# The DayCent-CABBI version

This document summarizes the model development that has been done for what we call the “DayCent\_CABBI” version. The base of this model was DailyDayCent\_muvp. Because of the additional features that were added to that base model, DayCent\_CABBI may also be referred to as DailyDayCent\_muvps\_gt, where muvps\_gt stands for:

m = methane

uv = Photodegradation of standing dead crops and surface litter by UV radiation

p = Photosynthesis (simplified Farquhar model)

s = standing dead tree snags

gt = grasstree plant functional type.

Recent model improvements include the following. All are described in more detail in this document.

* **Standing dead tree snags** for forests. Previously when trees died their wood fell to the ground. Now a portion of it can remain standing and decay more slowly.
* A new **grasstree plant functional type** (PFT) to simulate large biofuels crops. This PFT has a mixture of characteristics from the traditional CROP and TREE types (the traditional CROP and TREE types are still available). Currently, a GRAS represents large perennial grasses such as mischanthus, switchgrass, and sugarcane. In a schedule file they are designated with the “GRAS” keyword, and the grasstree.100 file contains the library of parameters for the GRAS type. In the near future it will also simulate annual biofuels crops such as sorghum.
* The following 3 updates were intended to provide more control over plant N uptake and thus the ammonium and nitrate concentrations that affect N2O fluxes:
  + We activated the **NO3PREF parameter** in the crop.100, tree.100, and grasstree.100 files. The quantifies a plant’s relative N preference for ammonium and nitrate.
  + **Plant luxury N uptake** allows the annual crops to store extra N early in the growing season and use it later in the growing season. This feature is only available to annual crops, and not to trees, grasstrees, or perennial crops/grasses.
  + **The top “Century” layer, the soil layer where soil organic matter and ammonium are assumed to exist, can consist of any number of finer soils.in layers**. Formerly, the top “Century” layer was hard-coded as the top 3 soils.in layers. To take advantage of this feature one only needs to adjust the ADEP(\*) parameters in the fix.100 file.
* There is a new **FLODEFF parameter** in the crop.100, tree.100, and grasstree.100 files that allows one to ramp down potential production when plants are in saturated soils. Also see the FLOD and DRAN events in the Table below that shows all schedule file events – these events were part of DayCent\_muvp, but the FLODEFF parameter was not.

FLODEFF(1) for crops/grasses is in crop.100, FLODEFF(2) for trees is in tree.100, and FLODEFF(3) for grasstrees in grasstree.100. FLODEFF is a multiplier on potential plant production when soil in the rooting zone is saturated. The flood effect on potential production is 1.0 at field capacity (or drier) and is decreased/increased linearly as soil in the rooting zone becomes wetter. A value of 1.0 = no effect of flooding on potential production. To decrease potential production when soils are saturated, use a value < 1.0. FLODEFF(1)=0.0 ceases production when soils are saturated. To increase potential production when soils are saturated, use a value > 1.0.

* **N tracegas model improvement: new pH effect on denitrification**. There are two new parameters in sitepar.in that allow you to turn on or off the pH effect on denitrification.

Also see parameter definitions in the following documents: crop100\_parameters\_muvps\_gt.docx, tree100\_parameters\_muvps\_gt.docx, and grasstree100\_parameters\_muvps\_gt.docx

# Standing dead wood biomass pools in DayCent

When trees die, part of them can remain standing instead falling to the ground.

## New variables stored in the binary file and available by list100:

### Pools

* dleavc – carbon in attached dead leaf biomass (g C m-2)
* dleave(3) – N, P, S in attached dead leaf biomass (g E m-2)
* dlvcis(2) – unlabeled and labeled carbon in attached dead leaf biomass (g C m-2)
* dfbrchc – carbon in attached dead fine branch biomass (g C m-2)
* dfbrche(3) – N, P, S in attached dead fine branch biomass (g E m-2)
* dfbrcis(2) – unlabeled and labeled carbon in attached dead fine branch biomass (g C m-2)
* dlwodc – carbon in attached dead standing large wood biomass (g C m-2)
* dlwode(3) – N, P, S in attached dead standing large wood biomass (g E m-2)
* dlwcis(2) – unlabeled and labeled carbon in standing large wood biomass (g C m-2)

### Aggregate pools

* dfrstc – total C in standing forest biomass (gC/m2)
* dfrste(3) – total N,P,S in standing forest biomass (gE/m2)

### Fluxes

* dw1mnr(MAXIEL) - mineralization from the decomposition of attached dead fine branches (gE m‑2mo‑1)
* dw2mnr(MAXIEL) - mineralization from the decomposition of standing dead large wood (Ge m‑2mo‑1)
* dwd1c2(ISOS) - heterotrophic respiration from the decomposition of attached dead fine branches (gCO2-C m‑2mo‑1)
* dwd2c2(ISOS) - heterotrophic respiration from the decomposition of standing dead large wood (gCO2-C m‑2mo‑1)
* wstduvc2(ISOS) – CO2 released when dead attached leaves undergo photodegradation (gCO2‑C m‑2mo‑1)
* awstduvc2 – annual accumulator for CO2 released when dead attached leaves undergo photodegradation (gCO2-C m‑2yr‑1)
* tcreta– annual accumulator of C returned to system as litter, dead surface wood, or charcoal during a TREM (tree removal) event for a forest/savanna system (g C m‑2yr‑1)
* tereta(3) – annual accumulator of N, P, S returned to system as litter, dead surface wood, or elemental return to mineral soil during a TREM (tree removal) event for a forest/savanna system (g E m‑2yr‑1)

Live counterparts to dead tree pools in the binary file:

rleavc, rleave(3), rlvcis(2), fbrchc, fbrche(3), fbrcis(2), rlwodc, rlwode(3), rlwcis(2)

Downed dead fine branches and large wood in the binary file:

wood1c, wood1e(3), wd1cis(2), wood2c, wood2e(3), wd2cis(2)

### New site.100 parameters (initial pool values that are used when not extending from a binary file)

* DLVCIS(2) – unlabeled and labeled carbon in attached dead leaf biomass (g C m-2)
* DFBRCIS (2) – unlabeled and labeled carbon in attached dead fine branch biomass (g C m-2)
* DLWCIS (2) – unlabeled and labeled carbon in standing large wood biomass (g C m-2)

Initial elemental pool values are determined using the maximum C:E ratios of leaves and wood and are not included in the site.100 file:

### New tree.100 parameters for standing dead wood snags

* DLVFALRT - fall rate of dead attached leaves (fraction per month, in absence of disturbance)
* DFBFALRT - fall rate of dead attached branches (fraction per month, in absence of disturbance)
* DLWFALRT - fall rate of dead standing large wood (fraction per month, in absence of disturbance)
* DECW4 - maximum decomposition rate constant for attached dead fine branches per year before temperature and moisture effects (same as soil surface) are applied (year-1).
* DECW5 - maximum decomposition rate constant for standing dead large wood per year before temperature and moisture effects (same as soil surface) are applied (year-1).

### Summary of pool C and elemental (N, P, S) transfers in forest model

* Transfer of live leaves to dead attached leaves
  + (rlvcis 🡪 dlvcis; rleave🡪 dleave)
* Transfer of live leaves to surface litter
  + (rlvcis 🡪 strcis and metcis; rleave🡪 struce and metabe)
* Transfer of dead attached leaves to surface litter
  + (dlvcis 🡪 strcis and metcis; dleave🡪 struce and metabe)
* Transfer of live fine branches to dead attached fine branches
  + (fbrcis 🡪 dfbrcis, fbrche 🡪 dfbrche)
* Transfer of live fine branches to downed dead branches
  + (fbrcis 🡪 wood1c; fbrche 🡪 wood1e)
* Transfer of dead attached fine branches to downed dead branches
  + (dfbrcis 🡪 wood1c; dfbrche 🡪 wood1e)
* Transfer of live large wood to dead standing large wood
  + (rlwcis🡪 dlwcis, rlwode🡪 dlwode)
* Transfer of live large wood to downed large wood
  + (rlwcis🡪 wd2cis, rlwode🡪 wood2e)
* Transfer of dead standing large wood to downed large wood
  + (dlwcis🡪 wd2cis, dlwode🡪 wood2e)

**Table 1.** Updated list of trem.100 parameters. New parameters are in green. Updated definitions of existing parameters are highlighted in yellow. New parameters were added and others were modified to manage dead tree snags, but some of the new parameters also effect harvest of grasstrees (next section).

|  |  |  |  |
| --- | --- | --- | --- |
| EVNTYP | Event type flag  = 0 for cutting, pruning, windstorm, or other non-fire event  = 1 for fire | index | 0,1 |
| REMF(1) | Fraction of live leaves (rleavc) that is KILLED in the event. The fraction 1.0 – lv2std(1) determines how much is removed by cutting or fire. | fraction | 0.0 – 1.0 |
| REMF(2) | Fraction of live fine branches (fbrchc) that is KILLED in the event. The fraction 1.0 – lv2std(2) determines how much is removed by cutting or fire. | fraction | 0.0 – 1.0 |
| REMF(3) | Fraction of live large wood (rlwodc) that is KILLED in the event. The fraction 1.0 – lv2std(3) determines how much is removed by cutting or fire. | fraction | 0.0 – 1.0 |
| REMF(4) | Fraction of dead fine branches on the ground (wood1c) that is removed. This parameter applies to non-fire events only. To burn dead fine branches on the surface one must schedule a FIRE event; see fire.100 parameters. | fraction | 0.0 – 1.0 |
| REMF(5) | Fraction of dead large wood on the ground (wood2c) that is removed. This parameter applies to non-fire events only. To burn dead large wood on the surface one must schedule a FIRE event; see fire.100 parameters. | fraction | 0.0 – 1.0 |
| REMF(6) | Fraction of existing dead attached leaves (dleavc) that is removed in the event. | fraction | 0.0 – 1.0 |
| REMF(7) | Fraction of existing dead attached fine branches (dfbrchc) that is removed in the event. | fraction | 0.0 – 1.0 |
| REMF (8) | Fraction of existing dead standing large wood (dlwodc) that is removed in the event. | 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 removed live leaves (those not transferred to dead attached leaf pool) that is returned to the system (ash or litter). | fraction | 0.0 – 1.0 |
| RETF(1,2) | Fraction of N in removed live leaves (those not transferred to dead attached leaf pool) that is returned to the system (ash or litter). | fraction | 0.0 – 1.0 |
| RETF(1,3) | Fraction of P in removed live leaves (those not transferred to dead attached leaf pool) that is returned to the system (ash or litter). | fraction | 0.0 – 1.0 |
| RETF(1,4) | Fraction of S in removed live leaves (those not transferred to dead attached leaf pool) that is returned to the system (ash or litter). | fraction | 0.0 – 1.0 |
| RETF(2,1) | Fraction of C in removed live fine branches (those not transferred to dead attached fine branch pool) that is returned to the system (ash or dead fine branches). | fraction | 0.0 – 1.0 |
| RETF(2,2) | Fraction of N in removed from live fine branches (those not transferred to dead attached fine branch pool) that is returned to the system (ash or dead fine branches). | fraction | 0.0 – 1.0 |
| RETF(2,3) | Fraction of P in removed live fine branches (those not transferred to dead attached fine branch pool) that is returned to the system (ash or dead fine branches). | fraction | 0.0 – 1.0 |
| RETF(2,4) | Fraction of S in removed live fine branches (those not transferred to dead attached fine branch pool) that is returned to the system (ash or dead fine branches). | fraction | 0.0 – 1.0 |
| RETF(3,1) | Fraction of C in removed live large wood (the portion not transferred to standing dead large wood pool) that is returned to the system (ash or dead large wood). | fraction | 0.0 – 1.0 |
| RETF(3,2) | Fraction of N in removed live large wood (the portion not transferred to standing dead large wood pool) that is returned to the system (ash or dead large wood). | fraction | 0.0 – 1.0 |
| RETF(3,3) | Fraction of P in removed live large wood (the portion not transferred to standing dead large wood pool) that is returned to the system (ash or dead large wood). | fraction | 0.0 – 1.0 |
| RETF(3,4) | Fraction of S in removed live large wood (the portion not transferred to standing dead large wood pool) that is returned to the system (ash or dead large wood). | fraction | 0.0 – 1.0 |
| RETF(4,1) | Fraction of C in removed dead attached leaves that is returned to the system (ash or litter). | fraction | 0.0 – 1.0 |
| RETF(4,2) | Fraction of N in removed dead attached leaves that is returned to the system (ash or litter). | fraction | 0.0 – 1.0 |
| RETF(4,3) | Fraction of P in removed dead attached leaves that is returned to the system (ash or litter). | fraction | 0.0 – 1.0 |
| RETF(4,4) | Fraction of S in removed dead attached leaves that is returned to the system (ash or litter). | fraction | 0.0 – 1.0 |
| RETF(5,1) | Fraction of C in removed dead attached fine branches that is returned to the system (ash or dead fine branches). | fraction | 0.0 – 1.0 |
| RETF(5,2) | Fraction of N in removed dead attached fine branches that is returned to the system (ash or dead fine branches). | fraction | 0.0 – 1.0 |
| RETF(5,3) | Fraction of P in removed dead attached fine branches that is returned to the system (ash or dead fine branches). | fraction | 0.0 – 1.0 |
| RETF(5,4) | Fraction of S in removed dead attached fine branches that is returned to the system (ash or dead fine branches). | fraction | 0.0 – 1.0 |
| RETF(6,1) | Fraction of C in removed standing dead large wood that is returned to the system (ash or dead large wood). | fraction | 0.0 – 1.0 |
| RETF(6,2) | Fraction of N in removed standing dead large wood that is returned to the system (ash or dead large wood). | fraction | 0.0 – 1.0 |
| RETF(6,3) | Fraction of P in removed standing dead large wood that is returned to the system (ash or dead large wood). | fraction | 0.0 – 1.0 |
| RETF(6,4) | Fraction of S in removed standing dead large wood that is returned to the system (ash or dead large wood). | fraction | 0.0 – 1.0 |
| LV2STD(1) | Fraction of killed live leaves that is transferred to dead attached leaves. (The fraction 1.0 – lv2std(1) is what gets removed). If event type is a fire then it is assumed that this transfer only killed the leaves but did not burn them. | fraction | 0.0 – 1.0 |
| LV2STD(2) | Fraction of killed fine branches that is transferred to dead attached fine branches. (The fraction 1.0 – lv2std(2) is what gets removed). If event type is a fire then it is assumed that this transfer only killed the branches but did not burn them. | fraction | 0.0 – 1.0 |
| LV2STD(3) | Fraction of killed live large wood that is transferred to dead standing large wood. (The fraction 1.0 – lv2std(3) is what gets removed). If event type is a fire then it is assumed that this transfer only killed the large wood but did not burn it. | fraction | 0.0 – 1.0 |

# Creating a grasstree to simulate large biofuels grasses

Development of the grasstree plant model started in 2014, but was never completed then. When CABBI funding began we saw this as the perfect opportunity to develop grasstree for simulating bioenergy crop production and sustainability. Therefore, you may see some of my notes from my original conversations with Bill Parton about the features of this plant model.

* Grasstrees have a new system option in the schedule file (GRASSTREESYS=4).
* Grasstrees have their own parameter set (grasstree.100) that is a combination of tree.100 and crop.100 parameters and some parameters unique to grasstrees.
* Grasstrees cannot be grown simultaneously with either crops or trees.
* Grasstrees can be annual (like forage sorghum) or perennial (like miscanthus, switchgrass, sugarcane)
* Self-shading, leaf death
* LAI flat at maximum until death or harvest. Maximum LAI is defined in grasstree.100 (GTMAXLAI).
* The grasstree.100 parameter, GTKLAI (stem biomass at half maximum LAI) will be about 100 gC m-2, which is much lower than it is for trees.
* Plant pools
  + Include live leaves, juvenile and mature fine roots, and coarse roots, plus three new pools: live stems, dead leaves (attached), and dead stems (standing)
  + There are no woody plant pools.
* C:N ratios of leaves and stems
  + The C:N ratios of live grasstree leaves and stems increase as the grass grows (dilution of N). This is also done in DayCent’s grass model, but DayCent’s tree model does not simulate an increasing C:N ratio in wood as the tree matures.
* Phenology
  + GFST, GLST in schedule file define maximum season length.
  + ~~For growing degree day option, the start of growth will be based on weekly running average of soil temperature. When this temperature exceeds~~ *~~tmpgerm~~* ~~growth begins, and degree days accumulation (~~*~~themunits~~*~~) also begins.~~
    - ~~Plant production based on growing degree days is already implemented in DayCent’s crop model, but not in DayCent’s tree model~~
* Senescence
  + Leaves and stems die
  + There are two kinds of senescence events that can be scheduled. 1) The SENM event occurs on a single day. Multiple SENM events can be scheduled near the end of the growing season, if desired. See GTSDETH(3-4) parameters in grasstree.100. 2) The GSEN event allows senescence to occur gradually over a specified period. This event is triggered by daylength. See DYLENSEN, GSENEDYS, GSENDETH(1), and GSENDETH(2) parameters in grasstree.100 (Table 5)
  + Retranslocation of N from leaves to elemental storage pool, located in the coarse roots (rhizomes)
  + Death of leaves and stems due to dryness or cold cannot occur at the same time as senescence.
* Frost kill can happen before senescence
  + Soil temperature controls death of fine roots. Maximum death rates occur when mean daily soil temperature is ≤ -2°C or ≥ 40°C. Also see ROOTDR(1-2) in grasstree.100
  + The 7-day running air temperature controls death of coarse roots (rhizomes) since they occur near the surface. Maximum death rates occur when the 7-day mean temperature is ≤ TCRKILL or ≥ 40°C. Also see ROOTDR(3) in grasstree.100. This way of computing coarse root depth was implemented 9/22/2021 (formerly soil temperature was used in the same way as it is for fine roots as described above) (Table 2). Death of coarse roots results in a reduction of carbohydrate storage.
  + Minimum daily temperature controls frost kill of leaves and stems (implemented 9/22/2021). Also see GTFSDETH(7-8) and TLSKILL(1-2) in grasstree.100 (Table 3).
  + Frost kill of leaves and stems cannot occur during senescence.
  + Death of leaves and stems due to dryness cannot occur on the same day as frost kill.

Table . Comparison of the different plant types in the DayCent model

|  |  |  |
| --- | --- | --- |
| **Crops/Grasses** | **Tree** | **Grass-Tree** |
| **Schedule file type** | | |
| CROP | TREE | GRAS |
| **Seasonality** | | |
| Annuals, perennials | Perennial only  Evergreen, deciduous, or drought deciduous | Annuals, perennials |
| **Live Plant Parts** | | |
| shoots | leaves | leaves |
| juvenile fine roots | juvenile fine roots | juvenile fine roots |
| mature fine roots | mature fine roots | mature fine roots |
|  | large wood | live stems |
|  | fine branches |  |
|  | coarse roots | Rhizomes (coarse roots) |
| **Dead Plant Parts** | | |
| Standing dead | dead leaves (attached) | dead leaves (attached) |
|  | Dead standing boles | dead stems (standing) |
|  | Dead fine branches (attached) |  |
|  | Downed large wood |  |
|  | Downed fine branches |  |
|  | Dead coarse roots |  |
| senescence | no senescence | senescence |
| phenology can be prescribed or related to growing degree days | no growing degree day based phenology | no growing degree day based phenology |
| C:N in shoots grows wider as crop/grass matures to simulate increased stem biomass |  | C:N in leaves and stems grows wider as grasstree matures and stem biomass increases |
|  | In savanna mode, trees can shade grasses, reducing the potential production of the grass | Self-shading with leaf death |
|  |  | extended water stress |
|  |  | low temperatures (shoot death) |

**Questions about grasstrees**

1. What are the differences between annual and perennial grasstrees?
   1. Dynamic C allocation (see below)
   2. Grasstrees partially or completely die with TREM (harvest) or senescence events (SENM or GSEN)
      1. SENM events occur in a single day.
      2. The new GSEN event (added 9/20/2021), will allow senescence to commence as soon as photoperiod criteria are met (daylength decreasing and daylength (hours) <= DYLENSEN < 12.0), then senescence will continue for the next GSENDYS days. (DYLENSEN and GSENEDYS are 2 new grasstree.100 parameters). With GSEN, a fraction of live above ground biomass dies each day such that after GSENEDYS, GSENDETH(1) and GSENDETH(2) fractions (2 other new grasstree.100 parameters) of live leaves and stems die, respecitively. (Note: the daily death rate is not simply 1/GSENEDYS when GSENDETH(1) is 100% as that daily rate would kill much less than 100%). A GSEN event is scheduled any time during the growing season, but must occur at least one day after the GFST event. The GSEN event will commence as soon as daylength criteria are met. If the GSEN event is scheduled when daylength < DYLENSEN, it will begin immediately and continue for GSENDYS.
      3. The model will not allow one to schedule a SENM event during the same period (execution will terminate). However, a SENM event can occur before or after the GSEN event’s duration.
      4. Both SENM and GSEN events stop plant growth as well.
   3. Grasstrees stop growing at GLST event (and with SENM and GSEN senescence events).
   4. There is no late season growth restriction for grasstrees. In the CROP model, perennial plants have late season growth restriction (both non-GDD and GDD) based on parameters CURGDYS and CLSGRES in crop.100, but annual crops do not have this feature.

Table . Grasstree.100 parameters that control death of fine and coarse roots from dryness and cold.

| ROOTDR(1) | Maximum **juvenile fine root** death rate with very dry soil or very cold/hot soil conditions (fraction/month); to get the daily root death rate, this fraction is divided by the number of days in the month then multiplied by another fraction that decreases as soil moisture increases and soil temperature approaches optimal conditions (~10 °C).  See watreff\_drootgt\_atanf.xlsx. | fraction | 0.0 – 1.0 |
| --- | --- | --- | --- |
| ROOTDR(2) | Maximum **mature fine root** death rate with very dry soil or very cold/hot soil conditions (fraction/month); to get the daily root death rate, this fraction is divided by the number of days in the month then multiplied by another fraction that decreases as soil moisture increases and soil temperature approaches optimal conditions (~10 °C).  See watreff\_drootgt\_atanf.xlsx. | fraction | 0.0 – 1.0 |
| ROOTDR(3) | Maximum **coarse root** death rate with very dry soil or very cold/hot temperatures (fraction/month); to get the daily root death rate, this fraction is divided by the number of days in the month then multiplied by another fraction that decreases as soil moisture increases and soil temperature approaches optimal conditions (~10 °C).  Update 9/15/2021: Coarse roots in perennial bioenergy crops such as miscanthus are assumed to be rhizomes close to the surface, therefore the 7-day running air temperature is used instead of soil temperature to compute temperature effects on rhizome death. Maximum coarse root death rate occurs when this 7-day air temperature is ≥ 40 °C or ≤ TCRKILL °C.  The value of this parameter should be reduced for grasstrees that do not have rhizomes close to the surface.  See watreff\_drootgt\_atanf.xlsx. | fraction | 0.0 – 1.0 |
| TCRKILL | Threshold temperature for maximum rhizome kill death due to cold. When 7-day running air temperature ≤ TCRKILL, the maximum rate of coarse root kill occurs. See ROOTDR(3). | °C | < 0.0 °C |

Table . Grasstree.100 parameters that control death of live leaves and stems

| GTFSDETH(7) | Maximum **leaf** death rate during a frost (fraction/day); this fraction is multiplied by a reduction factor, dthcold, which decreases linearly from 1.0 to 0.0 as minimum daily air temperature increases from, TLSKILL(1) to TLSKILL(2). Live leaves that die are transferred to dead attached leaf pool. With frost kill there is no N retranslocation from dying leaves is to internal storage. | fraction day‑1 | 0.0 – 1.0 |
| --- | --- | --- | --- |
| GTFSDETH(8) | Maximum **stem** death rate at during a frost (fraction/day); this fraction is multiplied by a reduction factor, dthcold, which decreases linearly from 1.0 to 0.0 as minimum daily air temperature increases from, TLSKILL(1) to TLSKILL(2). Live stems that die are transferred to standing dead stem pool. | fraction day‑1 | 0.0 – 1.0 |
| TLSKILL(1) | Threshold for maximum leaf/stem frost death. When daily minimum air temperature ≤ TLSKILL(1), the maximum rate of frost leaf/stem death occurs. See also GTFSDETH(7) and GTFSDETH(8). | °C | TLSKILL(1) < TLSKILL(2) < 0.0 |
| TLSKILL(2) | The warmest minimum daily air temperature that causes leaf/stem frost death. When daily minimum air temperature > TLSKILL(2), no frost leaf/stem frost death occurs. See also GTFSDETH(7) and GTFSDETH(8). | °C | TLSKILL(1) < TLSKILL(2) < 0.0 |

Table 5. Grasstree.100 parameters to control GSEN events.

| DYLENSEN | The daylength (hours) that triggers a GSEN event. Senescence will commence when daylength ≤ DYLENSEN and daylength is decreasing. | ≤ 12.0, and feasible for the latitude of the site. |
| --- | --- | --- |
| GSENEDYS | Number of days a GSEN event persists. Senescence will commence when daylength ≤ DYLENSEN and daylength is decreasing. | ~30 |
| GSENDETH(1) | Fraction of leaves which die over the GSENEDYS period with a GSEN (senescence) event. Live stems that die are transferred to standing dead stem pool. | fraction |
| GSENDETH (2) | Fraction of stems which die over the GSENEDYS period with a GSEN (senescence) event. Live stems that die are transferred to standing dead stem pool. | fraction |

1. Potential production is calculated with a combination of the same effects that control potential production from crops and trees. See the daily output files potcrp.csv, potfor.csv, and potgt.csv.
2. What conditions determine start of growth?
   1. Annuals: the GFST schedule file event.
   2. Perennials: the GFST schedule file event.
3. How is C dynamically allocated to the live parts: leaves, stems, fine roots, coarse roots?
   1. Grasstree.100 parameters *GTFRTC*(1-5) control allocation for annual plants.
   2. Grasstree.100 parameters *GTFRTCN*(1-2) and *GTFRTCW*(1-2) control allocation for perennial plants.
   3. The above parameters pertain to leaves and fine roots. What about stems? Coarse roots? Use *GTCFRAC*(2) and *GTCFRAC*(4).
   4. Dynamic C allocation will be similar to trees.
      1. Fine roots first
      2. Allometry for leaves. Use stem biomass (analogous to large wood) and KLAI.
      3. Remainder of C goes to STEM and CROOT, proportionally as defined by grasstree.100 parameters.
4. What conditions determine when harvest occurs?
   1. Annuals: A TREM event in the schedule file will trigger a harvest. Evntyp=2 allows for grain harvest.
   2. Perennials: A TREM event in the schedule file will trigger a harvest.
5. What conditions determine when senescence occurs for grasstree perennials? (This will work for grasstree annuals too).
   1. The SEMN schedule file event is triggered on the day it is scheduled. The GSEN event is scheduled at least one day after the GFST event but (preferably) before the autumn equinox; it is triggered by daylength and occurs over multiple days.
   2. Leaves and stems die
   3. Retranslocation of N from leaves to coarse roots (rhizomes).
   4. Crop.100 FSDETH(1-4) parameters determine fraction of shoots that die during senescence. Tree.100 parameters WOODDR(1-5) determine the fraction of each tree part that dies at senescence or the end of the growing season. In grasstree.100 I use GTFSDETH(1-8) for stems and leaves, and ROOTDR(1-3) for roots.
   5. Harvests for grasstrees and managed by a TREM event in the schedule file.
6. ~~What conditions determine when death occurs for annuals?~~
   1. ~~GLST schedule file event if death has not yet occurred by killing frost (?) or other means.~~
   2. ~~Leaves, stems, fine roots, coarse roots die~~
   3. ~~How to define transfer of live to dead leaves and live to dead stems?~~
   4. ~~How to transfer leaves and stems to plant litter~~
7. What conditions determine frost kill?
   1. ~~GDD: The minimum daily temperature falls below~~ *~~tmpkill~~* ~~and the crop has accumulated at least 50% of the~~ *~~ddbase~~* ~~thermal units.~~ 
      1. ~~Frost kill triggers a TREM and GLST event for annuals.~~
      2. ~~Frost kill triggers TREM(?), SENM, and GLST event for perennials.~~
8. Drought induced death is implemented similar to crops. The maximum fraction of leaves that die each month, *GTFSDETH(1)* (fraction/month, grasstree.100), is multiplied by a reduction factor depending on the soil water status. Live leaves that die are transferred to dead attached leaf pool. The maximum fraction of stems that die each month, *GTFSDETH(2)* (fraction/month, grasstree.100) is multiplied by a reduction factor depending on the soil water status. Live stems that die are transferred to standing dead stem pool. Parameters *ROOTDR(1-3)* determine the maximum fraction of juvenile fine roots, mature fine roots, and coarse roots that die each month in very dry conditions. This fraction is multiplied by a reduction factor depending on the soil water and soil temperature status.

The parameter *GTFSDETH(3)*specifies the fraction of leaves which die during senescence month (≥ 0.4). Live leaves that die are transferred to dead attached leaf pool. The parameter *gtfsdeth(4)* specifies the fraction of stems which die during senescence month (≥ 0.4). Live stems that die are transferred to standing dead stem pool.

Gradual leaf death also occurs self-shading that causes leaves at the bottom of the canopy to die. The parameter *GTFSDETH(5)* specifies the additional fraction of leaves which die when live leaf C is greater than *GTFSDETH(6)*, the level of live leaf C above which shading occurs and shoot senescence increases. Live leaves that die are transferred to dead attached leaf pool.

1. The parameters *SDFALLRT(1)* and *SDFALLRT(2)* (fraction/month, grasstree.100), specify the fraction of standing dead leaves and stems that fall each month. This plant material is incorporated into structural and metabolic surface litter as a function of lignin fractions*, GTLIG(1)* and *gtlig(2)*.
2. Lignin fractions of plant parts determined from fixed ratios, GTLIG(1-5) in grasstree.100.
3. How will a grasstree be scheduled?
   1. GFST, GLST define maximum season length.
   2. SENM or GSEN is needed to simulate senescence since there is currently no GDD triggering of senescence).
   3. Harvests are TREM events. The parameters for large wood (remf(3) , remf(5) , retf(3,1-4) will be ignored. The parameters that are used for fine branches will refer to stems. See below.
4. What are the changes to the photosynthesis model? None, grasstrees are similar to crops and trees.
   1. grossPsn is a function of LAI, VPD, temperature, PET
   2. All grossPsn gets transferred to carbohydrate storage (carbostg(3,1))
   3. All production, maintenance respiration, and growth respiration comes from the stored carbohydrate pool.
      1. None of these C fluxes are limited by the amount in the carbostg pool.
      2. carbostg can go be depleted without restricting growth or plant respiration. Currently, the model compensates for this depletion by automatically adding C to the carbostg pool to prevent it from going negative.
      3. More work needs to be done so carbostg restricts growth and respiration when it gets low.
   4. For all plant parts, maintenance respiration is proportional to live carbon and increases with daily average temperature. Relative fractions are defined in grasstree.100. For belowground parts, maintenance respiration is reduced by dry soil conditions.
   5. Growth respiration for each plant part is a fixed fraction of production. Fractions are defined in grasstree.100.
5. Harvest TREM events
   1. EVNTYP – 0 for cutting, windstorm, of other non-fire; 1 for fire; 2 for grain harvest and cutting.
   2. REMF(1) – Fraction of live leaves (gtleavc) that is KILLED in the event. The fraction 1.0 – LV2STD(1) determines how much is removed by cutting or fire.
   3. REMF(2) – Fraction of live stems (gtstemc) that is KILLED in the event. The fraction 1.0 – LV2STD(2) determines how much is removed by cutting or fire
   4. REMF(3) – not used
   5. REMF(4) – not used
   6. REMF(5) – not used
   7. REMF(6) – Fraction of existing dead attached leaves (dgtleavc) that is removed in the event.
   8. REMF(7) – Fraction of existing dead stems (dgtstemc) that is removed in the event.
   9. REMF(8) – not used
   10. FD(1) – fraction of fine root components that die
   11. FD(2) – fraction of coarse root components that die
   12. RETF(1,1-4) – Fraction of C ,N, P, and S in removed live leaves (those not transferred to dead attached leaf pool) that is returned to the system (ash or litter).
   13. RETF(2,1-4) – Fraction of C, N, P, and S in removed live stems (those not transferred to dead stem pool) that is returned to the system (ash or dead fine branches).
   14. RETF(3,1-4) – not used
   15. RETF(4,1-4) – Fraction of C, N, P, and S in removed dead attached leaves that is returned to the system (ash or litter).
   16. RETF(5,1-4) – Fraction of C, N, P and S in removed dead stems that is returned to the system (ash or dead fine branches).
   17. RETF(6,1-4) – not used
6. Schedule file options for grasstrees (**Table 6**).

**Table 6.** Schedule file events. The blue text indicates new grasstree keywords for the schedule files. The three right-most columns are programmer’s notes.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Event** | **Description** | **Booleans & other variables** | **Event day**  **of year** | **Other actions** |
| CROP <option> | Specify which crop.100 parameters are to be used. | none | none | Call cropin  Call co2eff |
| TREE <option> | Specify which tree.100 parameters are to be used. | none | none | Call treein  Call co2eff |
| GRAS | Specify which grasstree.100 parameters to use. | none | none | Call grasstreein  Call co2eff |
| FRST | Perennial crop/grass growth can commence | dofrst = true  frstschd = true | frstday  savefrstday | none |
| GFST | Grasstree growth can commence. Applies to both annuals and perennials. | dogfst = true  gfstschd = true | gfstday  savegfstday | none |
| TFST | Tree growth can commence | dofone = true | foneday | none |
| PLTM | Annual crop growth can commence. Does not apply to grasstrees. | doplnt = true  plntschd = true | plntday  saveplntday | none |
| SENM | Senescence (partial or complete death) of annual or perennial crop or grasstree; occurs on a single day. | dosene = true  senmschd = true | seneday | Implemented when dshootgt is called. |
| GSEN | Senescence (partial or complete death) of annual or perennial crop or grasstree; occurs gradually over user-specified number of day and is triggered by daylength. | dogtsene = .true. | gtseneday (not used) | Implemented when dshootgt is called. |
| LAST | Annual crops stop growing | dolast = true | lastday | none |
| TLST | Tree growth ceases | doflst = true | flstday | none |
| GLST | Grasstree growth ceases | doglst = true | glstday | none |
| HARV | Crop harvest. | dohrvt = true  harvschd = true | hrvtday | Call harvin |
| TREM | This event is used to specify tree harvest or tree burning. Can also be used for grasstree. | dotrem = true  tremharvschd = true (for harvest events) | tremday | Call tremin |
| FERT | Add inorganic fertilizer to any system. | dofert = true  aufert = savedfert | fertday | Call fertin |
| CULT | Cultivation effects last for up to 30 days after event is scheduled. | docult = true | cultday | Call cultin |
| OMAD | Organic matter addition to any system. | doomad = true | omadday | Call omadin |
| IRRI | Irrigation to any system once a week for 30 days. | doirri = true | irriday | Call irrgin |
| GRAZ | Grazing of crop/grass only for 30 days. Does not affect trees or grasstrees. | dograz = true | grazday | Call grazin |
| EROD | Erosion for any system for 30 days. | doerod = true  psloss | erodday | none |
| FIRE | This event is used to specify burning of dead wood and the litter in the current system, plus live shoots and standing dead for crops/grasses. | dofire(cursys) = true | fireday | Call firein |
| FLOD <option> | FLOD 0 - prevents soil water drainage and allows precipitation and irrigation to accumulate in the layers, but does not add extra water  FLOD 1 - prevents drainage and adds water to soil layers to keep them saturated |  |  |  |
| DRAN | return to normal, unflooded conditions, allows soil water to drain again |  |  |  |

Discussion with Bill, Friday 1/10/2014

Floating C:E ratios.

* For aboveground live parts (leaves and stems), we need a min and max C:E for zero biomass, and a min and max C:E for biomass > BIOMAX.
* For belowground live parts, we only need a min, max, and initial C:E.

Scheduling

* We will need a way to allow plants to stop growing and resume growing without killing the plant. For example, sugar cane does not senesce.
* We need to deal with the problem we had growing miscanthus in the South.
* Need to be able to go across years (check the way the scheduled “days” are checked).
* For GDD, start growth like a forest that begins when a certain temperature is reached (TMPLFS?). This is different that *TEMPGERM* since the start of growth does not necessarily mean germination.

Plant death, fall of standing dead.

* Need different drop rates for dead leaves and dead stems. See SDFALLRT(1-2) in grasstree.100.

**Notes from Andy Robertson about miscanthus**

Jan. 17, 2014

Planted as rhizomes (10,000 – 15,000 rhizomes/ha)

Retranslocation of N to rhizomes

Biomass distribution:

* 30% rhizomes
* 30% other roots
* 40% above-ground

~20 year life cycle

Yield

* 1-4 tC/ha/yr initial year of growth
* 15 tC/ha/yr Illinois
* 8-10 tC/ha/yr England

N-fixing – mychorrhizal association

Almost all leaves fall off before harvest

Leaves ligninize to stems

*Miscanthus x giganteus* – fertile, no flowers or seeds

Drought tolerant

miscan4 model (specializes in miscanthus, but ag productivity only)

# Modeling N uptake by crops in DayCent

The purpose of this section is to describe how we can alter the timing of plant N uptake in a realistic way in order to improve N2O emissions estimates. Nitrification inhibitors are not having the desired effect of reducing N2O emissions by 30% during the growing season. Instead, DayCent only models a delay in those N2O emissions. As soon as nitrification inhibitors lose their effect, N2O emissions spike due to residual ammonium. We needed a way for plant to take up more ammonium when the nitrification in being inhibited so that when the inhibitor effect is gone, there won’t be a spike in N2O emissions from lingering ammonium.

DayCent tries to meet plant N demand from these sources in the following order:

1. Internal N storage (crpstg(1))
2. Mineral N in the soils (ammonium + nitrate)
3. Symbiotic N fixation
4. Automatic N fertilization

Initially, the potential N demand for each plant part its potential plant production (gC m-2) divided by its minimum C:N ratio; the total N demand is the sum of N demand for each plant part. For shoots, the minimum C:N for new growth is determined by the PRAMN(1,1-2) and BIOMAX parameters and for roots it is determined by the PRBMN(1,1-2) parameters. (Table 4, Figure 1). If this potential N demand cannot be met by the 4 above sources, DayCent will increase the C:N until the demand can be met, and therefore produces new growth with a higher C:N. If the N demand can’t be met even when the maximum C:N ratios are used, then production is restricted. For shoots, the maximum C:N for new growth is determined by the PRAMX(1,1-2) and BIOMAX parameters and for roots it is determined by the PRBMX(1,1-2) parameters.

Table 7. Parameters that control C:N ratios in new growth in crops and grasses.

|  |  |  |  |
| --- | --- | --- | --- |
| 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(1,2) | Minimum aboveground C/N ratio with biomass > BIOMAX. | C/N ratio | 1.0 – 200.0 |
| PRAMX(1,1) | Maximum aboveground C/N ratio with zero biomass. | C/N ratio | 1.0 – 200.0 |
| PRAMX(1,2) | Maximum aboveground C/N ratio with biomass > BIOMAX. | C/N ratio | 1.0 – 400.0 |
| 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(1,2) | (N, slope) parameter for computing minimum C/N ratio for belowground matter as a linear function of annual precipitation. Usually set to 0.0. | change in C/N ratio per cm precipitation | 0.0 – 1.0 |
| 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(1,2) | (N, slope) parameter for computing maximum C/N ratio for belowground matter as a linear function of annual precipitation. Usually set to 0.0. | change in C/N ratio per cm precipitation | 0.0 – 1.0 |

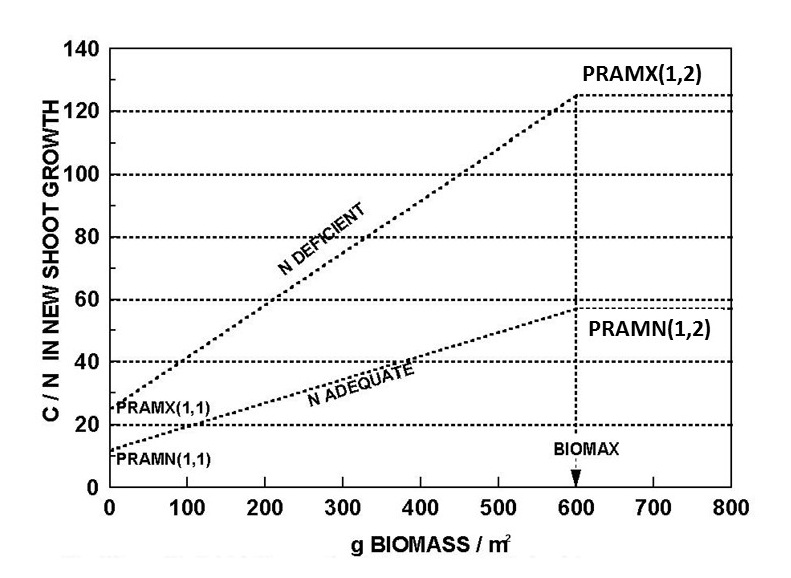


Figure 1. The crop.100 parameters that affect the C:N ratios of new crop/grass above-ground growth. There are similar parameters for the grasstree model.

## NO3PREF parameter in crop.100, tree.100, and grasstree.100

In DayCent, ammonium exists in the top 3-4 soils.in layers (~top 10-20 cm) only while nitrate may exist in all soil layers. Usually, the top 3-4 soils.in layers comprise the top Century layer with thickness defined by ADEP(1) in fix.100. DayCent’s plant model will take up N from all soil layers where roots exist (1..CLAYPG, 1..TLAYPG, or 1..GTLAYPG for the crop, tree, and grasstree types, respectively). The amount of mineral N removed from each layer is proportional to the N available in the layer divided by the total available N in the rooting zone. N uptake from any soil layer must also be partitioned into ammonium and nitrate uptake. Currently, plants take up nitrate in ammonium in proportion to the relative availability of each in the top 3 soils.in layers. Below the top Century layer, all N uptake is from nitrate.

NO3PREF is a crop- and tree-specific parameter in the crop.100, tree.100, and grasstree.100 files that indicates the plants preference for taking up nitrate vs. ammonium **in the top ADEP(1) cm of soil** (Table 5)**.** It has existed for a long time but was never actually used. Specifically, NO3PREF is the fraction of N demand that should be met by uptake of nitrate, and 1.0-NO3PREF was the fraction of N demand that should be met by uptake of ammonium. An adjustment in the actual fraction of nitrate uptake is made if there was not enough nitrate or ammonium to take up the specified fraction.

NO3PREF = -1 means take up nitrate and ammonium in proportion to their relative amounts. This is the current way DayCent computes the fraction of N uptake met by ammonium and nitrate.

NO3PREF =1.0 means the plant would try to meet its soil mineral N demand from nitrate only. If not enough nitrate is present to meet the demand, then ammonium could supplement uptake.

NO3PREF = 0.0 means the plant would try to meet its soil mineral N demand from ammonium only. If not enough ammonium is present to meet the demand, then ammonium could supplement uptake.

0.0 < NO3PREF < 1.0. The fraction of the soil mineral N demand that is fulfilled by nitrate, if available. If not enough nitrate exists, the plant will consume all the nitrate, then take up the remainder as ammonium.

## Plant Luxury N uptake

We can increase plant N uptake early in the growing season by lowering the minimum C:N ratios of shoots so the plant takes up extra N in its leaves. This uses up some of the soil ammonium that lingers from nitrification inhibitors. However, this stores N in live plant material (aglive(1)) where it is no longer available to meet the N demand for future growth; thus, extra N uptake early in the growing season can result in a deficiency of N later in the growing season.

For annual plants, a second way to control N uptake early in the growing season is to allow “Luxury N uptake” by setting the new parameters listed in Table 5 below. Luxury N uptake is an fixed fraction of regular plant inorganic N uptake from the soil each day (LUXEUPF(1)), and this extra N uptake is transferred to the internal N storage, crpstg(1), which can be used later to meet the N demand for new growth. The plant can start using the stored N to meet its N demand after CSTGDYS into the growing season, or sooner if it becomes N limited before CSTGDYS. In this way early N luxury uptake won’t cause a shortage of N for plants later in the growing season. For more information on these parameters, see Table 5.

Some rules about luxury N uptake.

* Luxury N uptake is only available to annual crops/grasses, not to trees or grasstrees.
* Luxury N uptake is the transfer of soil inorganic N to the internal N storage pool, crpstg(1), by the plant. This is in contrast to normal crop soil mineral N uptake that transfers N to aglive(1), bglivej(1), and bglivem(1).
* Luxury N uptake can only occur if the crop.100 parameter LUXEUPF(1) > 0.0.
* Luxury N uptake can only occur when the number of days in the growing season so far < CSTGDYS.
* The maximum amount of luxury N uptake that can occur in a day is LUXEUP(1)\* (normal plant soil inorganic N uptake). Actual luxury N uptake will be less than the maximum if

1. there is not enough inorganic N in the soil to meet this extra demand, or
2. the maximum amount of luxury N uptake would cause the C:N ratio of above ground plant material (defined as aglivc/(aglive(1)+crpstg(1)) to be < PRAMN(1,1). *(Note: because state variables aren’t actually updated until the end of the day, and many fluxes increase or reduce aglivc, aglive(1), and crpstg(1) in any given day, the calculation can’t be exact and the C:N may drop slightly below PRAMN(1,1) at times).*

* After CSTGDYS into the growing season, the plant can use up to CSTGEUPF(1)\*crpstg(1) to meet its demand for N.
* When LUXEUPF(1) = 0.0 indicating no luxury N uptake, plants will first use crpstg(1) to meet their demand for inorganic N. Therefore, in order for plants to be able to store luxury N and use it later, we had to prevent this from happening when LUXEUPF(1) > 0.0 according to the following conditions:
  + When there is sufficient mineral N in the soil, the plants can’t take up N from crpstg(1) until CSTGDYS after the growing season has begun.
  + There is sufficient mineral N in the soil when the “crop available to demand ratio” (crop\_a2drat) defined as mineral N available to the plant divided by the plant’s mineral N demand, is ≥ CSTGA2DRAT.
  + When there is NOT sufficient mineral N in the soil (when crop\_a2drat < CSTGA2DRAT) then the plant can use up to CSTGEUPF(1)\*crpstg(1) per day before CSTGDYS into the growing season.

Table 8. New crop.100 parameters for managing plant N uptake.

|  |  |  |  |
| --- | --- | --- | --- |
| Abbreviation | Description | Units | Range |
| NO3PREF | Nitrate preference. When both ammonium and nitrate are present, this is the fraction of N uptake that will come from nitrate (if possible). When this value is negative, ammonium and nitrate will be taken up in proportion to the amount available, which is the way DayCent has traditionally computed N uptake. | fraction | -1, 0.0 – 1.0 |
| LUXEUPF(1)  LUXEUPF(2) (not used)  LUXEUPF(3) (not used) | Fraction of luxury N/P/S uptake. (Currently this only applies to N). The additional amount, defined as the fraction of plant soil inorganic E uptake, that will be transferred from mineral soil E to internal E storage, crpstg(\*), when the number of days in the growing season < CSTGDYS. Luxury E uptake + plant soil mineral E uptake cannot exceed the amount of mineral soil E available. Additionally, luxury E uptake is limited so the C:N of above ground plant material, defined as aglivc/(aglive(1)+crpstg(1)) cannot be less than PRAMN(1,1). Used only when FRTCINDX = 2, 4, 5, or 6 (annual plants). | fraction per day | 0.0 – 1.0 |
| CSTGEUPF(1)  CSTGEUPF(2) (not used)  CSTGEUPF(3) (not used) | Fraction of internal N/P/S storage (crpstg(\*)) that can be used by plants that have been doing luxury E uptake (luxury E uptake occurs when LUXEUPF(\*) > 0). This fraction is used when the number of days in the growing season > CSTGDYS or when there is some N/P/S limitation to plant growth (when crop\_a2drat < CSTA2DRAT). (When crop\_a2drat ≥ CSGA2DRAT AND growing season days < CSTGDYS, there is no uptake from crpstg(\*)). Used only when FRTCINDX = 2, 4, 5, or 6 (annual plants). (Currently this only applies to N). | fraction per day | 0.0 – 1.0 |
| CSTGDYS | When there is luxury N uptake (when LUXEUPF(\*) > 0) , this is the maximum number of days after germination that a crop has to wait to start using internal E storage (crpstg(\*)) to fulfill nutrient demand. For nutrient poor conditions, determined by the ratio of mineral N available to plants to the supply of mineral N (crop\_a2drat), the crop can start using crpstg(\*) earlier in the growing season when the nutrient demand cannot be met by soil supply (when crop\_a2drat < CSTGA2DRAT). Used when only FRTCINDX = 2, 4, 5, or 6 (annual plants). Perennial plants can use crpstg(\*) at any time, and use that resource up before taking up N from other sources. | number of days | 0 – growing season length |
| CSTGA2DRAT | When there is luxury E uptake (when LUXEUPF(\*) > 0.0), this is the ratio of mineral E available to the plant mineral E demand (crop\_a2drat) that determines if internal E storage (crpstg(\*)) can be used when the number of days in the growing season < CSTGDYS. When crop\_a2drat < CSTGA2DRAT and growing days < CSTGDYS, crops can take of a fraction of crpstg(\*). When crop\_a2drat ≥ CSTGA2DRAT and growing days < CSTGDYS, there is no uptake from crpstg(\*). This parameter is not used when growing days > CSTGDYS. | ratio | 1. – 1.0 |

### Other parameter controls on plant N uptake and availability

**SFAVAIL(1)** – fraction of soil mineral N available to plants (vs. microbes). This parameter exists in the crop.100 file. (A long time ago it was a fix.100 parameter). Steve Ogle suggested this should be = 0.40 base on experimental data. Currently it may only be set to 0.15. Note: this limit applies to mineral N in the rooting zone (ADEP layers 1..CLAYPG) even though N uptake by heterotrophs and nitrifiers only occurs in the top ADEP(1) cm of soil (the top 3 soils.in layers). Denitrifiers have access to nitrate in all soil layers.

# Flexible number of soils.in layers in the top Century layer

The number of soils.in layers that comprise the top “Century” layer has traditionally been hard coded at three in the model (as in **Figure 2**). The top Century layer is where all the soil ammonium is assumed to exist, and the soil and moisture conditions in the top Century layer regulate soil organic matter decomposition, nitrification, and denitrification rates. Furthermore, the total ammonium and nitrate in the top Century layer is what is accessible to soil microbes during decomposition, thus it is where mineralization and immobilization occur. It is now possible to define the top Century layer to be any number of soils.in layers, as long as the ADEP(\*) parameters in the fix.100 file, and NLAYER in the site.100 file are set correctly.



**Figure 2.** 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. 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.

# New pH effect on denitrification

The final two parameters in the sitepar.in file can be used to turn on/off the pH effects during denitrification. See Wagena et al. (2017) and the spreadsheet *n2o\_pH-interactions2.xlsx* for more information.

0 / dofDpH: compute pH effect on total denitrification? (1=yes, 0=no)

0 / dofRpH: compute pH effect on Ratio N2:N2O during denitrification? (1=yes, 0=no)

# Nitrogen uptake distribution

The distribution of N uptake by CROP types (but not yet trees or grasstrees) can be base on one of the following criteria:

1. Total N uptake required for growth is distributed across soil layers in the rooting zone proportional to the amount of mineral N in each soil layer. This has been DayCent’s default.
2. Total N uptake required for growth is distributed across soil layers in the rooting zone proportional to the amount of transpiration that occurred in each layer.
3. Total N uptake required for growth is distributed across soil layers in the rooting zone proportional to the root distribution defined in soils.in.

The last soil.in layer let’s you chose between these three options. The default option is 0.

2 / dofwueup: plant N,P,S uptake by layer based on (0=N,P,S distribution,1=transpiration,2=root density)

# Annual grasstrees

Grasstrees have been assumed to be perennial (e.g. Switchgrass, Miscanthus). Annual grasstrees (e.g. sorghum, corn) are in development. To specify an annual grasstree, set gtfrtcindx=2 in grasstree.100. To specify a perennial grasstree, set gtfrctindx=1 in grasstree.100. The differences between perennials and annuals are summarized below.

|  |  |  |
| --- | --- | --- |
| GrassTree type | Perennial | Annual (in progress) |
|  |  |  |
| Schedule file start of growing season | GFST | GFST |
| Schedule file, end of growing season | GLST | GLST |
| Senescence | Scheduled with SENM event. Senescence occurs in one day. | A SENM event is usually not scheduled for annual crops, but it can be and its effect will be the same as for perennials. Senescence occurs in one day. |
| Allocation of carbon to fine roots | Fraction of C allocated to roots is computed using GTFRTCN(1-2) and GTFRTCW(1-2) parameters in grasstree.100 | Fraction of C allocated to roots is computed using GTFRTC(1) –  GTFRTC(5) parameters in grasstree.100 |
| Allocation to leaves | Total potential C production is calculated. Allocation of this C to leaves is computed after allocation to fine roots. It is dependent on how much stem biomass exists to support leaves. If stems can support more leaves than already exist, C will be allocated to leaves. | same as for perennials |
| Allocation to stems and coarse roots | If there is any remaining potential C after C has been allocated to fine roots and leaves, the remaining potential C will be split among stems and coarse roots using the relative proportion of GTCFRAC(2) and GTCFRAC(4) from grasstree.100. | same as for perennials |
| Rooting depth (number of layers) | Always GTLAYPG (grasstree.100) | Increases from 1 to GTLAYPG during the growing season. |
| Death of above-ground leaves and stems | Triggered by an SENM event (single day event), or by dry soil conditions. Death rates are controlled by GTFSDETH(1) –  GTFSDETH(6) in grasstree.100. | same as for perennials |
| Death of roots | Controlled by monthly death rates ROOTDR(1), ROOTDR(2), and ROOTDR(3) parameters in grasstree.100 modified by soil moisture and soil temperature stress. Root death is triggered by moisture or temperature stress, and by TREM and CULT events. | same as for perennials |
| grain harvest | None. For harvest, schedule a TREM event with evntyp=0 (cutting without grain harvest). | In progress. For harvest, schedule a TREM event with evntyp=2 (cutting plus grain harvest). |
| grain production | N/A | hi = harvest index  sumtran = sum of actual transpiration  sumpttr = sum of potential transpiration |

There is a new harvestgt.csv file with grasstree harvest amounts. This file is generated when the outfiles.in flag is set for this file, and when there is a grasstree TREM (harvest) event. This is analogous to harvest.csv when a CROP harvest is simulated with a HARV event.