $\delta\ ^{13}C/^{14}C$ value for autotrophic respiration for forest system for stable isotope labeling
DBGLIVC – $\delta\ ^{13}C/^{14}C$ value for grass/crop belowground live for stable isotope labeling
DCARBOSTG(1) – $\delta\ ^{13}C/^{14}C$ value for grass/crop system carbohydrate storage pool for stable isotope labeling
DCARBOSTG(2) – $\delta\ ^{13}C/^{14}C$ value for forest system carbohydrate storage pool for stable isotope labeling
DELOE – $\delta\ ^{13}C/^{14}C$ value for OE layer (soil structural, metabolic, som1c, som2c, and som3c) for stable isotope labeling
DELOI – $\delta\ ^{13}C/^{14}C$ value for OI layer (surface structural, metabolic, som1c, and som2c) for stable isotope labeling

DFROOTC – δ ^{13}C/^{14}C value for forest belowground live for stable isotope labeling
DHETRESP – δ ^{13}C/^{14}C value for heterotrophic respiration for stable isotope labeling
DSOILRESP – δ ^{13}C/^{14}C value for soil respiration for stable isotope labeling

The DayCent model can simulate labeling by either ^{14}C or ^{13}C. C labeling is specified in the schedule file. The ^{14}C simulations act as a labeled tracer from atmospheric sources or added organic matter (ASTLBL, omad.100). The c14data file contains a record of atmospheric ^{14}C concentrations which are used by the model to label new plant material, which then flows through the other organic matter pools. A sample c14data data file is included on the Daycent diskette.

Simulations using the option for ^{13}C give a constant label to plant material based on the value of DEL13C in the crop.100 and tree.100 files. This option will primarily be of use to follow the change in stable isotope signal when there has been a switch from C3 to C4 vegetation or vice-versa. Fractionation of the stable carbon isotopes is included in the model as discussed below.

The ^{13}C/^{12}C ratio in soil organic matter remains close to the ratio in the original vegetation, but fractionation during decomposition of the plant residues and soil organic matter can produce significant changes in the ratio. The magnitude and direction of the change in the ratio may vary with time and the prevailing environmental conditions (Stout and Rafter 1978, Stout et al. 1981).

^{13}C/^{12}C ratios are expressed relative to a standard as δ^{13}C values, where

Equation 42

$$\delta^{13}C = \frac{{}^{13}C/{}^{12}C_{sample} - {}^{13}C/{}^{12}C_{standard}}{{}^{13}C/{}^{12}C_{standard}} \times \frac{1000}{1}$$

The standard is carbonate from Pee Dee belemnite limestone and units are per mille (‰). Atmospheric CO$_2$, plant material, and soil organic matter are depleted in ^{13}C relative to the standard and therefore have negative δ^{13}C values. The more depleted in ^{13}C a material is, the more negative the δ^{13}C value will be.

Stout et al. (1981) identified four points in the biological carbon cycle where major fractionation of carbon isotopes occurs. The first takes place during photosynthesis with plant tissue being depleted in ^{13}C relative to atmospheric CO$_2$. Of considerable interest is the difference in δ^{13}C between plants with different photosynthesis pathways (Bender 1971, Smith and Epstein 1971). The C3 plants, with the Calvin pathway, have low δ^{13}C values (-24 to -34‰), while the C4 plants, with the Hatch and Slack pathway, have high δ^{13}C values (-6 to -19‰). This difference in stable carbon isotope signature can be used as a tracer for in situ labelling of soil organic matter when the dominant vegetation type has changed from C3 to C4 species or vice-versa (Cerri et al. 1985, Schwartz et al. 1986, Balesdent et al. 1987, Balesdent et al. 1988, Martin et al. 1990, Balesdent and Balabane 1992). The DayCent model has been modified to partition carbon production by plants to the two isotope pools on the basis of a $\delta^{13}C$ value nominated in the crop.100 file for each grassland or crop type.

The second major biological fractionation occurs in the synthesis of the major cell components (Stout et al. 1981). The data of Benner et al. (1987) for a variety of vascular plants showed that cellulose and hemicellulose were typically enriched in ^{13}C by 1 to 2 ‰ relative to whole plant material while lignin was depleted by 2 to 6‰. They observed a greater depletion of ^{13}C in grass lignins than in wood lignins, which they attributed to different amino acid precursors. In the DayCent model this fractionation in the partitioning of plant material (shoots and roots from crops and grasses, and leaves and fine roots from trees) to the structural and metabolic pools is accounted for as all of the plant lignin is assumed to enter the structural pool. The ^{13}C depletion of lignin relative to the whole plant ^{13}C signature can be altered (DLIGDF, fix.100). Because all dead wood and large tree roots enter dead wood pools, which are analogous to the structural pool, there was no need to account for ^{13}C fractionation in wood lignin.

The third major biological fractionation of carbon noted by Stout et al. (1981) is associated with animal consumption of plant material, with animal tissues being depleted in ^{13}C relative to the plant material on which they feed. This is not accounted for this in the model because the important comparison for the DayCent model is between $\delta^{13}C$ levels in feces and plant material.

The fourth major biological fractionation of carbon takes place during microbial metabolism (Stout et al. 1981). Macko and Estep (1984) examined the isotopic composition of an aerobic, heterotrophic bacteria growing on a variety of amino acid substrates. With most of substrates the bacterial cells were enriched in ^{13}C relative to the amino acid. They suggested that the CO_2 respired during the Krebs cycle would be isotopically depleted in ^{13}C. However, in an anaerobic environment methane evolved is very depleted in ^{13}C relative to the organic substrate, but the CO_2 evolved is enriched (Games and Hayes 1976). The net effect on the residual organic matter would depend on the relative size of the fluxes. Environmental effects on fractionation are also reflected in different patterns of stable isotope distribution in soil profiles (Stout and Rafter 1978). In well-drained mineral soils $\delta^{13}C$ values increase slightly with depth and soil age, which is consistent with respired CO_2 being slightly depleted in ^{13}C. In organic soils where decomposition is inhibited the $\delta^{13}C$ values decrease with depth. This could be due to the loss of readily decomposable plant fractions, such as sugars and proteins, with an accumulation of lignin, lipids and waxes in the residual plant material, resulting in depletion of ^{13}C relative to the original plant material (Stout et al. 1981). In other soils, with intermediate levels of drainage and organic matter accumulation, there may be no change in $\delta^{13}C$ values with depth indicating a balance between fractionation due to respiration and accumulation of the depleted plant fractions. All decomposition flows in the DayCent model are assumed to be the result of microbial activity and have an associated loss of CO_2. Fractionation of the carbon isotopes in the loss of CO_2 is allowed for (DRESP, fix.100). The coefficient for isotope discrimination was calibrated to give a slight increase in the $\delta^{13}C$ value for the total soil organic matter relative to the vegetation.

3.8.9. Enriched CO_2 Effects

The model was also enhanced to include the effects of documented changes in atmospheric CO_2 and thus predict the effects on crop production. The direct effects of an increase in atmospheric CO_2 concentration on soil processes will be insignificant because the CO_2 concentration in the soil atmosphere is already greatly elevated. However, the indirect effects on SOM mediated through effects on plant processes could be substantial and must be accounted for in simulations of the effect of global change on SOM (Long 1991). Net primary production, litter quality, and transpiration are all likely to be affected. Increases in atmospheric CO_2 concentration have increased plant production of a wide variety of species by an average of 33% for older studies (Kimball 1983). More recent research has found that a 100 ppm increase in CO_2 enhanced crop growth 2 to 25%, depending on plant species and geographical location (Mc Grath and Lobell 2013). Generally, the plant dry matter response to increasing rates of CO_2 can be approximated with a logarithmic response function (Gifford 1979, Goudriaan 1992):

Equation 43

$$NPP_E = NPP_0 * \left(1 + \beta * \ln\left[\frac{CO_2(E)}{CO_2(0)}\right]\right)$$

where $CO_2(E)$ and $CO_2(0)$ refer to atmospheric CO_2 concentrations (ppmv) in the enriched and control CO_2 environments, respectively, and NPP_E and NPP_0 refer to net primary production in enriched and control CO_2 environments. The value β is an empirical parameter which ranges between 0 and approximately 0.7.

The response to CO_2 is not simply due to the removal of a single limiting factor (Sinclair 1992), but results from a hierarchy of effects (Acock 1990).

First, increasing CO_2 has a direct effect on C availability by stimulating photosynthesis and reducing photorespiration (**Figure 42**). There is a very important difference between C3 species, such as wheat, and C4 species, such as corn, in this response. At present day CO_2 concentrations around 350 µmol mol^{-1}, C4 plants have higher rates of photosynthesis than C3 species. However, net photosynthesis in corn does not increase much beyond 400 µmol CO_2 mol^{-1}, while wheat responds to CO_2 levels up to 800 µmol mol^{-1} (Akita and Moss 1973). The growth response to CO_2 is usually lower in C4 species than in C3 species (Wong 1979, Rogers et al. 1983, Morison and Gifford 1984b, Cure and Acock 1986); Cure and Acock, 1986). With wheat, a growth response to elevated CO_2 is almost invariably obtained (Kimball 1983, Cure and Acock 1986)(Kimball, 1983; Cure and Acock, 1986). Corn sometimes shows no response to CO_2 (Hocking and Meyer 1991b). In a field study with elevated CO_2 in open top chambers, in which corn growth was increased by about 40%, there was no effect on net photosynthesis per unit leaf area (Rogers et al. 1983). Summarizing a number of experiments, Cure and Acock (1986) found average biomass responses of 31, 9, and 9% for wheat, corn and sorghum respectively. The main reason for responses to CO_2 in C4 species is due to improved water use efficiency as discussed below.

The second effect of increased CO_2 concentrations is a decrease in stomatal conductance (Moss et al. 1961, Akita and Moss 1973, Wong 1979, Rogers et al. 1983, Morison and Gifford 1984a) at high CO_2 concentrations, which reduces the transpiration rate per unit leaf area (**Figure 42**). Reduced transpiration will also increase the leaf temperature which can further increase photosynthesis (Acock 1990). The effect on stomatal conductance and transpiration is observed in both C3 and C4 species. Over a range of species Morison and Gifford (1984a) found that stomatal conductance was reduced by 36% while transpiration was reduced by 21%, the difference being attributed to the higher leaf temperatures. Similar average values of 34% and 23% for stomatal conductance and transpiration respectively were found in the literature survey of Cure and Acock (1986). Both an increase in photosynthesis and a decrease in transpiration result in an increase in the plant's water use efficiency.

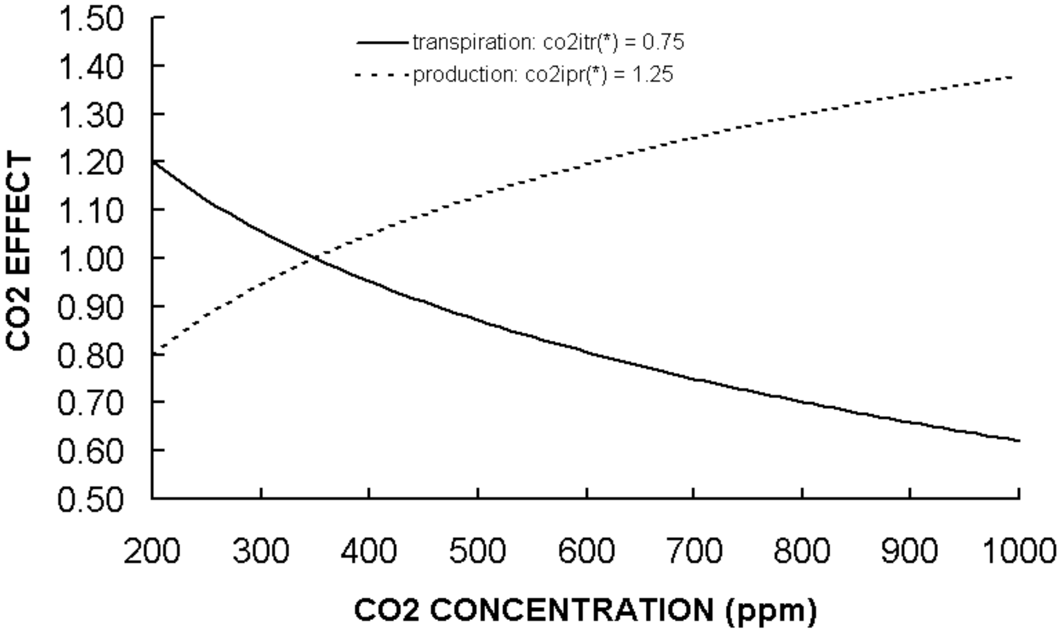


Figure 42 CO_2 Effect on Transpiration and Plant Production

The third major effect of increased CO_2 is a decrease in the plant N concentration in C3 species (Schmitt and Edwards 1981, Hocking and Meyer 1991b) and some C4 species (Lenka and Lal 2012). Clearly with a fixed nutrient supply, an increase in C assimilation is likely to result in lower plant nutrient concentrations due to a dilution effect, but this is not the only effect. Hocking and Meyer (1991a) clearly demonstrated that the critical plant N concentration for 90% maximum yield is decreased under elevated CO_2. However, CO_2 had little effect on the relationship between relative yield and the external N concentration. A practical implication of this is that similar fertilizer application rates will still allow near maximum yields under a high CO_2 environment, but that more fertilizer may be required to maintain similar grain protein concentrations (Hocking and Meyer 1991b)(Hocking and Meyer, 1991b). Physiologically, an increase in N use efficiency in C3 species with elevated CO_2 has been related to decreased concentrations of the enzyme ribulose 1,5-bisphosphate carboxylase (Schmitt and Edwards 1981) which catalyzes the initial carboxylation reaction in C3 species and accounts for a large proportion of the leaf protein.

A fourth effect of increased CO_2 on plant growth which affects SOM levels is an increase in root growth. Most studies with elevated CO_2 with grain crops in which root growth has been measured show very little or no effect on the root to shoot ratio (Cure and Acock 1986). However, there is some evidence that elevated CO_2 tends to increase root to shoot ratio for some trees and field crops (Lenka and Lal 2012).

The above effects can be taken into account in DayCent model simulations of global change effects by selecting the enriched CO_2 option in the schedule file (see Section 4.4.4 above, CO2 Systems option). This option can be implemented with either a constant CO_2 concentration or with a linear ramp with annual increments from an initial concentration to a final concentration; the parameters CO2RMP, CO2PPM(1), and CO2PPM(2) are found in the fix.100 file. The various effects of CO_2 described above are controlled by functions of the CO_2 concentration and crop or tree specific parameters in crop.100 and tree.100. Parameter values are set using reference concentrations of 350 and 700 ppm CO_2 for ambient and doubled CO_2 respectively.

The impact on maximum potential monthly production is described by a transformation of Equation 3 given above in order that the relative production for doubled CO_2 can be set for each crop (CO2IPR(*), crop.100, tree.100). The effect on potential transpiration rate also uses this equation with the fraction to which the transpiration will be reduced with a doubling of atmospheric CO_2 set (CO2ITR(*), crop.100, tree.100). The effect of elevated CO_2 on carbon to element ratios is similarly modelled with the effect of doubled CO_2 on the minimum and maximum ratios for N, P, and S, in the shoots of grasses and crops and in the leaves of trees set (CO2ICE(*,*,*), crop.100, tree.100). The effect of CO_2 on the allocation of C to roots is set by (CO2IRS(*), crop.100, tree.100) which specifies the proportional increase in the root to shoot ratio at doubled CO_2. A linear relationship of this effect with CO_2 concentration is assumed.

4. Supplementary Material for DayCent

- DayCent extensions
    - DayCent_Photosyn versions with simplified Farquhar photosynthesis
    - UV degradation of surface litter
    - Soil Priming
- Detailed Description of Model Algorithms
    - Soil Organic Matter Model
    - Trace Gas Model
- Spreadsheets for Primary Model Equations
- File100 and Mksitesoil Utilities
- Century/DayCent Reprints

These references should be checked against the EndNote bibliography below:

Forster et al. 2007: Forster, P., Ramaswamy, V., Artaxo, P., Bernsten, T., Betts, R., Fahey, D.W., Haywood, J., Lean, J., Lowe, D.C., Myhre, G., Nganga, J., Prinn, R., Raga, G., Schulz, M., Dorland, R.V. (2007). Changes in Atmospheric Constituents and in Radiative Forcing. In Solomon, S., Quin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M., Miller, H.L. (eds.), Climate Change 2007: The Physical Scientific Basis. Contribution of Working Group 1 to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press.

Hillel, D., 1977. Computer Simulation of Soil–Water Dynamics: A Compendium of Recent Work. International Development Research Center, Ottawa, Canada, pp. 90–94.

Potter et al. "Terrestrial Carbon Sinks for the United States Predicted from MODIS Satellite Data and Ecosystem Modeling", Earth Interactions, Volume 11 (2007), Paper No. 13.

5. Literature Cited

Acock, B. 1990. EFFECTS OF CARBON-DIOXIDE ON PHOTOSYNTHESIS, PLANT-GROWTH, AND OTHER PROCESSES.

Adair, E. C., W. J. Parton, S. J. Del Grosso, W. L. Silver, M. E. Harmon, S. A. Hall, I. C. Burke, and S. C. Hart. 2008. Simple three-pool model accurately describes patterns of long-term litter decomposition in diverse climates. Global Change Biology **14**:2636-2660.

Akita, S., and D. N. Moss. 1973. PHOTOSYNTHETIC RESPONSES TO CO2 AND LIGHT BY MAIZE AND WHEAT LEAVES ADJUSTED FOR CONSTANT STOMATAL APERTURES. Crop Science **13**:234-237.

Balesdent, J., and M. Balabane. 1992. MAIZE ROOT-DERIVED SOIL ORGANIC-CARBON ESTIMATED BY NATURAL C-13 ABUNDANCE. Soil Biology & Biochemistry **24**:97-101.

Balesdent, J., A. Mariotti, and B. Guillet. 1987. NATURAL C-13 ABUNDANCE AS A TRACER FOR STUDIES OF SOIL ORGANIC-MATTER DYNAMICS. Soil Biology & Biochemistry **19**:25-30.

Balesdent, J., G. H. Wagner, and A. Mariotti. 1988. SOIL ORGANIC-MATTER TURNOVER IN LONG-TERM FIELD EXPERIMENTS AS REVEALED BY C-13 NATURAL ABUNDANCE. Soil Science Society of America Journal **52**:118-124.

Bender, M. M. 1971. VARIATIONS IN C-13/C-12 RATIOS OF PLANTS IN RELATION TO PATHWAY OF PHOTOSYNTHETIC CARBON DIOXIDE FIXATION. Phytochemistry **10**:1239-&.

Benner, R., M. L. Fogel, E. K. Sprague, and R. E. Hodson. 1987. DEPLETION OF C-13 IN LIGNIN AND ITS IMPLICATIONS FOR STABLE CARBON ISOTOPE STUDIES. Nature **329**:708-710.

Bonan, G. B., M. D. Hartman, W. J. Parton, and W. R. Wieder. 2013. Evaluating litter decomposition in earth system models with long-term litterbag experiments: an example using the Community Land Model version 4 (CLM4). Global Change Biology **19**:957-974.

Bont, J. A. M. d., K. K. Lee, and D. F. Bouldin. 1978. Bacterial oxidation of methane in a rice paddy. Ecological Bulletin (Stockholm) **26**:91-96.

Burke, I. C., C. M. Yonker, W. J. Parton, C. V. Cole, K. Flach, and D. S. Schimel. 1989. TEXTURE, CLIMATE, AND CULTIVATION EFFECTS ON SOIL ORGANIC-MATTER CONTENT IN US GRASSLAND SOILS. Soil Science Society of America Journal **53**:800-805.

Cao, M. K., J. B. Dent, and O. W. Heal. 1995. Modeling methane emission from rice paddies. Global Biogeochemical Cycles **9**:183-195.

Cerri, C., C. Feller, J. Balesdent, R. Victoria, and A. Plenecassagne. 1985. PARTICLE-SIZE FRACTIONATION AND STABLE CARBON ISOTOPE DISTRIBUTION APPLIED TO THE STUDY OF SOIL ORGANIC-MATTER DYNAMICS. Comptes Rendus De L Academie Des Sciences Serie Ii **300**:423-&.

Cheng, K., S. M. Ogle, W. J. Parton, and G. X. Pan. 2013. Predicting methanogenesis from rice paddies using the DAYCENT ecosystem model. Ecological Modelling **261**:19-31.

Cole, C. V., G. S. Innis, and J. W. B. Stewart. 1977. SIMULATION OF PHOSPHORUS CYCLING IN SEMIARID GRASSLANDS. Ecology **58**:1-15.

Conrad, R. 1989. Control of methane production in terrestrial ecosystems. Pages 39-58 *in* M. O. Andreae and D. S. Schimel, editors. Exchange of Trace Gases Between Terrestrial Ecosystems and the Atmosphere. Wiley, Chichester.

Cooper, A. J. 1973. Root temperature and plant growth; a review. Commonw Bur Hortic Plant Crops Res Rev.

Cure, J. D., and B. Acock. 1986. CROP RESPONSES TO CARBON-DIOXIDE DOUBLING - A LITERATURE SURVEY. Agricultural and Forest Meteorology **38**:127-145.

Del Grosso, S., W. Parton, C. Keough, and M. Reyes-Fox. 2011. Special features of the dayCent modeling package and additional procedures for parameterization, calibration, validation, and applications. Pages 155-176 Soil Science Society of America Special Publication.

Del Grosso, S. J., A. D. Halvorson, and W. J. Parton. 2008. Testing DAYCENT model simulations of corn yields and nitrous oxide emissions in irrigated tillage systems in Colorado. Journal of Environmental Quality **37**:1383-1389.

Del Grosso, S. J., S. M. Ogle, W. J. Parton, and F. J. Breidt. 2010. Estimating uncertainty in N2O emissions from US cropland soils. Global Biogeochemical Cycles **24**.

Del Grosso, S. J., D. S. Ojima, W. J. Parton, E. Stehfest, M. Heistermann, B. DeAngelo, and S. Rose. 2009. Global scale DAYCENT model analysis of greenhouse gas emissions and mitigation strategies for cropped soils. Global and Planetary Change **67**:44-50.

Del Grosso, S. J., W. J. Parton, A. R. Mosier, M. D. Hartman, J. Brenner, D. S. Ojima, and D. S. Schimel. 2001. Simulated interaction of carbon dynamics and nitrogen trace gas fluxes using the DAYCENT model. Pages 303–332 *in* M. S. e. al., editor. Modeling carbon and nitrogen dynamics for soil management. CRC Press, Boca Raton, FL.

Del Grosso, S. J., W. J. Parton, A. R. Mosier, E. A. Holland, E. Pendall, D. S. Schimel, and D. S. Ojima. 2005. Modeling soil CO2 emissions from ecosystems. Biogeochemistry **73**:71-91.

Del Grosso, S. J., W. J. Parton, A. R. Mosier, D. S. Ojima, A. E. Kulmala, and S. Phongpan. 2000a. General model for N2O and N-2 gas emissions from soils due to dentrification. Global Biogeochemical Cycles **14**:1045-1060.

Del Grosso, S. J., W. J. Parton, A. R. Mosier, D. S. Ojima, C. S. Potter, W. Borken, R. Brumme, K. Butterbach-Bahl, P. M. Crill, K. Dobbie, and K. A. Smith. 2000b. General CH4 oxidation model and comparisons of CH4 oxidation in natural and managed systems. Global Biogeochemical Cycles **14**:999-1019.

Del Grosso, S. J., W. J. Parton, A. R. Mosier, M. K. Walsh, D. S. Ojima, and P. E. Thornton. 2006. DAYCENT national-scale simulations of nitrous oxide emissions from cropped soils in the United States. Journal of Environmental Quality **35**:1451-1460.

Eitzinger, J., W. J. Parton, and M. Hartman. 2000. Improvement and validation of a daily soil temperature submodel for freezing/thawing periods. Soil Science **165**:525-534.

Elliott, E. T., and C. A. Cambardella. 1991. PHYSICAL SEPARATION OF SOIL ORGANIC-MATTER. Agriculture Ecosystems & Environment **34**:407-419.

Flerchinger, G. N., and K. E. Saxton. 1989. Simultaneous heat and water model of freezing snow-residue–soil system: I. Theory and development. Trans. ASAE **32**:565-571.

Games, L. M., and J. Hayes. 1976. On the mechanisms of CO2 and CH4 production in natural anaerobic environments. Pages 51-73 *in* J. O. Nriagu, editor. Environmental Biogeochemistry 1: Carbon, nitrogen, phosphorus, sulfur, and selenium cycles. Ann Arbor Science, Ann Arbor.

Gifford, R. M. 1979. CARBON-DIOXIDE AND PLANT-GROWTH UNDER WATER AND LIGHT STRESS - IMPLICATIONS FOR BALANCING THE GLOBAL CARBON BUDGET. Search **10**:316-318.

Gilbert, B., and P. Frenzel. 1995. Methanotrophic bacteria in the rhizosphere of rice micrcosms and their effect on porewater methane concentration and methane emission. Biology and Fertility of Soils **20**:93-100.

Goudriaan, J. 1992. BIOSPHERE STRUCTURE, CARBON SEQUESTERING POTENTIAL AND THE ATMOSPHERIC C-14 CARBON RECORD. Journal of Experimental Botany **43**:1111-1119.

Hedley, M. J., J. W. B. Stewart, and B. S. Chauhan. 1982. CHANGES IN INORGANIC AND ORGANIC SOIL-PHOSPHORUS FRACTIONS INDUCED BY CULTIVATION PRACTICES AND BY LABORATORY INCUBATIONS. Soil Science Society of America Journal **46**:970-976.

Hillel, D. 1977. Computer Simulation of Soil-Water Dynamics: A Compendium of Recent Work (IDRC-082e). International Development Research Centre, Ottawa, Canada.

Hocking, P. J., and C. P. Meyer. 1991a. CARBON-DIOXIDE ENRICHMENT DECREASES CRITICAL NITRATE AND NITROGEN CONCENTRATIONS IN WHEAT. Journal of Plant Nutrition **14**:571-584.

Hocking, P. J., and C. P. Meyer. 1991b. EFFECTS OF CO2 ENRICHMENT AND NITROGEN STRESS ON GROWTH, AND PARTITIONING OF DRY-MATTER AND NITROGEN IN WHEAT AND MAIZE. Australian Journal of Plant Physiology **18**:339-356.

Holland, E. A., W. J. Parton, J. K. Detling, and D. L. Coppock. 1992. PHYSIOLOGICAL-RESPONSES OF PLANT-POPULATIONS TO HERBIVORY AND THEIR CONSEQUENCES FOR ECOSYSTEM NUTRIENT FLOW. American Naturalist **140**:685-706.

Holzapfel-Pschorn, A., R. Conrad, and W. Seiler. 1985. Production, oxidation and emission of methane in rice paddies. FEMS Microbiology Letters **31**:343-351.

Huang, Y., R. L. Sass, and F. M. Fisher. 1998. A semi-empirical model of methane emission from flooded rice paddy soils. Global Change Biology **4**:247-268.

Huang, Y., W. Zhang, X. H. Zheng, J. Li, and Y. Q. Yu. 2004. Modeling methane emission from rice paddies with various agricultural practices. Journal of Geophysical Research **109**:1-12.

Hutchinson, G. L., G. P. Livingston, and E. A. Brams. 1993. Nitric and nitrous oxide evolution from managed subtropical grassland. Pages 290-316 *in* R. S. Oremland, editor. Biogeochemistry of global change: Radiatively active trace gases. Chapman and Hall, Ne York.

Jenkinson, D. S., D. D. Harkness, E. D. Vance, D. E. Adams, and A. F. Harrison. 1992. CALCULATING NET PRIMARY PRODUCTION AND ANNUAL INPUT OF ORGANIC-MATTER

TO SOIL FROM THE AMOUNT AND RADIOCARBON CONTENT OF SOIL ORGANIC-MATTER. Soil Biology & Biochemistry **24**:295-308.

Jenkinson, D. S., and D. S. Powlson. 1976. EFFECTS OF BIOCIDAL TREATMENTS ON METABOLISM IN SOIL .1. FUMIGATION WITH CHLOROFORM. Soil Biology & Biochemistry **8**:167-177.

Jenkinson, D. S., D. S. Powlson, and R. W. M. Wedderburn. 1976. EFFECTS OF BIOCIDAL TREATMENTS ON METABOLISM IN SOIL .3. RELATIONSHIP BETWEEN SOIL BIOVOLUME, MEASURED BY OPTICAL MICROSCOPY, AND FLUSH OF DECOMPOSITION CAUSED BY FUMIGATION. Soil Biology & Biochemistry **8**:189-202.

Jenkinson, D. S., and J. H. Rayner. 1977. TURNOVER OF SOIL ORGANIC-MATTER IN SOME OF ROTHAMSTED CLASSICAL EXPERIMENTS. Soil Science **123**:298-305.

Kelly, R. H., W. J. Parton, G. J. Crocker, P. R. Grace, J. Klir, M. Korschens, P. R. Poulton, and D. D. Richter. 1997. Simulating trends in soil organic carbon in long-term experiments using the century model. Geoderma **81**:75-90.

Kelly, R. H., W. J. Parton, M. D. Hartman, L. K. Stretch, D. S. Ojima, and D. S. Schimel. 2000. Intra-annual and interannual variability of ecosystem processes in shortgrass steppe. Journal of Geophysical Research-Atmospheres **105**:20093-20100.

Kimball, B. A. 1983. CARBON-DIOXIDE AND AGRICULTURAL YIELD - AN ASSEMBLAGE AND ANALYSIS OF 430 PRIOR OBSERVATIONS. Agronomy Journal **75**:779-788.

Kludze, H. K., and R. D. Delanne. 1995. Straw application effects on methane and oxygen exchange and growth in rice. Soil Science Society of America Journal **59**:824-830.

Kuchler, A. W. 1993. Potential natural vegetation of the conterminous United States. Digital vector data in an Albers Equal Area Conic polygon network and derived raster data on a 5 km by 5 km Albers Equal Area 590´940 grid. Global Ecosystems Database Version 2.0. NOAA National Geophysical Data Center, Boulder, CO.

Lenka, N., and R. Lal. 2012. Soil-related constraints to the carbon-dioxide fertilization effect. Critical Reviews in Plant Sciences **31**:342-357.

Li, J. 1999. Model for methane emission from rice paddies and the related reducing techniques. Chinese Academy of Sciences, Beijing.

Linacre, E. T. 1977. SIMPLE FORMULA FOR ESTIMATING EVAPORATION RATES IN VARIOUS CLIMATES, USING TEMPERATURE DATA ALONE. Agricultural Meteorology **18**:409-424.

Long, S. P. 1991. MODIFICATION OF THE RESPONSE OF PHOTOSYNTHETIC PRODUCTIVITY TO RISING TEMPERATURE BY ATMOSPHERIC CO2 CONCENTRATIONS - HAS ITS IMPORTANCE BEEN UNDERESTIMATED. Plant Cell and Environment **14**:729-739.

Macko, S. A., and M. L. Estep. 1984. Microbial alteration of stable nitrogen and carbon isotopic compositions of organic matter. Organic Geochemistry **6**:787-790.

Martin, A., A. Mariotti, J. Balesdent, P. Lavelle, and R. Vuattoux. 1990. ESTIMATE OF ORGANIC-MATTER TURNOVER RATE IN A SAVANNA SOIL BY C-13 NATURAL ABUNDANCE MEASUREMENTS. Soil Biology & Biochemistry **22**:517-523.

Martin, R. E., M. C. Scholes, A. R. Mosier, D. S. Ojima, E. A. Holland, and W. J. Parton. 1998. Controls on annual emissions of nitric oxide from soils of the Colorado shortgrass steppe. Global Biogeochemical Cycles **12**:81-91.

Matthews, R. B., R. Wassmann, and J. Arah. 2000. Using a crop/soil simulation model and GIS techniques to assess methane emission from rice fields in Asia. I. Model development. Nutrient Cycling in Agroecosystems **58**:141-159.

Mc Grath, J. M., and D. B. Lobell. 2013. Regional disparities in the CO2 fertilization effect and implications for crop yields. Environmental Research Letters **8**.

McGill, W. B., and C. V. Cole. 1981. Comparative aspects of cycling of organic C, N, S and P through soil organic matter. Geoderma **28**:267-286.

Metherell, A. K. 1992. Simulation of soil organic matter dynamics and nutrient cycling in agroecosystems. Ph.D. Colorado State University, Ann Arbor.

Metherell, A. K., C. V. Cole, and W. J. Parton. 1993a. Dynamics and interactions of carbon, nitrogen, phosphorus, and sulphur cycling in grazed pastures.*in* XVII International Grassland Congress.

Metherell, A. K., L. A. Harding, C. V. Cole, and W. J. Parton. 1993b. CENTURY: soil organic matter model. Technical Document Tech Report Number 4, USDA-ARS, Fort Collins, Colorado, USA.

Monteith, J. L. 1981. CLIMATIC VARIATION AND THE GROWTH OF CROPS. Quarterly Journal of the Royal Meteorological Society **107**:749-774.

Morison, J. I. L., and R. M. Gifford. 1984a. PLANT-GROWTH AND WATER-USE WITH LIMITED WATER-SUPPLY IN HIGH CO2 CONCENTRATIONS .1. LEAF-AREA, WATER-USE AND TRANSPIRATION. Australian Journal of Plant Physiology **11**:361-374.

Morison, J. I. L., and R. M. Gifford. 1984b. PLANT-GROWTH AND WATER-USE WITH LIMITED WATER-SUPPLY IN HIGH CO2 CONCENTRATIONS .2. PLANT DRY-WEIGHT, PARTITIONING AND WATER-USE EFFICIENCY. Australian Journal of Plant Physiology **11**:375-384.

Moss, D. N., R. B. Musgrave, and E. R. Lemon. 1961. Photosynthesis Under Field Conditions. III. Some Effects of Light, Carbon Dioxide, Temperature, and Soil Moisture on Photosynthesis, Respiration, and Transpiration of Corn1. Crop Sci. **1**:83-87.

Nouchi, I. 1994. Mechanisms of methane transport through rice plants. Pages 87-104 *in* K. Minami, A. Mosier, and R. Sass, editors. CH4 and N2O: Global Emission and Controls from Rice Fields and Other Agricultural and Industrial Sources. Yokendo, Tokyo, Japan.

Ojima, D. S., W. J. Parton, D. S. Schimel, and C. E. Owensby. 1990. Simulated impacts of annual burning on prairie ecosystems.*in* S. L. Collins and L. Wallances, editors. Fire in North American Tallgrass Prairies. University of Oklahoma Press, Norman, Oklahoma.

Parashar, D. C., P. K. Gupta, J. Rai, and S. N. Singh. 1993. Effect of soil temperature on methane emission from paddy fields. Chemosphere **26**.

Parton, W., W. L. Silver, I. C. Burke, L. Grassens, M. E. Harmon, W. S. Currie, J. Y. King, E. C. Adair, L. A. Brandt, S. C. Hart, and B. Fasth. 2007a. Global-scale similarities in nitrogen release patterns during long-term decomposition. Science **315**:361-364.

Parton, W. J. 1978. Abiotic section of ELM. Pages 31-53 *in* G. S. Innis, editor. Grassland Simulation Model, Ecol. Studies, Vol. 26. Springer-Verlag, Inc., New York.

Parton, W. J. 1984. Predicting soil temperatures in a shortgrass steppe. Soil Science **138**:93-101.

Parton, W. J., C. V. Cole, J. W. B. Stewart, D. S. Ojima, and D. S. Schimel. 1989. Simulating regional patters of soil C, N, and P dynamics in the U.S. central grasslands region. Pages 99-108 *in* M. Clarholm and L. Bergstrom, editors. Ecology of Arable Land. Kluwer Academic Publishers.

Parton, W. J., M. Hartman, D. Ojima, and D. Schimel. 1998. DAYCENT and its land surface submodel: description and testing. Global and Planetary Change **19**:35-48.

Parton, W. J., E. A. Holland, S. J. Del Grosso, M. D. Hartman, R. E. Martin, A. R. Mosier, D. S. Ojima, and D. S. Schimel. 2001. Generalized model for NOx and N2O emissions from soils. Journal of Geophysical Research-Atmospheres **106**:17403-17419.

Parton, W. J., R. McKeown, V. Kirchner, and D. Ojima. 1992. Users guide for the CENTURY model. Colorado State University.

Parton, W. J., J. A. Morgan, G. M. Wang, and S. Del Grosso. 2007b. Projected ecosystem impact of the Prairie Heating and CO2 Enrichment experiment. New Phytologist **174**:823-834.

Parton, W. J., A. R. Mosier, D. S. Ojima, D. W. Valentine, D. S. Schimel, K. Weier, and A. E. Kulmala. 1996. Generalized model for N-2 and N2O production from nitrification and denitrification. Global Biogeochemical Cycles **10**:401-412.

Parton, W. J., D. S. Ojima, C. V. Cole, and D. S. Schimel. 1994. A GENERAL MODEL FOR SOIL ORGANIC MATTER DYNAMICS - SENSITIVITY TO LITTER CHEMISTRY, TEXTURE AND MANAGEMENT. Pages 147-167 *in* R. B. Bryant and R. W. Arnold, editors. Quantitative Modeling of Soil Forming Processes.

Parton, W. J., D. S. Schimel, C. V. Cole, and D. S. Ojima. 1987. ANALYSIS OF FACTORS CONTROLLING SOIL ORGANIC-MATTER LEVELS IN GREAT-PLAINS GRASSLANDS. Soil Science Society of America Journal **51**:1173-1179.

Parton, W. J., R. J. Scholes, K. Day, J. Carter, and R. Kelly. 2011. CENTURY-SAVANNA model for tree–grass ecosystem. Pages 443–462 *in* M. J. Hill and N. P. Hanan, editors. Ecosystem function in savanahs:Measurement and modeling at landscape to global scales. CRC Press, Boca Raton, FL.

Parton, W. J., J. M. O. Scurlock, D. S. Ojima, T. G. Gilmanov, R. J. Scholes, D. S. Schimel, T. Kirchner, J. C. Menaut, T. Seastedt, E. G. Moya, A. Kamnalrut, and J. I. Kinyamario. 1993. OBSERVATIONS AND MODELING OF BIOMASS AND SOIL ORGANIC-MATTER DYNAMICS FOR THE GRASSLAND BIOME WORLDWIDE. Global Biogeochemical Cycles **7**:785-809.

Parton, W. J., J. M. O. Scurlock, D. S. Ojima, D. S. Schimel, D. O. Hall, M. B. Coughenour, E. Garcia Moya, T. G. Gilmanov, A. Kamnalrut, J. I. Kinyamario, T. Kirchner, T. G. F. Kittel, J. C. Menaut, O. E. Sala, R. J. Scholes, J. A. van Veen, and S. G. Members. 1995. IMPACT OF CLIMATE-CHANGE ON GRASSLAND PRODUCTION AND SOIL CARBON WORLDWIDE. Global Change Biology **1**:13-22.

Parton, W. J., J. W. B. Stewart, and C. V. Cole. 1988. DYNAMICS OF C, N, P AND S IN GRASSLAND SOILS - A MODEL. Biogeochemistry **5**:109-131.

Paul, E. A., and D. A. Clark. 1989. Soil Microbiology and Biogeochemistry. Academic, San Diego, California.

Penman, H. L. 1948. Natural evaporation from open water, bare soil and grass. Proc. R. Soc. London **Ser. A.**:120-145.

Pepper, D. A., S. J. Del Grosso, R. E. McMurtrie, and W. J. Parton. 2005. Simulated carbon sink response of shortgrass steppe, tallgrass prairie and forest ecosystems to rising CO2 , temperature and nitrogen input. Global Biogeochemical Cycles **19**.

Potter, C., S. Klooster, A. Huete, and V. Genovese. 2007. Terrestrial Carbon Sinks for the United States Predicted from MODIS Satellite Data and Ecosystem Modeling. Earth Interactions **11**.

Potter, C. S., E. A. Davidson, and L. V. Verchot. 1996. Estimation of global biogeochemical controls and seasonality in soil methane consumption. Chemosphere **32**:2219-2246.

Rogers, H. H., G. E. Bingham, J. D. Cure, J. M. Smith, and K. A. Surano. 1983. RESPONSES OF SELECTED PLANT-SPECIES TO ELEVATED CARBON-DIOXIDE IN THE FIELD. Journal of Environmental Quality **12**:569-574.

Sass, R. L., F. M. Fisher, Y. B. Wang, F. T. Turner, and M. F. Jund. 1992. Methane emission from rice paddies: the effect of floodwater management. Global Biogeochemical Cycles **6**.

Saxton, K. E., and W. J. Rawls. 2006. Soil water characteristic estimates by texture and organic matter for hydrologic solutions. Soil Science Society of America Journal **70**:1569-1578.

Schmitt, M. R., and G. E. Edwards. 1981. PHOTOSYNTHETIC CAPACITY AND NITROGEN USE EFFICIENCY OF MAIZE, WHEAT, AND RICE - A COMPARISON BETWEEN C-3 AND C-4 PHOTOSYNTHESIS. Journal of Experimental Botany **32**:459-466.

Schutz, H., W. Seiler, and R. Conrad. 1989. Processes involved in formation and emission of methane in rice paddies. Biogeochemistry **7**:33-53.

Schutz, H., W. Seiler, and R. Conrad. 1990. Influence of soil temperature on methane emission from rice paddy fields. Biogeochemistry **11**:77-95.

Schwartz, D., A. Mariotti, R. Lanfranchi, and B. Guillet. 1986. C-13/C-12 RATIOS OF SOIL ORGANIC-MATTER AS INDICATORS OF VEGETATION CHANGES IN THE CONGO. Geoderma **39**:97-103.

Seiler, W., A. Holzapfel-Pschorn, R. Conrad, and D. Scharffe. 1984. Methane emission from rice paddies. Journal of Atmospheric Chemistry **1**:241-268.

Shangguan, X. J., and M. X. Wang. 1993. Possible measures for the reduction of methane emission from rice paddy fields. Adv. Earth Sci. **8**:55-62.

Shearer, M. J., and M. A. K. Khalil. 1993. Rice agriculture emissions. Pages 230-253 *in* M. A. K. Kahlil, editor. Atmospheric Methane: Sources, Sinks, and Role in Global Change. Springer-Verlag, Berlin.

Sinclair, T. R. 1992. MINERAL-NUTRITION AND PLANT-GROWTH RESPONSE TO CLIMATE CHANGE. Journal of Experimental Botany **43**:1141-1146.

Smart, D. R., J. M. Stark, and V. Diego. 1999. Resource limitations to nitric oxide emissions from a sagebrush-steppe ecosystem. Biogeochemistry **47**:63-86.

Smith, B. N., and S. Epstein. 1971. 2 CATEGORIES OF C-13/C-12 RATIOS FOR HIGHER PLANTS. Plant Physiology **47**:380-&.

Stout, J. D., K. M. Goh, and T. A. Rafter. 1981. Chemistry and turnover of naturally occurring resistant organic compounds in soil. Pages 1-73 *in* E. A. Paul and J. N. Ladd, editors. Soil Biochemistry.

Stout, J. D., and T. A. Rafter. 1978. The 13C/12C isotopic rations of some New Zealand tussock grassland soil. Pages 75-83 *in* B. W. Robinson, editor. Stable isotopes in the Earth Sciences. Science Information Division, DSIR, Wellington.

Thornton, P., and S. Running. 1999a. An improved algorithm for estimating incident daily solar radiation from measurements of temperature, humidity, and precipitation. Agricultural and Forest Meteorology **93**:211-228.

Thornton, P. E., H. Hasenauer, and M. A. White. 2000. Simultaneous estimation of daily solar radiation and humidity from observed temperature and precipitation: an application over complex terrain in Austria. Agricultural and Forest Meteorology **104**:255-271.

Thornton, P. E., and S. W. Running. 1999b. An improved algorithm for estimating incident daily solar radiation from measurements of temperature, humidity, and precipitation. Agricultural and Forest Meteorology **93**:211-228.

Thornton, P. E., S. W. Running, and M. A. White. 1997. Generating surfaces of daily meteorological variables over large regions of complex terrain. Journal of Hydrology **190**:214-251.

van Bodegon, P., F. Stams, L. Mollema, S. Boeke, and P. Leffelaar. 2001. Methane oxidation and competition for oxygen in the rice rhizosphere. Applied and Environ. Microbiol. **67**:3586-3597.

van Heemst, H. D. J. 1986. Physiological principles. Pages 13-26 *in* H. van Keulen and J. Wolf, editors. Modelling of agricultural production: weather, soils and crops. Pudoc Wageningen.

Wassmann, R., H. U. Neue, M. C. R. Alberto, R. S. Lantin, C. Bueno, D. Llenaresas, J. R. M. Arah, H. Papen, W. Seiler, and H. Rennenberg. 1996. Fluxes and pools of methane in wetland rice soil with varying organic inputs. Environmental Monitoring and Assessment **42**:163-173.

Wong, S. C. 1979. ELEVATED ATMOSPHERIC PARTIAL-PRESSURE OF CO2 AND PLANT-GROWTH .1. INTERACTIONS OF NITROGEN NUTRITION AND PHOTOSYNTHETIC CAPACITY IN C-3 AND C-4 PLANTS. Oecologia **44**:68-74.

Yarie, J., and B. Parton. 2005. Potential changes in carbon dynamics due to climate change measured in the past two decades. Canadian Journal of Forest Research-Revue Canadienne De Recherche Forestiere **35**:2258-2267.

Yienger, J. J., and H. Levy. 1995. EMPIRICAL-MODEL OF GLOBAL SOIL-BIOGENIC NOX EMISSIONS. Journal of Geophysical Research-Atmospheres **100**:11447-11464.

Zhang, Y., C. S. Li, C. C. Trettin, H. B. Li, and G. Sun. 2002. An integrated model of soil, hydrology, and vegetation for carbon dynamics in wetland ecosystems. Global Biogeochemical Cycles **16**.

Appendix 1

Warning this is a DRAFT document. The parameter ranges in the tables have not been reviewed.

Appendix 1.1 Crop/grass parameters (crop.100)

These crop.100 parameters are read for the initial crop/grass specified in the schedule file header, and for each subsequent crop/grass introduced in the schedule file with a CROP event.

prdx(1)	Coefficient for calculating total monthly potential production as a function of solar radiation outside the atmosphere. It functions as a radiation use efficiency scalar on potential production. It reflects the relative genetic potential of the plant; larger PRDX(1) values indicate greater growth potential.	scaling factor, (gC production) $*m^{-2}$ $*month^{-1}$ $*Langley^{-1}$	0.1 – 5.0
ppdf(1)	Optimum temperature for production for parameterization of a Poisson Density Function curve to simulate temperature effect on growth.	°C	10.0 – 40.0
ppdf(2)	Maximum temperature for production for parameterization of a Poisson Density Function curve to simulate temperature effect on growth.	°C	20.0 – 50.0
ppdf(3)	Right curve shape for parameterization of a Poisson Density Function curve to simulate temperature effect on growth.		0.0 – 1.0

ppdf(4)	Right curve shape for parameterization of a Poisson Density Function curve to simulate temperature effect on growth.		0.0 – 10.0
bioflg	Flag indicating whether production should be reduced by physical obstruction; 0=production should not be reduced; 1=production should be reduced.	index	0, 1
biok5	Level of aboveground standing dead + 10% strucc(1) C at which production is reduced to half maximum due to physical obstruction by dead material. Used only when ***bioflag*** = 1.	g C m^{-2}	0.0 – 2000.0
pltmrf	Planting month reduction factor to limit seedling growth; set to 1.0 for grass.	fraction	0.0 – 1.0
fulcan	Value of above ground live C (aglivc) at full canopy cover, above which potential production is not reduced. (Above which there is no restriction on seedling growth).	g C m^{-2}	50.0 – 200.0
frtcindx	**0** - use Great Plains equation to compute root to shoot ratio (fixed carbon allocation based on rainfall, perennial plant); **1** - perennial plant; **2** - annual plant; **3** - perennial plant, growing degree day; **4** - non-grain filling annual plant, growing degree day implementation; **5** - grain filling annual plant, growing degree day implementation; **6** - grain filling annual plant that requires a vernalization period (i.e. winter wheat), growing degree day implementation	index	0, 1, 2, 3, 4, 5, 6
frtc(1)	Fraction of C allocated to roots at planting, with no water or nutrient stress, used when FRTCINDX = 2, 4, 5, or 6.	fraction	0.0 – 1.0

frtc(2)	Fraction of C allocated to roots at time FRTC(3), with no water or nutrient stress, used when FRTCINDX = 2, 4, 5, or 6.	fraction	0.0 – 1.0
frtc(3)	Time after planting (days with soil temperature greater than RTDTMP) at which the FRTC(2) value is reached, used when FRTCINDX = 2, 4, 5, or 6.	number of days	
frtc(4)	Maximum increase in the fraction of C going to the roots due to water stress, used when FRTCINDX = 2, 4, 5, or 6.	fraction	0.0 – 1.0
frtc(5)	Maximum increase in the fraction of C going to the roots due to nutrient stress, used when FRTCINDX = 2, 4, 5, or 6.	fraction	0.0 – 1.0
cfrtcn(1)	Maximum fraction of C allocated to roots under maximum nutrient stress, used when FRTCINDX = 1 or 3.	fraction	0.0 – 1.0
cfrtcn(2)	Minimum fraction of C allocated to roots with no nutrient stress, used when FRTCINDX = 1 or 3.	fraction	0.0 – 1.0
cfrtcw(1)	Maximum fraction of C allocated to roots under maximum water stress, used when FRTCINDX = 1 or 3.	fraction	0.0 – 1.0
cfrtcw(2)	Minimum fraction of C allocated to roots with no water stress, used when FRTCINDX = 1 or 3.	fraction	0.0 – 1.0
biomax	Aboveground biomass level above which the minimum and maximum C/E ratios of new shoot increments equal pramn(*,2) and pramx(*,2) respectively.	g biomass m^{-2}	0 – 1000
pramn(1,1)	Minimum aboveground C/N ratio with zero biomass.	C/N ratio	1.0 – 100.0

pramn(2,1)	Minimum aboveground C/P ratio with zero biomass.	C/P ratio	1.0 – 9999.0
pramn(3,1)	Minimum aboveground C/S ratio with zero biomass.	C/S ratio	1.0 – 9999.0
pramn(1,2)	Minimum aboveground C/N ratio with biomass > biomax.	C/N ratio	1.0 – 200.0
pramn(2,2)	Minimum aboveground C/P ratio with biomass > biomax.	C/P ratio	1.0 – 9999.0
pramn(3,2)	Minimum aboveground C/S ratio with biomass > biomax.	C/S ratio	1.0 – 9999.0
pramx(1,1)	Maximum aboveground C/N ratio with zero biomass.	C/N ratio	1.0 – 200.0
pramx(2,1)	Maximum aboveground C/P ratio with zero biomass.	C/P ratio	1.0 – 9999.0
pramx(3,1)	Maximum aboveground C/S ratio with zero biomass.	C/S ratio	1.0 – 9999.0
pramx(1,2)	Maximum aboveground C/N ratio with biomass > biomax.	C/N ratio	1.0 – 400.0
pramx(2,2)	Maximum aboveground C/P ratio with biomass > biomax.	C/P ratio	1.0 – 9999.0
pramx(3,2)	Maximum aboveground C/S ratio with biomass > biomax.	C/S ratio	1.0 – 9999.0
prbmn(1,1)	(N, intercept) parameter for computing minimum C/N ratio for belowground matter as a linear function of annual precipitation.	C/N ratio	1.0 – 150.0
prbmn(2,1)	(P, intercept) parameter for computing minimum C/P ratio for belowground matter as a linear function of annual precipitation.	C/P ratio	0.0 – 9999.0
prbmn(3,1)	(S, intercept) parameter for computing minimum C/S ratio for belowground matter as a linear function of annual precipitation.	C/S ratio	0.0 – 9999.0

prbmn(1,2)	(N, slope) parameter for computing minimum C/N ratio for belowground matter as a linear function of annual precipitation.	change in C/N ratio per cm precipitation	0.0 – 1.0
prbmn(2,2)	(P, slope) parameter for computing minimum C/P ratio for belowground matter as a linear function of annual precipitation.	change in C/P ratio per cm precipitation	0.0 – 9999.0
prbmn(3,2)	(S, slope) parameter for computing minimum C/S ratio for belowground matter as a linear function of annual precipitation.	change in C/S ratio per cm precipitation	0.0 – 9999.0
prbmx(1,1)	(N, intercept) parameter for computing maximum C/N ratio for belowground matter as a linear function of annual precipitation.	C/N ratio	0.0 – 300.0
prbmx(2,1)	(P, intercept) parameter for computing maximum C/P ratio for belowground matter as a linear function of annual precipitation.	C/P ratio	0.0 – 9999.0
prbmx(3,1)	(S, intercept) parameter for computing maximum C/S ratio for belowground matter as a linear function of annual precipitation.	C/S ratio	0.0 – 9999.0
prbmx(1,2)	(N, slope) parameter for computing maximum C/N ratio for belowground matter as a linear function of annual precipitation.	change in C/N ratio per cm precipitation	0.0 – 1.0
prbmx(2,2)	(P, slope) parameter for computing maximum C/P ratio for belowground matter as a linear function of annual precipitation.	change in C/P ratio per cm precipitation	0.0 – 1.0

prbmx(3,2)	(S, slope) parameter for computing maximum C/S ratio for belowground matter as a linear function of annual precipitation.	change in C/S ratio per cm precipitation	0.0 – 1.0
fligni(1,1)	Intercept for equation to predict lignin content fraction based on annual rainfall for aboveground material.	g lignin C / g C	0.0 – 1.0
fligni(2,1)	Slope for equation to predict lignin content fraction based on annual rainfall for aboveground material. For crops, set to 0.	change in lignin fraction per cm precipitation	0.0 – 1.0
fligni(1,2)	Intercept for equation to predict lignin content fraction based on annual rainfall for juvenile fine root material.	g lignin C / g C	0.0 – 1.0
fligni(2,2)	Slope for equation to predict lignin content fraction based on annual rainfall for juvenile fine root material. For crops, set to 0.	change in lignin fraction per cm precipitation	0.0 – 1.0
fligni(1,3)	Intercept for equation to predict lignin content fraction based on annual rainfall for mature live fine root material	g lignin C / g C	0.0 – 1.0
fligni(2,3)	Slope for equation to predict lignin content fraction based on annual rainfall for mature live fine root material. For crops, set to 0.	change in lignin fraction per cm precipitation	0.0 – 1.0
himax	Maximum harvest index maximum, the fraction of aboveground live C (aglivc) allocated to grain at the time of harvest.	fraction	0.0 – 1.0
hiwsf	Harvest index water stress factor: 0=no effect of water stress; 1= no grain yield with maximum water stress.	fraction	0 – 1

himon(1)	Number of months prior to harvest in which to begin accumulating water stress effect on harvest index.	number of months	1 – 12
himon(2)	Number of months prior to harvest in which to stop accumulating water stress effect on harvest index.	number of months	1 – 12
efrgrn(1)	Fraction of above ground N which goes to grain.	fraction	0.0 – 1.0
efrgrn(2)	Fraction of above ground P which goes to grain.	fraction	0.0 – 1.0
efrgrn(3)	Fraction of above ground S which goes to grain.	fraction	0.0 – 1.0
vlossp	Fraction of above ground plant N which is volatilized (occurs during harvest and death).	fraction	0.0 – 1.0
fsdeth(1)	Maximum shoot death rate at very dry soil conditions (fraction/month); to get the monthly shoot death rate, this fraction is multiplied by a reduction factor depending on the soil water status.	fraction	0.0 – 1.0
fsdeth(2)	Fraction of shoots which die during senescence month; must be ≥ 0.4.	fraction	0.4 – 1.0
fsdeth(3)	Additional fraction of shoots which die when aboveground live C is greater than fsdeth(4).	fraction	0.0 – 1.0
fsdeth(4)	Level of aboveground C above which shading occurs and shoot senescence increases.	g C m^{-2}	0.0 – 500.0
fallrt	Fall rate (fraction of standing dead which falls each month).	fraction	0.0 – 1.0

rdrj	Maximum juvenile fine root death rate at very dry soil conditions (fraction/month); to get the monthly root death rate, this fraction is multiplied by a reduction fraction depending on the soil water status.	fraction	0.0 – 1.0
rdrm	Maximum mature fine root death rate at very dry soil conditions (fraction/month); to get the monthly root death rate, this fraction is multiplied by a reduction fraction depending on the soil water status.	fraction	0.0 – 1.0
rdsrfc	Fraction of the fine roots that are transferred into the surface litter layer (SRTUCC(1) and METABC(1)) upon root death, the remainder of the roots will go to the soil litter layer (STRUCC(2) and METABC(2))	fraction	0.0 – 1.0
rtdtmp	This parameter is used to determine the number of days since planting (number of days where soil temperature >= rtdtmp). In turn, the number of days since planting is used to determine fine root allocation for annual plants. See frtc(3).	°C	-5.0 – 5.0
crprtf(1)	Fraction of N retranslocated from grass/crop leaves at death.	fraction	0.0 – 1.0
crprtf(2)	Fraction of P retranslocated from grass/crop leaves at death.	fraction	0.0 – 1.0
crprtf(3)	Fraction of S retranslocated from grass/crop leaves at death.	fraction	0.0 – 1.0
mrtfrac	Fraction of fine root production that goes into mature roots.	fraction	0.0 – 1.0
snfxmx(1)	Symbiotic N fixation maximum for grass/crop.	g N fixed/g C new growth	0.0 – 1.0

del13c	Delta 13C value for stable isotope labeling		-30.0 – 0.0
co2ipr(1)	In a grass/crop system, the effect on plant production ratio of doubling the atmospheric CO_2 concentration from 350 ppm to 700 ppm.		0.5 – 1.5
co2itr(1)	In a grass/crop system, the effect on transpiration rate of doubling the atmospheric CO_2 concentration from 350 ppm to 700 ppm.		0.5 – 1.5
co2ice(1,*,*)	**In a grass/crop system, the effect on C/E ratios of doubling the atmospheric CO_2 concentration from 350 ppm to 700 ppm**		
co2ice(1,1,1)	(1,1,1) = minimum C/N; in a grass/crop system, the effect on C/E ratios of doubling the atmospheric CO_2 concentration from 350 ppm to 700 ppm.	C/N ratio	0.5 – 1.5
co2ice(1,1,2)	(1,1,2) = minimum C/P; in a grass/crop system, the effect on C/E ratios of doubling the atmospheric CO_2 concentration from 350 ppm to 700 ppm.	C/P ratio	0.5 – 1.5
co2ice(1,1,3)	(1,1,3) = minimum C/S; in a grass/crop system, the effect on C/E ratios of doubling the atmospheric CO_2 concentration from 350 ppm to 700 ppm.	C/S ratio	0.5 – 1.5
co2ice(1,2,1)	(1,2,1) = maximum C/N; in a grass/crop system, the effect on C/E ratios of doubling the atmospheric CO_2 concentration from 350 ppm to 700 ppm.	C/N ratio	0.5 – 1.5

co2ice(1,2,2)	(1,2,2) = maximum C/P; in a grass/crop system, the effect on C/E ratios of doubling the atmospheric CO_2 concentration from 350 ppm to 700 ppm.	C/P ratio	0.5 – 1.5
co2ice(1,2,3)	(1,2,3) = maximum C/S; in a grass/crop system, the effect on C/E ratios of doubling the atmospheric CO_2 concentration from 350 ppm to 700 ppm.	C/S ratio	0.5 – 1.5
co2irs(1)	In a grass/crop system, the effect on root/shoot ratio of doubling the atmospheric CO_2 concentration from 350 ppm to 700 ppm.		0.5 – 1.5
ckmrspmx(1)	Maximum fraction of aboveground live C that goes to maintenance respiration for crops.	fraction	0.0 – 1.0
ckmrspmx(2)	Maximum fraction of belowground juvenile root C that goes to maintenance respiration for crops.	fraction	0.0 – 1.0
ckmrspmx(3)	Maximum fraction of belowground mature root C that goes to maintenance respiration for crops.	fraction	0.0 – 1.0
cmrspnpp(1)	X1 value for line function that decreases maintenance respiration based on predicted aboveground production when the amount of carbon in the carbohydrate storage pool is less than (CMRSPNPP(3) * predicted aboveground production) for a grass/crop system		
cmrspnpp(2)	Y1 value for line function that decreases maintenance respiration based on predicted aboveground production when the amount of carbon in the carbohydrate storage pool is less than (CMRSPNPP(3) * predicted aboveground production) for a grass/crop system		

cmrspnpp(3)	X2 value for line function that decreases maintenance respiration based on predicted aboveground production when the amount of carbon in the carbohydrate storage pool is less than (CMRSPNPP(3) * predicted aboveground production) for a grass/crop system -OR- X1 value for line function that decreases maintenance respiration based on predicted aboveground production when the amount of carbon in the carbohydrate storage pool is between (CMRSPNPP(3) * predicted aboveground production) and (CMRSPNPP(5) * predicted aboveground production) for a grass/crop system		
cmrspnpp(4)	Y2 value for line function that decreases maintenance respiration based on predicted aboveground production when the amount of carbon in the carbohydrate storage pool is less than (CMRSPNPP(3) * predicted aboveground production) for a grass/crop system -OR- Y1 value for line function that decreases maintenance respiration based on predicted aboveground production when the amount of carbon in the carbohydrate storage pool is between (CMRSPNPP(3) * predicted aboveground production) and (CMRSPNPP(5) * predicted aboveground production) for a grass/crop system		
cmrspnpp(5)	X2 value for line function that decreases maintenance respiration based on predicted aboveground production when the amount of carbon in the carbohydrate storage pool is between (CMRSPNPP(3) * predicted aboveground production)and (CMRSPNPP(5) * predicted aboveground production) for a grass/crop system		

cmrspnpp(6)	Y2 value for line function that decreases maintenance respiration based on predicted aboveground production when the amount of carbon in the carbohydrate storage pool is between (CMRSPNPP(3) * predicted aboveground production) and (CMRSPNPP(5) * predicted aboveground production) for a grass/crop system -OR- Y value for line function that decreases maintenance respiration based on predicted aboveground production when the amount of carbon in the carbohydrate storage pool is greater than (CMRSPNPP(5)*predicted aboveground production) for a grass/crop system		
cgresp(1)	Maximum fraction of aboveground live C that goes to growth respiration for crops.	fraction	0.0 – 1.0
cgresp(2)	Maximum fraction of juvenile fine root live C that goes to growth respiration for crops.	fraction	0.0 – 1.0
cgresp(3)	Maximum fraction of mature fine root live C that goes to growth respiration for crops.	fraction	0.0 – 1.0
no3pref(1)	Maximum fraction of plant N uptake from NO_3-N. The remaining N uptake comes from NH_4-N. THIS PARAMETER IS NO LONGER USED IN THE MODEL!	fraction	0.0 – 1.0
claypg	Number of soil layers that crop roots can occupy. The value used as CLAYPG for annual plants will vary from 1 on the day that plant growth starts to CLAYPG as read from the CROP option on day FRTC(3) of plant growth	number of soil layers	1 - 9

cmix	Annual rate of mixing of surface SOM2C and soil SOM2C for grass/crop system, this value will also be used when running a savanna.	yr^{-1}	0.0 – 1.0
ddemerge	Number of growing degree days that need to accumulate after the PLTM event in order for plant emergence to occur when FRTCINDX = 4, 5, or 6.	number of degree days	
ddbase	Number of degree days required to trigger a senescence (SENM) event for a perennial (FRTCINDX = 3), maturity and harvest (HARV) for a non-grain filling annual (FRTCINDX = 4), or to reach anthesis (flowering) for a grain filling annual (FRTCINDX = 5 or 6).	number of degree days	
tmpkill	Temperature at which growth will stop when using the growing degree day submodel, will cause a SENM and LAST event when FRTCINDX = 3 or a HARV and LAST event if FRTCINDX = 4, 5, or 6, if the required number of thermal units have not been accumulated prior to trigger a SENM or a HARV event.	°C	
basetemp(1)	Base temperature for crop growth, growing degree days will accumulate only on days when the average temperature (a weighted average of the minimum and maximum daily temperature) is greater than the base temperature for the crop.	°C	
basetemp(2)	Ceiling on the maximum temperature used to compute the average temperature (a weighted average of the minimum and maximum daily temperature) for the growing degree day accumulation.	°C	

mnddhrv	Minimum number of degree days from anthesis (flowering) to harvest for grain filling annuals (FRTCINDX = 5 or 6) when there is full water stress.	number of degree days (°C)	
mxddhrv	Maximum number of degree days from anthesis (flowering) to harvest for grain filling annuals (FRTCINDX = 5 or 6) (no water stress).	number of degree days (°C)	
curgdys	Number of days of unrestricted growth in a grass/crop system.	number of days	
clsgres	Grass/crop late season growth restriction factor.		0.0 – 1.0
cmxturn	Maximum turnover rate per month of juvenile fine roots to mature fine roots through aging	fraction	0.0 – 1.0
wscoeff(1,1)	Water Stress Coefficient used to calculate the water stress multiplier on potential growth based on the relative water content of the wettest soil layer in the rooting zone (*maxrwcf, 0-1*). $\frac{1.0}{1.0+\exp\left(wscoeff\left(1,2\right)*\left(wscoeff\left(1,1\right)-maxrwcf\right)\right)}$	See h2ogef_calc.xlsx	0.2 – 0.5
wscoeff(1,2)	Water Stress Coefficient used to calculate the water stress multiplier on potential growth based on the relative water content of the wettest soil layer in the rooting zone. See comments above	See h2ogef_calc.xlsx	6.0 – 30.0
ps2mrsp(1)	Fraction of photosynthesis that goes to maintenance respiration.	fraction	0.0 – 1.0

sfavail(1)	Fraction of N available per day to plants. Formerly FAVAIL(1) in fix.100.		0.0 – 1.0
Photosynthesis parameters only			
amax(1)	Maximum net CO_2 assimilation rate assuming maximum possible PAR, all intercepted, no temperature, water or vapor pressure deficit stress.	nmol CO_2 g^{-1} (leaf biomass) sec^{-1}	
amaxfrac(1)	Average daily maximum photosynthesis as a fraction of amax.	fraction	0.0 – 1.0
amaxscalar1(1)	Multiplier used to adjust aMax based on growthDays1 days since germination	scalar	
amaxscalar2(1)	Multiplier used to adjust aMax based on growthDays2 days since germination.	scalar	0.8 – 1.6
amaxscalar3(1)	Multiplier used to adjust aMax based on growthDays3 days since germination.	scalar	0.7 – 1.5
amaxscalar4(1)	Multiplier used to adjust aMax based on growthDays4 days since germination.	scalar	0.3 – 0.8
attenuation(1)	Light attenuation coefficient.		
basefolrespfrac(1)	Basal foliage respiration rate, as percentage of maximum net photosynthesis rate.		
cfracleaf(1)	Factor for converting leaf biomass to carbon (leaf biomass * cFracLeaf = leaf carbon).	g C / g biomass	

dvpdexp(1)	Exponential value in vapor pressure deficit effect on photosynthesis equation. dVpd = dVpdSlope * exp(vpd*dVpdExp)		
dvpdslope(1)	Slope value in vapor pressure deficit effect on photosynthesis equation. dVpd = dVpdSlope * exp(vpd*dVpdExp)		
growthdays1(1)	Number of days after germination to start using aMaxScalar1.	number of days	
growthdays2(1)	Number of days after germination to start using aMaxScalar2.	number of days	
growthdays3(1)	Number of days after germination to start using aMaxScalar3.	number of days	
growthdays4(1)	Number of days after germination to start using aMaxScalar4.	number of days	
halfsatpar(1)	Photosynthetically active radiation (PAR) at which photosynthesis occurs at 1/2 of theoretical maximum.	Einsteins * m^{-2} ground area * day^{-1}	
leafcspwt(1)	Grams of carbon in a square meter of leaf area.	g C m^{-2} leaf area	
psntmin(1)	Minimum temperature at which net photosynthesis occurs.	°C	
psntopt(1)	Optimal temperature at which net photosynthesis occurs.	°C	

Appendix 1.2 Cultivation parameters (cult.100)

These cult.100 parameters apply to CULT events in the schedule file.

cultra(1)	Fraction of aboveground live transferred to standing dead	fraction	0.0 – 1.0
cultra(2)	Fraction of aboveground live transferred to surface litter	fraction	0.0 – 1.0
cultra(3)	Fraction of aboveground live transferred to the top soil layer	fraction	0.0 – 1.0
cultra(4)	Fraction of standing dead transferred to surface litter	fraction	0.0 – 1.0
cultra(5)	Fraction of standing dead transferred to top soil layer	fraction	0.0 – 1.0
cultra(6)	Fraction of surface litter transferred to top soil layer	fraction	0.0 – 1.0
cultra(7)	Fraction of roots transferred to top soil layer	fraction	0.0 – 1.0
clteff(1)	Cultivation effect on soil som1 (active pool) decomposition; functions as a multiplier on the decomposition rate to increase decomposition in the *month* of cultivation	fraction	1.0 – 15.0
clteff(2)	Cultivation effect on soil som2 (slow pool) decomposition; functions as a multiplier on the decomposition rate to increase decomposition in the *month* of cultivation	fraction	1.0 – 15.0
clteff(3)	Cultivation effect on soil som3 (passive pool) decomposition; functions as a multiplier on the decomposition rate to increase decomposition in the *month* of cultivation	fraction	1.0 – 15.0

clteff(4)	Cultivation effect on soil structural litter decomposition; functions as a multiplier on the decomposition rate to increase decomposition in the *month* of cultivation	fraction	1.0 – 15.0

The multipliers for increased decomposition will be used for one month.

Appendix 1.3 Fertilization parameters (fert.100)

These fert.100 parameters apply to FERT events in the schedule file.

feramt(1)	Amount of N to be added	g N m^{-2}	0.0 - 9999
feramt(2)	Amount of P to be added	g P m^{-2}	0.0 - 9999
feramt(3)	Amount of S to be added	g S m^{-2}	0.0 - 9999

aufert	Key for automatic fertilization aufert = 0: no automatic fertilization aufert < 1.0: automatic fertilizer may be applied to remove some nutrient stress without increasing nutrient concentration above the minimum level; the value of aufert is the fraction of potential C production (temperature and moisture limited) which will be maintained aufert > 1.0: automatic fertilizer may be applied to remove nutrient stress and increase nutrient concentrations above the minimum level; a value of aufert between 1.0 and 2.0 determines the extent to which nutrient concentration is maintained between the minimum and maximum levels aufert = 2.0 automatic fertilizer may be applied to remove nutrient stress and increase nutrient concentrations to the maximum level		Do not use this option
ninhib	Reduction factor on nitrification rates due to nitrification inhibitors added to the site with the fertilizer. This parameter value is used as a multiplier in the calculation of the nitrification rate. A value of 1.0 for this parameter will have no effect on the nitrification rate.	fraction	0.0-1.0
ninhtm	How long, in number of simulation weeks, to simulate the effect of the nitrogen inhibitor from the fertilizer addition.	Number of weeks	
frac_no3	Fraction of N fertilizer that is nitrate (frac_no3 + frac_nh4 = 1.0).	fraction	0.0-1.0

frac_nh4	Fraction of N fertilizer that is ammonium (frac_no3 + frac_nh4 = 1.0).	fraction	0.0-1.0

A new parameter, NINHIB, added to the FERT.100 file represents a reduction factor on nitrification rates due to nitrification inhibitors added to the site with the fertilizer. This parameter value is used as a multiplier in the calculation of the nitrification rate. A value of 1.0 for this parameter will have no effect on the nitrification rate.

Additionally the NINHTM parameter added to the FERT.100 file determines how long, in number of simulation weeks, to simulate the effect of the nitrogen inhibitor from the fertilizer addition.

Appendix 1.4 Fire parameters for crops and grasses (fire.100)

These fire.100 parameters apply to FIRE events in the schedule file. To remove live tree parts, one must schedule a TREM event (see trem.100).

flfrem	Fraction of live shoots removed by a fire event.	fraction	0.0 – 1.0
fdfrem(1)	Fraction of standing dead plant material removed by a fire event.	fraction	0.0 – 1.0
fdfrem(2)	Fraction of surface litter removed by a fire event.	fraction	0.0 – 1.0
fdfrem(3)	Fraction of dead fine branches removed by a fire event.	fraction	0.0 – 1.0
fdfrem(4)	Fraction of dead large wood removed by a fire event.	fraction	0.0 – 1.0
fret(1,1)	Fraction of C in the burned aboveground material (live shoots, standing dead, and litter) returned to the system following a fire event as charcoal in the passive SOM pool.	fraction	0.0 – 1.0
fret(1,2)	Fraction of N in the burned aboveground material (live shoots, standing dead, and litter) returned to the system following a fire event.	fraction	0.0 – 1.0
fret(1,3)	Fraction of P in the burned aboveground material live shoots, standing dead, and litter) returned to the system following a fire event.	fraction	0.0 – 1.0
fret(1,4)	Fraction of S in the burned aboveground material (live shoots, standing dead, and litter) returned to the system following a fire event.	fraction	0.0 – 1.0
fret(2,1)	Fraction of C in the burned dead fine branch material returned to the system following a fire event as charcoal in the passive SOM pool.	fraction	0.0 – 1.0
fret(2,2)	Fraction of N in the burned dead fine branch material returned to the system following a fire event.	fraction	0.0 – 1.0

fret(2,3)	Fraction of P in the burned dead fine branch material returned to the system following a fire event.	fraction	0.0 – 1.0
fret(2,4)	Fraction of S in the burned dead fine branch material returned to the system following a fire event.	fraction	0.0 – 1.0
fret(3,1)	Fraction of C in the burned dead large wood material returned to the system following a fire event as charcoal in the passive SOM pool.	fraction	0.0 – 1.0
fret(3,2)	Fraction of N in the burned dead large wood material returned to the system following a fire event.	fraction	0.0 – 1.0
fret(3,3)	Fraction of P in the burned dead large wood material returned to the system following a fire event.	fraction	0.0 – 1.0
fret(3,4)	Fraction of S in the burned dead large wood material returned to the system following a fire event.	fraction	0.0 – 1.0
frtsh	Additive effect of burning on root/shoot ratio.	fraction	0.0 – 1.0
fnue(1)	Increase in maximum C/N ratio of shoots due to fire.	C/N ratio increment	0.0 – 10.0
fnue(2)	Increase in maximum C/N ratio of roots due to fire	C/N ratio increment	0.0 – 10.0

Fire code changes for charcoal:

There have been changes to fire code so that removal, by burning, of dead fine branches and dead large wood will occur as the result of a FIRE event rather than of a TREM event. A TREM fire event will burn only live leaves, live fine branches, and live large wood. A TREM cutting, windstorm or other non-fire event will allow the removal of dead fine branches and dead large wood in the same manner as Century 4.0. When burning dead fine branches and dead large through a FIRE event the burned carbon in the dead wood can be returned to the system as charcoal in the passive SOM pool.

Appendix 1.5 General parameters that are common (fixed) for all types of biomes (fix.100).

These fix.100 parameters are required for each simulation and are not related to any one specific event in the schedule file.

adep(1)	thickness of soil layer 1	cm	0 – 20
adep(2)	thickness of soil layer 2	cm	0 – 60
adep(3)	thickness of soil layer 3	cm	0 – 60
adep(4)	thickness of soil layer 4	cm	0 – 60
adep(5)	thickness of soil layer 5	cm	0 – 60
adep(6)	thickness of soil layer 6	cm	0 – 60
adep(7)	thickness of soil layer 7	cm	0 – 60
adep(8)	thickness of soil layer 8	cm	0 – 60
adep(9)	thickness of soil layer 9	cm	0 – 60
adep(10)	thickness of soil layer 10	cm	0 – 60
agppa	*Intercept* parameter in the equation estimating potential aboveground biomass production for calculation of root/shoot ratio of crops and grasses (used only if crop.100 parameter frtc(1) = 0)	g biomass m^{-2} yr^{-1}	

agppb	*Slope* parameter in the equation estimating potential aboveground biomass production for calculation of root/shoot ratio of crops and grasses (used only if crop.100 parameter frtc(1) = 0) . NOTE - agppb is multiplied by annual precipitation (cm).	g biomass m^{-2} yr^{-1} cm^{-1}	
aneref(1)	Ratio of rain/potential evapotranspiration below which there is no negative impact of soil anaerobic conditions on decomposition.	cm/cm	0.0 – 10.0
aneref(2)	Ratio of rain/potential evapotranspiration below which there is maximum negative impact of soil anaerobic conditions on decomposition.	cm/cm	0.0 – 10.0 aneref(2) > aneref(1)
aneref(3)	Minimum value of the impact of soil anaerobic conditions on decomposition; functions as a multiplier for the maximum decomposition rate.	fraction	0.0 – 1.0 0=no decomposition under anaerobic conditions, 1=no anaerobic effect

animpt	Slope term used to vary the impact of soil anaerobic conditions on decomposition flows to the passive soil organic matter pool. See somdec.f. cflow from som1c(2) to som3c cfs1s3 = tcflow * fps1s3 * (1.0 + animpt * (1.0 - anerb)) cflow from som2c(2) to som3c cfs2s3 = tcflow * fps2s3 * (1.0 + animpt * (1.0 - anerb))		
awtl(1-10)	**Weighing factors for transpiration loss for soil layers 1-10 (only nlayer+1 values used; nlayer is a site.100 parameter); indicates which fraction of the available water can be extracted by the roots**		
awtl(1)	Weighing factor for transpiration loss for layer 1		
awtl(2)	Weighing factor for transpiration loss for layer 2		
awtl(3)	Weighing factor for transpiration loss for layer 3		
awtl(4)	Weighing factor for transpiration loss for layer 4		
awtl(5)	Weighing factor for transpiration loss for layer 5		
awtl(6)	Weighing factor for transpiration loss for layer 6		
awtl(7)	Weighing factor for transpiration loss for layer 7		
awtl(8)	Weighing factor for transpiration loss for layer 8		
awtl(9)	Weighing factor for transpiration loss for layer 9		

awtl(10)	Weighing factor for transpiration loss for layer 10		
bgppa	*Intercept* parameter in the equation estimating potential belowground biomass production for calculation of root/shoot ratio for crops and grasses (used only if crop.100 parameter frtc(1) = 0)	g biomass m^{-2} yr^{-1}	
bgppb	*Slope* parameter in the equation estimating potential belowground biomass production for calculation of root/shoot ratio ofr crops and grasses (used only if crop.100 parameter frtc(1) = 0) . NOTE: bgppb is multiplied by annual precipitation (cm)	g biomass m^{-2} yr^{-1} cm^{-1}	
co2ppm(1)	Initial parts per million for CO_2 effect.	ppm	294 – 1000
co2ppm(2)	Final parts per million for CO_2 effect.	ppm	294 – 1000
co2rmp	Flag indicating whether CO_2 effect should be: = 0 step function = 1 ramp function	index	0, 1
damr(1,1)	Fraction of surface N absorbed by residue.	fraction	0 – 0.10
damr(1,2)	Fraction of surface P absorbed by residue.	fraction	0 – 0.10
damr(1,3)	Fraction of surface S absorbed by residue.	fraction	0 – 0.10
damr(2,1)	Fraction of soil N absorbed by residue.	fraction	0 – 0.10
damr(2,2)	Fraction of soil P absorbed by residue.	fraction	0 – 0.10
damr(2,3)	Fraction of soil S absorbed by residue.	fraction	0 – 0.10

damrmn(1)	Minimum C/N ratio allowed in residue after direct absorption.	C/N ratio	
damrmn(2)	Minimum C/P ratio allowed in residue after direct absorption.	C/P ratio	
damrmn(3)	Minimum C/S ratio allowed in residue after direct absorption.	C/S ratio	
dec1(1)	Maximum decomposition rate of surface structural litter, strucc(1).	yr^{-1}	
dec1(2)	Maximum decomposition rate of soil structural litter, strucc(2).	yr^{-1}	
dec2(1)	Maximum decomposition rate of surface metabolic litter, metabc(1).	yr^{-1}	
dec2(2)	Maximum decomposition rate of soil metabolic litter, metabc(2).	yr^{-1}	
dec3(1)	Maximum decomposition rate of surface active organic matter, som1c(1).	yr^{-1}	
dec3(2)	Maximum decomposition rate of soil active organic matter, som1c(2).	yr^{-1}	
dec4	Maximum decomposition rate of soil passive organic matter, som3c	yr^{-1}	
dec5(1)	Maximum decomposition rate of surface slow organic matter, somc2(1).	yr^{-1}	
dec5(2)	Maximum decomposition rate of soil slow organic matter; som2c(2).	yr^{-1}	
deck5	Available soil water content at which shoot and root death rates are half maximum.	cm	

dligdf	Difference in delta 13C for lignin compared to whole plant delta 13C. See partit.f.		
dresp	Discrimination factor for 13C during decomposition of organic matter due to microbial respiration.		
edepth	Depth of the single soil layer where C, N, P, and S dynamics are calculated (only affects C, N, P, S loss by erosion).	meters	
elitst	Fraction of total surface litter that contributes to the biomass insulation effect on soil surface temperature relative to live and standing dead biomass.	fraction	0.0 – 1.0
enrich	Enrichment factor for SOM losses due to erosion. This factor reflects the variation in SOM with depth through the simulation layer. It is common for SOM density (g cm^{-3}) to decrease with depth below the surface organic horizons.		
favail(1)	fraction of N available per day to plants. NOTE: THIS PARAMETER HAS BEEN MOVED TO CROP.100 AND TREE.100 IN PHOTOSYNTHESIS VERSION	fraction	0.0 – 1.0
	Note: There is no favail(2) in the fix.100 parameter file. This value, the fraction of labile (non-sorbed) P in the surface layer available to plants, is calculated in the model.		
favail(3)	Fraction of S available per day to plants.	fraction	0.0 – 1.0
favail(4)	Minimum fraction of P available per day to plants.	fraction	0.0 – 1.0
favail(5)	Maximum fraction of P available per day to plants.	fraction	0.0 – 1.0

favail(6)	Mineral N in surface layer corresponding to maximum fraction of P available.	gN m^{-2}	
fleach(1-5)	**texeff = fleach(1) + fleach(2) * sand** **frlech(iel) = texeff * fleach(iel+2) * fsol** **where iel = 1,2,3. See simsom.f**		
fleach(1)	Intercept value for a normal day to compute the fraction of mineral N, P, and S which will leach to the next layer when there is a saturated water flow; normal leaching is a function of sand content	fraction	0.0 – 1.0
fleach(2)	Slope value for a normal day to compute the fraction of mineral N, P, and S which will leach to the next layer when there is a saturated water flow; normal leaching is a function of sand content.		0.0 – 1.0
fleach(3)	Leaching fraction multiplier for N to compute the fraction of mineral N which leaches to the next layer when there is a saturated water flow; normal leaching is a function of sand content.	fraction	0.0 – 1.0
fleach(4)	Leaching fraction multiplier for P to compute the fraction of mineral P which leaches to the next layer when there is a saturated water flow; normal leaching is a function of sand content.	fraction	0.0 – 1.0
fleach(5)	Leaching fraction multiplier for S to compute the fraction of mineral S which leaches to the next layer when there is a saturated water flow; normal leaching is a function of sand content.	fraction	0.0 – 1.0

fwloss(1)	Scaling factor for interception and evaporation of precipitation by live and standing dead biomass.	scaling factor	0.0 – 1.0
fwloss(2)	Scaling factor for bare soil evaporation of precipitation.	scaling factor	0.0 – 1.0
fwloss(3)	Scaling factor for transpiration water loss.	scaling factor	0.0 – 1.0
fwloss(4)	Scaling factor for potential evapotranspiration.	scaling factor	0.0 – 1.0
fxmca	*Intercept* for effect of biomass on non-symbiotic soil N fixation; used only when ***nsnfix*** = 1		
fxmcb	*Slope* control for effect of biomass on non-symbiotic soil N fixation; used only when ***nsnfix*** = 1		
fxmxs	Maximum *monthly* (not daily) non-symbiotic soil N-fixation rate (reduced by effect of N:P ratio, used when ***nsnfix*** = 1)		
fxnpb	N/P control for N-fixation based on availability of top soil layer (used when ***nsnfix*** = 1)		

gremb	Grazing effect reduction on root:shoot ratio for grzeff types 4, 5, 6 (grzeff is a graz.100 parameter) root:shoot = 1.0 – FLGREM * GREMB Restrict production due to grazing (grzeff): = 0 grazing has no direct effect on production = 1 linear impact on above-ground production (agp) = 2 quadratic impact on agp and root/shoot ratio = 3 quadratic impact on root/shoot ratio = 4 linear impact on root/shoot ratio = 5 quadratic impact on agp and linear impact on root/shoot ratio = 6 linear impact on agp and root/shoot ratio	index	0, 1, 2, 3, 4, 5, 6
idef	Flag for method of computing water effect on decomposition. See calcdefac.c. = 1 option using the relative water content of top 3 “daycent” soil layers. Strictly increasing function. = 2 ratio option (rainfall/potential evaporation rate). Strictly increasing function. = 3 option using soil texture and water-filled pore space (wfps) in top 3 “daycent” soil layers. Bell-shaped curve. Increases to optimal value of wfps, then decreases as soil wfps approaches 1 (soil saturation).	index	1, 2, 3
lhzf(1)	Lower horizon factor for active pool; = fraction of active pool (SOM1CI(2,*)) used in computation of lower horizon pool sizes for soil erosion routines.	fraction	0.0 – 1.0

lhzf(2)	Lower horizon factor for slow pool; = fraction of slow pool (SOM2CI(*) used in computation of lower horizon pool sizes for soil erosion routines.	fraction	0.0 – 1.0
lhzf(3)	Lower horizon factor for passive pool; = fraction of passive pool (SOM3CI(*) used in computation of lower horizon pool sizes for soil erosion routines.	fraction	0.0 – 1.0
minlch	Critical water flow for leaching of minerals (cm of H_2O leached per day below 30 cm soil depth).	cm of H_2O per day	
nsnfix	Equals 1 if non-symbiotic N fixation should be based on N:P ratio in mineral pool, otherwise non-symbiotic N fixation is based on annual precipitation.	index	0, 1
ntspm	Number of time steps per **day** (not month) for the decomposition submodel	integer	1 (formerly 4 times a month) DO NOT CHANGE!
omlech(1)	*Intercept* for the effect of sand on leaching of organic compounds.		
omlech(2)	*Slope* for the effect of sand on leaching of organic compounds.		
omlech(3)	*Amount* of water that needs to flow out of water layer 2 to produce leaching of organics.	cm of H_2O per day	
p1co2a(1) or p1co2a(SRFC)	*Intercept* parameter which controls flow from *surface* organic matter with fast turnover, som1c(1), to CO_2 (fraction of C lost to CO_2 when there is no sand in the soil)	fraction	0.0 – 1.0

p1co2a(2) or p1co2a(SOIL)	*Intercept* parameter which controls flow from *soil* organic matter with fast turnover, som1c(2), to CO_2 (fraction of C lost to CO_2 when there is no sand in the soil)	fraction	0.0 – 1.0
p1co2b(1) or p1co2b(SRFC)	*Slope* parameter which controls flow from *surface* organic matter with fast turnover rate, som1c(1), to CO_2 (slope is multiplied by the fraction sand content of the soil)	fraction	0.0 – 1.0
p1co2b(2) or p1co2b(SOIL)	*Slope* parameter which controls flow from *soil* organic matter with fast turnover rate, som1c(2), to CO_2 (slope is multiplied by the fraction sand content of the soil)	fraction	0.0 – 1.0
p2co2(1) or p2co2(SRFC)	Fraction of C lost as CO_2 when the slow surface organic matter pool (som2c(1)) decomposes.	fraction	0.0 – 1.0
p2co2(2) or p2co2(SOIL)	Fraction of C lost as CO_2 when the slow soil organic matter pool (som2c(2)) decomposes.	fraction	0.0 – 1.0
p3co2	Fraction of C lost as CO_2 when the passive soil organic matter pool (som3c) decomposes.	fraction	0.0 – 1.0
pabres	Amount of residue which will give maximum direct absorption of N. See partit.f.	gC m^{-2}	

peftxa	*Intercept* parameter for regression equation to compute the effect of soil texture on the microbe decomposition rate (the effect of texture when there is no sand in the soil). See eftext calculation in prelim.f. The factor eftext is used in somdec.f and affects the flow out of som1c(2). eftext = peftxa + peftxb * sand	fraction	0.0 – 1.0, such that eftext ≤ 1
peftxb	*Slope* parameter for regression equation to compute the effect of soil texture on microbe decomposition rate; the slope is multiplied by the sand content fraction. See eftext calculation in prelim.f. The factor eftext is used in somdec.f and affects the flow out of som1c(2). eftext = peftxa + peftxb * sand	fraction	0 – 1, such that eftext ≤ 1
phesp(1)	Minimum pH for determining the effect of pH on the solubility of secondary P (flow of secondary P to mineral P) (for texesp(2) = m * (pH input) + b, m and b calculated using these phesp values).		
phesp(2)	Value of texesp(2), the solubility of secondary P, corresponding to minimum pH.	yr^{-1}	

phesp(3)	Maximum pH for determining effect on solubility of secondary P (flow of secondary P to mineral P) (for texesp(2) = m * (pH input) + b, m and b calculated using these phesp values).		
phesp(4)	Value of texesp(2), the solubility of secondary P, corresponding to maximum pH.	yr^{-1}	
pligst(1) or pligst(SRFC)	Effect of lignin fraction (g lignin C / g C) on *surface* structural or fine branch and large wood decomposition. See litdec.f and woodec.f. exp(-pligst(SRFC) * lignin_fraction)		
pligst(2) or pligst(SOIL)	Effect of lignin_fraction (g lignin C / g C) on *soil* structural or coarse root decomposition. See litdec.f and woodec.f. exp(-pligst(SOIL) * lignin_fraction)		
pmco2(1) or pmco2(SRFC)	Fraction of C lost as CO_2 when *surface* metabolic litter (metabc(1)) decomposes.	fraction	0.0 – 1.0
pmco2(2) or pmco2(SOIL)	Fraction of C lost as CO_2 when *soil* metabolic litter (metabc(2)) decomposes.	fraction	0.0 – 1.0
pmnsec(1)	Slope for N; controls the flow from mineral to secondary N.	yr^{-1}	
pmnsec(2)	Slope for P; controls the flow from mineral to secondary P.	yr^{-1}	
pmnsec(3)	Slope for S; controls the flow from mineral to secondary S.	yr^{-1}	

pmntmp	Effect of biomass on minimum surface temperature.		
pmxbio	Maximum live+dead biomass (leaves + standing dead + elitst*litter) level for insulation effect in soil surface temperature calculation. Maximum dead biomass (standing dead + 10%*litter) level for calculation of the potential negative effect on plant (crop and grass) growth of physical obstruction by standing dead and surface litter.		
pmxtmp	Effect of biomass on maximum surface temperature.		
pparmn(1)	Controls the flow from parent material to mineral compartment (fraction of parent material that flows to mineral N).	yr^{-1}	0.0 – 1.0
pparmn(2)	Controls the flow from parent material to mineral compartment (fraction of parent material that flows to mineral P).	yr^{-1}	0.0 – 1.0
pparmn(3)	Controls the flow from parent material to mineral compartment (fraction of parent material that flows to mineral S).	yr^{-1}	0.0 – 1.0
pprpts(1)	Minimum ratio of available water to PET which would completely limit production assuming water content = 0		**Not used in photosynthesis model?**
pprpts(2)	Effect of water content on the intercept.		**Not used in photosynthesis model?**

pprpts(3)	Lowest ratio of available water to PET at which there is no restriction on production.	cm/cm	**Not used in photosynthesis model?**
ps1co2(1) or ps1co2(SRFC)	The fraction of C lost as CO_2 when *surface* structural litter decomposes to active *surface* organic matter pool strucc(1) → som1c(1)	fraction	0.0 – 1.0
ps1co2(2) or ps1co2(SOIL)	The fraction of C lost as CO_2 when *soil* structural litter decomposes to the active *soil* organic matter pool. strucc(2) → som1c(2)	fraction	0.0 – 1.0
ps1s3(1)	*Intercept* value for the effect of clay on the flow from active soil organic matter to passive soil organic matter; the fraction of decomposed som1c(2) (after accounting for respiration losses) that goes to som3c. som1c(2) → som3c fps1s3 = ps1s3(1) + ps1s3(2) * clay	fraction	0.0 – 1.0, such that fps1s3 ≤ 1.0
ps1s3(2)	*Slope* value for the effect of clay on the flow from active soil organic matter to passive soil organic matter; the fraction of decomposed som1c(2) (after accounting for respiration losses) that goes to som3c. som1c(2) → som3c fps1s3 = ps1s3(1) + ps1s3(2) * clay	fraction	0.0 – 1.0, such that fps2s3 ≤ 1.0

ps2s3(1)	*Intercept* value for the effect of clay on the flow from slow soil organic matter to passive soil organic matter; the fraction of decomposed som2c(2) (after accounting for respiration losses) that goes to som3c. som2c(2) → som3c fps2s3 = ps2s3(1) + ps2s3(2) * clay	fraction	0.0 – 1.0, such that fps2s3 ≤ 1.0
ps2s3(2)	*Slope* value for the effect of clay on the flow from slow soil organic matter to passive soil organic matter; the fraction of decomposed som2c(2) (after accounting for respiration losses) that goes to som3c. som2c(2) → som3c fps2s3 = ps2s3(1) + ps2s3(2) * clay	fraction	0.0 – 1.0, such that fps2s3 ≤ 1.0
psecmn(1)	Controls the flow from secondary to mineral N	yr^{-1}	0.0 – 1.0
psecmn(2)	controls the flow from secondary to mineral P. May be reset in code! See pschem.f. psecmn(2) = 12.0 * (***texesp***(2) + ***texesp***(3) * sand)	yr^{-1}	0.0 – 1.0
psecmn(3)	Controls the flow from secondary to mineral S.	yr^{-1}	0.0 – 1.0
psecoc1	Controls the flow from secondary to occluded P.	yr^{-1}	0.0 – 1.0
psecoc2	Controls the back flow from occluded to secondary P.	yr^{-1}	0.0 – 1.0

rad1p(1,1)	Intercept used to calculate addition term for C/N ratio of slow SOM formed from surface active pool		**Not used?**
rad1p(2,1)	Slope used to calculate addition term for C/N ratio of slow SOM formed from surface active pool		**Not used?**
rad1p(3,1)	Minimum allowable C/N used to calculate addition term for C/N ratio of slow SOM formed from surface active pool		**Not used?**
rad1p(1,2)	Intercept used to calculate addition term for C/P ratio of slow SOM formed from surface active pool		**Not used?**
rad1p(2,2)	Slope used to calculate addition term for C/P ratio of slow SOM formed from surface active pool		**Not used?**
rad1p(3,2)	Minimum allowable C/P used to calculate addition term for C/P ratio of slow SOM formed from surface active pool		**Not used?**
rad1p(1,3)	Intercept used to calculate addition term for C/S ratio of slow SOM formed from surface active pool		**Not used?**
rad1p(2,3)	Slope used to calculate addition term for C/S ratio of slow SOM formed from surface active pool		**Not used?**
rad1p(3,3)	Minimum allowable C/S used to calculate addition term for C/S ratio of slow SOM formed from surface active pool		**Not used?**
rcestr(1)	C/N ratio for structural material, strucc(1) and strucc(2). See partit.f.	C/N ratio	

rcestr(2)	C/P ratio for structural material, strucc(1) and strucc(2). See partit.f.	C/P ratio	
rcestr(3)	C/S ratio for structural material, strucc(1) and strucc(2). See partit.f.	C/S ratio	
rictrl	Root impact control term used by rtimp; used for calculating the impact of root biomass on nutrient availability.		
riint	Root impact intercept used by rtimp; used for calculating the impact of root biomass on nutrient availability.		
rsplig	Fraction of lignin flow (in structural decomposition) lost as CO_2. See declig.f.	fraction	0.0 – 1.0
seed	Random number generator seed value.		**Not used?**
spl(1) or spl(INTCPT)	*Intercept* parameter for metabolic litter (vs. structural litter) split		
spl(2) or spl(SLOPE)	*Slope* parameter for metabolic split (fraction metabolic is a function of lignin to N ratio). Note: this value should be entered as a positive number, but in the code it is negated so it becomes a *negative* slope (meaning that the fraction of residue going to metabolic litter (vs. structural litter) *decreases* with an increasing lignin to N ratio).		
strmax(1) or strmax(SRFC)	Maximum amount of *surface* structural material that will decompose. See litdec.f.	g C m^{-2}	
strmax(2) or strmax(SOIL)	Maximum amount of *soil* structural material that will decompose. See litdec.f.	g C m^{-2}	

texepp(1)	Texture effect on parent P mineralization: = 1 include the effect of texture using the remaining texepp values with the arctangent function = 0 use pparmn(2) in the weathering equation		
texepp(2)	x location of inflection point used in determining texture effect on parent P mineralization		
texepp(3)	y location of inflection point used in determining texture effect on parent P mineralization		
texepp(4)	Step size (distance from the maximum point to the minimum point) used in determining texture effect on parent P mineralization		
texepp(5)	Slope of the line at the inflection point used in determining texture effect on parent P mineralization		
texesp(1)	Texture effect on secondary P flow to mineral P = 1 include the effect of pH and sand content using the equation specified by texesp(2) (a function of pH and phesp(1-4)) and texesp(3) = 0 to use psecmn(2) in the weathering equation		
	Note: texesp(2) is not included in the fix.100 file.		
texesp(3)	Slope value used in determining effect of sand content on secondary P flow to mineral P		

teff(1-4)	**Coefficients in the equation for computing the temperature effect on decomposition**		
teff(1)	"x" location of inflection point	ºC	
teff(2)	"y" location of inflection point		
teff(3)	step size (distance from the maximum point to the minimum point)		
teff(4)	slope of line at inflection point		
tmelt(1)	Snow melt parameter (*tmax* is maximum daily air temperature °C) $melt = tmelt(2) * (tmax - tmelt(1)) * srad_{langleys}$	°C	If tmax – tmelt(1) < 0 then melt=0
tmelt(2)	Snow melt parameter $melt = tmelt(2) * (tmax - tmelt(1)) * srad_{langleys}$	cm SWE (°C langleys)$^{-1}$	
varatAB(*,*)	**Variable C/E ratios for material entering SOM pools. 'A' refers to the SOM pool (1,2,3). 'B' refers to the location; =1 for surface and =2 for soil. For the first subscript 1=Maximum, 2=Minimum, 3=Amount). The second subscript refers to the element (N=1, P=2, S=3).**		
varat11(1,1)	Maximum C/N ratio for material entering surface som1, som1c(1).	C/N ratio	
varat11(2,1)	Minimum C/N ratio for material entering surface som1, som1c(1).	C/N ratio	

varat11(3,1)	Amount of N present when minimum ratio applies.	g N m^{-2}	
varat11(1,2)	Maximum C/P ratio for material entering surface som1, som1c(1).	C/P ratio	
varat11(2,2)	Minimum C/P ratio for material entering surface som1, som1c(1).	C/P ratio	
varat11(3,2)	Amount of P present when minimum ratio applies.	g P m^{-2}	
varat11(1,3)	Maximum C/S ratio for material entering surface som1, som1c(1).	C/S ratio	
varat11(2,3)	Minimum C/S ratio for material entering surface som1, som1c(1).	C/S ratio	
varat11(3,3)	Amount of S present when minimum ratio applies.	g S m^{-2}	
varat12(1,1)	Maximum C/N ratio for material entering soil som1, som1c(2).	C/N ratio	
varat12(2,1)	Minimum C/N ratio for material entering soil som1, som1c(2).	C/N ratio	
varat12(3,1)	Amount of N present when minimum ratio applies.	g N m^{-2}	
varat12(1,2)	Maximum C/P ratio for material entering soil som1, som1c(2).	C/P ratio	
varat12(2,2)	Minimum C/P ratio for material entering soil som1, som1c(2).	C/P ratio	
varat12(1,3)	Maximum C/S ratio for material entering soil som1, som1c(2).	C/S ratio	

varat12(2,3)	Minimum C/S ratio for material entering soil som1, som1c(2).	C/S ratio	
varat12(3,3)	Amount of S present when minimum ratio applies.	g S m^{-2}	
varat21(1,1)	Maximum C/N ratio for material entering surface som2, som2c(1).	C/N ratio	
varat21(2,1)	Minimum C/N ratio for material entering surface som2, som2c(1).	C/N ratio	
varat21(3,1)	Amount of N present when minimum ratio applies.	g N m^{-2}	
varat21(1,2)	Maximum C/P ratio for material entering surface som2, som2c(1).	C/P ratio	
varat21(2,2)	Minimum C/P ratio for material entering surface som2, som2c(1).	C/P ratio	
varat21(3,2)	Amount of P present when minimum ratio applies.	g P m^{-2}	
varat21(1,3)	Maximum C/S ratio for material entering surface som2, som2c(1).	C/S ratio	
varat21(2,3)	Minimum C/S ratio for material entering surface som2, som2c(1).	C/S ratio	
varat21(3,3)	Amount of S present when minimum ratio applies.	g S m^{-2}	
varat22(1,1)	Maximum C/N ratio for material entering soil som2, som2c(2).	C/N ratio	
varat22(2,1)	Minimum C/N ratio for material entering soil som2, som2c(2).	C/N ratio	

varat22(3,1)	Amount of N present when minimum ratio applies.	g N m^{-2}	
varat22(1,2)	Maximum C/P ratio for material entering soil som2, som2c(2).	C/P ratio	
varat22(2,2)	Minimum C/P ratio for material entering soil som2, som2c(2).	C/P ratio	
varat22(3,2)	Amount of P present when minimum ratio applies.	g P m^{-2}	
varat22(1,3)	Maximum C/S ratio for material entering soil som2, som2c(2).	C/S ratio	
varat22(2,3)	Minimum C/S ratio for material entering soil som2, som2c(2).	C/S ratio	
varat22(3,3)	Amount of S present when minimum ratio applies.	g S m^{-2}	
varat3(1,1)	Maximum C/N ratio for material entering som3, som3c	C/N ratio	
varat3(2,1)	Minimum C/N ratio for material entering som3, som3c	C/N ratio	
varat3(3,1)	Amount of N present when minimum ratio applies.	g N m^{-2}	
varat3(1,2)	Maximum C/P ratio for material entering som3, som3c.	C/P ratio	
varat3(2,2)	Minimum C/P ratio for material entering som3, som3c.	C/P ratio	
varat3(3,2)	Amount of P present when minimum ratio applies.	g P m^{-2}	
varat3(1,3)	Maximum C/S ratio for material entering som3, som3c.	C/S ratio	
varat3(2,3)	Minimum C/S ratio for material entering som3, som3c.	C/S ratio	

varat3(3,3)	Amount of S present when minimum ratio applies.	g S m^{-2}	
vlosse	Fraction per day of excess N (i.e. N left in the soil after nutrient uptake by the plant) which is volatilized.	fraction	Obsolete parameter, set to 0.0 in simsom.f, replaced by trace gas model.
vlossg	Fraction per day of gross mineralization which is volatilized.	fraction	Obsolete parameter, set to 0.0 in simsom.f, replaced by trace gas model.

For DDCentEVI the following parameters regulating some cultivation effects and methane flux calculations are optional parameters in the fix.100 file. They were moved from sitepar.in to fix.100, but at a later time may be moved to crop.100 so they can be crop-specific. If they are not specified in fix.100 they will be set to the default values specified below.

Fix.100 Cultivation Effects (optional)	**Description**	**Units**	**Range**	**Default value**
XEFCLTEF	Duration of Cultivation Effect	# x months days=x*30.4375	??	??
MAXCLTEF	Maximum Cultivation Effect		??	??
Fix.100 Methane parameters (optional)				
FLDN2D (a.k.a. floodN2delay)	FLooDed N2/N2O ratio Days (7)	# days	0 - 7	7
FLN2OR (a.k.a. flood_N2toN2O)	N2/N2O ratio for flooded state	ratio	100 – 1000 -1 disable	100

CO2CH4 (a.k.a. CO2_to_CH4)	fraction of CO_2 from soil respiration used to produce CH_4	fraction	0.0 – 1.0	0.50
MXCH4F (a.k.a. frCH4emit)	MaXimum Fraction of CH_4 production emitted by plants.	fraction	0.0 – 1.0	0.55
FREXUD (formerly frac_to_exudates)	FRaction EXUDates; root production fraction released as exudate	fraction	0.35 – 0.60 as described in Cao et al. 1995	0.45
AEH	differential coefficient (Aeh)			0.23
DEH	differential coefficient (Deh)			0.16
BEHFL (a.k.a. Beh_flood)	lower-limit value for Eh during flooding course	mv		-250.0
BEHDR (a.k.a. Beh_drain)	upper-limit value of Eh during drainage course	mv		300
METHZR (formerly zero_root_frac)	fraction CH_4 emitted via bubbles when zero root biomass	fraction	0.0 – 1.0	0.7
MRTBLM (a.k.a. ch4rootlim)	Root biomass that when exceeded starts to reduce CH_4 bubble formation (crops)	g biomass m^{-2}		1.0

Appendix 1.6 Grazing parameters (graz.100)

These graz.100 parameters apply to GRAZ events in the schedule file.

flgrem	Fraction of live shoots (aglivc) removed by a grazing event over a one month period. The daily removal rate is approximately flgrem/30.	fraction	0.0 – 1.0
fdgrem	Fraction of standing dead (stdedc) removed by a grazing event over a one month period. The daily removal rate is approximately fdgrem/30.	fraction	0.0 – 1.0
gfcret	Fraction of consumed C which is excreted in feces and urine	fraction	0.0 – 1.0
gret(1)	Fraction of consumed N which is excreted in feces and urine (should take into account N losses due to leaching or volatilization from the manure)	fraction	0.0 – 1.0
gret(2)	Fraction of consumed P which is excreted in feces and urine (should take into account P losses due to leaching or volatilization from the manure)	fraction	0.0 – 1.0
gret(3)	Fraction of consumed S which is excreted in feces and urine (should take into account S losses due to leaching or volatilization from the manure)	fraction	0.0 – 1.0

grzeff	Effect of grazing on production = 0 no direct effect = 1 moderate effect (linear decrease in above-ground production, below-ground production determined by root:shoot ratio) = 2 intensively grazed production effect (quadratic effect on above- and below-ground production) = 3 intensively grazed production effect (quadratic effect on below-ground production) = 4 moderate effect (linear decrease in below-ground production) = 5 intensively grazed production effect (quadratic effect on above-ground production, linear decrease on above ground production) = 6 moderate effect (linear decrease in above- and below-ground production)	index	0, 1, 2, 3, 4, 5, 6
fecf(1)	Fraction of excreted N which goes into feces (rest goes into urine)	fraction	0.0 – 1.0
fecf(2)	Fraction of excreted P which goes into feces (rest goes into urine)	fraction	0.0 – 1.0
fecf(3)	Fraction of excreted S which goes into feces (rest goes into urine)	fraction	0.0 – 1.0
feclig	Lignin fraction of feces	g lignin / g feces	0.0 – 1.0

Grazing change:

The GRET(1) parameter from the GRAZ.100 file is no longer being used. The value for GRET(1) now being used in the model equations is calculated based on soil texture so that the fraction of consumed N that is returned is now a function of clay content.

Grazing events will continue for a month and restrictions on production due to grazing will be effect for one month.

Appendix 1.7 Harvest parameters for crops/grasses (harv.100)

These harv.100 parameters apply to HARV events in the schedule file and apply to crop/grass harvests only. To harvest tree biomass, one must schedule a TREM event (see trem.100).

aglrem	Fraction of aboveground live which will not be affected by harvest operations.	fraction	0.0 – 1.0
bglrem	Fraction of belowground live which will not be affected by harvest operations.	fraction	0.0 – 1.0
flghrv	Flag indicating if grain is to be harvested = 0 if grain is not to be harvested = 1 if the grain is to be harvested	index	0, 1
rmvstr	Fraction of the aboveground residue that will be removed. Does not apply when grain is not harvested.	fraction	0.0 – 1.0
remwsd	Fraction of the remaining residue that will be left standing. Does not apply when grain is not harvested.	fraction	0.0 – 1.0
hibg	Fraction of roots that will be harvested.	fraction	0.0 – 1.0

Appendix 1.8 Irrigation parameters (irri.100)

These irri.100 parameters apply to month-long IRRI events in the schedule file. For some versions of DayCent that implement the daily irrigation event, IRIG, these parameters also apply?

auirri	controls application of automatic irrigation = 0 automatic irrigation is off = 1 irrigate to field capacity = 2 irrigate with a specified amount of water applied = 3 irrigate to field capacity plus PET = 4 irrigate entire rooting zone to field capacity (option 4 is not available for all versions of DayCent)	index	0, 1, 2, 3, 4
fawhc	fraction of available water holding capacity below which automatic irrigation will be used when auirri = 1 or 2	fraction	0.0 – 1.0
irraut	amount of water to apply automatically when auirri = 2	cm	0.0 - 1000
irramt	amount of water to apply regardless of soil water status	cm	0.0 - 1000

Appendix 1.9 Organic matter addition including mulch, manure, and compost (omad.100)

These omad.100 parameters apply to OMAD events in the schedule file.

omadtyp**	Organic matter addition type. =1,3 add organic matter to surface litter pool. =2,4 add organic matter to surface slow pool (som2 pool) because it is partially decomposed, like compost.	index	1, 2, 3, 4
astgc	amount of C added with the addition of organic matter	g C m^{-2}	0.0 - 9999
astlbl	omadtyp=1,2 (or 1.0 – 2.0)**: **concentration** of the added organic matter C which is labeled omadtyp=3,4 (or 3.0 – 4.0)**: **fraction** of the added organic matter C which is labeled	fraction	0.0 – 1.0
astlig	lignin fraction content of organic matter	g lignin C / g C	0.0 – 1.0
astrec(1)	C/N ratio of added organic matter	C/N ratio	1.0 - 500
astrec(2)	C/P ratio of added organic matter	C/P ratio	1.0 - 9999
astrec(3)	C/S ratio of added organic matter	C/S ratio	1.0 - 9999

*****Note: some versions of DayCent allow omadtyp to be a floating point number to mixed types of OMAD additions in a single event.***

1.0 ≤ OMAPTYP ≤ 2.0: The fraction that goes to surface som2 is OMADTYP – 1.0. The remaining goes to the surface litter pools.
3.0 ≤ OMAPTYP ≤ 4.0: The fraction that goes to surface som2 is OMADTYP – 3.0. The remaining goes to the surface litter pools.

Appendix 1.10 Site specific parameters (<site>.100)

These <site>.100 parameters are site-specific. A <site>.100 file is required for each simulation. The name of the <site>.100 file to read is specified near the top of the schedule file.

precip(1)	Mean precipitation for January	cm mo^{-1}	
precip(2)	Mean precipitation for February	cm mo^{-1}	
precip(3)	Mean precipitation for March	cm mo^{-1}	
precip(4)	Mean precipitation for April	cm mo^{-1}	
precip(5)	Mean precipitation for May	cm mo^{-1}	
precip(6)	Mean precipitation for June	cm mo^{-1}	
precip(7)	Mean precipitation for July	cm mo^{-1}	
precip(8)	Mean precipitation for August	cm mo^{-1}	
precip(9)	Mean precipitation for September	cm mo^{-1}	
precip(10)	Mean precipitation for October	cm mo^{-1}	
precip(11)	Mean precipitation for November	cm mo^{-1}	

precip(12)	Mean precipitation for December	cm mo^{-1}	
prcstd(1)	Standard deviation for January precipitation	cm mo^{-1}	
prcstd(2)	Standard deviation for February precipitation	cm mo^{-1}	
prcstd(3)	Standard deviation for March precipitation	cm mo^{-1}	
prcstd(4)	Standard deviation for April precipitation	cm mo^{-1}	
prcstd(5)	Standard deviation for May precipitation	cm mo^{-1}	
prcstd(6)	Standard deviation for June precipitation	cm mo^{-1}	
prcstd(7)	Standard deviation for July precipitation	cm mo^{-1}	
prcstd(8)	Standard deviation for August precipitation	cm mo^{-1}	
prcstd(9)	Standard deviation for September precipitation	cm mo^{-1}	
prcstd(10)	Standard deviation for October precipitation	cm mo^{-1}	
prcstd(11)	Standard deviation for November precipitation	cm mo^{-1}	
prcstd(12)	Standard deviation for December precipitation	cm mo^{-1}	
prcskw(1)	skewness value for January precipitation		
prcskw(2)	skewness value for February precipitation		
prcskw(3)	skewness value for March precipitation		

prcskw(4)	skewness value for April precipitation		
prcskw(5)	skewness value for May precipitation		
prcskw(6)	skewness value for June precipitation		
prcskw(7)	skewness value for July precipitation		
prcskw(8)	skewness value for August precipitation		
prcskw(9)	skewness value for September precipitation		
prcskw(10)	skewness value for October precipitation		
prcskw(11)	skewness value for November precipitation		
prcskw(12)	skewness value for December precipitation		
tmn2m(1)	Mean minimum daily temperature at 2 meters for January	ºC	
tmn2m(2)	Mean minimum daily temperature at 2 meters for February	ºC	
tmn2m(3)	Mean minimum daily temperature at 2 meters for March	ºC	
tmn2m(4)	Mean minimum daily temperature at 2 meters for April	ºC	
tmn2m(5)	Mean minimum daily temperature at 2 meters for May	ºC	
tmn2m(6)	Mean minimum daily temperature at 2 meters for June	ºC	
tmn2m(7)	Mean minimum daily temperature at 2 meters for July	ºC	

tmn2m(8)	Mean minimum daily temperature at 2 meters for August	ºC	
tmn2m(9)	Mean minimum daily temperature at 2 meters for September	ºC	
tmn2m(10)	Mean minimum daily temperature at 2 meters for October	ºC	
tmn2m(11)	Mean minimum daily temperature at 2 meters for November	ºC	
tmn2m(12)	Mean minimum daily temperature at 2 meters for December	ºC	
tmx2m(1)	Mean maximum daily temperature at 2 meters for January	ºC	
tmx2m(2)	Mean maximum daily temperature at 2 meters for February	ºC	
tmx2m(3)	Mean maximum daily temperature at 2 meters for March	ºC	
tmx2m(4)	Mean maximum daily temperature at 2 meters for April	ºC	
tmx2m(5)	Mean maximum daily temperature at 2 meters for May	ºC	
tmx2m(6)	Mean maximum daily temperature at 2 meters for June	ºC	
tmx2m(7)	Mean maximum daily temperature at 2 meters for July	ºC	
tmx2m(8)	Mean maximum daily temperature at 2 meters for August	ºC	
tmx2m(9)	Mean maximum daily temperature at 2 meters for September	ºC	

tmx2m(10)	Mean maximum daily temperature at 2 meters for October	ºC	
tmx2m(11)	Mean maximum daily temperature at 2 meters for November	ºC	
tmx2m(12)	Mean maximum daily temperature at 2 meters for December	ºC	
SRADJ(1)	Solar radiation adjustment for cloud cover & transmission coefficient for January	0.1 – 1.0	DDcentEVI only sradadj(1) in sitepar.in
SRADJ(2)	Solar radiation adjustment for cloud cover & transmission coefficient for February	0.1 – 1.0	DDcentEVI only sradadj(2) in sitepar.in
SRADJ(3)	Solar radiation adjustment for cloud cover & transmission coefficient for March	0.1 – 1.0	DDcentEVI only sradadj(3) in sitepar.in
SRADJ(4)	Solar radiation adjustment for cloud cover & transmission coefficient for April	0.1 – 1.0	DDcentEVI only sradadj(4) in sitepar.in
SRADJ(5)	Solar radiation adjustment for cloud cover & transmission coefficient for May	0.1 – 1.0	DDcentEVI only sradadj(5) in sitepar.in
SRADJ(6)	Solar radiation adjustment for cloud cover & transmission coefficient for June	0.1 – 1.0	DDcentEVI only sradadj(6) in sitepar.in
SRADJ(7)	Solar radiation adjustment for cloud cover & transmission coefficient for July	0.1 – 1.0	DDcentEVI only sradadj(7) in sitepar.in
SRADJ(8)	Solar radiation adjustment for cloud cover & transmission coefficient for August	0.1 – 1.0	DDcentEVI only sradadj(8) in sitepar.in
SRADJ(9)	Solar radiation adjustment for cloud cover & transmission coefficient for September	0.1 – 1.0	DDcentEVI only sradadj(9) in sitepar.in
SRADJ(10)	Solar radiation adjustment for cloud cover & transmission coefficient for October	0.1 – 1.0	DDcentEVI only sradadj(10) in sitepar.in
SRADJ(11)	Solar radiation adjustment for cloud cover & transmission coefficient for November	0.1 – 1.0	DDcentEVI only sradadj(11) in sitepar.in
SRADJ(12)	Solar radiation adjustment for cloud cover & transmission coefficient for December	0.1 – 1.0	DDcentEVI only sradadj(12) in sitepar.in

RAINHR	Duration of each rain event	hours	DDcentEVI only hours_rain in sitepar.in
	Site Specific Parameters		
ivauto	Use Burke's equations to initialize soil C pools = 0 the user has supplied the initial values = 1 initialize using the grass soil parameters = 2 initialize using the crop soil parameters = 3 initialize using the forest soil parameters	index	1, 2, 3
nelem	Number of elements (besides C) to be simulated: 1 = simulate N only 2 = simulate N, P 3 = simulate N, P, S	index	1, 2, 3
sitlat	Latitude	decimal degrees	
sitlng	Longitude	decimal degrees	
ELEV	elevation	meters	DDcentEVI only Elevation in sitepar.in
SITSLP	site slope,	degrees	DDcentEVI only Site slope in sitepar.in
ASPECT	site aspect	degrees	DDcentEVI only Aspect in sitepar.in

EHORIZ	site east horizon	degrees	DDcentEVI only Ehoriz in sitepar.in
WHORIZ	site west horizon	degrees	DDcentEVI only Whoriz in sitepar.in
sand	Fraction of sand in soil.	fraction	0.0 – 1.0 Overwritten by values in the file soils.in Removed from DDcentEVI
silt	Fraction of silt in soil.	fraction	0.0 – 1.0 Overwritten by values in the file soils.in Removed from DDcentEVI
clay	Fraction of clay in soil.	fraction	0.0 – 1.0 Overwritten by values in the file soils.in Removed from DDcentEVI

rock	Fraction of rock in soil.	fraction	0.0 – 1.0 Overwritten by values in the file soils.in Removed from DDcentEVI
bulkd	Soil bulk density.	g cm^{-3} or kg $liter^{-1}$	0.0 – 2.0 Overwritten by values in the file soils.in Removed from DDcentEVI
nlayer	Number of soil layers in water model (maximum of 9); used only to calculated the amount of water available for survival of the plant.	count	1 – 9
nlaypg	Number of soil layers in the top level of the water model; determines avh2o(1), used for plant growth and root death.	count	1 – ***nlayer*** Overwritten by values of claypg or tlaypg in the crop.100 or tree.100 files.

drain	The fraction of excess water lost by drainage; indicates whether a soil is sensitive for anaerobiosis (drain=0) or not (drain=1). Anaerobic conditions (high soil water content) cause decomposition to decrease.	fraction	0 – 1 (DRAIN=1 for well drained sandy soils and DRAIN=0 for a poorly drained clay soil)
basef	Fraction of the soil water content of layer ***nlayer*** + 1 which is lost via base flow.	fraction	0.0 – 1.0
stormf	This parameter is not used by DayCent since the runoff calculation (infiltration excess) replaces the stormflow calculation used by monthly Century.	fraction	0.0 – 1.0
precro	Amount of monthly rainfall required in order for runoff to occur.	cm	Used by monthly Century only
fracro	Fraction of the monthly rainfall, over PRECRO, which is lost via runoff.	fraction	0.0 – 1.0 Used by monthly Century only

swflag	**SWFLAG is always 0 in DayCent regardless of the value set in <site>.100. Values of field capacity and wilting point are always read from soils.in.** In monthly Century this flag indicates the source of the values for AWILT and AFIEL, either from actual data from the site.100 file or from equations from Gupta and Larson (1979) or Rawls et al. (1982). = 0 use actual data from the site.100 file = 1 use G & L for both awilt (-15 bar) and afiel (-0.33 bar) = 2 use G & L for both awilt (-15 bar) and afiel (-0.10 bar) = 3 use Rawls for both awilt (-15 bar) and afiel (-0.33 bar) = 4 use Rawls for both awilt (-15 bar) and afiel (-0.10 bar) = 5 use Rawls for afiel (-0.33 bar) with actual data for awilt = 6 use Rawls for afiel (-0.10 bar) with actual data for awilt	index	0 , 1, 2, 3, 4, 5, 6
awilt(1)	Wilting point of soil layer 1; used only if swflag = 0, 5, or 6	fraction	0.0 – 1.0 Recalculated from values in the file soils.in Removed from DDcentEVI

awilt(2)	Wilting point of soil layer 2; used only if swflag = 0, 5, or 6	fraction	0.0 – 1.0 Recalculated from values in the file soils.in Removed from DDcentEVI
awilt(3)	Wilting point of soil layer 3; used only if swflag = 0, 5, or 6	fraction	0.0 – 1.0 Recalculated from values in the file soils.in Removed from DDcentEVI
awilt(4)	Wilting point of soil layer 4; used only if swflag = 0, 5, or 6	fraction	0.0 – 1.0 Recalculated from values in the file soils.in Removed from DDcentEVI
awilt(5)	Wilting point of soil layer 5; used only if swflag = 0, 5, or 6	fraction	0.0 – 1.0 Recalculated from values in the file soils.in Removed from DDcentEVI

awilt(6)	Wilting point of soil layer 6; used only if swflag = 0, 5, or 6	fraction	0.0 – 1.0 Recalculated from values in the file soils.in Removed from DDcentEVI
awilt(7)	Wilting point of soil layer 7; used only if swflag = 0, 5, or 6	fraction	0.0 – 1.0 Recalculated from values in the file soils.in Removed from DDcentEVI
awilt(8)	Wilting point of soil layer 8; used only if swflag = 0, 5, or 6	fraction	0.0 – 1.0 Recalculated from values in the file soils.in Removed from DDcentEVI
awilt(9)	Wilting point of soil layer 9; used only if swflag = 0, 5, or 6	fraction	0.0 – 1.0 Recalculated from values in the file soils.in Removed from DDcentEVI

awilt(10)	Wilting point of soil layer 10; used only if swflag = 0, 5, or 6	fraction	0.0 – 1.0 Recalculated from values in the file soils.in Removed from DDcentEVI
afiel(1)	Field capacity of soil layer 1; used only if swflag = 0, 5, or 6	fraction	0.0 – 1.0 Recalculated from values in the file soils.in Removed from DDcentEVI
afiel(2)	Field capacity of soil layer 2; used only if swflag = 0, 5, or 6	fraction	0.0 – 1.0 Recalculated from values in the file soils.in Removed from DDcentEVI
afiel(3)	Field capacity of soil layer 3; used only if swflag = 0, 5, or 6	fraction	0.0 – 1.0 Recalculated from values in the file soils.in Removed from DDcentEVI

afiel(4)	Field capacity of soil layer 4; used only if swflag = 0, 5, or 6	fraction	0.0 – 1.0 Recalculated from values in the file soils.in Removed from DDcentEVI
afiel(5)	Field capacity of soil layer 5; used only if swflag = 0, 5, or 6	fraction	0.0 – 1.0 Recalculated from values in the file soils.in Removed from DDcentEVI
afiel(6)	Field capacity of soil layer 6; used only if swflag = 0, 5, or 6	fraction	0.0 – 1.0 Recalculated from values in the file soils.in Removed from DDcentEVI
afiel(7)	Field capacity of soil layer 7; used only if swflag = 0, 5, or 6	fraction	0.0 – 1.0 Recalculated from values in the file soils.in Removed from DDcentEVI

afiel(8)	Field capacity of soil layer 8; used only if swflag = 0, 5, or 6	fraction	0.0 – 1.0 Recalculated from values in the file soils.in Removed from DDcentEVI
afiel(9)	Field capacity of soil layer 9; used only if swflag = 0, 5, or 6	fraction	0.0 – 1.0 Recalculated from values in the file soils.in Removed from DDcentEVI
afiel(10)	Field capacity of soil layer 10; used only if swflag = 0, 5, or 6	fraction	0.0 – 1.0 Recalculated from values in the file soils.in Removed from DDcentEVI
PH	Soil pH		1.0 – 14.0
pslsrb	Slope term which controls the fraction of mineral P that is labile	?	
sorpmx	Maximum P sorption potential for a soil	?	

SUBLIM	Multiplier on sublimation	Scaling factor	DDcentEVI only sublimscale in sitepar.in
REFLEC	vegetation reflectivity/albedo	fraction	DDcentEVI only reflec in sitepar.in
ALBEDO	snow albedo	fraction	DDcentEVI only albedo in sitepar.in
DMPFLUX	Dampens strong fluxes of water between soil layers	In h2oflux routine (0.000001 = original value)	DDcentEVI only dmpflux in sitepar.in
HPOTD	hydraulic water potential of deep storage layer	cm (?)	DDcentEVI only hpotdeep in sitepar.in
KSATD	saturated hydraulic conductivity of deep storage layer	cm sec^{-1}	DDcentEVI only ksatdeep in sitepar.in
TBMIN	minimum temperature for bottom soil layer	ºC	DDcentEVI only tbotmn in sitepar.in
TBMAX	maximum temperature for bottom soil layer	ºC	DDcentEVI only tbotmx in sitepar.in

DMPFCT	damping factor for calculating soil temperature by layer	Scaling factor	DDcentEVI only dmp in sitepar.in
TIMLAG	days from Jan 1 to coolest temp at bottom of soil (days)	Number of days	DDcentEVI only timlag in sitepar.in
NCOEFF	minimum water/temperature limitation coefficient for nitrify	Scaling factor	DDcentEVI only Ncoeff in sitepar.in
DNSTRT	turn off respiration restraint on denitrification starting on this day days	day of year	DDcentEVI only jdayStart in sitepar.in
DNEND	turn off respiration restraint on denitrification ends on this day	day of year	DDcentEVI only jdayEnd in sitepar.in
NADJFC	maximum proportion of nitrified N lost as N_2O @ field capacity	fraction	DDcentEVI only N2Oadjust_fc in sitepar.in
NADJWP	minimum proportion of nitrified N lost as N_2O @ wilting point	fraction	DDcentEVI only N2Oadjust_wp in sitepar.in

MAXNIT	maximum daily nitrification amount	g N m^{-2} day^{-1}	DDcentEVI only MaxNitAmt in sitepar.in
MINO3	fraction of new net mineralization that goes to NO3 (0.0-1.0)	0.0 – 1.0	DDcentEVI only netmn_to_no3 in sitepar.in
WFPSNIP	adjustment on inflection point for the water filled pore space effect on denitrification curve	< 1.0 allow denitrification to occur at lower soil water content > 1.0 require wetter conditions for denitrification	DDcentEVI only wfpsdnitadj in sitepar.in
N2N2OA	N_2/N_2O ratio adjustment factor for computing the N_2/N_2O ratio during non-flooded conditions. Values > 1.0 increase this ratio, values (0.0-1.0) decrease this ratio. For flooded conditions see FLN2OR in fix.100.	scalar	DDcentEVI only N2N2Oadj in sitepar.in
	External Inputs		
epnfa(1) or epnfa(INCPT)	*Intercept* value for determining the effect of annual precipitation on atmospheric N fixation (wet and dry deposition)	g N m^{-2} yr^{-1}	
epnfa(2) or epnfa(SLOPE)	*Slope* values for determining the effect of annual precipitation on atmospheric N fixation (wet and dry deposition)	g N m^{-2} yr^{-1}	0.0 – 1.0
epnfs(1) or epnfs(INCPT)	*Intercept* value for determining the effect of annual precipitation on non-symbiotic soil N fixation; not used if fix.100 value nsnfix = 1	g N m^{-2} yr^{-1}	

epnfs(2) or epnfs(SLOPE)	*Slope* value for determining the effect of annual precipitation on non-symbiotic soil N fixation; not used if fix.100 value nsnfix = 1	g N m^{-2} yr^{-1}	0.0 – 1.0
satmos(1) or satmos(INCPT)	*Intercept* value for atmospheric S inputs as a linear function of annual precipitation	g S m^{-2} yr^{-1} cm^{-1}	
satmos(2) or satmos(SLOPE)	*Slope* value for atmospheric S inputs as a linear function of annual precipitation	g S m^{-2} yr^{-1} cm^{-1}	0.0 – 1.0
sirri	S concentration in irrigation water	mg S L^{-1}	0.0 – 1000.0
	Initial Soil Organic Matter Pools		
som1ci(1,1)	Initial value of the active surface organic matter pool (UNLABL)	g C m^{-2}	0.0 – 99,999
som1ci(1,2)	Initial value of the active surface organic matter pool (LABELD)	g C m^{-2}	0.0 – 99,999
som1ci(2,1)	Initial value of the active soil organic matter pool (UNLABL)	g C m^{-2}	0.0 – 99,99
som1ci(2,2)	Initial value of the active soil organic matter pool (LABELD)	g C m^{-2}	0.0 – 99,99
som2ci(1,1)	Initial value of the slow surface organic matter pool (UNLABL)	g C m^{-2}	0.0 – 99,99
som2ci(1,2)	Initial value of the slow surface organic matter pool (LABELD)	g C m^{-2}	0.0 – 99,99
som2ci(2,1)	Initial value of the slow soil organic matter pool (UNLABL)	g C m^{-2}	0.0 – 99,99

som2ci(2,2)	Initial value of the slow soil organic matter pool (LABELD)	g C m^{-2}	0.0 – 99,99
som3ci(1)	Initial value of the passive soil organic matter pool (UNLABL)	g C m^{-2}	0.0 – 99,99
som3ci(2)	Initial value of the passive soil organic matter pool (LABELD)	g C m^{-2}	0.0 – 99,99
rcesA(*,*)	**A = the SOM pool (1, 2, 3); the first subscript = SRFC, SOIL; the second subscript = N, P, S.**		
rces1(1,1)	Initial C/N ratio for surface som1	C/N ratio	1.0 – 1000
rces1(1,2)	Initial C/P ratio for surface som1	C/P ratio	1.0 – 1000
rces1(1,3)	Initial C/S ratio for surface som1	C/S ratio	1.0 – 1000
rces1(2,1)	Initial C/N ratio for soil som1	C/N ratio	1.0 – 1000
rces1(2,2)	Initial C/P ratio for soil som1	C/P ratio	1.0 – 1000
rces1(2,3)	Initial C/S ratio for soil som1	C/S ratio	1.0 – 1000
rces2(1,1)	Initial C/N ratio for surface som2	C/N ratio	1.0 – 1000
rces2(1,2)	Initial C/P ratio for surface som2	C/P ratio	1.0 – 1000
rces2(1,3)	Initial C/S ratio for surface som2	C/S ratio	1.0 – 1000
rces2(2,1)	Initial C/N ratio for soil som2	C/N ratio	1.0 – 1000
rces2(2,2)	Initial C/P ratio for soil som2	C/P ratio	1.0 – 1000

rces2(2,3)	Initial C/S ratio for soil som2	C/S ratio	1.0 – 1000
rces3(1)	Initial C/N ratio for som3	C/N ratio	1.0 – 1000
rces3(2)	Initial C/P ratio for som3	C/P ratio	1.0 – 1000
rces3(3)	Initial C/S ratio for som3	C/S ratio	1.0 – 1000
clittr(1,1)	Initial *surface* litter pool (UNLABL) Structural + Metabolic	g C m^{-2}	0.0 – 9999
clittr(1,2)	Initial *surface* litter pool (LABELD) Structural + Metabolic	g C m^{-2}	0.0 – 9999
clittr(2,1)	Initial *soil* litter pool (UNLABL) Structural + Metabolic	g C m^{-2}	0.0 – 9999
clittr(2,2)	Initial *soil* litter pool (LABELD) Structural + Metabolic	g C m^{-2}	0.0 – 9999
rcelit(1,1)	Initial C/N ratio of *surface* litter Structural + Metabolic	g N m^{-2}	1.0 – 1000
rcelit(1,2)	Initial C/P ratio of *surface* litter Structural + Metabolic	g P m^{-2}	1.0 – 1000
rcelit(1,3)	Initial C/S ratio of *surface* litter Structural + Metabolic	g S m^{-2}	1.0 – 1000

rcelit(2,1)	Initial C/N ratio of *soil* litter Structural + Metabolic	g N m^{-2}	1.0 – 1000
rcelit(2,2)	Initial C/P ratio of *soil* litter Structural + Metabolic	g P m^{-2}	1.0 – 1000
rcelit(2,3)	Initial C/S ratio of *soil* litter Structural + Metabolic	g S m^{-2}	1.0 – 1000
aglcis(1) or aglcis(UNLABL)	Initial value of the above ground live C pool for crops/grasses (UNLABL)	g C m^{-2}	1.0 – 9999
aglcis(2) or aglcis(LABELD)	Initial value of the above ground live C pool for crops/grasses (LABELD)	g C m^{-2}	1.0 – 9999
aglive(1)	Initial value of the above ground live N pool for crops/grasses	g N m^{-2}	1.0 – 9999
aglive(2)	Initial value of the above ground live P pool for crops/grasses	g P m^{-2}	1.0 – 9999
aglive(3)	Initial value of the above ground live S pool for crops/grasses	g S m^{-2}	1.0 – 9999
bglcis(1) or bglcis(UNLABL)	Initial value of the below ground live C pool for crops/grasses (UNLABL)	g C m^{-2}	1.0 – 9999
bglcis(2) or bglcis(LABELD)	Initial value of the below ground live C pool for crops/grasses (LABELD)	g C m^{-2}	1.0 – 9999
bglive(1)	Initial value of the below ground live P pool for crops/grasses	g N m^{-2}	1.0 – 9999

bglive(2)	Initial value of the below ground live S pool for crops/grasses	g P m^{-2}	1.0 – 9999
bglive(3)	Initial value of the below ground live P pool for crops/grasses	g S m^{-2}	1.0 – 9999
stdcis(1) or stdcis(UNLABL)	Initial value of the standing dead C pool for crops/grasses (UNLABL)	g C m^{-2}	1.0 – 9999
stdcis(2) or stdcis(LABELD)	Initial value of the standing dead C pool for crops/grasses (LABELD)	g C m^{-2}	1.0 – 9999
stdede(1)	Initial value of the standing dead N pool for crops/grasses	g N m^{-2}	1.0 – 9999
stdede(2)	Initial value of the standing dead P pool for crops/grasses	g P m^{-2}	1.0 – 9999
stdede(3)	Initial value of the standing dead S pool for crops/grasses	g S m^{-2}	1.0 – 9999
	Initial Forest pools		
rlvcis(1) or rlvcis(UNLABL)	Initial value of the live leaf C pool for trees/shrubs (UNLABL)	g C m^{-2}	1.0 – 9999
rlvcis(2) or rlvcis(LABELD)	Initial value of the live leaf C pool for trees/shrubs (LABELD)	g C m^{-2}	1.0 – 9999
rleave(1)	Initial value of the live leaf N pool for trees/shrubs	g N m^{-2}	1.0 – 9999
rleave(2)	Initial value of the live leaf P pool for trees/shrubs	g P m^{-2}	1.0 – 9999
rleave(3)	Initial value of the live leaf S pool for trees/shrubs	g S m^{-2}	1.0 – 9999
fbrcis(1) or fbrcis(UNLABL)	Initial value of the live fine branch C pool for trees/shrubs (UNLABL)	g C m^{-2}	1.0 – 9999
fbrcis(2) or fbrcis(LABELD)	Initial value of the live fine branch C pool for trees/shrubs (LABELD)	g C m^{-2}	1.0 – 9999

fbrche(1)	Initial value of the live fine branch N pool for trees/shrubs	g N m^{-2}	1.0 – 9999
fbrche(2)	Initial value of the live fine branch P pool for trees/shrubs	g P m^{-2}	1.0 – 9999
fbrche(3)	Initial value of the live fine branch S pool for trees/shrubs	g S m^{-2}	1.0 – 9999
rlwcis(1) or rlwcis(UNLABL)	Initial value of the live large wood C pool for trees/shrubs (UNLABL)	g C m^{-2}	1.0 – 99,999
rlwcis(2) or rlwcis(LABELD)	Initial value of the live large wood C pool for trees/shrubs (LABELD)	g C m^{-2}	1.0 – 99,999
rlwode(1)	Initial value of the live large wood N pool for trees/shrubs	g N m^{-2}	1.0 – 9999
rlwode(2)	Initial value of the live large wood P pool for trees/shrubs	g P m^{-2}	1.0 – 9999
rlwode(3)	Initial value of the live large wood S pool for trees/shrubs	g S m^{-2}	1.0 – 9999
frtcis(1) or frtcis(UNLABL)	Initial value of the live fine root C pool for trees/shrubs (UNLABL)	g C m^{-2}	1.0 – 9999
frtcis(2) or frtcis(LABELD)	Initial value of the live fine root C pool for trees/shrubs (LABELD)	g C m^{-2}	1.0 – 9999
froote(1)	Initial value of the live fine root N pool for trees/shrubs	g N m^{-2}	1.0 – 9999
froote(2)	Initial value of the live fine root P pool for trees/shrubs	g P m^{-2}	1.0 – 9999
froote(3)	Initial value of the live fine root S pool for trees/shrubs	g S m^{-2}	1.0 – 9999
crtcis(1) or crtcis(UNLABL)	Initial value of the live coarse root C pool for trees/shrubs (UNLABL)	g C m^{-2}	1.0 – 99,999
crtcis(2) or crtcis(LABELD)	Initial value of the live coarse root C pool for trees/shrubs (LABELD)	g C m^{-2}	1.0 – 99,999
croote(1)	Initial value of the live coarse root N pool for trees/shrubs	g N m^{-2}	1.0 – 9999

croote(2)	Initial value of the live coarse root P pool for trees/shrubs	g P m^{-2}	1.0 – 9999
croote(3)	Initial value of the live coarse root S pool for trees/shrubs	g S m^{-2}	1.0 – 9999
wd1cis(1) or wd1cis(UNLABL)	Initial value of the dead fine branch C pool for trees/shrubs (UNLABL)	g C m^{-2}	1.0 – 99,999
wd1cis(2) or wd1cis(LABELD)	Initial value of the dead fine branch C pool for trees/shrubs (LABELD)	g C m^{-2}	1.0 – 99,999
wd2cis(1) or wd2cis(UNLABL)	Initial value of the dead large wood C pool for trees/shrubs (UNLABL)	g C m^{-2}	1.0 – 99,999
wd2cis(2) or wd2cis(LABELD)	Initial value of the dead large wood C pool for trees/shrubs (LABELD)	g C m^{-2}	1.0 – 99,999
wd3cis(1) or wd3cis(UNLABL)	Initial value of the dead coarse root C pool for trees/shrubs (UNLABL)	g C m^{-2}	1.0 – 99,999
wd3cis(2) or wd3cis(LABELD)	Initial value of the dead coarse root C pool for trees/shrubs (LABELD)	g C m^{-2}	1.0 – 99,999
	Initial Soil Mineral pools		
minerl(1,1)	Mineral N in soil layer 1	g N m^{-2}	0.0 – 1000
minerl(2,1)	Mineral N in soil layer 2	g N m^{-2}	0.0 – 1000
minerl(3,1)	Mineral N in soil layer 3	g N m^{-2}	0.0 – 1000
minerl(4,1)	Mineral N in soil layer 4	g N m^{-2}	0.0 – 1000
minerl(5,1)	Mineral N in soil layer 5	g N m^{-2}	0.0 – 1000
minerl(6,1)	Mineral N in soil layer 6	g N m^{-2}	0.0 – 1000
minerl(7,1)	Mineral N in soil layer 7	g N m^{-2}	0.0 – 1000

minerl(8,1)	Mineral N in soil layer 8	g N m^{-2}	0.0 – 1000
minerl(9,1)	Mineral N in soil layer 9	g N m^{-2}	0.0 – 1000
minerl(10,1)	Mineral N in soil layer 10	g N m^{-2}	0.0 – 1000
minerl(1,2)	Mineral P in soil layer 1	g P m^{-2}	0.0 – 1000
minerl(2,2)	Mineral P in soil layer 2	g P m^{-2}	0.0 – 1000
minerl(3,2)	Mineral P in soil layer 3	g P m^{-2}	0.0 – 1000
minerl(4,2)	Mineral P in soil layer 4	g P m^{-2}	0.0 – 1000
minerl(5,2)	Mineral P in soil layer 5	g P m^{-2}	0.0 – 1000
minerl(6,2)	Mineral P in soil layer 6	g P m^{-2}	0.0 – 1000
minerl(7,2)	Mineral P in soil layer 7	g P m^{-2}	0.0 – 1000
minerl(8,2)	Mineral P in soil layer 8	g P m^{-2}	0.0 – 1000
minerl(9,2)	Mineral P in soil layer 9	g P m^{-2}	0.0 – 1000
minerl(10,2)	Mineral P in soil layer 10	g P m^{-2}	0.0 – 1000
minerl(1,3)	Mineral S in soil layer 1	g S m^{-2}	0.0 – 1000
minerl(2,3)	Mineral S in soil layer 2	g S m^{-2}	0.0 – 1000
minerl(3,3)	Mineral S in soil layer 3	g S m^{-2}	0.0 – 1000

minerl(4,3)	Mineral S in soil layer 4	g S m^{-2}	0.0 – 1000
minerl(5,3)	Mineral S in soil layer 5	g S m^{-2}	0.0 – 1000
minerl(6,3)	Mineral S in soil layer 6	g S m^{-2}	0.0 – 1000
minerl(7,3)	Mineral S in soil layer 7	g S m^{-2}	0.0 – 1000
minerl(8,3)	Mineral S in soil layer 8	g S m^{-2}	0.0 – 1000
minerl(9,3)	Mineral S in soil layer 9	g S m^{-2}	0.0 – 1000
minerl(10,3)	Mineral S in soil layer 10	g S m^{-2}	0.0 – 1000
parent(1)	Mineral N in parent material	g N m^{-2}	0.0 – 9999
parent(2)	Mineral P in parent material	g P m^{-2}	0.0 – 9999
parent(3)	Mineral S in parent material	g S m^{-2}	0.0 – 9999
secndy(1)	Secondary Mineral N	g N m^{-2}	0.0 – 9999
secndy(2)	Secondary Mineral P	g P m^{-2}	0.0 – 9999
secndy(3)	Secondary Mineral S	g S m^{-2}	0.0 – 9999
occlud	P in occluded pool	g P m^{-2}	0.0 – 9999

	Initial Water parameters rwcf = (vswc-vswcmin) / (fieldc-vswcmin) Note: this parameter is no longer used to initialize soil water content (swc) for a new run. (Use ***fswcinit*** in sitepar.in to initialize swc). RWCF may be used to initialize swc when the site file is used in an extend.		
rwcf(1)	Relative water content fraction for CENTURY soil layer 1	fraction	0.0 – 1.0
rwcf(2)	Relative water content fraction for CENTURY soil layer 2	fraction	0.0 – 1.0
rwcf(3)	Relative water content fraction for CENTURY soil layer 3	fraction	0.0 – 1.0
rwcf(4)	Relative water content fraction for CENTURY soil layer 4	fraction	0.0 – 1.0
rwcf(5)	Relative water content fraction for CENTURY soil layer 5	fraction	0.0 – 1.0
rwcf(6)	Relative water content fraction for CENTURY soil layer 6	fraction	0.0 – 1.0
rwcf(7)	Relative water content fraction for CENTURY soil layer 7	fraction	0.0 – 1.0
rwcf(8)	Relative water content fraction for CENTURY soil layer 8	fraction	0.0 – 1.0
rwcf(9)	Relative water content fraction for CENTURY soil layer 9	fraction	0.0 – 1.0
rwcf(10)	Relative water content fraction for CENTURY soil layer 10	fraction	0.0 – 1.0
snlq	Initial amount of liquid water in snow.	cm	0.0 - 1000
snow	Initial amount of snow (as snow water equivalents).	cm	0.0 - 1000

SNWINS	snow effect on soil surface temp 0 = not insulating, 1 = insulating There might be additional options for DDcentEVI	index	DDcentEVI only SnowFlag in sitepar.in

Appendix 1.11 Tree/Forest parameters (tree.100)

These tree.100 parameters are read for the initial tree specified in the schedule file header, and for each subsequent tree introduced in the schedule file with a TREE event.

decid	= 0 if forest is evergreen = 1 if forest is deciduous = 2 if forest is drought deciduous	index	0, 1, 2
prdx(2)	Coefficient for calculating total monthly potential production as a function of solar radiation outside the atmosphere. It functions as a radiation use efficiency scalar on potential production. It reflects the relative genetic potential of the plant; larger PRDX(2) values indicate greater growth potential.	scaling factor, (gC production) $*m^{-2}$ $*month^{-1}$ $*Langley^{-1}$	0.1 – 5.0
ppdf(1)	Optimum temperature for production for parameterization of a Poisson Density Function curve to simulate temperature effect on growth	ºC	10.0 – 40.0
ppdf(2)	Maximum temperature for production for parameterization of a Poisson Density Function curve to simulate temperature effect on growth	ºC	20.0 – 50.0
ppdf(3)	left curve shape for parameterization of a Poisson Density Function curve to simulate temperature effect on growth		0.0 – 1.0
ppdf(4)	right curve shape for parameterization of a Poisson Density Function curve to simulate temperature effect on growth		0.0 – 10.0
cerfor(1,*,*)	***minimum* C/E ratio for forest compartments**		
cerfor(1,1,1)	(1,1,1) = N, leaf	C/N ratio	1.0 – 200.0
cerfor(1,1,2)	(1,1,2) = P, leaf	C/P ratio	1.0 – 9999.0

cerfor(1,1,3)	(1,1,3) = S, leaf	C/S ratio	1.0 – 9999.0
cerfor(1,2,1)	(1,2,1) = N, fine root	C/N ratio	1.0 – 200.0
cerfor(1,2,2)	(1,2,2) = P, fine root	C/P ratio	1.0 – 9999.0
cerfor(1,2,3)	(1,2,3) = S, fine root	C/S ratio	1.0 – 9999.0
cerfor(1,3,1)	(1,3,1) = N, fine branch	C/N ratio	1.0 – 1000.0
cerfor(1,3,2)	(1,3,2) = P, fine branch	C/P ratio	1.0 – 9999.0
cerfor(1,3,3)	(1,3,3) = S, fine branch	C/S ratio	1.0 – 9999.0
cerfor(1,4,1)	(1,4,1) = N, large wood	C/N ratio	1.0 – 1500.0
cerfor(1,4,2)	(1,4,2) = P, large wood	C/P ratio	1.0 – 9999.0
cerfor(1,4,3)	(1,4,3) = S, large wood	C/S ratio	1.0 – 9999.0
cerfor(1,5,1)	(1,5,1) = N, coarse root	C/N ratio	1.0 – 1500.0
cerfor(1,5,2)	(1,5,2) = P, coarse root	C/P ratio	1.0 – 9999.0
cerfor(1,5,3)	(1,5,3) = S, coarse root	C/S ratio	1.0 – 9999.0
cerfor(2,*,*)	***maximum* C/E ratio for forest compartments**		
cerfor(2,1,1)	(2,1,1) = N, leaf	C/N ratio	1.0 – 200.0
cerfor(2,1,2)	(2,1,2) = P, leaf	C/P ratio	1.0 – 9999.0

cerfor(2,1,3)	(2,1,3) = S, leaf	C/S ratio	1.0 – 9999.0
cerfor(2,2,1)	(2,2,1) = N, fine root	C/N ratio	1.0 – 200.0
cerfor(2,2,2)	(2,2,2) = P, fine root	C/P ratio	1.0 – 9999.0
cerfor(2,2,3)	(2,2,3) = S, fine root	C/S ratio	1.0 – 9999.0
cerfor(2,3,1)	(2,3,1) = N, fine branch	C/N ratio	1.0 – 1000.0
cerfor(2,3,2)	(2,3,2) = P, fine branch	C/P ratio	1.0 – 9999.0
cerfor(2,3,3)	(2,3,3) = S, fine branch	C/S ratio	1.0 – 9999.0
cerfor(2,4,1)	(2,4,1) = N, large wood	C/N ratio	1.0 – 1500.0
cerfor(2,4,2)	(2,4,2) = P, large wood	C/P ratio	1.0 – 9999.0
cerfor(2,4,3)	(2,4,3) = S, large wood	C/S ratio	1.0 – 9999.0
cerfor(2,5,1)	(2,5,1) = N, coarse root	C/N ratio	1.0 – 1500.0
cerfor(2,5,2)	(2,5,2) = P, coarse root	C/P ratio	1.0 – 9999.0
cerfor(2,5,3)	(2,5,3) = S, coarse root	C/S ratio	1.0 – 9999.0
cerfor(3,*,*)	***initial* C/E ratio for forest compartments**		
cerfor(3,1,1)	(3,1,1) = N, leaf	C/N ratio	1.0 – 200.0
cerfor(3,1,2)	(3,1,2) = P, leaf	C/P ratio	1.0 – 9999.0

cerfor(3,1,3)	(3,1,3) = S, leaf	C/S ratio	1.0 – 9999.0
cerfor(3,2,1)	(3,2,1) = N, fine root	C/N ratio	1.0 – 200.0
cerfor(3,2,2)	(3,2,2) = P, fine root	C/P ratio	1.0 – 9999.0
cerfor(3,2,3)	(3,2,3) = S, fine root	C/S ratio	1.0 – 9999.0
cerfor(3,3,1)	(3,3,1) = N, fine branch	C/N ratio	1.0 – 1000.0
cerfor(3,3,2)	(3,3,2) = P, fine branch	C/P ratio	1.0 – 9999.0
cerfor(3,3,3)	(3,3,3) = S, fine branch	C/S ratio	1.0 – 9999.0
cerfor(3,4,1)	(3,4,1) = N, large wood	C/N ratio	1.0 – 1500.0
cerfor(3,4,2)	(3,4,2) = P, large wood	C/P ratio	1.0 – 9999.0
cerfor(3,4,3)	(3,4,3) = S, large wood	C/S ratio	1.0 – 9999.0
cerfor(3,5,1)	(3,5,1) = N, coarse root	C/N ratio	1.0 – 1500.0
cerfor(3,5,2)	(3,5,2) = P, coarse root	C/P ratio	1.0 – 9999.0
cerfor(3,5,3)	(3,5,3) = S, coarse root	C/S ratio	1.0 – 9999.0
decw1	Maximum decomposition rate constant for wood1 (dead fine branch) per year before temperature and moisture and pH effects are applied. (See woodec.f)	yr^{-1}	0.0 – 5.0
decw2	Maximum decomposition rate constant for wood2 (dead large wood) per year before temperature and moisture and pH effects are applied. (See woodec.f)	yr^{-1}	0.0 – 5.0

decw3	Maximum decomposition rate constant for wood3 (dead coarse root) per year before temperature and moisture and pH effects are applied. (See woodec.f)	yr^{-1}	0.0 – 5.0
fcfrac(*,1)	**C allocation fraction of new production for juvenile forest (time < swold) .** **Fractions of C allocated to woody parts are internally normalized to 1.0 after C allocation to leaves and fine roots occurs.		
fcfrac(1,1)	(1,1) = leaves Obsolete parameter – C allocation to leaves is determine dynamically and is regulated by the amount of wood biomass that can support the leaf biomass.	fraction	0.0 – 1.0
fcfrac(2,1)	(2,1) = fine roots Obsolete parameter – C allocation to fine roots is determined dynamically according to soil nutrient and moisture status. See tfrtcn(*) and tfrtcw(*) parameters.	fraction	0.0 – 1.0
fcfrac(3,1)**	(3,1) = relative fraction of C allocated to fine branches	fraction	0.0 – 1.0
fcfrac(4,1)**	(4,1) = relative fraction of C allocated to large wood	fraction	0.0 – 1.0
fcfrac(5,1)**	(5,1) = relative fraction of C allocated to coarse roots	fraction	0.0 – 1.0
fcfrac(*,2)	**C allocation fraction of new production for mature forest (time ≥ swold) .** **Fractions of C allocated to woody parts are internally normalized to 1.0 after C allocation to leaves and fine roots occurs.		
fcfrac(1,2)	(1,2) = leaves Obsolete parameter – C allocation to leaves is determine dynamically and is regulated by the amount of wood biomass that can support the leaf biomass.	fraction	0.0 – 1.0

fcfrac(2,2)	(2,2) = fine roots Obsolete parameter – C allocation to fine roots is determined dynamically according to soil nutrient and moisture status. See tfrtcn(*) and tfrtcw(*) parameters.	fraction	0.0 – 1.0
fcfrac(3,2)**	(3,2) = relative fraction of C allocated to fine branches	fraction	0.0 – 1.0
fcfrac(4,2)**	(4,2) = relative fraction of C allocated to large wood	fraction	0.0 – 1.0
fcfrac(5,2)**	(5,2) = relative fraction of C allocated to coarse roots	fraction	0.0 – 1.0
tfrtcn(1)	Maximum fraction of C allocated to fine roots under maximum nutrient stress.	fraction	0.0 – 1.0
tfrtcn(2)	Minimum fraction of C allocated to fine roots with no nutrient stress.	fraction	0.0 – 1.0
tfrtcw(1)	Maximum fraction of C allocated to fine roots under maximum water stress.	fraction	0.0 – 1.0
tfrtcw(2)	Minimum fraction of C allocated to fine roots with no water stress.	fraction	0.0 – 1.0
leafdr(*)	***Monthly* death rate fractions for leaves for each month 1-12**		**0.0 – 1.0**
leafdr(1)	Death rate fractions for leaves for January.	fraction	0.0 – 1.0
leafdr(2)	Death rate fractions for leaves for February.	fraction	0.0 – 1.0
leafdr(3)	Death rate fractions for leaves for March.	fraction	0.0 – 1.0
leafdr(4)	Death rate fractions for leaves for April.	fraction	0.0 – 1.0
leafdr(5)	Death rate fractions for leaves for May.	fraction	0.0 – 1.0
leafdr(6)	Death rate fractions for leaves for June.	fraction	0.0 – 1.0

leafdr(7)	Death rate fractions for leaves for July.	fraction	0.0 – 1.0
leafdr(8)	Death rate fractions for leaves for August.	fraction	0.0 – 1.0
leafdr(9)	Death rate fractions for leaves for September.	fraction	0.0 – 1.0
leafdr(10)	Death rate fractions for leaves for October.	fraction	0.0 – 1.0
leafdr(11)	Death rate fractions for leaves for November.	fraction	0.0 – 1.0
leafdr(12)	Death rate fractions for leaves for December.	fraction	0.0 – 1.0
btolai	Biomass to leaf area index (LAI) conversion factor for trees.	units LAI / g biomass	Biome specific 0.001 – 0.02 (see below)
klai	Large wood mass at which half of theoretical maximum leaf area (***maxlai***) is achieved.	g C m^{-2}	
laitop	Parameter determining the relationship between LAI and forest production: LAI effect = 1 - exp(***laitop*** * LAI).		
maxlai	Theoretical maximum leaf area index achieved in a mature forest.		0.0 – 50.0
maxldr	Multiplier for effect of N availability on leaf death rates (evergreen forest only); ratio between death rate at unlimited vs. severely limited N status.		0.0 – 1.0
forrtf(1)	Fraction of N retranslocated from green forest leaves before litterfall	fraction	0.0 – 1.0

forrtf(2)	Fraction of P retranslocated from green forest leaves before litterfall	fraction	0.0 – 1.0
forrtf(3)	Fraction of S retranslocated from green forest leaves before litterfall		
sapk	controls the ratio of sapwood to total stem wood; it is equal to both the large wood mass (rlwodc) at which half of large wood is sapwood, and the theoretical maximum sapwood mass achieved in a mature forest. This parameter is no longer used in DayCent calculations but is needed as a placeholder in the tree.100 file.	g C m^{-2}	NO LONGER USED
swold	Year at which to switch from juvenile to mature forest C allocation fractions for production	simulation year	Within the simulation period
wdlig(1)	Lignin fraction of leaves	g lignin C/ g C	0.0 – 1.0
wdlig(2)	Lignin fraction of juvenile fine roots.	g lignin C / g C	0.0 – 1.0
wdlig(3)	Lignin fraction of fine branches. (See woodec.f)	g lignin C / g C	0.0 – 1.0
wdlig(4)	Lignin fraction of large wood. (See woodec.f)	g lignin C / g C	0.0 – 1.0

wdlig(5)	Lignin fraction of coarse roots. (See woodec.f)	g lignin C / g C	0.0 – 1.0
wdlig(6)	Lignin fraction of mature fine roots.	g lignin C / g C	0.0 – 1.0
wooddr(*)	***Monthly* death rate fractions for forest components:**		
wooddr(1)	Controls the proportion of *leaves* that drop during senescence month or at the end of the growing season when ***decid*** = 1 or 2. This is especially useful for drought-deciduous systems where only a portion of the leaves drop. Also useful when you are attempting to simulate a deciduous/coniferous mixed system of forest.	fraction	0.0 – 1.0
wooddr(2)	juvenile fine roots	fraction	0.0 – 1.0
wooddr(3)	fine branches	fraction	0.0 – 1.0
wooddr(4)	large wood	fraction	0.0 – 1.0
wooddr(5)	coarse roots	fraction	0.0 – 1.0
wooddr(6)	mature fine roots	fraction	0.0 – 1.0
wrdsrfc	Fraction of the fine roots that are transferred into the surface litter layer (STRUCC(1) and METABC(1)) upon fine root death, the remainder of the roots will go to the soil litter layer (STRUCC(2) and METABC(2))	fraction	0.0 – 1.0
wmrtfrac	Fraction of fine root production that goes to mature roots	fraction	0.0 – 1.0

snfxmx(2)	Maximum symbiotic N fixation for forest (actual symbiotic N fixation will be less if available mineral N is sufficient for growth)	g N fixed / g C net production	0.0 – 1.0
del13c	Delta 13C value for stable isotope labeling		-30.0 – 0.0
co2ipr(2)	In a forest system, the effect on plant production (ratio) of doubling the atmospheric CO_2 concentration from 350 ppm to 700 ppm	scaling factor	0.5 – 1.5
co2itr(2)	In a forest system, the effect on transpiration rate (ratio) of doubling the atmospheric CO_2 concentration from 350 ppm to 700 ppm	scaling factor	0.5 – 1.5
co2ice(2,*,*)	**In a forest system, the effect on C/E ratios of doubling the atmospheric CO_2 concentration from 350 ppm to 700 ppm**		
co2ice(2,1,1)	(2,1,1) = minimum C/N	scaling factor	0.5 – 1.5
co2ice(2,1,2)	(2,1,2) = minimum C/P	scaling factor	0.5 – 1.5
co2ice(2,1,3)	(2,1,3) = minimum C/S	scaling factor	0.5 – 1.5
co2ice(2,2,1)	(2,2,1) = maximum C/N	scaling factor	0.5 – 1.5
co2ice(2,2,2)	(2,2,2) = maximum C/P	scaling factor	0.5 – 1.5
co2ice(2,2,3)	(2,2,3) = maximum C/S	scaling factor	0.5 – 1.5
co2irs(2)	In a forest system, the effect on root-shoot ratio of doubling the atmospheric CO_2 concentration from 350 ppm to 700 ppm	scaling factor	0.5 – 1.5
basfc2	(savanna only) relates tree basal area to grass N fraction; higher value gives more N to trees; if not running savanna, set to 1.0		

basfct	(savanna only) ratio between basal area and wood biomass (cm2/g); it is equal to (form factor * wood density * tree height); if not running savanna, set to 1.0		The equation for computing tree basal area has been changed therefore ***basfct*** is given a a default value of 1.0.
sitpot	Site Potential multiplier. Savannas Only. Site Potential determines the relative competiveness of grasses and trees for available mineral N; the larger the site potential, the greater the fraction of mineral N available to grasses as opposed to trees. Site potential is a dynamic function of average annual precipitation, and SITPOT is a multiplier of site potential. Increasing SITPOT increases the competiveness of grasses, decreasing it increases the competiveness of tress. A value of the 1.0 indicates no multiplicative effect.		0.1 – 2.0 (1.0)
maxnp		N:P ratio	currently not being used?
fkmrspmx(1)	Maximum fraction of live leaf C that goes to maintenance respiration for trees	fraction	0.0 – 1.0
fkmrspmx(2)	Maximum fraction of live juvenile fine root C that goes to maintenance respiration for trees	fraction	0.0 – 1.0
fkmrspmx(3)	Maximum fraction of live fine branch C that goes to maintenance respiration for trees	fraction	0.0 – 1.0
fkmrspmx(4)	Maximum fraction of live large wood C that goes to maintenance respiration for trees	fraction	0.0 – 1.0

fkmrspmx(5)	Maximum fraction of live coarse root C that goes to maintenance respiration for trees	fraction	0.0 – 1.0
fkmrspmx(6)	Maximum fraction of live mature fine root C that goes to maintenance respiration for trees	fraction	0.0 – 1.0
fmrsplai(1)	X1 value for line function that decreases maintenance respiration based on optimal leaf carbon when the amount of carbon in the carbohydrate storage pool is less than (***fmrsplai*** (3) * optimal leaf carbon) for a forest system		
fmrsplai(2)	Y1 value for line function that decreases maintenance respiration based on optimal leaf carbon when the amount of carbon in the carbohydrate storage pool is less than (***fmrsplai*** (3) * optimal leaf carbon) for a forest system		
fmrsplai(3)	X2 value for line function that decreases maintenance respiration based on optimal leaf carbon when the amount of carbon in the carbohydrate storage pool is less than (***fmrsplai***(3) * optimal leaf carbon) for a forest system OR X1 value for line function that decreases maintenance respiration based on optimal leaf carbon when the amount of carbon in the carbohydrate storage pool is between (***fmrsplai*** (3) * optimal leaf carbon) and (***fmrsplai*** (5) * optimal leaf carbon) for a forest system		

fmrsplai(4)	Y2 value for line function that decreases maintenance respiration based on optimal leaf carbon when the amount of carbon in the carbohydrate storage pool is less than (***fmrsplai*** (3) * optimal leaf carbon) for a forest system OR Y1 value for line function that decreases maintenance respiration based on optimal leaf carbon when the amount of carbon in the carbohydrate storage pool is between (***fmrsplai*** (3) * optimal leaf carbon) and (***fmrsplai*** (5) * optimal leaf carbon) for a forest system		
fmrsplai(5)	X2 value for line function that decreases maintenance respiration based on optimal leaf carbon when the amount of carbon in the carbohydrate storage pool is between (***fmrsplai*** (3) * optimal leaf carbon) and (***fmrsplai*** (5) * optimal leaf carbon) for a forest system		
fmrsplai(6)	Y2 value for line function that decreases maintenance respiration based on optimal leaf carbon when the amount of carbon in the carbohydrate storage pool is between (***fmrsplai*** (3) * optimal leaf carbon) and (***fmrsplai*** (5) * optimal leaf carbon) for a forest system OR Y value for line function that decreases maintenance respiration based on optimal leaf carbon when the amount of carbon in the carbohydrate storage pool is greater than (***fmrsplai*** (5) * optimal leaf carbon) for a forest system		
fgresp(1)	Maximum fraction of live leaf C that goes to growth respiration for trees	fraction	0.0 – 1.0

fgresp(2)	Maximum fraction of live juvenile fine root C that goes to growth respiration for trees	fraction	0.0 – 1.0
fgresp(3)	Maximum fraction of live fine branch C that goes to growth respiration for trees	fraction	0.0 – 1.0
fgresp(4)	Maximum fraction of live large wood C that goes to growth respiration for trees	fraction	0.0 – 1.0
fgresp(5)	Maximum fraction of live coarse root C that goes to growth respiration for trees	fraction	0.0 – 1.0
fgresp(6)	Maximum fraction of live mature fine root C that goes to growth respiration for trees	fraction	0.0 – 1.0
no3pref(2)	Fraction of N uptake that is nitrate for trees. NO LONGER USED IN THE MODEL!	fraction	0.0 – 1.0
tlaypg	number of soil layers used to determine water and mineral N, P, and S that are available for tree growth	Number of soil layers	1 – 9
tmix	Annual rate that surface SOM2C that is mixed into (transferred to) soil SOM2C in a forest system	yr^{-1}	0.0 – 1.0
tmplff	Temperature at which leaf drop will occur in a deciduous tree type	ºC	

tmplfs	Temperature at which leaf out will occur in a deciduous tree type.	ºC	
furgdys	Number of days of unrestricted wood growth in a deciduous forest system	number of days	
flsgres	Deciduous forest late season growth restriction factor.		
tmxturn	Maximum turnover rate per month of juvenile fine roots to mature fine roots through aging	?	
wscoeff(2,1)	Water Stress Coefficient used to calculate the water stress multiplier on potential growth based on the relative water content of the wettest soil layer in the rooting zone (*maxrwcf, 0-1*). $\frac{1.0}{1.0+\exp\left(wscoeff\left(2,2\right)*\left(wscoeff\left(2,1\right)-maxrwcf\right)\right)}$	See wscoeff.xlsx	0.2 – 0.5
wscoeff(2,2)	Water Stress Coefficient used to calculate the water stress multiplier on potential growth based on the relative water content of the wettest soil layer in the rooting zone. See comments above	See wscoeff.xlsx	6.0 – 30.0
ps2mrsp(2)	Fraction of photosynthesis that goes to maintenance respiration	fraction	0.0 – 1.0
sfavail(2)	Fraction of N available per day to plants. Formerly FAVAIL(1) in fix.100.		0.0 – 1.0

amax(2)	Maximum net CO_2 assimilation rate assuming maximum possible PAR, all intercepted, no temperature, water or vapor pressure deficit stress.	nmol CO_2 g^{-1} (leaf biomass) sec^{-1}	
amaxfrac(2)	Average daily maximum photosynthesis as a fraction of amax.	fraction	0.0 – 1.0
amaxscalar1(2)	Multiplier used to adjust aMax based on growthDays1 days since germination	scalar	
amaxscalar2(2)	Multiplier used to adjust aMax based on growthDays2 days since germination.	scalar	0.8 – 1.6
amaxscalar3(2)	Multiplier used to adjust aMax based on growthDays3 days since germination.	scalar	0.7 – 1.5
amaxscalar4(2)	Multiplier used to adjust aMax based on growthDays4 days since germination.	scalar	0.3 – 0.8
attenuation(2)	Light attenuation coefficient.		
basefolrespfrac(2)	Basal foliage respiration rate, as percentage of maximum net photosynthesis rate		
cfracleaf(2)	factor for converting leaf biomass to carbon (leaf biomass * cFracLeaf = leaf carbon)	g C / g biomass	

dvpdexp(2)	Exponential value in vapor pressure deficit effect on photosynthesis equation. dVpd = dVpdSlope * exp(vpd*dVpdExp)		
dvpdslope(2)	Slope value in vapor pressure deficit effect on photosynthesis equation. dVpd = dVpdSlope * exp(vpd*dVpdExp)		
growthdays1(2)	Number of days after germination to start using aMaxScalar1.	number of days	
growthdays2(2)	Number of days after germination to start using aMaxScalar2.	number of days	
growthdays3(2)	Number of days after germination to start using aMaxScalar3.	number of days	
growthdays4(2)	Number of days after germination to start using aMaxScalar4.	number of days	
halfsatpar(2)	Photosynthetically active radiation (PAR) at which photosynthesis occurs at 1/2 of theoretical maximum.	Einsteins * m^{-2} ground area * day^{-1}	
leafcspwt(2)	Grams of carbon in a square meter of leaf area	g C m^{-2} leaf area	
psntmin(2)	minimum temperature at which net photosynthesis occurs	ºC	
psntopt(2)	optimal temperature at which net photosynthesis occurs	ºC	

btolai by biome	**units LAI / g biomass**
arctic tundra	0.008
arid savanna/shrubland	0.007
boreal forest	0.004
coniferous/deciduous mix forest	0.007
grassland	0.008
maritime coniferous forest	0.004
temperate coniferous forest	0.004
temperate coniferous savanna	0.004
temperate deciduous savanna	0.010
temperate mixed savanna	0.007
tropical evergreen forest	0.010
tropical savanna	0.006

warm temperate deciduous forest	0.010

Appendix 1.12 Tree removal parameters (trem.100)

These trem.100 parameters apply to TREM events and include live tree removal by fire and non-burning events. Grass/crop, surface litter, and dead wood burning parameters are scheduled with FIRE events (see in fire.100).

evntyp	Event type flag = 0 for cutting, pruning, windstorm, or other non-fire event = 1 for fire	index	0,1
remf(1)	Fraction of material component removed from live leaves.	fraction	0.0 – 1.0
remf(2)	Fraction of material component removed from live fine branches.	fraction	0.0 – 1.0
remf(3)	Fraction of material component removed from live large wood.	fraction	0.0 – 1.0
remf(4)	Fraction of material component removed from dead fine branches. This parameter applies to non-fire events only. To burn dead fine branches one must schedule a FIRE event; see fire.100 parameters.	fraction	0.0 – 1.0
remf(5)	Fraction of material component removed from dead large wood. This parameter applies to non-fire events only. To burn dead large wood one must schedule a FIRE event; see fire.100 parameters.	fraction	0.0 – 1.0
fd(1)	Fraction of fine root components that die.	fraction	0.0 – 1.0
fd(2)	Fraction of coarse root components that die.	fraction	0.0 – 1.0
retf(1,1)	Fraction of C in killed live leaves that is returned to the system (ash or litter).	fraction	0.0 – 1.0

retf(1,2)	Fraction of N in killed live leaves that is returned to the system (ash or litter).	fraction	0.0 – 1.0
retf(1,3)	Fraction of P in killed live leaves that is returned to the system (ash or litter).	fraction	0.0 – 1.0
retf(1,4)	Fraction of S in killed live leaves that is returned to the system (ash or litter).	fraction	0.0 – 1.0
retf(2,1)	Fraction of C in killed fine branches that is returned to the system (ash or dead fine branches).	fraction	0.0 – 1.0
retf(2,2)	Fraction of N in killed fine branches that is returned to the system (ash or dead fine branches).	fraction	0.0 – 1.0
retf(2,3)	Fraction of P in killed fine branches that is returned to the system (ash or dead fine branches).	fraction	0.0 – 1.0
retf(2,4)	Fraction of S in killed fine branches that is returned to the system (ash or dead fine branches).	fraction	0.0 – 1.0
retf(3,1)	Fraction of C in killed large wood that is returned to the system (ash or dead large wood).	fraction	0.0 – 1.0
retf(3,2)	Fraction of N in killed large wood that is returned to the system (ash or dead large wood).	fraction	0.0 – 1.0
retf(3,3)	Fraction of P in killed large wood that is returned to the system (ash or dead large wood).	fraction	0.0 – 1.0

retf(3,4)	Fraction of S in killed large wood that is returned to the system (ash or dead large wood).	fraction	0.0 – 1.0

Fire code changes for charcoal:

There have been changes to fire code so that removal, by burning, of dead fine branches and dead large wood will occur as the result of a FIRE event rather than of a TREM event. A TREM fire event will burn only live leaves, live fine branches, and live large wood. A TREM cutting, windstorm or other non-fire event will allow the removal of dead fine branches and dead large wood in the same manner as Century 4.0. When burning dead fine branches and dead large through a FIRE event the burned carbon in the dead wood can be returned to the system as charcoal in the passive SOM pool. (See the changes in the FIRE.100 input parameters for more information on how the charcoal return is parameterized.)

Appendix 1.13 Additional site information needed by DDcentEVI with methanogenisis (sitepar.in).

These are sitepar.in parameters formerly used with DDcentEVI. Recent versions of DDcentEVI no longer read the sitepar.in file, and include these parameters in the <site>.100 file instead. See next sections for sitepar.in format for DailyDayCent and DayCent_Photosyn_UV.

Parameter Name	Description	Units	Comments or Valid Range
usexdrvrs	Use extra weather drivers. Designates the format of the weather file 0 = no extra drivers 1 = PET drivers 2 = psyn drivers (N/A)* 3 = both PET and psyn (N/A)* 4 = EVI Note: 2, 3 are not implemented in DayCentEVI version since these options are available to DDcent_Photosysn_UV only	index	0, 1, 4 See details about weather file formats below
sublimscale	Multiplier on sublimation	Scaling factor	0.0 – 1.0 Updating not recommended
reflec	vegetation reflectivity/albedo	fraction	0.0 – 1.0
albedo	Snow albedo	fraction	0.0 – 1.0
fswcinit	initial swc as fraction of field capacity	fraction	0.0 – 1.0

dmpflux	Dampens strong fluxes of water between soil layers	In h2oflux routine (0.000001 = original value)	0.000001 - 0.000008 Updating not recommended
hours_rain	duration of each rain event	hours	2 – 24 (valid values must be a multiple of 2)
drainlag	# of days between rainfall event and drainage of soil (-1=computed)	number of days	-1, 0, 1, 2, 3, 4, 5
hpotdeep	hydraulic water potential of deep storage layer	-cm	
ksatdeep	saturated hydraulic conductivity of deep storage layer	cm sec^{-1}	
tbotmn tbotmx	min and max temperature for bottom soil layer	°C	
dmp	Soil time step damping factor for calculating soil temperature by layer. Relates to how fast the heat gets into/out of the soil.	Scaling factor	
timlag	days from Jan 1 to coolest temp at bottom of soil (days)	Number of days	
Ncoeff	minimum water/temperature reduction on nitrification	Scaling factor	
jdayStart jdayEnd	turn off respiration restraint on denitrification between these days	days of year	
N2Oadjust_fc	maximum proportion of nitrified N lost as N_2O @ field capacity	fraction	0.0 – 1.0

N2Oadjust_wp	minimum proportion of nitrified N lost as N_2O @ wilting point	fraction	0.0 – 1.0
MaxNitAmt	maximum daily nitrification rate	g N m^{-2} day^{-1}	
SnowFlag	snow effect on soil surface temp: 0 = not insulating, 1 = insulating	boolean	0,1
netmn_to_no3	fraction of new net mineralization automatically converted to nitrate each day. The remaining fraction is added to the ammonium pool.	fraction	0.0-1.0
wfpsdnitadj	adjustment on inflection point for the water filled pore space effect on denitrification curve	< 1.0 allows denitrification to occur at lower soil water content > 1.0 requires wetter conditions for denitrification	0.1 – 2.0
n2n2oadj	N_2/N_2O ratio adjustment coefficient		0.1 – 2.0
elevation	elevation	meters	0 - 5000
slope	site slope	degrees	0 - 60
aspect	site aspect	degrees	0 - 360
ehoriz	site east horizon	degrees	0 - 180

whoriz	site west horizon	degrees	0 - 180
1 sradadj[1]	Srad adjust for cloud cover & transmission coeff for January. Multiplies incoming solar radiation <u>when it is calculated from air temperature</u>, not when srad is read from weather file.	fraction	0.0 – 1.0
2 sradadj[2]	Srad adjust for cloud cover & transmission coeff for February	fraction	0.0 – 1.0
3 sradadj[3]	Srad adjust for cloud cover & transmission coeff for March	fraction	0.0 – 1.0
4 sradadj[4]	Srad adjust for cloud cover & transmission coeff for April	fraction	0.0 – 1.0
5 sradadj[5]	Srad adjust for cloud cover & transmission coeff for May	fraction	0.0 – 1.0
6 sradadj[6]	Srad adjust for cloud cover & transmission coeff for June	fraction	0.0 – 1.0

7 sradadj[7]	Srad adjust for cloud cover & transmission coeff for July	fraction	0.0 – 1.0
8 sradadj[8]	Srad adjust for cloud cover & transmission coeff for August	fraction	0.0 – 1.0
9 sradadj[9]	Srad adjust for cloud cover & transmission coeff for September	fraction	0.0 – 1.0
10 sradadj[10]	Srad adjust for cloud cover & transmission coeff for October	fraction	0.0 – 1.0
11 sradadj[11]	Srad adjust for cloud cover & transmission coeff for November	fraction	0.0 – 1.0
12 sradadj[12]	Srad adjust for cloud cover & transmission coeff for December	fraction	0.0 – 1.0

sitepar.in example of DDCentEVI (methane parameters highlighted in yellow have been moved to the fix.100 file or are no longer used) :

```
0         / usexdrvrs     - 0 = no extra drivers, 1 = PET drivers, 4 - EVI (not implemented 2 = psyn drivers, 3 = both)
1         / sublimscale
0.18      / reflec        - vegetation reflectivity (frac) hardwoods = 0.20 spruce = 0.10
0.65      / albedo        - snow albedo (frac)
0.000008  / dmpflux       - in h2oflux routine (0.000001 = original value)
10        / hours_rain    - duration of each rain event
0         / drainlag      - # of days between rainfall event and drainage of soil (-1=computed)
-200      / hpotdeep      - hydraulic water potential of deep storage layer (units?)
```

```
0.0003     / ksatdeep         - saturated hydraulic conductivity of deep storage layer (cm/sec)
0.0 12.4   / tbotmn tbotmx     - min and max temperature for bottom soil layer (degrees C)
0.003      / dmp              - damping factor for calculating soil temperature by layer
30.0       / timlag           - days from Jan 1 to coolest temp at bottom of soil (days)
0.03       / Ncoeff           - min water/temperature limitation coefficient for nitrify
0 0        / jdayStart jdayEnd - turn off respiration restraint on denit between these Julian dates
0.012      / N2Oadjust_fc     - maximum proportion of nitrified N lost as N2O @ field capacity   1) 0.010  2) 0.015  3) 0.012
0.012      / N2Oadjust_wp     - minimum proportion of nitrified N lost as N2O @ wilting point    1) 0.002  2) 0.010  3) 0.012
1.0        / MaxNitAmt        - maximum daily nitrification amount (gN/m^2) (0.4)  1.0 is value suggested by delgrosso Apr 19, 2012
1          / SnowFlag         - snow insulation effect on soil surface temp: 0 = not insulating, 1 = insulating
0.2        / netmn_to_no3     - fraction of new net mineralization that goes to NO3 (0.0-1.0)
1.0        / wfpsdnitadj      - adjustment on inflection point for WFPS effect on denit
1.0        / N2N2Oadj         - N2/N2O ratio adjustment coefficient
-1.0       / flood_N2toN2O    - N2/N2O ratio for flooded state (100.0) (moved to  FLN2OR in fix.100)
0.15       / CO2_to_CH4       - fraction of CO2 from soil respiration used to produce CH4 (moved to CO2CH4 in fix.100)
0.5        / C6H12O6_to_CH4   - reaction of anaerobic carbohydrate fermentation with methanogenesis (mole weight C6H12O6 to CH4)
0.45       / frac_to_exudates  - fraction of root production that is root exudates (moved to FREXUD in fix.100)
0.23       / Aeh              - differential coefficient (Aeh) (moved to AEH in fix.100)
0.16       / Deh              - differential coefficient (Deh) (moved to DEH in fix.100)
-250.0     / Beh_flood        - low-limit value for Eh during flooding course (mv) (moved to BEHFL in fix.100)
300.0      / Beh_drain        - upper-limit value of Eh during drainage course (mv) (moved to BEHDR in fix.100)
0.7        / zero_root_frac   - fraction CH4 emitted via bubbles when zero root biomass (0.0-1.0)
62.0       / elevation        - elevation, meters Crowley
0.0        / slope            - site slope, degrees
0.0        / aspect           - site aspect, degrees
0.0        / ehoriz           - site east horizon, degrees
0.0        / whoriz           - site west horizon, degrees
0.42       / sradadj[1]       - solar radiation surface transmission
0.50       / sradadj[2]       - solar radiation surface transmission
0.53       / sradadj[3]       - solar radiation surface transmission
0.57       / sradadj[4]       - solar radiation surface transmission
0.62       / sradadj[5]       - solar radiation surface transmission
```

```
0.69    / sradadj[6]     - solar radiation surface transmission
0.71    / sradadj[7]     - solar radiation surface transmission
0.66    / sradadj[8]     - solar radiation surface transmission
0.58    / sradadj[9]     - solar radiation surface transmission
0.52    / sradadj[10]     - solar radiation surface transmission
0.46    / sradadj[11]     - solar radiation surface transmission
0.45    / sradadj[12]     - solar radiation surface transmission
```

Appendix 1.14 Additional site information needed by DailyDayCent (sitepar.in).

See previous section for sitepar.in format for DDcentEVI and next section for DayCent_Photosyn_UV.

usexdrvrs	Use extra weather drivers. Designates the format of the weather file. (See **Weather Drivers** section at the end of this document). 0 = no extra drivers 1 = PET drivers		0, 1, 2, 3 See details about weather file formats below
sublimscale	Multiplier on sublimation	Scaling factor	0.0 – 1.0 Updating not recommended
reflec	vegetation reflectivity/albedo	fraction	0.0 – 1.0
albedo	snow albedo	fraction	0.0 – 1.0
fswcinit	initial soil water content, fraction of field capacity	fraction	0.5 – 1.0
dmpflux	Dampens strong fluxes of water between soil layers	In h2oflux routine (0.000001 = original value)	0.000001 - 0.000008 Updating not recommended
hours_rain	duration of each rain event	hours	2 – 24 (valid values must be a multiple of 2)
drainlag	# of days between rainfall event and drainage of soil (-1=computed)	number of days	-1, 0, 1, 2, 3, 4, 5

1 <ws> watertable	January (0=no water table , 1=water table)	index	0, 1
2 <ws> watertable	February (0=no water table , 1=water table)	index	0, 1
3 <ws> watertable	March (0=no water table , 1=water table)	index	0, 1
4 <ws> watertable	April (0=no water table , 1=water table)	index	0, 1
5 <ws> watertable	May (0=no water table , 1=water table)	index	0, 1
6 <ws> watertable	June (0=no water table , 1=water table)	index	0, 1
7 <ws> watertable	July (0=no water table , 1=water table)	index	0, 1
8 <ws> watertable	August (0=no water table , 1=water table)	index	0, 1
9 <ws> watertable	September (0=no water table , 1=water table)	index	0, 1
10 <ws> watertable	October (0=no water table , 1=water table)	index	0, 1
11 <ws> watertable	November (0=no water table , 1=water table)	index	0, 1
12 <ws> watertable	December (0=no water table , 1=water table)	index	0, 1
hpotdeep	hydraulic water potential of deep storage layer	cm (?)	
ksatdeep	saturated hydraulic conductivity of deep storage layer	cm sec^{-1}	
1 <ws> cldcov	Average cloud cover for January	%	0 - 100

2 <ws> cldcov	Average cloud cover for February	%	0 - 100
3 <ws> cldcov	Average cloud cover for March	%	0 - 100
4 <ws> cldcov	Average cloud cover for April	%	0 - 100
5 <ws> cldcov	Average cloud cover for May	%	0 - 100
6 <ws> cldcov	Average cloud cover for June	%	0 - 100
7 <ws> cldcov	Average cloud cover for July	%	0 - 100
8 <ws> cldcov	Average cloud cover for August	%	0 - 100
9 <ws> cldcov	Average cloud cover for September	%	0 - 100
10 <ws> cldcov	Average cloud cover for October	%	0 - 100
11 <ws> cldcov	Average cloud cover for November	%	0 - 100
12 <ws> cldcov	Average cloud cover for December	%	0 - 100
tbotmn <ws> tbotmx	minimum and maximum temperature for bottom soil layer	ºC	
dmp	damping factor for calculating soil temperature by layer	Scaling factor	
timlag	days from Jan 1 to coolest temp at bottom of soil (days)	Number of days	
Ncoeff	minimum water/temperature limitation coefficient for nitrify	Scaling factor	

jdayStart <ws> jdayEnd	turn off respiration restraint on denitrification between these days	days of year	
N2Oadjust_fc	maximum proportion of nitrified N lost as N_2O @ field capacity	fraction	0.0 – 1.0
N2Oadjust_wp	minimum proportion of nitrified N lost as N_2O @ wilting point	fraction	0.0 – 1.0
MaxNitAmt	maximum daily nitrification amount	g N m^{-2} day^{-1}	0.2 – 2.0
SnowFlag	flag to turn on/off the insulating effect of snow on soil surface temperature. 0 = not insulating, 1 = insulating	Index	0, 1
netmn_to_no3	coefficient to control the fraction of new net mineralization that goes to nitrate	fraction	0.0 – 1.0
wfpsdnitadj	adjustment on inflection point for the water filled pore space effect on denitrification curve	< 1.0 allows denitrification to occur at lower soil water content > 1.0 requires wetter conditions for denitrification	0.1 – 2.0
n2n2oadj	N_2/N_2O ratio adjustment coefficient		0.1 – 2.0

<ws> = white space

Appendix 1.15 Additional site information needed by DayCent_Photosyn_UV (sitepar.in).

See previous sections for sitepar.in format for DDcentEVI and DailyDayCent

usexdrvrs	Use extra weather drivers. Designates the format of the weather file. (See **Weather Drivers** section at the end of this document). 0 = no extra drivers 1 = PET drivers 2 = photosynthesis drivers 3 = photosynthesis and PET drivers		0, 1, 2, 3 See details about weather file formats below
sublimscale	Multiplier on sublimation	Scaling factor	0.0 – 1.0 Updating not recommended
reflec	vegetation reflectivity/albedo	fraction	0.0 – 1.0
albedo	Snow albedo	fraction	0.0 – 1.0
fswcinit	initial swc, fraction of field capacity	fraction	0.5 – 1.0
dmpflux	Dampens strong fluxes of water between soil layers	In h2oflux routine (0.000001 = original value)	0.000001 - 0.000008 Updating not recommended
hours_rain	duration of each rain event	hours	2 – 24 (valid values must be a multiple of 2)

drainlag	# of days between rainfall event and drainage of soil (-1=computed)	number of days	-1, 0, 1, 2, 3, 4, 5
1 <ws> watertable	January (0=no water table , 1=water table)	index	0, 1
2 <ws> watertable	February (0=no water table , 1=water table)	index	0, 1
3 <ws> watertable	March (0=no water table , 1=water table)	index	0, 1
4 <ws> watertable	April (0=no water table , 1=water table)	index	0, 1
5 <ws> watertable	May (0=no water table , 1=water table)	index	0, 1
6 <ws> watertable	June (0=no water table , 1=water table)	index	0, 1
7 <ws> watertable	July (0=no water table , 1=water table)	index	0, 1
8 <ws> watertable	August (0=no water table , 1=water table)	index	0, 1
9 <ws> watertable	September (0=no water table , 1=water table)	index	0, 1
10 <ws> watertable	October (0=no water table , 1=water table)	index	0, 1
11 <ws> watertable	November (0=no water table , 1=water table)	index	0, 1
12 <ws> watertable	December (0=no water table , 1=water table)	index	0, 1
hpotdeep	hydraulic water potential of deep storage layer	cm (?)	
ksatdeep	saturated hydraulic conductivity of deep storage layer	cm sec^{-1}	

1 <ws> cldcov	Average cloud cover for January	%	0 - 100
2 <ws> cldcov	Average cloud cover for February	%	0 - 100
3 <ws> cldcov	Average cloud cover for March	%	0 - 100
4 <ws> cldcov	Average cloud cover for April	%	0 - 100
5 <ws> cldcov	Average cloud cover for May	%	0 - 100
6 <ws> cldcov	Average cloud cover for June	%	0 - 100
7 <ws> cldcov	Average cloud cover for July	%	0 - 100
8 <ws> cldcov	Average cloud cover for August	%	0 - 100
9 <ws> cldcov	Average cloud cover for September	%	0 - 100
10 <ws> cldcov	Average cloud cover for October	%	0 - 100
11 <ws> cldcov	Average cloud cover for November	%	0 - 100
12 <ws> cldcov	Average cloud cover for December	%	0 - 100
tbotmn <ws> tbotmx	min and max temperature for bottom soil layer	ºC	
dmp	damping factor for calculating soil temperature by layer	Scaling factor	
timlag	days from Jan 1 to coolest temp at bottom of soil (days)	Number of days	

Ncoeff	min water/temperature limitation coefficient for nitrify	Scaling factor	
jdayStart <ws> jdayEnd	turn off respiration restraint on denitrification between these days	days of year	
N2Oadjust_fc	maximum proportion of nitrified N lost as N_2O @ field capacity	fraction	0.0 – 1.0
N2Oadjust_wp	minimum proportion of nitrified N lost as N_2O @ wilting point	fraction	0.0 – 1.0
MaxNitAmt	maximum daily nitrification amount	g N m^{-2} day^{-1}	0.2 – 2.0
SnowFlag	snow effect on soil surface temp 0 = not insulating, 1 = insulating	index	0, 1
netmn_to_no3	fraction of new net mineralization that goes to NO3	fraction	0.0 – 1.0
wfpsdnitadj	adjustment on inflection point for the water filled pore space effect on denitrification curve	< 1.0 allows denitrification to occur at lower soil water content > 1.0 requires wetter conditions for denitrification	0.0 – 2.0
N2N2Oadj	N_2/N_2O ratio adjustment coefficient		1.0
elevation	elevation	meters	0 - 5000
slope	site slope,	degrees	0 - 60

aspect	site aspect	degrees	0 - 360
ehoriz	site east horizon	degrees	0 - 180
whoriz	site west horizon	degrees	0 - 180
1 <ws> sradadj	srad adjust for cloud cover & transmission coeff for January	fraction	0.0 – 1.0
2 <ws> sradadj	Srad adjust for cloud cover & transmission coeff for February	fraction	0.0 – 1.0
3 <ws> sradadj	Srad adjust for cloud cover & transmission coeff for March	fraction	0.0 – 1.0
4 <ws> sradadj	Srad adjust for cloud cover & transmission coeff for April	fraction	0.0 – 1.0
5 <ws> sradadj	Srad adjust for cloud cover & transmission coeff for May	fraction	0.0 – 1.0
6 <ws> sradadj	Srad adjust for cloud cover & transmission coeff for June	fraction	0.0 – 1.0
7 <ws> sradadj	Srad adjust for cloud cover & transmission coeff for July	fraction	0.0 – 1.0

8 <ws> sradadj	Srad adjust for cloud cover & transmission coeff for August	fraction	0.0 – 1.0
9 <ws> sradadj	Srad adjust for cloud cover & transmission coeff for September	fraction	0.0 – 1.0
10 <ws> sradadj	Srad adjust for cloud cover & transmission coeff for October	fraction	0.0 – 1.0
11 <ws> sradadj	Srad adjust for cloud cover & transmission coeff for November	fraction	0.0 – 1.0
12 <ws> sradadj	Srad adjust for cloud cover & transmission coeff for December	fraction	0.0 – 1.0
tminintercept	slope for adjusting minimum temperature for VPD dewpoint calc		
tminslope	intercept for adjusting minimum temperature for VPD dewpoint calc		
maxphoto	maximum carbon loss due to photodecomposition	µg C/KJ srad	0.0 - ??
bioabsorp	litter biomass for full absorption of solar radiation	g biomass	200
mti_mx_incr_r	MTI max increase ratio	unitless	1.0
mti_mn_sr	MTI min effective solar radiation	KJ srad	0.0
mti_mx_sr	MTI max effective solar radiation	KJ srad	30000
mdr_mn_redc_r	MDR min reduce ratio	unitless	1.0

mdr_mn_sr	MDR min effective solar radiation	KJ srad	0.0
mdr_mx_sr	MDR max effective solar radiation	KJ srad	30000
photo_co2_fraction	Fraction of C flow loss due to photodecomp	fraction	0.0 – 1.0
maxphoto_lig_slp	maxphoto init. lignin slope	ug C / KJ srad / unit lignin fraction	0.0 - ??

<ws> = white space

Example sitepar.in for DayCent_Photosyn_UV:

```
0          / 1 = Use extra weather drivers (solrad, rhumid, windsp), 0 = don't use (for PET)
1.0        / sublimscale - multiplier on sublimation (1.0 no effect)
0.18     / reflec - vegetation reflectivity (frac) /
0.65     / albedo of snow (frac) */
0.90     / fswcinit - initial swc, fraction of field capacity
0.000001 / dmpflux - in h2oflux routine (0.000001 = original value)
10       / hours_rain - duration of each rain event
0       / drainlag - # of days between rainfall event and drainage of soil (-1=computed)
1  0     / watertable[month] - 0 = no water table, 1 = water table
2  0
3  0
4  0
5  0
6  0
7  0
8  0
9  0
10 0
11 0
12 0
-200     / hpotdeep - hydraulic water potential of deep storage layer (units?)
```

```
0.0003   / ksatdeep - saturated hydraulic conductivity of deep storage layer (cm/sec)
1  58    / cldcov[month] - cloud cover (%)
2  58
3  58
4  58
5  58
6  58
7  58
8  58
9  58
10 58
11 58
12 58
0.0 12.4 / tbotmn, tbotmx:  min and max temperature for bottom soil layer (degrees C)
0.003  / dmp: damping factor for calculating soil temperature by layer
30.0      / timlag: days from Jan 1 to coolest temp at bottom of soil (days)
0.03     / Ncoeff: min water/temperature limitation coefficient for nitrify
0 0      / jdayStart jdayEnd: turn off respiration restraint on denit between these Julian dates
0.014   / N2Oadjust_fc: maximum proportion of nitrified N lost as N2O at field capacity
0.003    / N2Oadjust_wp: minimum proportion of nitrified N lost as N2O at wilting point
0.4      / MaxNitAmt: maximum daily nitrification amount (gN/m^2)
1        / SnowFlag: snow effect on soil surface temp: 0 = not insulating, 1 = insulating
0.2      / netmn_to_no3: fraction of new net mineralization that goes to NO3 (0.0-1.0)
1.34             / wfpsadjdnit: adjustment on inflection point for WFPS effect on denit
0.94             / n2n2oadj: N2/N2O ratio adjustment coefficient
129.0    / ELEV: elevation, meters
0.0      / SITSLP: site slope, degrees
0.0      / ASPECT: site aspect, degrees
0.0      / ehoriz: site east horizon, degrees
0.0      / whoriz: site west horizon, degrees
1   0.5          / sradadj[month]: solar radiation adjust for cloud cover & transmission coeff
2   0.5
3   0.5
4   0.5
```

```
5   0.5
6   0.5
7   0.5
8   0.5
9   0.5
10  0.5
11  0.5
12  0.5
1.0       / tminslope – slope for adjusting minimum temperature for VPD dewpoint calc
0.0        / tminintercept –  intercept for adjusting minimum temperature for VPD dewpoint calc
0          / maximum carbon loss due to photodecomposition (ug C/KJ srad)
200.0   / litter biomass for full absorption of solar radiation (g biomass)
1.0        / MTI max increase ratio (unitless)
0.0       / MTI min effective solar radiation (KJ srad)
30000.0  / MTI max effective solar radiation (KJ srad)
1.0        / MDR min reduce ratio (unitless)
0.0       / MDR min effective solar radiation (KJ srad)
30000.0  / MDR max effective solar radiation (KJ srad)
0.70      / Fraction of C flow loss due to photodecomp (0.0-1.0): photo_co2_fraction
0.0       / maxphoto init. lignin slope (ug C / KJ srad / unit lignin fraction)
```

Weather Drivers

The “use extra weather drivers” parameter designates the format of the weather file. The minimum requirements are those columns 1 – 7, common to all formats.

<u>Use extra weather drivers = 0</u>

Column 1 - Day of month, 1-31
Column 2 - Month of year, 1-12
Column 3 - Year (4 digits)
Column 4 - Day of the year, 1-366
Column 5 - Maximum temperature for day, ºC
Column 6 - Minimum temperature for day, ºC
Column 7 - Precipitation for day, cm

<u>Use extra weather drivers = 1</u>

Column 1 - Day of month, 1-31
Column 2 - Month of year, 1-12
Column 3 - Year (4 digits)
Column 4 - Day of the year, 1-366
Column 5 - Maximum temperature for day, ºC
Column 6 - Minimum temperature for day, ºC
Column 7 - Precipitation for day, cm
Column 8 - Solar radiation, langleys day^{-1}
Column 9 - Relative humidity, %, 1-100
Column 10 - Wind speed, miles per hour

<u>Use extra weather drivers = 2</u>

Column 1 - Day of month, 1-31
Column 2 - Month of year, 1-12
Column 3 - Year (4 digits)

Column 4 - Day of the year, 1-366
Column 5 - Maximum temperature for day, ºC
Column 6 - Minimum temperature for day, ºC
Column 7 - Precipitation for day, cm
Column 8 - Solar radiation, W m^{-2} day^{-1}
Column 9 - vapor pressure deficit, kPa day^{-1}

Use extra weather drivers = 3 (DayCent Photosyn UV only)

Column 1 - Day of month, 1-31
Column 2 - Month of year, 1-12
Column 3 - Year (4 digits)
Column 4 - Day of the year, 1-366
Column 5 - Maximum temperature for day, ºC
Column 6 - Minimum temperature for day, ºC
Column 7 - Precipitation for day, cm
Column 8 - Solar radiation, langleys day^{-1}
Column 9 - Relative humidity, %, 1-100
Column 10 - Wind speed, miles per hour
Column 11 - Solar radiation, mean W m^{-2} day^{-1}
Column 12 - vapor pressure deficit, kPa day^{-1}

Use extra weather drivers = 4 (DDcentEVI only)

Column 1 - Day of month, 1-31
Column 2 - Month of year, 1-12
Column 3 - Year (4 digits)
Column 4 - Day of the year, 1-366
Column 5 - Maximum temperature for day, ºC
Column 6 - Minimum temperature for day, ºC
Column 7 - Precipitation for day, cm
Column 8 - Solar radiation, mean W m^{-2} day^{-1}
Column 9 - EVI (units??)

Appendix 1.16 Soils Data (soils.in)

A soils.in file is required for each simulation and is not associated with any one specific event.

Column 1 – Upper depth of soil layer (cm)
Column 2 – Lower depth of soil layer (cm)
Column 3 – Bulk density of soil layer (g cm^{-3})
Column 4 – Field capacity of soil layer, volumetric fraction
Column 5 – Wilting point of soil layer, volumetric fraction
Column 6 – Evaporation coefficient for soil layer (currently not being used)
Column 7 – Fraction of roots in soil layer, these values must sum to 1.0 but if they don't the model will normalize the values to 1.0
Column 8 – Fraction of sand in soil layer, 0.0 - 1.0
Column 9 – Fraction of clay in soil layer, 0.0 - 1.0
Column 10 – Organic matter in soil layer, fraction 0.0 - 1.0
Column 11 – The amount that volumetric soil water content can drop below wilting point for soil layer (*deltamin*, volumetric fraction). The minimum soil water content of a layer = wilting point – deltamin.
Column 12 – Saturated hydraulic conductivity of soil layer (ksat, cm sec^{-1})
Column 13 – pH of soil layer

NOTES:
Fraction of silt for soil layer is computed as follows:
silt = 1.0 - (sand + clay)

For the trace gas subroutines it is currently recommended to use the following layering structure for the top 3 soil layers in your soils.in file:

layer 1 - 0.0 cm to 2.0 cm
layer 2 - 2.0 cm to 5.0 cm
layer 3 - 5.0 cm to 10.0 cm

The depth structure in this file should match the ADEP(*) values in the fix.100 file in such a way that the boundaries for the soil layer depths can be matched with the ADEP(*) values. For example, using the file above and ADEP(1-10) values of 10, 20, 15, 15, 30, 30, 30, 30, 30, and 30:

ADEP(*) parameters in fix.100:

```
10.00000        'ADEP(1)'
20.00000        'ADEP(2)'
15.00000        'ADEP(3)'
15.00000        'ADEP(4)'
30.00000        'ADEP(5)'
30.00000        'ADEP(6)'
30.00000        'ADEP(7)'
30.00000        'ADEP(8)'
30.00000        'ADEP(9)'
30.00000        'ADEP(10)'
```

layers 1, 2 and 3 match the first 10 centimeter ADEP(1) value
layers 4 and 5 match the second 20 centimeter ADEP(2) value
layer 6 matches the third 15 centimeter ADEP(3) value
layer 7 matches the fourth 15 centimeter ADEP(4) value
layers 8 and 9 match the first 30 centimeter ADEP(5) value
layers 10 and 11 match the second 30 centimeter ADEP(6) value
layer 12 matches the third 30 centimeter ADEP(7) value
ADEP(8-10) are not used.

The value for NLAYER in the <site>.100 file should be set to match the number of ADEP values that you are using when you match the layering to the soils.in file. For the example above NLAYER should be set to 7.

layer #	thickness (cm)	upper depth (cm)	lower depth (cm)	bulk density (g cm^{-3})	field capacity (volumetric)	wilting point (volumetric)	evap. coefficient	frac. of roots	sand fraction	clay fraction.	organic matter fraction	deltamim (volumetric)	ksat (cm sec^{-1})	pH
1	2	0	2	0.83	0.1212	0.0345	0.8	0.01	0.9	0.02	0.02	0.008	0.042	4.5
2	3	2	5	0.83	0.1212	0.0345	0.2	0.04	0.9	0.02	0.02	0.008	0.042	4.5
3	5	5	10	0.83	0.1212	0.0345	0	0.25	0.9	0.01	0.02	0.006	0.042	4.5
4	10	10	20	0.83	0.1212	0.0345	0	0.3	0.9	0.01	0.02	0.004	0.042	4.5
5	10	20	30	1.01	0.1212	0.0345	0	0.1	0.9	0.02	0.02	0.002	0.042	4.5
6	15	30	45	1.01	0.125	0.0345	0	0.05	0.9	0.02	0.02	0.000	0.042	4.5
7	15	45	60	1.01	0.065	0.0345	0	0.04	0.9	0.03	0.01	0.000	0.042	4.5
8	15	60	75	1.01	0.065	0.0345	0	0.03	0.96	0.03	0.01	0.000	0.042	4.5
9	15	75	90	1.01	0.065	0.0345	0	0.02	0.96	0.03	0.01	0.000	0.042	4.5
10	15	90	105	1.23	0.065	0.0345	0	0.01	0.96	0.03	0.01	0.000	0.042	4.5
11	15	105	120	1.23	0.065	0.0345	0	0	0.96	0.03	0.01	0.000	0.042	4.5
12	30	120	150	1.23	0.065	0.0345	0	0	0.96	0.03	0.01	0.000	0.042	4.5

Table soils.in. An example *soils.in* parameter file for defining DayCent soil layers. (Note: the actual soils.in file does not have a row with column names, nor does have the first column layer #). The minimum volumetric soil water content of a layer (*swclimit*) is calculated from two columns, *swclimit = wilting point – deltamin*. The value *ksat* is the saturated hydraulic conductivity (cm sec^{-1}). The *sand* and *clay* weight fractions used by the decomposition model are computed as the weighted average their corresponding values in top 3 soil layers of this file. The organic matter weight fraction (*org*) in *soils.in* is only used in the soil temperature model. The value of *silt = 1.0 – sand – clay*, except in the soil temperature model *silt = 1.0 – sand – clay – org*. The SAND, SILT, CLAY, values in the *<site>.100* file are ignored. Likewise, the values BULKD, PH, AFIEL(*), and AWILT(*) in the *<site>.100* file are recalculated from values in the *soils.in* file. The bands of colors are to illustrate that multiple DayCent soil layers may comprise a single CENTURY soil layer

Appendix 2: DayCent Output Files

Time representation in output files

DayCent ASCII output files are produced in addition to the monthly output in the *.bin file. Simulation time in the DayCent output file is represented as a decimal value with the value preceding the decimal point representing the year of the simulation and the value after the decimal point representing the month in the simulation using the following values:

Jan – .00
Feb – .08
Mar – .17
Apr – .25
May – .33
Jun – .42
Jul – .50
Aug – .58
Sep – .67
Oct – .75
Nov – .83
Dec – .92

The *.bin file that is produced when using DayCent contains monthly output values. Simulation times for the monthly output from the *.bin file are represented as a decimal value with the value preceding the decimal point representing the year of the simulation and the value after the decimal point representing the month in the simulation using the following values:
Jan – .08
Feb – .17
Mar – .25
Apr – .33
May – .42
Jun – .50
Jul – .58
Aug – .67
Sep – .75
Oct – .83
Nov – .92
Dec – 1.00

These month fractions are added to the year value so that, for example January of year 1998 will output as time 1998.08 (1998 + .08) and December of year 1998 will output as time 1999.00 (1999 + 1.00).

Note that the monthly time values in the *.bin files are shifted by 1/12 from the DayCent ASCII *.out output files such that:

*.out file	*.bin file

--------------	-------------
Jan – .00	Jan – .08
Feb – .08	Feb – .17
Mar – .17	Mar – .25
Apr – .25	Apr – .33
May – .33	May – .42
Jun – .42	Jun – .50
Jul – .50	Jul – .58
Aug – .58	Aug – .67
Sep – .67	Sep – .75
Oct – .70	Oct – .83
Nov – .83	Nov – .92
Dec – .92	Dec – 1.00

DayCent *.out and *.csv files

bio.out – Daily above and below ground live carbon

time (Column 1) – Simulation time (see above)
dayofyr (Column 2) – Day of the year (1 – 366)
aglivc (Column 3) – Carbon in aboveground live for grass/crop (g C m^{-2})
bglivcj (Column 4) – Carbon in juvenile live fine roots for grass/crop (g C m^{-2})
bglivcm (Column 5) – Carbon in mature live fine roots for grass/crop (g C m^{-2})
aglivn (Column 6) – Nitrogen in aboveground live for grass/crop (g N m^{-2})
bglivnj (Column 7) – Nitrogen in juvenile live fine roots for grass/crop (g N m^{-2})
bglivnm (Column 8) – Nitrogen in mature live fine roots for grass/crop (g N m^{-2})
rleavc (Column 9) – Carbon in forest system leaf component (g C m^{-2})
frootcj (Column 10) – Carbon in forest system juvenile fine root component (g C m^{-2})
frootcm (Column 11) – Carbon in forest system mature fine root component (g C m^{-2})
fbrchc (Column 12) – Carbon in forest system fine branch component (g C m^{-2})
rlwodc (Column 13) – Carbon in forest system large wood component (g C m^{-2})
crootc (Column 14) – Carbon in forest system coarse root component (g C m^{-2})
h2ogef(1) (Column 15) – Water effect on crop/grass production (0.0 – 1.0)
h2ogef(2) (Column 16) – Water effect on forest production (0.0 – 1.0)

cflows.out – Daily carbon flows to soil organic matter pools

time (Column 1) – Simulation time (see above)
dayofyr (Column 2) – Day of the year (1 – 366)
som11tosom21 (Column 3) – Carbon flow from active surface organic matter pool to slow surface organic matter pool (g C m^{-2} d^{-1})
som12tosom22 (Column 4) – Carbon flow from active soil organic matter pool to slow soil organic matter pool (g C m^{-2} d^{-1})
som12tosom3 (Column 5) – Carbon flow from active soil organic matter pool to passive soil organic matter pool (g C m^{-2} d^{-1})
som21tosom11 (Column 6) – Carbon flow from slow surface organic matter pool to active surface organic matter pool (g C m^{-2} d^{-1})

som21tosom22 (Column 7) – Carbon flow from slow surface organic matter pool to slow soil organic matter pool (g C m^{-2} d^{-1})
som22tosom12 (Column 8) – Carbon flow from slow soil organic matter pool to active soil organic matter pool (g C m^{-2} d^{-1})
som22tosom3 (Column 9) – Carbon flow from slow soil organic matter pool to passive soil organic matter pool (g C m^{-2} d^{-1})
som3tosom12 (Column 10) – Carbon flow from passive soil organic matter pool to active soil organic matter pool (g C m^{-2} d^{-1})
metc1tosom11 (Column 11) – Carbon flow from surface metabolic pool to active surface organic matter pool (g C m^{-2} d^{-1})
metc2tosom12 (Column 12) – Carbon flow from soil metabolic pool to active soil organic matter pool (g C m^{-2} d^{-1})
struc1tosom11 (Column 13) – Carbon flow from surface structural pool to active surface organic matter pool (g C m^{-2} d^{-1})
struc1tosom21 (Column 14) – Carbon flow from surface structural pool to slow surface organic matter pool (g C m^{-2} d^{-1})
struc2tosom12 (Column 15) – Carbon flow from soil structural pool to active soil organic matter pool (g C m^{-2} d^{-1})
struc2tosom22 (Column 16) – Carbon flow from soil structural pool to slow soil organic matter pool (g C m^{-2} d^{-1})
wood1tosom11 (Column 17) – Carbon flow from dead fine branch pool to active surface organic matter pool (g C m^{-2} d^{-1})
wood1tosom21 (Column 18) – Carbon flow from dead fine branch pool to slow surface organic matter pool (g C m^{-2} d^{-1})
wood2tosom11 (Column 19) – Carbon flow from dead large wood pool to active surface organic matter pool (g C m^{-2} d^{-1})
wood2tosom21 (Column 20) – Carbon flow from dead large wood pool to slow surface organic matter pool (g C m^{-2} d^{-1})
wood3tosom12 (Column 21) – Carbon flow from dead coarse root pool to active soil organic matter pool (g C m^{-2} d^{-1})
wood3tosom22 (Column 22) – Carbon flow from dead coarse root pool to slow soil organic matter pool (g C m^{-2} d^{-1})

co2.out – Daily CO_2 concentrations by layer

time (Column 1) – Simulation time (see above)
dayofyr (Column 2) – Day of the year (1 – 366)
CO2_ppm[0] (Column 3) – CO2 concentration in first layer of soil profile (index 0), as defined in the soils.in file (ppm)
CO2_ppm[1] (Column 4) – CO2 concentration in second layer of soil profile (index 1), as defined in the soils.in file (ppm)
...
CO2_ppm[n-1] (Column n+2) – CO2 concentration in layer n of the soil profile (index n-1), as defined in the soils.in file (ppm)

NOTE:
n = number of soil layers

daily.out – Daily evapotranspiration, defac, soil temperature, snow water, and growing degree day variables

time (Column 1) – Simulation time (see above)
dayofyr (Column 2) – Day of the year (1 – 366)
PET(cm) (Column 3) – Potential evapotranspiration rate (cm H2O d^{-1})
agdefac (Column 4) – Surface decomposition factor based on temperature and moisture (0 – 1)
bgdefac (Column 5) – Soil decomposition factor based on temperature and moisture (0 – 1)
stemp(C) (Column 6) – Average soil temperature near the soil surface (°C)
snow (Column 7) – Snowpack water content (cm H_2O)
snlq (Column 8) – Liquid snow water content (cm H_2O)
thermunits (Column 9) – Accumulator of thermal units for growing degree day implementation (°C)

aglivc (Column 10) –
aggreenc (Column 11) –
hwstress (Column 12) –
scenfrac (Column 13) –

dc_sip.csv – Daily evaporation, transpiration, respiration, system C, and NPP

time (Column 1) – Simulation time (see above)
dayofyr (Column 2) – Day of the year (1 – 366)
trandly (Column 3) – Water transpired from soil (cm H_2O d^{-1})
evapdly (Column 4) – Water evaporated from the soil (cm H_2O d^{-1})
intrcpt (Column 5) – Evaporation of precipitation that was intercepted by the standing crop and litter biomass (cm H_2O d^{-1})
sublim (Column 6) – Water sublimated from the snowpack (cm H_2O d^{-1})
drain (Column 7) – Water in outflow that comes from drainage out of the soil profile (cm H_2O d^{-1})
runoff (Column 8) – Water (rain or snowmelt) that did not infiltrate soil profile (cm H_2O d^{-1})
ppt (Column 9) – Precipitation for the day (cm H_2O d^{-1})
accum (Column 10) – Snow added to the snowpack (cm H_2O d^{-1})
melt (Column 11) – Snow melted from the snowpack, if daily air temperature is warm enough (cm H_2O d^{-1})
snow (Column 12) – Current snowpack (equiv. cm H_2O)
snlq (Column 13) – The liquid water in the snowpack (cm H_2O)
petdly (Column 14) – Potential evapotranspiration rate (cm H_2O d^{-1})
stemp (Column 15) – Soil surface temperature (°C)
wc_2cm (Column 16) – Water holding capacity of a 2 cm soil layer (cm H_2O)
wc_3cm (Column 17) – Water holding capacity of a 3 cm soil layer (cm H_2O)
wc_5cm (Column 18) – Water holding capacity of a 5 cm soil layer (cm H_2O)
wc_10cm (Column 19) – Water holding capacity of a 10 cm soil layer (cm H_2O)
wc_15cm (Column 20) – Water holding capacity of a 15 cm soil layer (cm H_2O)
wc_30cm (Column 21) – Water holding capacity of a 30 cm soil layer (cm H_2O)
CO2resp (Column 22) – Heterotrophic CO_2 respiration (g C m^{-2} d^{-1})
mcprd(1) (Column 23) – Daily NPP for shoots for grass/crop system (g C m^{-2} d^{-1})
mcprd(2) (Column 24) – Daily NPP for juvenile roots for grass/crop system (g C m^{-2} d^{-1})
mcprd(3) (Column 25) – Daily NPP for mature roots for grass/crop system (g C m^{-2} d^{-1})
mfprd(1) (Column 26) – Daily NPP for live leaves for tree system (g C m^{-2} d^{-1})

mfprd(2) (Column 27) – Daily NPP for live juvenile fine roots for tree system (g C m^{-2} d^{-1})
mfprd(6) (Column 28) – Daily NPP for live mature fine roots for tree system (g C m^{-2} d^{-1})
mfprd(3) (Column 29) – Daily NPP for live fine branches for tree system (g C m^{-2} d^{-1})
mfprd(4) (Column 30) – Daily NPP for live large wood for tree system (g C m^{-2} d^{-1})
mfprd(5) (Column 31) – Daily NPP for live coarse roots for tree system (g C m^{-2} d^{-1})
NPP (Column 32) – Summation of all production values (g C m^{-2} d^{-1})
NEE (Column 33) – Net ecosystem exchange (NPP - CO2resp) (g C m^{-2} d^{-1})
aglivc (Column 34) – Above ground live carbon for crop/grass (g C m^{-2})
bglivcj (Column 35) – Juvenile fine root live carbon for crop/grass (g C m^{-2})
bglivcm (Column 36) – Mature fine root live carbon for crop/grass (g C m^{-2})
rleavc (Column 37) – Leaf live carbon for forest (g C m^{-2})
frootcj (Column 38) – Juvenile fine root live carbon for forest (g C m^{-2})
frootcm (Column 39) – Mature fine root live carbon for forest (g C m^{-2})
fbrchc (Column 40) – Fine branch live carbon for forest (g C m^{-2})
rlwodc (Column 41) – Large wood live carbon for forest (g C m^{-2})
crootc (Column 42) – Coarse root live carbon for forest (g C m^{-2})
tlai (Column 43) – LAI of the tree leaves (m^2 m^{-2})
stdedc (Column 44) – Standing dead carbon (g C m^{-2})
wood1c (Column 45) – Dead fine branch carbon (g C m^{-2})
wood2c (Column 46) – Dead large wood carbon (g C m^{-2})
wood3c (Column 47) – Dead coarse root carbon (g C m^{-2})
strucc(1) (Column 48) – Carbon in structural component of surface litter (g C m^{-2})
metabc(1) (Column 49) – Carbon in metabolic component of surface litter (g C m^{-2})
strucc(2) (Column 50) – Carbon in structural component of soil litter (g C m^{-2})
metabc(2) (Column 51) – Carbon in metabolic component of soil litter (g C m^{-2})
som1c(1) (Column 52) – Carbon in surface active soil organic matter (g C m^{-2})
som1c(2) (Column 53) – Carbon in soil active soil organic matter (g C m^{-2})
som2c(1) (Column 54) – Carbon in surface slow soil organic matter (g C m^{-2})
som2c(2) (Column 55) – Carbon in soil slow soil organic matter (g C m^{-2})
som3c (Column 56) – Carbon in passive soil organic matter (g C m^{-2})
totsysc (Column 57) – Total system carbon, summation of all live carbon, dead carbon, and soil organic matter carbon pools (g C m^{-2})

NOTE: This file contains comma separated values.

deadc.out- Daily carbon in dead plant material

time (Column 1) – Simulation time (see above)
dayofyr (Column 2) – Day of the year (1 – 366)
stdedc (Column 3) – C in standing dead material for grass/crop (g C m^{-2})
metabc(1) (Column 4) – metabolic C in surface litter (g C m^{-2})
strucc(1) (Column 5) – surface litter structural C (g C m^{-2})
wood1c (Column 6) – C in wood1 (dead fine branch) component of forest system (g C m^{-2})
wood1c (Column 7) – C in wood2 (dead large wood) component of forest system (g C m^{-2})
wood3c (Column 8) – C in wood3 (dead coarse roots) component of forest system (g C m^{-2})

dels.out – Daily delta 13C/14C values

time (Column 1) – Simulation time (see above)

dayofyr (Column 2) – Day of the year (1 – 366)
deloi (Column 3) – Daily delta 13C/14C value for heterotrophic respiration for the OI layer (surface metabolic, structural, and som1c) (g C m^{-2} d^{-1})
deloe (Column 4) – Daily delta 13C/14C value for heterotrophic respiration for the OE layer (surface som2c) (g C m^{-2} d^{-1})
dsrfclit (Column 5) – Daily delta 13C/14C value for heterotrophic respiration for the surface litter (surface metabolic, structural, som1c, and som2c) (g C m^{-2} d^{-1})
dsmnrl (Column 6) – Daily delta 13C/14C value for heterotrophic respiration for the mineral soil (soil metabolic, structural, som1c, som2c, and som3c) (g C m^{-2} d^{-1})
dhetresp (Column 7) – Daily delta 13/14C value for heterotrophic respiration (g C m^{-2} d^{-1})
dsoilresp (Column 8) – Daily delta 13/14C value for soil respiration (heterotrophic + root autotrophic) (g C m^{-2} d^{-1})
dcmresp (Column 9) – Daily delta 13C/14C value for crop/grass maintenance respiration (g C m^{-2} d^{-1})
dfmresp (Column 10) – Daily delta 13C/14C value for forest maintenance respiration (g C m^{-2} d^{-1})
dcgresp (Column 11) – Daily delta 13C/14C value for crop/grass growth respiration (g C m^{-2} d^{-1})
dfgresp (Column 12) – Daily delta 13C/14C value for forest growth respiration (g C m^{-2} d^{-1})
dccarbostg (Column 13) – Daily delta 13C/14C value for crop/grass carbohydrate storage pool (g C m^{-2})
dfcarbostg (Column 14) – Daily delta 13C/14C value for forest carbohydrate storage pool (g C m^{-2})

dN2lyr.out – Daily N_2 fluxes due to denitrification by soil layer

time (Column 1) – Simulation time (see above)
dayofyr (Column 2) – Day of the year (1 – 366)
dN2_g/m2[0] (Column 3) – N_2 flux from the first layer of soil profile (index 0), as defined in the soils.in file (g N m^{-2} d^{-1})
dN2_g/m2[1] (Column 4) – N_2 flux from the second layer of soil profile (index 1), as defined in the soils.in file (g N m^{-2} d^{-1})
...
dN2_g/m2[n-1] (Column n+2) – N_2 flux from the layer n of soil profile (index n-1), as defined in the soils.in file (g N m^{-2} d^{-1})

NOTE:
n = number of soil layers

dN2Olyr.out – Daily N_2O fluxes due to denitrification by soil layer

time (Column 1) – Simulation time (see above)
dayofyr (Column 2) – Day of the year (1 – 366)
dN2O_g/m2[0] (Column 3) – N2O flux from the first layer of soil profile (index 0), as defined in the soils.in file (g N m^{-2} d^{-1})
dN2O_g/m2[1] (Column 4) – N2O flux from the second layer of soil profile (index 1), as defined in the soils.in file (g N m^{-2} d^{-1})
...
dN2O_g/m2[n-1] (Column n+2) – N2O flux from the layer n of soil profile (index n-1), as defined in the soils.in file (g N m^{-2} d^{-1})

NOTE:
n = number of soil layers

harvest.csv – State of the system at time of harvest

time (Column 1) – Simulation time

dayofyr (Column 2) – Day of the year (1 – 366)

crpval (Column 3) – numerical representation of the current crop

agcacc (Column 4) – growing season accumulator for aboveground carbon production, reset to 0.0 on LAST event (g C m^{-2} yr^{-1})

bgcjacc (Column 5) – growing season accumulator for juvenile fine root carbon production, reset to 0.0 on LAST event (g C m^{-2} yr^{-1})

bgcmacc (Column 6) – growing season accumulator for mature fine root carbon production, reset to 0.0 on LAST event (g C m^{-2} yr^{-1})

cgrain (Column 7) – amount of carbon in harvested grain and tubers during a harvest event (g C m^{-2} $harvest^{-1}$)

egrain(N) (Column 8) – amount of nitrogen in harvested grain and tubers during a harvest event (g N m^{-2} $harvest^{-1}$)

egrain(P) (Column 9) – amount of phosphorus in harvested grain and tubers during a harvest event (g P m^{-2} $harvest^{-1}$)

egrain(S) (Column 10) – amount of sulfur in harvested grain and tubers during a harvest event (g S m^{-2} $harvest^{-1}$)

crmvst (Column 11) – amount of carbon removed as straw during a harvest event (sum of cstraw and stdstraw) (g C m^{-2} $harvest^{-1}$)

ermvst(N) (Column 12) – amount of nitrogen in straw removed during a harvest event (sum of estraw(N) and estdstraw(N)) (g N m^{-2} $harvest^{-1}$)

ermvst(P) (Column 13) – amount of phosphorus in straw removed during a harvest event (sum of estraw(P) and estdstraw(P)) (g P m^{-2} $harvest^{-1}$)

ermvst(S) (Column 14) – amount of sulfur in straw removed during a harvest event (sum of estraw(S) and estdstraw(S)) (g S m^{-2} $harvest^{-1}$)

cstraw (Column 15) – amount of carbon removed from aboveground live pool as straw during a harvest event (g C m^{-2} $harvest^{-1}$)

estraw(N) (Column 16) – amount of nitrogen in straw removed from aboveground live pool during a harvest event (g N m^{-2} $harvest^{-1}$)

estraw(P) (Column 17) – amount of phosphorus in straw removed from aboveground live pool during a harvest event (g P m^{-2} $harvest^{-1}$)

estraw(S) (Column 18) – amount of sulfur in straw removed from aboveground live pool during a harvest event (g S m^{-2} $harvest^{-1}$)

stdstraw (Column 19) – amount of carbon removed from standing dead pool as straw during a harvest event (g C m^{-2} $harvest^{-1}$)

estdstraw(N) (Column 20) – amount of nitrogen in straw removed from standing dead pool during a harvest event (estdstraw(N)) (g N m^{-2} $harvest^{-1}$)

estdstraw(P) (Column 21) – amount of phosphorus in straw removed from standing dead pool during a harvest event (estdstraw(P)) (g P m^{-2} $harvest^{-1}$)

estdstraw(S) (Column 22) – amount of sulfur in straw removed from standing dead pool during a harvest event (estdstraw(S)) (g S m^{-2} $harvest^{-1}$)

addsdc (Column 23) – amount of carbon transferred from aboveground live carbon pool (aglivc) to standing dead carbon pool (stdedc) due to a grain harvest event (g C m^{-2} $harvest^{-1}$)

addsde(N) (Column 24) – amount of nitrogen transferred from aboveground live nitrogen pool (aglive(N)) to standing dead nitrogen pool (stdede(N)) due to a grain harvest event (g N m^{-2} $harvest^{-1}$)

addsde(P) (Column 25) – amount of phosphorus transferred from aboveground live phosphorus pool (aglive(P)) to standing dead phosphorus pool (stdede(P)) due to a grain harvest event (g P m^{-2} $harvest^{-1}$)

addsde(S) (Column 26) – amount of sulfur transferred from aboveground live sulfur pool (aglive(S)) to standing dead sulfur pool (stdede(S)) due to a grain harvest event (g S m^{-2} $harvest^{-1}$)

resid (Column 27) – amount of residue straw carbon added to the surface litter pool (metabc(1) and strucc(1)) during a grain harvest event (g C m^{-2} $harvest^{-1}$)

reside(N) (Column 28) – amount of residue straw nitrogen added to the surface litter pool (metabe(1,1) and struce(1,1)) during a grain harvest event (g N m^{-2} $harvest^{-1}$)

reside(P) (Column 29) – amount of residue straw phosphorus added to the surface litter pool (metabe(1,2) and struce(1,2)) during a grain harvest event (g P m^{-2} $harvest^{-1}$)

reside(S) (Column 30) – amount of residue straw sulfur added to the surface litter pool (metabe(1,3) and struce(1,3)) during a grain harvest event (g S m^{-2} $harvest^{-1}$)

irrapp (Column 31) – amount of irrigation applied since the previous HARV event (cm H_2O $harvest^{-1}$)

fertapp(N) (Column 32) – amount of nitrogen fertilizer applied since previous HARV event (g N m^{-2} $harvest^{-1}$)

fertapp(P) (Column 33) – amount of phosphorus fertilizer applied since previous HARV event (g P m^{-2} $harvest^{-1}$)

fertapp(S) (Column 34) – amount of sulfur fertilizer applied since previous HARV event (g S m^{-2} $harvest^{-1}$)

omadapp (Column 35) – amount of carbon added to the system through organic matter addition events since the previous HARV event (g C m^{-2} $harvest^{-1}$)

omaeapp(N) (Column 36) – amount of nitrogen added to the system through organic matter addition events since the previous HARV event (g N m^{-2} $harvest^{-1}$)

omaeapp(P) (Column 37) – amount of phosphorus added to the system through organic matter addition events since the previous HARV event (g P m^{-2} $harvest^{-1}$)

omaeapp(S) (Column 38) – amount of for sulfur added to the system through organic matter addition events since the previous HARV event (g S m^{-2} $harvest^{-1}$)

strmac(1) (Column 39) – accumulator of stream flow (base flow + runoff) since the beginning of the year (cm H_2O yr^{-1}).

strmac(2) (Column 40) – accumulator for mineral N leached out of the bottom of the soil profile into stream flow since the beginning of the year (g N m^{-2} yr^{-1})

strmac(3) (Column 41) – accumulator for mineral P leached out of the bottom of the soil profile into stream flow since the beginning of the year (g P m^{-2} yr^{-1})

strmac(4) (Column 42) – accumulator for mineral S leached out of the bottom of the soil profile into stream flow since the beginning of the year (g S m^{-2} yr^{-1})

strmac(5) (Column 43) – accumulator for organic C leached from the soil organic layer into stream flow since the beginning of the year (g C m^{-2} yr^{-1})

strmac(6) (Column 44) – accumulator for organic N leached from the soil organic layer into stream flow since the beginning of the year (g N m^{-2} yr^{-1})

strmac(7) (Column 45) – accumulator for organic P leached from the soil organic layer into stream flow since the beginning of the year (g P m^{-2} yr^{-1})

strmac(8) (Column 46) – accumulator for organic S leached from the soil organic layer into stream flow since the beginning of the year (g S m^{-2} yr^{-1})

cgracc (Column 47) – accumulator for carbon in harvested grain and tubers since the beginning of the year (sum of cgrain) (g C m^{-2} yr^{-1})

egracc(N) (Column 48) –accumulator of nitrogen in harvested grain and tubers since the beginning of the year (sum of egrain(N)) (g N m^{-2} yr^{-1})

egracc(P) (Column 49) –accumulator of phosphorus in harvested grain and tubers since the beginning of the year (sum of egrain(P)) (g P m^{-2} yr^{-1})

egracc(S) (Column 50) –accumulator of sulfur in harvested grain and tubers since the beginning of the year (sum of egrain(S)) (g S m^{-2} yr^{-1})

accrst (Column 51) –accumulator of carbon in straw removed during harvest since the beginning of the year (sum of crmvst) (g C m^{-2} yr^{-1})

accrste(N) (Column 52) –accumulator of nitrogen in straw removed during harvest since the beginning of the year (sum of ermvst(N)) (g N m^{-2} yr^{-1})

accrste(P) (Column 53) –accumulator of phosphorus in straw removed during harvest since the beginning of the year (sum of ermvst(P)) (g P m^{-2} yr^{-1})

accrste(S) (Column 54) –accumulator of sulfur in straw removed during harvest since the beginning of the year (sum of ermvst(3)) (g S m^{-2} yr^{-1})

ctubesj (Column 55) – amount of carbon removed from juvenile fine root carbon pool (bglivcj) as tubers during a harvest event (g C m^{-2} $harvest^{-1}$)

etubesj(N) (Column 56) – amount of nitrogen removed from juvenile fine root nitrogen pool (bglivej(N)) as tubers during a harvest event (g N m^{-2} $harvest^{-1}$)

etubesj(P) (Column 57) – amount of phosphorus removed from juvenile fine root phosphorus pool (bglivej(P)) as tubers during a harvest event (g P m^{-2} $harvest^{-1}$)

etubesj(S) (Column 58) – amount of sulfur removed from juvenile fine root sulfur pool (bglivej(S)) as tubers during a harvest event (g S m^{-2} $harvest^{-1}$)

ctubesm (Column 59) – amount of carbon removed from mature fine root carbon pool (bglivcm) as tubers during a harvest event (g C m^{-2} $harvest^{-1}$)

etubesm(N) (Column 60) – amount of nitrogen removed from mature fine root nitrogen pool (bglivem(N)) as tubers during a harvest event (g N m^{-2} $harvest^{-1}$)

etubesm(P) (Column 61) – amount of phosphorus removed from mature fine root phosphorus pool (bglivem(P)) as tubers during a harvest event (g P m^{-2} $harvest^{-1}$)

etubesm(S) (Column 62) – amount of sulfur removed from mature fine root sulfur pool (bglivem(S)) as tubers during a harvest event (g S m^{-2} $harvest^{-1}$)

srfclittrj (Column 63) – amount of dead juvenile fine root carbon transferred to surface litter pool (metabc(1) and strucc(1)) due to a harvest event (g C m^{-2} $harvest^{-1}$)

esrfclittrj(N) (Column 64) – amount of dead juvenile fine root nitrogen transferred to surface litter pool (metabe(1,1) and struce(1,1)) due to a harvest event (g N m^{-2} $harvest^{-1}$)

esrfclittrj(P) (Column 65) – amount of dead juvenile fine root phosphorus transferred to surface litter pool (metabe(1,2) and struce(1,2)) due to a harvest event (g P m^{-2} $harvest^{-1}$)

esrfclittrj(S) (Column 66) – amount of dead juvenile fine root sulfur transferred to surface litter pool (metabe(1,3) and struce(1,3)) due to a harvest event (g S m^{-2} $harvest^{-1}$)

soillittrj (Column 67) – amount of dead juvenile fine root carbon transferred to soil litter pool (metabc(2) and strucc(2)) due to a harvest event (g C m^{-2} $harvest^{-1}$)

esoillittrj(N) (Column 68) – amount of dead juvenile fine root nitrogen transferred to soil litter pool (metabe(2,1) and struce(2,1)) due to a harvest event (g N m^{-2} $harvest^{-1}$)

esoillittrj(P) (Column 69) – amount of dead juvenile fine root phosphorus transferred to soil litter pool (metabe(2,2) and struce(2,2)) due to a harvest event (g P m^{-2} $harvest^{-1}$)

esoillittrj(S) (Column 70) – amount of dead juvenile fine root sulfur transferred to soil litter pool (metabe(2,3) and struce(2,3)) due to a harvest event (g S m^{-2} $harvest^{-1}$)

srfclittrm (Column 71) – amount of dead mature fine root carbon transferred to surface litter pool (metabc(1) and strucc(1)) due to a harvest event (g C m^{-2} $harvest^{-1}$)

esrfclittrm(N) (Column 72) – amount of dead mature fine root nitrogen transferred to surface litter pool (metabe(1,1) and struce(1,1)) due to a harvest event (g N m^{-2} $harvest^{-1}$)
esrfclittrm(P) (Column 73) – amount of dead mature fine root phosphorus transferred to surface litter pool (metabe(1,2) and struce(1,2)) due to a harvest event (g P m^{-2} $harvest^{-1}$)
esrfclittrm(S) (Column 74) – amount of dead mature fine root sulfur transferred to surface litter pool (metabe(1,3) and struce(1,3)) due to a harvest event (g S m^{-2} $harvest^{-1}$)
soillittrm (Column 75) – amount of dead mature fine root carbon transferred to soil litter pool (metabc(2) and strucc(2)) due to a harvest event (g C m^{-2} $harvest^{-1}$)
esoillittrm(N) (Column 76) – amount of dead mature fine root nitrogen transferred to soil litter pool (metabe(2,1) and struce(2,1)) due to a harvest event (g N m^{-2} $harvest^{-1}$)
esoillittrm(P) (Column 77) – amount of dead mature fine root phosphorus transferred to soil litter pool (metabe(2,2) and struce(2,2)) due to a harvest event (g P m^{-2} $harvest^{-1}$)
esoillittrm(S) (Column 78) – amount of dead mature fine root sulfur transferred to soil litter pool (metabe(2,3) and struce(2,3)) due to a harvest event (g S m^{-2} $harvest^{-1}$)

NOTE: This file contains comma separated values.

livec.out – Daily carbon in live plant material

time (Column 1) – Simulation time (see above)
dayofyr (Column 2) – Day of the year (1 – 366)
aglivc (Column 3) – C in aboveground live for grass/crop (g C m^{-2})
bglivcj (Column 4) – C in live juvenile fine roots for grass/crop (g C m^{-2})
bglivcm (Column 5) – C in live mature fine roots for grass/crop (g C m^{-2})
rleavc (Column 6) – C in forest system leaf component (g C m^{-2})
frootcj (Column 7) – C in forest system juvenile fine root component (g C m^{-2})
frootcm (Column 8) – C in forest system mature fine root component (g C m^{-2})
fbrchc (Column 9) – C in forest system fine branch component (g C m^{-2})
rlwodc (Column 10) – C in forest system large wood component (g C m^{-2})
crootc (Column 11) – C in forest system coarse root component (g C m^{-2})

methane.out – Methanogenesis and Methane Oxidation

(This file is not generated by versions of DayCent that lack methanogenesis).

year (Column 1) – Simulation year
DOY (Column 2) – Day of the year (1 – 366)
aglivc (Column 3) – C in aboveground live for grass/crop (g C m^{-2})
bglivcj (Column 4) – C in live juvenile fine roots for grass/crop (g C m^{-2})
bglivcm (Column 5) – C in live mature fine roots for grass/crop (g C m^{-2})
prev_mcprd1 (Column 6) – NPP of shoots on the previous day (g C m^{-2} d^{-1})
prev_mcprd2 (Column 7) – NPP of juvenile fine roots on the previous day (g C m^{-2} d^{-1})
prev_mcprd3 (Column 8) – NPP of mature fine roots on the previous day (g C m^{-2} d^{-1})
COM (Column 9) – Sum of CO_2 losses from heterotrophic decomposition of metabc(1), metabc(2), strucc(1), strucc(2), som1c(1), som1c(2), som2c(1), som2c(2), som3c (g C m^{-2})
ppt (Column 10) – Precipitation for day (cm H_2O d^{-1})
irri (Column 11) – Irrigation for day (cm H_2O d^{-1})
watr2sat (Column 12) – Amount of water automatically added to the system to bring ** the soil water content in the full soil profile to saturation (cm H_2O d^{-1})

avgst_10cm (Column 13) – Average soil temperature in top 10 cm of soil profile (°C)
TI (Column 14) – Soil temperature index for CH_4 production (0.0 - 1.0)
Cr (Column 15) – Carbohydrates derived from rice plants (g C m^{-2})
Eh (Column 16) – Effect of water management on soil redox potential (mv)
Feh (Column 17) – Reduction factor of effect of soil redox potential (Eh) on CH_4 production (0.0 – 1.0)
CH4_prod (Column 18) – Total CH_4 production (g C m^{-2} d^{-1})
CH4_Ep (Column 19) – CH_4 emitted via plants (g C m^{-2} d^{-1})*
CH4_Ebl (Column 20) – CH_4 emitted via bubbles (g C m^{-2} d^{-1})*
CH4_oxid (Column 21) – CH_4 oxidation (g C m^{-2} d^{-1})

* The net CH_4 flux from flooded systems is CH4_Ep + CH4_Ebl. This sum is less than CH4_prod since it accounts for CH_4 oxidation as CH_4 bubbles to the surface. CH4_oxid applies to dryland soils only.

nflux.out – Nitrogen Trace gases

time (Column 1) – Simulation time (see above)
dayofyr (Column 2) – Day of the year (1 – 366)
nit_N2O-N (Column 3) – Nitrous oxide nitrification (g N ha^{-1} d^{-1})
dnit_N2O-N (Column 4) – Nitrous oxide denitrification (g N ha^{-1} d^{-1})
dnit_N2-N (Column 5) – Elemental inert nitrogen gas denitrification (g N ha^{-1} d^{-1})
NO-N (Column 6) – Nitric oxide (g N ha^{-1} d^{-1})
CUM-N2O (Column 7) – Annual accumulator for nitrous oxide (g N ha^{-1} yr^{-1})
CUM-NO (Column 8) – Annual accumulator for nitric oxide (g N ha^{-1} yr^{-1})

psyn.out – Daily photosynthesis for DayCent_Photosyn versions

time (Column 1) – Simulation time (see above)
dayofyr (Column 2) – Day of the year (1 – 366)
tmindly (Column 3) – Minimum temperature for day (°C)
tmaxdly (Column 4) – Maximum temperature for day (°C)
prcann (Column 5) – Average annual precipitation for site (cm)
pptdly (Column 6) – Precipitation (cm H2O d^{-1})
aetdly (Column 7) – Actual evapotranspiration (cm H2O d^{-1})
petdly (Column 8) – Potential evapotranspiration rate (cm H2O d^{-1})
daylength (Column 9) – Fraction of day that has sunlight (0 – 1)
srad (Column 10) – Mean shortwave radiation during daylight hours (W m^{-2})
avg_temp (Column 11) – Average temperature for daylight hours (°C)
avg_vpd (Column 12) – Average vapor pressure deficit (kPa)
crpLAI (Column 13) – Grass/crop system leaf area index
crpdTemp (Column 14) – Decrease in photosynthesis due to temperature for grass/crop system (0 – 1)
crpdVpd (Column 15) – Decrease in photosynthesis due to vapor pressure deficit for grass/crop system (0 – 1)
crpdWater (Column 16) – Effect of water stress on photosynthesis for grass/crop system (0 – 1)
crpLtEff (Column 17) – Decrease in photosynthesis due to amount of light absorbed for grass/crop system (0 – 1)
crpPGrPsn (Column 18) – Potential photosynthesis, without water stress, for grass/crop system (g C * m^{-2} ground area * day^{-1})
crpGrPsn (Column 19) – Gross photosynthesis, with water stress, for grass/crop system (g C * m^{-2} ground area * day^{-1})

forLAI (Column 20) – Forest system leaf area index
fordTemp (Column 21) – Decrease in photosynthesis due to temperature for forest system (0 – 1)
fordVpd (Column 22) – Decrease in photosynthesis due to vapor pressure deficit for forest system (0 – 1)
fordWater (Column 23) – Effect of water stress on photosynthesis for forest system (0 – 1)
forLtEff (Column 24) – Decrease in photosynthesis due to amount of light absorbed for forest system (0 – 1)
forPGrPsn (Column 25) – Potential photosynthesis, without water stress, for forest system (g C * m^{-2} ground area * day^{-1})
forGrPsn (Column 26) – Gross photosynthesis, with water stress, for forest system (g C * m^{-2} ground area * day^{-1})

resp.out – Daily respiration

time (Column 1) – Simulation time (see above)
dayofyr (Column 2) – Day of the year (1 – 366)
oiresp (Column 3) – Daily heterotrophic respiration from OI layer (g C m^{-2} d^{-1})
oeresp (Column 4) – Daily heterotrophic respiration from OE layer (g C m^{-2} d^{-1})
slitrsp (Column 5) – Daily heterotrophic respiration from surface litter (oiresp + oeresp) . For DayCent UV versions, slitrsp also includes abiotic CO_2-C loss from UV degradation of standing dead biomass and surface litter (g C m^{-2} d^{-1})
sminrlrsp (Column 6) – Daily heterotrophic respiration from mineral soil (g C m^{-2} d^{-1})
hresp (Column 7) – Daily heterotrophic respiration (g C m^{-2} d^{-1})
crtjresp (Column 8) – Daily growth and maintenance respiration from crop/grass juvenile fine root pool (g C m^{-2} d^{-1})
crtmresp (Column 9) – Daily growth and maintenance respiration from crop/grass mature fine root pool (g C m^{-2} d^{-1})
frtjresp (Column 10) – Daily growth and maintenance respiration from forest juvenile fine root pool (g C m^{-2} d^{-1})
frtmresp (Column 11) – Daily growth and maintenance respiration from forest mature fine root pool (g C m^{-2} d^{-1})
frtcresp (Column 12) – Daily growth and maintenance respiration from forest coarse root pool (g C m^{-2} d^{-1})
sresp (Column 13) – Daily soil respiration (heterotrophic + root autotrophic) (g C m^{-2} d^{-1})
mresp (Column 14) – Daily maintenance respiration (g C m^{-2} d^{-1})
gresp (Column 15) – Daily growth respiration (g C m^{-2} d^{-1})
mrspflux(1) (Column 16) – Daily maintenance respiration flux from storage pool (CARBOSTG(1,*) to C source/sink for grass/crop system (g C m^{-2} d^{-1})
mrspflux(2) (Column 17) – Daily maintenance respiration flux from storage pool (CARBOSTG(2,*) to C source/sink for tree system (g C m^{-2} d^{-1})
cmrspflux(1) (Column 18) – Amount of daily maintenance respiration flux from aboveground grass/crop material that flows from the grass/crop carbohydrate storage pool (CARBOSTG(1,*)) to the C source/sink pool (CSRSNK) (g C m^{-2} d^{-1})
cmrspflux(2) (Column 19) – Amount of daily maintenance respiration flux from juvenile fine root grass/crop material that flows from the grass/crop carbohydrate storage pool (CARBOSTG(1,*)) to the C source/sink pool (CSRSNK) (g C m^{-2} d^{-1})
cmrspflux(3) (Column 20) – Amount of daily maintenance respiration flux from mature fine root grass/crop material that flows from the grass/crop carbohydrate storage pool (CARBOSTG(1,*)) to the C source/sink pool (CSRSNK) (g C m^{-2} d^{-1})

fmrspflux(1) (Column 21) – Amount of daily maintenance respiration flux from live leaf material that flows from the tree carbohydrate storage pool (CARBOSTG(2,*)) to the C source/sink pool (CSRSNK) (g C m^{-2} d^{-1})
fmrspflux(2) (Column 22) – Amount of daily maintenance respiration flux from live juvenile fine root material that flows from the tree carbohydrate storage pool (CARBOSTG(2,*)) to the C source/sink pool (CSRSNK) (g C m^{-2} d^{-1})
fmrspflux(6) (Column 23) – Amount of daily maintenance respiration flux from live mature fine root material that flows from the tree carbohydrate storage pool (CARBOSTG(2,*)) to the C source/sink pool (CSRSNK) (g C m^{-2} d^{-1})
fmrspflux(3) (Column 24) – Amount of daily maintenance respiration flux from live fine branch material that flows from the tree carbohydrate storage pool (CARBOSTG(2,*)) to the C source/sink pool (CSRSNK) (g C m^{-2} d^{-1})
fmrspflux(4) (Column 25) – Amount of daily maintenance respiration flux from live large wood material that flows from the tree carbohydrate storage pool (CARBOSTG(2,*)) to the C source/sink pool (CSRSNK) (g C m^{-2} d^{-1})
fmrspflux(5) (Column 26) – Amount of daily maintenance respiration flux from live coarse root material that flows from the tree carbohydrate storage pool (CARBOSTG(2,*)) to the C source/sink pool (CSRSNK) (g C m^{-2} d^{-1})
mrspann(1) (Column 27) – Accumulator for annual maintenance respiration for grass/crop (g C m^{-2} yr^{-1})
mrspann(2) (Column 28) – Accumulator for annual maintenance respiration for tree (g C m^{-2} yr^{-1})
tavedly (Column 29) – Mean air temperature over production period (°C)
mrspTempEffect(1,1) (Column 30) – Temperature effect on maintenance respiration for aboveground crop/grass biomass (0.0 – 1.0)
mrspTempEffect(1,2) (Column 31) – Temperature effect on maintenance respiration for belowground crop/grass biomass (0.0 – 1.0)
mrspWaterEffect(1) (Column 32) – Water effect on maintenance respiration for crop/grass system (0.0 – 1.0)
mrspTempEffect(2,1) (Column 33) – Temperature effect on maintenance respiration for leaves, fine branch, and large wood forest system components (0.0 – 1.0)
mrspTempEffect(2,2) (Column 34) – Temperature effect on maintenance respiration for juvenile fine root, mature fine root, and coarse root forest system components (0.0 – 1.0)
mrspWaterEffect(2) (Column 35) – Water effect on maintenance respiration for forest system (0.0 – 1.0)
grspflux(1) (Column 36) – Daily growth respiration flux from storage pool (CARBOSTG(1,*) to C source/sink for grass/crop system (g C m^{-2} d^{-1})
grspflux(2) (Column 37) – Daily growth respiration flux from storage pool (CARBOSTG(2,*) to C source/sink for tree system (g C m^{-2} d^{-1})
cgrspflux(1) (Column 38) – Amount of daily growth respiration flux from aboveground grass/crop material that is blown off into the atmosphere during plant carbon production (g C m^{-2} d^{-1})
cgrspflux(2) (Column 39) – Amount of daily growth respiration flux from juvenile fine root grass/crop material that is blown off into the atmosphere during plant carbon production (g C m^{-2} d^{-1})
cgrspflux(3) (Column 40) – Amount of daily growth respiration flux from mature fine root grass/crop material that is blown off into the atmosphere during plant carbon production (g C m^{-2} d^{-1})
fgrspflux(1) (Column 41) – Amount of daily growth respiration loss from live leaf material that is blown off into the atmosphere during plant carbon production (g C m^{-2} d^{-1})
fgrspflux(2) (Column 42) – Amount of daily growth respiration loss from live juvenile fine root material that is blown off into the atmosphere during plant carbon production (g C m^{-2} d^{-1})

fgrspflux(6) (Column 43) – Amount of daily growth respiration loss from live mature fine root material that is blown off into the atmosphere during plant carbon production (g C m^{-2} d^{-1})
fgrspflux(3) (Column 44) – Amount of daily growth respiration loss from live fine branch material that is blown off into the atmosphere during plant carbon production (g C m^{-2} d^{-1})
fgrspflux(4) (Column 45) – Amount of daily growth respiration loss from live large wood material that is blown off into the atmosphere during plant carbon production (g C m^{-2} d^{-1})
fgrspflux(5) (Column 46) – Amount of daily growth respiration loss from live coarse root material that is blown off into the atmosphere during plant carbon production (g C m^{-2} d^{-1})
grspann(1) (Column 47) – Accumulator for annual growth respiration for grass/crop (g C m^{-2} yr^{-1})
grspann(2) (Column 48) – Accumulator for annual growth respiration for tree (g C m^{-2} yr^{-1})
mcprd(1) (Column 49) – Daily NPP for shoots for grass/crop system (g C m^{-2} d^{-1})
mcprd(2) (Column 50) – Daily NPP for juvenile roots for grass/crop system (g C m^{-2} d^{-1})
mcprd(3) (Column 51) – Daily NPP for mature roots for grass/crop system (g C m^{-2} d^{-1})
mfprd(1) (Column 52) – Daily NPP for live leaves for tree system (g C m^{-2} d^{-1})
mfprd(2) (Column 53) – Daily NPP for live juvenile fine roots for tree system (g C m^{-2} d^{-1})
mfprd(6) (Column 54) – Daily NPP for live mature fine roots for tree system (g C m^{-2} d^{-1})
mfprd(3) (Column 55) – Daily NPP for live fine branches for tree system (g C m^{-2} d^{-1})
mfprd(4) (Column 56) – Daily NPP for live large wood for tree system (g C m^{-2} d^{-1})
mfprd(5) (Column 57) – Daily NPP for live coarse roots for tree system (g C m^{-2} d^{-1})
carbostg(1,1) (Column 58) – Unlabeled C in carbohydrate storage for grass/crop system (g C m^{-2})
carbostg(1,2) (Column 59) – Labeled C in carbohydrate storage for grass/crop system (g C m^{-2})
carbostg(2,1) (Column 60) – Unlabeled C in carbohydrate storage for forest system (g C m^{-2})
carbostg(2,2) (Column 61) – Labeled C in carbohydrate storage for forest system (g C m^{-2})

soilc.out – Daily carbon in soil organic matter pools

time (Column 1) – Simulation time (see above)
dayofyr (Column 2) – Day of the year (1 – 366)
metabc(2) (Column 3) – metabolic C in soil litter (g C m^{-2})
strucc(2) (Column 4) – soil litter structural C (g C m^{-2})
som1c(1) (Column 5) – C in surface active pool soil organic matter (g C m^{-2})
som1c(2) (Column 6) – C in soil active soil pool organic matter (g C m^{-2})
som2c(1) (Column 7) – C in surface slow pool soil organic matter (g C m^{-2})
som2c(2) (Column 8) – C in soil slow pool soil organic matter (g C m^{-2})
som3c (Column 9) – C in passive pool soil organic matter (g C m^{-2})

soiln.out – Daily soil ammonium and nitrate by soil layer

time (Column 1) – Simulation time (see above)
dayofyr (Column 2) – Day of the year (1 – 366)
ammonium (Column 3) – Soil ammonium in top 10 centimeters of soil (ppm)
NO3_ppm[0] (Column 4) – Nitrate in soil layer 1 (index 0) of the soil profile, as defined in the soils.in file (ppm)
NO3_ppm[1] (Column 5) – Nitrate in soil layer 2 (index 1) of the soil profile, as defined in the soils.in file (ppm)
...
NO3_ppm[n-1] (Column n+3) – Nitrate in soil layer n (index n-1) of the soil profile, as defined in the soils.in file (ppm)

NOTE:
n = number of soil layers defined in soils.in file

soiltavg.out – Daily average soil temperature by layer

no column headers

Column 1 – Simulation time (see above)
Column 2 – Day of the year (1 – 366)
Column 3 – Average soil temperature for soil layer 1, as defined in soils.in file (°C)
Column 4 – Average soil temperature for soil layer 2, as defined in soils.in file (°C)
...
Column n+2 – Average soil temperature for soil layer n, as defined in soils.in file (°C)

NOTE:
n = number of soil layers defined in soils.in file

soiltmax.out – Daily maximum soil temperature by layer

no column headers

Column 1 – Simulation time (see above)
Column 2 – Day of the year (1 – 366)
Column 3 – Maximum soil temperature for soil layer 1, as defined in soils.in file (°C)
Column 4 – Maximum soil temperature for soil layer 2, as defined in soils.in file (°C)
...
Column n+2 – Maximum soil temperature for soil layer n, as defined in soils.in file (°C)

NOTE:
n = number of soil layers defined in soils.in file

soiltmin.out – Daily minimum soil temperature by layer

no column headers

Column 1 – Simulation time (see above)
Column 2 – Day of the year (1 – 366)
Column 3 – Minimum soil temperature for soil layer 1, as defined in soils.in file (°C)
Column 4 – Minimum soil temperature for soil layer 2, as defined in soils.in file (°C)
...
Column n+2 – Minimum soil temperature for soil layer n, as defined in soils.in file (°C)

NOTE:
n = number of soil layers defined in soils.in file

stemp_dx.out – Daily soil temperature every few centimeters

no column headers

Column 1 – Simulation time (see above)
Column 2 – Day of the year (1 – 366)
Column 3 – Soil temperature for first soil layer division (°C)

Column 4 – Soil temperature for second soil layer division (°C)
...
Column n+2 – Soil temperature for soil layer division n (°C)

WARNING:
This file can become very large.

summary.out – Daily climate, trace gas, and heterotrophic respiration

time (Column 1) – Simulation time (see above)
dayofyr (Column 2) – Day of the year (1 – 366)
tmax (Column 3) – Maximum air temperature for day (°C)
tmin (Column 4) – Minimum air temperature for day (°C)
ppt (Column 5) – Precipitation for day (cm)
N2Oflux (Column 6) – Nitrous oxide flux (g N ha^{-1} d^{-1})
NOflux (Column 7) – Nitric oxide flux (g N ha^{-1} d^{-1})
CH4 (Column 8) – Methane oxidation (g C ha^{-1} d^{-1})
NIT (Column 9) – Gross nitrification (g N ha^{-1} d^{-1})
CO2resp (Column 10) – Heterotrophic CO_2 respiration for the day (g C ha^{-1} d^{-1})

sysc.out – Daily system carbon

time (Column 1) – Simulation time (see above)
dayofyr (Column 2) – Day of the year (1 – 366)
livec (Column 3) – C live material (g C m^{-2}) (aglivc + bglivcj + bglivcm + rleavc + frootcj + frootcm + fbrchc + rlwodc + crootc)
deadc (Column 4) – C in dead material (g C m^{-2}) (stdedc + metabc(1) + strucc(1) + wood1c + wood2c + wood3c)
soilc (Column 5) – C in soil organic matter pools (g C m^{-2}) (metabc(2) + strucc(2) + som1c(1) + som1c(2) + som2c(1) + som2c(2) + som3c)

sysc (Column 6) – System C (g C m^{-2}) (livec + deadc + soilc)

CO2resp (Column 7) – Summation of heterotrophic CO_2 respiration for the day (g C m^{-2})

tgmonth.out – monthly summation of trace gas fluxes

time (Column 1) – Simulation time (see above)
N2Oflux (Column 2) – Monthly accumulator for nitrous oxide (g N_2O-N m^{-2} mo^{-1})
NOflux (Column 3) – Monthly accumulator for nitric oxide (g NO-N m^{-2} mo^{-1})
N2flux (Column 4) – Monthly accumulator for nitrogen (N_2) gas (g N m^{-2} mo^{-1})
CH4 (Column 5) – Monthly accumulator for methane oxidation (g CH_4-C m^{-2} mo^{-1})
NIT (Column 6) – Monthly accumulator for gross nitrification (g N m^{-2} mo^{-1})
PPT (Column 7) – Monthly accumulator for precipitation, includes irrigation (cm mo^{-1})

vswc.out – Daily volumetric soil water content by layer

no column headers

Column 1 – Simulation time (see above)
Column 2 – Day of the year (1 – 366)

Column 3 – Volumetric soil water content for soil layer 1, as defined in soils.in file (0.0 – 1.0)
Column 4 – Volumetric soil water content for soil layer 2, as defined in soils.in file (0.0 – 1.0)
...
Column n+2 – Volumetric soil water content for soil layer n, as defined in soils.in file (0.0 – 1.0)

NOTE:
n = number of soil layers defined in soils.in file

watrbal.out – Daily water balance

time (Column 1) – Simulation time (see above)
dayofyr (Column 2) – Day of the year (1 – 366)
ppt (Column 3) – Precipitation plus irrigation (cm H_2O d^{-1})
accum (Column 4) – Amount of snow added to the snowpack (cm H_2O d^{-1})
dsnlq (Column 5) – Difference in liquid water in the snowpack from the beginning of the day to the end of the day (cm H_2O)
melt (Column 6) – Snow melted from the snow pack (cm H_2O d^{-1})
intrcpt (Column 7) – Evaporation of precipitation that was intercepted by standing crop and litter biomass (cm H_2O d^{-1})
evap (Column 8) – Evaporation from the soil (cm H_2O d^{-1})
transp (Column 9) – Transpiration (cm H_2O d^{-1})
sublim (Column 10) – Amount of snow sublimated (equivalent cm H_2O d^{-1})
dswc (Column 11) – Difference in the soil water content from the beginning of the day to the end of the day (cm H_2O)
outflow (Column 12) – outflow (Column 12) – Total stream flow. Outflow includes runoff (column 16) plus base flow (cm H_2O d^{-1})
balance (Column 13) – Daily water balance, computed as:
balance = (soil water content at beginning of day - soil water content at end of day) + precipitation + snow melt - accumulation - interception - evaporation - transpiration - outflow (should be equal to zero)
snow (Column 14) – Snow water equivalent (SWE) of frozen water in snow pack (cm H_2O)
snlq (Column 15) – Amount of liquid water stored in the snowpack (cm H_2O)
runoff (Column 16) – Runoff (rainfall/melt infiltration excess) (cm H_2O d^{-1})

NOTE:
Values that are negative represent water losses (i.e. intrcpt, evap, transp, sublim, outflow, runoff). The model does not attempt to maintain a water balance when simulating a water table during FLOD events. Irrigation is included in the ppt column.

wflux.out – Daily water flux through the bottom of soil layers

time (Column 1) – Simulation time (see above)
dayofyr (Column 2) – Day of the year (1 – 366)
wflux[0] (Column 3) – Water flux from soil layer 1 (index 0) to soil layer 2 (index 1), as defined in soils.in file (cm H_2O d^{-1})
wflux[1] (Column 4) – Water flux from soil layer 2 (index 1) to soil layer 3 (index 2), as defined in soils.in file (cm H_2O d^{-1})
...

wflux[n-1] (Column n+2) – Water flux from soil layer n (index n-1) to deep storage layer n+1 (index n) (cm H_2O d^{-1})

NOTES:
Negative wflux values represent upward flow (evaporation), positive values represent downward flow (drainage).

n = number of soil layers defined in soils.in file

wfps.out – Daily water filled pore space by layer

no column headers

Column 1 – Simulation time (see above)
Column 2 – Day of the year (1 – 366)
Column 3 – Water filled pore space for soil layer 1, as defined in soils.in file, value from 0 to 1 where 1 = saturation
Column 4 – Water filled pore space for soil layer 2, as defined in soils.in file, value from 0 to 1 where 1 = saturation
...
Column n+2 – Water filled pore space for soil layer n, as defined in soils.in file, value from 0 to 1 where 1 = saturation

NOTE:
n = number of soil layers defined in soils.in file

year_cflows.out – Annual accumulators for carbon flows to SOM pools

time (Column 1) – Simulation time (see above)
asom11tosom21 (Column 2) – carbon flow from active surface organic matter pool to slow surface organic matter pool (g C m^{-2} yr^{-1})
asom12tosom22 (Column 3) – Annual accumulator for carbon flow from active soil organic matter pool to slow soil organic matter pool (g C m^{-2} yr^{-1})
asom12tosom3 (Column 4) – Annual accumulator for carbon flow from active soil organic matter pool to passive soil organic matter pool (g C m^{-2} yr^{-1})
asom21tosom11 (Column 5) – Annual accumulator for carbon flow from slow surface organic matter pool to active surface organic matter pool (g C m^{-2} yr^{-1})
asom21tosom22 (Column 6) – Annual accumulator for carbon flow from slow surface organic matter pool to slow soil organic matter pool (g C m^{-2} yr^{-1})
asom22tosom12 (Column 7) – Annual accumulator for carbon flow from slow soil organic matter pool to active soil organic matter pool (g C m^{-2} yr^{-1})
asom22tosom3 (Column 8) – Annual accumulator for carbon flow from slow soil organic matter pool to passive soil organic matter pool (g C m^{-2} yr^{-1})
asom3tosom12 (Column 9) – Annual accumulator for carbon flow from passive soil organic matter pool to active soil organic matter pool (g C m^{-2} yr^{-1})
ametc1tosom11 (Column 10) – Annual accumulator for carbon flow from surface metabolic pool to active surface organic matter pool (g C m^{-2} yr^{-1})

ametc2tosom12 (Column 11) – Annual accumulator for carbon flow from soil metabolic pool to active soil organic matter pool (g C m^{-2} yr^{-1})

astruc1tosom11 (Column 12) – Annual accumulator for carbon flow from surface structural pool to active surface organic matter pool (g C m^{-2} yr^{-1})

astruc1tosom21 (Column 13) – Annual accumulator for carbon flow from surface structural pool to slow surface organic matter pool (g C m^{-2} yr^{-1})

astruc2tosom12 (Column 14) – Annual accumulator for carbon flow from soil structural pool to active soil organic matter pool (g C m^{-2} yr^{-1})

astruc2tosom22 (Column 15) – Annual accumulator for carbon flow from soil structural pool to slow soil organic matter pool (g C m^{-2} yr^{-1})

awood1tosom11 (Column 16) – Annual accumulator for carbon flow from dead fine branch pool to active surface organic matter pool (g C m^{-2} yr^{-1})

awood1tosom21 (Column 17) – Annual accumulator for carbon flow from dead fine branch pool to slow surface organic matter pool (g C m^{-2} yr^{-1})

awood2tosom11 (Column 18) – Annual accumulator for carbon flow from dead large wood pool to active surface organic matter pool (g C m^{-2} yr^{-1})

awood2tosom21 (Column 19) – Annual accumulator for carbon flow from dead large wood pool to slow surface organic matter pool (g C m^{-2} yr^{-1})

awood3tosom12 (Column 20) – Annual accumulator for carbon flow from dead coarse root pool to active soil organic matter pool (g C m^{-2} yr^{-1})

awood3tosom22 (Column 21) – Annual accumulator for carbon flow from dead coarse root pool to slow soil organic matter pool (g C m^{-2} yr^{-1})

year_summary.out – Annual accumulators for trace gas fluxes

time (Column 1) – Simulation time (see above)
N2Oflux (Column 2) – Annual accumulator for nitrous oxide (g N m^{-2} yr^{-1})
NOflux (Column 3) – Annual accumulator for nitric oxide (g N m^{-2} yr^{-1})
N2flux (Column 4) – Annual accumulator for nitrogen gas (g N m^{-2} yr^{-1})
CH4 (Column 5) – Annual accumulator for methane oxidation (g C m^{-2} yr^{-1})
NIT (Column 6) – Annual accumulator for gross nitrification (g N m^{-2} yr^{-1})
ANNPPT (Column 7) – Annual accumulator for precipitation, includes irrigation (cm yr^{-1})

Output variables from the binary (.bin) file

Use the list100 utility to extract any of the following variables from the binary file. Note: soil layer values in this file refer to the Century soil layers as defined in fix.100, not the finer DayCent layers defined in soils.in.

aagdefac – average annual value of *agdefac*, the decomposition factor which combines the effects of temperature and moisture for the surface decomposition (replaces *adefac*)

abgdefac – average annual value of *bgdefac*, the decomposition factor which combines the effects of temperature and moisture for the soil decomposition (replaces *adefac*)

accrst – annual accumulator of C in straw removed for grass/crop (sum of crmvst) (g C m^{-2} yr^{-1})

accrste(1) – annual accumulator for N from harvested straw (sum of ermvst(1)) (g N m^{-2} yr^{-1})

accrste(2) – annual accumulator for P from harvested straw (sum of ermvst(2)) (g P m^{-2} yr^{-1})

accrste(3) – annual accumulator for S from harvested straw (sum of ermvst(3)) (g S m^{-2} yr^{-1})

acrcis(1) – growing season accumulator for unlabeled C production by isotope in forest system coarse root component (g C m^{-2} yr^{-1} $season^{-1}$)

acrcis(2) – growing season accumulator for labeled C production by isotope in forest system coarse root component (g C m^{-2} yr^{-1} $season^{-1}$)

afbcis(1) – growing season accumulator for unlabeled C production by isotope in forest system fine branch component (g C m^{-2} yr^{-1} $season^{-1}$)

afbcis(2) – growing season accumulator for labeled C production by isotope in forest system fine branch component (g C m^{-2} yr^{-1} $season^{-1}$)

afrcisj(1) – unlabeled growing season accumulator for C production in forest system juvenile fine root component (TFST-TLST) (g C m^{-2} yr^{-1} $season^{-1}$) (replaces *afrcis(1)*)

afrcisj(2) – labeled growing season accumulator for C production in forest system juvenile fine root component (TFST-TLST) (g C m^{-2} yr^{-1} $season^{-1}$) (replaces *afrcis(2)*)

afrcism(1) – unlabeled growing season accumulator for C production in forest system mature fine root component (TFST-TLST) (g C m^{-2} yr^{-1} $season^{-1}$) (replaces *afrcis(1)*)

afrcism(2) – labeled growing season accumulator for C production in forest system mature fine root component (TFST-TLST) (g C m^{-2} yr^{-1} $season^{-1}$) (replaces *afrcis(2)*)

agcacc – growing season accumulator for aboveground C production (g C m^{-2} yr^{-1})

agcisa(1) – growing season accumulator for unlabeled aboveground C production for grass/crop (g C m^{-2} yr^{-1} $season^{-1}$)

agcisa(2) – growing season accumulator for labeled aboveground C production for grass/crop (g C m^{-2} yr^{-1} $season^{-1}$)

agcmth(12) – aboveground C production for the grass/crop for the current month, 1-12 (g C m^{-2})

agcprd – aboveground C production for the grass/crop over the last completed growing season (g C m^{-2} yr^{-1})

agdefac – decomposition factor based on temperature and moisture for surface decomposition (replaces *defac*)

aglcis(1) – unlabeled aboveground C by isotope for grass/crop (g C m^{-2})

aglcis(2) – labeled aboveground C by isotope for grass/crop (g C m^{-2})

aglcn – aboveground live C/N ratio, = -999 if either component = 0 for grass/crop

aglivc – C in aboveground live for grass/crop (g C m^{-2})

aglive(1) – N in aboveground live for grass/crop (g N m^{-2})

aglive(2) – P in aboveground live for grass/crop (g P m^{-2})

aglive (3) – S in aboveground live for grass/crop (g S m^{-2})

alvcis(1) – growing season accumulator for unlabeled C production in forest system leaf component (g C m^{-2} yr^{-1} $season^{-1}$)

alvcis(2) – growing season accumulator for labeled C production in forest system leaf component (g C m^{-2} yr^{-1} $season^{-1}$)

alwcis(1) – growing season accumulator for unlabeled C production in forest system large wood component (g C m^{-2} yr^{-1} $season^{-1}$)

alwcis(2) – growing season accumulator for labeled C production in forest system large wood component (g C m^{-2} yr^{-1} $season^{-1}$)

aminrl(1) – mineral N in layer 1 before uptake by plants

aminrl(2) – mineral P in layer 1 before uptake by plants

aminrl(3) – mineral S in layer 1 before uptake by plants

amt1c2 – annual accumulator for surface CO_2 loss due to microbial respiration during litter decomposition (g C m^{-2} yr^{-1})

amt2c2 – annual accumulator for soil CO_2 loss due to microbial respiration during litter decomposition (g C m^{-2} yr^{-1})

anerb – the effect of soil anaerobic conditions on decomposition; used as a multiplier on all belowground decomposition flows

annet – annual evapotranspiration (sum of monthly evap + tran) (cm yr^{-1})

arspmth(1,1) – unlabeled monthly autotrophic respiration for grass/crop system (g C m^{-2})

arspmth(1,2) – labeled monthly autotrophic respiration for grass/crop system (g C m^{-2})

arspmth(2,1) – unlabeled monthly autotrophic respiration for forest system (g C m^{-2})

arspmth(2,2) – labeled monthly autotrophic respiration for forest system (g C m^{-2} mo^{-1})

as11c2 – annual accumulator for CO_2 loss due to microbial respiration during soil organic matter decomposition of surface *som1* to *som2* (g C m^{-2} yr^{-1})

as12c2 – annual accumulator for CO_2 loss due to microbial respiration during soil organic matter decomposition of soil som1 to soil som2 and som3 (replaces *as21c2*) (g C m^{-2} yr^{-1})

as21c2 – annual accumulator for CO_2 loss due to microbial respiration during soil organic matter decomposition of surface som2 to surface som1 (new definition) (g C m^{-2} yr^{-1})

as22c2 – annual accumulator for CO_2 loss due to microbial respiration during soil organic matter decomposition of soil som2 to soil som1 and som3 (replaces *as2c2*) (g C m^{-2} yr^{-1})

as3c2 – annual accumulator for CO_2 loss due to microbial respiration during soil organic matter decomposition of som3 to soil som1 (g C m^{-2} yr^{-1})

asmos(1) – soil water content of layer 1 (cm)

asmos(2) – soil water content of layer 2 (cm)

asmos(3) – soil water content of layer 3 (cm)

asmos(4) – soil water content of layer 4 (cm)

asmos(5) – soil water content of layer 5 (cm)

asmos(6) – soil water content of layer 6 (cm)

asmos(7) – soil water content of layer 7 (cm)

asmos(8) – soil water content of layer 8 (cm)

asmos(9) – soil water content of layer 9 (cm)

asmos(10) – soil water content of layer 10 (cm)

ast1c2 – annual accumulator for CO_2 loss due to microbial respiration during litter decomposition of surface structural into som1 and som2 (g C m^{-2} yr^{-1})

ast2c2 – annual accumulator for CO_2 loss due to microbial respiration during litter decomposition of soil structural into som1 and som2 (g C m^{-2} yr^{-1})

ast1uvc2 - For DayCent UV versions this is an annual accumulator for the abiotic CO_2 loss from UV degradation of surface litter (g C m^{-2} yr^{-1})

astduvc2 - For DayCent UV versions this is an annual accumulator for the abiotic CO_2 loss from UV degradation of standing dead biomass (g C m^{-2} yr^{-1})

avh2o(1) – water available to grass/crop/tree for growth in soil profile (sum of Century layers 1 through claypg or tlaypg) (cm H_2O)

avh2o(2) – water available to grass/crop/tree for survival in soil profile (sum of all Century layers in profile, 1 through nlayer) (cm H_2O)

avh2o(3) – water in the first two Century soil layers (cm H_2O)

bgcjacc – growing season accumulator for juvenile fine root C production for grass/crop (FRST-LAST) (g C m^{-2} yr^{-1} $season^{-1}$) (replaces *bgcacc*)

bgcmacc – growing season accumulator for mature fine root C production for grass/crop (FRST-LAST) (g C m^{-2} yr^{-1} $season^{-1}$) (replaces *bgcacc*)

bgcisja(1) – unlabeled growing season accumulator for juvenile fine root C production for grass/crop (FRST-LAST) (g C m^{-2} yr^{-1} $season^{-1}$) (replaces *bgcisa(1)*)

bgcisja(2) – labeled growing season accumulator for juvenile fine root C production for grass/crop (FRST-LAST) (g C m^{-2} yr^{-1} $season^{-1}$) (replaces *bgcisa(2)*)

bgcisma(1) – unlabeled growing season accumulator for mature fine root C production for grass/crop (FRST-LAST) (g C m^{-2} yr^{-1} $season^{-1}$) (replaces *bgcisa(1)*)

bgcisma(2) – labeled growing season accumulator for mature fine root C production for grass/crop (FRST-LAST) (g C m^{-2} yr^{-1} $season^{-1}$) (replaces *bgcisa(2)*)

bgcjmth(12) – juvenile fine root C production for grass/crop for the current month, 1-12 (g C m^{-2}) (replaces *bgcmth(12)*)

bgcmmth(12) – mature fine root C production for grass/crop for the current month, 1-12 (g C m^{-2}) (replaces *bgcmth(12)*)

bgcjprd – juvenile fine root C production for the grass/crop over the last completed growing season (g C m^{-2} yr^{-1}) (replaces *bgcprd*)

bgcmprd – mature fine root C production for the grass/crop over the last completed growing season (g C m^{-2} yr^{-1}) (replaces *bgcprd*)

bgdefac – decomposition factor based on temperature and moisture for soil decomposition (replaces *defac*)

bglcisj(1) – unlabeled juvenile fine root live C for grass/crop (g C m^{-2}) (replaces bglcis(1))

bglcisj(2) – labeled juvenile fine root live C for grass/crop (g C m^{-2}) (replaces *bglcis(2)*) bglcism(1) – unlabeled mature fine root live C for grass/crop (g C m^{-2}) (replaces *bglcis(1)*)

bglcism(2) – labeled mature fine root live C for grass/crop (g C m^{-2}) (replaces *bglcis(2)*)

bglcnj – juvenile fine root live C/N ratio for grass/crop; = -999 if either component = 0 (replaces *bglcn*)

bglcnm – mature fine root live C/N ratio for grass/crop; = -999 if either component = 0 (replaces *bglcn*)

bglivcj – C in juvenile fine root live for grass/crop (g C m^{-2}) (replaces *bglivc*)

bglivcm – C in mature fine root live for grass/crop (g C m^{-2}) (replaces *bglivc*)

bglivej(1) – N in juvenile fine root live for grass/crop (g N m^{-2}) (replaces *bglive(1)*)

bglivej(2) – P in juvenile fine root live for grass/crop (g P m^{-2}) (replaces *bglive(2)*)

bglivej(3) – S in juvenile fine root live for grass/crop (g S m^{-2}) (replaces bglive(3))

bglivem(1) – N in mature fine root live for grass/crop (g N m^{-2}) (replaces *bglive(1)*)

bglivem(2) – P in mature fine root live for grass/crop (g P m^{-2}) (replaces *bglive(2)*)

bglivem(3) – S in mature fine root live for grass/crop (g S m^{-2}) (replaces *bglive(3)*)

carbostg(1,1) – unlabeled C in carbohydrate storage for grass/crop system (g C m^{-2})

carbostg(1,2) – labeled C in carbohydrate storage for grass/crop system (g C m^{-2})

carbostg(2,1) – unlabeled C in carbohydrate storage for forest system (g C m^{-2})

carbostg(2,2) – labeled C in carbohydrate storage for forest system (g C m^{-2})

cautoresp(1) – annual accumulator for unlabeled autotrophic respiration for grass/crop system (g C m^{-2} yr^{-1})

cautoresp(2) – annual accumulator for labeled autotrophic respiration for grass/crop system (g C m^{-2} yr^{-1})

cgracc – annual accumulator for grain and tuber production for grass/crop (sum of cgrain) (g C m^{-2} yr^{-1})

cgrain – economic yield of C in grain + tubers for grass/crop from the most recent harvest event (g C m^{-2} harvest^{-1})

cgrspflux(1) – monthly growth respiration flux from aboveground live grass/crop material that is blown off from the carbohydrate storage pool (*carbostg(1,*)*) into the atmosphere (*csrsnk*) during plant carbon production (g C m^{-2})

cgrspflux(2) – monthly growth respiration flux from juvenile live fine roots grass/crop material that is blown off from the carbohydrate storage pool (*carbostg(1,*)*) into the atmosphere (*csrsnk*) during plant carbon production (g C m^{-2})

cgrspflux(3) – monthly growth respiration flux from mature live fine roots grass/crop material that is blown off from the carbohydrate storage pool (*carbostg(1,*)*) into the atmosphere (csrsnk) during plant carbon production (g C m^{-2})

cinput – annual C inputs

cisgra(1) – unlabeled C in grain (g C m^{-2}) for grass/crop

cisgra(2) – labeled C in grain (g C m^{-2}) for grass/crop

clittr(1,1) – surface, unlabeled residue (g C m^{-2})

clittr(1,2) – surface, labeled residue (g C m^{-2})

clittr(2,1) – soil, unlabeled residue (g C m^{-2})

clittr(2,2) – soil, labeled residue (g C m^{-2})

cltfac(1) – effect of cultivation on decomposition for som1; = clteff(1) if cultivation occurs in the current month; = 1 otherwise

cltfac(2) – effect of cultivation on decomposition for som2; = clteff(2) if cultivation occurs in the current month; = 1 otherwise

cltfac(3) – effect of cultivation on decomposition for som3; = clteff(3) if cultivation occurs in the current month; = 1 otherwise

cltfac(4) – effect effect of cultivation on decomposition for structural; = clteff(4) if cultivation occurs in the current month; = 1 otherwise

cmrspflux(1) – monthly maintenance respiration flux from aboveground live grass/crop material that flows from the grass/crop carbohydrate storage pool (*carbostg(1,*)*) to the C source/sink pool (*csrsnk*) (g C m^{-2})

cmrspflux(2) – monthly maintenance respiration flux from live juvenile fine root grass/crop material that flows from the grass/crop carbohydrate storage pool (*carbostg(1,*)*) to the C source/sink pool (*csrsnk*) (g C m^{-2})

cmrspflux(3) – monthly maintenance respiration flux from live mature fine root grass/crop material that flows from the grass/crop carbohydrate storage pool (*carbostg(1,*)*) to the C source/sink pool (*csrsnk*) (g C m^{-2})

co2cce(1,1,1) – the calculated effect on grass/crop minimum C/N ratios of doubling the atmospheric CO_2 concentration from 350 ppm to 700 ppm

co2cce(1,1,2) – the calculated effect on grass/crop minimum C/P ratios of doubling the atmospheric CO_2 concentration from 350 ppm to 700 ppm

co2cce(1,1,3) – the calculated effect on grass/crop minimum C/S ratios of doubling the atmospheric CO_2 concentration from 350 ppm to 700 ppm

co2cce(1,2,1) – the calculated effect on grass/crop maximum C/N ratios of doubling the atmospheric CO_2 concentration from 350 ppm to 700 ppm

co2cce(1,2,2) – the calculated effect on grass/crop maximum C/P ratios of doubling the atmospheric CO_2 concentration from 350 ppm to 700 ppm

co2cce(1,2,3) – the calculated effect on grass/crop maximum C/S ratios of doubling the atmospheric CO_2 concentration from 350 ppm to 700 ppm

co2cce(2,1,1) – the calculated effect on forest minimum C/N ratios of doubling the atmospheric CO_2 concentration from 350 ppm to 700 ppm

co2cce(2,1,2) – the calculated effect on forest minimum C/P ratios of doubling the atmospheric CO_2 concentration from 350 ppm to 700 ppm

co2cce(2,1,3) – the calculated effect on forest minimum C/S ratios of doubling the atmospheric CO_2 concentration from 350 ppm to 700 ppm

co2cce(2,2,1) – the calculated effect on forest maximum C/N ratios of doubling the atmospheric CO_2 concentration from 350 ppm to 700 ppm

co2cce(2,2,2) – the calculated effect on forest maximum C/P ratios of doubling the atmospheric CO_2 concentration from 350 ppm to 700 ppm

co2cce(2,2,3) – the calculated effect on forest maximum C/S ratios of doubling the atmospheric CO_2 concentration from 350 ppm to 700 ppm

co2cpr(1) – in a grass/crop system, the calculated effect on potential production of doubling the atmospheric CO_2 concentration from 350 ppm to 700 ppm

co2cpr(2) – in a forest system, the calculated effect on potential production of doubling the atmospheric CO_2 concentration from 350 ppm to 700 ppm

co2crs(1) – in a grass/crop system, the calculated effect on root-shoot ratio of doubling the atmospheric CO_2 concentration from 350 ppm to 700 ppm

co2crs(2) – in a forest system, the calculated effect on root-shoot ratio of doubling the atmospheric CO_2 concentration from 350 ppm to 700 ppm co2ctr(1) – in a forest system, the calculated effect on grass/crop transpiration rate of doubling the atmospheric CO_2 concentration from 350 ppm to 700 ppm

co2ctr(2) – in a forest system, the calculated effect on forest transpiration rate of doubling the atmospheric CO_2 concentration from 350 ppm to 700 ppm

cproda – annual accumulator of C production in grass/crop + forest = net primary production (g C m^{-2} yr^{-1})

cprodc – total monthly C production for grass/crop (g C m^{-2} mo^{-1})

cprodf – total monthly C production for forest (g C m^{-2} mo^{-1})

creta – annual accumulator of C returned to system during grazing/fire for grass/crop (g C m^{-2} yr^{-1})

crmvst – amount of C removed through straw during most recent harvest event for grass/crop (g C m^{-2} $harvest^{-1}$)

crootc – C in forest system coarse root component (g C m^{-2})

croote(1) – N in forest system coarse root component (g N m^{-2})

croote(2) – P in forest system coarse root component (g P m^{-2})

croote(3) – S in forest system coarse root component (g S m^{-2})

crpstg(1) – retranslocation N storage pool for grass/crop (g N m^{-2})

crpstg(2) – retranslocation P storage pool for grass/crop (g P m^{-2})

crpstg(3) – retranslocation S storage pool for grass/crop (g S m^{-2})

crpval – a numerical representation of the current crop, used for sorting output by crop; created by a system of assigning values to characters as in A=1,B=2,etc. and 1=0.1, 2=0.2, etc. and adding the values together (example: AB2 = 3.2)

crtacc – growing season accumulator for C production in forest system coarse root component (g C m^{-2} yr^{-1} $season^{-1}$)

crtcis(1) – unlabeled C in forest system coarse root component (g C m^{-2})

crtcis(2) – labeled C in forest system coarse root component (g C m^{-2})

crtprd – coarse root component C production for the forest system over the last completed growing season (g C m^{-2} yr^{-1})

csrsnk(1) – unlabeled C source/sink (g C m^{-2})

csrsnk(2) – labeled C source/sink (g C m^{-2})

dautoresp(1) – delta 13/14C value for autotrophic respiration for grass/crop system for stable isotope labeling

dautoresp(2) – delta 13/14C value for autotrophic respiration for forest system for stable isotope labeling

dbglivc – delta 13C/14C value for grass/crop belowground live, juvenile and mature live fine roots, for stable isotope labeling

dbglivcj – delta 13C/14C value for grass/crop juvenile live fine roots for stable isotope labeling

dbglivcm – delta 13C/14C value for grass/crop mature live fine roots for stable isotope labeling

dblit – delta 13C value for belowground litter for stable isotope labeling

dcarbostg(1) – delta 13/14C value for grass/crop system carbohydrate storage pool for stable isotope labeling

dcarbostg(2) – delta 13/14C value for forest system carbohydrate storage pool for stable isotope labeling

deloe – delta 13C/14C value for OE layer (soil structural, metabolic, som1c, som2c, and som3c) for stable isotope labeling

deloi – delta 13C/14C value for OI layer (surface structural, metabolic, som1c, and som2c) for stable isotope labeling

dfrootc – delta 13C/14C value for forest belowground live, juvenile and mature fine roots, for stable isotope labeling

dfrootcj – delta 13C/14C value for forest juvenile live fine roots for stable isotope labeling

dfrootcm – delta 13C/14C value for forest mature live fine roots for stable isotope labeling

dhetresp – delta 13/14C value for heterotrophic respiration for stable isotope labeling

dmetc(1) – delta 13C value for metabolic surface C in for stable isotope labeling

dmetc(2) – delta 13C value for metabolic soil C in for stable isotope labeling

dslit – delta 13C value for surface litter for stable isotope labeling

dsoilresp – delta 13/14C value for soil respiration for stable isotope labeling dsom1c(1) – delta 13C value for som1c(1) for stable isotope labeling

dsom1c(2) – delta 13C value for som1c(2) for stable isotope labeling

dsom2c(1) – delta 13C/14C value for *som2c(1)* for stable isotope labeling

dsom2c(2) – delta 13C/14C value for *som2c(2)* for stable isotope labeling (replaces *dsom2c*)

dsom3c – delta 13C value for som3c for stable isotope labeling

dsomsc – delta 13C value for soil organic matter for stable isotope labeling

dsomtc – delta 13C value for total soil C for stable isotope labeling

dstruc(1) – delta 13C value for belowground structural surface C for stable isotope labeling

dstruc(2) – delta 13C value for belowground structural soil C for stable isotope labeling

egracc(1) – annual accumulator of N in grain + tuber production for grass/crop (sum of egrain(1)) (g N m^{-2} yr^{-1})

egracc(2) – annual accumulator of P in grain + tuber production for grass/crop (sum of egrain(2)) (g P m^{-2} yr^{-1})

egracc(3) – annual accumulator of S in grain + tuber production for grass/crop (sum of egrain(3)) (g S m^{-2} yr^{-1})

egrain(1) – economic yield of N in grain + tubers for grass/crop from the most recent harvest event (g N m^{-2} $harvest^{-1}$)

egrain(2) – economic yield of P in grain + tubers for grass/crop from the most recent harvest event (g P m^{-2} $harvest^{-1}$)

egrain(3) – economic yield of S in grain + tubers for grass/crop from the most recent harvest event (g S m^{-2} $harvest^{-1}$)

elimit – indicator of the limiting element

= 1 if N is the limiting element
= 2 if P is the limiting element
= 3 if S is the limiting element

eprodc(1) – annual monthly N uptake for grass/crop (g N m^{-2} mo^{-1})

eprodc(2) – annual monthly P uptake for grass/crop (g P m^{-2} mo^{-1})

eprodc(3) – annual monthly S uptake for grass/crop (g S m^{-2} mo^{-1})

eprodf(1) – annual monthly N uptake in forest system (g N m^{-2} mo^{-1})

eprodf(2) – annual monthly P uptake in forest system (g P m^{-2} mo^{-1})

eprodf(3) – annual monthly S uptake in forest system (g S m^{-2} mo^{-1})

ereta(1) – annual accumulator of N returned to system during grazing/fire for grass/crop (g N m^{-2} yr^{-1})

ereta(2) – annual accumulator of P returned to system during grazing/fire for grass/crop (g P m^{-2} yr^{-1})

ereta(3) – annual accumulator of S returned to system during grazing/fire for grass/crop (g S m^{-2} yr^{-1})

ermvst(1) – amount of N removed as straw during most recent harvest event for grass/crop (g N m^{-2} harvest^{-1})

ermvst(2) – amount of P removed as straw during most recent harvest event for grass/crop (g P m^{-2} harvest^{-1})

ermvst(3) – amount of S removed as straw during most recent harvest event for grass/crop (g S m^{-2} harvest^{-1})

esrsnk(1) – N source/sink (g N m^{-2})

esrsnk(2) – P source/sink (g P m^{-2})

esrsnk(3) – S source/sink (g S m^{-2})

eupacc(1) – growing season accumulator for N uptake by grass, crop or tree (g N m^{-2} yr^{-1} season^{-1})

eupacc(2) – growing season accumulator for P uptake by grass, crop or tree (g P m^{-2} yr^{-1} season^{-1})

eupacc(3) – growing season accumulator for S uptake by grass, crop or tree (g S m^{-2} yr^{-1} season^{-1})

eupaga(1) – aboveground growing season accumulator for N uptake by plants for grass/crop (g N m^{-2} yr^{1} season^{-1})

eupaga(2) – aboveground growing season accumulator for P uptake by plants for grass/crop (g P m^{-2} yr^{-1} season^{-1})

eupaga(3) – aboveground growing season accumulator for S uptake by plants for grass/crop (g S m^{-2} yr^{-1} season^{-1})

eupbga(1) – belowground growing season accumulator for N uptake by plants for grass/crop (g N m^{-2} yr^{-1} season^{-1})

eupbga(2) – belowground growing season accumulator for P uptake by plants for grass/crop (g P m^{-2} yr^{-1} $season^{-1}$)

eupbga(3) – belowground growing season accumulator for S uptake by plants for grass/crop (g S m^{-2} yr^{-1} $season^{-1}$)

eupprd(1) – N uptake by grass, crop, or tree over the last completed growing season (g N m^{-2} yr^{-1})

eupprd(2) – P uptake by grass, crop, or tree over the last completed growing season (g P m^{-2} yr^{-1})

eupprd(3) – S uptake by grass, crop, or tree over the last completed growing season (g S m^{-2} yr^{-1})

eupprt(1,1) – growing season accumulator for N leaf uptake by forest component (g N m^{-2} yr^{-1} $season^{-1}$)

eupprt(1,2) – growing season accumulator for P leaf uptake by forest component (g P m^{-2} yr^{-1} $season^{-1}$)

eupprt(1,3) – growing season accumulator for S leaf uptake by forest component (g S m^{-2} yr^{-1} $season^{-1}$)

eupprt(2,1) – growing season accumulator for N fine root uptake by forest component (g N m^{-2} y^{-1} $season^{-1}$)

eupprt(2,2) – growing season accumulator for P fine root uptake by forest component (g P m^{-2} yr^{-1} $season^{-1}$)

eupprt(2,3) – growing season accumulator for S fine root uptake by forest component (g S m^{-2} yr^{-1} $season^{-1}$)

eupprt(3,1) – growing season accumulator for N fine branch uptake by forest component (g N m^{-2} yr^{-1} $season^{-1}$)

eupprt(3,2) – growing season accumulator for P fine branch uptake by forest component (g P m^{-2} yr^{-1} $season^{-1}$)

eupprt(3,3) – growing season accumulator for S fine branch uptake by forest component (g S m^{-2} yr^{-1} $season^{-1}$)

eupprt(4,1) – growing season accumulator for N large wood uptake by forest component (g N m^{-2} yr^{-1} $season^{-1}$)

eupprt(4,2) – growing season accumulator for P large wood uptake by forest component (g P m^{-2} yr^{-1} $season^{-1}$)

eupprt(4,3) – growing season accumulator for S large wood uptake by forest component (g S m^{-2} yr^{-1} $season^{-1}$)

eupprt(5,1) – growing season accumulator for N coarse root uptake by forest component (g N m^{-2} yr^{-1} $season^{-1}$)

eupprt(5,2) – growing season accumulator for P coarse root uptake by forest component (g P m^{-2} yr^{-1} $season^{-1}$)

eupprt(5,3) – growing season accumulator for S coarse root uptake by forest component (g S m^{-2} yr^{-1} $season^{-1}$)

evap – monthly evaporation including bare soil evaporation, evaporation of precipitation intercepted by plant and litter biomass, and sublimation (cm mo^{-1})

fautoresp(1) – annual accumulator for unlabeled autotrophic respiration for forest system (g C m^{-2} yr^{-1})

fautoresp(2) – annual accumulator for labeled autotrophic respiration for forest system (g C m^{-2} yr^{-1})

fbracc – growing season accumulator for C production in forest system fine branch component (g C m^{-2} yr^{-1} $season^{-1}$)

fbrchc – C in forest system fine branch component (g C m^{-2})

fbrche(1) – N in forest system fine branch component (g N m^{-2})

fbrche(2) – P in forest system fine branch component (g P m^{-2})

fbrche(3) – S in forest system fine branch component (g S m^{-2})

fbrcis(1) – unlabeled C in forest system fine branch component (g C m^{-2})

fbrcis(1) – labeled C in forest system fine branch component (g C m^{-2})

fbrprd – fine branch component C production for the forest system over the last completed growing season (g C m^{-2} yr^{-1})

fcacc – growing season accumulator for C production in forest system (g C m^{-2} yr^{-1} $season^{-1}$)

fcmth(12) – forest system C production for the grass/crop for the current month, 1-12 (g C m^{-2})

fcprd – forest system C production over the last completed growing season (g C m^{-2} yr^{-1})

fertac(1) – annual accumulator for N fertilizer (g N m^{-2} yr^{-1})

fertac(2) – annual accumulator for P fertilizer (g P m^{-2} yr^{-1})

fertac(3) – annual accumulator for S fertilizer (g S m^{-2} yr^{-1})

fertot(1) – accumulator for N fertilizer

fertot(2) – accumulator for P fertilizer fertot(3) – accumulator for S fertilizer

fertprd(1) – growing season accumulator for N fertilizer (g N m^{-2} yr^{-1} $season^{-1}$)

fertprd(2) – growing season accumulator for P fertilizer (g P m^{-2} yr^{-1} $season^{-1}$)

fertprd(3) – growing season accumulator for S fertilizer (g S m^{-2} yr^{-1} $season^{-1}$)

fertmth(12,1) – N fertilizer added to the system for the month, 1-12 (g N m^{-2})

fertmth(12,2) – P fertilizer added to the system for the month, 1-12 (g P m^{-2})

fertmth(12,3) – S fertilizer added to the system for the month, 1-12 (g S m^{-2})

fgrspflux(1) – monthly growth respiration flux from live leaf material that is blown off from the carbohydrate storage pool (*carbostg(2,*)*) into the atmosphere (*csrsnk*) during plant carbon production (g C m^{-2})

fgrspflux(2) – monthly growth respiration flux from juvenile live fine root material that is blown off from the carbohydrate storage pool (*carbostg(2,*)*) into the atmosphere (*csrsnk*) during plant carbon production (g C m^{-2})

fgrspflux(3) – monthly growth respiration flux from live fine branch material that is blown off from the carbohydrate storage pool (*carbostg(2,*)*) into the atmosphere (*csrsnk*) during plant carbon production (g C m^{-2})

fgrspflux(4) – monthly growth respiration flux from live large wood material that is blown off from the carbohydrate storage pool (*carbostg(2,*)*) into the atmosphere (*csrsnk*) during plant carbon production (g C m^{-2})

fgrspflux(5) – monthly growth respiration flux from live coarse root material that is blown off from the carbohydrate storage pool (*carbostg(2,*)*) into the atmosphere (*csrsnk*) during plant carbon production (g C m^{-2})

fgrspflux(6) – monthly growth respiration flux from mature live fine root material that is blown off from the carbohydrate storage pool (*carbostg(2,*)*) into the atmosphere (*csrsnk*) during plant carbon production (g C m^{-2})

fmrspflux(1) – amount of monthly maintenance respiration flux from live leaf material that flows from the tree maintenance respiration storage pool (*carbostg(2,*)*) to the C source/sink pool (*csrsnk*) (g C m^{-2})

fmrspflux(2) – amount of monthly maintenance respiration flux from juvenile live fine root material that flows from the tree maintenance respiration storage pool (*carbostg(2,*)*) to the C source/sink pool (*csrsnk*) (g C m^{-2})

fmrspflux(3) – amount of monthly maintenance respiration flux from live fine branch material that flows from the tree maintenance respiration storage pool (*carbostg(2,*)*) to the C source/sink pool (*csrsnk*) (g C m^{-2})

fmrspflux(4) – amount of monthly maintenance respiration flux from live large wood material that flows from the tree maintenance respiration storage pool (*carbostg(2,*)*) to the C source/sink pool (*csrsnk*) (g C m^{-2})

fmrspflux(5) – amount of monthly maintenance respiration flux from live coarse root material that flows from the tree maintenance respiration storage pool (*carbostg(2,*)*) to the C source/sink pool (*csrsnk*) (g C m^{-2})

fmrspflux(6) – amount of monthly maintenance respiration flux from mature live fine root material that flows from the tree maintenance respiration storage pool (*carbostg(2,*)*) to the C source/sink pool (*csrsnk*) (g C m^{-2})

forstg(1) – retranslocation N storage pool for forest

forstg(2) – retranslocation P storage pool for forest

forstg(3) – retranslocation S storage pool for forest

frootcj – C in forest system juvenile fine root component (g C m^{-2}) (replaces *frootc*)

frootcm – C in forest system mature fine root component (g C m^{-2}) (replaces *frootc*)

frootej(1) – N in forest system juvenile fine root component (g N m^{-2}) (replaces *froote(1)*)

frootej(2) – P in forest system juvenile fine root component (g P m^{-2}) (replaces *froote(2)*)

frootej(3) – S in forest system juvenile fine root component (g S m^{-2}) (replaces *froote(3)*)

frootem(1) – N in forest system mature fine root component (g N m^{-2}) (replaces *froote(1)*)

frootem(2) – P in forest system mature fine root component (g P m^{-2}) (replaces *froote(2)*)

frootem(3) – S in forest system mature fine root component (g S m^{-2}) (replaces *froote(3)*)

frstc – sum of C in forest system live components (g C m^{-2}) (rleavc + frootc + fbrchc + rlwodc + crootc)

frste(1) – sum of N in forest system live components (g N m^{-2}) (rleave(N) + froote(N) + fbrche(N) + rlwode(N) + croote(N))

frste(2) – sum of P in forest system live components (g P m^{-2}) (rleave(P) + froote(P) + fbrche(P) + rlwode(P) + croote(P)) frste(3) – sum of S in forest system live components (g S m^{-2}) (rleave(S) + froote(S) + fbrche(S) + rlwode(S) + croote(S))

frtjacc – growing season accumulator for C production in forest system juvenile fine root component (TFST-TLST) (g C m^{-2} yr^{-1} $season^{-1}$) (replaces *frtacc*)

frtmacc – growing season accumulator for C production in forest system mature fine root component (TFST-TLST) (g C m^{-2} yr^{-1} $season^{-1}$) (replaces *frtacc*)

frtcisj(1) – unlabeled C in forest system juvenile fine root component (g C m^{-2}) (replaces *frtcis(1)*)

frtcisj(2) – labeled C in forest system juvenile fine root component (g C m^{-2}) (replaces *frtcis(2)*)

frtcism(1) – unlabeled C in forest system mature fine root component (g C m^{-2}) (replaces *frtcis(1)*)

frtcism(2) – labeled C in forest system mature fine root component (g C m^{-2}) (replaces *frtcis(2)*)

frtjprd – juvenile fine root component C production for the forest system over the last completed growing season (g C m^{-2} yr^{-1}) (replaces *frtprd*)

frtmprd – mature fine root component C production for the forest system over the last completed growing season (g C m^{-2} yr^{-1}) (replaces *frtprd*)

fsysc – total C in forest system i.e. sum of soil organic matter, trees, dead wood, forest litter

fsyse(1) – total N in forest system i.e. sum of soil organic matter, trees, dead wood, forest litter

fsyse(2) – total P in forest system i.e. sum of soil organic matter, trees, dead wood, forest litter

fsyse(3) – total S in forest system i.e. sum of soil organic matter, trees, dead wood, forest litter

gromin(1) – gross mineralization of N (g N m^{-2} mo^{-1})

gromin(2) – gross mineralization of P (g P m^{-2} mo^{-1})

gromin(3) – gross mineralization of S (g S m^{-2} mo^{-1})

grspann(1) – total annual growth respiration for grass/crop system (g C m^{-2} yr^{-1})

grspann(2) – total annual growth respiration for forest system (g C m^{-2} yr^{-1})

grspflux(1) – growth respiration flow from the carbohydrate storage pool (*carbostg(1,*)*) for the grass/crop system (g C m^{-2})

grspflux(2) – growth respiration flow from the carbohydrate storage pool (*carbostg(2,*)*) for the forest system (g C m^{-2})

grspmth(1) – total monthly growth respiration for grass/crop system (g C m^{-2} yr^{-1})

grspmth(2) – total monthly growth respiration for forest system (g C m^{-2} yr^{-1})

harmth – = 0 in non-harvest months
= 1 in a harvest month

hi – harvest index (cgrain/aglivc at harvest) for grass/crop

irract – actual amount of irrigation (cm H_2O mo^{-1})

irrtot – accumulator for irrigation (cm H_2O)

lhzcac – accumulator for C inputs to 0-20 cm layer from the lower horizon pools associated with soil erosion (g C m^{-2})

lhzeac(1) – accumulator for N inputs to 0-20 cm layer from the lower horizon pools associated with soil erosion (g N m^{-2})

lhzeac(2) – accumulator for P inputs to 0-20 cm layer from the lower horizon pools associated with soil erosion (g P m^{-2})

lhzeac(3) – accumulator for S inputs to 0-20 cm layer from the lower horizon pools associated with soil erosion (g S m^{-2})

metabc(1) – total C in metabolic surface litter (g C m^{-2})

metabc(2) – total C in metabolic soil litter (g C m^{-2})

metabe(1,1) – total N in metabolic surface litter (g N m^{-2})

metabe(1,2) – total P in metabolic surface litter (g P m^{-2})

metabe(1,3) – total S in metabolic surface litter (g S m^{-2})

metabe(2,1) – total N in metabolic soil litter (g N m^{-2})

metabe(2,2) – total P in metabolic soil litter (g P m^{-2})

metabe(2,3) – total S in metabolic soil litter (g S m^{-2})

metcis(1,1) – unlabeled C in metabolic surface litter (g C m^{-2})

metcis(1,2) – labeled C in metabolic surface litter (g C m^{-2})

metcis(2,1) – unlabeled C in metabolic soil litter (g C m^{-2})

metcis(2,2) – labeled C in metabolic soil litter (g C m^{-2})

metmnr(1,1) – net mineralization for N for surface metabolic litter (g N m^{-2} mo^{-1})

metmnr(1,2) – net mineralization for P for surface metabolic litter (g P m^{-2} mo^{-1})

metmnr(1,3) – net mineralization for S for surface metabolic litter (g S m^{-2} mo^{-1})

metmnr(2,1) – net mineralization for N for soil metabolic litter (g N m^{-2} mo^{-1})

metmnr(2,2) – net mineralization for P for soil metabolic litter (g P m^{-2} mo^{-1})

metmnr(2,3) – net mineralization for S for soil metabolic litter (g S m^{-2} mo^{-1})

minerl(1,1) – mineral N content for layer 1 (g N m^{-2})

minerl(2,1) – mineral N content for layer 2 (g N m^{-2})

minerl(3,1) – mineral N content for layer 3 (g N m^{-2})

minerl(4,1) – mineral N content for layer 4 (g N m^{-2})

minerl(5,1) – mineral N content for layer 5 (g N m^{-2})

minerl(6,1) – mineral N content for layer 6 (g N m^{-2})

minerl(7,1) – mineral N content for layer 7 (g N m^{-2})

minerl(8,1) – mineral N content for layer 8 (g N m^{-2})

minerl(9,1) – mineral N content for layer 9 (g N m^{-2})

minerl(10,1) – mineral N content for layer 10 (g N m^{-2})

minerl(1,2) – mineral P content for layer 1 (g P m^{-2})

minerl(2,2) – mineral P content for layer 2 (g P m^{-2})

minerl(3,2) – mineral P content for layer 3 (g P m^{-2})

minerl(4,2) – mineral P content for layer 4 (g P m^{-2})

minerl(5,2) – mineral P content for layer 5 (g P m^{-2})

minerl(6,2) – mineral P content for layer 6 (g P m^{-2})

minerl(7,2) – mineral P content for layer 7 (g P m^{-2})

minerl(8,2) – mineral P content for layer 8 (g P m^{-2})

minerl(9,2) – mineral P content for layer 9 (g P m^{-2})

minerl(10,2) – mineral P content for layer 10 (g P m^{-2})

minerl(1,3) – mineral S content for layer 1 (g S m^{-2})

minerl(2,3) – mineral S content for layer 2 (g S m^{-2})

minerl(3,3) – mineral S content for layer 3 (g S m^{-2})

minerl(4,3) – mineral S content for layer 4 (g S m^{-2})

minerl(5,3) – mineral S content for layer 5 (g S m^{-2})

minerl(6,3) – mineral S content for layer 6 (g S m^{-2})

minerl(7,3) – mineral S content for layer 7 (g S m^{-2})

minerl(8,3) – mineral S content for layer 8 (g S m^{-2})

minerl(9,3) – mineral S content for layer 9 (g S m^{-2})

minerl(10,3) – mineral S content for later 10 (g S m^{-2})

mrspann(1) – total annual maintenance respiration for grass/crop system (g C m^{-2} yr^{-1})

mrspann(2) – total annual maintenance respiration for forest system (g C m^{-2} yr^{-1})

mrspflux(1) – maintenance respiration flow to storage pool from grass/crop system (g C m^{-2})

mrspflux(2) – maintenance respiration flow to storage pool from forest system (g C m^{-2})

mrspmth(1) – total monthly maintenance respiration for grass/crop system (g C m^{-2} yr^{-1})

mrspmth(2) – total monthly maintenance respiration for forest system (g C m^{-2} yr^{-1})

mt1c2(1) – total monthly unlabeled surface CO_2 loss due to microbial respiration during litter decomposition (g C m^{-2} mo^{-1})

mt1c2(2) – total monthly labeled surface CO_2 loss due to microbial respiration during litter decomposition (g C m^{-2} mo^{-1})

mt2c2(1) – total monthly unlabeled soil CO_2 loss due to respiration (g C m^{-2} mo^{-1})

mt2c2(2) – total monthly labeled soil CO_2 loss due to respiration (g C m^{-2} mo^{-1})

nfix – amount of symbiotic N fixation (g N m^{-2} yr^{-1})

nfixac – accumulator for amount of symbiotic N fixation (g N m^{-2} yr^{-1})

n2oacc – growing season accumulator for N_2O flux, reset to 0.0 on LAST event (g N m^{-2} yr^{-1})

n2oprd – N_2O flux over the last completed growing season (g N m^{-2} yr^{-1} $season^{-1}$)

n2omth(12) – monthly accumulator of N_2O flux for the current month, 1-12 (g N m^{-2})

occlud – occluded P (g P m^{-2})

omadac – annual accumulator of C added to system through organic matter addition events (g C m^{-2} yr^{-1})

omadae(1) – annual accumulator of N added to system through organic matter addition events (g N m^{-2} yr^{-1})

omadae(2) – annual accumulator of P added to system through organic matter addition events (g P m^{-2} yr^{-1})

omadae(3) – annual accumulator of S added to system through organic matter addition events (g P m^{-2} yr^{-1})

omadmte(12,1) – N added to the system through organic matter addition events for the month, 1-12 (g N m^{-2})

omadmte(12,2) – P added to the system through organic matter addition events for the month, 1-12 (g P m^{-2})

omadmte(12,3) – S added to the system through organic matter addition events for the month, 1-12 (g S m^{-2})

omadmth(12) – C added to the system through organic matter addition events for the month, 1-12 (g C m^{-2})

omadprd – growing season accumulator of C added to system through organic matter addition events (g C m^{-2} yr^{-1} $season^{-1}$)

omadpre(1) – growing season accumulator of N added to system through organic matter addition events (g N m^{-2} yr^{-1} $season^{-1}$)

omadpre(2) – growing season accumulator of P added to system through organic matter addition events (g P m^{-2} yr^{-1} $season^{-1}$)

omadpre(3) – growing season accumulator of S added to system through organic matter addition events (g S m^{-2} yr^{-1} $season^{-1}$)

omadtot – annual accumulator for C added to the system through organic matter addition events (g C m^{-2} yr^{-1})

omaetot(1) – annual accumulator for N added to the system through organic matter addition events (g N m^{-2} yr^{-1})

omaetot(2) – annual accumulator for P added to the system through organic matter addition events (g P m^{-2} yr^{-1})

omaetot(3) – annual accumulator for S added to the system through organic matter addition events (g S m^{-2} yr^{-1})

parent(1) – parent material N (g N m^{-2})

parent(2) – parent material P (g P m^{-2})

parent(3) – parent material S (g S m^{-2})

pet – monthly potential evapotranspiration (cm mo^{-1})

petann – annual potential evapotranspiration (sum of monthly pet) (cm yr^{-1})

plabil – sum of labile phosphate in all layers (g P m^{-2})

prcann – annual precipitation computed as the sum of site.100 file PRECIP(*) values after precipitation scalars are applied (cm yr^{-1})

prcfal – fallow period precipitation; the amount of rain which falls during the months after harvest until the month before the next planting (cm)

ptagc – growing season accumulator for potential aboveground C production for grass/crop (g C m^{-2} yr^{-1} $season^{-1}$)

ptbgc – growing season accumulator for potential belowground C production for grass/crop (g C m^{-2} yr^{-1} $season^{-1}$)

pttr – potential transpiration water loss for the month (cm mo^{-1})

rain – monthly precipitation (including rainfall and snowfall) (cm mo^{-1})

relyld – relative yield for grass, crop, or tree production resp(1) – annual unlabeled CO_2 respiration from decomposition (g C m^{-2}). For DayCent UV versions, resp(1) also includes unlabeled abiotic CO_2 loss from UV degradation of standing dead biomass and surface litter (st1uvc2(1) + stduvc2(1)).

resp(2) – annual labeled CO_2 respiration from decomposition (g C m^{-2}). For DayCent UV versions, resp(2) also includes labeled abiotic CO_2 loss from UV degradation of standing dead biomass and surface litter (st1uvc2(2) + stduvc2(2).

respmth(1) – total monthly unlabeled CO_2 respiration from decomposition (g C m^{-2}). For DayCent UV versions, respmth(1) also includes unlabeled abiotic CO_2 loss from UV degradation of standing dead biomass and surface litter.

respmth(2) – total monthly labeled CO_2 respiration from decomposition (g C m^{-2}). For DayCent UV versions, respmth(2) also includes unlabeled abiotic CO_2 loss from UV degradation of standing dead biomass and surface litter.

rleavc – C in forest system leaf component (g C m^{-2})

rleave(1) – N in forest system leaf component (g N m^{-2})

rleave(2) – P in forest system leaf component (g P m^{-2})

rleave(3) – S in forest system leaf component (g S m^{-2})

rlvacc – growing season accumulator for C production in forest system live leaves (g C m^{-2} yr^{-1} $season^{-1}$)

rlvcis(1) – unlabeled C in forest system large wood component (g C m^{-2})

rlvcis(2) – labeled C in forest system large wood component (g C m^{-2})

rlvprd – leaf component C production for the forest system over the last completed growing season (g C m^{-2} yr^{-1})

rlwacc – growing season accumulator for C production in forest system large wood component (g C m^{-2} yr^{-1} $season^{-1}$)

rlwcis(1) – unlabeled C in forest system large wood component (g C m^{-2})

rlwcis(2) – labeled C in forest system large wood component (g C m^{-2})

rlwodc – C in forest system large wood component (g C m^{-2})

rlwode(1) – N in forest system large wood component (g N m^{-2})

rlwode(2) – P in forest system large wood component (g P m^{-2})

rlwode(3) – S in forest system large wood component (g S m^{-2})

rlwprd – large wood component C production for the forest system over the last completed growing season (g C m^{-2} yr^{-1})

rnpml1 – mineral N/P ratio used to control soil N-fixation using a regression equation based on Kansas data

runoff – monthly runoff (cm H_2O mo^{-1})

rwcf(1) – relative water content fraction for layer 1 (0.0 – 1.0, 1.0=field capacity)

rwcf(2) – relative water content fraction for layer 2 (0.0 – 1.0, 1.0=field capacity)

rwcf(3) – relative water content fraction for layer 3 (0.0 – 1.0, 1.0=field capacity)

rwcf(4) – relative water content fraction for layer 4 (0.0 – 1.0, 1.0=field capacity)

rwcf(5) – relative water content fraction for layer 5 (0.0 – 1.0, 1.0=field capacity)

rwcf(6) – relative water content fraction for layer 6 (0.0 – 1.0, 1.0=field capacity)

rwcf(7) – relative water content fraction for layer 7 (0.0 – 1.0, 1.0=field capacity)

rwcf(8) – relative water content fraction for layer 8 (0.0 – 1.0, 1.0=field capacity)

rwcf(9) – relative water content fraction for layer 9 (0.0 – 1.0, 1.0=field capacity)

rwcf(10) – relative water content fraction for layer 10 (0.0 – 1.0, 1.0=field capacity)

s1mnr(1,1) – net mineralization for surface active pool *som1e*(1,1) (g N m^{-2} mo^{-1})

s1mnr(1,2) – net mineralization for surface active pool *som1e*(1,2) (g P m^{-2} mo^{-1})

s1mnr(1,3) – net mineralization for surface active pool *som1e*(1,3) (g S m^{-2} mo^{-1})

s1mnr(2,1) – net mineralization for soil active pool *som1e*(2,1) (g N m^{-2} mo^{-1})

s1mnr(2,2) – net mineralization for soil active pool *som1e*(2,1) (g P m^{-2} mo^{-1})

s1nmr(2,3) – net mineralization for soil active pool *som1e*(2,1) (g S m^{-2} mo^{-1})

s2mnr(1,1) – net mineralization for N for surface slow pool *som2e*(1,1) (g N m^{-2} mo^{-1})

s2mnr(1,2) – net mineralization for P for surface slow pool *som2e*(1,2) (g P m^{-2} mo^{-1})

s2mnr(1,3) – net mineralization for S for surface slow pool *som2e*(1,3) (g S m^{-2} mo^{-1})

s2mnr(2,1) – net mineralization for N for soil slow pool *som2e*(2,1) (replaces *s2mnr(1)*) (g N m^{-2} mo^{-1})

s2mnr(2,2) – net mineralization for P for soil slow pool *som2e*(2,2) (replaces *s2mnr(2)*) (g P m^{-2} mo^{-1})

s2mnr(2,3) – net mineralization for S for soil slow pool *som2e*(2,3) (replaces *s2mnr(2)*) (g S m^{-2} mo^{-1})

s3mnr(1) – net mineralization for N for passive pool *som3e*(1) (g N m^{-2} mo^{-1})

s3mnr(2) – net mineralization for P for passive pool *som3e*(2) (g P m^{-2} mo^{-1})

s3mnr(3) – net mineralization for S for passive pool *som3e*(3) (g S m^{-2} mo^{-1})

s11c2(1) – total monthly unlabeled CO_2 loss due to microbial respiration during soil organic matter decomposition of soil som1 to som2 and som3 (g C m^{-2} mo^{-1})

s11c2(2) – total monthly labeled CO_2 loss due to microbial respiration during soil organic matter decomposition of soil som1 to som2 and som3 (g C m^{-2} mo^{-1})

s12c2(1) – total monthly unlabeled CO_2 loss due to microbial respiration during soil organic matter decomposition of soil som1 to som2 and som3 (replaces *s21c2(1)*) (g C m^{-2} mo^{-1})

s12c2(2) – total monthly labeled CO_2 loss due to microbial respiration during soil organic matter decomposition of soil som1 to som2 and som3 (replaces *s21c2(1)*) (g C m^{-2} mo^{-1})

s21c2(1) – total monthly unlabeled CO_2 loss due to microbial respiration during soil organic matter decomposition of surface som2 to surface som1 (g C m^{-2} mo^{-1}))

s21c2(2) – total monthly labeled CO_2 loss due to microbial respiration during soil organic matter decomposition of surface som2 to surface som1 (g C m^{-2} mo^{-1})

s22c2(1) – total monthly unlabeled CO_2 loss due to microbial respiration during soil organic matter decomposition of soil som2 to soil som1 and som3 (g C m^{-2} mo^{-1})

s22c2(2) – total monthly labeled CO_2 loss due to microbial respiration during soil organic matter decomposition of soil som2 to soil som1 and som3 (g C m^{-2} mo^{-1})

s3c2(1) – total monthly unlabeled CO_2 loss due to microbial respiration during soil organic matter decomposition of som3 to soil som1 (g C m^{-2} mo^{-1})

s3c2(2) – total monthly labeled CO_2 loss due to microbial respiration during soil organic matter decomposition of som3 to soil som1 (g C m^{-2} mo^{-1})

satmac – accumulator for atmospheric S deposition (g S m^{-2})

sclosa – accumulated C lost from soil organic matter by erosion (total C for entire simulation) (g C m^{-2})

scloss – total C loss from soil organic matter by erosion for current month (g C m^{-2})

sdrema – annual accumulator of C removed from standing dead during grazing/fire for grass/crop ($g\ C\ m^{-2}\ yr^{-1}$)

sdrmae(1) – annual accumulator of N removed from standing dead during grazing/fire for grass/crop ($g\ N\ m^{-2}\ yr^{-1}$)

sdrmae(2) – annual accumulator of P removed from standing dead during grazing/fire for grass/crop ($g\ P\ m^{-2}\ yr^{-1}$)

sdrmae(3) – annual accumulator of S removed from standing dead during grazing/fire for grass/crop ($g\ S\ m^{-2}\ yr^{-1}$)

sdrmai(1) – annual accumulator of unlabeled C removed from standing dead during grazing/fire for grass/crop ($g\ C\ m^{-2}\ yr^{-1}$)

sdrmai(2) – annual accumulator of labeled C removed from standing dead during grazing/fire for grass/crop ($g\ C\ m^{-2}\ yr^{-1}$)

secndy(1) – secondary mineral N ($g\ N\ m^{-2}$)

secndy(2) – slowly sorbed P ($g\ P\ m^{-2}$)

secndy(3) – secondary mineral S ($g\ S\ m^{-2}$)

shrema – annual accumulator of C removed from live shoots during grazing/fire for grass/crop ($g\ C\ m^{--2}\ yr^{-1}$)

shrmae(1) – annual accumulator of N removed from live shoots during grazing/fire for grass/crop ($g\ N\ m^{-2}\ yr^{-1}$)

shrmae(2) – annual accumulator of P removed from live shoots during grazing/fire for grass/crop ($g\ P\ m^{-2}\ yr^{-1}$)

shrmae(3) – annual accumulator of S removed from live shoots during grazing/fire for grass/crop ($g\ S\ m^{-2}\ yr^{-1}$)

shrmai(1) – annual accumulator of unlabeled C removed from live shoots during grazing/fire for grass/crop ($g\ C\ m^{-2}\ yr^{-1}$)

shrmai(2) – annual accumulator of labeled C removed from live shoots during grazing/fire for grass/crop ($g\ C\ m^{-2}\ yr^{-1}$)

sirrac – accumulator for irrigation S inputs ($g\ S\ m^{-2}$)

snfxac(1) – annual grass/crop accumulator for symbiotic N fixation

snfxac(2) – annual forest accumulator for symbiotic N fixation snlq – liquid water in snowpack (cm)

snow – snowpack water content (cm H_2O)

soilnm(1) – annual accumulator for net mineralization of N in soil compartments (soil organic matter + belowground litter + dead coarse roots) (g N m^{-2} yr^{-1})

soilnm(2) – annual accumulator for net mineralization of P in soil compartments (soil organic matter + belowground litter + dead coarse roots) (g P m^{-2} yr^{-1})

soilnm(3) – annual accumulator for net mineralization of S in soil compartments (soil organic matter + belowground litter + dead coarse roots) (g S m^{-2} yr^{-1})

som1c(1) – total C in active surface organic matter pool (g C m^{-2})

som1c(2) – total C in active soil organic matter pool (g C m^{-2})

som1ci(1,1) – unlabeled C in active surface organic matter pool (g C m^{-2})

som1ci(1,2) – labeled C in active surface organic matter pool (g C m^{-2})

som1ci(2,1) – unlabeled C in active soil organic matter pool (g C m^{-2})

som1ci(2,2) – labeled C in active soil organic matter pool (g C m^{-2})

som1e(1,1) – total N in active surface organic matter pool (g N m^{-2})

som1e(1,2) – total P in active surface organic matter pool (g P m^{-2})

som1e(1,3) – total S in active surface organic matter pool (g S m^{-2})

som1e(2,1) – total N in active soil organic matter pool (g N m^{-2})

som1e(2,2) – total P in active soil organic matter pool (g P m^{-2})

som1e(2,3) – total S in active soil organic matter pool (g S m^{-2})

som2c(1) – total C in slow surface organic matter pool (g C m^{-2})

som2c(2) – total C in slow soil organic matter pool (g C m^{-2})

som2ci(1,1) – unlabeled C in slow surface organic matter pool (g C m^{-2})

som2ci(1,2) – labeled C in slow surface organic matter pool (g C m^{-2})

som2ci(2,1) – unlabeled C in slow soil organic matter pool (g C m^{-2})

som2ci(2,2) – labeled C in slow soil organic matter pool (g C m^{-2})

som2e(1,1) – total N in slow surface organic matter pool (g N m^{-2})

som2e(1,2) – total P in slow surface organic matter pool (g P m^{-2})

som2e(1,3) – total S in slow surface organic matter pool (g S m^{-2})

som2e(2,1) – total N in slow soil organic matter pool (g N m^{-2})

som2e(2,2) – total P in slow soil organic matter pool (g P m^{-2})

som2e(2,3) – total S in slow soil organic matter pool (g S m^{-2})

som3c – total C in passive soil organic matter pool (g C m^{-2})

som3ci(1) – unlabeled C in passive soil organic matter pool (g C m^{-2})

som3ci(2) – labeled C in passive soil organic matter pool (g C m^{-2})

som3e(1) – total N in passive soil organic matter pool (g N m^{-2})

som3e(2) – total P in passive soil organic matter pool (g P m^{-2})

som3e(3) – total S in passive soil organic matter pool (g S m^{-2})

somsc – sum of labeled and unlabeled C from som1c(2), som2c(2), and som3c (g C m^{-2})

somsci(1) – sum of unlabeled C in som1c(2,1), som2c(2,1), som3c (g C m^{-2})

somsci(2) – sum of labeled C in som1ci(2,2), som2ci(2,2), som3ci(2) (g C m^{-2})

somse(1) – sum of N in som1e(2,1), som2e(2,1), and som3e(1) (g N m^{-2})

somse(2) – sum of P in som1e(2,2), som2e(2,2), and som3e(2) (g P m^{-2})

somse(3) – sum of S in som1e(2,3), som2e(2,3), and som3e(3) (g S m^{-2})

somtc – total soil C including belowground structural and metabolic: somsc + strucc(2) + metabc(2) (g C m^{-2})

somtci(1) – total unlabeled C in soil including belowground structural + metabolic: somsci(1) + strcis(2,1) + metcis(2,1) (g C m^{-2})

somtci(2) – total labeled C in soil including belowground structural + metabolic: somsci(2) + strcis(2,2) + metcis(2,2) (g C m^{-2})

somte(1) – total N in soil organic matter including belowground structural + metabolic: somse(1) + struce(2,1) + metabe(2,1) (g N m^{-2})

somte(2) – total P in soil organic matter including belowground structural + metabolic: somse(2) + struce(2,2) + metabe(2,2) (g P m^{-2})

somte(3) – total S in soil organic matter including belowground structural + metabolic: somse(3) + struce(2,3) + metabe(2,3) (g S m^{-2})

srspann(1) – total annual soil respiration for grass/crop system (sum of maintenance and growth respiration for fine roots) (g C m^{-2})

srspann(2) – total annual soil respiration for forest system (sum of maintenance and growth respiration for fine and coarse roots) (g C m^{-2})

srspmth(1) – total monthly soil respiration for grass/crop system (sum of maintenance and growth respiration for fine roots) (g C m^{-2})

srspmth(2) – total monthly soil respiration for forest system (sum of maintenance and growth respiration for fine and coarse roots) (g C m^{-2})

st1c2(1) – total monthly unlabeled CO_2 loss due to microbial respiration during litter decomposition of surface structural into som1 and som2 (g C m^{-2} mo^{-1})

st1c2(2) – total monthly labeled CO_2 loss due to microbial respiration during litter decomposition of surface structural into som1 and som2 (g C m^{-2} mo^{-1})

st2c2(1) – total monthly unlabeled CO_2 loss due to microbial respiration during litter decomposition of soil structural into som1 and som2 (g C m^{-2} mo^{-1})

st2c2(2) – total monthly labeled CO_2 loss due to microbial respiration during litter decomposition of soil structural into som1 and som2 (g C m^{-2} mo^{-1})

stdcis(1) – unlabeled C in standing dead for grass/crop (g C m^{-2})

stdcis(2) – labeled C in standing dead for grass/crop (g C m^{-2})

stdedc – C in standing dead material for grass/crop (g C m^{-2})

stdede(1) – N in standing dead for grass/crop (g N m^{-2})

stdede(2) – P in standing dead for grass/crop (g P m^{-2})

stdede(3) – S in standing dead for grass/crop (g S m^{-2})

st1uvc2(1) - For DayCent UV versions this is unlabeled abiotic CO_2 loss from UV degradation of surface litter (g C m^{-2} mo^{-1})

st1uvc2(2) - For DayCent UV versions this is labeled abiotic CO_2 loss from UV degradation of surface litter (g C m^{-2} mo^{-1})

stduvc2(1) - For DayCent UV versions this is unlabeled abiotic CO_2 loss from UV degradation of standing dead biomass (g C m^{-2} mo^{-1})

stduvc2(2) - For DayCent UV versions this is labeled abiotic CO_2 loss from UV degradation of standing dead biomass (g C m^{-2} mo^{-1})

stemp – average soil temperature (°C)

strcis(1,1) – unlabeled C in structural surface litter (g C m^{-2})

strcis(1,2) – labeled C in structural surface litter (g C m^{-2})

strcis(2,1) – unlabeled C in structural soil litter (g C m^{-2})

strcis(2,2) – labeled C in structural soil litter (g C m^{-2})

stream(1) – stream flow (base flow + runoff) (cm H_2O mo^{-1})

stream(2) – mineral N leached out of the bottom of the soil profile into stream flow (g N m^{-2} mo^{-1})

stream(3) – mineral P leached out of the bottom of the soil profile into stream flow (g P m^{-2} mo^{-1})

stream(4) – mineral S leached out of the bottom of the soil profile into stream flow (g S m^{-2} mo^{-1})

stream(5) – organic C leached out of the soil organic layer into stream flow (g C m^{-2} mo^{-1})

stream(6) – organic N leached out of the soil organic layer into stream flow (g N m^{-2} mo^{-1})

stream(7) – organic P leached out of the soil organic layer into stream flow (g P m^{-2} mo^{-1})

stream(8) – organic S leached out of the soil organic layer into stream flow (g S m^{-2} mo^{-1})

strlig(1) – lignin content of surface structural residue (g lignin / g C of structural residue)

strlig(2) – lignin content of soil structural reside (g lignin / g C of structural residue)

strmac(1) – annual accumulator for stream(1), stream flow (base flow + runoff) (cm H_2O yr^{-1})

strmac(2) – annual accumulator for stream(2), mineral N leached out of the bottom of the soil profile into stream flow (g N m^{-2} yr^{-1})

strmac(3) – annual accumulator for stream(3), mineral P leached out of the bottom of the soil profile into stream flow (g P m^{-2} yr^{-1})

strmac(4) – annual accumulator for stream(4), mineral S leached out of the bottom of the soil profile into stream flow (g S m^{-2} yr^{-1})

strmac(5) – annual accumulator for stream(5), organic C leached out of the soil organic layer into stream flow (g C m^{-2} yr^{-1})

strmac(6) – annual accumulator for stream(6), organic N leached out of the soil organic layer into stream flow (g N m^{-2} yr^{-1})

strmac(7) – annual accumulator for stream(7), organic P leached out of the soil organic layer into stream flow (g P m^{-2} yr^{-1})

strmac(8) – annual accumulator for stream(8), organic S leached out of the soil organic layer into stream flow (g S m^{-2} yr^{-1})

strmnr(1,1) – net mineralization for surface N for structural litter (g N m^{-2} mo^{-1})

strmnr(1,2) – net mineralization for surface P for structural litter (g P m^{-2} mo^{-1})

strmnr(1,3) – net mineralization for surface S for structural litter (g S m^{-2} mo^{-1})

strmnr(2,1) – net mineralization for soil N for structural litter (g N m^{-2} mo^{-1})

strmnr(2,2) – net mineralization for soil P for structural litter (g P m^{-2} mo^{-1})

strmnr(2,3) – net mineralization for soil S for structural litter (g S m^{-2} mo^{-1})

strucc(1) – total C in structural surface litter (g C m^{-2})

strucc(2) – total C in structural soil litter (g C m^{-2})

struce(1,1) – total N in surface structural litter (g N m^{-2})

struce(1,2) – total P in surface structural litter (g P m^{-2})

struce(1,3) – total S in surface structural litter (g S m^{-2})

struce(2,1) – total N in soil structural litter (g N m^{-2})

struce(2,2) – total P in soil structural litter (g P m^{-2})

struce(2,3) – total S in soil structural litter (g S m^{-2})

sumnrs(1) – annual accumulator for net mineralization of N from all compartments except structural and wood (g N m^{-2} yr^{-1})

sumnrs(2) – annual accumulator for net mineralization of P from all compartments except structural and wood (g P m^{-2} yr^{-1})

sumnrs(3) – annual accumulator for net mineralization of S from all compartments except structural and wood (g S m^{-2} yr^{-1})

sumrsp – monthly maintenance respiration in the forest system (g C m^{-2})

tave – average air temperature (° C)

tcerat(1) – total C/N ratio in soil organic matter including belowground structural + metabolic

tcerat(2) – total C/P ratio in soil organic matter including belowground structural + metabolic

tcerat(3) – total C/S ratio in soil organic matter including belowground structural + metabolic

tcnpro – total C/N ration for grass, crop, or tree production

tcrem – total C removed during forest removal events (g C m^{-2})

terem(1) – total N removed during forest removal events (g N m^{-2})

terem(2) – total P removed during forest removal events (g P m^{-2})

terem(3) – total S removed during forest removal events (g S m^{-2})

tgzrte(1) – total N returned in feces and urine from a grazing event (g N m^{-2})

tgzrte(2) – total P returned in feces and urine from a grazing event (g P m^{-2})

tgzrte(3) – total S returned in feces and urine from a grazing event (g S m^{-2})

tlittr(1,1) – unlabeled surface residue (*clittr(1,1)*) plus unlabeled surface som1c *(som1ci(1,1)*) and unlabeled surface som2c (*som2ci(1,1)*) (g C m^{-2})

tlittr(1,2) – labeled surface residue (*clittr(1,2)*) plus labeled surface som1c (*som1ci(1,2)*) and labeled surface som2c (*som2ci(1,2)*) (g C m^{-2})

tlittr(2,1) – unlabeled soil residue (*clittr(2,1)*) plus unlabeled soil som1c (*som1ci(2,1)*) and unlabeled soil som2c (*som2ci(2,1)*) (g C m^{-2})

tlittr(2,2) – labeled soil residue (*clittr(2,2)*) plus labeled soil som1c (*som1ci(2,2)*) and labeled soil som2c (*som2ci(2,2)*) (g C m^{-2})

tminrl(1) – total mineral N summed across layers (g N m^{-2})

tminrl(2) – total mineral P summed across layers (g P m^{-2})

tminrl(3) – total mineral S summed across laters (g S m^{-2})

tnetmn(1) – annual accumulator of net mineralization for N from all compartments (g N m^{-2} yr^{-1})

tnetmn(2) – annual accumulator of net mineralization for P from all compartments (g P m^{-2} yr^{-1})

tnetmn(3) – annual accumulator of net mineralization for S from all compartments (g S m^{-2} yr^{-1})

tomres(1) – total unlabeled C in soil, belowground, and aboveground litter

tomres(2) – total labeled C in soil, belowground, and aboveground litter

totalc – total C including source/sink (g C m^{-2})

totale(1) – total N including source/sink (g N m^{-2})

totale(2) – total P including source/sink (g P m^{-2})

totale(3) – total S including source/sink (g S m^{-2})

totc – minimum annual total non-living C (g C m^{-2}), where total is:
som1c(SOIL) + som1c(SRFC) + som2c + som3c + strucc(SOIL) + strucc(SRFC) + metabc(SOIL) + metabc(SRFC)

totsysc – total system C *(aglivc + bglivcj + bglivcm + stdedc + strucc(1) + strucc(2) + metabc(1) + metabc(2) + rleavc + frootcj + frootcm + fbrchc + rlwodc + crootc + wood1c + wood2c + wood3c + som1c(1) + som1c(2) + som2c(1) + som2c(2) + som3c)* (g C m^{-2})

totsyse(1) – total N in system (*aglive(1) + bglivej(1) + bglivem(1) + stdede(1) + struce(1,1) + struce(2,1) + metabe(1,1) + metabe(2,1) + rleave(1) + frootej(1) + frootem(1) + fbrche(1) + rlwode(1) + croote(1) + wood1e(1) + wood2e(1) + wood3e(1) + som1e(1,1) + som1e(2,1) + som2e(1,1) + som2e(2,1) + som3e(1)* (g N m^{-2})

totsyse(2) – total P in system (*aglive(2) + bglivej(2) + bglivem(2) + stdede(2) + struce(1,2) + struce(2,2) + metabe(1,2) + metabe(2,2) + rleave(2) + frootej(2) + frootem(2) + fbrche(2) + rlwode(2) + croote(2) + wood1e(2) + wood2e(2) + wood3e(2) + som1e(1,2) + som1e(2,2) + som2e(1,2) + som2e(2,2) + som3e(2)* (g P m^{-2})

totsyse(3) – total S in system (*aglive(3) + bglivej(3) + bglivem(3) + stdede(3) + struce(1,3) + struce(2,3) + metabe(1,3) + metabe(2,3) + rleave(3) + frootej(3) + frootem(3) + fbrche(3) + rlwode(3) + croote(3) + wood1e(3) + wood2e(3) + wood3e(3) + som1e(1,3) + som1e(2,3) + som2e(1,3) + som2e(2,3) + som3e(3)* (g S m^{-2})

tran – monthly transpiration (cm mo^{-1})

voleac – annual accumulator for N volatilization as a function of N remaining after uptake by grass, crop, or tree (g N m^{-2} yr^{-1}). This output variable is no longer valid for DayCent. See year_summary.out for annual N-gas emissions from nitrification/denitrification.

volex – volatilization loss as a function of mineral N remaining after uptake by grass, crop, or tree (g N m^{-2} mo^{-1}). This output variable is no longer valid for DayCent. See tgmonth.out for monthly N-gas emissions from nitrification/denitrification.

volexa – accumulator for N volatilization as a function of N remaining after uptake by grass, crop, or tree (total N for entire simulation) (g N m^{-2}). This output variable is no longer valid for DayCent. See year_summary.out for annual N-gas emissions from nitrification/denitrification.

volgac – annual accumulator for N volatilized as a function of gross mineralization (g N m^{-2} yr^{-1}). This output variable is no longer valid for DayCent. See year_summary.out for annual N-gas emissions from nitrification/denitrification.

volgm – volatilization loss of N as a function of gross mineralization (g N m^{-2} mo^{-1}). This output variable is no longer valid for DayCent. See tgmonth.out for monthly N-gas emissions from nitrification/denitrification.

volgma – accumulator for N volatilized as a function of gross mineralization (g N m^{-2}) (total N for entire simulation). This output variable is no longer valid for DayCent. See year_summary.out for annual N-gas emissions from nitrification/denitrification.

volpac – annual accumulator for N volatilized from plants at harvest, senescence, and/or from grazing removal for grass/crop (g N m^{-2} yr^{-1})

volpl – volatilization of N from plants during at harvest, senescence, and/or from grazing removal for grass/crop (g N m^{-2} mo^{-1}).

volpla – accumulator for N volatilization at harvest, senescence, and/or from grazing removal for grass/crop (total N for entire simulation) (g N m^{-2})

w1lig – lignin content of dead fine branches of forest system (fraction lignin in wood1, 0.0 – 1.0)

w1mnr(1) – N mineralized from the wood1 (dead fine branch) component of a forest system (g N m^{-2})

w1mnr(2) – P mineralized from the wood1 (dead fine branch) component of a forest system (g P m^{-2})

w1mnr(3) – S mineralized from the wood1 (dead fine branch) component of a forest system (g P m^{-2})

w2lig – lignin content of dead large wood of forest system (fraction lignin in wood2, 0.0 – 1.0)

w2mnr(1) – N mineralized from the wood2 (dead large wood) component of a forest system (g N m^{-2})

w2mnr(2) – P mineralized from the wood2 (dead large wood) component of a forest system (g P m^{-2})

w2mnr(3) – S mineralized from the wood2 (dead large wood) component of a forest system (g S m^{-2})

w3lig – lignin content of dead coarse roots of forest system (fraction lignin in wood3, 0.0 – 1.0)

w3mnr(1) – N mineralized from the wood3 (dead coarse root) component of a forest system (g N m^{-2})

w3mnr(2) – P mineralized from the wood3 (dead coarse root) component of a forest system (g P m^{-2})

w3mnr(3) – S mineralized from the wood3 (dead coarse root) component of a forest system (g S m^{-2})

wd1c2(1) – total monthly unlabeled dead fine branch respiration (g C m^{-2} mo^{-1})

wd1c2(2) – total monthly labeled dead fine branch respiration (g C m^{-2} mo^{-1})

wd1cis(1) – unlabeled C in forest system wood1 (dead fine branch) material (g C m^{-2})

wd1cis(2) – labeled C in forest system wood1 (dead fine branch) material (g C m^{-2})

wd2c2(1) – total monthly unlabeled dead large wood respiration (g C m^{-2} mo^{-1})

wd2cis(1) – unlabeled C in forest system wood2 (dead large wood) material (g C m^{-2})

wd2cis(2) – labeled C in forest system wood2 (dead large wood) material (g C m^{-2})

wd2c2(2) – total monthly labeled dead large wood respiration (g C m^{-2} mo^{-1})

wd3c2(1) – total monthly unlabeled dead coarse roots respiration (g C m^{-2} mo^{-1})

wd3c2(2) – total monthly labeled dead coarse roots respiration (g C m^{-2} mo^{-1})

wd3cis(1) – unlabeled C in forest system wood3 (dead coarse root) material (g C m^{-2})

wd3cis(2) – labeled C in forest system wood3 (dead coarse root) material (g C m^{-2})

wdfx – annual atmospheric and non-symbiotic soil N fixation based on annual precipitation (wet and dry deposition) (g N m^{-2})

wdfxa – annual N fixation in atmosphere (wet and dry deposition) (g N m^{-2})

wdfxaa – annual accumulator for atmospheric N inputs (g N m^{-2} yr^{-1})

wdfxas – annual accumulator for soil N-fixation inputs (g N m^{-2} yr^{-1})

wdfxma – monthly N fixation in atmosphere (g N m^{-2})

wdfxms – monthly non-symbiotic soil N fixation (g N m^{-2})

wdfxs – annual non-symbiotic soil N fixation based on precipitation rather than soil N/P ratio (g N m^{-2})

wood1c – C in wood1 (dead fine branch) component of forest system (g C m^{-2})

wood1e(1) – N in wood1 (dead fine branch) component of forest system (g N m^{-2})

wood1e(2) – P in wood1 (dead fine branch) component of forest system (g P m^{-2})

wood1e(3) – S in wood1 (dead fine branch) component of forest system (g S m^{-2})

wood2c – C in wood2 (dead large wood) component of forest system (g C m^{-2})

wood2e(1) – N in wood2 (dead large wood) component of forest system (g N m^{-2})

wood2e(2) – P in wood2 (dead large wood) component of forest system (g P m^{-2})

wood2e(3) – S in wood2 (dead large wood) component of forest system (g S m^{-2})

wood3c – C in wood3 (dead coarse roots) component of forest system (g C m^{-2})

wood3e(1) – N in wood3 (dead coarse roots) component of forest system (g N m^{-2})

wood3e(2) – P in wood3 (dead coarse roots) component of forest system (g P m^{-2})

wood3e(3) – S in wood3 (dead coarse roots) component of forest system (g S m^{-2})

woodc – sum of C in wood components of forest system (g C m^{-2})

woode(1) – sum of N in wood components of forest system (g N m^{-2})

woode(2) – sum of P in wood components of forest system (g P m^{-2})

woode(3) – sum of S in wood components of forest system (g S m^{-2})

NOTE: The growing season accumulator values for carbon production (*acrcis(*), afbcis(*), afrcis(*), agcacc, agcisa(*), alvcis(*), alwcis(*), bgcacc, bgcisa(*), crtacc, fbracc, fcacc, frtacc, ptagc, ptbgc, rlvacc, rlwacc*) and the growing season accumulator values for E uptake (*eupacc(*), eupaga(*), eupbga(*), and eupprt(*,*)*) output for the simulation were being reset to 0.0 at the start of the growing season, when a FRST, PLTM, or TFST event occurred. These production output variables would seem to indicate that production was still occurring because the output variables were not set back to zero at the end of a growing season and would retain a constant value until the next FRST, PLTM or TFST event occurred. These accumulators are now being reset to 0.0 at the end of the simulation timestep in which a LAST or TLST event occurs, after the output for the timestep has been saved to the output file.

Old way:

Accumulators initialized to 0.0 at start of run

Accumulators reset to 0.0 on FRST, PLTM, or TFST and begin accumulation
New way:
Accumulators initialized to 0.0 at start of run
Accumulators begin accumulation on FRST, PLTM, or TFST
Accumulators reset to 0.0 on LAST or TLST after output written to file

The new growing season production variables, AGCPRD, BGCPRD, CRTPRD, EUPPRD(*), FBRPRD, FCPRD, FRTPRD, RLVPRD, and RLWPRD, are set equal to the value of their associated accumulator value when a LAST or TLST occurs. These values can be used when examining yearly output to see the amount of production that occurred over the previously completed growing season. These growing season production variables will be set back to zero in January if no production has occurred over the previous 12 month period.

The new growing season accumulators for fertilizer addition (FERTAC, FERTMTH, and FERTPRD), organic matter addition (OMADAC, OMACAE, OMADMTE, OMADMTH, OMADPRD, and OMADPRD), and N_2O flux (N2OACC, N2OMTH, and N2OPRD) are currently being tracked for the grass/crop system only and will be reset on a LAST event.